SUBMISSION TO THE

NUNAVUT WILDLIFE MANAGEMENT BOARD

FOR

Information: **Decision: X**

Issue: Recommendation to address the decline of the Bathurst caribou herd.

Background:

- In the mid-1980's close to half a million Bathurst caribou were present on their annual range. From 2006 to 2009 the herd declined to about 32,000 caribou. In 2012, the most recent survey, the herd was estimated at 35,000 caribou suggesting the herd had been relatively stable from 2009 to 2012.
- In December 2010 new management regulations were adopted by the Northwest Territories to address conservation concerns. This included the closure of outfitting and commercial harvest as well as a limitation of the aboriginal harvest to a maximum of 300 caribou.
- In Nunavut, the Bathurst Caribou herd is harvested by Kugluktuk, Bathurst Inlet and Bay Chimo (with an estimated overall harvest of 100 per year, of which 70 are for sport hunts). When the herd was at historic highs and was closer to Kugluktuk, that community also harvested from the herd.
- In December 2014 the Northwest Territories implemented a harvest moratorium in for the 2014 - 2015 winter harvest season. They are allowing a harvest of 15 that can be harvested under a special permit, for ceremonial purposes.
- A full population survey is scheduled for June 2015 and results will be available late in 2015. On receipt of the survey results DOE will share them with the HTO's and RWO for discussion on what further management actions may be necessary.

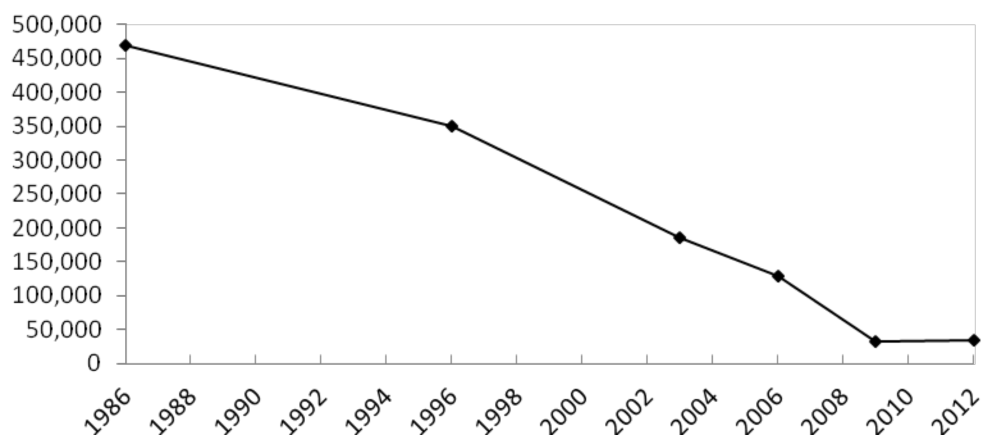

Figure 1 Survey history of the Bathurst Caribou Herd from 1986 to 2012.

Current Status

- In June 2014, a reconnaissance survey was flown near the peak of calving. The total estimated number of caribou at least one year old was 3,594 ± 2,133 compared to 14,390 ± 6,109 in June 2012.
- This reconnaissance survey suggests that Bathurst caribou on the calving ground (one year older) have further declined by approximately 73% between 2013 and 2014. The population could be now be lower the 15,000.
- Of 18 collared Bathurst caribou cows, 17 were found in the June 2014 survey area, suggesting that the calving location was consistent with previous years and a high proportion of the herd's cow were on the calving ground during the reconnaissance survey.
- In the past, the calving ground reconnaissance surveys have been a reliable index of abundance in tracking population trend when compared to full population assessments and trend based on aerial photo-surveys conducted every 3 years.

Consultations:

- The following consultations have been conducted on the conservation issues:
    - September 9, 2014 - Kugluktuk HTO board meeting
    - September 22, 2014 - Kugluktuk community information and consultations
    - October 1, 2014 - Bay Chimo and Bathurst HTO meeting
    - October 9-10, 2014 - Technical Meeting 1, GN and NTI participation
    - October 15-18, 2014 - KWRB AGM meeting
    - October 22-23, 2014 - Technical Meeting 2, GN participation
    - October 31, 2014 - Kugluktuk HTO board meeting
- Consultations to specifically discuss an interim TAH of 100 with NTI, Bathurst Inlet and Bay Chimo HTOs, and the KRWB occurred on January 30, 2015 and on February 11, 2015 with the HTO of Kugluktuk. While there was recognition of substantial conservation concerns and the need for harvest limitations, there was no consensus on the proposed TAH of 100.

Recommendation

- That the NWMB establish a Nunavut TAH of 100 for the Bathurst Caribou Herd.
- That following the receipt of the results from the planned June 1015 survey, and discussions with the HTOs and RWO, that the NWMB review the need for further management actions.

HTO Consultation

Bluenose East and Bathurst Caribou
October 31, 2014

Issues:
Information meeting on the Alarming trends in size of the Bluenose-East caribou herd and the Bathurst Caribou from the 2014 reconnaissance calving ground survey.

Purpose of the Consultations:

A HTO consultation was organized in Kugluktuk on October 31, 2014 as the Bluenose East and the Bathurst herds appear to be in serious decline. The main objective to the meeting was to discuss with the HTO members the potential actions that GN-DOE could be implemented and identify more clearly what action the Kugluktuk HTO already identify. The objectives were then to work together, listen to local needs and priorities, listen to Inuit, learn from their way of life, and to discuss potential management short-term action.

Communities visited: Kugluktuk

Representatives:
GN, DoE, Wildlife Biologist: Lisa-Marie Leclerc
HTO Kugluktuk, Assistant Manager: Johnny
HTO Kugluktuk, Board members (4 members).

Subjects discussed and community views:

- Recommendation to prevent HTO from buying meat due to encouraging people to harvest more than they need
- Upcoming trapping program on wolves, wolverine, grizzly, etc
- Concerns regarding collaring wolves addressed
- Wanting to see pelt prices on wolves increased to encourage harvest
- Agreeance that hunters will bring in skulls of trapped carnivores in exchange for compensation
- 80/20 program not believed to work due to hunters not willing to wait for a particular sex or age to show up while hunting
- Bulls avoided this time of year due to taste, and a mixed harvest is taken according to season due to the taste of meat and thickness of the hide
- Restricting exploration camps/activity during the caribou migration
- Sign or posters to encourage people to think about hunting only what they need
- Possible funding for getting youth involved in butchering to learn how to properly harvest and collect a kill in the field.
- March/april suggested to be the best time of year for such a program
- Concerns regarding the Bluenose and Union herds discussed

- Local community members are aware of where some wolf dens are located
- Wolf pelts worth $300-350
- Increasing interest in living out in outposts in community members
- Expression of interest in providing gut samples on harvest caribou

HTO Consultation

Bathurst Caribou
January 29, 2015

Issues:
Information meeting on the Alarming trends in size of the Bathurst Caribou from the 2014 reconnaissance calving ground survey.

Purpose of the Consultations:

A HTO consultation, with the HTO of Bay Chimo and Bathurst Inlet, was organized in Cambridge Bay on January 29, 2015 as the Bathurst herd appear to be in serious decline. The main objective to the meeting was to discuss with the two HTO boards on the GN position of establishing an interim measure of 100 TAH for the Bathurst caribou. The TAH will be reviewed after the next population survey happening in June 2015.

Communities visited: Kugluktuk

Representatives:
GN, DoE, Wildlife Biologist: Lisa-Marie Leclerc
HTO Bathurst, Board member (4 members)
HTO Bay Chimo, Board members (4 members).
KRWB: Ema and Attima Haldari
NTI: Bert Dean

Subjects discussed and community views:

- Bathurst HTO is concerned to have caribou for the future generations.
- KWRB mentioned that the Inuit harvest is not a problem as they take only a negligible harvest.
- Lisa: Thus, my point was that GN-DOE takes care of regulating not only the Inuit harvest, but also the non-beneficiary and as of right now there is nothing that stop 20 none-beneficiaries to take 5 tags each and harvest more caribou than what the Inuit presently take.
- Lisa: GN-DoE position was an interim TAH of 100 to reflect what the Inuit are actually harvesting.
- Bathurst Inlet came back with a TAH of 150.
- Inquiry about a wolf control program: Not supported by the GN
- The 100-150 TAH will be a temporary measure until the June survey is done and then we can revisit the TAH.
- They also want to be part of this survey and I spoke with GNWT to reserve them a place as observer.
- Due to the status of the Bathurst herd, the monitoring effort will increased and they will be opportunity to review the TAH every 3 years to readjust with the new population number.
- There seem to be some concerns about the sport harvest from the Bay Chimo HTO.
- Thus, when the TAH is given to the HTO, they have free disposition of the TAH and this will be up to them how to allocate it.

HTO Consultation

Bluenose East and Bathurst Caribou
February 2, 2015

Issues:
Information meeting on the Alarming trends in size of the Bluenose-East caribou herd and the Bathurst Caribou from the 2014 reconnaissance calving ground survey.

Purpose of the Consultations:

A HTO consultation was organized in Kugluktuk on February 02, 2012 as the Bluenose East and the Bathurst herds appear to be in serious decline. The main objective to the meeting was to discuss with the HTO boards on the GN position of establishing an interim measure of 100 TAH for the Bathurst caribou and an interim measure of 1,000 for the Bluenose-East caribou. The TAH will be reviewed after the next population survey happening in June 2015.

Communities visited: Kugluktuk

Representatives:
GN, DoE, Wildlife Biologist: Lisa-Marie Leclerc
GN,DoE, Wildlife Technician, Myles Lamont
HTO Kugluktuk, Assistant Manager: Johnny
HTO Kugluktuk, Board members (5 members).

Subjects discussed and community views:

- Point made that fewer people on the land despite community increase
- Mention that Bathurst caribou showing empty stomachs when cleaned
- Mention of GN focusing only on Iqaluit instead of Kugluktuk and the herds that have been declining here for multiple years.
- Discussion regarding setting up a caribou group composed of local hunters, harvesters, GN, HTO and expanding that idea to other communities.
- Concern regarding 100 tags being distributed just to Bathurst area only
- Request for any NWMB public hearings to be held in Kugluktuk
- Questions regarding the frequency and span caribou fluctuations.
- Mention of HTO of Kugluktuk's' voluntary actions to halt all sport hunting on Bluenose-east prior to any mention of pop decline
- Displeasure expressed regarding the efforts to consult on Baffin issues and lack of support and initiative from the GN shown in the Kitikmeot
- Frustrations regarding trophy tag (sport harvest) allocation from Cam Bay and Bathurst Inlet when people are hunting western herds around Kugluktuk which are voluntarily withheld here.
- Concern regarding enforcement of legislation and preventing hunting in some areas due to lack of staff and the vast and remotes area to cover.
- Partial distribution of tags

- Displeasure expressed regarding Maliks poster presentation in Ottawa and not being informed of that project despite having their names attached to it.
- Displeasure expressed regarding the stop of the wolf sample collection program, when GNWT have increased their incentive from $350 to $800 for pelt.
- Price incentives for females over males due to the ease of accessing male reproduction organs. During the winter time it is impossible to collect female organs and the sample will be biased.
- Bluenose-East TAH, 1000 animals for Kugluktuk didn't sit well with the chair and is concerned regarding community members breaking the law.
- Request to see "taking care of caribou" (Bluenose management plan) document for the next meeting in April.
- Between the 23-27th, community consultation in town for Bluenose/Bathurst- Caribou Week.
- Local hunters are willing to limit harvest if asked.

Public Consultation

Bluenose East and Bathurst Caribou
September 22, 2014

Issues:
Information meeting on the Alarming trends in size of the Bluenose-East caribou herd and the Bathurst Caribou from the 2014 reconnaissance calving ground survey.

Purpose of the Consultations:

A community consultation was organized in Kugluktuk on September 22, 2014 as the Bluenose East and the Bathurst herds appear to be in serious decline. The main objective to the meeting was to inform the community members of this decline based on the new reconnaissance calving ground surveys. In addition, this meeting gave a unique opportunity to hear and gather the community members' knowledge and concerns about these herds. The objectives were then to work together, listen to local needs and priorities, listen to Inuit, learn from their way of life, and to discuss potential management recommendations.

Communities visited: Kugluktuk

Representatives:
GN, DoE, Wildlife Biologist: Lisa-Marie Leclerc
HTO Kugluktuk, Chairperson: David Nivingalok
HTO Kugluktuk, Manager: Barbara Adjun
Community members: around 15 participants

Supporting document:
Attached PowerPoint Presentation: GN_Consultation

-The difference between a reconnaissance survey and a population estimate was put forward so the participant could know the limitation of the last survey, but understand that it is the "trend" of the decline that is alarming. New population survey will be done in the summer of 2015.

Subjects discussed and community views:

Community knowledge:
-The Bathurst caribou number must be going down as there were no caribou around Bathurst Inlet this summer.
-Hunters have seen a lot of caribou south of Dismal Lake in late April.
-The Bluenose East caribou are known to have calved north-east of Bluenose Lake and this area should also be taking into consideration for the next population survey.
-25 km to the East of the community, for the past two years there is not much cow at this location as it used to be.
-We need to be careful about the management goal. They put a TAH on Peary caribou for the number to increase and then they declined due to the limit in the habitat capacity, diseases. So having a too high number is not necessarily healthy.

-The rut is a very exhausting period for the male caribou as they fight with other bulls and mating, and weak bull could be an easy target for predator. A hunter reported to have observed very tired bulls.
-1 prime bull could get around 20 cows pregnant. So they are to an important factor to consider to make the population increase.
-The caribou are getting used to the high number of wolf in the calving area, they do not seems to be afraid of them.

Harvest:
-There is currently no sport hunting on the Bluenose and the Dolphin and Union caribou herds
-Kugluktuk HTO sent letters to stop the sport hunt on the Bathurst herds.
-Kugluktuk HTO stopped the sport hunt in the Contwoyto Lake area.
-Hunters do not target prime bulls or pregnant females.
-Nunavut hunters go by snowmobile or ATV to go hunting which restrict the access to the herd due to the terrain. In NWT, they have access to charter plane to hunt the Bluenose Caribou herd.

Predators:
-There is an increase in number of wolf and grizzly, but there is less hunters harvesting them.
-The interaction predator-prey is very complex as you have three predators (wolf, wolverine, grizzly bears) and two main preys (caribou, muskox).
-The price of the wolf pelt is down which do not support the cost to go out hunting.
-Extend the wolf season.
-In the past, Inuit use to kill the wolf in the den to control the predator.
-You don't want to kill them all, as they are useful to take the diseases animals and maintain the herd healthy.
-We need a balance.

Monitoring information:
-Community members suggested to have field report booklet to record note, observation and harvest. Someone commented that they used to have it, but nobody was filling them out.
-Hunters do not have all a GPS while out on the land. They will be interested in participating to the MESA program form NWMB.
-Distributing harvesting calendar which could also use as a tool to collect local, community, and traditional knowledge.

Concerns:
-People feel unsecure to report their harvest, so the number will be used to set up the TAH.
-The participants would like to have some action put together before the population reach a to low level.
-The community members would like to be kept informed about the status of their herd but having a poster that the coop or a wildlife new board.

Suggestions:
-We need to work more closely together
-We can only manage our action and impact, we cannot manage the caribou.
-Establish a caribou board or working group in the community.
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An Estimate of Breeding Females and Analyses of Demographics For The Bathurst Herd of Barren-ground Caribou: 2012 Calving Ground Photographic Survey

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2014

File Report No. 142

ABSTRACT

We conducted a calving ground photo survey of the Bathurst barren-ground caribou (*Rangifer tarandus groenlandicus*) herd from 3-8 June, 2012. The main objective was to obtain an estimate of breeding females that could be compared to estimates from previous similar surveys that have been conducted since 1986. Of particular interest was whether or not the herd had stabilized from the steep decline documented in the 2009 survey. Consistent with previous calving ground photographic survey methods, data from collared caribou and systematic reconnaissance surveys at ten km intervals in the calving ground area were used to delineate the core calving areas, to assess calving status, to allocate sampling to geographic strata of similar caribou density, and to time the photographic survey plane to coincide with the peak of calving. Unlike previous surveys, transect surveys were conducted at 5 km instead of 10 km intervals in the core calving area. Reconnaissance surveys revealed that the majority of breeding caribou were congregated in a relatively small (914 km^2) area with non-breeding caribou distributed in lower densities to the south. Based on collar movements and observed proportions of calves, it was determined that the peak of calving occurred on or about 5 June, 2012 and the photo plane survey was conducted on 6 June. Photo plane survey effort (transect spacing) was stratified into high and medium density blocks with the highest coverage (79.1%) in the high density stratum where the majority of breeding caribou were. The higher level of coverage allowed an adequate number of lines (22) to be placed in the stratum as a means of offsetting potential variance caused by clumped distribution of caribou. Survey conditions were ideal with zero cloud cover, minimal winds and minimal snow cover. Two lower density strata were also surveyed with visual strip-transect methods. Ground-based composition surveys were conducted from 6-8 June to

estimate the proportion of breeding caribou in each of the strata. Survey results revealed that 87.4% of caribou on the core calving ground were within the high density stratum (914 km^2) with 8% occurring in the medium density stratum (644 km^2) and the rest in the two low density strata. The estimate of 1+ yr old caribou on the core calving ground was 24,166 (SE=1,853.6, CI=20,310-28,020) caribou. Using the results of the ground composition survey to adjust this number for breeding females, the estimate of breeding females was 15,935 (SE=1,407.2, CI=13,009-18,861). The estimate of breeding females was very precise with a coefficient of variation (CV) of 8.8%. Comparison of this estimate with the previous estimate of breeding females from 2009 of 16,649 (SE=2,181, 95% CI=12,188-21,110) suggests that the breeding female segment of the herd declined slightly, though not significantly. The rate of decline was much lower than between the 2006 and 2009 calving ground surveys. Results from a data-driven demographic modeling exercise suggest that adult female survival rate was 0.78 (CI range 0.75-0.82) in 2012, which is still below levels needed for a stable herd. A conservative bull-dominated harvest strategy with minimal cow harvest is recommended to minimize adult cow mortality. An increase in the number of radio collars on the herd would greatly assist in managing and monitoring this herd, including more reliable estimates of adult female survival rate.

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INTRODUCTION

The Bathurst caribou herd of barren ground caribou (*Rangifer tarandus groenlandicus*) was named based on its calving ground documented west of Bathurst Inlet since the mid-1990s (Sutherland and Gunn 1996). The Bathurst herd ranges from Bathurst Inlet with the calving range within Nunavut, summer range straddling the border between Nunavut and the Northwest Territories (NWT) and winter range in NWT and northern Saskatchewan (Figure 1). Given its proximity to many communities, the Bathurst herd has been a principal country food and cultural resource for Aboriginal hunters from several groups. In addition, it was harvested by guided outfitter hunts and by NWT resident hunters until 2010.

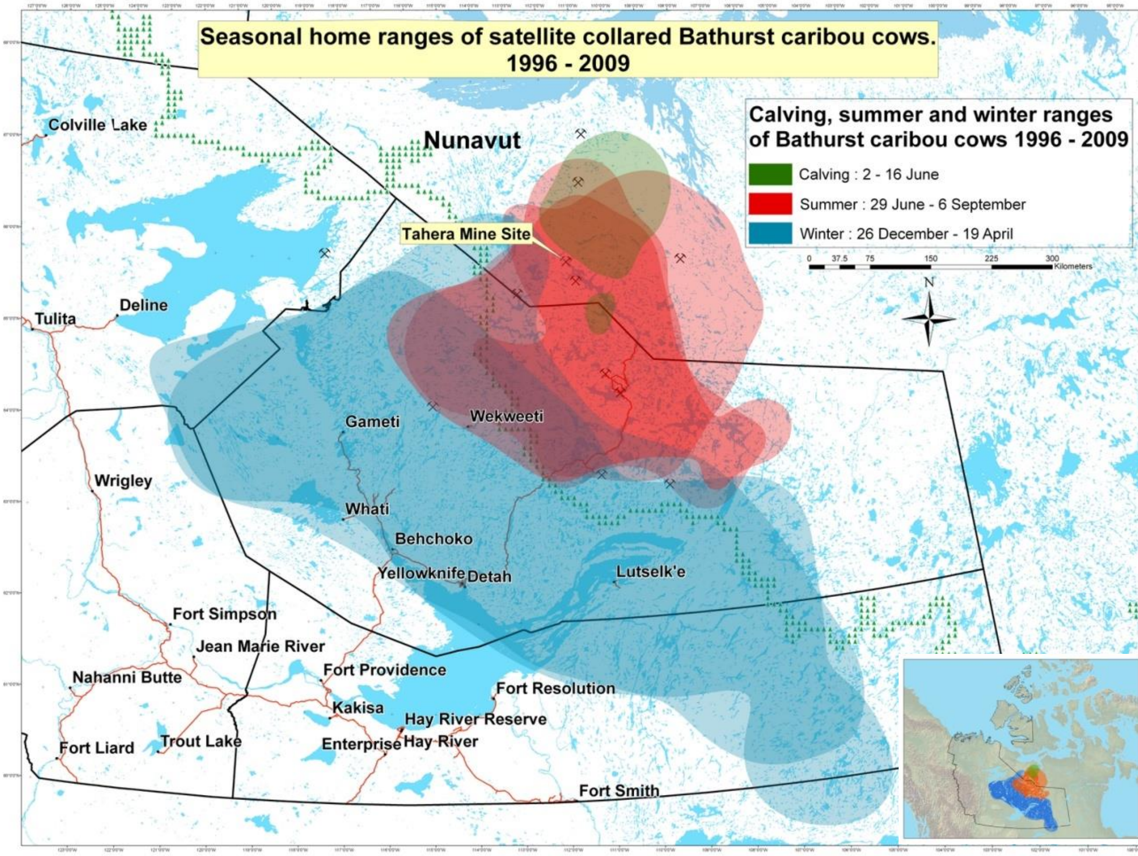

Figure 1: Calving, summer and winter ranges of the Bathurst herd, 1996-2009, based on accumulated radio collar locations of cows. Ranges were delineated using Kernel home range (Worton 1989) smoothing of seasonal radio collared cow locations (Nagy et al. 2011). The location of the Bathurst range relative to the NWT is shown as an inset with Nunavut being to the immediate north of the NWT.

The Bathurst herd of barren-ground caribou was one of the largest of the migratory tundra caribou herds in northern Canada in the 1980s. Herd size was estimated from the number of breeding females, which declined from 203,800 (95% CI=178,197-229,403) caribou in 1986 to 55,593 (95% CI=37,147-74,039) in 2006 and 16,604 (95% CI=12,153-21,056) in 2009 (Heard and Williams 1991, Gunn et al. 1997, Gunn et al. 2005, Nishi et al. 2007, Nishi et al. 2010) (Figure 2). This rapid decline prompted a reduction of hunter harvest of over 90% as well as further investigation of causes of the decline of the Bathurst herd (Adamczewski et al. 2009, Boulanger et al. 2011).

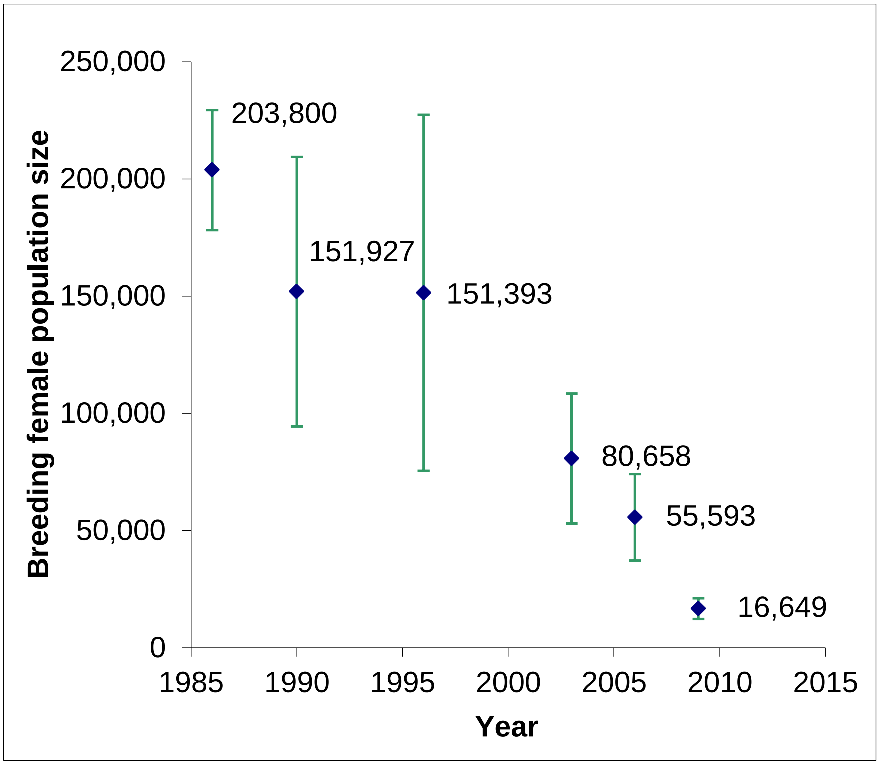

Figure 2: Trends of breeding female estimates for the Bathurst herd from 1986-2009.

This report presents estimates of breeding females and associated herd size for the Bathurst caribou herd from a calving ground survey conducted from 3-8 June 2012. The Bathurst herd has been surveyed using the same calving ground methodology since 1986 (Gunn et al. 1997, Gunn et al. 2005, Nishi et al. 2007, Nishi 2010, Nishi et al. 2010). Therefore, an additional objective was the estimation of overall trend in the population size of the herd. The results from this survey will provide an indication of stabilization or potential herd recovery since the last survey in 2009.

METHODS

The calving ground survey was conducted as a sequence of steps.

1. Locations from collared caribou, historic records of calving ground use and systematic aerial reconnaissance surveys of the Bathurst calving area were conducted to identify core calving areas in the general area to the southwest of Bathurst Inlet.

2. A systematic reconnaissance survey was conducted where transects in 10 km intervals were flown to determine areas where breeding females were concentrated (5 km intervals in the high density areas), as well as locations of bulls, yearlings and non-breeding cows near the calving ground. How far calving had progressed was also assessed from the proportion of cows with newborn calves.

3. Using data from the reconnaissance survey, geographic areas called strata were delineated for sampling by the photo plane with the most sampling effort dedicated to areas with the highest densities of breeding female caribou.

4. A photographic survey plane was then used to sample the higher density and medium density areas while visual strip-transect surveys were used to estimate caribou in lower density strata.

5. While the photo plane conducted the aerial survey, a ground-based composition survey was conducted using a helicopter that landed repeatedly within each stratum to determine the proportion of breeding caribou.

6. Using the estimate of total caribou within the strata and the estimate of proportion of breeding females within the strata, an estimate of breeding females was derived.

7. The breeding female estimate was then used to estimate the total size of the herd and trends in breeding females (Heard 1985, Heard and Williams 1990, Gunn and Russell 2008).

Each component is next described in detail.

Analysis of collared caribou data

Data from collared caribou were monitored during the survey to assess relative location of breeding females on calving ground areas. In addition, change in movement rates was assessed to determine the timing of calving. In general, caribou movement rates are reduced to less than 5 km/day during the peak of calving and for an interval after calving (Gunn et al. 1997, Nishi et al. 2007, Gunn et al. 2008, Gunn and Russell 2008, Nishi et al. 2010). Status of calving was also verified on 3 June shortly after arrival at the base camp by flying the core calving area and by observing the proportion of cows with calves. This information was used to time the photo survey near the peak of calving, when caribou movement rates in the survey area would be lowest.

The relative dispersion of caribou, as indicated by successive minimum convex polygon areas (Mohr 1947), was also assessed to determine if caribou were clustered during the peak of calving compared to time periods immediately before or after calving. The minimum convex polygon method simply connects the outermost caribou locations to provide an index of the overall dispersion of caribou within the herd.

Reconnaissance surveys to delineate strata

As with previous surveys, visual transects were surveyed with 10 km spacing between lines in areas presumed to be the main calving area, as well as the surrounding areas. This resulted in survey ground coverage of 8% for the reconnaissance survey. As in 2009 (Nishi et al. 2010), the Tahera Mine was used to base survey operations (Figure 1). Two DeHavilland Turbo Beaver aircraft were used for surveys, each equipped with a radar altimeter to ensure consistent survey altitude. In visual surveys, caribou were counted within a 400 m strip on each side of the survey plane (800 m total, Gunn and Russell 2008). Strip width was defined by the wheel of the airplane on the inside and wooden doweling defined on the wing strut. Planes were flown at an average survey speed of 160 km/h at an average altitude of 120 m above the ground to ensure that the strip width of the plane remained constant.

Two observers were used on both sides of the survey airplane to minimize the chance of missing caribou. Previous research (Boulanger et al. 2010) demonstrated that this approach increases sightability compared to single observers. During the survey the two observers communicated to ensure that groups of caribou were not double counted.

Caribou groups were classified by whether or not they contained breeding caribou. Breeding caribou were defined by female caribou with hard antlers or presence of calves. A female with a hard antler potentially indicated that the caribou had yet to give birth. Non-breeding caribou were also classified as yearlings (as indicated by a short face and small body), bulls (as indicated by thick, bulbous antlers and large body) and non-antlered females. In most cases, each group was recorded individually, but in some cases groups were combined given that each plane only had a single data recorder. Data were recorded on a tablet computer by a single data recorder in the plane (Figure 3). As each data point was entered, a real-time GPS waypoint was generated, allowing geo-referencing of the survey data.

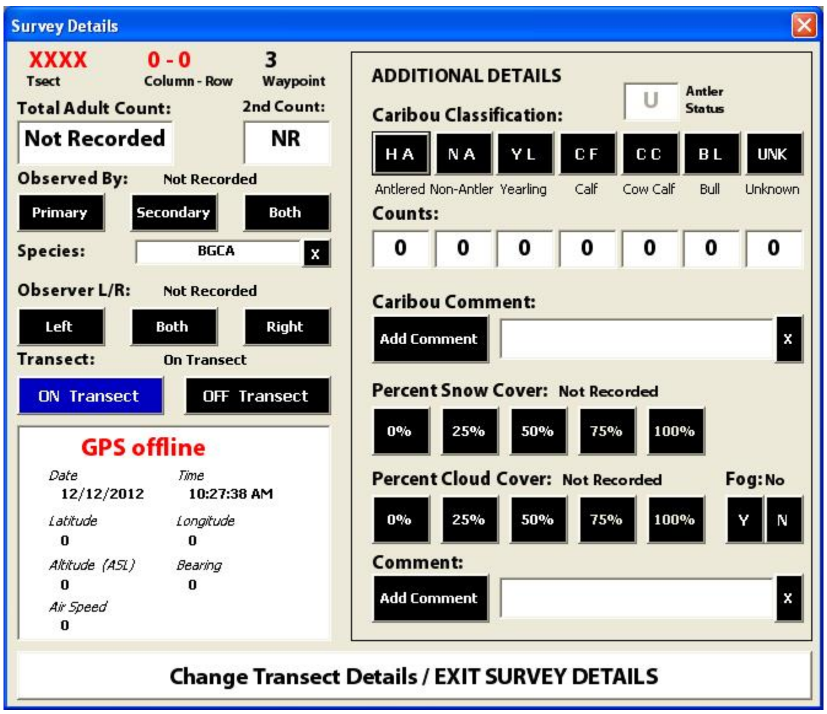

Figure 3: The tablet data entry screen used during reconnaissance surveys. A GPS waypoint was obtained for each observation, allowing efficient entry and management of survey data. In addition, the unique segment unit number was also assigned by the software for each observation to summarize caribou density and composition along the transect lines.

Transects were divided into 10 km north-south segments to summarize the distribution of geo-referenced caribou counts (Figures 3 and 10). The density of each segment was estimated by dividing the count of caribou by the survey area of the segment (0.8 km strip width x 10 km = 8 km^2). The segment was classified as a breeder segment if at least one breeding caribou was detected. Segments were then displayed spatially and used to delineate core calving ground strata based on the composition and density of the segments.

Unlike previous surveys, the core calving area, as indicated by higher densities of breeding caribou, was surveyed at 5 km line spacing. This approach allowed higher resolution in terms of defining caribou distribution and more precise estimates of caribou density within the core calving area. The survey ground coverage for areas with 5 km transects was approximately 16%.

Areas that were to the far west and far east including points to the east of Bathurst Inlet were surveyed to ensure that no larger aggregations of breeding caribou were missed.

Stratification and allocation of survey effort

The main objective of the survey was to obtain a precise and accurate estimate of breeding caribou on the calving ground. To achieve this objective, the survey area was stratified, a procedure in which neighbouring segments with similar density were grouped into a contiguous area so that each stratum enveloped caribou distributions of similar densities. In addition, stratification was used to determine if a stratum required the use of a photo survey plane, or if visual estimates could be used to estimate density. Strata that contained medium to high densities of breeding caribou were surveyed using the photo survey plane, with strata that had low densities being surveyed visually. Given that the objective of the survey was to estimate breeding females, only areas that contained breeding females were surveyed. Areas that contained non-breeders were not surveyed after initial reconnaissance since they would not contribute to the breeding female population estimate.

Once the survey strata were delineated, an estimate of caribou numbers was derived from the reconnaissance data using the formulas of Jolly (1969). The relative population size of each stratum and the degree of variation of each estimate was used to allocate the number of transects in each stratum that would be sampled by the photo-plane, or visual estimate plane.

Two potential strategies for allocation were considered for the aerial survey. First, optimal allocation of survey effort was considered based on sampling theory (Heard 1987, Thompson 1992, Krebs 1998). Optimal allocation basically assigned more effort to strata with higher densities given that the amount of variation in counts is proportional to the relative density and size of caribou within the stratum. Optimal allocation was estimated using estimates of population size for each stratum and survey variance. In the case of this survey, enough photos were available to allow 2,405 km of photo surveys. In addition, it was determined that visual survey planes could survey 2,400 km of transects in a single day.

If strata were reasonably small, then optimal allocation was further adjusted to ensure an adequate number of transect lines for each stratum. In particular, previous surveys suggested that there should be a minimum of ten transects per stratum with closer to 20 transects being optimal for high density areas. In general, coverage should be at least 15% with higher levels of coverage for high density strata. In the context of sampling, increasing the number of lines in a stratum is “insurance” in that it minimizes the influence of any one line on estimate precision. As populations become more clustered, a higher number of transect lines is required to achieve adequate precision (Thompson 1992, Krebs 1998).

Estimation of caribou on the calving ground

For the photo strata, Geographic Air Survey Limited was contracted to fly aerial transects. They used a twin engine Aero-Commander aircraft with a camera mounted on the belly of the aircraft. The aircraft flew at an altitude of 1,100 m above the ground with altitude determined by a radar altimeter which resulted in photos at a scale of 1:4,000. Caribou detected on photos were counted by Derek Fisher, president of Green Link Forestry Inc., Edmonton, AB. The number of caribou counted was tallied by stratum and transect.

For visual surveys, the DeHavilland Turbo Beaver aircraft was used with two observers on each side of the aircraft and a data recorder on each side. The number of caribou sighted by observers was then entered into tablet computers and summarized by transect and stratum.

The counts of caribou by transect and stratum, the total survey area, the proportion of the stratum sampled and number of lines sampled were used to estimate the total number of caribou on each survey stratum using the formulas of Jolly (1969). The actual estimate of caribou in any given stratum is the total count of caribou seen on transects in the stratum divided by the proportional coverage of the stratum. Because calves were not counted, the estimate of caribou in each stratum pertained to 1+ yr old caribou. Confidence limits for estimates were based upon a *t*-statistic with degrees of freedom calculated using the number of lines surveyed in all strata and survey variances (Gasaway et al. 1986).

Composition of breeding and non-breeding caribou on the calving ground

Immediately after photo and visual surveys commenced, composition sampling was undertaken on each of the survey strata. For this, a helicopter (ASTAR 350B2) from Great Slave Lake Helicopters was used to systematically survey groups of caribou allowing more in-depth classification of caribou by breeding status. Caribou groups were predominantly observed from the ground, with a few small groups classified from the air. Caribou were classified following the methods of Gunn et al. (2005) where antler status, presence of an udder and presence of calf is used to categorize females by breeding status while also counting yearlings and bulls (Figure 4).

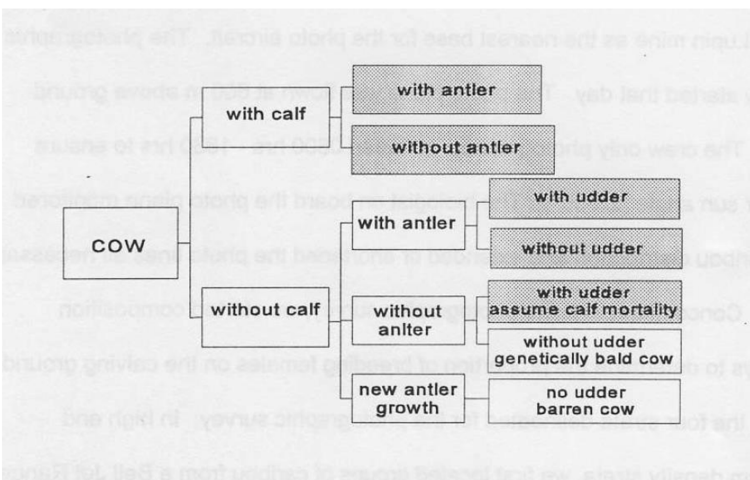

Figure 4: Classification of breeding females used in composition surveys. Shaded boxes were classified as breeding females [diagram from Gunn et al. (2005)].

The number of each group in Figure **2**4 was totalled as well as the number 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 proportions, standard errors and percentile-based confidence limits for the proportion of breeding caribou.

Estimation of breeding females

Breeding females were estimated by multiplying the estimate of total (1+ yr old) caribou on each stratum by the estimated proportion of breeding females in each stratum from composition surveys. This step basically eliminated the non-breeding females, yearlings and bulls from the estimate of total caribou on the calving ground. Each of these measurements has 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).

Estimation of total herd size

Total herd size was estimated in a two-step process. First, the total number of adult (1.5+ yr old) females in the herd was estimated by dividing the estimate of breeding females on the calving ground by the assumed pregnancy rate of 0.72 [Dauphine (1976) and Heard and Williams (1991)]. The estimate of total females was then divided by the estimated proportion of females in the herd based on bull:cow ratios from fall composition surveys conducted in 2011 and 2012 to provide an estimate of total adult caribou in the herd (Heard and Williams 1991). Note that this estimate corresponds to adult caribou and will not include calves of the previous year that were yearlings on the calving ground. All of the estimates associated with herd size have standard errors and the delta method (Buckland et al. 1993) was used to combine variance for the entire herd estimate.

Trends in breeding females

The time series of breeding female estimates was used to assess overall trends in population size for the herd. Trends in breeding female estimates correspond best to the overall reproductive potential of the herd and therefore provide a good indication of overall herd status. Two methods were used to assess trends.

Comparison of estimates with 2009 estimates

As an initial step, the 2012 estimate of breeding females was compared with the 2009 estimate to determine if the two estimates were statistically different, using a *t*-test (Zar 1996) with variances and degrees of freedom calculated using the formulas of Gasaway et al. (1986). This comparison gave an initial indication of change in population size, but did not consider the survey interval between the two surveys. Two regression-based approaches were used to further explore trend.

Weighted regression

Weighted least squares analysis was used to estimate trend from the time series of data (Brown and Rothery 1993). Each estimate of breeding females was weighted by the inverse of its variance to account for unequal variances of surveys and to give more weight to the more precise surveys.

The main question of interest in the regression analysis was whether the trend as indicated by the change from 2009 to 2012 was different than the longer-term trend indicated by previous analyses up to 2009. Previous analyses had indicated that the trend was negative and best described by a cubic polynomial term (Boulanger 2010). Hence, model building focused on comparison of the fit of this model to the newer data set compared to a model that had a breakpoint and new trend from 2009-2012. In addition, other linear and non-linear trend models were considered. The relative fit of models was evaluated using the sample-size-corrected Akaike Information Criterion (AIC_c) index of model fit (Burnham and Anderson 1998). The model with the lowest AIC_c score was considered the most parsimonious, optimizing the tradeoff between bias and precision (Burnham and Anderson 1998). The difference between any given model and the most supported (ΔAIC_c) was used to evaluate the relative fit of models when their AIC_c scores were similar. In general, any model with a ΔAIC_c score of ≤ 2 was considered to be supported by the data. Analyses were conducted with PROC GENMOD and PROC REG within SAS statistical package (SAS Institute 2000).

The population size was log transformed to partially account for the exponential nature of population change (Thompson 1998). Annual population change (λ) was estimated using the ratio of successive predicted population sizes from the regression model. The per capita growth rate (r) was related to the population rate of change (λ) using the equation $\lambda = e^r = N_{t+1}/N_t$. If $\lambda=1$ then a population is stable; values greater or >1 indicate increasing and declining populations, respectively.

Monte Carlo simulation

We used a Monte Carlo simulation technique to provide an estimate of the variance in trend based on the breeding female estimates for each of the surveys (Manly 1997).

The basic question this simulation exercise asked was: “If these studies were repeated many times what would the estimated trends and associated variances be given the levels of precision of each of the individual surveys?” This analysis determined the maximal and most likely range of trend estimates that could be observed from this data set when the variance of each of the surveys was accounted for. The following procedure was used for simulations:

1. *The sampling procedure for each year was simulated using estimates of variance from each of the surveys*. The estimated mean and variance were used from each survey to generate random population sizes for each of the years of the survey. This is best explained in terms of confidence interval (CI) estimation. For a given estimate the 95% CI is the population estimate $\pm\ t_{(\alpha=0.05,2,df)}$*SE. For each simulation a random *t*-distribution variate with associated degrees of freedom for each survey was generated. This random variate was then multiplied by the SE and added to the population estimate resulting in a random population size that followed the general probabilistic distribution of estimates. If done repeatedly, this procedure would create a distribution of estimates for each of the surveys that fell within the given CI. Formulas of Gasaway et al. (1986) were used to estimate degrees of freedom for *t*-statistics.

2. *The sampling procedure was simulated and trend estimates were estimated using regression analysis*. A random set of breeding female estimates were generated for each of the five sampling occasions using the process above and the parameters listed in Table 1. The most supported AIC_c regression model was used for estimation.

This procedure was repeated for 1,000 *pseudo* data sets that resulted in 1,000 estimates of trend.

3. *Estimates of trend from the pseudo data sets were analyzed.* Mean estimates and percentile-based CI based on successive changes in population size were estimated using the *pseudo* data sets.

Exploration of demographic factors influencing population trend

One of the most important questions for the Bathurst herd was whether the breeding female segment of the population was increasing or stable. If the number of breeding cows is stable, then the herd has the potential to increase. The most direct metric that indicates the status of breeding females is their survival rate, which is the proportion of breeding females that survive from one year to the next. This metric, along with productivity (recruitment of yearlings to adult breeding females) determines the overall trend in breeding females. For example, if breeding female survival is high then productivity in previous years can be low and the overall trend in breeding females can be stable. Alternatively, if productivity is consistently high, then slight reductions in adult survival rate can be tolerated. The interaction of these various indicators can be difficult to interpret and a population model can help further test hypotheses regarding breeding female status.

We used the ordinary least squares (OLS) model developed for the Bathurst herd (Boulanger et al. 2011) to further explore demographic trends in the Bathurst data. For this exercise, we used the 2009 and 2012 breeding female estimates as well as calf:cow ratios, bull:cow ratios, estimates of proportion of breeding females, and adult female survival rates from collared caribou 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 herd. The OLS model 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). The details of this model are given in Boulanger et al. (2011).

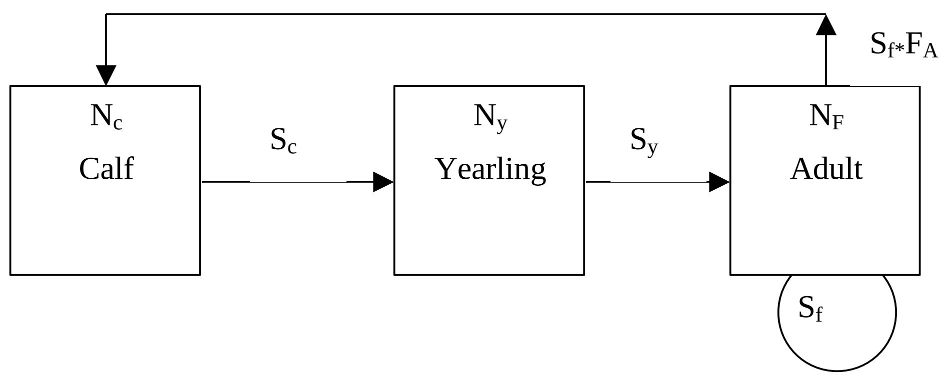

Figure 5: Underlying stage matrix life history diagram for the caribou demographic model. This diagram pertains to the female segment of the population. Nodes are population sizes of calves (N_c), yearlings (N_y) and adult females (N_F). Each node is connected by survival rates of calves (S_c), yearlings (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.

An assumption of the OLS model is that net movement of Bathurst caribou to or from adjacent calving grounds (Bluenose-East and Ahiak) is negligible so that the primary influence of change in population size is survival and recruitment of caribou within the Bathurst herd. This assumption was tested using multi-state models (as detailed in Appendix 1), which found negligible net movement of radio collared caribou between adjacent calving grounds.

We restricted the data set for this exercise to survey results between 2007 and 2012. Using this approach ensured that past demographic values, that were recorded during the decline, did not unduly influence the estimates for the principal time frame of interest (the interval between the 2009 and 2012 surveys). This interval basically covered potential recruitment into the breeding female class since any female calf born 2007-2009 had the potential to become a breeding female in 2012 and breeding females recruited prior to 2007 were accounted for by the 2009 calving ground estimate of breeding females (Table 1). It was assumed that a calf born in 2007 would not breed in the fall after it was born, or the fall of its second year, but it could breed in its third year. It was considered a non-breeder until 2010. Given this time-lag, productivity (calves born) in 2007, 2008 and 2009 had the most direct bearing on the number of new breeding females on the calving ground that were not accounted for in the 2009 breeding female estimate. Calves born after 2009 would not have matured to be counted as breeding females and thus productivity for this time period was less relevant to the 2012 breeding female estimate.

Table 1: A schematic of the assumed timeline in the OLS analysis in which calves born are recruited into the breeding female segment (green boxes) of the population. The OLS model assumes that caribou are not capable of breeding in the fall rut until they are recruited into the adult class on the fall prior to the breeding ground survey. Productivity (calves born) in 2007-2009 had the most direct bearing on recruitment of breeding females counted on the 2012 survey (brown boxes). Calves born prior to 2007 were counted as breeding females in the 2009 survey and calves born after 2009 had not recruited into the breeding female segment and were therefore not counted. Surveys in 2006, 2009 and 2012 estimated breeding females.

Calf born	Status 2006	2007	2008	2009	2010	2011	2012
2006	calf	yearling	non-breeder	breeder	breeder	breeder	breeder
2007		calf	yearling	non-breeder	breeder	breeder	breeder
2008			calf	yearling	non-breeder	breeder	breeder
2009				calf	yearling	non-breeder	breeder
2010					calf	yearling	non-breeder
2011						calf	yearling
2012							calf

We used a sequential model building process where we first built a model that considered the dominant trends in productivity (calf survival) as indicated by calf:cow ratios. We then tested for trends in adult female survival and adult male survival. The main reason for testing the male survival models was to explore hypotheses regarding change in bull:cow ratios as opposed to a comprehensive analysis of male survival. Models were compared using information theoretic methods as for the breeding female trend analysis.

Estimates of adult female survival were then compared to levels of productivity to assess the demographic mechanisms for change in the relative numbers of breeding females. This same exercise was conducted for the bull segment of the population. Various adult female survival values were input into the most supported model to determine the relative influence of adult female survival on breeding female trend and on overall herd trend.

One potential bias in calf:cow ratios prior to 2009 was lowered over-winter survival of cows due to harvest after calves had weaned. In this case, the calf:cow ratio was potentially over-estimated as an estimate of productivity since the denominator (cow numbers) was reduced relative to the numerator (calf numbers). We conducted sensitivity analyses on this issue by considering models that estimated separate survival rates for the period prior to 2009 and by directly modeling the bias by introducing a term into calf:cow ratios that reduced adult survival rate, mimicking the potential bias.

While the OLS model uses the relative precision of field measurements as a means of weighting the influence of data sets in the model, it still is a deterministic population model. Thus the predictions of the model do not necessarily provide an assessment of uncertainty in OLS model prediction. We further considered how the OLS model predictions related to the point estimates of breeding female numbers, as well as the confidence limits of the breeding female estimate. This provided an indication of the range of adult female survival values that could occur within the range of the confidence limits of the 2012 breeding female estimate.

RESULTS

Survey conditions

Weather during the survey was ideal with temperatures between 10 and 20°C, low to moderate winds and minimal cloud cover. High temperatures prior to the survey resulted in low snow cover in the majority of the survey area compared to the 2009 survey. In general, snow cover was less than 5% (Figure 6) and sightability of caribou was optimal. The early spring was indicated by low snow cover as well as the Hood River being ice-free during the time of the survey.

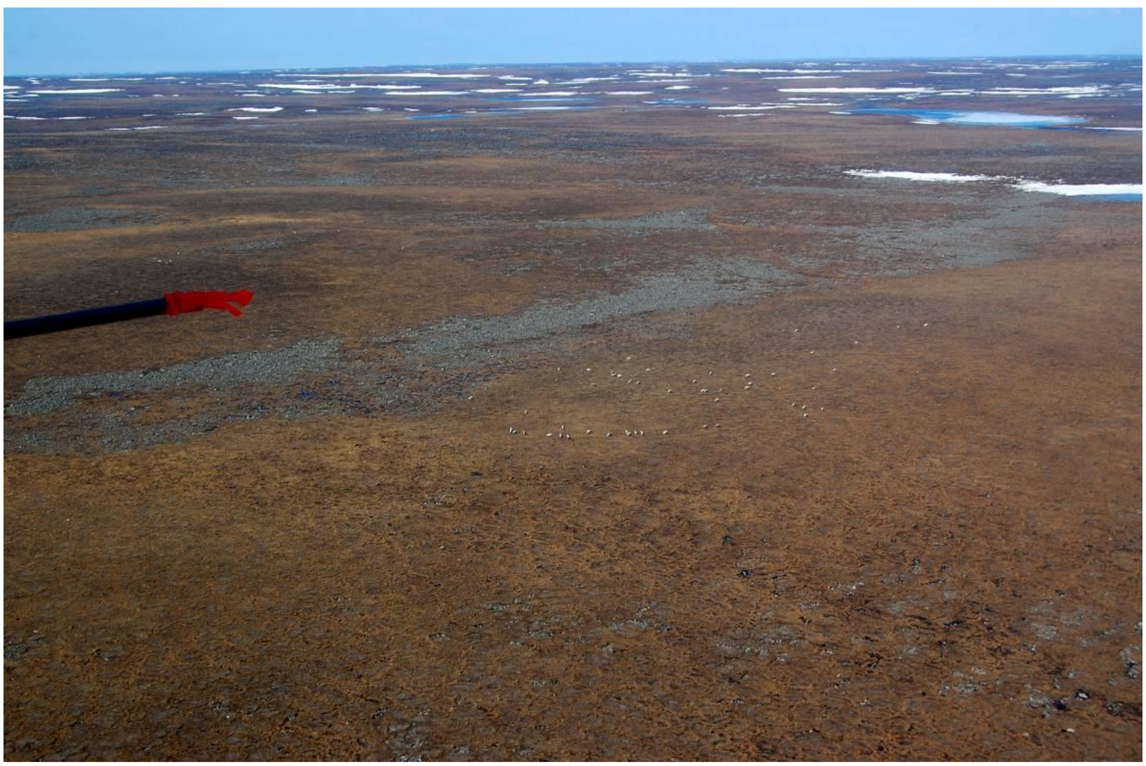

Figure 6: A group of caribou observed in the high density stratum on 5 June, 2012. In general, snow cover was minimal (<5%) for the core survey area with minimal cloud cover during surveys. The black-red bar is the survey strip marker.

Analysis of collared caribou data

Eighteen adult female caribou were tracked during the calving ground survey using GPS collars. The general path of movements to the calving ground was north-northeast (Figure 7). The date of arrival on the core calving area as delineated by crossing of latitude 66.4°N (which was the approximate southern boundary for survey strata in 2009 and 2011) for 17 of 19 collared caribou was 22 May, 2012. This contrasts with 2009 when 11 of 14 collared caribou did not pass this latitude until 2 June. We suspect that the early spring and snow melt improved travel conditions and led to a relatively early arrival of caribou on the calving ground.

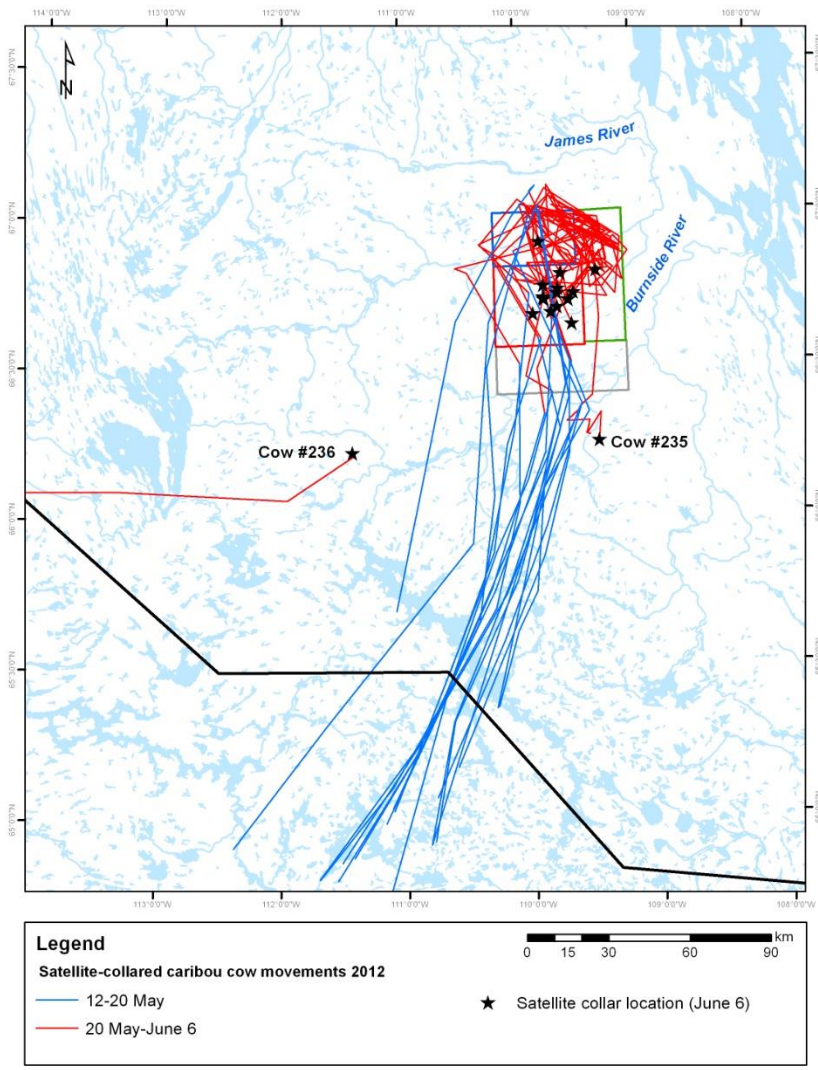

Figure 7: Movements of collared caribou to the calving ground area from 12 May to 6 June. Locations from 12-20 May are given as a blue line and locations from 21 May to 6 June are given as a red line. The location of caribou during the photo survey on 6 June is noted.

All collared caribou congregated in the core calving area except for a female that was approximately 17 km south of the core area (ID=235) and a female that was 58 km to the southwest (ID=236) (Figure 7). A survey plane flew in the general area of collared caribou 235 and spotted an isolated hard antler female caribou but did not detect any large congregations of breeding caribou or presence of calves. More exactly, no caribou were spotted on the segment closest to the collared caribou location and of the nine segments surrounding the location, only four hard antlered caribou were spotted (of 34 caribou seen total in the adjacent segments). Caribou 236 had arrived from the west in isolation from other collared caribou. Aerial survey in the vicinity of this caribou did not detect any clusters of breeding caribou and/or presence of calves. Both of these caribou appeared isolated from the main groups of breeding caribou to the north and were likely non-breeders.

Movement rate estimates (Figure 8) indicated that rates decreased until 5 June and stayed low until 13 June suggesting that the peak of calving started on 5 June with increased movement after 13 June which was likely when calves became more mobile.

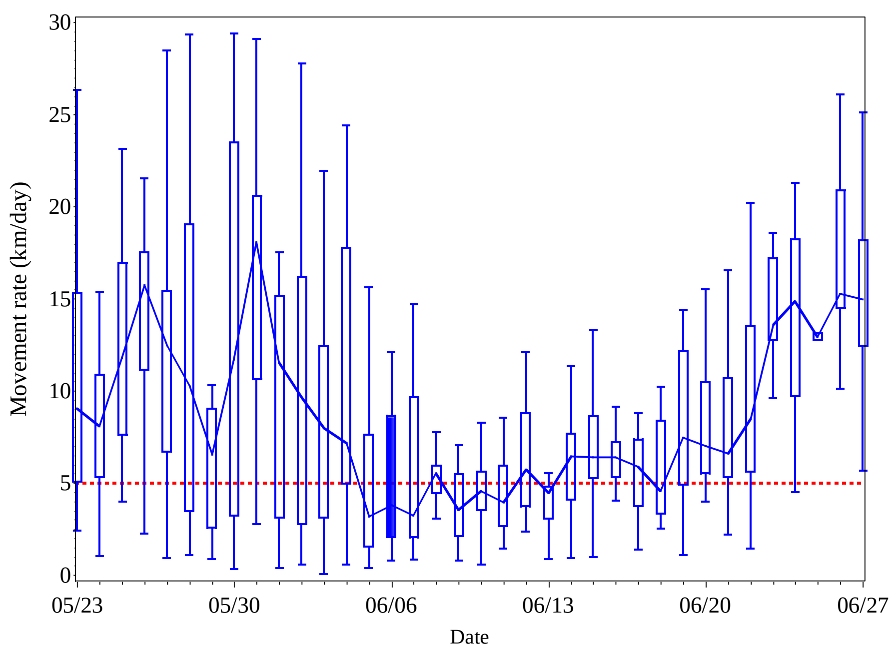

Figure 8: Movement rates (km/day) for Bathurst caribou before, during and after the calving ground survey. The distribution of movement rates is shown as box-plots with lines connecting median values, the boxes denote 25th and 75th percentiles and the whiskers denote the range of the data. The solid blue box indicates 6 June when the photo survey occurred.

A plot of minimum convex polygon area using locations of individual caribou by each date also revealed that the caribou congregated into a successively smaller area with the most notable decreases occurring in late May when caribou arrived into the vicinity of the calving ground (Figure 9). Areas were calculated with and without caribou 236 which was separated from the main group of collars and approached the calving ground from the west (Figure 9). On 6 June the core group of collared caribou (with caribou 236 excluded from the area estimate) were in an area of 1,050 km^2.

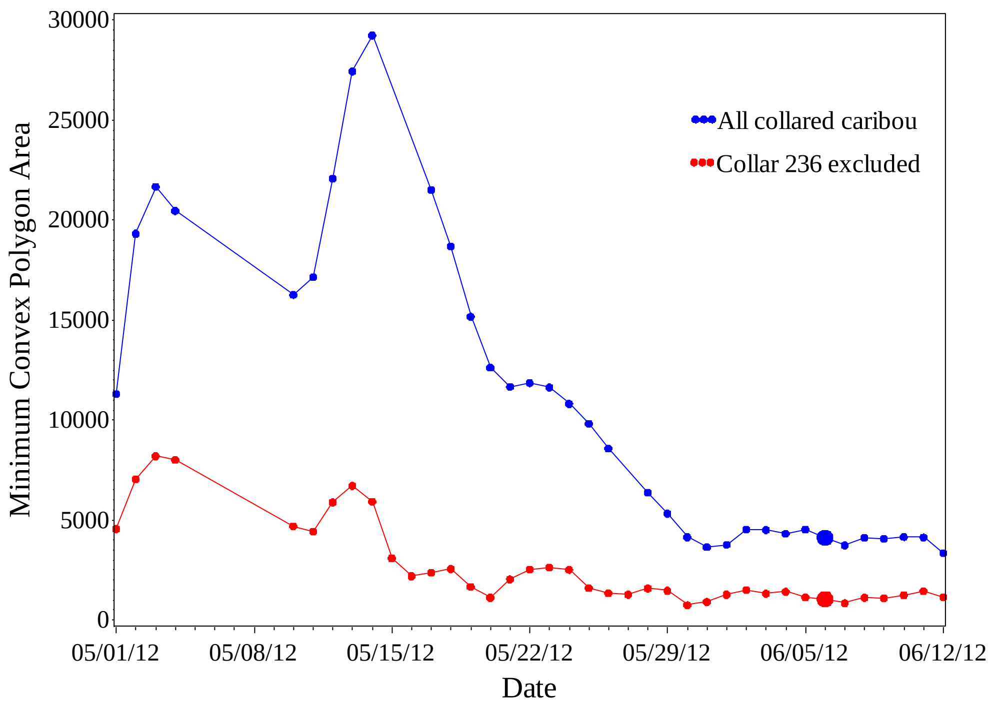

Figure 9: Minimum convex polygon area (km^2) by date for collared caribou in the vicinity of the Bathurst calving ground. Areas were produced with and without caribou 236 that was to the west of the calving ground (Figure 7)**.**

Reconnaissance surveys to delineate strata

Two DeHavilland Turbo Beaver aircraft flew reconnaissance surveys from 3-7 June to initially delineate the core calving area and then verify non-occupancy in areas surrounding the core calving area as summarized in Table 2. In total, 10,605 km of transect sampling were flown during reconnaissance and visual surveys. The results of systematic reconnaissance surveys revealed that the majority of breeding females were in a relatively small area of approximately 30 by 30 km. Few to no caribou were detected in areas to the west and to the east and areas to the south were composed mainly of non-breeding caribou (Figure 10). Low densities of breeding and non-breeding caribou were detected to the north.

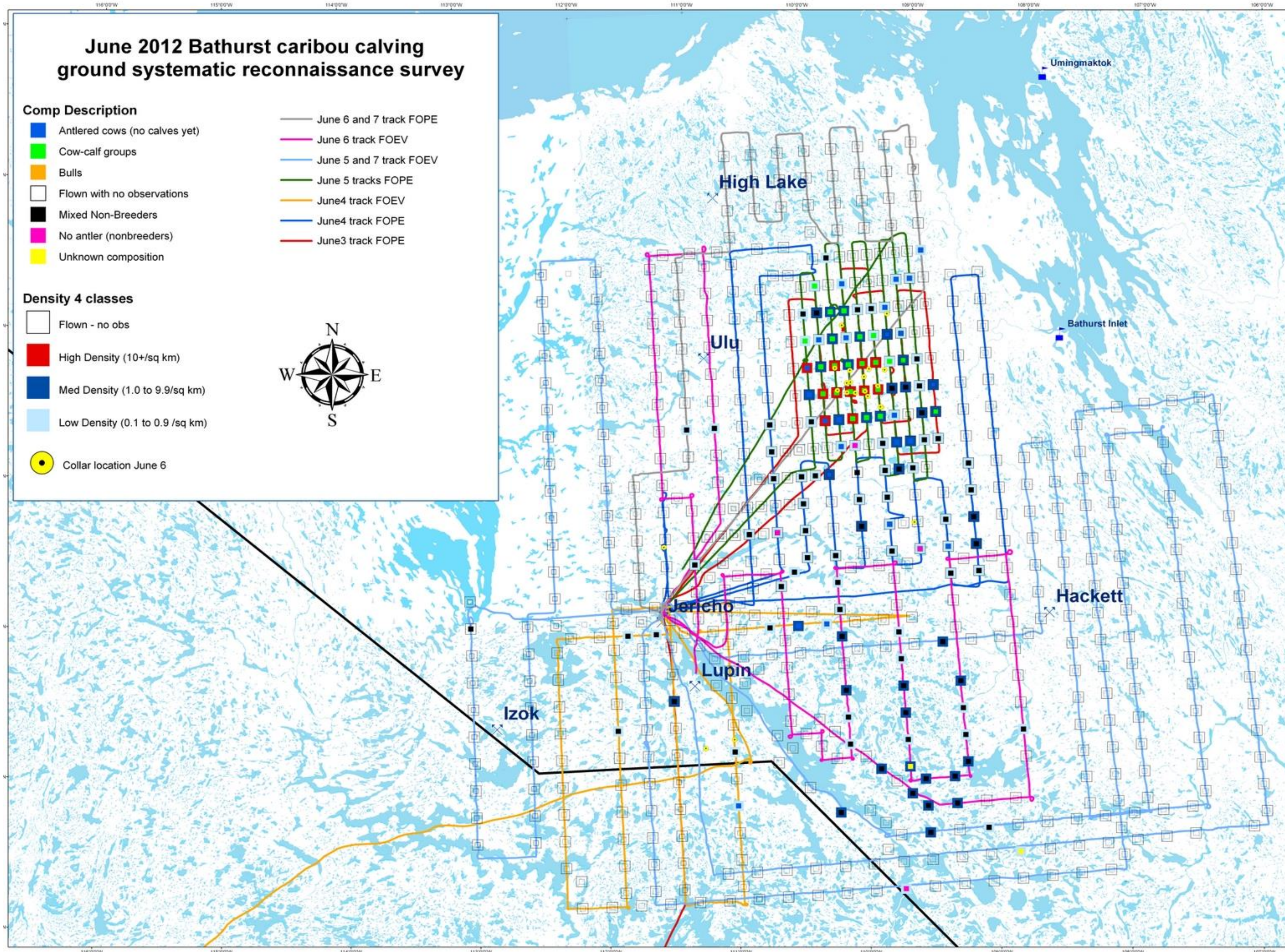

Figure 10: Reconnaissance survey coverage for two Turbo Beaver aircrafts (FOEP and FOEV) with flight lines by date.

Table 2: Summary of reconnaissance and visual survey efforts of the two Turbo Beaver aircraft during the 2012 calving ground survey as also summarized in Figure 10.

Date	Turbo Beaver 1 (FOPE)	Turbo Beaver 2 (FYOP)
3 June	• Yellowknife to Jericho • Preliminary delineation of core calving area and assessment of breeding status of caribou	• Yellowknife
4 June	• Segments immediately to the west, south and east of core calving area (delineated on 3 June)	• Yellowknife to Jericho • Segments to the southwest of Jericho
5 June	• Systematic reconnaissance and further delineation of core calving area	• Segments to the southeast of Jericho
6 June	• Visual survey of the Low East and Low South stratum • Further reconnaissance survey of areas to the west of core calving area to verify non-occupancy	• Areas to the northwest of core calving area to verify non-occupancy of breeding females.
7 June	• Survey of areas to the north and west of core calving area to verify non-occupancy of breeding females.	• Survey of area to the south of Bathurst Inlet to verify non-occupancy of breeding females.

In three segments to the south, single hard antlered caribou or small groups of hard antlered caribou were observed but in all cases these groups were small in size (segment group sizes of one, four hard antlered caribou in two segments to the south of the core calving area). To the north, a single hard antlered caribou was observed to the northeast of the core calving area but adjacent segments contained no caribou or non-breeding caribou (Figure 10, 11). We are confident that the stratified survey area included the core breeding female population.

Stratification and allocation of survey effort

The core calving area was initially surveyed on 3 June with the primary objectives of delineating the core calving area and to obtain a first assessment of how far calving had progressed. On 5 June, a systematic survey was conducted in which the core calving area was surveyed with 5 km spacing and the adjoining areas at the standard 10 km transect spacing

(Figure 11). From this, strata were defined based on gradients in density observed in reconnaissance surveys.

The area 20 km to the north of the proposed segments had single or small groups of antlered caribou spotted in four of the segments, but the actual densities in this area were low (average density=0.06 caribou/km^2). The actual survey coverage in this area was 16% given that transect lines spaced at 5 km intervals were sampled. If the segment densities were extrapolated to this area the resulting estimate of caribou was 56. Given the low densities of caribou, this area was not surveyed further.

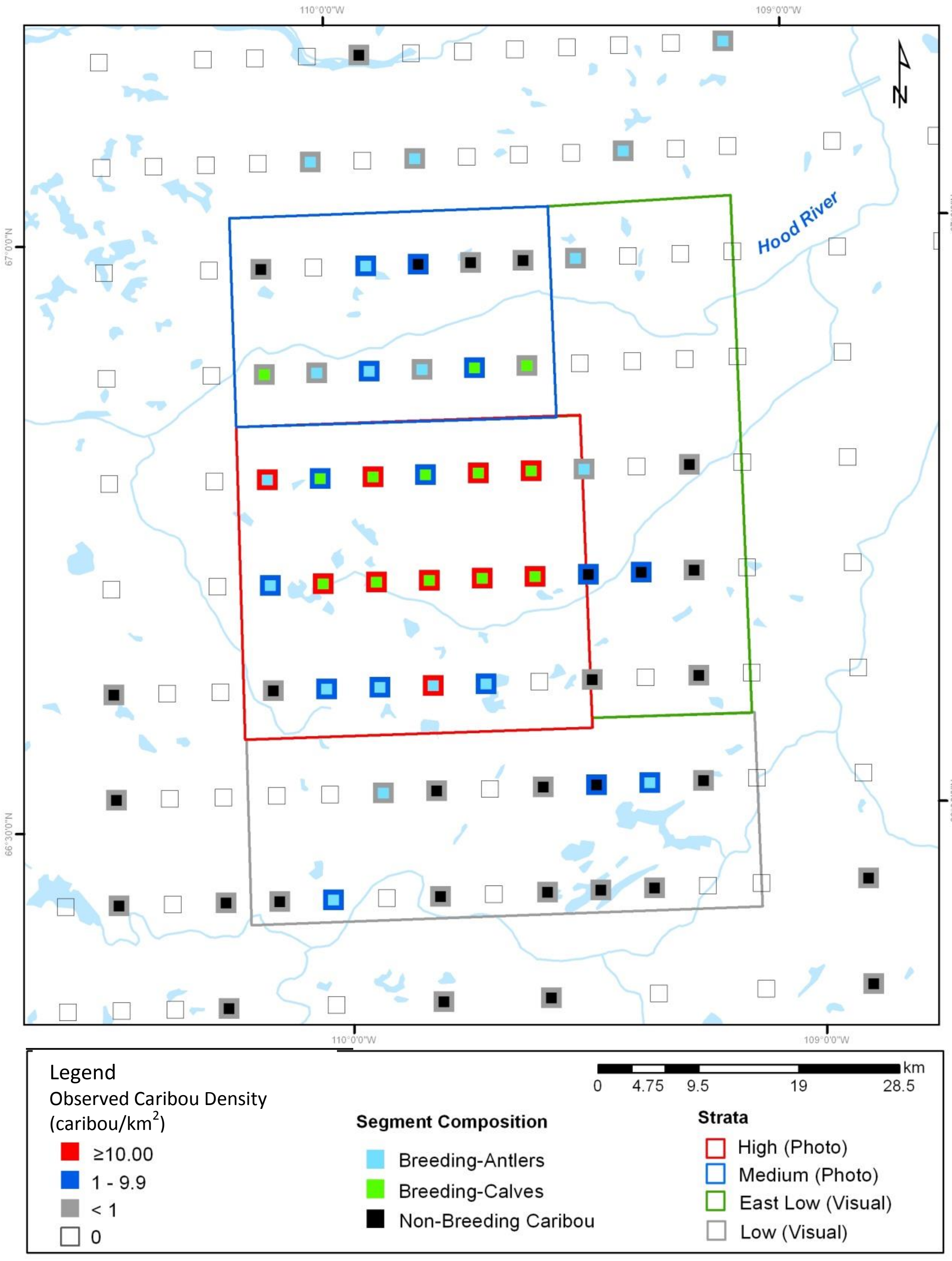

Figure 11: Segment densities and composition with sampling strata.

Comparison of the proportion of calves counted in the eventual medium and high density strata showed an approximate doubling (high stratum) to tripling (medium stratum) of the proportion of calves from 3-5 June, suggesting that the caribou were close to the peak of calving (Table 3). The estimates of proportion of calves will be conservative given lower sightability of newborn calves compared to adults. The estimated proportion of calves associated with peak of calving in 2009 was 27.1% (based upon eight segments) (Nishi et al. 2010) and percentages of calves were close to this on 5 June, 2012. Composition surveys on 6 and 7 June resulted in estimates of 49% (2,258 calves/4,612 1+yr caribou) and 60.9% (337 calves/553 1+ yr caribou) respectively. Overall, our data indicate that the peak of calving likely occurred 3-5 June and thus the photo survey occurred at or near the peak of calving.

Table 3: Summary of the number of total caribou observed, calves observed and proportion of calves for segments surveyed in the medium and high density strata. Only segments surveyed on both 3 and 5 June were included in the comparison to ensure the same general sampling areas were used to assess trends.

Stratum	Date	Total caribou counted	Total calves counted	Proportion of calves	Number of segments
High	3 June	888	112	12.6%	10
	5 June	1,582	378	23.9%	10
Medium	3 June	347	41	11.8%	6
	5 June	101	40	39.6%	6

Inspection of segment densities revealed higher densities in the core area with lower densities (<5 caribou/km^2) in all other strata (Figure 12). In particular, there were very high densities of caribou in the northeast corner of the proposed high stratum. Of the 19 collared caribou that were monitored, 15 were on the high stratum, one on the medium stratum, one on the Low East stratum and two to the south of calving ground sampling area on 6 June. The same numbers of collared caribou were present on each of the survey strata on 7 June suggesting little or no movement of caribou out of the strata during the photo survey.

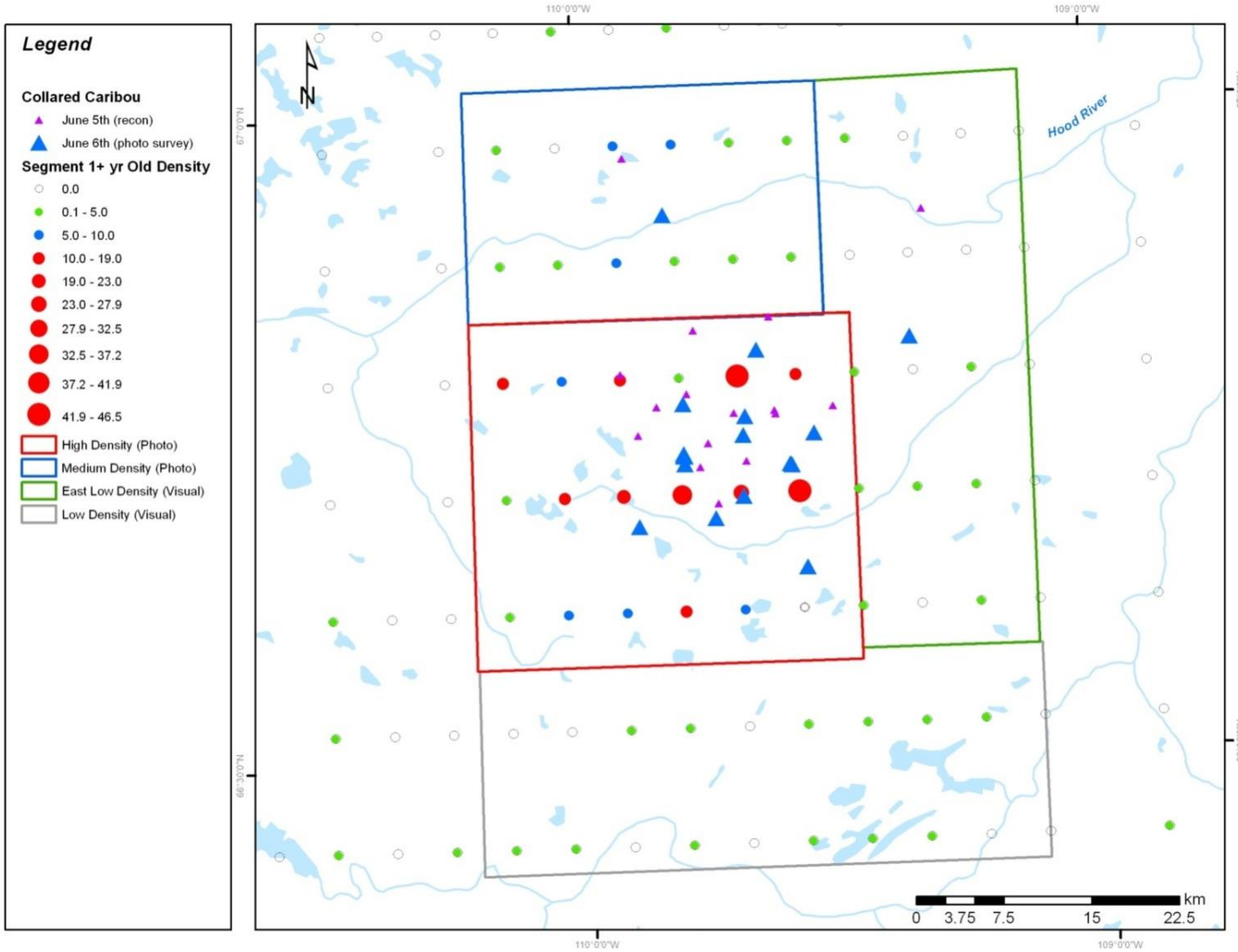

Figure 12: Segment densities as indicated by color coding and symbol size. Locations of GPS collared caribou during the reconnaissance survey of the core area (5 June) and during the photo and visual survey (6 June) are also shown.

Estimates from reconnaissance flying corroborated that the majority of breeding caribou were in the high density stratum area (approximately 86%) with 8.1% in medium density and the rest in lower density strata (Table 4). The estimates from the initial reconnaissance flights were not meant to provide precise estimates of caribou on survey strata.

Table 4: Summary of strata defined from reconnaissance survey with relative estimates of caribou numbers. Stratum and transect dimensions are given as well as reconnaissance-based estimates of stratum density ($\hat{\boldsymbol{D}}$) and stratum population size ($\hat{\boldsymbol{N}}$).

Stratum	Dimensions		Transects			Reconnaissance estimates			
	Area (km^2)	Baseline (km)	Max. possible	Sampled	Ave. width	$\hat{D}$	$\hat{N}$	$SE(\hat{N})$	% of sum of $\hat{N}$
High	914.24	28.2	32.6	6	32.7	15.20	12,313	2363.9	85.6
Medium	644.00	32.1	21.7	6	19.9	2.17	1,172	245.1	8.1
Low East	782.91	48.5	60.6	6	16.0	0.35	274	160.5	1.9
Low South	865.74	48.7	60.9	6	18.1	0.66	575	288.9	4.0

The large range of densities within the high strata created a potential issue of large variation in densities between survey lines which would result in lower precision of estimates (Figure 13). The relatively small area of high densities precluded further stratification of sampling given that the likelihood of larger-scale caribou movement between strata increases as strata size is reduced. For example, the relatively large size of the high density strata ensured that all of the collared caribou that were within the high strata on 5 June were still encompassed by this stratum on 6 June. If this stratum were smaller, it would be possible that caribou would move out of the strata between reconnaissance and photo surveys, or during photo surveys. This would increase possibilities for double-counting and compromise the population estimates.

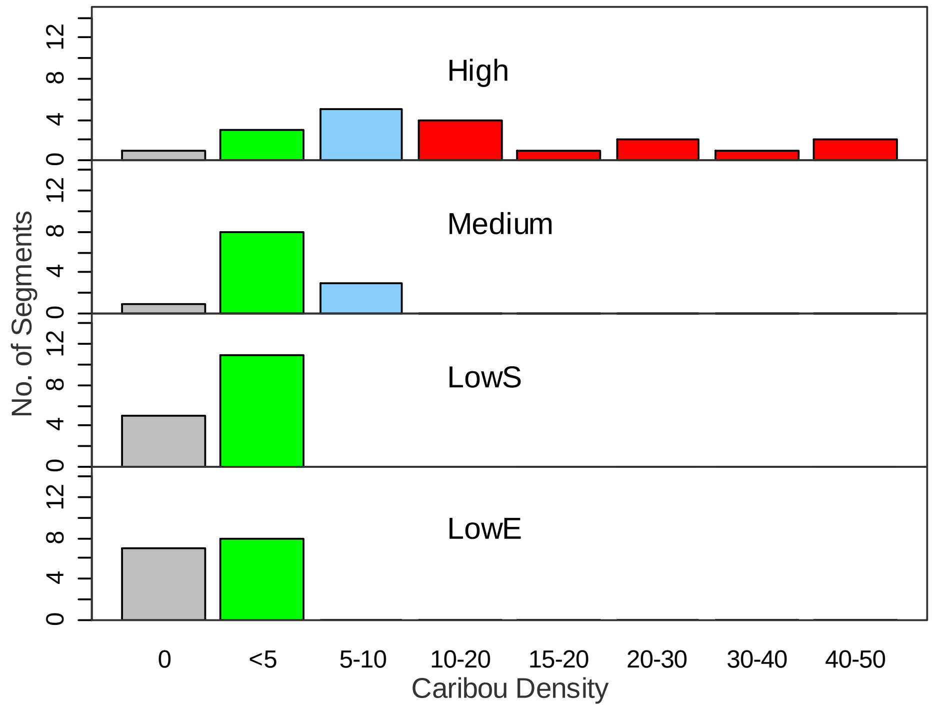

Figure 13: Frequencies of segments of different densities (caribou/km^2) observed during reconnaissance surveys for each stratum.

As a first step in planning transects within strata, estimates of caribou on each stratum were run through an allocation program to assess the proportional photo survey effort each stratum should receive to optimize estimate (Table 5). The program suggested that the high photo stratum receive most (90%) of the survey effort compared to the medium stratum. This amounted to more than 100% survey coverage if the entire number of photos available was used. We scaled this amount down to a number of transects (22) that would most likely ensure adequate survey precision. The resulting coverage (72%) was higher than high stratum had received in previous surveys. However, we felt higher coverage was justified as this area had a large range of caribou densities. Adding more lines and coverage was "insurance" against potential issues of low precision created by sampling this clustered distribution of caribou.

Table 5: Allocation of effort to photo strata based upon maximum km of photo transects possible (2,400 km).

Stratum	Based on population size	Based on variance	Km of transect	Coverage	Proportion survey effort
High	72	75	2,153.9	≥100%	0.90
Medium	13	8	251.1	37.2%	0.10

To further ensure adequate precision for the high stratum, we assessed spatial trends in segment densities to ensure that transects were sampled perpendicular to gradients in density. Transects in the high stratum were oriented East-West due to the gradient in density from East to West (Figure 14) and therefore transect sampling occurred against this gradient. In contrast, in the South to North direction, densities were highest in the middle of the strata with lower densities on the northern and southern sections.

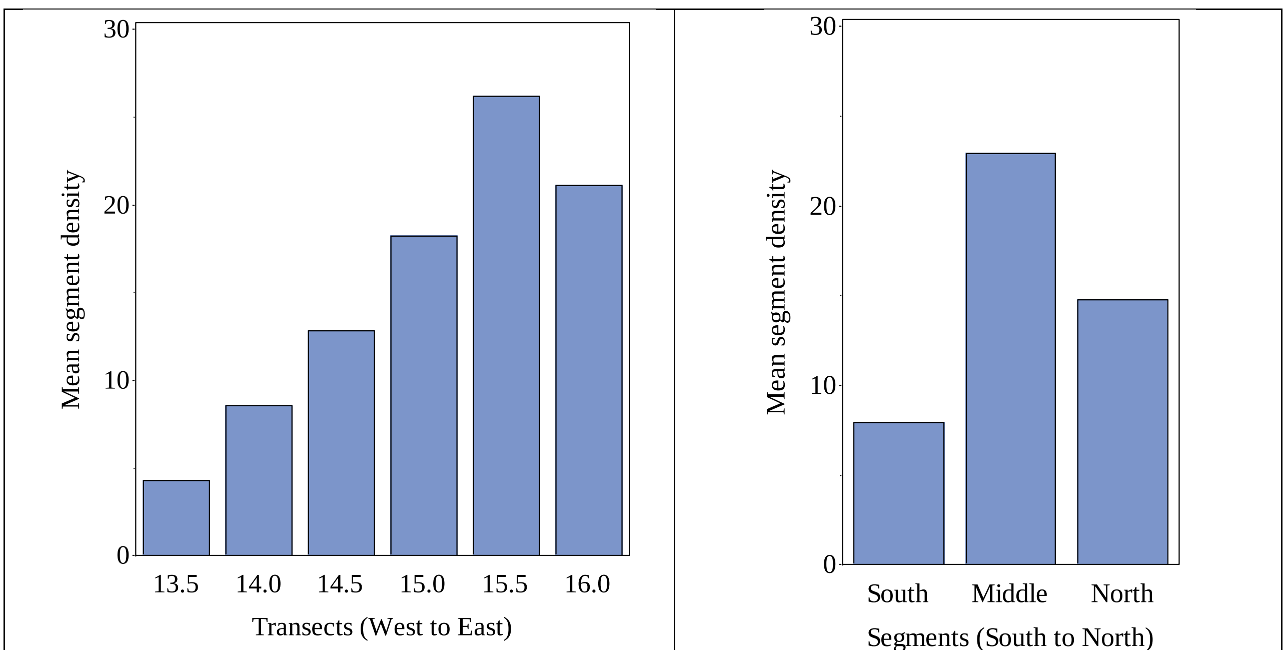

Figure 14: Segment densities from reconnaissance surveys (caribou/km^2) grouped West to East (left figure) and South to North (right figure) demonstrating the west to east density gradient in the high stratum. Transect lines were flown at 5 km intervals in the north to south direction resulting in six transects for this direction. For the South to North direction, segments were spaced at 10 km intervals, resulting in three segments.

The medium density stratum was sampled in a North to South direction due to its North-South gradient in density and received 14 survey lines. This amount of effort was close to that recommended by optimal allocation (Table 5).

The low strata had very low densities of caribou and contained mainly non-breeding caribou (Table 4). Therefore, these areas received enough coverage to ensure adequate estimates of precision, but did not require substantive survey effort. The final layout of strata had most of the survey effort occurring in the high and medium photo strata with less effort in the visual strata (Table 6). The final layout for transects is shown in Figure 15.

Table 6: Final dimensions and survey effort for each stratum. Sampling coverage is based upon transect area compared to total stratum area.

Stratum	Survey type	Maximum transects	Area of stratum (km^2)	Average transect width (w_i)	Base line width (l_i)	Transects sampled	Sampling coverage
High [A]	photo	30.8	914.2	32.7	28.2	22	71.9%
Medium	photo	35.1	644.0	19.9	32.1	14	39.6%
LowE[A]	visual	60.6	782.9	16.0	48.5	12	21.2%
LowS	visual	60.9	865.7	18.1	48.7	15	25.1%

[A]Stratum was flown in an East to West direction.

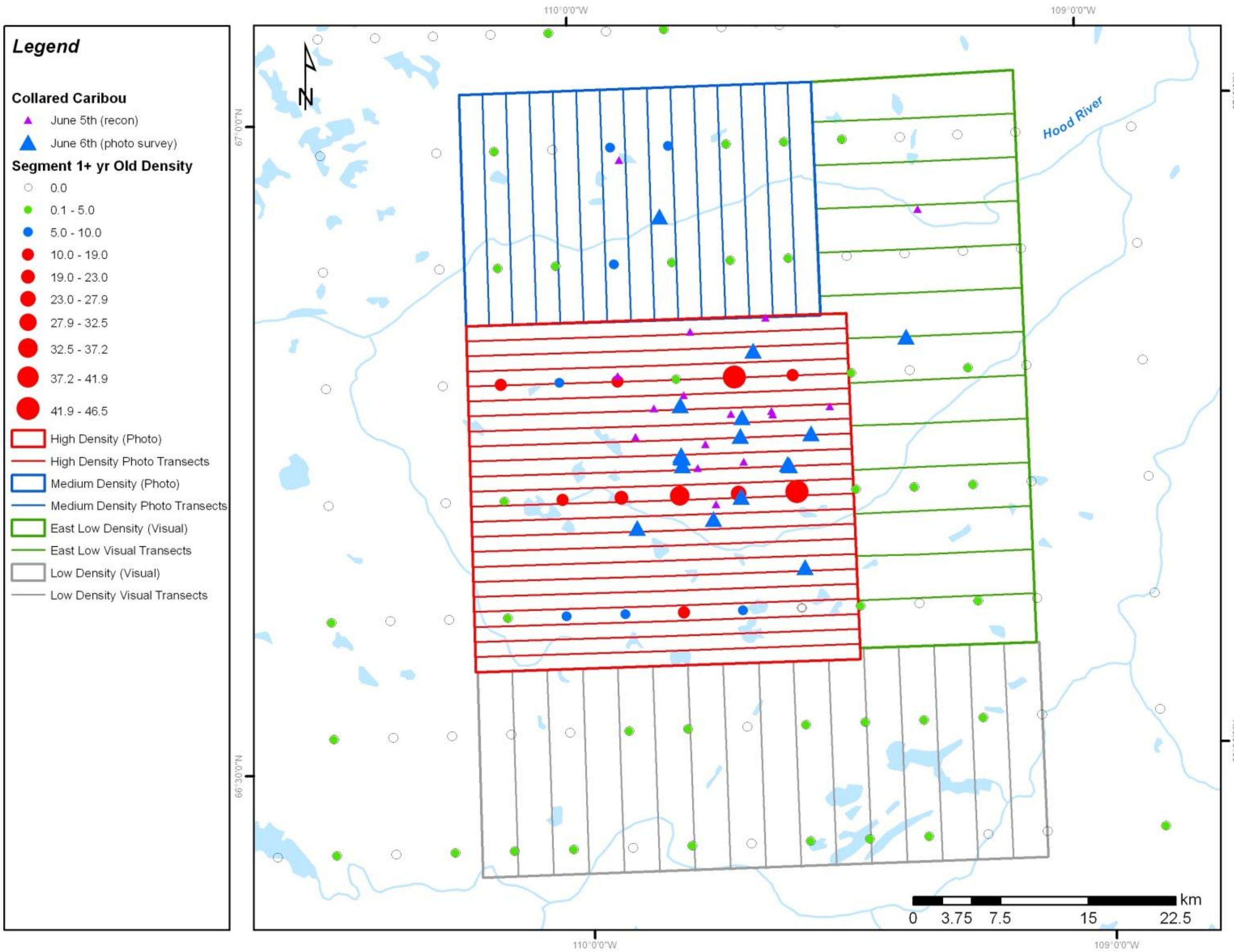

Figure 15: Final strata layout with transect lines, segment densities and collared caribou locations during the recon survey (5 June) and visual and photo survey (6 June).

Photo and visual survey

The high and medium photo strata were flown on 6 June with the majority of the photography completed by early afternoon and the medium stratum being surveyed during the later afternoon. The visual strata were surveyed on the same day with the Low East and Low South strata completed by early afternoon. Survey conditions were favorable with unlimited survey ceilings.

The majority of caribou (87.4%) were estimated to be within the high stratum with 8% occurring in the medium photo stratum and the remainder of caribou in the Low East (0.9%) and

Low South (3.6%) visual strata (Table 7). Coefficients of variation on estimates ranged from 0.08 for the high stratum to 0.46 on the Low East stratum. Because the majority of caribou were in the high stratum, the precision of the estimate from this stratum mainly dictated the precision of the overall estimate of one year old and older caribou on the calving ground (0.08). The resulting total estimate of 1+ caribou on the calving ground was 24,166 (SE=1,853.6, CI=20,310-28,020). CI were based upon a *t*-statistic of 2.08 with 21° of freedom.

Table 7: Estimates of the total number of caribou on the calving ground for each stratum. The standard error (SE), CV and percent of the total estimate is given for each stratum. Raw data for individual transects is given in Appendices 3-4.

Stratum Characteristics					Caribou Numbers in Survey Strata					
Stratum	Lines flown	Transect area	Stratum area	Coverage	Caribou counted	Average density	$\widehat{N}$	SE	CV	% of sum of $\widehat{N}$
<u>Photo strata</u>										
High	22	657.7	914.2	71.9%	15,201	23.1	21,129.6	1,750.5	0.08	87.4
Medium	14	254.8	644.0	39.6%	768	3.0	1,940.8	558.2	0.29	8.0
<u>Visual strata</u>										
Low East	12	166.1	782.9	21.2%	47	0.3	221.5	102.5	0.46	0.9
Low South	15	217.0	865.7	25.1%	219	1.0	873.6	222.4	0.25	3.6
Totals							24,166	1853.6	0.08	

Despite higher coverage, the actual km of photo transects flown in 2012 were 998 km in comparison with 5,156 km flown in 2009. This was due to the core calving area in 2012 being much smaller than in 2009 and thus high coverage could be achieved with less flying. For example the area of the high and medium strata in 2009 was 2,608.1 and 2,113.1 km^2 whereas the area of the high and medium for 2012 was 914.2 and 644 km^2 (Figure 16). The relatively small area for the high and medium in 2012 allowed the photo-plane to survey the high and medium density strata quickly and with high coverage.

A randomized re-sampling exercise was conducted to assess the relationship between survey coverage, estimates of caribou in survey strata and precision of estimates of caribou in survey strata. This exercise, which is presented in Appendix 2, demonstrated that higher coverage (n=20 lines with coverage=65%) was required in the 2012 survey to obtain estimates of higher precision (coefficients of variation of less than 10%) for caribou on the high stratum calving ground. Ground coverage of 49% (15 lines) would have resulted in a CV of 13.4%. The population estimate varied little with small changes in coverage.

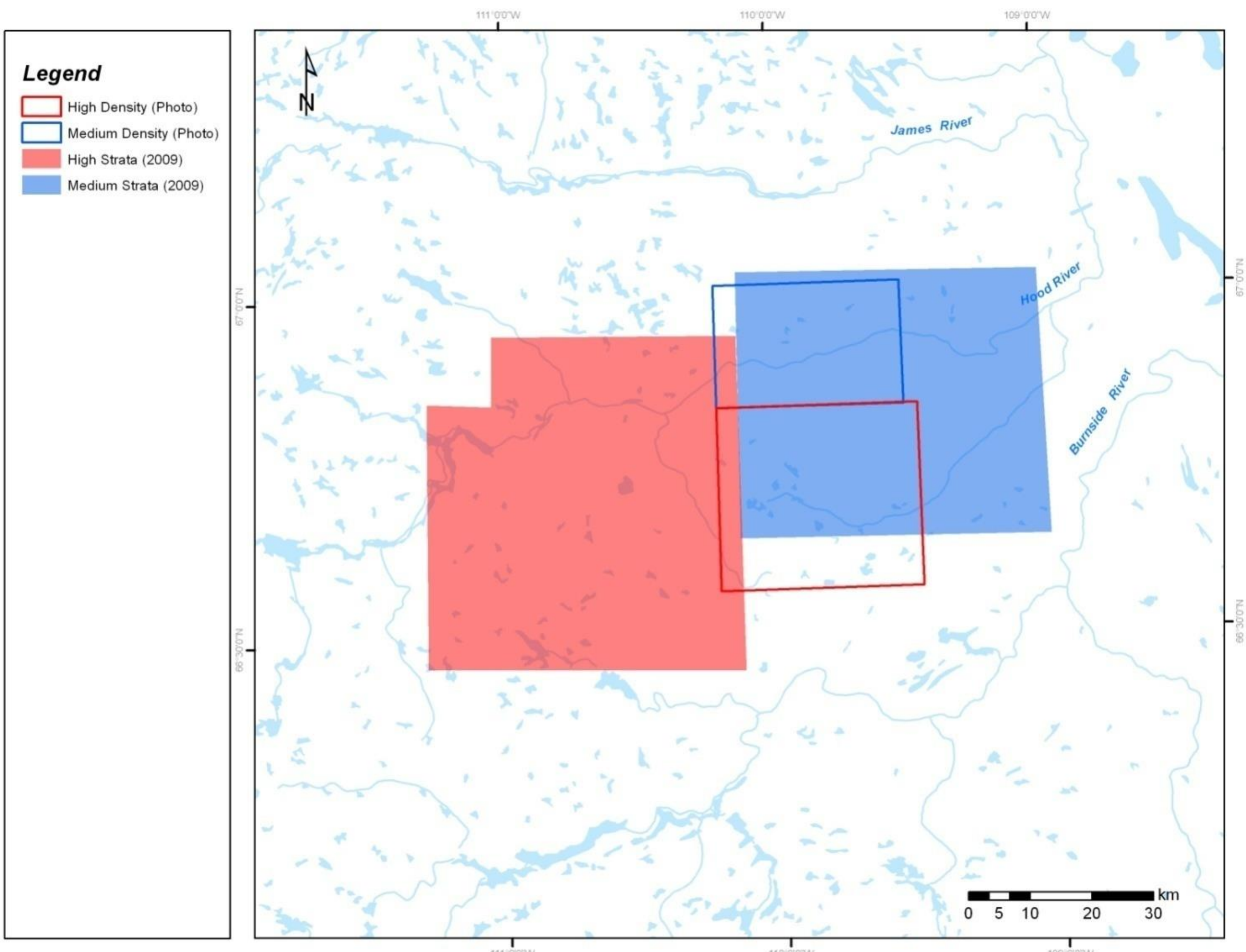

Figure 16: High and medium photo strata for the 2009 (coloured polygons) and 2012 (open polygons) Bathurst calving ground surveys.

Distribution of caribou densities on the high and medium strata revealed the highest densities in the middle lines of the strata suggesting that caribou were well delineated by stratum boundaries (Figure 17).

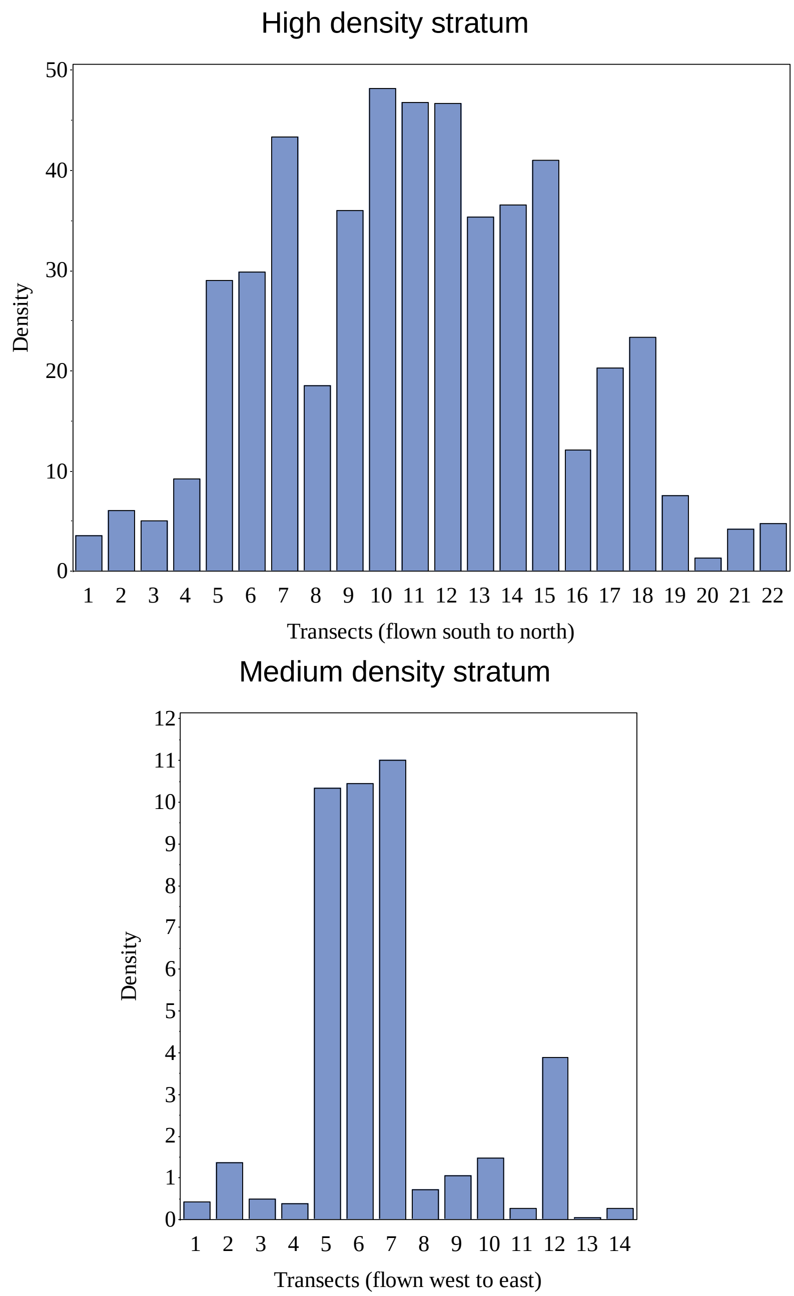

Figure 17: Densities of caribou on each transect line for the high and medium strata as estimated by counts of caribou on each stratum (from photos) divided by the area of each transect.

Composition on calving ground

Composition surveys were conducted on the High, Medium and Low South strata from 6-8 June. During this time, 86 groups and 5,245 caribou were classified with most groups (64) classified on the high density stratum (Figure 18).

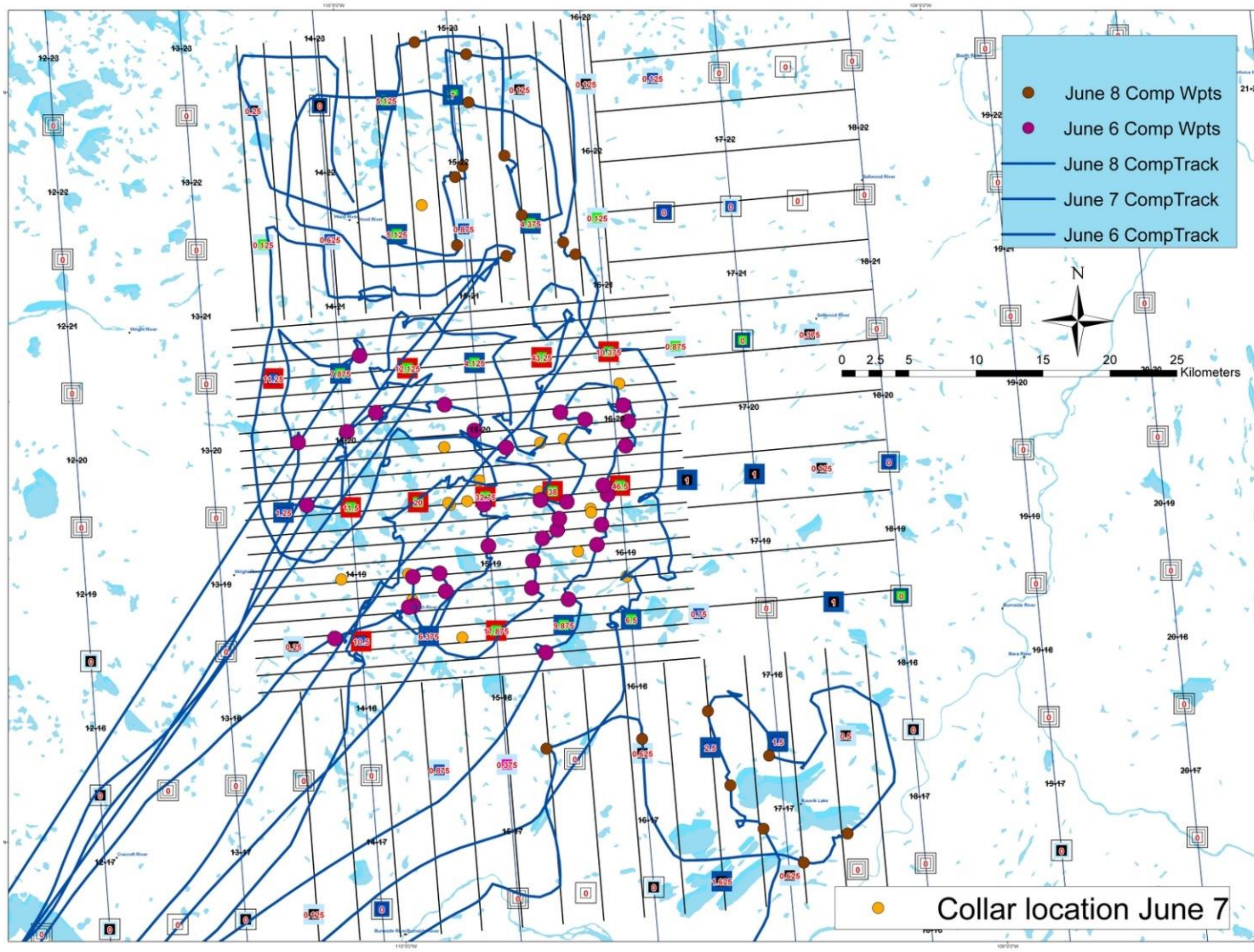

Figure 18: Flight tracks and waypoints for the composition survey. Waypoints for groups are missing for 7 June.

The proportion of groups and numbers of caribou classified roughly conformed to the proportion of caribou on each stratum (Table 8). Group sizes were much higher on the high density stratum than elsewhere. The Low East stratum was not revisited due to very low numbers of caribou during the visual survey. The proportion of calves estimated on the high and medium strata was 49% (2,258 calves/4,612 1+yr caribou) and 60.9% (337 calves/553 1+ yr caribou) respectively, further demonstrating that the photo survey occurred close to the peak of calving. A more exact estimate with non-breeders eliminated results in proportion calves of 71.2% (2,258 calves/3,171 breeding caribou) and 87.1% (337 calves/553 breeding caribou) for the high and medium strata respectively. This estimate corresponds best to the actual proportion of calves relative to breeding caribou, whereas the estimate with all caribou corresponds best to estimates that were derived during reconnaissance surveys (where detailed classification of caribou was not conducted).

Table 8: Summary of composition samples in the Low South, Medium and High strata. Raw data collected during surveys is given in Appendix 4.

Category		**Sum of counts**			**Mean group sizes**		
		High	**Medium**	**Low South**	**High**	**Medium**	**Low South**
Groups sampled		64	14	8			
Breeding females	Antler & udder	1,619	97	0	25.30	6.93	0.00
	No antler & udder	873	257	0	13.64	18.36	0.00
	Antler & no udder	679	33	5	10.61	2.36	0.63
Non-breeding	No Antler/udder	718	93	32	11.22	6.64	4.00
	Yearlings	720	73	43	11.25	5.21	5.38
	Bulls	3	0	0	0.05	0.00	0.00
Calves		2,258	337	0	35.28	24.07	0.00
All 1+ yr caribou		4,612	553	80	72.06	39.50	10.00

The proportion of breeding females was estimated by the ratio of the sum of the breeding females divided by the number of 1+ yr caribou observed (Table 9). Bootstrap resampling was used to estimate percentile based confidence limits, estimates of SE and bias-corrected point estimates.

Table 9: Estimates of proportion breeding females, SE, 95% CI and CV in the Low South, Medium and High strata using bootstrap resampling methods.

	Proportion breeding females				
Stratum	Proportion	SE	CI		CV
High	0.687	0.028	0.632	0.741	0.041
Medium	0.691	0.071	0.527	0.828	0.103
Low South	0.063	0.041	0.008	0.179	0.647

Estimation of breeding females

The estimated proportion of breeding females was multiplied by population estimates from each stratum to obtain estimates of breeding females and associated variances (Table 10). The total estimate of breeding females was 15,935 with corresponding 95% CI of 13,009-18,861.

Table 10: Estimates of breeding females based upon estimates of caribou in each stratum and composition surveys.

Stratum	Total 1+ yr caribou			Composition proportion of breeding females			Estimated breeding females		
	$\hat{N}$	SE	CV	Proportion	SE	CV	$\hat{N}_{breedf}$	SE	CV
High	21,130	1,750.54	0.083	0.687	0.028	0.04	14,525	1,345.50	0.093
Medium	1,941	558.23	0.288	0.691	0.071	0.10	1,341	409.99	0.306
LowE	222	102.50	0.463	0.063	0.041	0.65	14	11.19	0.796
LowS	874	222.41	0.255	0.063	0.041	0.65	55	38.57	0.696
Total	24,167	1,853.64	0.077				15,935	1,407.15	0.088

Estimation of total herd size

Fall composition surveys

Fall composition surveys were conducted on 21-24 October, 2008, 23-26 October, 2011 and on 22 and 23 October, 2012. The main survey of interest was the 2012 fall composition estimate but the 2008 and 2011 surveys were also considered. In 2012, 33 groups and 4,272 caribou were classified (Table 11).

Table 11: Summary statistics for fall composition surveys conducted in 2011 and 2012.

Statistic	**Year**		
	2008	2011	2012
Number of groups	42	52	33
Mean group size	84.05	95.5	129.5
Total caribou	3,529	4,964	4,272
Total adults (1.5+ yr old)	2,868	4,105	3,710
Total cows	2,074	2,598	2,369
Total calves	661	859	562
Total bulls	794	1,507	1,341

Of most interest was the proportion of adult females in the composition surveys, which would then be used to estimate the proportion of adult females in the Bathurst herd. The bootstrap-based estimate of proportion of adult females (cows) for 2011 and 2012 was 0.631 and 0.638, respectively (Table 12). The 2012 estimate was used for the extrapolated population size estimate. The proportion of adult females decreased (and subsequently the proportion bulls increased) compared to the 2008 fall composition survey.

Table 12: Proportion cows and bull:cow ratios from 2008, 2011 and 2012 fall composition surveys. The proportion is based upon the total adults counted (excluding calves) as listed in Table 11.

Year	**Proportion cows**	**SE**	**CI**		**Bull:cow ratio**	**SE**	**CI**	
2008	0.723	0.013	0.697	0.750	0.383	0.025	0.334	0.435
2011	0.631	0.013	0.606	0.655	0.585	0.033	0.526	0.651
2012	0.638	0.014	0.610	0.664	0.567	0.035	0.505	0.640

Extrapolated estimate of total herd size

The extrapolated estimate of total herd size was derived in a sequential process. First, the estimate of breeding females was divided by the assumed pregnancy rate (0.72, Dauphine 1976) to estimate the total number of adult (1.5+ yr old) females in the herd of 22,132 (±6,140) caribou. This estimate was then divided by the proportion of adult females in the herd (Table 12) of 0.638 to estimate the total herd size of 34,690 (1.5+ yr old) caribou (Table 13).

Table 13: Extrapolated estimate of total herd size for 2012 using breeding female estimates (Table 10) and estimates of proportion of adult females in the entire herd from 2012 fall composition surveys (Table 12).

Survey data	Estimate	SE	CV	CI	
Number of caribou on the breeding ground	24,167	1,853.6	0.08	20,312	28,020
Number of breeding females	15,935	1,407.2	0.09	13,009	18,861
Proportion adult females in the entire herd	0.638	0.01	0.02		
Proportion 1.5+ yr females pregnant	0.72		0.10		
Total population estimate	**34,690**	**4,691.1**	**0.14**	**24,934**	**44,445**

One notable difference in the extrapolated estimate for 2012 is that it is based on an estimate of proportion adult females in the herd of 0.638, which was different than the estimate for the 2009 estimate of 0.723 (Table 12). If the 2008 proportion of cows estimate is used the resulting extrapolated estimate is 30,611 (CI=21,906-39,316). From this comparison it can be seen that that an apparent increase of 4,078 caribou is due to the change in estimated proportion of adult females in the herd. Of the two estimates, the estimate of 34,690 (CI=24,934-44,445) is preferred as it is based upon more recent ground composition survey data.

Table 14: Extrapolated estimate of total herd size for 2012 using breeding female estimates (Table 10) and estimates of proportion of adult females in the entire herd from 2008 fall composition surveys (Table 12).

Survey data	Estimate	SE	CV	CIL	CIR
Number of caribou on the breeding ground	24,167	1853.6	0.08	20,312	28,022
Number of breeding females	15,935	1407.1	0.09	13,009	18,861
Proportion females in the entire herd	0.723	0.0	0.03		
Proportion 1.5+ yr females pregnant	0.72		0.10		
Total population estimate	30,611	4185.8	0.14	21,906	39,316

We recognize that pregnancy rate varies in barren-ground caribou herds and consideration should be given to improving the estimate of pregnancy rate used to estimate extrapolated herd size by using values more reflective of the herd's conditions at the time of the survey. At this time, we have relied with the Bathurst herd on estimates of the number of breeding females as the key demographic segment of the herd; the calving photo survey measures this number with precision.

Trend in breeding females

Estimates of breeding females have varied from a high of 203,800 caribou in 1986 to the estimate of 15,935 in 2012. The relative difference (gross change) in breeding female population size between surveys was estimated by the ratio of successive estimates. This ratio was then scaled to the annual interval (Table 15). From this it can be seen that on an annual basis, the breeding female population size has declined between all surveys (except 1990 and 1996) with the largest decline between 2006 and 2009. Between 2009 and 2012, the rate of change is close to 1 suggesting that the rapid rate of decline observed between 2009 and 2012 has been reduced in magnitude.

Table 15: Breeding female estimates (N) used in the trend analysis and estimates of gross change (change in population size between surveys) and annual change (λ). Standard errors (SE) for change are based on the combined error of the two population estimates. The yearly interval (Int.) between surveys is also given.

Year						**Change**						
	N	SE	CI		CV	Gross	SE	Int.	Annual	SE	CI	
1986	203,800	12,695.7	178,197	229,403	0.062							
1990	151,927	25,805.0	94,430	209,424	0.170	0.75	0.13	4	0.93	0.07	0.80	1.06
1996	151,393	35,144.0	75,469	227,317	0.232	1.00	0.29	6	1.00	0.12	0.77	1.23
2003	80,756	13,167.1	52,878	108,438	0.163	0.53	0.15	7	0.91	0.06	0.80	1.03
2006	55,593	8,813.0	37,147	74,039	0.159	0.69	0.16	3	0.88	0.09	0.71	1.06
2009	16,649	2,181.0	12,153	21,056	0.131	0.30	0.06	3	0.67	0.04	0.60	0.74
2012	15,935	1,407.1	13,009	18,861	0.088	0.96	0.15	3	0.99	0.09	0.81	1.16

The general trend also can be seen with a plot of breeding female population size estimates (Figure 19) which illustrates the overall decline of estimates with an accelerated decline from 2006-2009 followed by minimal change from 2011-2012. Using a two-tailed *t*-test, there is no statistical difference in the 2009 and 2012 estimates (t=0.28, df=47, p=0.78).

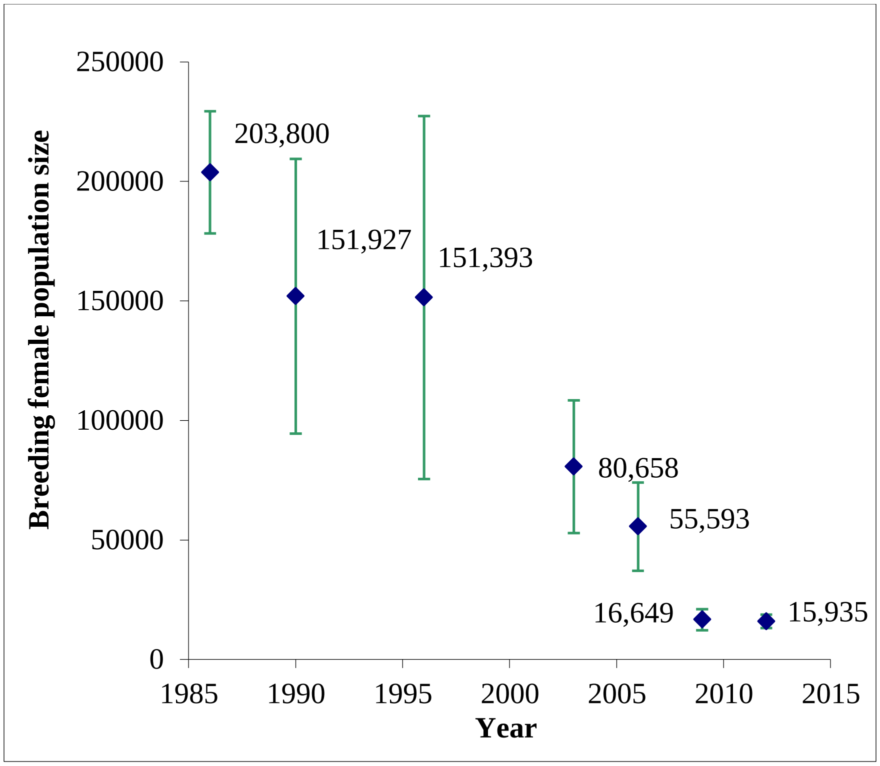

Figure 19: Breeding female estimates with associated CI used in the trend analysis.

Weighted regression

The main question addressed with regression analysis was whether the change in trend observed between 2009 and 2012 (Table 15) was statistically significant. In the analysis of the 2009 data set, Boulanger (2010) found that the downward trend of Bathurst herd was best described by a cubic polynomial model. The question therefore was whether this model of exponential decline still described the trend, or a model that assumed a cut-point (change) in trend was more supported.

Model selection results suggested that a model that assumed the cubic trend from 1986 to 2009 (yr^3), followed by a cut-point in 2009 (yr_{2009}) and a different trend from 2009-2012 ($T_{2009-2012}$) (Table 16, model 1) was most supported. This model was more supported than a model with quadratic and cubic terms (model 2) or the original cubic term model used in the 2009 analysis (model 3) or other trend models (models 4-7).

Table 16: Model selection results for trend analysis of Bathurst breeding cow estimates. Akaike Information Criteria (AIC_c), the difference in AIC_c values between the *i*th and most supported model 1 (ΔAIC_c), Akaike weights (w_i), number of parameters (*K*) and log-likelihood (*LogL*) are presented.

Model No.	Model	AIC_c	ΔAIC_c	w_i	*K*	*LogL*
1	$yr^3 + yr_{2009} + T_{2009-2012}$	15.22	0.00	0.76	4	6.35
2	$yr^2\ yr^3$	17.28	1.98	0.11	3	-1.64
3	yr^3	17.69	2.39	0.07	2	-5.34
4	$yr\ yr^3$	17.79	2.48	0.06	3	-1.89
5	$yr + yr_{>06}$	29.69	14.39	0.00	3	-7.85
6	$yr\ yr^2\ yr^3$	31.24	15.94	0.00	4	-1.62
7	yr	33.48	18.18	0.00	2	-14.74

Parameter estimates from model 1 demonstrated that all parameters were significant (Table 17).

Table 17: Regression model parameter estimates and Chi-square test results.

Parameter	Estimate	SE	CI		χ^2	$P(\chi^2)$
Intercept	12.186	0.057	12.074	12.298	45,692.000	<.0001
yr^3	-0.141	0.016	-0.173	-0.109	74.450	<.0001
Yr_{2009}	-6.776	1.488	-9.691	-3.861	20.760	<.0001
$T_{2009-2012}$	0.261	0.062	0.141	0.382	17.94	<.0001

A plot of the regression line (back transformed to population size units) is shown in Figure 20. The grey lines are 95% CI around the trend line. The circles are data points. The CI are irregular as they are accounting for varying degrees of variance in each of the point estimates. For example, the 1986, 2003, 2009 and 2012 surveys had the best precision and therefore the CI are tightest around these points.

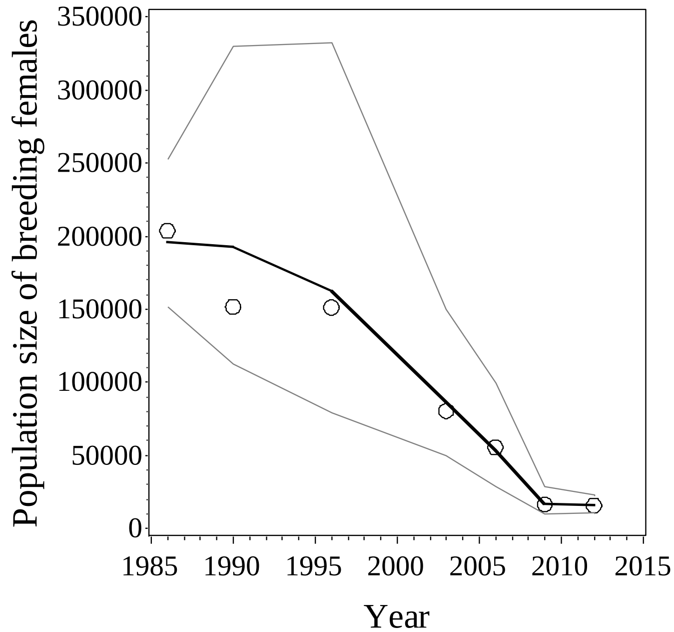

Figure 20: Predicted trend for breeding females from weighted least squares regression analysis. Grey lines are CI on predictions. Circles are estimates from each calving ground survey.

Monte Carlo simulation analysis of the regression model allowed an estimate of λ and associated confidence limits for the interval between 2009 and 2012. The estimates of λ from the Monte Carlo analysis for 2012 is 0.99 (SE=0.057, CI=0.86 to 1.08) with a corresponding r estimate of –0.010 (SE=0.058, CI=-0.143 to 0.086). The distribution of λ estimates was symmetrically defined around the point estimate of 0.97 (Figure 21). This estimate is higher than the λ from 2008-09 of 0.76 (SE=0.17, CI=0.74 to 0.80) with a corresponding *r* estimate of -0.26 (SE=0.027, CI=-0.31 to -0.22) (Boulanger 2010).

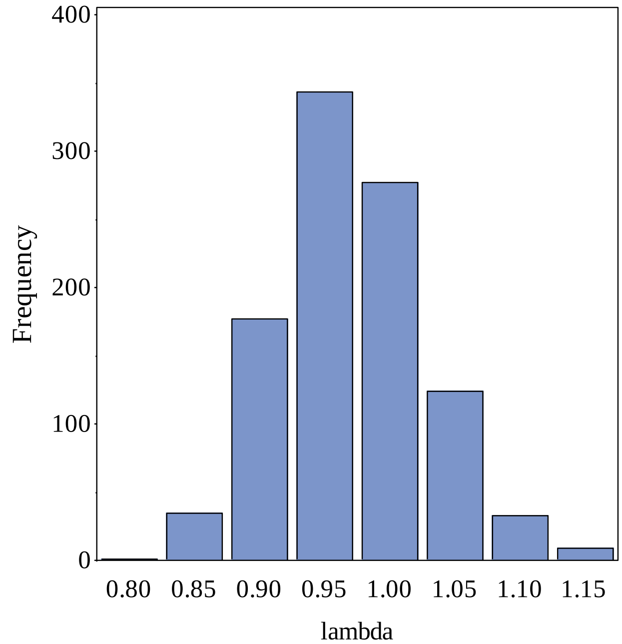

Figure 21: Distributions of population rate of change (λ) for 2012 generated using Monte Carlo simulation trials.

Analysis of demography

Twenty two field measurements were compared to OLS model predictions for the demographic modeling exercise. Initial model building focused on building a parsimonious model to explain variation in productivity (calf survival and fecundity) (Table 18). A model with yearly trends in calf survival and constant values for fecundity was most supported with an AIC_c weight of 0.999 (Table 18, model 1). Using the base productivity model, various cow and bull survival trend models were tested with none of the models showing substantial support. We used the most supported model with constant adult female survival rates to further estimate and explore demography of the Bathurst herd. Model averaging of estimates from candidate models was not required given the high level of support (AIC_c weight of 0.999) of the most supported model.

Table 18: AIC_c model selection for demographic analysis of Bathurst data (2007-2012). Akaike Information Criteria (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 sum of penalties are presented. Trend models were indicated by a T (T-log-linear, T^2=quadratic, T^3=cubic), year-specific trends were indicated by a subscript under the T symbol. Yearly models allowed unique values for each year in the analysis. A constant model assumed the parameter was constant from 2007-2012.

No	**Calf survival (S_c)**	**Fecundity (F_a)**	**Cow survival (S_f)**	**Bull survival (S_m)**	**AIC_c**	**ΔAIC_c**	**w_i**	**K**	**∑Penalties**
1	Yearly	Constant	Constant	Constant	71.58	0	0.999	11	23.18
2	Yearly	T	Constant	Constant	78.42	6.83	0.001	12	19.75
3	Yearly	Constant	$T_{2007-2010}$, $T_{2011-2012}$	Constant	80.36	8.77	0.000	12	21.69
4	$T+T^2+T^3$	Constant	Constant	Constant	80.70	9.11	0.000	9	47.70
5	Yearly	Constant	$T_{2007-2008}$, $T_{2009-2012}$	Constant	81.28	9.70	0.000	12	22.62
6	Yearly	Constant	Constant	T	81.33	9.74	0.000	12	22.66
7	Yearly	Constant	T	Constant	81.83	10.25	0.000	12	23.17
8	Yearly	Constant	$T_{2007-2009}$, $T_{2010-2012}$	Constant	92.11	20.53	0.000	13	20.61
9	Yearly	Constant	T	T	81.85	10.26	0.000	12	23.18
10	Yearly	Constant	$T_{2007-2009}$, $T_{2010-2012}$	$T_{2007-2009}$, $T_{2010-2012}$	93.97	22.39	0.000	13	22.47
11	Yearly	Constant	$T+T^2$	Constant	93.34	21.76	0.000	13	21.84
12	T+T2	Constant	Constant	Constant	105.12	33.54	0.000	8	78.04
13	Yearly	Constant	Yearly	Constant	157.12	85.54	0.000	16	16.32
14	$T_{2007-2010}$, T_{2011}	Constant	Constant	Constant	243.93	172.34	0.000	7	221.93

Estimates of parameters from model 1 demonstrated temporal variation in calf survival and constant values for other parameters. Most notably adult female survival was estimated as 0.78. Yearling survival was estimated also at 0.78, adult male survival at 0.71 and fecundity at 0.84 (Figure 22). Calf survival varied from 0.68 in 2010 to 0.06 in 2012.

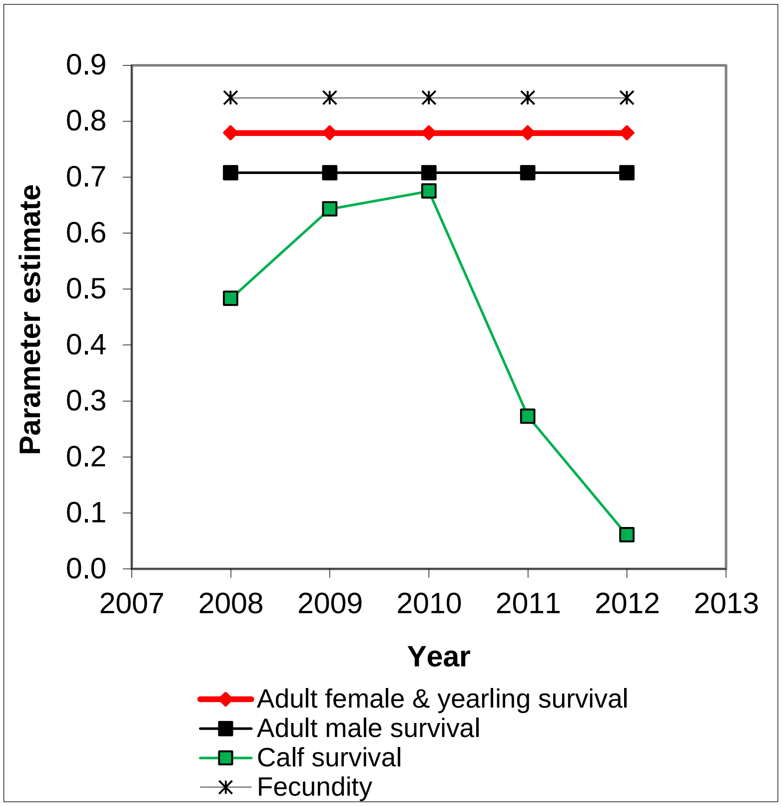

Figure 22: Estimate of demographic parameters from the most supported OLS model (Table 18, model 1).

Comparison of field estimates and OLS model predictions suggested reasonable model fit with OLS predictions occurring within the confidence limits of field estimates in most cases (Figure 23). Trends in spring calf:cow ratios suggested reasonably high productivity until 2012 when calf:cow ratios declined. Adult female survival estimates from collared caribou were very imprecise due to low numbers of collared caribou; hence determination of trend was problematic. Proportion of females breeding was within the confidence limits of field estimates. Note that the proportion of females breeding estimated for the OLS model excluded yearlings and bulls and therefore was different (higher) than proportion breeding females on the calving ground used for breeding female estimates (Table 9) as detailed in Boulanger et al (2012). Survival rates from collared caribou were low in 2010 and 2011 with the OLS model estimates being just within the upper limit of the confidence limits of the collar-based estimates.

OLS model predictions suggest a declining trend (yearly change λ=0.94) in breeding female numbers (Figure 23). This is lower than the estimate of λ from the weighted least squares regression of 0.99 (Figure 21). The trend in breeding females from the OLS model is based upon the combined inference from other data sources as shown by the fitted lines in Figure 23 and therefore may be a better estimate of change in the breeding female population. The predictions of the OLS model of breeding female population size fall well within the confidence limits of the breeding female estimates from the 2009 and 2012 surveys (Figure 23).

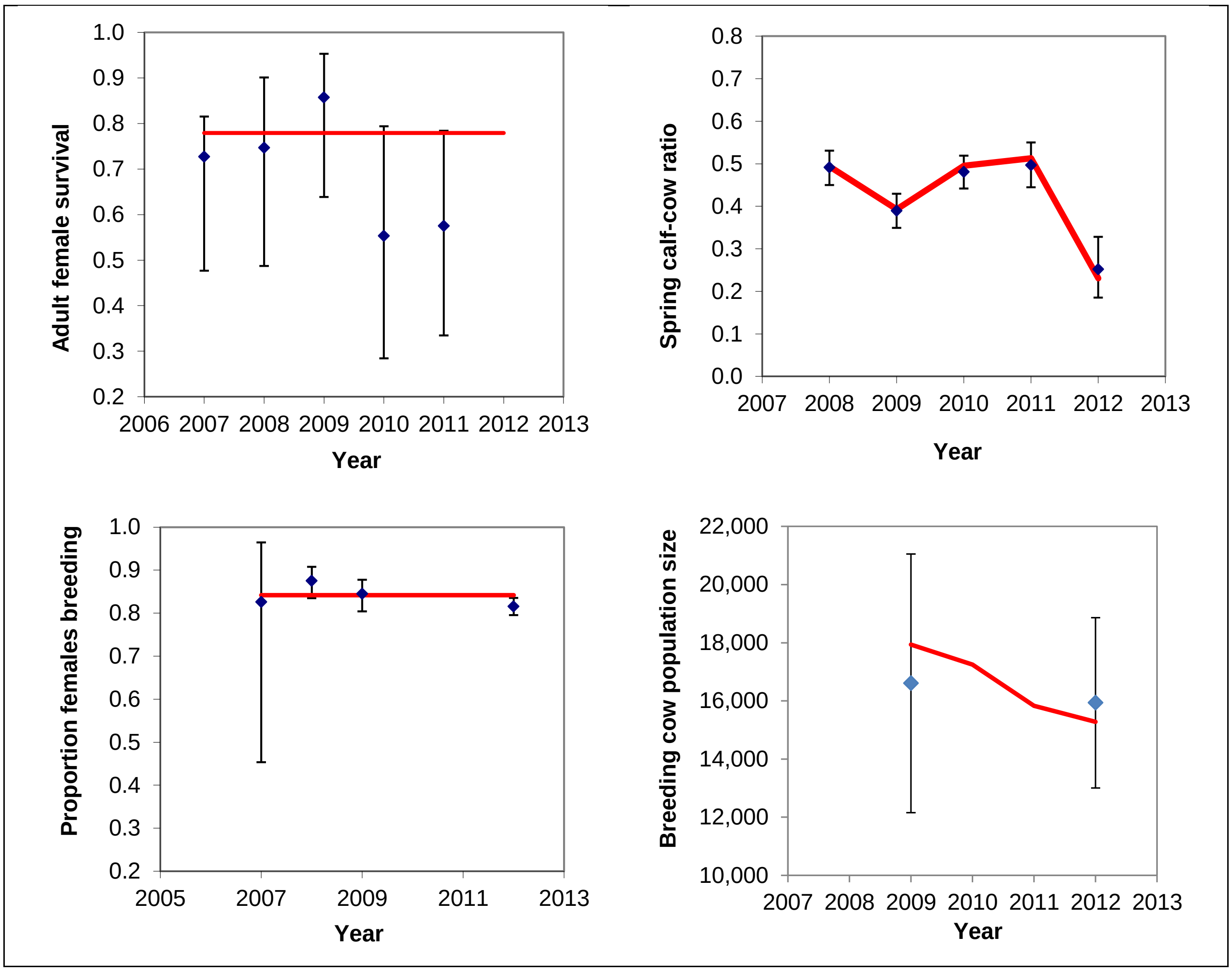

Figure 23: Estimates of adult female survival (from collared caribou), spring calf:cow ratios (from March composition surveys), proportion females breeding and breeding cow (female) population size estimates (from calving ground surveys). OLS model predictions are given as red lines (from model 1, Table 18).

The bull:cow ratio increased over the duration of the study. This was presumably due to higher levels of productivity, as explored further later in the report (Figure 24). The OLS model-predicted fall calf:cow ratios displayed a similar trend to the spring calf:cow ratio. A calf:cow ratio from the fall of 2008 was not included (0.32) because its value was lower than the corresponding spring 2009 calf:cow ratio (0.39). This value was not likely given that the proportion of calves should decrease and not increase over the winter. This value created model-fitting issues with the OLS model and therefore it was excluded from the analysis.

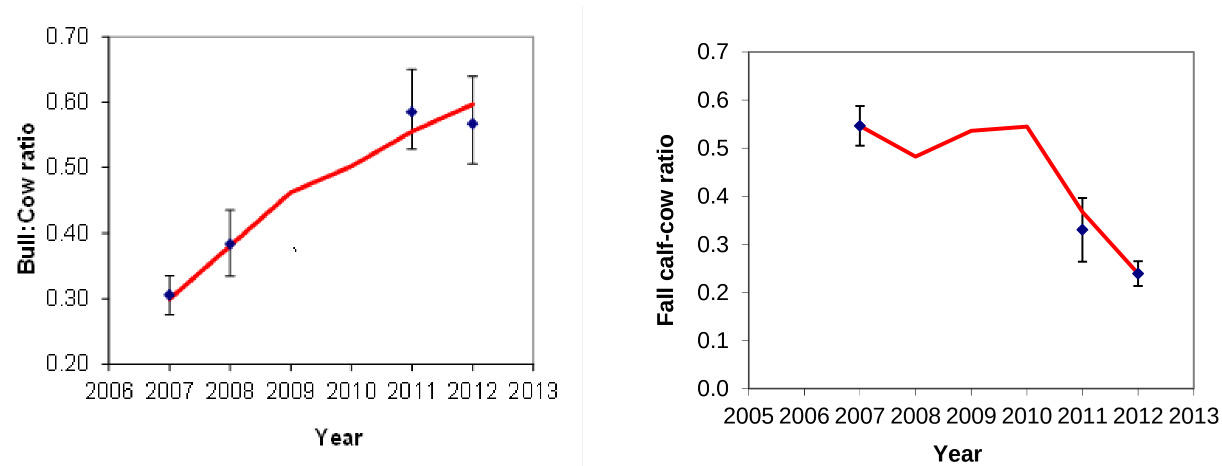

Figure 24: Estimates of bull:cow ratios and fall calf:cow ratios from fall composition surveys. The 2008 fall calf:cow ratio was not included into the analysis due to potential bias issues with this measurement. OLS model predictions are given as red lines.

Population size estimates for each of the age classes in the demographic model suggested a decline for adult females, calves and yearlings, but a slight increase in bulls. Assuming a pregnancy rate of adult cows of 0.72, we derived an extrapolated herd estimate using the OLS estimate of the bull:cow ratio for 2012 (0.60) of 33,887 which was close to the extrapolated estimate of 34,690 (CI=24,934-44,445) (Table 13). The main objective of the OLS model was to explore demography and not estimate herd size, however, the fact that these two estimates are similar is reassuring.

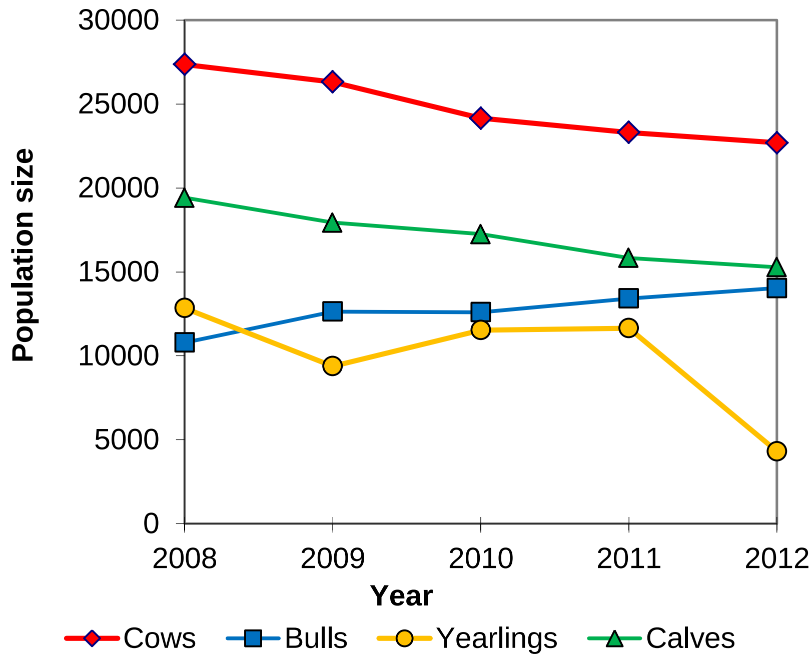

Figure 25: Estimates of population size for each age-sex class from the most supported OLS model (Table 18).

The increase in bulls may seem counterintuitive; however, the reason for this is that the amount of recruitment of yearlings into the bull segment was relatively high compared to the actual size of the bull population (Figure 25). In contrast, the recruitment of yearlings into the female segment, which is larger, is relatively low (Figure 26). Thus the bull segment of the population had a net gain (recruitment>mortality), whereas adult cows had a net loss (mortality>recruitment). This general trend also explained the increase in the bull:cow ratio observed in fall composition surveys (Figure 24).

In general, an increasing bull:cow ratio is associated with improving population trend. But in the case of this analysis, the predicted OLS model increase in the bull:cow ratio, was partially due to a *decrease* in cow abundance with a slight increase in bull abundance. The increase in the bull:cow ratio of the Bathurst herd in this context further highlights why data from age ratios should be interpreted cautiously (Harris et al. 2007).

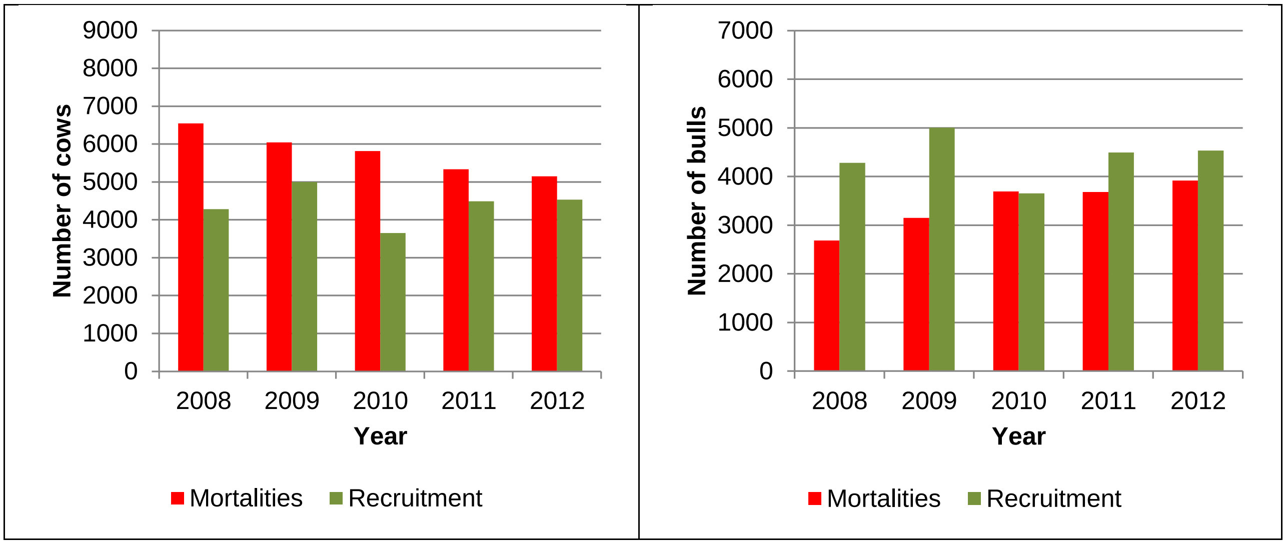

Figure 26: The estimated relative number of adult cows and bull mortalities compared to estimated recruitment into the bull and cow age class from the OLS model. Note that the number of recruits for bulls and cows is the same each year. This estimate assumes an equal sex ratio of yearlings so that equal numbers are recruited into the bull and cow age classes.

One potential issue with measures of productivity prior to 2009 was bias of calf:cow ratios due to reduced over-winter survival rates of cows and subsequent inflation of calf:cow ratios. If these ratios were positively biased, then estimates of adult female survival for 2012 from the OLS model would be negatively biased. We first considered models that had separate survival rates for the period prior to 2009 in model selection (Table 18; models 3 and 10). These models were not supported by the data [ΔAIC_c=8.77 (model 3) and ΔAIC_c=93.97 (model 10)]. This was most likely due to imprecise survival rates from the collared caribou and the fact that the decline prior to 2009 was not explicitly modeled. Estimates of adult female survival for 2007-2008 and 2009-2012 were 0.73 and 0.79 respectively (Figure 27). Thus the estimates of survival from this model were relatively close to that of the constant survival model (of 0.78 for 2012).

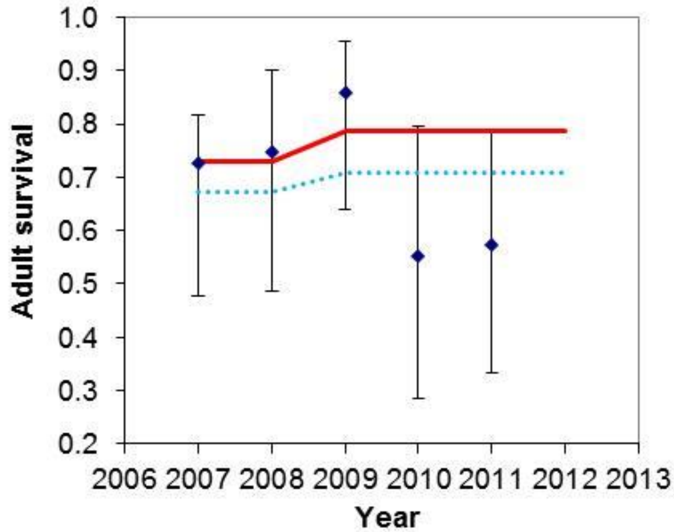

Figure 27: Estimates of adult female survival (red line) and adult male survival (blue line) from model 10, (Table 18).

To further explore potential bias caused by calf:cow ratios prior to 2009 we added a term that reduced female survival in the denominator of the OLS calf:cow ratio term. This reduced adult female survival to 0.67, which was equal to that estimated from the historic analysis of the Bathurst data up to 2009 (Boulanger et al. 2011). The resulting estimate of 2012 cow survival was 0.79. We therefore concluded that the general estimate of reduced adult female survival of 0.78 was reasonably robust to potential sampling issues with productivity estimates prior to 2009.

A potential issue with only using breeding female estimates from 2009 and 2012 was that the effect of the decline from 2006-2009 on productivity was not explicitly modeled. To investigate this we conducted additional runs that included the 2006 estimate and modeled the declining adult female survival rate during this interval. The resulting estimate of adult female survival for 2012 was 0.76 which suggested that the main effect of not including earlier data is a slight lowering of estimated 2012 adult female survival. The main conclusion from this exercise was that the estimate of adult survival of 0.78 would not be changed substantially and certainly not increased, by inclusion of earlier demographic data.

The OLS model is a deterministic model and it does not fully consider the level of variation and uncertainty in each of the demographic parameters. We were interested in how robust the estimated adult survival value was to the uncertainty in the 2012 breeding female estimate. In other words, if we assumed the base model for productivity, what would be the effect of varying adult female survival and what values of adult survival would be needed to cause the OLS model to predict higher breeding female population sizes? To explore this we used a range of values for adult survival and noted the corresponding estimate of breeding female size and trend in breeding female size. We also noted the AIC_c value that was generated that indicated how well a hypothesized adult survival value fit the model. Other productivity parameters were held constant and therefore the main factor influencing model fit was adult female survival.

Results of this sensitivity analysis suggested that adult female survival values of approximately 0.75-0.82 were possible with the corresponding OLS predicted breeding female size still occurring within the confidence limits of the field based breeding female estimate (Figure 28). The lowest AIC_c values corresponded to the point estimate of adult survival of 0.78.

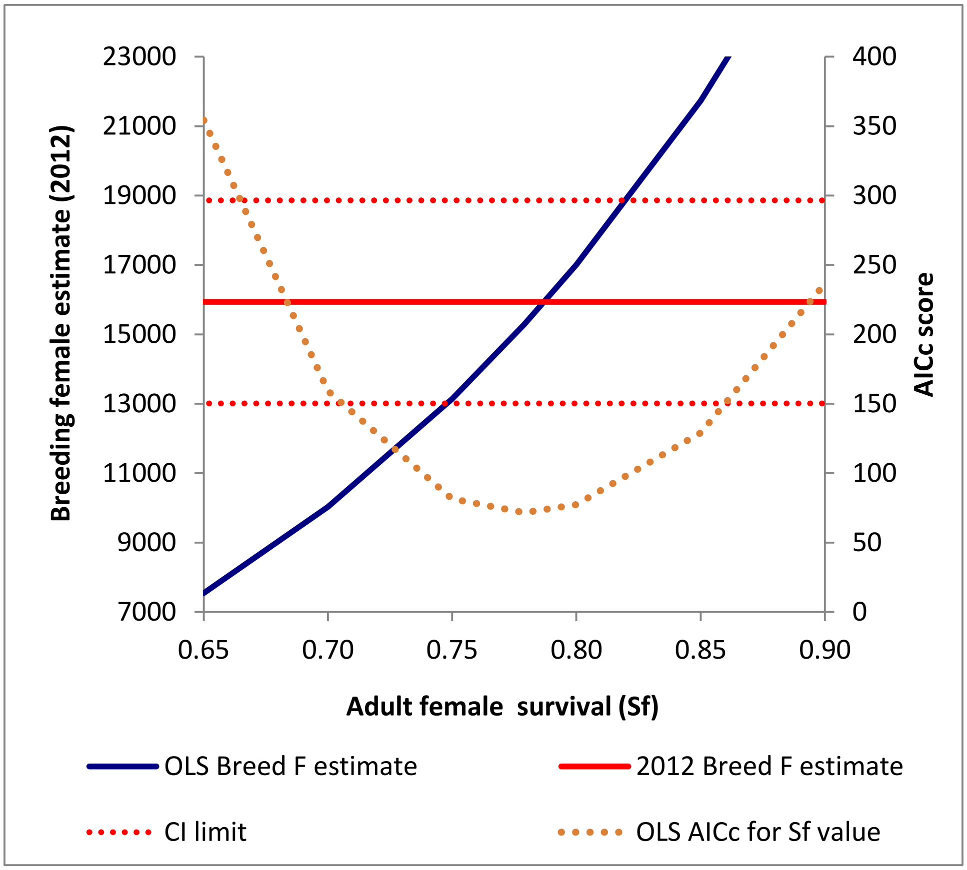

Figure 28: OLS model estimates of 2012 breeding female population size as a function of different values of adult female survival. The actual field estimate for 2012 is shown as a red line with corresponding confidence limits as dotted red lines. The predicted population estimate from the OLS model is shown as a blue line and the AIC_c score corresponding to the adult survival value is given as brown dotted line. Adult survival values with the lowest AIC_c score display the best fit to the data.

The sensitivity analysis demonstrates that if adult survival rates were at levels estimated in 2009 (0.67) the likely estimates of breeding females in 2012 would have been less than 9,000 caribou. If cow harvest levels of 3,000-5,000 caribou/yr would have continued then the adult survival value would have continued to decrease below 0.67 as that harvest would have been eliminating a successively higher proportion of the cow population (Boulanger et al. 2011). In this case, the number of breeding females would have been much lower than 9,000. Alternatively, if survival had increased to 0.85 the estimate would have been over 21,000 breeding female caribou.

In summary, the OLS model analysis suggests that the most likely level for adult female survival is lower than that needed for a stable herd. However, this result should be interpreted in the context of the overall uncertainty in the breeding female estimates (Figure 28) and the uncertainties in the modeling outcomes. Regardless, we can conclude the adult cow survival has increased to about 0.78 since the level estimated for 2009 from the 1986-2009 analysis of 0.67 (Boulanger et al. 2011).

DISCUSSION

The general results of this analysis suggest that the rapid rate of decline of the Bathurst caribou herd 2006-2009 has slowed substantially by 2012 (Figure 19). The relatively high precision of the breeding female estimate helps ensure that this result is robust to sampling variance. Compared to previous years, the core calving area was reduced in size (Figure 16), but densities of caribou within the calving ground were much higher. This allowed an efficient survey effort with relatively high coverage in the photographic strata. Given the high densities and variation in densities within strata (Figure 17), the higher coverage (71.9%) for the high density stratum provided high survey precision in the face of aggregated clusters of caribou within the survey strata.

The results of this survey likely reflect in large part the limited harvest strategy that was put in place after the 2009 survey. Prior to the 2009 survey harvest levels of up to 3,000-5000 cows and 1,000-2,000 bulls were occurring on an annual basis (Adamczewski et al. 2009, Boulanger et al. 2011). If this harvest level had continued it is likely that the number of breeding females would have been less than 9,000 for the 2012 survey (Figure 28). The OLS demographic analysis estimated that adult female survival rate was 0.78 [CI range=0.75-0.82 (Figure 28)] in 2012, as compared to the estimate based on the large decline from 2006-2009 of 0.67 (Boulanger et al. 2011). It is likely that one reason for the increase in survival rate is the reduction of harvest pressure. However, the adult survival rate is still not at levels estimated in 1986 (0.85) or as estimated based on the reduction of harvest of 0.87 (Boulanger and Adamczewski 2010).

One noteworthy difference between surveys was the much smaller extent of the calving ground core in 2012 compare to 2009 (Figure 16). The combined area of the high and medium strata for 2012 was 33% of the area of the 2009 high and medium strata (Nishi et al. 2010). However the average densities for the high and medium strata in 2009 were 6.76 and 2.49

caribou/km^2 compared to average densities of 23.1 and 3.0 caribou/km^2 in 2012 (Table 7). Caribou were basically congregated into a much smaller area at higher densities in 2012 compared to 2009. One potential reason for this is that there was virtually no snow cover and an earlier spring period in 2012, allowing easier travel conditions for caribou that may have resulted in increased congregation. Other factors, such as the influence of predators (that also would have had better travel conditions) may have resulted in increased aggregation as a response to predation. During the 2006 calving ground survey (Nishi et al. 2007), the average density in the high stratum (1,253.7 km^2) was 49.3 caribou/km^2 so the observed densities in the high density stratum in 2012 were similar during the two years. Densities in the range of 49 caribou/km^2 were observed on the central lines of the high stratum in 2012 (Figure 17). It could be argued that the relatively small size of the core calving area in 2012 was due to caribou exhibiting historic levels of aggregation, but the resulting area was smaller due to the lower overall population size of the herd.

Interpretation of breeding female estimates

The main target population for the calving ground surveys is breeding female caribou. An inherent assumption of this method is that breeding females will congregate on the calving ground, allowing the photo survey to estimate this component of the herd. The breeding females are the most important component of the herd given they produce calves and their numbers reflect the relative productivity and ability of the herd to increase. However, it is important to understand potential time lags between the production of calves and recruitment of these calves into the breeding female segment. In general, it takes females one to three years to mature and be capable of producing calves and most commonly females first have high pregnancy rates at 2.5 years of age (Bergerud et al. 2008). The actual pregnancy rate of yearlings has been shown to vary by herd. Dependent on whether the herd is increasing, stable or decreasing, pregnancy rates of yearlings can vary from 2% [Kaminuriak, 1966 (Dauphine 1976)] to 48% [George River

Herd 1976-1982 (Bergerud et al. 2008)]. Regardless, until a female caribou matures, it is not counted as a breeding female. Therefore, trends of breeding females will not reflect productivity events that occurred in the previous one to three years dependent on pregnancy rates of yearlings, two and three year olds. However, current trends in breeding females will reflect productivity for 2009 and years prior as well as relative survival rates for adult females up to the survey (Table 19). This is of great interest given that reduced survival of females was a primary cause for the rapid decline in breeding female population size that occurred between 2006 and 2009 (Adamczewski et al. 2009, Boulanger et al. 2011).

Table 19: A hypothetical timeline for a female calf that was born during the 2009 calving ground survey. Given that caribou do not breed until they are two to three years old the 2012 estimate of breeding females mainly reflects recruitment events that occurred in 2009 and years before. Pregnancy rates are based upon Dauphine (1976) and Bergerud et al (2008).

Group	**Year**				
	2009	**2010**	**2011**	**2012**	**2013**
Age class during survey	Calf	Yearling	2 year old	3 year old	4 year old
On calving ground?	Yes	maybe	maybe	More likely	Most likely
Classified/counted as a breeding female?	No	No	Less likely	**More likely**	**Most likely**
Bred in fall after c.g. survey? (*pregnancy rate*)	No (*0%*)	Less likely (*2-48%*)	More likely (*48-95%*)	Most likely (*82-96%*)	Very likely (*95-96%*)

The OLS model exercise provided a way to model the time-lags in productivity and assesses how this potentially affected the number of breeding cows in the 2012 survey. In the case of the OLS model, it was assumed that any caribou older than a yearling for the fall prior to a breeding survey had the potential to breed and the proportion of these adult female caribou breeding was estimated by the fecundity parameter. The data from 2007-2012 were considered in this analysis (Table 1) so that caribou that were calves in 2007 were available to be recruited into the breeding female age class for the 2012 survey. This analysis suggested that productivity had been reasonably good and that the estimated number of breeding females in

2012 was due partially to lower survival rates (0.78). If survival rates were higher then a larger number of breeding females would have been estimated. However, as noted earlier, the range of uncertainty in the 2012 estimate (as indicated by confidence limits) demonstrate that it is possible that adult survival was higher than that indicated by the point estimate of population size.

Management Implications and Recommendations

The results of the 2012 survey indicate that the herd size has somewhat stabilized when compared to the results of the 2009 survey. Further analysis of the demographic data suggests that the population of breeding females is “fragile” with estimated adult female survival rates still below levels needed for herd stability or levels estimated in the 1980s. Given this, we make the following recommendations.

1. The herd’s ability to stabilize and increase depends most on breeding cows surviving in large numbers and producing calves, thus a continued conservative, bull-dominated approach to caribou harvest would give the herd the best opportunity to recover. One challenge of interpreting the demographics of the Bathurst caribou herd is imprecise survival rates from collared caribou given that in most years only 20 or less caribou have been collared. Low sample sizes of collared caribou also make it more difficult to delineate different herds on winter ranges. Given this, we suggest an increase in number of collared caribou to 50-60, with some collars on bulls, to allow better determination of survival rates, which in turn will aid to determine how well the herd is recovering.

2. Continued monitoring of the number of breeding cows on calving ground via annual reconnaissance surveys should occur with an emphasis on recommendations made in Boulanger (2011) to strive for adequate precision. In addition, spring composition surveys should continue on an annual basis to monitor relative recruitment.

3. The photo survey of the calving ground should be repeated in 2015 to allow for rigorous assessment of population size and trend.

The 2012 calving ground photo survey benefited from excellent survey and photographic weather conditions and resulted in one of the most precise surveys for this herd to date.

The results of the 2012 survey demonstrate that decline in population size of the Bathurst herd observed from previous surveys has been slowed. However, the current status of this herd is considered fragile given the fact that the number of breeding cows has not increased and that recruitment has been low in the past two years.

The future trend of the Bathurst herd is difficult to predict, as migratory barren-ground caribou herds do not always return to high numbers on a predictable cycle, nor do they necessarily return to the same peak numbers (Bergerud et al. 2008). The Bathurst herd faces other stressors in 2013, including climate change and the cumulative effects of development. A cautious overall approach to management of harvest and other human influences on this herd will provide this herd with its best opportunity to recover to larger numbers and higher productivity.

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APPENDIX 1: Assessment of movement of collared caribou between the Bathurst, Ahiak and Bluenose-East calving grounds.

Records of movement of collared caribou from 2005-2012 were used to assess movements of adult cows between the Bathurst, Bluenose-East and Ahiak calving grounds. This analysis, originally conducted in 2010 (Adamczewski et al. 2009, Boulanger et al. 2011), used multi-state models (Hestbeck et al. 1991, Brownie et al. 1993, White et al. 2006) to estimate the probability of a cow "switching" calving grounds.

The question of movement between populations or areas has been addressed extensively as part of mark-recapture analyses of other wildlife species. In particular, multi-strata models (Hestbeck et al. 1991, Brownie et al. 1993) estimate emigration and immigration rates from different areas, which in the case of caribou are calving ground areas. Data for a multi-strata model is entered as a yearly encounter history with a caribou defined by what calving ground it was observed on. For example, say caribou 100 was seen on the Bathurst herd calving ground in 2000 but on the Ahiak in 2001, was not detected in 2002 and then detected in 2002 on the Bathurst. The data in the model would be entered as:

BA0B

where B denotes Bathurst herd, A denotes Ahiak herd and 0 denotes not observed. The model then uses this sequence to estimate the probability that a caribou that is on the Bathurst herd calving ground one year will be on the Ahiak calving ground the following year and vice versa. This is analogous to emigration/immigration rates between herds.

Multi-strata models estimate rates of movement (termed transition probabilities) between calving grounds, yearly survival and recapture rate. Yearly survival was not of interest in this analysis and we assumed that capture probability was 1. Namely, a caribou that had a collar had a probability of detection of 1 on the calving ground. Assumptions about herd-specific survival can affect movement estimates and so we investigated models that considered herd-specific and pooled survival rates. As part of program MARK (White and Burnham 1999), it was also possible to constrain multi-strata models to test particular hypotheses about movement between calving grounds. In particular, we investigated whether there was net emigration from the Bathurst calving ground that would be suggested if emigration rates from the Bathurst herd were distinctly different (larger) than immigration rates. There was no documented movement between the Ahiak and Bluenose-East and therefore movement rates between these two herds were fixed at 0. The fit of models was evaluated using the Akaike Information Criterion (AIC) index of model fit. The model with the lowest AIC_c score was considered the most parsimonious, thus minimizing estimate bias and optimizing precision (Burnham and Anderson 1998). The difference in AIC_c values between the most supported model and other models (ΔAIC_c) was also used to evaluate the fit of models when their AIC_c scores were close. In general, any model with a ΔAIC_c score of <2 was worthy of consideration.

Records of radio collared caribou from 2005-2012 were considered for the multi-state analysis given that this period was most relevant to changes in breeding female population size between the recent (2006-2012) breeding female surveys. Two hundred eighty seven collared caribou were available for the analysis which extended from 2005-2012.

A summary of movement events (Table 20) was initially used to assess sample sizes in the data set. The previous and current strata summarized sequential movement events of caribou. For example, for the Bathurst calving ground, a caribou on the calving ground one year returned back to the calving ground the next year in 54 occasions. In three occasions, a caribou on the Bathurst calving ground occurred on the Ahiak calving ground in the following year. Caribou were only captured once and others were only captured once in (2012) and therefore could not contribute to estimation of movements. In general, there were few movement events where caribou switched calving grounds; fidelity to calving grounds was high.

Table 20: Summary of movement events from 2005-2012 for the Bathurst, Ahiak and Bluenose-East collared caribou.

Current stratum	Previous stratum			Other events		
	Ahiak	Bathurst	Bluenose-East	Detected once	First year of collaring	Totals
Ahiak	83	3	0	40	55	181
Bathurst	1	54	2	38	36	131
Bluenose-East	0	3	73	69	49	194
Totals	84	60	75	147	140	506

Model selection results suggested that there was not a detectable difference between emigration and immigration rates for the Bathurst-Ahiak or Bathurst-Bluenose-East (Table 21; model 1). Models that assumed that equal emigration rates of caribou to the Bluenose-East and Ahiak herd (model 2) and equal immigration from the Ahiak and Bluenose-East herds to the Bathurst herd, as well as model, that assumed equal immigration and emigration rates from adjacent herds (model 3) were also supported.

Table 21: Model selection results for multi-strata model analysis of movements between the Ahiak, Bathurst and Bluenose-East herds. Sample-size adjusted Akaike Information Criteria (AIC_c), difference in AIC_c between most supported and given model (ΔAIC_c), Akaike weight (w_i), the number of parameters (K) and deviance (an index of model fit) are given. Herds are symbolized by Bathurst (B), Ahiak(A) and Bluenose-East (E). Movement rates are symbolized by the ordering of herds. For example BA symbolizes movements from the Bathurst to the Ahiak.

No	Model	AIC_c	ΔAIC_c	w_i	K	Deviance
1	BA=AB=BE=EB, AE=EA	738.46	0.00	0.414	4	267.4
2	BA=BE, AB=EB, AE=EA	739.02	0.57	0.312	5	265.9
3	BA=AB, BE=EB, AE=EA	740.00	1.54	0.192	5	266.8
4	BA, BE, AB, EB, AE=AE	741.95	3.49	0.072	7	264.7
5	BA=AB=BE=EB=AE=EA	745.84	7.38	0.010	3	276.8

Model averaged estimates of probability of movement between herds suggested that rates of movement between calving grounds were low (<0.05) for all herds and that emigration and immigration rates were similar for herds adjacent to the Bathurst (Figure 29). There was a slight suggestion of higher rates of emigration than immigration for the Bathurst; however, this difference was not statistically discernible as suggested by overlap of confidence limits and support for a model that assumed equal rates of immigration and emigration for Bluenose-East/Bathurst and Bathurst/Ahiak calving grounds (Table 21; model 1).

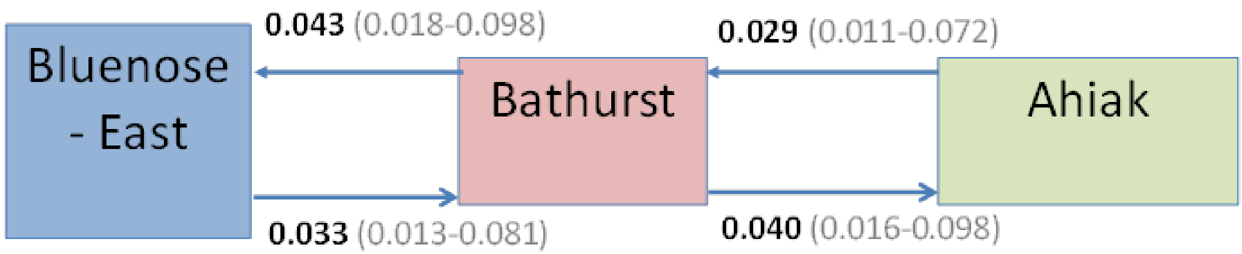


Figure 29: Model averaged estimates of movement from the multi-state model analysis (Table 21). Each arrow and associated estimate is the probability of directional yearly movement of collared caribou between adjacent calving grounds. Movement rates for the Bluenose-East to Ahiak and vice versa were estimated at 0 given that no movements of this type were observed (Table 20).

The general conclusion from this analysis was that net movement of caribou from the Bathurst to adjoining herds was very low. This finding and the fact that the relative population sizes of the Bluenose-East Herd and Ahiak herd are higher than the Bathurst, suggests that movement of caribou between calving grounds did not contribute significantly to the demographic variation within the Bathurst. This general finding of robustness of the Bathurst calving ground based on spatial affiliation of female caribou was also reported in the study of Nagy et al. (2011). The rates of exchange between neighboring herds in this study echo earlier results from Canadian caribou herds. Parker (1972) found that 20 of 442 (4.5%) ear-tagged Beverly caribou switched to the Qamanirjuaq range and 8 of 131 (6.1%) Qamanirjuaq caribou switched to the Beverly range in the 1970s. Similarly, Heard and Stenhouse (1992) placed 112 radio collars over four years on the Qamanirjuaq and neighboring herds and reported that four cows (3.6%) switched calving grounds. Elsewhere, just one of 175 cows (0.6%) radio collared between 1981-1990 switched calving grounds between the Mentasta and Nelchina herds in Alaska (Lieb et al. 1994).

APPENDIX 2: Effect of the number of transect lines surveyed and overall coverage on high density stratum estimates

The coverage for the high density stratum by the photo plane (71.9%) was higher than in previous Bathurst caribou surveys. The high degree of coverage was due to the relatively small size of the stratum and subsequent higher coverage resulting from the 22 lines sampled. Sampling 22 transect lines with resulting higher coverage ensured that a precise estimate would result given the highly clustered groups of caribou within the stratum.

To explore the effects of high coverage on survey precision and estimated caribou numbers (N), we randomly re-sampled transects from the high stratum and incrementally reduced the number of lines that went into the estimate of caribou. A bootstrap method was used where lines were resampled with replacement (Manly 1997). This method approximated precision and mean estimates if the stratum were sampled with a reduced number of lines and overall coverage. From this exercise, we found that we would have needed at least 20 lines (coverage=65%) to ensure a CV of less than 10% and at least ten lines (coverage=32%) to ensure a CV of less than 20% (Figure 30). A CV of 13.4% would have been obtained if coverage was 49% (15 transect lines). As expected, the actual mean estimate of N across re-samplings was approximately the same at different levels of coverage. The main effect of reducing coverage was reduced estimate precision.

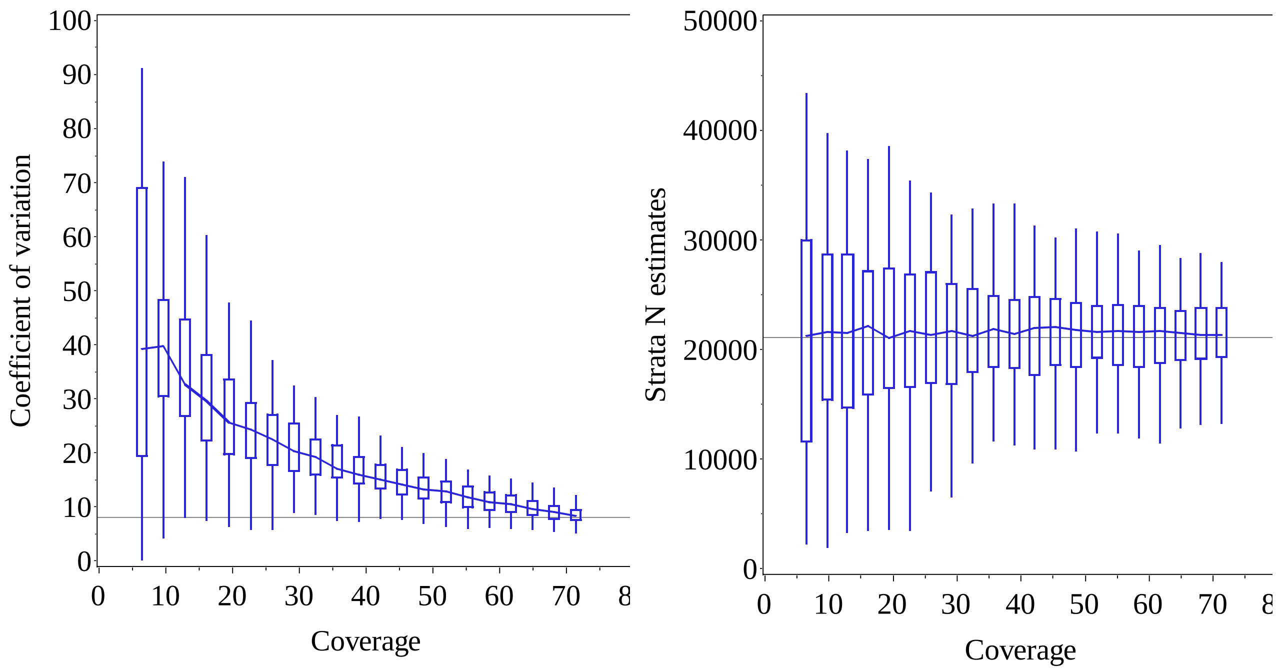


Figure 30: The effect of bootstrap randomized resampling of transect lines in the high photo stratum. The figure on the left shows the estimated CV as a function of coverage and the right figure shows the mean N estimate as a function of survey coverage. Each box delineates the 25th and 75th percentile and the upper and lower lines delineate the range of values observed in randomized resampling.

The main conclusion from this exercise was that there was not a noticeable asymptote in levels of precision at increasing coverage. This was most likely due to the clustered nature of caribou within the stratum (Figure 17). In general CV of 20% or less are required for management with optimal levels of precision at 10% or less for precise tracking of population trends as is needed for OLS model (Figure 22) and regression analyses (Figure 20). Therefore, our strategy of increasing coverage above 50% for the high stratum was justified in that it yielded a very precise estimate for the stratum. However, we emphasize that our sampling situation was unique in that caribou were situated in a relatively small area and therefore extra lines could be added with minimal cost compared to the usual sampling scenarios in which caribou are found within larger survey areas.

APPENDIX 3: Raw count data for photo and visual strata sampled on 6 June, 2012

Table 22: Count data for photo strata from surveys on June 6, 2012.

Stratum	Transect	Length (km)	Strip width (km)	Transect area (km^2)	Caribou (1+ yr) counted
High	1	32.65	0.9144	29.86	105
High	2	32.65	0.9144	29.86	181
High	3	32.65	0.9144	29.86	149
High	4	32.65	0.9144	29.86	275
High	5	32.65	0.9144	29.86	867
High	6	32.65	0.9144	29.86	891
High	7	32.65	0.9144	29.86	1,293
High	8	32.65	0.9144	29.86	553
High	9	32.65	0.9144	29.86	1,075
High	10	32.65	0.9144	29.86	1,438
High	11	32.65	0.9144	29.86	1,396
High	12	32.74	0.9144	29.94	1,398
High	13	32.74	0.9144	29.94	1,058
High	14	32.74	0.9144	29.94	1,095
High	15	32.74	0.9144	29.94	1,228
High	16	32.74	0.9144	29.94	362
High	17	32.74	0.9144	29.94	608
High	18	32.74	0.9144	29.94	698
High	19	32.74	0.9144	29.94	225
High	20	32.74	0.9144	29.94	38
High	21	32.74	0.9144	29.94	127
High	22	32.74	0.9144	29.94	141
Medium	1	19.98	0.9144	18.27	8
Medium	2	19.89	0.9144	18.19	25
Medium	3	19.89	0.9144	18.19	9
Medium	4	19.89	0.9144	18.19	7
Medium	5	19.89	0.9144	18.19	188
Medium	6	19.89	0.9144	18.19	190
Medium	7	19.87	0.9144	18.17	200
Medium	8	19.87	0.9144	18.17	13
Medium	9	19.87	0.9144	18.17	19
Medium	10	19.91	0.9144	18.21	27

Stratum	*Number*	*Breeding females*	*Non-breeders*	*Stratum*	*Number*
Medium	11	19.92	0.9144	18.21	5
Medium	12	19.94	0.9144	18.23	71
Medium	13	19.94	0.9144	18.23	1
Medium	14	19.94	0.9144	18.23	5

Table 23: Caribou counted in visual strata on 6 June, 2012.

Stratum	Transect	Length (km)	Strip width (km)	Transect area (km^2)	Caribou (1+ yr) counted
Low East	1	17.37	0.8	13.896	0
Low East	2	17.37	0.8	13.896	1
Low East	3	17.37	0.8	13.896	0
Low East	4	17.37	0.8	13.896	0
Low East	5	17.38	0.8	13.904	1
Low East	6	15.1	0.8	12.08	3
Low East	7	15.1	0.8	12.08	0
Low East	8	15.1	0.8	12.08	15
Low East	9	15.1	0.8	12.08	1
Low East	10	15.1	0.8	12.08	4
Low East	11	15.1	0.8	12.08	3
Low East	12	15.1	0.8	12.08	19
Low East	13	15.1	0.8	12.08	0
Low South	1	17.8	0.8	14.24	0
Low South	2	17.8	0.8	14.24	2
Low South	3	17.8	0.8	14.24	0
Low South	4	17.8	0.8	14.24	10
Low South	5	17.8	0.8	14.24	63
Low South	6	17.8	0.8	14.24	13
Low South	7	17.8	0.8	14.24	3
Low South	8	17.8	0.8	14.24	20
Low South	9	17.8	0.8	14.24	1
Low South	10	17.8	0.8	14.24	17
Low South	11	18.66	0.8	14.928	33
Low South	12	18.66	0.8	14.928	15
Low South	13	18.66	0.8	14.928	18
Low South	14	18.66	0.8	14.928	18
Low South	15	18.66	0.8	14.928	6

APPENDIX 4: Raw composition data for estimation of proportion breeding females

Table 24: Raw composition data from ground composition surveys on calving ground (6-8 June, 2012).

Stratum	*Number*	*Breeding females*			*Non-breeders*			
		Antlers/udders	No antler/udder	Antler/no udder	No antler-no udder	calves	yearlings	bulls
High	1	0	0	0	6	0	3	0
High	2	22	10	10	33	14	25	0
High	3	9	2	13	24	1	28	0
High	4	15	2	16	37	8	26	0
High	5	25	10	13	17	35	22	0
High	6	32	15	55	36	31	49	0
High	7	14	14	12	8	15	15	0
High	8	18	13	15	7	24	17	0
High	9	11	7	12	12	13	13	0
High	10	3	0	12	6	3	12	0
High	11	8	5	20	10	11	13	0
High	12	87	30	33	29	91	31	0
High	13	74	44	12	2	101	6	0
High	14	42	14	3	6	50	3	0
High	15	54	13	7	2	68	1	0
High	16	16	1	10	12	13	7	0
High	17	41	7	19	16	51	16	0
High	18	0	0	0	1	0	2	0
High	19	13	0	2	0	12	1	0
High	20	32	5	14	1	42	6	0
High	21	1	0	0	1	0	0	0
High	22	1	0	5	3	4	3	0
High	23	4	2	1	3	5	16	0
High	24	1	1	1	3	1	4	0
High	25	6	12	11	11	20	22	0
High	26	43	38	18	7	79	4	0
High	27	72	59	3	5	120	2	0
High	28	11	5	7	5	14	0	3
High	29	22	31	6	8	55	0	0
High	30	3	1	11	8	2	16	0
High	31	32	42	18	3	84	1	0
High	32	13	14	40	10	24	41	0
High	33	34	20	32	39	59	16	0
High	34	21	3	11	3	30	0	0

Stratum	*Number*	*Breeding females*	*Non-breeders*					
		Antlers/udders	No antler/udder	Antler/no udder	No antler-no udder	calves	yearlings	bulls
High	35	1	1	6	11	2	7	0
High	36	5	0	1	2	3	13	0
High	37	0	0	2	7	0	9	0
High	38	5	0	0	7	5	0	0
High	39	37	5	14	8	23	24	0
High	40	18	0	2	18	25	13	0
High	41	26	44	3	3	69	9	0
High	42	67	62	1	6	104	1	0
High	43	10	6	0	3	10	4	0
High	44	53	56	3	12	140	0	0
High	45	38	28	7	5	55	6	0
High	46	75	35	4	3	100	0	0
High	47	49	20	3	6	65	8	0
High	48	25	14	5	6	40	3	0
High	49	2	3	0	3	5	1	0
High	50	3	1	1	2	4	2	0
High	51	17	18	0	4	25	1	0
High	52	42	10	1	4	50	3	0
High	53	34	6	5	0	40	9	0
High	54	0	0	5	2	0	1	0
High	55	13	5	9	3	20	5	0
High	56	6	0	20	12	1	42	0
High	57	0	0	17	10	0	30	0
High	58	6	4	94	78	7	31	0
High	59	25	5	15	28	27	19	0
High	60	125	41	0	43	129	32	0
High	61	54	42	8	27	98	17	0
High	62	65	29	7	18	79	6	0
High	63	11	11	4	5	20	0	0
High	64	27	7	0	8	32	3	0
Medium	1	0	2	0	2	3	0	0
Medium	2	5	0	0	3	5	5	0
Medium	3	0	0	1	0	0	3	0
Medium	4	15	20	3	12	31	18	0
Medium	5	9	7	2	25	7	3	0
Medium	6	0	1	6	3	1	3	0
Medium	7	6	9	1	2	36	4	0
Medium	8	16	71	2	4	74	3	0
Medium	9	16	64	9	24	76	20	0
Medium	10	1	1	0	1	2	3	0
Medium	11	3	8	0	5	9	1	0
Medium	12	23	69	2	1	85	3	0

Stratum	*Number*	*Breeding females*	*Non-breeders*					
		Antlers/udders	No antler/udder	Antler/no udder	No antler-no udder	calves	yearlings	bulls
Medium	13	1	0	7	7	1	5	0
Medium	14	2	5	0	4	7	2	0
LowS	1	0	0	1	2	0	6	0
LowS	2	0	0	3	3	0	4	0
LowS	3	0	0	0	7	0	14	0
LowS	4	0	0	1	2	0	1	0
LowS	5	0	0	0	9	0	9	0
LowS	6	0	0	0	3	0	0	0
LowS	7	0	0	0	3	0	8	0
LowS	8	0	0	0	3	0	1	0

Overview: Monitoring of Bathurst and Bluenose-East Caribou Herds, Sept. 2014
Government of the Northwest Territories, Environment and Natural Resources

Summary:
This document provides an overview of population trend, other monitoring, and management of the Bathurst and Bluenose-East (BE) caribou herds in NWT and NU, with the emphasis on the last 5 years (2009-2014). Results from a reconnaissance survey conducted in June 2014 on the calving grounds of the Bathurst herd suggests this herd, which had been considered stable 2009-2012, has declined since 2012. Results from calving ground photo surveys of the BE herd indicate this herd has declined substantially 2010-2013. The June 2014 calving ground reconnaissance survey results suggest the BE herd has continued to decline rapidly. Photo surveys are planned for the spring of 2015 to allow more precise trend estimates for both herds.

Two main sections of this overview describe results of population surveys, calving ground reconnaissance surveys, estimates of cow survival rate, spring recruitment surveys, fall composition surveys, pregnancy rates, harvest estimates, movements of collared caribou between neighbouring herds, and the management context for each herd. Information on wolf monitoring on the Bathurst range and recent wolf harvest is included. A section on long-term cycles or fluctuations of migratory caribou herds and demographic indicators of decline (low pregnancy rates, low calf recruitment and low adult cow survival) follows. The overview concludes with assessments of population trend in the Bathurst and Bluenose-East herds 2009-2014 and possible explanations for the June 2014 calving ground reconnaissance survey results.

For the Bathurst herd, the likeliest explanation for the low numbers of caribou on the calving grounds in 2014 is a combination of low natural survival rates, reduced calf productivity and survival, and to some extent harvest. Harvest of the Bathurst herd on its main winter range (management zones RBC02 and RBC03) has been greatly reduced since 2010 but some harvest is unreported and some harvest has likely occurred outside these zones. For example, harvest of Bathurst caribou may be occurring in RBC01, where the Bathurst and BE herds overlap in winter. Issues related to the reconnaissance survey methods may have affected survey results but are unlikely to account for the large apparent drop in numbers of caribou on the calving grounds. Assessment of movements of collared caribou between the Bathurst's calving grounds and its neighbouring herds' calving grounds showed no evidence of large-scale emigration from the Bathurst range 2010-2014.

For the BE herd, a combination of low natural survival, reduced calf recruitment, low pregnancy rates in some years, and a substantial cow harvest are the most probable reasons for the herd's substantial decline 2010-2013 and the continued and potentially accelerated decline to June 2014. Issues related to the reconnaissance survey methods may have affected the survey results but are unlikely to account for the large apparent decrease in caribou on the calving grounds. Assessment of movements of collared caribou between the BE's calving grounds and its neighbouring herds' calving grounds showed no evidence of large-scale emigration from the BE range 2010-2014.

1. Table of Contents

2. Introduction

In the Northwest Territories (NWT), all migratory barren-ground caribou herds monitored by the Government of the Northwest Territories Department of Environment and Natural Resources (GNWT ENR) declined substantially between 2000 and 2006-2009. As a result of these declines, monitoring of the herds was increased and management actions were taken to address declines. Population surveys have been carried out every 3 years; in addition, other monitoring has been carried out to better understand the conditions each herd is facing.

One of the monitoring surveys that ENR has used is a calving ground reconnaissance survey in June near the peak of calving. These surveys are flown by small fixed-wing aircraft at a fixed elevation above ground with 2 observers on each side. Numbers and types of caribou seen are recorded in a strip 400m wide on each side of the plane. The results are used to map the calving grounds and to provide an indicator of the numbers of caribou at least one year old on the calving ground, most of which will be breeding cows (cows with calves or cows about to calve). Estimates of caribou numbers from these surveys do not provide precise population estimates as the ground coverage is low and the variance on the estimates is large. However, these surveys have to date reliably tracked population trend when compared to more intensive calving ground photo surveys flown at 3-year intervals.

In June 2014, reconnaissance surveys were flown over the calving grounds of the Bathurst and BE caribou herds (Fig. 1) using methods consistent with previous similar surveys. In the BE herd, survey results indicated that the rapid decline documented 2010-2013 from calving ground photo surveys has continued and may have accelerated. In the Bathurst herd, previous June surveys had indicated a stable trend 2009-2012, but the June 2014 results suggested a large decline since 2012. Results of these surveys, in combination with other monitoring information, were considered serious enough to set up a meeting Aug. 27 2014 in Yellowknife with Aboriginal leaders and co-management boards to review the information and discuss what management actions should be considered. In response to comments and questions at that meeting, further meetings and more detailed review of information were planned for October 2014, along with a further leaders' meeting in early November.

The purpose of this document is to provide an overview of technical information on the two herds, mostly gathered by ENR, with the emphasis on 2009-2014. Results of monitoring are summarized with limited interpretation of trends. Two main sections describe monitoring and management of the Bathurst and BE herds. A summary on cyclical changes in caribou herds over time and on the demographic indicators of decline in caribou follows. The overview concludes with an assessment of the two herds' trend to 2014 and the likeliest explanations for the June 2014 survey results. This document is not an exhaustive analysis of these subjects, but references listed and other reports and papers provide greater detail.

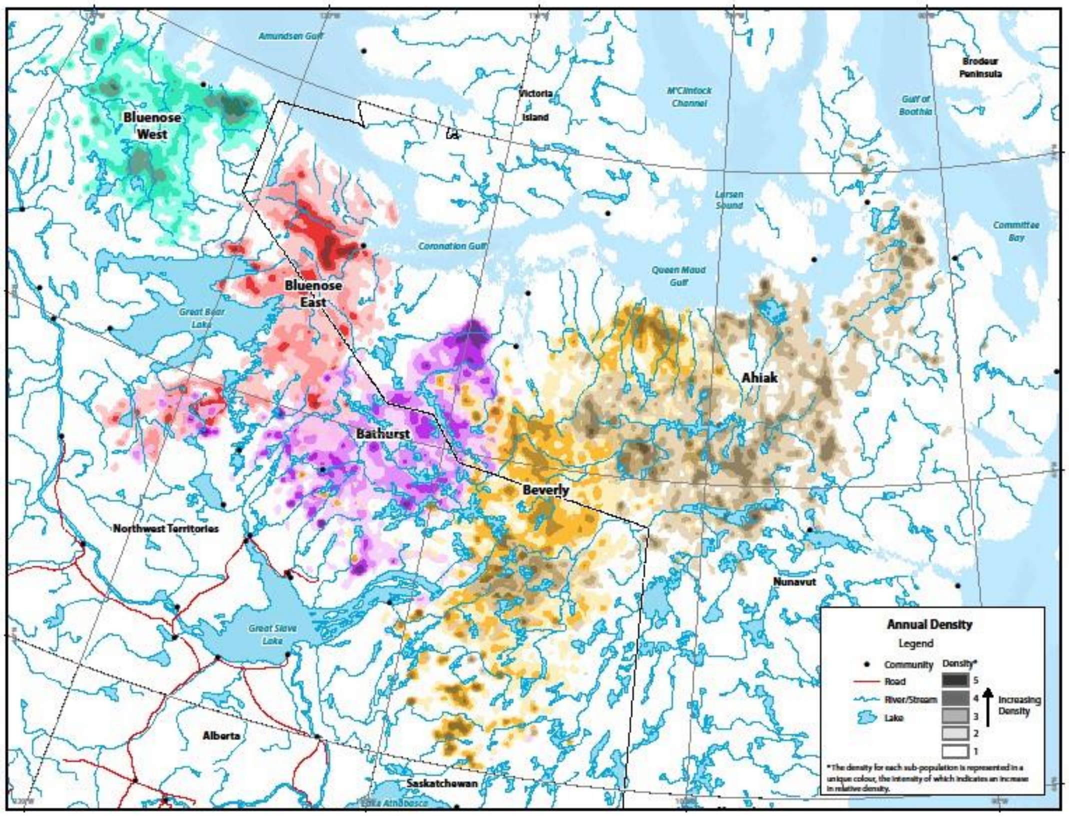


Fig. 1 Annual ranges of the Bathurst and Bluenose-East caribou herds, based on collar locations 2006-2012, and neighbouring herds. Darker areas were used more heavily than lighter more peripheral areas. Calving grounds are at the north end of the annual ranges.

Photo J. Adamczewski

3. Bathurst Herd

3.1 Population Surveys

Calving ground photo surveys have been used since the 1980s to estimate the numbers of breeding females in the Bathurst herd in June (Fig. 2). These estimates have been extrapolated to estimates of adult caribou (1.5 year-old or older) using measures of herd-wide pregnancy rate and sex ratio to account for non-pregnant cows and bulls, many of which will not be on the calving ground. Methods used in these surveys are described by Boulanger et al. (2014a) for the June 2012 Bathurst survey. Figure 2 shows the six estimates of breeding females and extrapolated herd estimates from calving ground photo-surveys of the Bathurst herd 1986-2012. The herd numbered nearly 500,000 in 1986, then declined slowly through the 1990s and more rapidly in the 2000s. The most rapid decline occurred between 2006 and 2009 when the estimate of breeding females declined from about 55,600 to 15,900, with a similar trend in overall herd size. From 2009 to 2012 the herd showed a stable trend of 32,000-35,000 adult caribou. A further calving ground photo-survey is planned for June 2015.

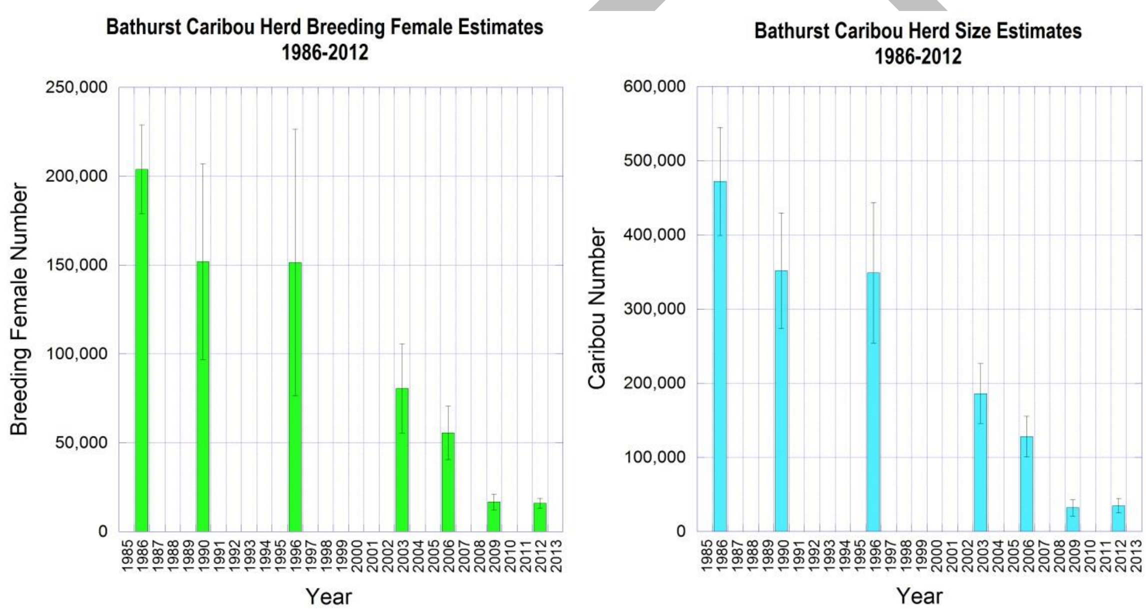


Fig. 2. Estimates of breeding females & adult caribou (1.5-year-old+) in the Bathurst herd 1986-2012

3.2 Calving Ground Reconnaissance Surveys

Reconnaissance surveys on the calving grounds are less intensive and much less expensive than calving ground photo-surveys. They provide information on where a herd’s calving grounds are that year, and they provide an indicator of the numbers of caribou at least one year old on the calving ground; a high proportion of these adults are usually breeding females. The surveys are flown in June near the peak of calving using small planes that fly lines spaced 5 or 10 km apart. These surveys are not designed to provide a precise population estimate, but when flown consistently and repeated over time, they can give an index of trend in the numbers of caribou on the calving ground. Methods and results of a June 2014 calving ground reconnaissance survey for the Bathurst herd are described by Boulanger et al. (2014b) along with results from previous similar surveys beginning in 2006. Fig. 3 shows the trend in numbers of 1-year-old or older caribou found on the calving grounds 2006-2014 for the Bathurst herd (note the 2011 survey was unsuccessful).

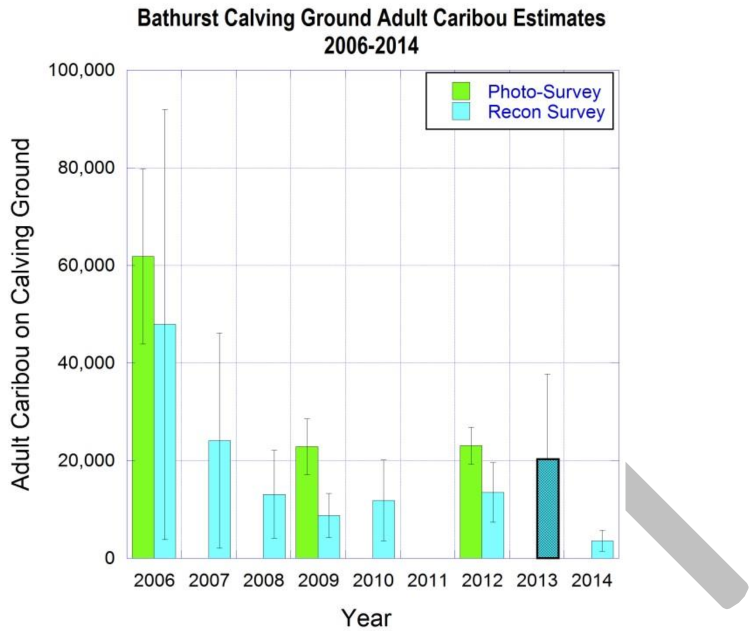


Fig. 3. Trend in numbers of caribou at 1-year-old or older on the Bathurst calving grounds 2006-2014

Figure 3 also includes the estimates of 1-year-old or older (adult) caribou on the Bathurst calving grounds derived from the calving ground photo-surveys in 2006, 2009 and 2012. Reconnaissance surveys are the initial phase of calving ground photo-surveys and are followed by more intensive photo-surveys of higher-density blocks and visual surveys of lower-density blocks. The higher numbers from the photo-surveys reflect the more complete counts of larger groups in higher-density areas from photos, compared to initial visual counts completed during reconnaissance flying. Overall, results of the reconnaissance surveys paralleled results of the photo-surveys between 2006 and 2009 and between 2009 and 2012. Numbers of adult caribou from the reconnaissance surveys declined rapidly 2006-2009, then showed a stable trend 2009-2012, in parallel to the numbers of adults estimated on the photo-survey.

A reconnaissance survey was flown June 9, 2013 (at the end of the June 2013 Bluenose-East calving photo survey) but occurred just after a snow-storm (Fig. 4). Observers' ability to sight caribou was poor. Very low numbers of caribou were seen (95 in total on transect) but this was thought in large part due to the ground conditions. The survey was suspended after the main calving area had been flown. A second reconnaissance survey was carried out on June 13, 2013 after the snow melted but it was well past the peak of calving and larger groups seen may have reflected initial post-calving aggregation. Estimates from June 13 2013 are included in Fig. 3 but may have been inflated by a few of these larger groups, which can include non-breeding cows, yearlings and bulls. Results of both recon flights in June 2013 should be considered with caution.

Fig. 4. Snow cover on the Bathurst calving ground June 9, 2013 (left), reconnaissance lines flown that day (middle) and reconnaissance lines flown June 13, 2013 (right). Green dots are collared cow locations and red triangles are locations of caribou groups seen.

Fig. 5. Flight lines on June 8-9 2014 reconnaissance survey of Bathurst calving ground.

Results of the June 2014 Bathurst reconnaissance survey were described by Boulanger et al. (2014b) and included in Fig. 3. Weather and visibility were excellent, similar to 2012. Results of this survey suggest the Bathurst has declined since 2012. Because of the limited coverage and large variance on reconnaissance surveys, the results should be treated with caution. The 2012 recon survey resulted in an estimate of 14,390 ± 6,109 adults 1-year-old or older on the calving ground, while the 2014 recon survey resulted in an estimate of 3,594 ± 2,133 adults. Of 18 satellite-collared Bathurst caribou in June 2014, 17 were within the survey area (Fig. 5), suggesting that a high proportion of the herd's cows were on the calving ground.

Monitoring from 1996 to 2014 has shown that female caribou have consistently used the same general area southeast of Bathurst Inlet for calving (e.g. Boulanger et al. 2014a). The Bathurst herd appears to have continued to maintain a single concentrated calving area even at lower numbers (Fig. 6), presumably to maintain the advantages of gregarious calving (Bergerud et al. 2008, Griffith et al. 2002).

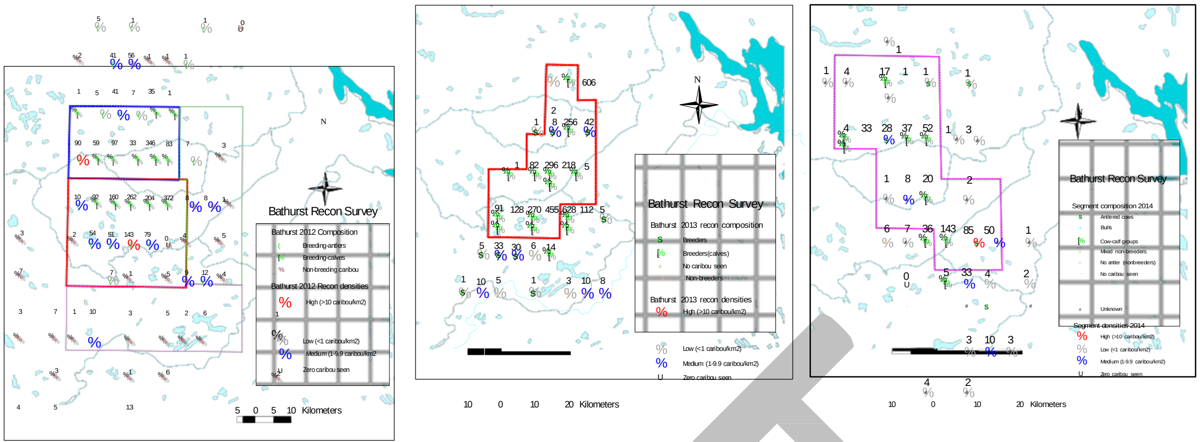


Fig. 6. Survey coverage, segment densities, and composition for the 2012 (left), 2013 (middle, June 13) and 2014 (right) Bathurst reconnaissance surveys (details in Boulanger et al. 2014b).

3.3 Adult cow survival estimates

Survival of adult female caribou is a key demographic variable for caribou herds, although it is difficult to measure. Stability of caribou herds is more closely tied to survival rates of cows than to other demographic variables (Fancy et al. 1994, Boulanger et al. 2011). Fig. 7 shows estimates of cow mortality rate compared to population rate of change based on caribou herds in Alaska, NWT and Quebec.

Overall, stable herds had cow mortality rates of 17% or less (survival of 83% or higher). Population modeling for the Bathurst herd has similarly suggested that cow survival rates of about 86% are needed for a stable herd (Boulanger et al. 2011). Estimation of cow survival rates has been carried out from collared cows in herds where collar numbers are adequate (e.g. 100 collared cows in Western Arctic and Porcupine herds) but has been difficult for the Bathurst herd, given that numbers of collars have averaged less than 20 at any given time. Cow survival has been estimated instead from a population model that uses all demographic information for the herd (Boulanger et al. 2011, 2014a). Analysis by Boulanger et al. (2011, 2014a) provided cow survival estimates for the Bathurst herd of 86% in 1985, 73% 2007-2008, 67% in 2009 and 78-79% 2009-2012. This suggested that cow survival had increased from the period of rapid decline in the Bathurst herd up to 2009, but might still be marginal 2009-2012 despite a stable herd trend 2009-2012 (Boulanger et al. 2014a).

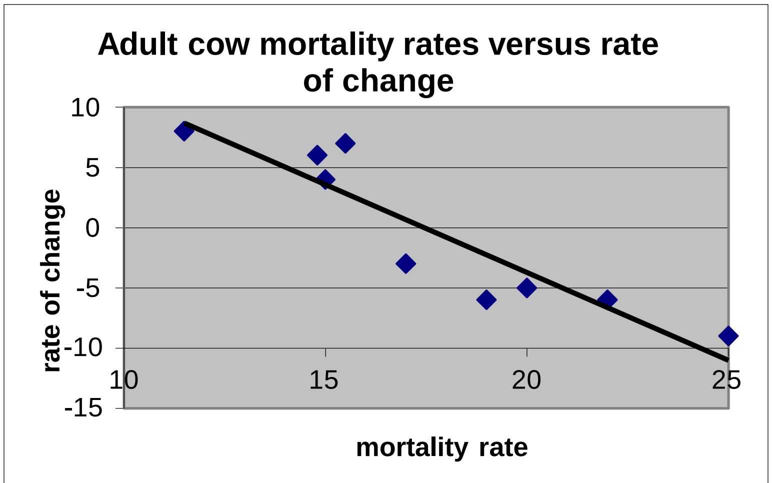


Fig. 7. Adult cow caribou mortality rate compared to population rate of change in barren-ground caribou herds (courtesy of D. Russell, CARMA, pers. comm. 2009). Herds with a rate of change of 0 are stable, increasing if the rate of change is above 0, and decreasing if the rate of change is negative.

3.4 Spring calf recruitment surveys

Spring calf recruitment surveys have been carried out frequently for the Bathurst herd since 1985. The key result from these surveys is a calf:cow ratio that provides an index of the proportion of the previous year's calves that survived to about 10 months of age. Mortality of calves in their first 6 months is often high, while calves that reach a year of age generally survive at rates similar to adults. Caution is needed in interpreting calf:cow ratios, as they can be affected by the survival rate of calves (numerator) as well as the survival rate of cows (denominator). In general, sustained calf:cow ratios of less than 20 calves:100 cows are clearly indicative of a declining natural trend in the herd. Ratios of 35-40:100 or higher usually indicate a herd likely stable and possibly increasing; however, the proportion of calves needed for a stable herd depends in part on adult female survival rates. In the George River herd, if adult and yearling female survival was 80%, then a fall calf:cow ratio of 52:100 was needed for a stable herd, while fall calf:cow ratios of 39:100 was needed for a stable herd if adult and yearling female survival was at 85% (Crête et al. 1996). In a similar way, Boulanger and Adamczewski (2014) suggested that if adult female survival was 85% in a caribou herd, spring calf:cow ratios averaging about 40:100 would be needed for stability. At cow survival estimates of 67% (Bathurst herd in 2009), the herd could not produce enough calves to achieve stability (Boulanger et al. 2011).

Calf recruitment and natural survival rates of adults show a correlation (with substantial variance) that suggests that environmental conditions favouring good calf survival also generally favour good natural adult survival (Fig.8, adapted from Bergerud 2000). Reduced spring calf:cow ratios may thus be indicators of concurrent reduced natural survival among adult caribou..

Spring calf:cow ratios for the Bathurst herd between 1985 and 2014 are shown in Fig. 9. In general, calf:cow ratios were consistently above 30:100 and frequently exceeded 40:100 from 1985 to 1995. From 2000 to 2006, calf:cow ratios declined from 29:100 to a low of 9:100 in 2006. Over this period, the herd had a declining natural trend, and a rapid decline based on calving photo-surveys and calving ground reconnaissance surveys. Higher ratios of 37-49:100 were recorded 2007-2011, over a period when the herd began to stabilize. Ratios in 2007, 2008 and 2009 may have been inflated by high cow mortality before the Bathurst harvest was substantially restricted in 2010.

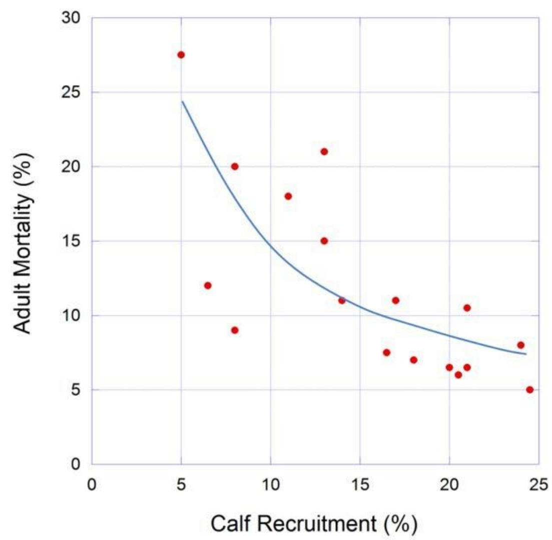


Fig. 8. Correlation between adult natural mortality rates of caribou and calf recruitment. Adapted from Bergerud, A.T. 2000. Ch. 31 (Caribou) in Ecology and management of large mammals in North America, Prentice-Hall.

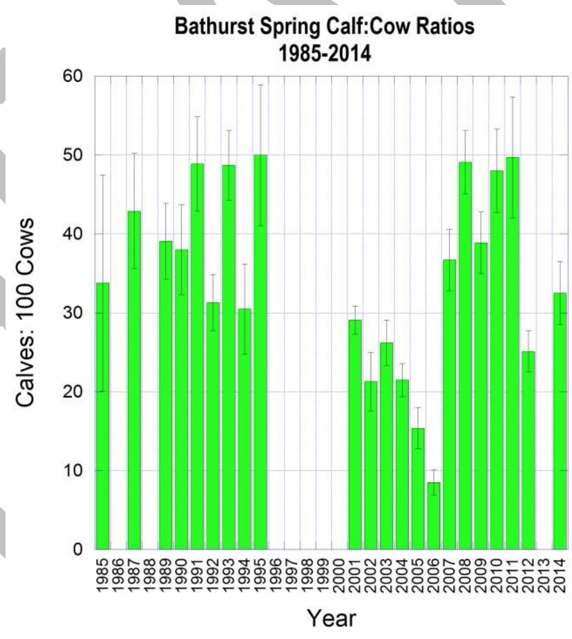


Fig. 9. Spring (late-winter) calf:cow ratios for the Bathurst herd 1985-2014.

The most recent Bathurst spring calf:cow ratios were 25:100 in 2012 and 32:100 in 2014. These are lower than the ratios recorded 2007-2011. A spring composition survey was not carried out in 2013 due to substantial mixing of Bathurst and Bluenose-East caribou. However, a fall composition survey was carried out for the Bathurst herd in Oct. 2012 (calves born in 2012); the calf:cow ratio was 24:100. Fall calf-cow ratios (calves 5 months old) are generally similar and usually slightly higher than spring ratios (calves 10 months old). This would indicate consistently lower calf recruitment 2012-2014 (calves born in 2011, 2012 and 2013) than in 2010 and 2011 (calves born 2009 and 2010) in the Bathurst herd.

3.5 Fall composition surveys

Fall composition surveys have been conducted periodically for the Bathurst herd. The main focus of these surveys is to provide an estimate of sex ratio (bulls:100 cows) in the herd. The surveys are carried out in mid-late October near the peak of the breeding season or rut. At this time of year, with adequate spatial coverage, all segments of the herd are mixed and the male:female ratio can be estimated reliably. At other times of year, cows with calves are usually segregated (found in different areas) from bulls, yearlings and non-breeding cows. Fig. 10 shows fall bull:cow ratios for the Bathurst herd from 2004 to 2012. Bull:cow ratios between 2004 and 2008 ranged between 31 and 38 bulls:100 cows, and were higher in 2011 and 2012 at 56-58 bulls:100 cows. Bull:cow ratios in barren-ground caribou are biased towards females, as males have higher mortality rates than females at all ages and ratios of about 50:100 are common (Bergerud 2000). Ratios below 50:100 are consistent with herds experiencing poor conditions, as demonstrated for the Bathurst herd by the low bull:cow ratios in this herd 2000-2006. Increased bull:cow ratios in 2011 and 2012 appear consistent with the herd's stabilizing trend 2009-2012. As with calf:cow ratios, however, bull:cow ratios are influenced by mortality rates of both bulls and cows; high cow mortality can inflate bull:cow ratios. This may in large part account for the apparently high bull:cow ratios in 2011 and 2012 (discussed further by Boulanger et al. 2014a).

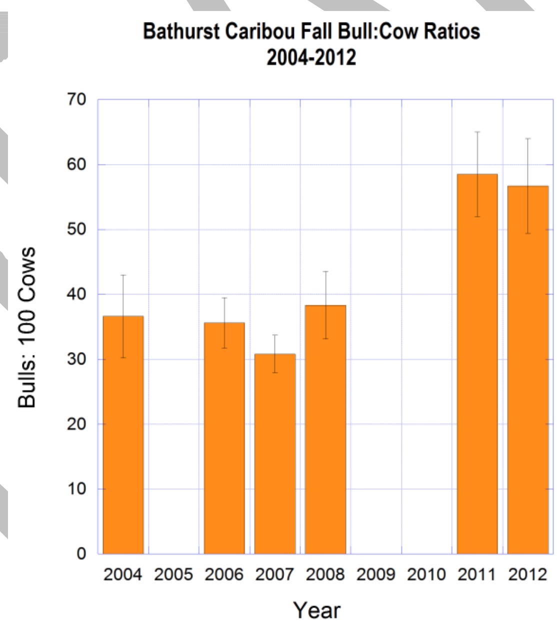


Fig. 10. Fall bull:cow ratios in the Bathurst herd 2004-2012

3.6 Pregnancy Rates

Information on pregnancy rates of Bathurst caribou cows has been collected periodically since 1990 from hunter-killed cows in the winter, but in many of the years the sample size has been small (10-15 cows or less). The low sample sizes make it difficult to consider these rates as reliably representing the herd's average pregnancy rate. In some years, pregnancy rates of

Bathurst cows have also been determined in cows captured in March/April and tested for progesterone in the serum (high in pregnant cows and very low in non-pregnant cows). The results are listed in Table 1. In most years, pregnancy rates have been relatively high (80% or more). A year that stood out for both an adequate sample size (n=150) and a low pregnancy rate (63%) was 2005; this was a year during a period (2000-2006) when Bathurst calf recruitment was consistently low (9-20 calves: 100 cows) and the herd was declining rapidly. In 1994, by contrast, 107 of 116 (92%) hunter-killed Bathurst cows were pregnant; these contrasting rates illustrate the range of pregnancy rates that have been documented in the herd.

Table 1. Pregnancy rates of Bathurst caribou cows 1990-2014 recorded either from hunter-killed animals or from blood samples of caribou captured for collar deployment.

Date	Hunter kits/Collections	Collaring	Combined
March 2014	n/a	9/13	
March 2013	Adult Cows: 5/5	7/8	12/13 (92.3%)
March 2012	n/a	13/14	
February 2011	Adult Cows: 20/25 (80%)	12/14	32/39 (82.0%)
March 2010	Adult Cows: 10/14 (71.4%)	12/14	22/28 (78.6%)
April 2009	Adult Cows: 25/28 (89.3%)		
March 2008	Adult Cows: 26/26 (100%)		
March 2005	Adult Cows: 95/150 (63.3%)		
March 1995	Adult Cows: 10/13 (76.9%)		
March 1994	Adult Cows: 107/116 (92.2%)		
March 1992	Adult Cows: 11/14 (78.5%)		
March 1991	Adult Cows: 6/10 (60%)		
March 1990	Adult Cows: 10/10 (100%)		

An NWT-wide collar deployment across multiple herds in March/April 2012 resulted in pregnancy being tested from serum progesterone in 138 cows at capture. The overall pregnancy rate was 61% (84/139), similar to the 63% recorded in Bathurst cows in 2005 during a period of rapid decline in the herd. For Bathurst cows, 12 of 13 captured or harvested females were pregnant in 2013 but this is a small sample. Although the limited Bathurst data do not provide evidence of a low pregnancy rate in 2012, the relatively low pregnancy rate across several herds on a large scale in 2012 may be indicative of a range-wide effect in several herds mediated by weather resulting in poor summer range condition leading to many cows being lean in the fall breeding season (Cameron et al. 1993, Cameron 1994).

Table 2. Pregnancy rates in 138 caribou cows captured March/April 2012 during collar deployments for herds across the NWT.

Herd	Blood collected (females)	# Pregnant	Pregnancy Rate
Bathurst	13	12	92.3
Bluenose-East	42	27	64.3
Beverly and Ahiak	27	16	59.3
Bluenose-West	34	17	50.0
Cape Bathurst	12	7	58.3
Tuktoyaktuk Peninsula	10	5	50.0
Totals	**138**	**84**	**60.9**

3.7 Harvest Estimates

Hunter harvest from the Bathurst herd has not been monitored reliably in all years. The harvest was estimated at 4000-6000/year, mostly cows, in 2007-2008 and 2008-2009, based on check-station results, hunter interviews and officer patrols carried out by ENR North Slave wildlife staff (Adamczewski et al. 2009). This estimate included 419 and 223 bulls taken in 2008 and 2009 by outfitter clients, less than 100 bulls taken annually by resident hunters, and an estimated 4000-5000 taken by Aboriginal hunters, primarily cows on the winter range. There is a limited harvest in Nunavut by Aboriginal hunters and outfitters.

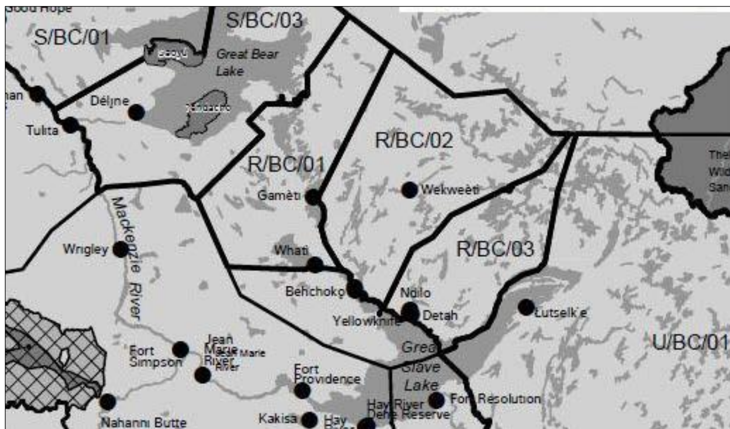
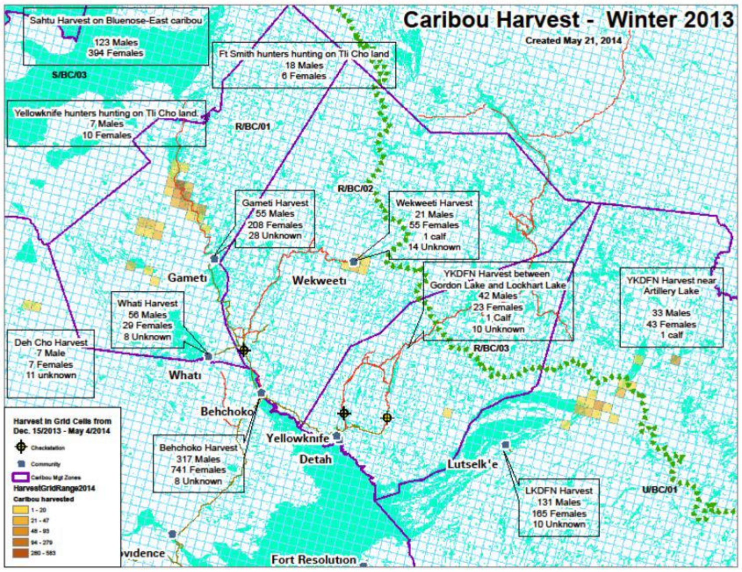


Fig. 11. NWT barren-ground caribou management zones in the main Bathurst caribou winter range and adjacent areas

Resident and outfitter harvest was closed at the end of 2009 in the NWT and Aboriginal harvest restricted to 300 or less (80% bulls or 60 or less cows), by agreement with the Tlicho government and the Yellowknives Dene First Nation in 2010. The restricted harvest applied in two management zones (RBC02 and RBC03) created to include the main NWT Bathurst winter range (Fig. 11).

Since the major harvest restrictions on the Bathurst herd in 2010, harvest in the North Slave region (primarily zones UBC01, RBC01, RBC02 and RBC03) has been monitored by a combination of check-stations, community monitors, officer patrols and estimates of community harvest from wildlife officers (Nunavut). Locations of harvested caribou are mapped and assigned to herd based on zones and collared cow locations. An example of mapped harvest from winter 2013 is shown in Fig. 12, along with a summary of estimated harvest before 2010 and Bathurst harvest as reported for RBC02 and RBC03 from 2010 to 2013. Harvest reported for RBC02 and 03 has averaged 191 caribou with a variable sex ratio. These estimates are considered under-reported; they do not include harvest in Nunavut, wounding losses or harvest of Bathurst caribou in zones outside RBC02 and RBC03.



Bathurst Harvest Estimates

2007-2009:
4000-6000/year, mostly cows

2009-2013*:
Monitors, officers, check-stations

Year	Estimated	% cows
2009-2010	300	65
2010-2011	213	58
2011-2012	87	82
2012-2013	166	42
Average	191	62

* As reported for RBC02 and RBC03; total harvest may be under-reported

Fig.12. An example of winter harvest mapped for North Slave communities and caribou management zones (left) and a summary of harvest estimates for the Bathurst herd 2007-2013 (right). Sex ratio of a portion of the reported harvest was reported as unknown; table includes sex ratio for caribou where it was reported.

To assess the likelihood and potential extent of harvest of Bathurst caribou outside the two zones where caribou harvest is limited to 300 or less (RBC02 and RBC03), winter collar locations of Bathurst and BE caribou were mapped for each winter (Dec-April) from 2010 to 2014 (Fig. 13). In addition, the numbers of collar locations, the percentages of collar locations, and the numbers of individual collared caribou from the 2 herds found in each of 5 management zones were tabulated (Table 3).

In general, BE caribou were primarily found in RBC01 and SBC03, south, east and north of Great Bear Lake, but were also found in RBC02 in 4 of the 5 winters. Bathurst collared caribou wintered mostly in RBC02 and RBC03, but 8, 14, 12, 24 and 0% of the collared caribou locations were in RBC01 in 2010, 2011, 2012, 2013, and 2014, respectively. Bathurst collared caribou also were found in UBC01 to a limited extent in 2012 and 2013; in 2013, 13% of the Bathurst collar locations were in UBC01.

Bathurst caribou wintering outside of RBC02 and RBC03 could have been exposed to additional harvest in RBC01 and to a lesser extent in UBC01. Most of the estimated/reported BE harvest since 2010 has been in RBC01, with average harvest estimated at about 2700/year, mostly cows. However, as noted further on in this summary, this estimate is considered under-reported and may be 4000 or more. The relative sizes of the two herds (Bathurst smaller than BE) and the predominance of use of RBC01 and SBC03 by BE caribou would suggest that most of the caribou harvest in RBC01 has been from the BE herd. Defining the Bathurst herd's winter distribution has been challenging due to the low collar numbers on this herd; there have generally been more collars on BE caribou. If a substantial part of the Bathurst herd wintered in RBC01 where harvest of several thousand caribou is estimated to have occurred, then some of this harvest was likely Bathurst caribou (e.g., in 2013 in the Hottah Lake area southeast of Great Bear Lake (Fig. 14).

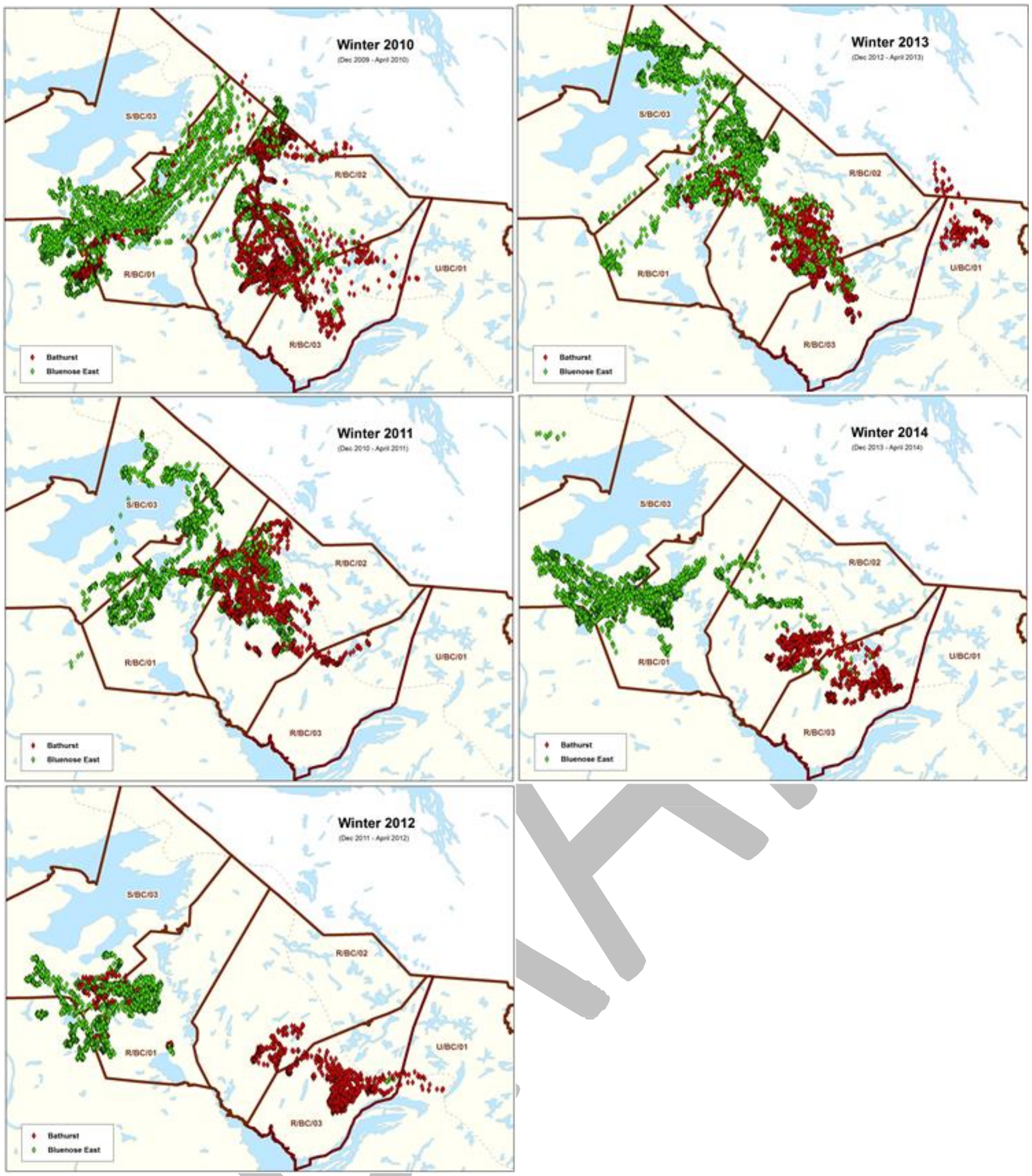


Fig. 13. Composite maps of collared caribou locations of Bluenose-East (green) and Bathurst (red) caribou during winter (Dec.-April) of 2010-2014 in relation to NWT barren-ground caribou management zones. RBC02 and RBC03 are the zones where Bathurst caribou harvest has been limited to 300 or less since Jan. 2010.

Table 3. Numbers of collared caribou locations, percentages of collar locations, and numbers of collared caribou occurring in or near NWT game management zones RBC01, RBC02, RBC03, SBC03 and UBC01 in winters 2010-2014. These numbers apply to the maps in Fig. 13.

WINTER 2010

BATHURST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	5647	464	4387	556	0	4	236
% POINTS		0.08	0.78	0.10	0.00	0.00	0.04
# COLLARS	26	3	17	15	0	1	2

BLUENOSE EAST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	9842	4111	1836	68	1008	0	2819
% POINTS		0.42	0.19	0.01	0.10	0.00	0.29
# COLLARS	56	46	15	4	22	0	25

WINTER 2011

BATHURST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	3782	548	3046	188	0	0	0
% POINTS		0.14	0.81	0.05	0.00	0.00	0.00
# COLLARS	21	9	21	1			

BLUENOSE EAST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	7738	3652	2718	0	1364	0	4
% POINTS		0.47	0.35	0.00	0.18	0.00	0.00
# COLLARS	35	23	15		15		1

WINTER 2012

BATHURST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	1870	216	382	1145	102	25	0
% POINTS		0.12	0.20	0.61	0.00	0.01	0.00
# COLLARS	25	4	8	15	1	6	

BLUENOSE EAST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	5829	3793	0	10	894	0	1132
% POINTS		0.65	0.00	0.00	0.15	0.00	0.19
# COLLARS	68	60		1	17		10

WINTER 2013

BATHURST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	2114	501	942	369	0	272	30
% POINTS		0.24	0.45	0.17	0.00	0.13	0.01
# COLLARS	20	7	13	6		2	2

BLUENOSE EAST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	9494	3258	1473	119	4582	0	62
% POINTS		0.34	0.16	0.01	0.48	0.00	0.01
# COLLARS	51	28	22	3	25		3

WINTER 2014

BATHURST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	1582	0	887	694	0	1	0
% POINTS		0.00	0.56	0.44	0.00	0.00	0.00
# COLLARS	23		17	12		1	

BLUENOSE EAST – HUNTING ZONES

	TOTAL	R/BC/01	R/BC/02	R/BC/03	S/BC/03	U/BC/01	OUT
LOCATIONS	7142	3715	457	26	2544	0	400
% POINTS		0.52	0.06	0.00	0.36	0.00	0.06
# COLLARS	40	31	5	1	22		4

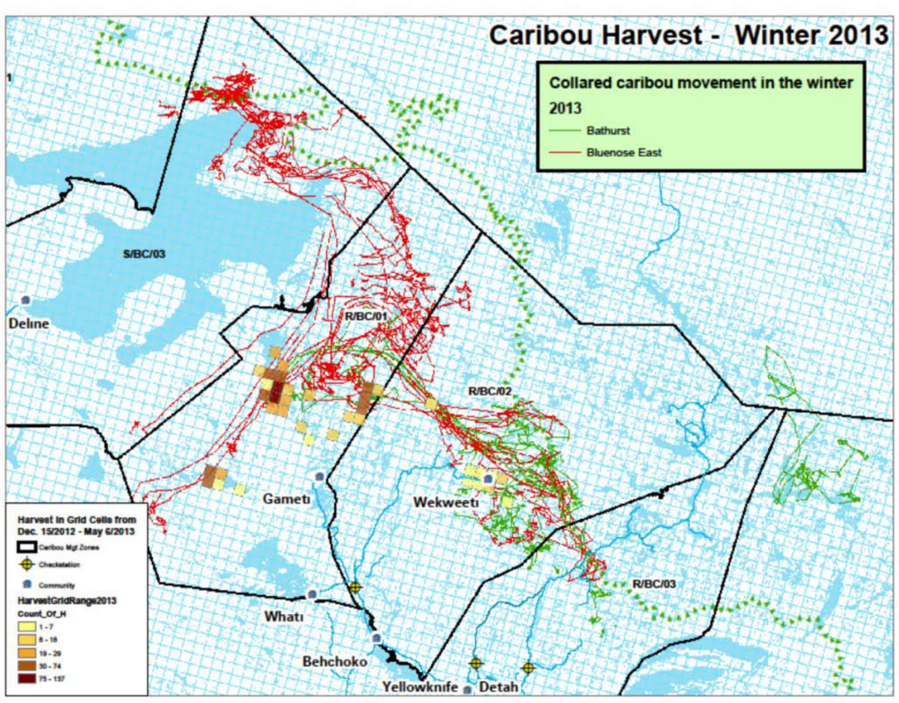


Fig. 14. Movements of collared Bathurst (green) and Bluenose-East (red) caribou in winter 2013 (Dec 2012-April 2013) in relation to caribou management zones and main harvest areas. Squares are 10x10km, coloured squares show areas where harvest was recorded and darker colours show areas with greater levels of harvest.

3.8 Wolf monitoring and harvest

Trends in the number of wolves in theNWT are of management interest because wolves are the main predator of barren-ground caribou. However, wolves are difficult to count at the population scale and high costs and potential biases inherent in existing techniques have limited efforts. Wolves on the tundra follow barren-ground caribou as caribou migrate from summer ranges on the tundra to winter ranges typically in the boreal forest. Although counting wolves in forested areas is problematic because of trees, wolves are more easily observed in the tundra. Wolves on the tundra raise their pups in dens, which are visible from the air. Wolves tend to re-use their den site each year and therefore annual surveys of den use (occupancy) over a wide area can provide a technique to monitor annual changes in wolf numbers.

Wolf numbers in the Bathurst summer range have been monitored by annual den surveys since 1996, although not always for trend analysis. Prior to 2006, different study objectives involving radio-collared wolves restricted the survey area covered. From 2006 to 2012, sampling coverage increased to establish a more representative area for monitoring trends of tundra-denning wolves. An occupancy (e.g., presence/absence) approach is used with 10 km x 10 km grid cells serving as the sampling unit. Previous research and local knowledge have shown that wolves tend to den on eskers and other gravel deposits where they can dig into the ground. Therefore, grid cells do not have to be surveyed in their entirety for wolves, but can be stratified by eskers and esker-like habitat within cells. An example of the area surveyed for wolf den occupancy is shown for summer 2012 (Fig. 15).

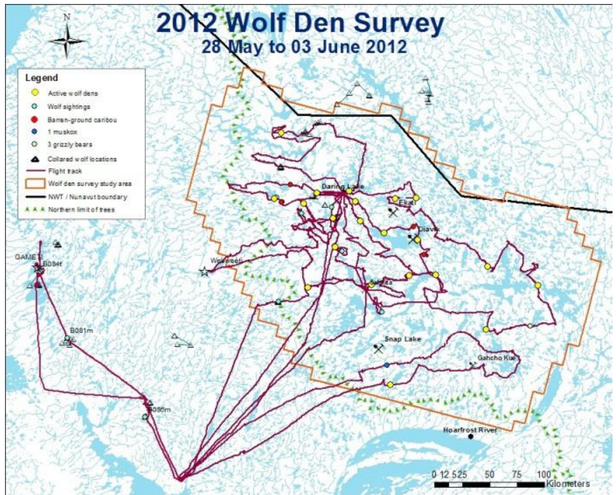


Fig. 15. Wolf den reconnaissance survey in Bathurst summer range in 2012 (D. Cluff, ENR)

An aerial survey in mid- to late August has been flown to all the active wolf dens found earlier that spring in each year to count the number of pups at dens. The number of dens visited that have pups is a subset of the number of dens found active in spring because pups could be relocated to another site and not discovered or all the pups could have died and so the parents no longer have to return to the same site for pup-rearing (Fig 16a). Ground observations of active dens are done in late summer where logistics permit to improve the accuracy of aerial counts. The most reliable number of wolf pups observed at each site in late summer or early fall is used to estimate recruitment of pups to the population. The average number of pups observed at a den or rendezvous site has declined in recent years (Fig 16b).

The pup recruitment survey in August cannot distinguish between total litter loss or site relocation as the reason why pups are not observed at revisited dens that were active earlier in spring. Doing so is critical to understand the distribution and recruitment of pups in late summer and to determine if this monitoring is an effective index of wolf abundance without using radio-collars. To address this problem, M.Sc. graduate student M. Klaczek from University of Northern British Columba (UNBC) was brought on to track collared wolves at dens to quantify the extent of litter loss at dens during 2013 and 2014. The annual spring den occupancy survey was not completed during this time.

Summary of NWT Wolf Project 2013/2014 (M. Klaczek, UNBC)

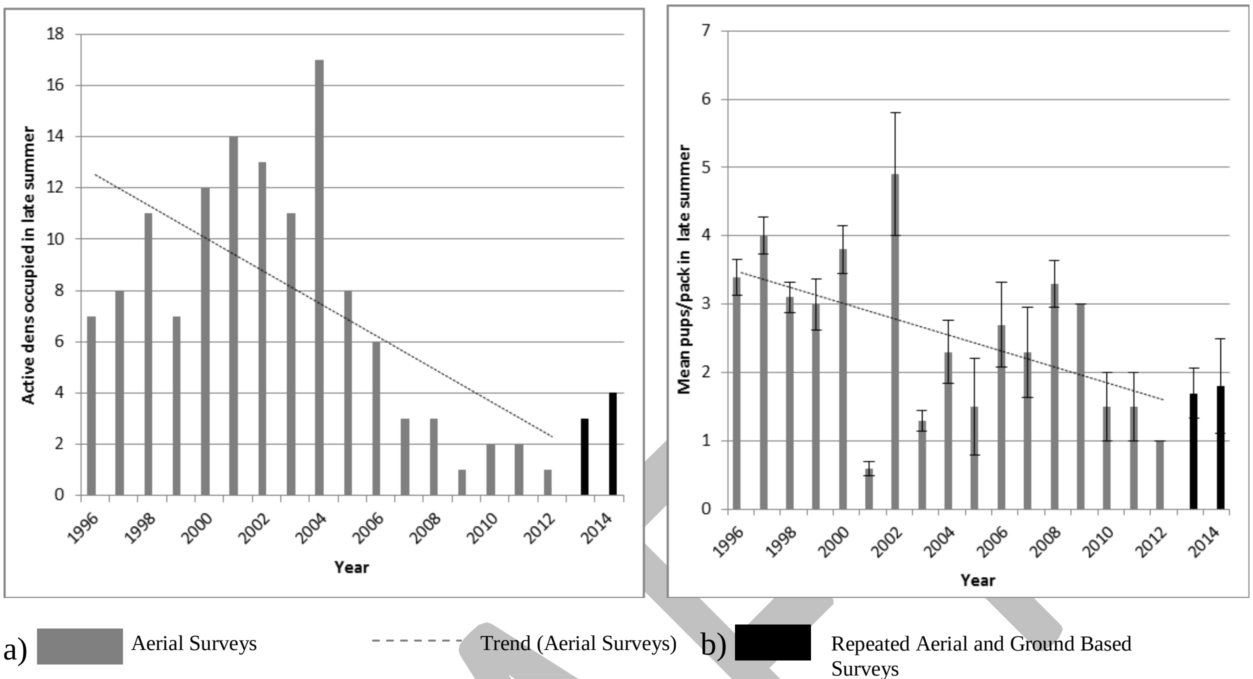


Figure 16. Observed a) number of active dens and b) pup recruitment (± SE) during annual aerial surveys (1996-2012) and repeated aerial/ground based surveys of tracked individual packs (2013-2014) on the summer range of the Bathurst herd, Northwest Territories and Nunavut Canada.

From 21-24 June, 2013, 16 female wolves were captured representing individual packs; 15 were breeding (lactating) females and 1 was a subadult (non-lactating) female. Over the 2013 and 2014 denning periods, 27 wolf packs (17 and 10 respectively) were monitored, 15 of which were monitored via a GPS collared adult female (N collared wolves = 15 and 4 in 2013 and 2014 denning periods respectively). Over 5 field sessions (total = 35 days; 3 and 2 sessions in 2013 and 2014 respectively), over 204 aerial checks were conducted to track wolf packs by visiting known den sites, radio-tracking, or by visiting clusters of GPS locations that may have represented a relocated den or rendezvous site. Over 111 hours were spent observing wolf dens/rendezvous sites on the ground over 66 separate field visits.

During the 2013 denning period, 6 of the 15 packs with a GPS collared female lost their pups by the end of August. The mean number of pups/pack declined throughout the denning period from 2.9 (± 0.31 SE) in July, 2.0 (± 0.40 SE) in August, and 1.7 (± 0.37 SE) in early September. Only 3 packs remained at their respective whelping den throughout the denning period (until early September); litter loss accounted for half of observed den abandonment. Eight active den sites (packs with pups) were located during the 2014 denning period. Only 2 of the 4 remaining GPS-collared females bred in 2014, however, wolf 432 likely lost her pups in early July, just prior to field surveys. The mean number of pups/pack declined throughout the 2014 denning period from 2.6 (± 0.6 SE) in early July to 1.8 (± 0.7 SE) in late August. Similar to 2013, only half of the monitored packs (4 of 8) remained at their whelping den throughout the denning period.

High rates of den abandonment and low pup recruitment observed during the 2013 and 2014 denning periods were consistent with observations recorded during late summer aerial surveys since 2007 (Figure 16). These results indicate that annual recruitment of pups has declined recently. Our results corroborate previous observations on wolf populations in both Alaska (Boertje and Stephenson 1992) and elsewhere in North America (Keith 1983, Fuller 1989, Fuller et al. 2003) such that varying levels of ungulate biomass strongly influence wolf population dynamics. This may mean that the wolf tundra population on the Bathurst caribou range has also decreased, although it is not clear if this represents a change in distribution or a change in abundance.

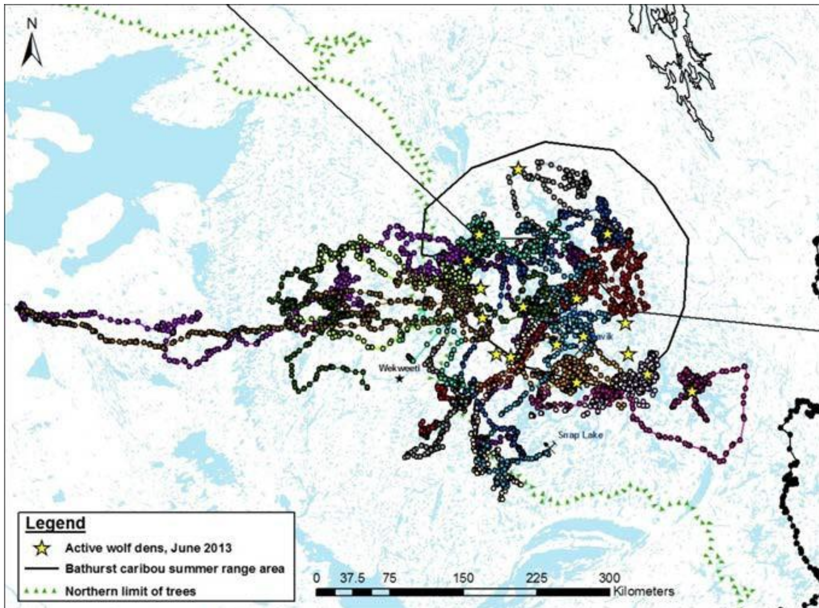


Fig. 17. Far-ranging movements of satellite-collared wolves captured in the Bathurst den survey area Oct-Dec 2013 (D. Cluff and M. Klaczek unpublished data). Different colours identify individual wolves.

Initial mapping of the movements of satellite-collared wolves captured at dens in the Bathurst range in 2013 provided an indication of the far-ranging movements of these tundra wolves in the fall and early winter (Fig. 17), over much larger distances than previously thought. These movement behaviours make the interpretation of den survey trends difficult. Further review of the information is required.

<u>Wolf Harvest in the North Slave Region 2008-2014</u>

As part of efforts to stabilize the caribou herds and promote their recovery, a program of increased incentives for wolf harvest was initiated in 2008/09 in the North Slave Region. Initially, financial incentives were $200 for prime pelts and $100 for carcasses. Carcasses were necropsied for a variety of samples. The intent was to increase harvest of wolves on the Bathurst winter range by 80 to 100 wolves. Only 25 wolf carcasses were submitted in the 2008-09 season. This program continued for a second year until an NWT-wide wolf carcass collection replaced it for the 2010-11 season. At that time, financial incentives were increased to $400 for prime pelts and $200 for carcasses. These programs had limited success and it is likely that survival rates of adult and calf Bathurst caribou were not meaningfully altered. For the 2013-14 season, the North Slave Region dropped back to a skull only program and payment was $50/skull, although the $400 payment per pelt was maintained. Currently, the wolf skull collection program and pelt price incentives are continuing for the 2014-15 harvest year.

Wolf harvests have been monitored annually. The total numbers of wolf carcasses reported in the North Slave Region in 2009-2010, 2010-2011, 2011-2012, and 2012-2013 were 19, 41, 80, 56 and 25 respectively (average 44, Table 1). Of the 221 wolves harvested in total, 59 were associated with dumps or sewage lagoons, 59 were taken from areas where collared Bathurst cows have not occurred in recent years (i.e., east of Great Slave Lake in areas near Artillery Lake, Reliance and Lutsel K'e), and 20 were taken in the Yellowknife area.

Table 4. Wolf Carcass/Skull Collection in the North Slave Region 2009-2014.

Location	2009-10*	2010-11	2011-12	2012-13	2013-14[a]
Dumps/Sewage Lagoons:					
Yellowknife/Dettah		2	2	6	
Lutsel K'e			1		
Behchoko	1	3	16	13	3
Gameti/Whati	3				4
Wekweeti		1			4
General area/Outside of:					
Yellowknife		13	4	3	
Lutsel K'e		1	6		
Behchoko/Hwy 3	1	3	2	8	3
Gameti/Whati		1			
Wekweeti			4	1	
Great Slave Lake area	3		4		
Winter Roads	4	5	7	2	9
Fort Reliance	5	1	10	6	
Artillery Lake/Sandy Lake area		9	17	4	
Grandin Lake/Hottah Lake area	1				1
other sites within NSR			3	8	1
received from outside the North Slave Region			3	1	
no location info	1	2	1	4	
TOTAL:	19	41	80	56	25

*harvest year spans 01 July to 30 June
[a]skull collection only

3.9 Movements of collared Bathurst and Bluenose-East caribou to other ranges

When declines of caribou herds are detected from population surveys, a key question that is asked is whether the caribou could have moved to a neighbouring herd's range. To address this question, June locations of collared cows where there were at least 2 consecutive annual locations were assessed for the Bathurst and BE herds for 2010-2014, along with their neighbours to the east and west (Fig. 18). Of 149 pairs of consecutive June locations for the five herds in Fig. 18, 144 (96.6%) returned to same calving ground and 5 (3.3%) switched to a neighbouring calving ground. These rates of switching are consistent with previous similar low rates of collared cow movements to neighbouring ranges (e.g. Bathurst herd 2006-2009, Adamczewski et al. 2009). While the collar sample size is limited, this assessment suggests that large-scale movements of the Bathurst herd (and BE herd) to other ranges did not occur 2010-2014.

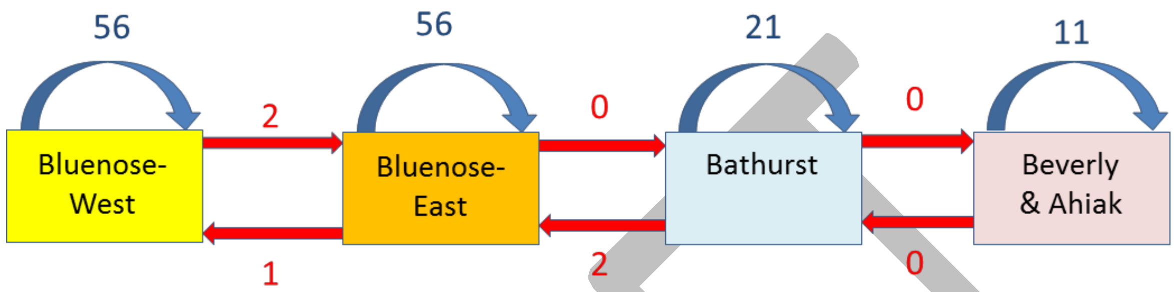


Fig. 18. Frequencies of switching between calving grounds of collared caribou cows from 5 neighbouring herds where at least 2 consecutive June locations were known, 2010-2014. Each pair of locations represents one data point. The numbers of cases where a cow returned to the same calving ground are in blue and the cows that switched are in red.

3.10 Management context for the Bathurst herd

An overall management plan for the entire range of the Bathurst herd is not in place as of Sept. 2014. However, a number of management initiatives have occurred or are underway for the herd.

Overall Bathurst herd management:
An initial management plan for the Bathurst herd was put together by a co-management process 2000-2004 by the Bathurst Caribou Management Planning Committee and a draft plan was completed in Nov. 2004 (BCMPC 2004). This plan was not signed off by all parties.

Since June 2012, there has been an ongoing effort by the Wekeezhii Renewable Resource Board (WRRB), Tlicho Government, and GNWT to develop a long term comprehensive management process for the herd, as required under section 12.5 of the Tlicho agreement. This initiative has included several meetings of the Bathurst Caribou Management Working Group, which is tasked with developing a mechanism to manage the Bathurst over the long-term. This mechanism may be a caribou board or body, similar to the Porcupine Caribou Management Board or Beverly and Qamanirjuaq Caribou Management Board. A Bathurst Caribou Harvesters' Gathering (Barnaby and Simmons 2013) was held in Jan. 2013 to help define this management mechanism.

Short-term management:
Initial harvest reductions were implemented by ENR in 2006 after a population survey showed a significant decline in the Bathurst caribou herd. Harvest allowed for resident hunters was reduced to 2 bulls/year and big-game outfitter tags were reduced from 1241 bulls in 2006 to 691 in 2007. After a further and more rapid decline documented in 2009, resident and big-game

outfitter harvest in the Bathurst range was reduced to 0. Aboriginal harvest was reduced to a target of 300 caribou (80% bulls) in management zones RBC02 and RBC03. These 300 caribou were divided equally between the Tlicho and Yellowknives Dene First Nation. Harvest has been monitored by a combination of community monitors, check-stations and officer patrols. These actions have occurred through joint management proposals submitted by the Tlicho government and GNWT-ENR to the WRRB in 2009 and 2010, an agreement between YKDFN and ENR in 2010, and recommendations since 2010 by the WRRB. The May 2010 joint management proposal and WRRB recommendations of Oct. 2010 can be found on the WRRB public registry.

In 2014, GNWT and the Tlicho submitted an updated joint proposal for management of Bathurst caribou in Wek'eezhi to the WRRB. Suggested actions included continued harvest management and a more focused predator management program centered around the Tlicho communities. Both governments were consulting on this proposal prior to announcement of the August 27 2014 meeting with Aboriginal leaders, political leaders, and co-management boards.

Land Management:
In recognition of concerns over the cumulative effects of development on the Bathurst range (including the calving grounds in Nunavut), ENR initiated a number of collaborative programs between 2012 and 2014 that related to land management. These include a range management planning process for the entire Bathurst range, a cumulative effects assessment, monitoring, and management framework, and a number of workshops focused on wildlife monitoring better suited to cumulative effects assessment, including increased emphasis on standardized monitoring protocols.

4. Bluenose-East Herd

4.1 Population Surveys

Before 2000, the Bluenose-East (BE) herd was surveyed as part of the "Bluenose" herd (Cape Bathurst, Bluenose-West and BE herds combined). Population surveys specific to the BE herd were initiated in 2000. Post-calving surveys were carried out in July and a Lincoln-Petersen estimator of herd size was used (Fig. 19). The herd was estimated at nearly 120,000 in 2000, appeared to decline to about 65,000 by 2006, then increased to an estimated 99,000 in 2010.

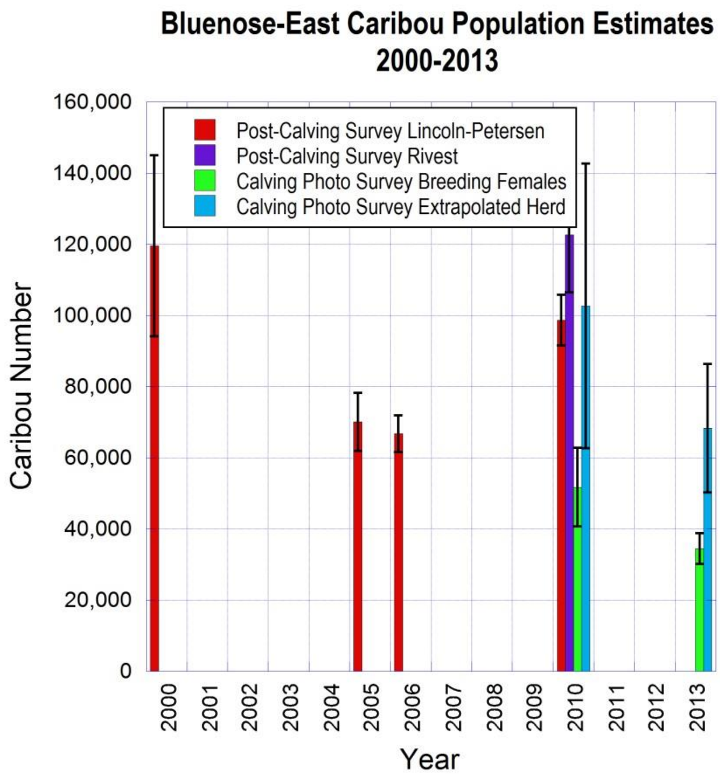


Fig. 19. Lincoln-Petersen and Rivest population estimates from a July 2010 post-calving survey from the Bluenose-East herd.

In 2010, ENR carried out a calving photo survey of the BE herd as well as a post-calving survey in July. This was the first side-by-side comparison of the two survey methods on the same herd in the same year in the NWT. Details on the survey methods and population estimates are provided by Adamczewski et al. (2014). In brief, the June photo-survey is designed to provide an estimate of the numbers of breeding females on the calving grounds. This can be extrapolated to an estimate of herd size using ratios to add in non-pregnant cows and males. The post-calving survey is based on photos of caribou groups that are tightly aggregated in July in response to biting flies. Groups may number tens, hundreds or thousands and include males and females at least one year old. An adequate number of collars is needed to find the caribou groups, and a statistical correction is then applied to account for caribou not found.

From the June 2010 survey, an estimate of breeding females of about 51,700 was derived. An estimate of adult caribou at least 1.5-years-old in the herd (ca. 102,700) was extrapolated from the estimate of breeding females using estimates of sex ratio from a fall composition survey and an estimate of pregnancy rate in cows at least 1.5-years-old.

From the July 2010 survey, photos were taken of 41 groups of caribou that included 44 of 47 collars in the herd, and 92,481 caribou at least one year old were counted on the photos. An estimate of herd size using a Lincoln-Petersen (LP) estimator provided a herd estimate of about 98,600 caribou at least one year old. A more recent and statistically more sound estimator of herd size using calculations of Rivest gave a herd estimate of 122,700 caribou at least one year old. This estimator had not previously been used in the NWT but has been accepted in Alaska and Québec, where it was developed.

Overall, all herd estimates from 2010 indicated a herd of at least 100,000 adult caribou (1-year-old+) and a likely herd size of about 120,000.

A post-calving survey of the BE herd was attempted in July 2012 but was unsuccessful due to insufficient aggregation of caribou in much of the herd. This survey method has failed previously with the BE herd in other years and has failed in other caribou herds (e.g. Porcupine and Western Arctic herds in Alaska); it requires that nearly all the herd form large dense groups that can be photographed.

A calving photo-survey of the BE herd was carried out successfully in June 2013 and reported by Boulanger et al. (2014c). Estimates of the number of breeding females, extrapolated herd size and the number of 1-year-old+ caribou estimated in the June survey area are shown in Fig. 19. The estimate of breeding females and extrapolated herd size both declined significantly; the number of breeding females was reduced by 1/3 at 34,500 and the extrapolated herd estimate was reduced by a similar margin.

4.2 Calving ground reconnaissance surveys

As described earlier for the Bathurst herd, calving ground reconnaissance surveys have been used for some caribou herds in the NWT to map calving grounds and as a lower-cost indicator to monitor the numbers of caribou on a herd's calving grounds, most of which are breeding cows. For the BE herd, reconnaissance surveys of the calving grounds were the initial step in calving photo-surveys in 2010 and 2013. A further calving reconnaissance survey was carried out in June 2014; results were reported by Boulanger et al. (2014d). Results of these reconnaissance surveys are shown in Fig. 20, along with estimates of adults (1-year-old+) on the main calving area from the more intensive calving ground photo-surveys.

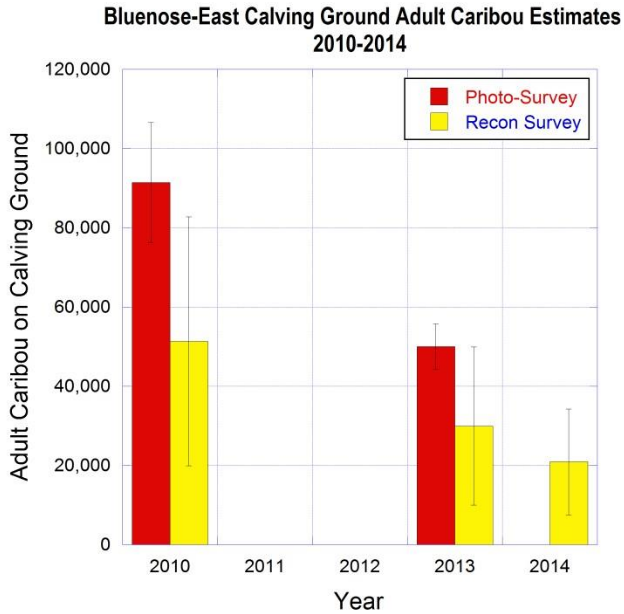


Fig. 20. Estimates of adult caribou (1-year-old+) on the Bluenose-East herd's calving grounds in 2010, 2013 and 2014 from calving photo-surveys and reconnaissance surveys

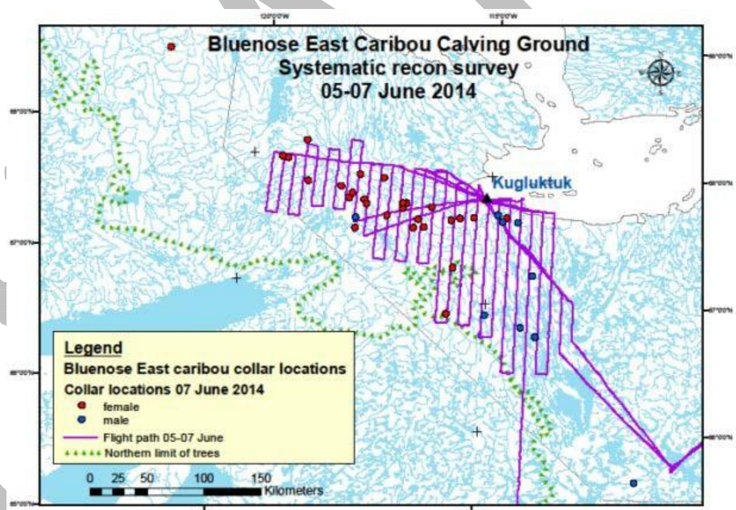


Fig. 21. Flight lines and collared caribou locations (cows red, bulls blue) from June 5-7 2014 calving reconnaissance survey over Bluenose-East calving grounds. Bulls, non-breeding cows and yearlings have been generally found south and east of Kugluktuk in recent years while the main calving grounds have been west of Kugluktuk.

Estimates from the reconnaissance surveys paralleled the trend in breeding females and extrapolated herd size in Fig. 21. Because of the relatively low coverage and high variance on reconnaissance surveys, the results should be interpreted with caution. However, the relatively rapid declining trend for the Bluenose-East herd 2010-2013 appears to be continuing. Flight lines flown on the BE 2014 June recon survey are shown in Fig. 21, with collar locations of cows and bulls. As in recent surveys of this calving ground, most of the collared cows were in the main calving area west of Kugluktuk, while most of the bulls and a few cows were south and east of Kugluktuk where bulls, yearlings and non-breeding cows were concentrated in 2010 (Adamczewski et al. 2014).

4.3 Spring calf recruitment surveys

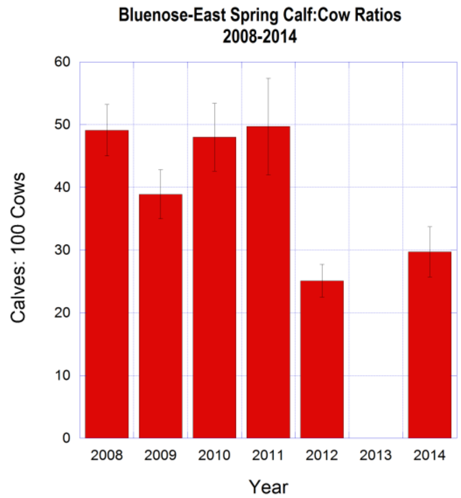


Fig. 22. Spring calf:cow ratios for the Bluenose-East herd 2008-2014 (no survey in 2013 because herds were mixed)

As described earlier for the Bathurst herd, spring (late-winter) composition surveys to monitor the ratio of calves:100 cows are used to provide an index of the number of calves in a caribou herd surviving to about 10 months of age. Recent spring calf:cow ratios for the BE herd are shown in Fig. 23. Similar to the Bathurst herd, calf:cow ratios of 38-50:100 cows were recorded 2008-2011, but lower ratios of 24 and 30 were recorded in 2012 and 2014.

4.4 Adult cow survival estimates

As noted earlier, caribou population trend is most sensitive to the survival rate of adult cows and cow survival rates of about 83% or higher are generally associated with stable herds. Cow survival based on a model that uses all demographic information available for a population was estimated at 73-75% for the BE herd 2010-2013 (Boulanger et al. 2014c), consistent with the rapid decline documented from surveys over this period.

4.5 Fall composition surveys

Fall composition surveys to estimate the ratio of bulls:cows in the BE herd were carried out in late October 2009 and 2013. In 2009, 4,531 caribou in 79 groups were classified and 42.6 bulls:100 cows were observed. In 2013, 5,381 caribou in 117 groups were classified and a similar ratio of 42.9 bulls:100 cows was observed. Bull:cow ratios of about 50:100 are common in caribou (Bergerud 2000).

4.6 Pregnancy and condition

Information on pregnancy rates in Bluenose-East caribou is available 2010-2014 from health and condition monitoring carried out collaboratively with Tlicho government and monitors during winter harvest of caribou; a summary is included in Appendix 1. Pregnancy rates were determined in late winter by the presence of a fetus, with the results in Table 5 below.

Table 5. Pregnancy rates of Bluenose_east caribou cows 2010-2014 recorded either from hunter-killed animals or from blood samples of caribou captured for collar deployment.

Date	Hunter kits/Collections	Collaring	Combined
March 2014	Adult Cows 44/50 (88%)	7/8 (87.5%)	51/58 (87.9%)
March 2013	Adult Cows: 17/21 (81.0%)		
March 2012	Adult Cows 22/29 (75.9%)	27/42 (64.3%)	49/71 (69.0%)
February 2011	Adult Cows: 11/11 (100%)		
March 2010	Adult Cows: 31/48 (64.6%)	8/9 (88.9%)	22/28 (68.4%)

Additional pregnancy information was available in 2010, 2012 and 2014 from cows captured in late winter to deploy collars (Table 5). Blood was collected and pregnancy was assessed based on serum progesterone levels (high in pregnant cows, very low in non-pregnant cows). In 2010, 8 of 9 cows were pregnant (89.0%); in 2012, 27 of 42 were pregnant (64%) and in 2014 7 of 8 were pregnant (87.5%). Results from smaller samples of 10-15 or less should be used with caution.

Additional information on pregnancy rates of cows captured for collar deployment NWT-wide in March/April 2012 are listed in Table 2 (included earlier in the Bathurst caribou section). The overall pregnancy rates across herds in 2012 was 60.9%.

Condition of hunter-killed Bluenose-East caribou from Tlicho hunters included measuring back fat at the base of the tail. Average back fat thickness was about 10mm in 2010 and 2011, lower at less than 4mm in 2012 and slightly higher in 2013 and 2014 (Fig. 25). As a comparison, backfat thickness averaged 13.9 mm in late winter in Beverly caribou at least 2 years old 1980-1987 (n=696) at a time when the Beverly herd was increasing (Thomas and Kiliaan 1998). Backfat averaged 16mm in pregnant cows (n=583) and 3.1mm in non-pregnant Beverly cows (n=113). By this standard, Bluenose-East cows were relatively lean overall 2010-2014, their condition was relatively poor in 2012 and marginally better in 2013 and 2014.

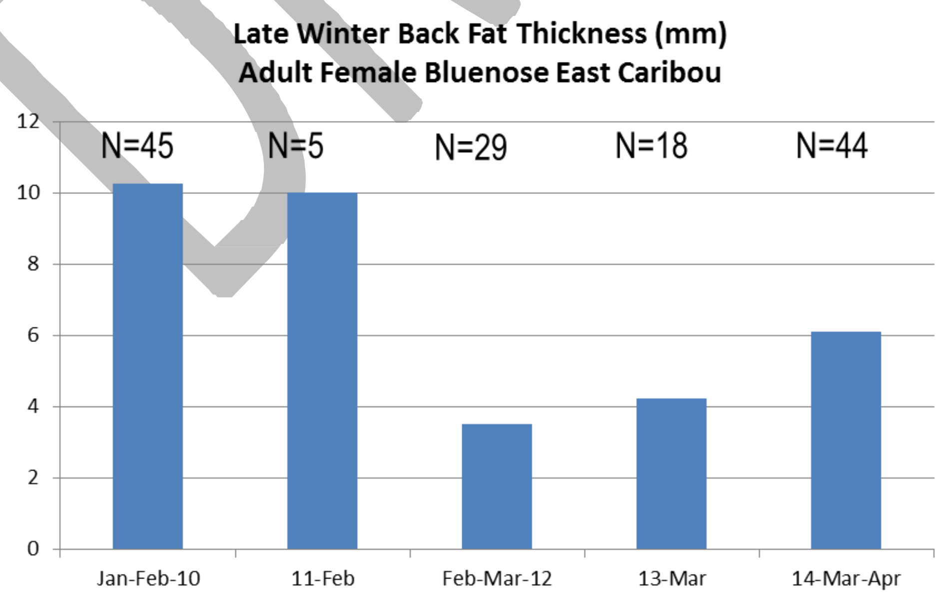
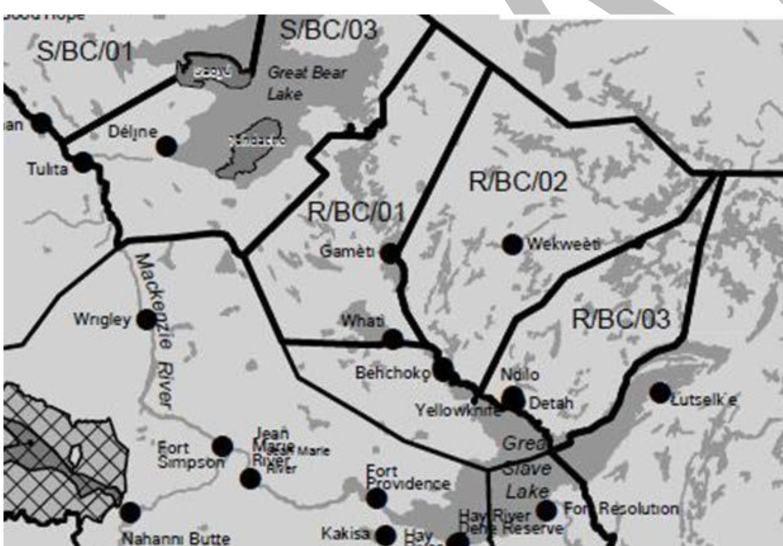


Fig. 24. Back fat thickness in hunter-killed Bluenose-East caribou cows during winters 2010-2014 as collected by Tlicho hunters during community hunts.

To place the pregnancy rates estimated for the BE herd 2010-2014 in context, the pregnancy rate of Beverly cows at least 2 years old averaged 83.7% 1980-1987 (n=708) and 86.1% in cows at least 3 years old (n=588) at a time when the Beverly herd was growing. In the George River herd, pregnancy rates of breeding-age cows averaged 89-100% during a period of increase in the herd in the 1970s, and were 59-78% during the early 1990s when the herd was declining (Bergerud et al. 2008). Recognizing the limited sample sizes in some years, the pregnancy information suggests that BE caribou had relatively low pregnancy rates in 2010 and 2012 and better pregnancy rates in 2011, 2013 and 2014. The NWT-wide low pregnancy rate in multiple herds points to a large-scale effect, possible weather-mediated, that may have affected cow condition in the breeding season on some ranges (Cameron et al. 1993) in 2012. The BE condition data 2010-2014 suggest that caribou were relatively lean over this period in comparison to the Beverly herd in the early 1980s, particularly in 2012-2014.

4.7 Harvest estimates

Harvest of the BE caribou herd was traditionally associated with the community of Deline on Great Bear Lake on the herd's winter range. Some harvest was also associated with Kugluktuk in Nunavut and Tlicho communities in NWT; however the main harvest in the North Slave region in winter was from the Bathurst herd before 2010. Resident harvest and guided-outfitter harvest of barren-ground caribou was also primarily from the Bathurst herd prior to 2010.



Bluenose-East Harvest Estimates

1998-2005:
Deline 1260/year, 60% cows (SRRB)
Limited harvest NU, Tlicho

2009-2013*:
Monitors, officers, check-stations
Primarily zones RBC01 & SBC03

Year	Estimated	% cows
2009-2010	3,466	65
2010-2011	2,918	65
2011-2012	1,766	65
2012-2013	2,562	65
Average	2,678	65

* Considered under-reported

Fig. 25. Barren-ground caribou management zones in the NWT (mostly North Slave region, left) and estimates of harvest from the BE herd 1998-2005 and 2009-2013 (right)

Since the major harvest restrictions on the Bathurst herd in 2010, harvest in the North Slave region (primarily zones UBC01, RBC01, RBC02 and RBC03) has been monitored by a combination of check-stations, community monitors, officer patrols and estimates of community harvest from wildlife officers (Deline, Nunavut). Based on collar locations, the BE herd has wintered primarily in RBC01 and SBC03, with some use of RBC02 (Fig. 13). Overlap of winter range use with the Bathurst herd has been substantial in some winters. Locations of harvested caribou are mapped and assigned to herd based on zones and collared cow locations. The average estimated/reported BE harvest has been about 2,700 caribou/year, and likely at least 65% cows (Fig. 26). These estimates are considered minimums; wounding losses are not included, some harvest is un-reported and the true harvest may be at least 4000/year. The increased BE harvest since the winter of 2009-2010 may reflect a deflected Bathurst harvest. Some of the harvest in RBC01 has likely been from the Bathurst herd (Figs 13 and 14, Table 1), but the predominance of BE collar locations and the relative sizes of the two herds suggest most of this harvest has been from the BE herd.

4.8 Movements of collared Bluenose-East caribou

In the earlier section on Bathurst caribou, rates of switching between Bathurst and BE calving grounds and neighbouring herds on either side were assessed based on collared cows for which two or more consecutive annual calving ground locations were known (Fig. 18b). This graphic is shown again below. Sample numbers for the BE herd were higher than for the Bathurst herd, which increases confidence in the rates of switching and fidelity reported. As with the Bathurst herd, there was no evidence for large-scale movement from the Bluenose-East calving ground 2010-2014.

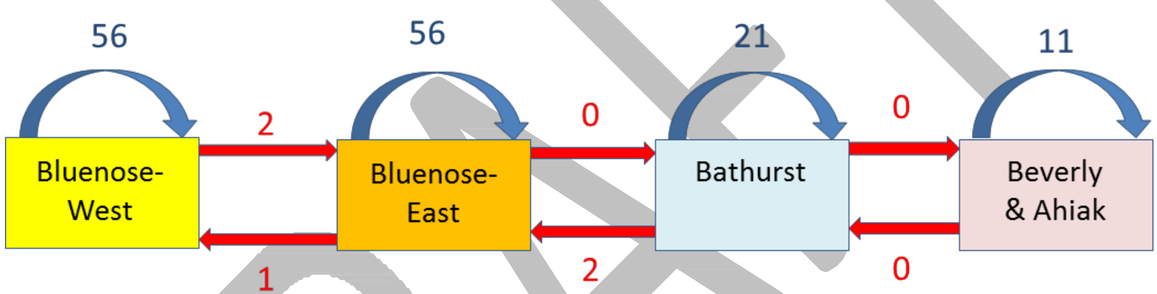


Fig. 18 (shown earlier). Frequencies of switching between calving grounds of collared caribou cows from 5 neighbouring herds where at least 2 consecutive June locations were known, 2010-2014. Each pair of locations represents one data point. The numbers of cases where a cow returned to the same calving ground are in blue and the cows that switched are in red.

4.9 Management context for the Bluenose-East herd

<u>Overall Bluenose-East herd management:</u>
A management plan developed through a co-management process for the Bluenose caribou herd was finalized in 2000, but was not signed off by all participants. Understanding of the "Bluenose" herd evolved in the 1990s, particularly with the use of satellite radio-collars that demonstrated that there were three separate calving grounds and three separate herds in this region. These were then named the Cape Bathurst, Bluenose-West and Bluenose-East herds. Beginning in 2000, post-calving population surveys specific to the three herds were first carried out.

A management plan for the Cape Bathurst, Bluenose-West and Bluenose-East herds was developed by the Advisory Committee for Cooperation on Wildlife Management (ACCWM, composed of chairs of co-management boards) beginning in 2007 and is expected to be finalized in 2014 (ACCWM 2014a). The plan provides for monitoring and management options depending on the herds' status. A companion document (ENR/ACCWM 2014) was developed by ENR as a technical report on the status, ranges and biological monitoring of the herd. A second companion document (ACCWM 2014b) is a summary of community engagement meetings and comments from community participants 2007-2013 in several rounds of meetings.

Short-term management:
Resident and guided-outfitter harvest of BE caribou was closed in 2010 after declines were documented in the Bathurst and other barren-ground caribou herds. Aboriginal harvest of this herd is not currently restricted. A portion of the BE herd may winter in management zones RBC02 and RBC03, where Aboriginal harvest has been restricted since 2010 to promote recovery of the Bathurst herd. Harvest of BE caribou was monitored 1998-2005 in the Sahtu region by the Sahtu Renewable Resources Board (SRRB). Since 2010, harvest of this herd (primarily in the in the North Slave region) has been monitored by a combination of community monitors, check-stations, officer patrols and estimates of community harvest from wildlife officers (Deline, Kugluktuk). Recommendations for voluntary Aboriginal harvest restriction were made in 2006 by the SRRB and in 2010 by the WRRB, but were not enacted.

Land Management:
The ACCWM management plan includes recommendations on land use that depend on the herds' status. Overall, current concerns over mining, roads and other land uses are limited for the BE range when compared to the Bathurst range. ENR has initiated a number of collaborative programs between 2012 and 2014 for the Bathurst range, including a range management planning process, a cumulative effects framework and regional scale monitoring programs in collaboration with diamond mines. These programs may have application to the BE herd's range in the future.

5. Caribou cycles and demographics of decline

5.1 Caribou cycles

Large changes in abundance of migratory barren-ground caribou herds have long been known to Aboriginal hunters and elders (Beaulieu 2012, Bergerud et al. 2008) and have been recognized by biologists from surveys and other monitoring (Bergerud et al. 2008). Presence of caribou on winter ranges southeast of Great Slave Lake in the Rocher River area alternated between scarcity and abundance on a 30-year cycle with peaks in 1924, 1954, 1984 and an expected peak in 2014 (Beaulieu 2012). Traditional knowledge of Tlicho elders identified a high in Bathurst caribou in the 1940s and low numbers before and after this peak (Zalatan et al. 2006); a method of tracking abundance of caribou from annual spruce root scars on traditional migration trails also identified higher Bathurst caribou numbers in the 1940s and identified a more recent high in the 1980s and 1990s that concurred with biologists' surveys over the more recent period (Zalatan et al. 2006, Fig. 26).

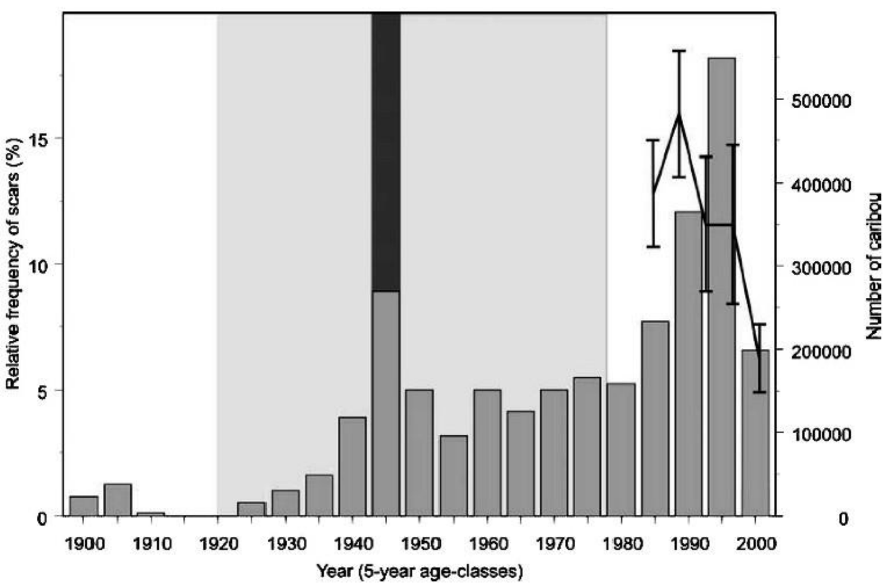


FIGURE 3. Bathurst herd caribou numbers from aerial photography surveys (1984–2003; black line; means ± SE), and abundance patterns (high = dark gray shading or low = light gray shading) derived from traditional knowledge of elders from the Dogrib First Nation relative to the scar frequency distribution for the northwest sites (Bathurst herd; bars).

Fig. 26. Relative abundance of caribou on traditional Bathurst migratory ranges inferred from spruce root scars 1900-2000, from Tlicho (Dogrib) elders (1920s-1980s), and from biologists' surveys (1980s-2000s), from Zalatan et al. (2006).

Large changes in Bathurst caribou abundance are not unique to this herd; the George River herd in Quebec/Labrador was very low in the 1950s (Bergerud et al. 2008), then increased to a peak of 700,000-800,000 in the late 1980s or early 1990s and has since declined to an estimated 14,200 in 2014 (Fig. 27).

A re-construction of the George River herd's relative abundance since the 1700s by Bergerud et al. (2008) using spruce root scarring along with related information including hunter success at traditional water crossings suggests that the length of cycles between high and low caribou numbers is not always predictable (Fig. 28), and that the highs and lows are variable. This re-construction suggested historic highs in the late 1700s, late 1800s and late 1900s and additional smaller peaks in the 1900s. These long-term fluctuations have likely occurred many times over thousands of years, with or without significant human influences.

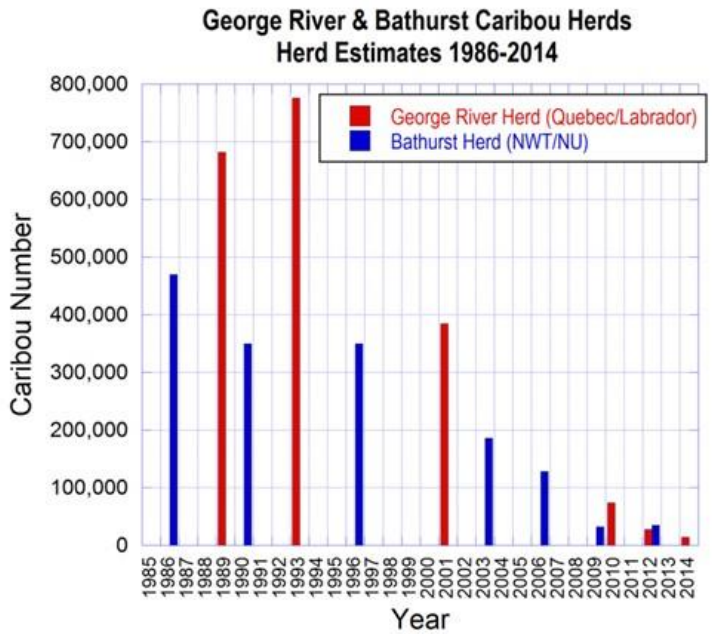


Fig. 27. Relative abundance of the Bathurst caribou herd in NWT/NU and of the George River herd in Quebec/Labrador 1985-2014. Bathurst estimates GNWT ENR extrapolated from calving photo-surveys; GR estimates 1989-2001 from co-management plan for this herd 2004 and from news-stories CBC 2010-2014.

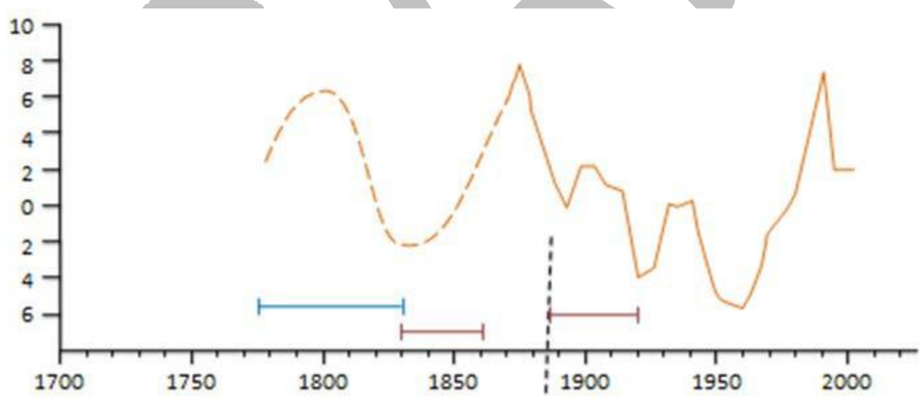


Fig. 28. Re-constructed relative abundance of the George River caribou herd 1750-2000 based on spruce root scarring, adapted from Bergerud et al. (2008).

One further example from an Alaskan/Yukon caribou herd demonstrates that long-term fluctuations in numbers of caribou herds may not follow a predictable cycle; herds may sometimes decline to relatively low numbers and remain there for extended periods. The Fortymile herd was once estimated at 300,000-500,000 in the 1920s, declined to about 50,000 in the 1950s, then declined further to a low estimated at 7,000 in the early 1970s (Valkenburg et al. 1994). Fig. 29 charts the history of this herd from 1950 to 1990. The prolonged low in caribou numbers appeared to result from a combination of high harvest, wolf predation, poor weather, and years of very poor calf recruitment (missing cohorts), and included two periods of wolf control. A recovery program for this herd included harvest limitation and non-lethal wolf removal and has been considered a successful example of a recovery program developed through a co-management process (Gronquist et al. 2005).

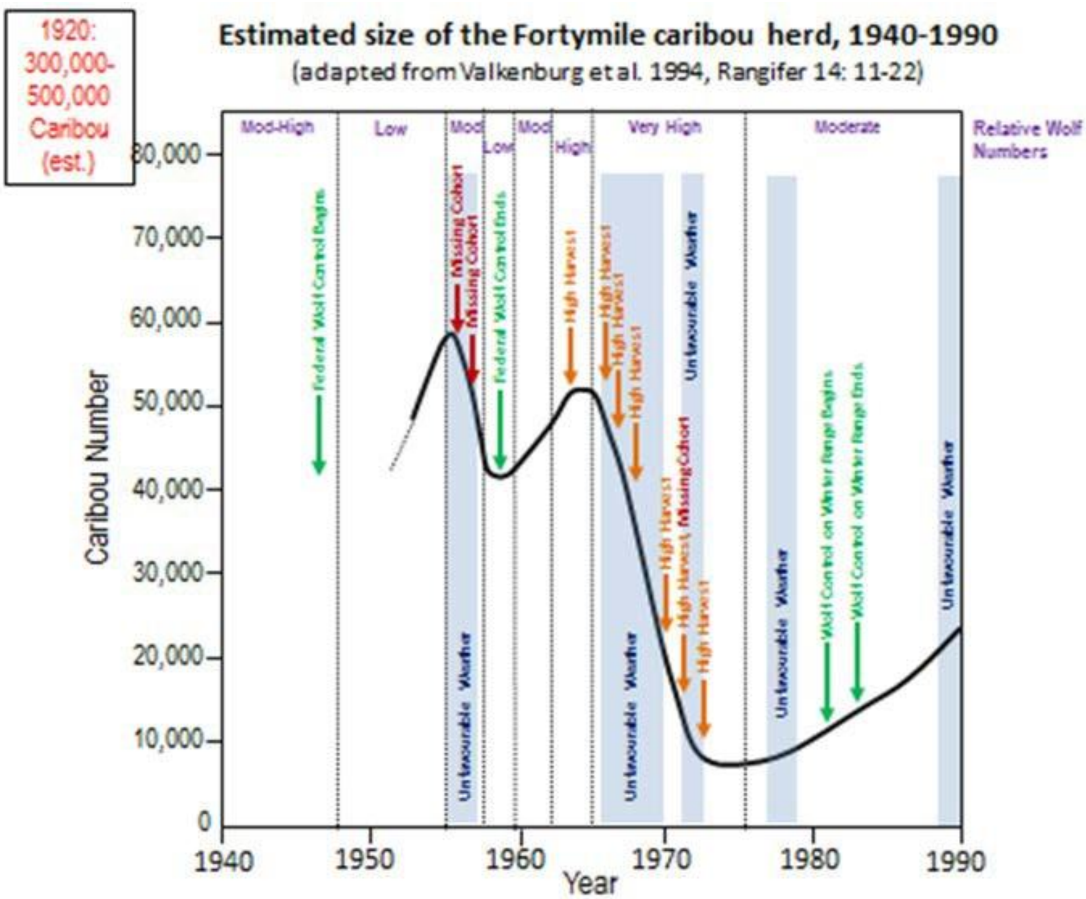


Fig. 29. Estimated size of the Fortymile caribou herd 1940-1990, adapted from Valkenburg et al. 1994.

Factors that drive cycles

Factors that drive large-scale increases and decreases of caribou herds are multiple and no one single factor explains these changes fully. However, because trends in caribou abundance are often similar regionally (Gunn 2003; exceptions do occur between neighbouring herds), climatic factors are likely key drivers that operate at large geographic scales (Gunn 2003, Vors and Boyce 2009). Decadal weather oscillations (North Atlantic Oscillation NAO, Arctic Oscillation AO, and Pacific Decadal Oscillation PDO) have been linked to population trend in four migratory tundra caribou herds in Alaska (Joly et al. 2011), but each herd was affected differently. Poorer growth of summer vegetation and reduced access to forage in winter (poor snow conditions) were likely main effects of adverse weather conditions (Joly et al. 2011).

One of the key effects of climate on migratory caribou is productivity of vegetation on the summer range (Gunn 2003); if cows have good foraging conditions over the summer, they are likely to be in good condition during the breeding season, leading to high pregnancy rates and high initial calf productivity and early calf survival in the following June (Cameron et al. 1993). Conversely, caribou cows in poor condition may not be pregnant every year (Cameron 1994).

At very high density, caribou may affect tundra vegetation negatively (thus their own forage and condition) by heavy grazing and trampling, as documented for the George River herd in the early 1990s (Manseau et al. 1996). However, negative effects of weather and environmental conditions can occur when herds are not at peak numbers. Between 2000 and 2006, late calving and low calf productivity and a likely declining natural trend were documented in the Cape Bathurst, Bluenose-West and Bathurst herds (Adamczewski et al. 2009). The large geographic scale covered by these 3 herds and the similarity of the effects over the same time period implicate weather (possibly affecting summer range and cow condition in the breeding season) as a likely key factor. All three of these herds were well below their historic highest herd size.

Predicting the effects of future weather on caribou is challenging as altered weather may have multiple implications for caribou (Joly et al. 2011). Research on the Beverly herd's winter range in the 1980s (Thomas et al. 1996, 1998) and on the Bathurst herd's winter range in the 2000s (Barrier and Johnson 2012) demonstrated caribou avoidance of recently burned areas (40-60 years) and a preference for forest at least 100 years old (Thomas et al. 1996, 1998) but suggested that overall winter range quality and lichen availability were adequate for these herds during the study periods. An increased frequency of big-fire years (such as 2014 in the NWT, Fig. 30) could have negative implications for caribou winter range if the forest shifts to a much younger age distribution with less of the slow-growing lichen caribou depend on in winter in older forests (Joly et al. 2012, Gustine et al. 2014).

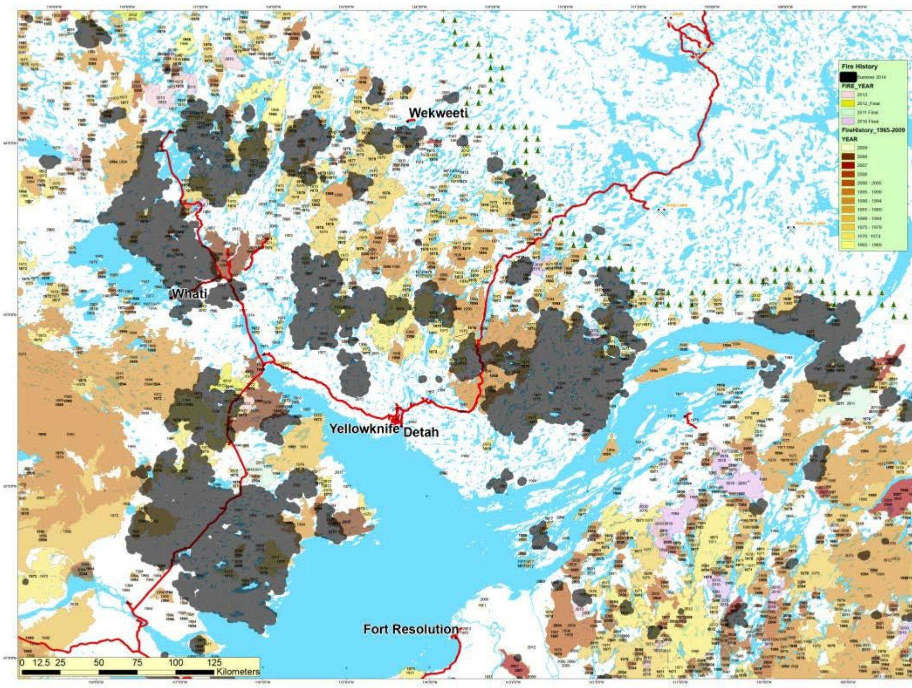


Fig. 30. Fire map showing burned areas from recent decades in the NWT in the region surrounding Great Slave Lake. Fires of 2014 are in grey. This map should be considered a draft as the fire season had not ended when the fires were mapped.

Predation is most likely to affect migratory caribou population trend at lower numbers and may prolong the period of low numbers (Valkenburg et al. 1994, Gunn 2003, Bergerud et al. 2008). Hunter harvest is also most likely to affect caribou herds at lower numbers, particularly if the herd is declining naturally and if the scale of the harvest is large relative to herd size and composed primarily of breeding cows (Boulanger et al. 2011). Declines in the Cape Bathurst, Bluenose-West and Bathurst herds showed a similar pattern of a natural declining trend 2000-2006/2007 that was accelerated at lower numbers by substantial harvest (Adamczewski et al. 2009), with a shift to a stabilizing trend in all three herds following major harvest restriction and improved calf productivity and survival (Fig. 31).

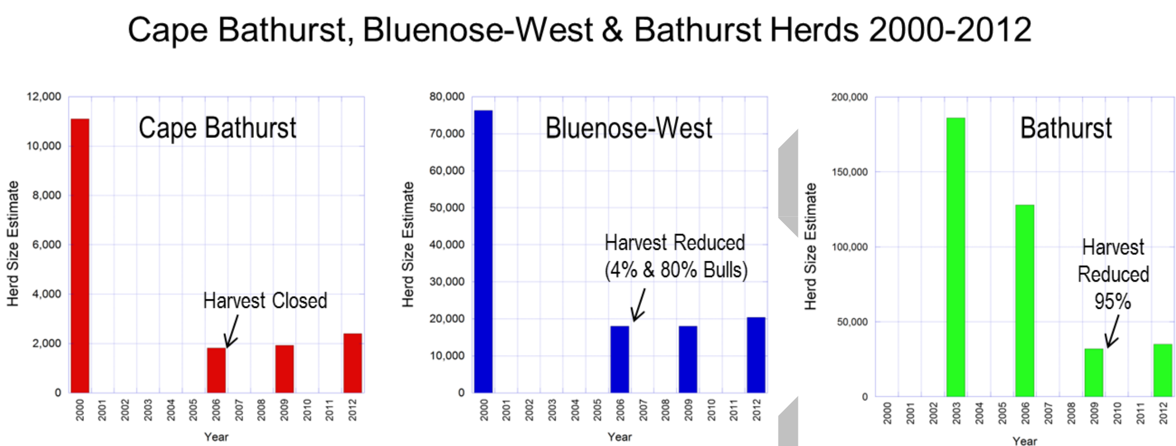


Fig. 31. Population trend and harvest reduction in the Cape Bathurst, Bluenose-West and Bathurst herds 2000-2012.

5.2 Demographics of decline in caribou

Clearly defining longer-term drivers of change in caribou herds is complex; weather can play a major role at various times of year, while predators and harvest may have smaller or larger impacts depending on herd size and trend. At a shorter time-scale in any particular herd, whether the herd is increasing, stable or declining is ultimately an annual balance between losses (caribou that die) and gains (calves that are born and survive to add to the herd). Key variables are (1) pregnancy rate or initial productivity, (2) calf survival through the first year, and (3) survival rate of cows, cow survival being the most critical to population trend (Fancy et al. 1994, Crête et al. 1996, Boulanger et al. 2011). Factors affecting caribou abundance will likely translate into changes in these vital rates. For example, a year or a period of years with very good summer range conditions and limited insect harassment will likely manifest as years with high pregnancy rates and high summer calf survival. Predators (wolves and bears) affect survival rates of calves and adults, and a substantial cow harvest will reduce the survival rate of cows.

In the George River herd in Québec/Labrador, pregnancy rates during the herd's increasing phase in the 1970s averaged 89-100%, cow survival estimates averaged 90-95%, and late-winter calf:cow ratios averaged 28-60 calves:100 cows (Bergerud et al. 2008). In the 1990s when the herd was in the early stages of decline, pregnancy rates averaged 59-78%, cow survival averaged 80-84% and late-winter calf recruitment averaged 9-19 calves:100 cows (Bergerud et al. 2008). A combination of low vital rates can lead to very rapid rates of decline: the George River herd was estimated at 74,000 in 2010, 27,600 in 2012 and 14,200 in 2014.

6. Bathurst & Bluenose-East population trend in 2014

6.1 Bathurst Herd in 2014

In this section the evidence for decline in the Bathurst herd 2010-2014 is assessed and likely causes for the low numbers of caribou recorded during the June 2014 calving ground reconnaissance surveys are considered. For clarity, possible explanations for the low numbers of caribou seen during the reconnaissance surveys are listed in Table 6, divided into potential factors resulting from the survey and potential biological factors.

<u>Survey-related factors</u>
The main limitation of June calving ground reconnaissance surveys is that they have relatively low coverage and the variance on estimates of caribou numbers is high. The relatively low precision means that survey estimates could be higher or lower than the true numbers. The Bathurst core calving area in June 2014 was small, so that even with 5-km spacing on flight lines, there were only 8 lines flown over the core calving area. The June 9 and 13, 2013 core calving areas were also small and had few survey lines (Boulanger et al. 2014b). A more precise photo-survey in June would have higher coverage and a lower variance attached to estimates of caribou numbers. However, despite the high variance, previous reconnaissance surveys of the Bathurst herd have reliably tracked the trend found in more precise calving ground photo surveys 2006-2009 and 2009-2012.

One potential reason for low numbers of caribou seen during the June 2014 reconnaissance survey could be if the pregnancy rate was low, meaning a significant numbers of cows were not on the main calving area. Information on pregnancy in Bathurst cows in 2014 was limited. Collared cows usually show a clear drop in movement rates when they calve. Movement rates of some collared cows did not decline below 5 km a day for a significant period of time in 2014 compared to 2012 and 2013 (Boulanger et al. 2013b), suggesting these cows were not pregnant. The pregnancy rate among 13 cows captured in March 2014 for collar deployment was 69% (9/13). However, 17 of 18 Bathurst collared cows were in the core calving area during the June 2014 survey, suggesting that a large proportion of the herd's cows (pregnant and non-pregnant) were on the calving grounds. Some non-pregnant cows are found on the calving grounds at the peak of calving in June, while others may be south of it (e.g. BE herd in 2010, Adamczewski et al. 2014).

Weather conditions during the June 2014 survey were excellent and snow cover on the main calving ground was limited, similar to 2012. The issues that occurred in June 2013 (poor sightability on June 9 due to patchy snow cover, possible post-calving aggregation on June 13) did not apply to 2014 or 2012.

If there were significant numbers of breeding cows in areas outside the survey area, this could have biased the survey results low. However, the Bathurst herd appears to have maintained a pattern of a single concentrated core calving area with very few cows in peripheral areas in recent years (see Fig. 6, Nishi et al. 2014, Bathurst calving ground in 2009, and Boulanger et al 2014a, Bathurst calving ground 2012) that continued in 2013 and 2014. In calving photo surveys (2006, 2009 and 2012), collared cow locations have consistently coincided with the concentrated calving area defined in each year.

<u>Biological factors</u>
The likeliest reasons for the apparent decline in caribou on the Bathurst calving ground are low cow survival rates and reduced productivity.

Previous demographic analyses suggested that survival rates of breeding females in the Bathurst herd had improved from 2006-2009 but were still low in 2009-2012 (78%). This analysis considered whether breeding female population size was at the expected number given recruitment levels (as estimated from calf-cow ratios) in years prior to the calving ground survey. The breeding female population size was lower than expected, which suggested that female adult survival was low and potentially limiting the ability of the herd to increase. It is unlikely that harvest alone could have resulted in the apparent decline 2012-2014 on the calving grounds, suggesting that the natural survival rate of Bathurst cows may have been reduced over this period. Lower spring calf:cow ratios 2012-2014 may also be indicative of lower natural cow survival rates, given the correlation between calf recruitment and natural survival rates of caribou (Bergerud 2000).

Reduced calf survival in 2012 and 2013 could have contributed to the low caribou numbers seen on the Bathurst calving ground in 2014. Evidence for reduced pregnancy rates in this herd is limited, with some indication of reduced pregnancy rates in 2014. NWT-wide, the 61% pregnancy rate in cows captured for collars in 2012 suggests a large-scale, potentially weather-mediated effect, although 12 of 13 Bathurst cows captured that year were pregnant.

The role of harvest in the apparent Bathurst decline is somewhat difficult to assess. Aboriginal caribou harvest in RBC02 and RBC03 has been limited to 300 annually since 2010 to promote recovery of the Bathurst herd. There is likely some additional unreported harvest and some wounding loss, and the target sex ratio of 20% or less cows has not generally been achieved. However, this scale of harvest from a herd of 32,000-35,000 (300-400 or around 1% of the herd) could not account for the apparent decline 2012-2014.

Low numbers of Bathurst collars have made it difficult to assess how much of the Bathurst herd has wintered in RBC01. The possibility of significant Bathurst caribou harvest in RBC01 in some winters (e.g. 2013, see Fig. 14) exists but is difficult to quantify.

There was no evidence for large-scale movement from the Bathurst herd to either of its neighbours (Bluenose-East and Beverly and Ahiak herds) from 2010 to 2014, based on the high fidelity of collared cows returning annually to the Bathurst calving ground (Fig. 18b).

Table 6: Potential reasons for decline in estimates of the Bathurst herd in 2014

Reason for decline	Evidence	Likelihood
Survey-related factors		
Low coverage (16%), high variance on recon resulted in larger aggregations of caribou not being sampled	Possible given lower recon survey coverage, but low coverage could bias the estimate low or high. Photo-survey with higher coverage will provide more precise, definitive estimate. Reconnaissance surveys have tracked trend well in BE and Bathurst herds.	Possible
Lower pregnancy rate resulted in fewer females in the core calving area.	Movement rates never declined to below 5 km per day for some collared cows. 9 of 13 (69%) of Bathurst cows captured Mar 2014 were pregnant (small sample). However, 17 of 18 collared caribou were in core area June 2014, main calving area was one well-defined block.	Possible
Lower sightability of caribou on calving ground compared to previous years	No evidence; survey conditions nearly ideal (good weather, little snow) similar to 2012.	Low
Breeding caribou not in the core calving area with collared caribou were missed	Very low densities of caribou were detected on the margins of the core area. 2012 core area was of similar size. Herd has maintained a single core area for calving since 1996. 17 of 18 collared cows in core calving area.	Low
Biological factors		
Declining trend due to reduced overall adult (cow) survival rates	Demographic analysis with the 2012 survey (Boulanger et al. 2014a) suggested that female survival rates in 2012 (78%) were still below levels needed for stable herd, herd status "fragile".	Probable Probable
Reduced natural (cow) survival rates	Lower recruitment in 2012, 2013, 2014 than in 2010-2011; reduced recruitment correlated with reduced natural adult survival (Bergerud 2000); harvest alone could not account for apparent decline 2012-2014.	Possible/Probable
Harvest mortality decreased number of breeding females, decreased overall cow survival rates	Estimated/reported harvest in RBC03 and RBC03 300 or less with variable sex ratio; some harvest may have occurred in RBC01 because of overlap with BE herd in some winters (e.g., 2013) but low collar numbers limit assessment. Some un-reported harvest occurs.	Possible Possible
Low pregnancy rate in some winters associated with low calf productivity and survival	Limited info on Bathurst pregnancy rates available; pregnancy has been generally high (small samples).	Low
Reduced calf recruitment 2012-2014 affected recon survey results in 2014	Reduced spring calf:cow ratios 2012, 2013, 2014. Calves born 2012 and 2013 (but not 2014) could influence 2014 survey results.	
Large-scale movement of cows from Bathurst range to other herds	Rates of collared cow switching to neighbouring herds very low 2010-2014 (consistent with other studies). Caveat in analysis is low collar numbers.	

6.2 Bluenose-East Herd in 2014

In this section, the evidence for decline in the Bluenose-East herd 2010-2014 is assessed and likely causes for the low numbers of caribou recorded during the June 2014 reconnaissance survey are considered. For clarity, possible explanations for the low numbers of caribou seen during the reconnaissance survey are listed in Table 7, divided into potential factors resulting from the survey and potential biological factors.

<u>Survey-related factors</u>
The main limitation of the June reconnaissance surveys is that they have relatively low coverage and the variance on estimates of caribou numbers is high. This means that survey estimates could be higher or lower than the true numbers. A more precise photo-survey in June would have higher coverage and a lower variance attached to estimates of caribou numbers. However, there were 20 flight lines over the main BE calving area in 2014 (See Fig. 22); this herd's calving ground has been spatially much larger than the Bathurst calving ground. Previous reconnaissance surveys of the Bathurst herd have reliably tracked the trend observed in more precise calving photo surveys 2006-2009 and 2009-2012, and in the BE herd 2010-2013.

Another potential reason for low numbers of caribou seen during the June 2014 BE reconnaissance survey could be if the pregnancy rate was low, meaning significant numbers of cows were not on the main calving area. The pregnancy rate of hunter-killed BE caribou in winter 2014 was 88% (44 of 50), which indicates a relatively high pregnancy rate that winter. In addition, the reconnaissance survey coverage was comprehensive, taking in the main calving area west of Kugluktuk and the areas south and east of Kugluktuk where bulls, yearlings and non-breeding cows have been found in recent years, and including nearly all the cow and bull collars.

Weather conditions during the June 2014 BE survey were good and snow cover on the main calving ground was limited. There was greater snow cover on more peripheral western portions of the survey area but few caribou in the area. Overall, observers' ability to sight caribou was good.

If there were significant numbers of breeding cows in areas outside the survey area, this could have biased the survey results low. However, the June 2014 BE recon survey coverage was comprehensive (see Fig. 22 and Boulanger et al. 2014d), covered the main calving area that has been documented since 2010 and earlier, and included coverage of the areas east and south of Kugluktuk where non-breeding cows, yearlings and bulls have been concentrated during several surveys. Previous surveys in 2010 and 2013 (Adamczewski et al. 2014, Boulanger et al. 2014c) did not detect any aggregations of breeding cows in these southern/eastern areas. The likelihood of a large proportion of the herd's cows being missed by the collars and by the extent of the survey area is low. Overall, survey-related factors in June 2014 are unlikely to have contributed significantly to the apparent decline in the herd.

Table 7: Potential reasons for decline in estimates of the Bluenose East herd in 2014

Reason for decline	Evidence	Likelihood
Survey-related factors		
Low coverage (8%), high variance on recon resulted in larger aggregations of caribou not being sampled	Possible given the lower reconnaissance survey coverage, but low coverage & high variance could bias count low or high. Photo-survey with higher coverage provide more precise, definitive estimate. Recon surveys have tracked trend well in BE and Bathurst herds.	Possible
Lower pregnancy rate resulted in fewer females in the core calving area.	Movement rates of collared females were below 5 km/day during survey with most cows in the core calving area. Initial reconnaissance survey covered areas with collared cows and bulls. Pregnancy in hunter-killed BE caribou in 2014 was 88% (44 of 50).	Low
Lower sightability of caribou on calving ground compared to previous years	Possible that snow cover reduced counts in peripheral areas of the calving ground (to the west). Unlikely to cause a large degree of bias in estimates. Generally good survey conditions 2014.	Low
Breeding caribou not in the core calving area with collared caribou were missed	Seven of 12 female caribou were contained within the core calving area. Lower densities of caribou were observed around collared caribou not in the core area. Overall survey area was comprehensive.	Low
Biological factors		
Demographic decline 2010-2013 continued due to reduced overall adult (cow) survival rates	Demographic analysis (part of 2013 survey report, Boulanger et a. 2014c) suggested female survival rates were low (0.73-0.75); possible combination of reduced natural survival rates and harvest.	Probable
Reduced natural (cow) survival rates	Lower recruitment in 2012 and 2014 than in 2010-2011; reduced recruitment correlated with reduced natural adult survival (Bergerud 2000); harvest alone could not account for 2010-2013 breeding female decline (Boulanger et al. 2013c).	Probable
Harvest mortality decreased number of breeding females, decreased overall cow survival rates	Estimated/reported harvest was at least 2700 caribou/year with at least 65% cows. Harvest was likely under-reported. Harvest has likely not declined in size 2010-2014, thus effect has likely increased as herd declined.	Probable
Low pregnancy rate in 2010 and 2012 associated with poor condition and reduced calf productivity	Pregnancy rate (hunter-killed) 64% in 2010; 76% (hunter-killed), 64% (captured cows) in 2012. Caribou relatively lean 2010-2014 (hunter-killed).	Possible
Reduced calf recruitment 2012-2014 affected recon survey results in 2014	Somewhat lower spring calf:cow ratios 2012 and 2014; no ratio for 2013. Calves born 2012 and 2013 (but not 2014) could influence 2014 survey results.	Possible
Large-scale movement of cows from BE range to other herds	Rates of collared cow switching to neighbouring herds very low 2010-2014 (consistent with other studies).	Low

<u>Biological factors</u>

The likeliest biological explanation for the reduced numbers of caribou on the BE calving grounds in June 2014 is a continuation of the decline documented from June 2010 and June 2013 calving photo surveys. This was likely the result of a combination of low natural survival rates, reduced pregnancy rates in some years (2010 and 2012), reduced calf recruitment 2012-2014, and a substantial harvest of primarily breeding cows.

Modeling by Boulanger et al. (2014c) suggested that harvest alone could not account for the reduction in numbers of breeding females from 2010 to 2014 in this herd, thus low natural survival rates likely contributed to the herd's decline over this period. At overall cow survival rates of 73-75% (Boulanger et al. 2014c), the herd would not be able to maintain stability even with very high calf recruitment. Lower spring calf:cow ratios 2012 and 2014 may also be indicative of lower natural cow survival rates, given the correlation between calf recruitment and natural survival rates of caribou (Bergerud 2000). Condition of BE hunter-killed cows from winters 2010-2014 was relatively poor, particularly in 2012 when low pregnancy rates were documented.

Reduced productivity and survival rates combined with substantial harvest of females from a declining herd have the potential to create a continued or accelerated decline, as was observed for the Bathurst herd from 2006 to 2009 (Adamczewski et al. 2009, Boulanger et al. 2011). A similar pattern was found in the Cape Bathurst and Bluenose-West herds from 2000 to 2006 (Adamczewski et al. 2009, Boulanger et al. 2011). In the case of the Bathurst herd, the annual decline in the herd accelerated from 11.7% between 2003 and 2006 to 33.1% between 2006 and 2009. The Bluenose-East herd showed a similar annual decline rate of 16.4% 2010-2013; and may be accelerating as observed in other herd declines in the NWT.

There was no evidence for large-scale movement from the BE herd to either of its neighbours (Bluenose-West and Bathurst herds) from 2010 to 2014, based on the high fidelity of collared cows returning annually to the BE calving ground (Fig. 18b).

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8. Appendix 1. Bluenose East Caribou Health and Condition Monitoring 2010-2014 Preliminary Results; information gathered by Tlicho hunters and monitors on community hunts.

Hunter Sampling Kits:

- Information Requested:
    - Unique individual animal identification number
    - Date of harvest
    - Location of harvest
    - Hunter name
    - Comments: general & any observed abnormalities
    - Estimated age (calf, yearling, young adult, moderate adult, old adult)
    - Sex of caribou (male or female)
    - Pregnant – visual observation of fetus (yes or no)
    - Lactation status –milk in udder (yes or no)
    - Condition – hunter assessment (skinny, not bad, fat, very fat)
    - Measurement of back fat (ruler provided)
- Samples Requested:
    - Kidney + Fat
    - Incisor bar for tooth aging
    - Metatarsus (bone marrow fat analysis)

Hunter Caribou Collection & Sampling Summary:
2010

- Total caribou sample kits submitted: 114
- Sample Collection Timing:
    - 43 harvested between January 16, 2010
        - Grandin Lake
    - 71 harvested on February 13, 2010
        - Grandin Lake
- Sex composition of harvest: 49 females, 52 males, 13 not identified

2011

- Total caribou sample kits submitted: 19
- Sample Collection Timing:
    - harvested between February 7 and February 18, 2011
        - Whati (n=17, location not specified)
- Sex composition of harvest: 12 females, 2 males, 5 not identified

2012

- Total caribou sample kits submitted: 40
- Sample Collection Timing:
    - 32 harvested between on February 23, 2012

(Grandin River, Grandin Lake)

- 8 harvested March 4-5, 2012 (Location not specified)

- Sex composition of harvest: 31 females, 6 males, 3 not identified

2013

- Total caribou sample kits submitted: 50
- Sample Collection Timing:
    - All harvested between on March 22-23, 2013 (Hottah Lake)

  - 8 harvested March 4-5, 2012 (Location not specified)
- Sex composition of harvest: 20 females, 6 males, 24 not identified

2014

- Total caribou sample kits submitted: 70
- Sample Collection Timing:
  - All harvested between on March 30th- April 1st, 2014 (Hottah Lake)
- Sex composition of harvest: 55 females, 5 males, 10 not identified

<u>Age</u>

Teeth submitted to Matson's Laboratory for exact age determination by cementum analysis for 2010 to 2013.

2010

Estimated Age of Harvest (hunters):

- Cows
  - 1 calf
  - 5 yearlings
  - 32 adults

- Bulls
  - 6 calves
  - 16 yearlings
  - 24 adults
  - 28 age not recorded

Tooth Cementum Age

Age Range: 1- 11
Gender: M (bull).F (cow).U (unspecified)
N= 35

Age	Number of Animals	M.F.U
1	5	4.1.0
2	11	3.3.5
3	10	6.1.3
4	2	2.0.0
5	4	2.0.2
6	0	0.0.0
7	1	0.1.0
8	0	0.0.0
9	1	0.1.0
10	0	0.0.0
11	1	0.0.1

2011

Tooth Cementum Age

Age Range: 1- 13
Gender: M (bull).F (cow).U (unspecified)
N=16

Age	Number of Animals	M.F.U
1	3	0.2.1
2	0	0.0.0
3	4	0.3.1
4	1	0.0.1
5	1	0.1.0
6	1	1.0.0
7	3	0.2.1
8	1	0.1.0
9	0	0.0.0
10	1	0.1.0
11	0	0.0.0
12	0	0.0.0
13	1	0.1.0

2012

Tooth Cementum Age

Age Range: 1- 9
Gender: M (bull).F (cow).U (unspecified)
N=36

Age	Number of Animals	M.F.U
1	1	0.1.0
2	5	1.4.0
3	8	1.6.1
4	9	2.6.1
5	3	0.2.1
6	2	0.2.0
7	4	0.4.0
8	0	0.4.0
9	4	0.4.0

2013

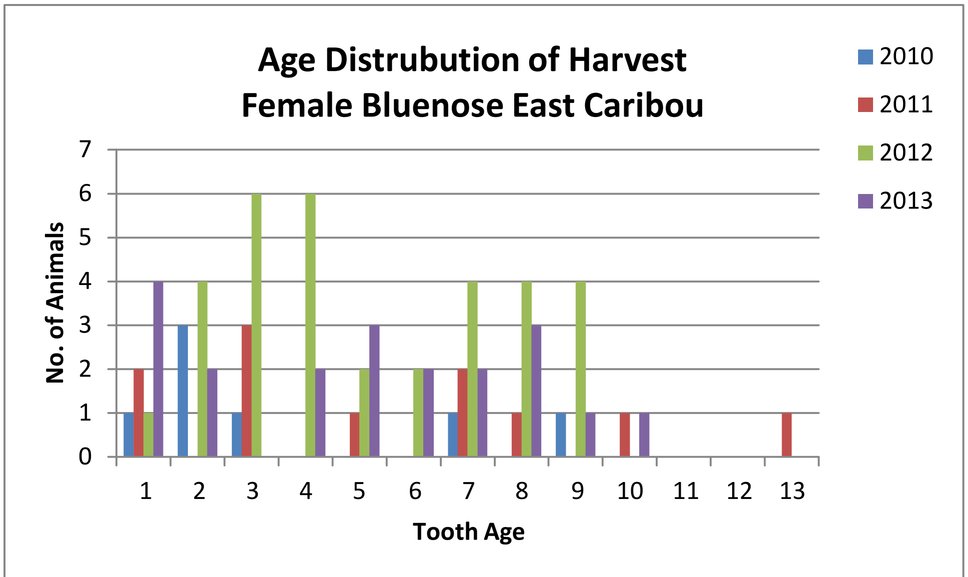
Tooth Cementum Age

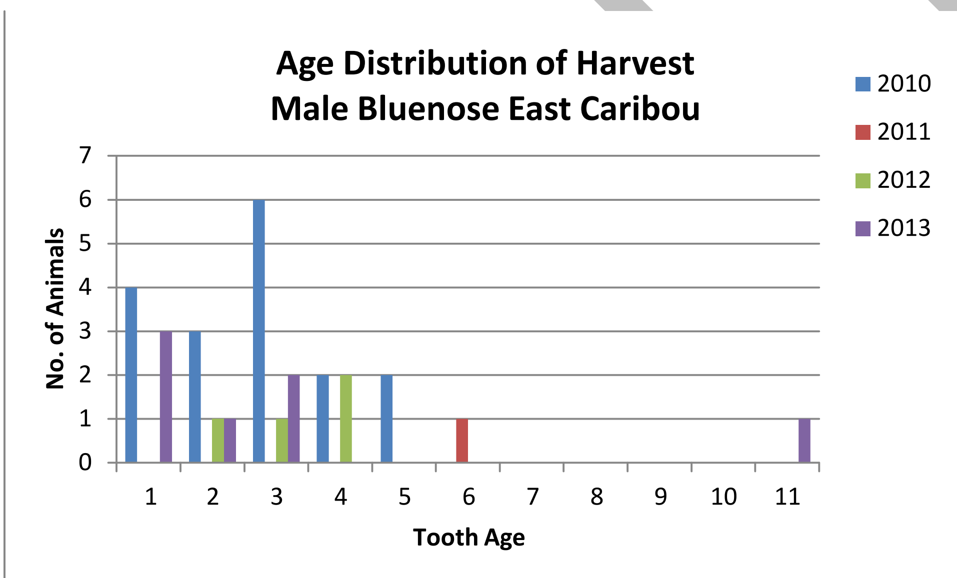
Age Range: 1- 13
Gender: M (bull).F (cow).U (unspecified)
N=29

Age	Number of Animals	M.F.U
1	8	3.4.1
2	3	1.2.0
3	2	2.0.0
4	2	0.2.0
5	3	0.3.0
6	2	0.2.0
7	2	0.2.0
8	3	0.3.0
9	1	0.1.0
10	1	0.1.0
11	1	1.0.0
12	0	0.0.0
13	1	0.1.0

2014 Age pending

Conclusion: a lot of young animals harvested in 2013. This could suggest recruitment into the population which is good; however sample sizes are limited.





Field Assessment of Condition (hunters):

An assessment of the body condition of each caribou was done by hunters using a subjective condition score with four categories (*skinny*, *not bad*, *fat* and *very fat*). Hunter assessments suggested caribou were generally in generally good body condition for the age, sex and time of year, with a range in condition scores for each sampling interval.

2010

Not assessed

2011

- Cows
  - Very fat: 0
  - Fat: 2
  - Not bad: 9

    - Skinny: 1

- Bulls
    - Very fat: 0
    - Fat: 0
    - Not bad: 0
    - Skinny: 2
    - Not recorded: 6

2012

- Cows
    - Very fat: 0
    - Fat: 6
    - Not bad: 21
    - Skinny: 2

- Bulls
    - Very fat: 0
    - Fat: 0
    - Not bad: 6
    - Skinny: 0
    - Not recorded: 5

2013

- Cows
    - Very fat: 0
    - Fat: 3
    - Not bad: 11
    - Skinny: 6

- Bulls
    - Very fat: 0
    - Fat: 0
    - Not bad: 1
    - Skinny: 5
    - Not recorded: 25

2014

- Cows
    - Very fat: 0
    - Fat: 5
    - Not bad: 44
    - Skinny: 12

- Bulls
    - Very fat: 0
    - Fat: 0

- Not bad: 2
- Skinny: 3
- Not recorded: 22

- Conclusions: Bulls generally in worse body condition than cows – cows generally in good body condition. This supports what we know about cows/bulls at this time of year.

Back Fat Measurements:
Back fat measurements (mm) were taken by hunters by measuring the thickness of fat over the back at the base of the tail.

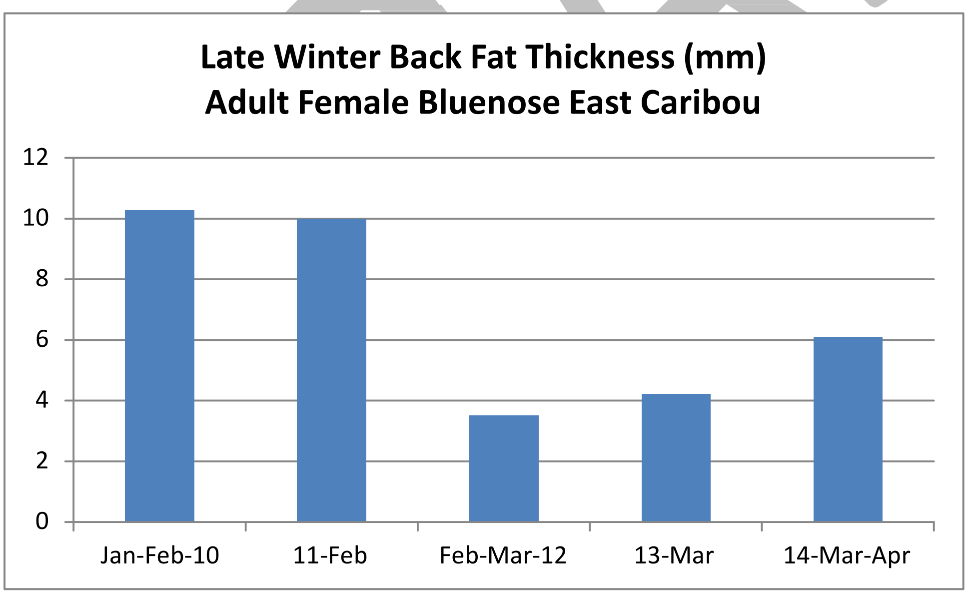
- **2010** Adult cows (n=45): mean 10.27 +/- 9.9 (range 0-38)
  Adult bulls (n=40): mean 2.35 +/- 4.0 (range 0-23)

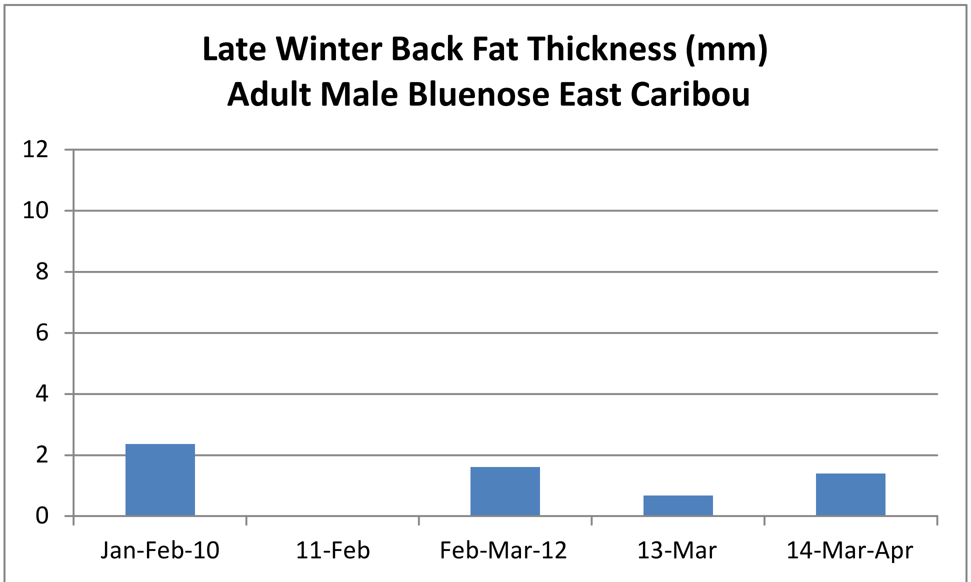
- **2011** Adult cows (n=5): mean 10.0 +/- 10.0 (range 0-20)
  Adult bulls (n=1): mean 0

- **2012** Adult cows (n=29): mean 3.52 +/- 4.46 (range 0-15)
  Adult bulls (n=5): mean 1.60 +/- 3.58 (range 0-8)

- **2013** Adult cows (n=18): mean 4.22 +/- 5.43 (range 0-15)
  Adult bulls (n=6): mean 0.67 +/- 0.82 (range 0-2)

- **2014** Adult cows (n=44): mean 6.10 +/- 7.28 (range 0-35)
  Adult bulls (n=5): mean 1.40 +/- 1.34 (range 0-3)



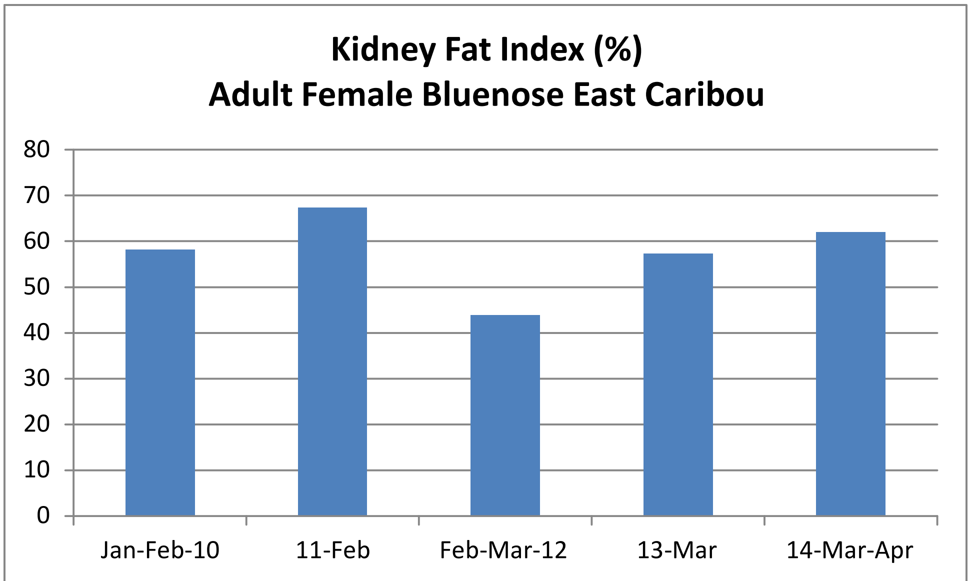


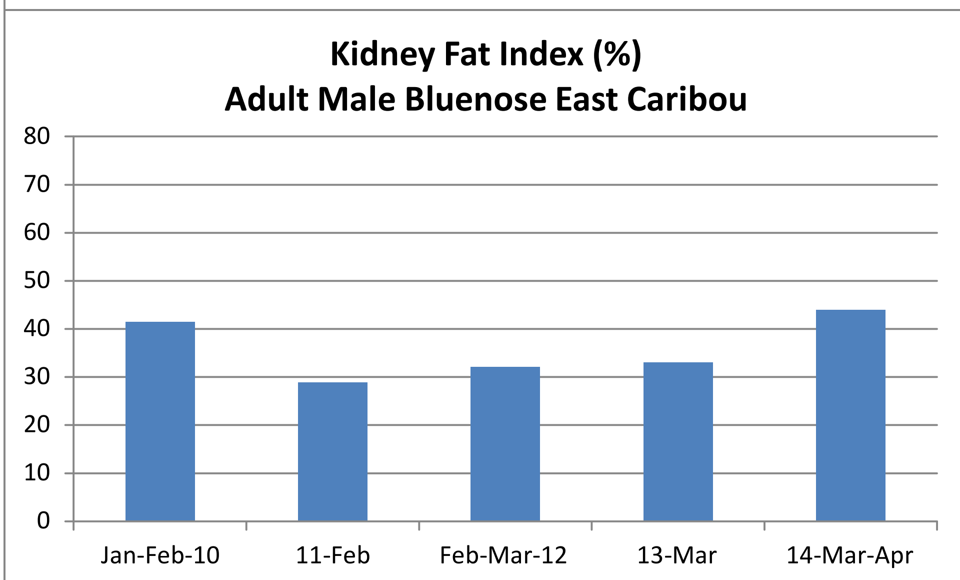
Conclusions: cows in generally better body condition than bulls – this supports hunter assessment of body condition data. Body condition of cows in 2014 was generally better than that in 2012 and 2013.

Kidney Fat:

Kidney fat index (KFI) is a widely used measure used as an indicator of abdominal fat reserves (Harder and Kirkpatrick 1994). Kidneys were evaluated using a standardized technique to provide a ratio of the weight of the kidney fat to the weight of the kidney X 100; the KFI is reported as a percentage and can be >100%. The amount of kidney fat was variable within and between sampling periods, with all animals having some amount of kidney fat stores.

- **2010** Adult cows (n=38): mean 58.2% +/- 27.3 (range 0.5- 114.1%) Adult bulls (n=39): mean 41.5% +/- 29.9 (range 12.0 – 175.8%) Gender not recorded (n=9): mean 42.8% +/- 7.3 (range (31.3-53.6%)
- **2011** Adult cows (n=12): mean 67.4% +/- 30.5 (range 36.6 – 155.4%)
  Adult bulls (n=2): mean 28.9% +/- 18.5 (range 15.8-42.0%)
  Gender not recorded (n=5): mean 48.9% +/- 21.6 (range (18.7-72.2%)
- **2012** Adult cows (n=30): mean 43.8% +/- 20.5 (range 12.43 – 92.3%)
  Adult bulls (n=6): mean 32.1% +/- 11.4 (range 20.0- 50.8%)
- **2013** Adult cows (n=21): mean 57.3% +/- 23.3 (range 25.0 – 105.1%)
  Adult bulls (n=6): mean 33.0% +/- 16.0 (range 11.5- 49.3%)
- **2014** Adult cows (n=49): mean 62.0% +/- 24.4 (range 13.0 – 129.0%)
  Adult bulls (n=5): mean 44.0% +/- 20.5 (range 25.0- 74.0%)
  Gender not recorded (n=11): mean 71.0% +/- 31.1 (range (38.0-151.0%)





Conclusions: same as above – cows in better body condition than bulls. Animals generally in good body condition. KFI >30 is generally good body condition.

Generally, there appears to be an increasing trend in back fat and kidney fat stores from 2012 to 2014.

Bone Marrow Fat:
Fat content of the bone marrow has long been related to the physiological condition of animals. Neiland (1970) reported the percent fat in the marrow of barren-ground caribou was almost identical to percent oven-dry weight. Bone marrow fat is the last reserve to be mobilized and reflects condition only at the lower end of an overall animal condition after other body fat deposits have been exhausted. The results here are reported as the % oven dry-weight of bone marrow from the metatarsus.

- **2013** Adult cows (n=21): mean 83.0% +/- 22 (range 37.0 – 130.8%)
  Adult bulls (n=7): mean 93.4% +/- 5.9 (range 81.5 – 97.1%)

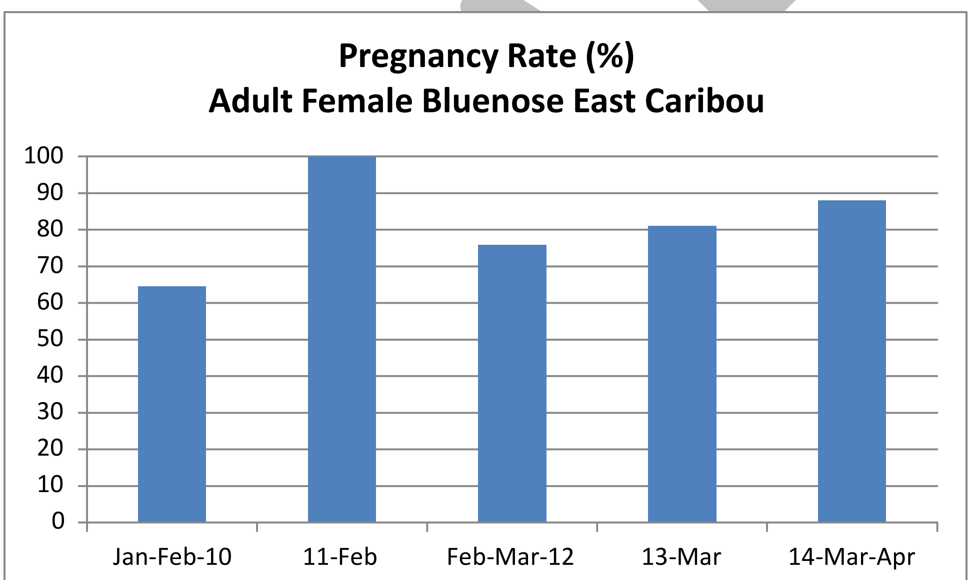
- **2014** Adult cows (n=55): mean 92.8% +/- 5.4 (range 60.0 – 97.6%)
  Adult bulls (n=5): mean 86.6% +/- 11.0 (range 67.6 – 96.0%)
  Gender not recorded (n=10): mean 90.9% +/- 8.3 (range (68.0-97.3%)

Bone marrow fat >75% is good body condition. Based on bone marrow assessment, animals were in good body condition. Fat stores are used up in order from subcutaneous fat (under the skin) to kidney fat, to bone marrow fat. Bone marrow fat is the last to go. Generally only a good indicator of body condition at the lower end of the range, when animals are in really poor shape. In 2014, caribou had excellent bone marrow fat stores.

Pregnancy Rates:

Pregnancy rates were determined in late winter by the presence of a fetus.

- **2010** Adult cows: 31/48 (64.6%)
- **2011** Adult cows: 11/11 (100.0%)
- **2012** Adult cows: 22/29 (75.9%)
- **2013** Adult cows: 17/21 (81.0%)
- **2014** Adult cows: 44/50 (88.0%)



Pregnancy Data for Collared Caribou March 2012

Pregnancy status determined based on analysis of serum progesterone levels

2010
Pregnancy Rate: **8/9 (89.0%)**

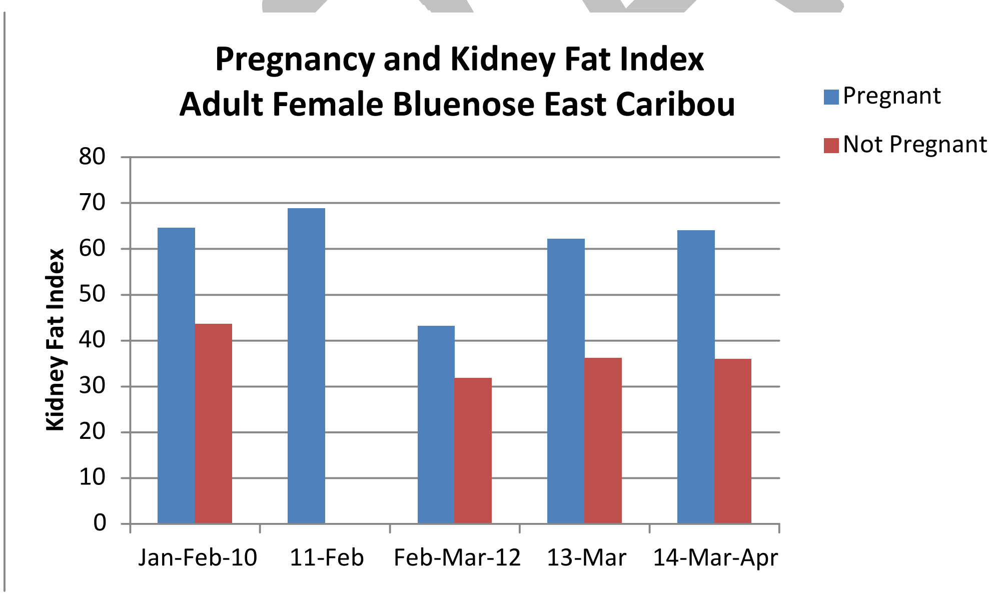
2012
Pregnancy Rate: **27/42 (64.0%)**

2014
Pregnancy Rate: **7/8 (87.5%)**

Hunter assessed pregnancy rates appear to be in line with those found through analysis of serum (blood) progesterone levels from collared caribou at the time of collaring, recognizing some of the limited sample sizes involved..

Kidney Fat Index in Relation to Pregnancy

- **2010** Pregnant (n=25): mean 64.6% +/- 26.2 (range 3.2- 114.1%)
  Not Pregnant (n=12): mean 43.6% +/- 27.3 (range 0.5 – 95.1%)
- **2011** Pregnant (n=11): mean 68.8% +/- 31.6 (range 36.6 – 155.4%)
- **2012** Pregnant (n=22): mean 43.2% +/- 18.2 (range 12.43 – 73.5%)
  Not pregnant (n=6): mean 31.9% +/- 12.2 (range 16.6- 50.0%)
- **2013** Pregnant (n=17): mean 62.2% +/- 21.9 (range 35.5 – 105.1%)
  Not pregnant (n=4): mean 36.3% +/- 18.3 (range 25.0- 63.4%)
- **2014** Pregnant (n=40): mean 64.0% +/- 23.3 (range 16.0 – 129.0%)
  Not Pregnant (n=4): mean 36.0% +/- 29.8 (range 13.0- 79.0%)



Pregnant caribou generally appear to have higher kidney fat index (aka better body condition) than those that were not pregnant. This supports the importance of good body condition in maintaining reproductive potential of the herd.

Generally, animals appeared to be in better body condition in 2014 than in the previous two years. This was reflected by a higher recorded pregnancy rate. Since interpretation is limited by a small sample size, trends are not statistically validated, however, they do give some indication of the health status of the herd. The sample size obtained in 2014 was larger than that in previous years which gives more strength to the data.

9. Appendix 2: Stable, declining and increasing caribou herds: A simple view of the numbers

Caribou herds can increase or decline at substantial rates. The 3 examples below are for a herd of 100,000 that is (1) stable, (2) declining, or (3) increasing, with corresponding survival and pregnancy rates. The calculations are simplified but realistic, and the rates of change, survival and pregnancy are based on known examples from caribou herds in North America. Even in a stable or increasing herd, there is high turnover and many caribou die every year. However, the deaths are spread out over large areas and over the entire year, and predators and scavengers usually dispose of dead caribou within a few days. Only in cases of mass die-offs (e.g. Peary caribou in 1974-1975) are large numbers of carcasses likely to be found, in situations where predators and scavengers are unable to keep up with the dead caribou available.

Example 1: Stable herd of 100,000
End of May: 60,000 cows, 40,000 bulls (1 year old or older), 83% pregnancy in the cows.

Just after calving in early June: 60,000 cows, 40,000 bulls, 50,000 newborn calves (total 150,000).

A year later (end of May again):

Cows had mortality rate of 15% (survival 85%) so 9000 died, 51,000 lived.
Bulls had mortality rate of 30% (survival 70%) so 12,000 died, 28,000 lived.
Calves had mortality rate of 58% (survival 42%) so 29,000 died, 21,000 lived to one year.
Total 51,000 cows + 28,000 bulls + 21,000 yearlings (male and female) = 100,000 (stable herd).
Calf:cow ratio in May would be about 41 calves:100 cows.

Mortality rates of calves are always highest, bulls generally have higher mortality rates than cows, and cows usually have the lowest mortality rates. Assuming here that calves at one year (yearlings) have mortality rates similar to adults; they are usually similar.

Over that year, 9,000 + 12,000 + 29,000 died (50,000 total).

Example 2: Herd of 100,000 declining at 19%/year
(note estimated Bluenose-East decline rate 2010-2013 was 16%/year)

End of May: 60,000 cows and 40,000 bulls, pregnancy rate of 67%.

Just after calving in June: 60,000 cows, 40,000 bulls, 40,000 calves (total 140,000).

A year later (end of May again):

Cows had mortality rate of 25% (survival 75%) so 15,000 died, 45,000 lived.
Bulls had mortality rate of 35% (survival 65%) so 14,000 died, 26,000 lived.
Calves had mortality rate of 75% (survival 25%) so 30,000 died, 10,000 lived.
Total 45,000 + 26,000 + 10,000 = 81,000, decline of 19%.
Calf:cow ratio in May would be about 22 calves:100 cows.

Over that year, 59,000 (15,000 + 14,000 + 30,000) caribou died.

Example 3: Herd of 100,000 growing at 13%/year

(note George River caribou herd was increasing at an estimated 14%/year 1950s-1980s)

End of May: 60,000 cows and 40,000 bulls, pregnancy rate of 90%.

Just after calving in June: 60,000 cows, 40,000 bulls, 54,000 calves (total 154,000).

A year later (end of May again):

Cows had mortality rate of 10% (survival 90%) so 6,000 died, 54,000 lived.
Bulls had mortality rate of 20% (survival 80%) so 8,000 died, 32,000 lived.
Calves had mortality rate of 50% (survival 50%) so 27,000 died, 27,000 lived.
Total 54,000 + 32,000 + 27,000 = 113,000, increase of 13%.
Calf:cow ratio in May would be about 50 calves:100 cows.

Over that year, 41,000 (6,000 + 8,000 + 27,000) caribou died.

An Estimate of Breeding Females and Analyses of Demographics For The Bathurst Herd of Barren-ground Caribou: 2012 Calving Ground Photographic Survey

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[2]Environment and Natural Resources, Government of Northwest Territories

2014
File Report No. 142 ii iii

ABSTRACT

We conducted a calving ground photo survey of the Bathurst barren-ground caribou (*Rangifer tarandus groenlandicus*) herd from 3-8 June, 2012. The main objective was to obtain an estimate of breeding females that could be compared to estimates from previous similar surveys that have been conducted since 1986. Of particular interest was whether or not the herd had stabilized from the steep decline documented in the 2009 survey. Consistent with previous calving ground photographic survey methods, data from collared caribou and systematic reconnaissance surveys at ten km intervals in the calving ground area were used to delineate the core calving areas, to assess calving status, to allocate sampling to geographic strata of similar caribou density, and to time the photographic survey plane to coincide with the peak of calving. Unlike previous surveys, transect surveys were conducted at 5 km instead of 10 km intervals in the core calving area. Reconnaissance surveys revealed that the majority of breeding caribou were congregated in a relatively small (914 km^2) area with non-breeding caribou distributed in lower densities to the south. Based on collar movements and observed proportions of calves, it was determined that the peak of calving occurred on or about 5 June, 2012 and the photo plane survey was conducted on 6 June. Photo plane survey effort (transect spacing) was stratified into high and medium density blocks with the highest coverage (79.1%) in the high density stratum where the majority of breeding caribou were. The higher level of coverage allowed an adequate number of lines (22) to be placed in the stratum as a means of offsetting potential variance caused by clumped distribution of caribou. Survey conditions were ideal with zero cloud cover, minimal winds and minimal snow cover. Two lower density strata were also surveyed with visual strip-transect methods. Ground-based composition surveys were conducted from 6-8 June to iv

estimate the proportion of breeding caribou in each of the strata. Survey results revealed that 87.4% of caribou on the core calving ground were within the high density stratum (914 km^2) with 8% occurring in the medium density stratum (644 km^2) and the rest in the two low density strata. The estimate of 1+ yr old caribou on the core calving ground was 24,166 (SE=1,853.6, CI=20,310-28,020) caribou. Using the results of the ground composition survey to adjust this number for breeding females, the estimate of breeding females was 15,935 (SE=1,407.2, CI=13,009-18,861). The estimate of breeding females was very precise with a coefficient of variation (CV) of 8.8%. Comparison of this estimate with the previous estimate of breeding females from 2009 of 16,649 (SE=2,181, 95% CI=12,188-21,110) suggests that the breeding female segment of the herd declined slightly, though not significantly. The rate of decline was much lower than between the 2006 and 2009 calving ground surveys. Results from a data-driven demographic modeling exercise suggest that adult female survival rate was 0.78 (CI range 0.75-0.82) in

survival and harvest. We suggest that continued monitoring and more complete harvest reporting are essential to better understand this decline. A conservative approach to harvest should be considered in the short-term, along with close monitoring of the herd.

Overview: Monitoring of Bathurst and Bluenose-East Caribou Herds, Sept. 2014
Government of the Northwest Territories, Environment and Natural Resources
Summary:

This document provides an overview of population trend, other monitoring, and management of the Bathurst and Bluenose-East (BE) caribou herds in NWT and NU, with the emphasis on the last 5 years (2009-2014). Results from a reconnaissance survey conducted in June 2014 on the calving grounds of the Bathurst herd suggests this herd, which had been considered stable 2009-2012, has declined since 2012. Results from calving ground photo surveys of the BE herd indicate this herd has declined substantially 2010-2013. The June 2014 calving ground reconnaissance survey results suggest the BE herd has continued to decline rapidly. Photo surveys are planned for the spring of 2015 to allow more precise trend estimates for both herds. Two main sections of this overview describe results of population surveys, calving ground reconnaissance surveys, estimates of cow survival rate, spring recruitment surveys, fall composition surveys, pregnancy rates, harvest estimates, movements of collared caribou between neighbouring herds, and the management context for each herd. Information on wolf monitoring on the Bathurst range and recent wolf harvest is included. A section on long-term cycles or fluctuations of migratory caribou herds and demographic indicators of decline (low pregnancy rates, low calf recruitment and low adult cow survival) follows. The overview concludes with assessments of population trend in the Bathurst and Bluenose-East herds 2009-2014 and possible explanations for the June 2014 calving ground reconnaissance survey results.

For the Bathurst herd, the likeliest explanation for the low numbers of caribou on the calving grounds in 2014 is a combination of low natural survival rates, reduced calf productivity and survival, and to some extent harvest. Harvest of the Bathurst herd on its main winter range (management zones RBC02 and RBC03) has been greatly reduced since 2010 but some harvest is unreported and some harvest has likely occurred outside these zones. For example, harvest of Bathurst caribou may be occurring in RBC01, where the Bathurst and BE herds overlap in winter. Issues related to the reconnaissance survey methods may have affected survey results but are unlikely to account for the large apparent drop in numbers of caribou on the calving grounds. Assessment of movements of collared caribou between the Bathurst's calving grounds and its neighbouring herds' calving grounds showed no evidence of large-scale emigration from the Bathurst range 2010-2014.

For the BE herd, a combination of low natural survival, reduced calf recruitment, low pregnancy rates in some years, and a substantial cow harvest are the most probable reasons for the herd's substantial decline 2010-2013 and the continued and potentially accelerated decline to June 2014. Issues related to the reconnaissance survey methods may have affected the survey results but are unlikely to account for the large apparent decrease in caribou on the calving grounds. Assessment of movements of collared caribou between the BE's calving grounds and its neighbouring herds' calving grounds showed no evidence of large-scale emigration from the BE range 2010-2014.