Interim report: Estimates of breeding females and herd size from the 2015 Bathurst calving ground survey.

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This document presents estimates of caribou on Bathurst core calving ground area based on photo and visual surveys conducted during the 2015 Bathurst and Bluenose East calving ground surveys. The main objective of this report is to provide an update on estimates for the Bathurst herd from the 2015 calving ground survey needed for discussion of conservation strategies. Future reports will provide more details on field methods and analyses.

Methods and Results

Reconnaissance and stratification

Extensive reconnaissance flights were conducted to ensure that the core calving area of the Bathurst was delineated (Figure 1). Transect spacing was 5 kilometers in the vicinity of the core area with 10 kilometer spacing in outlying areas. The majority of the reconnaissance of the core area occurred on June 4th.

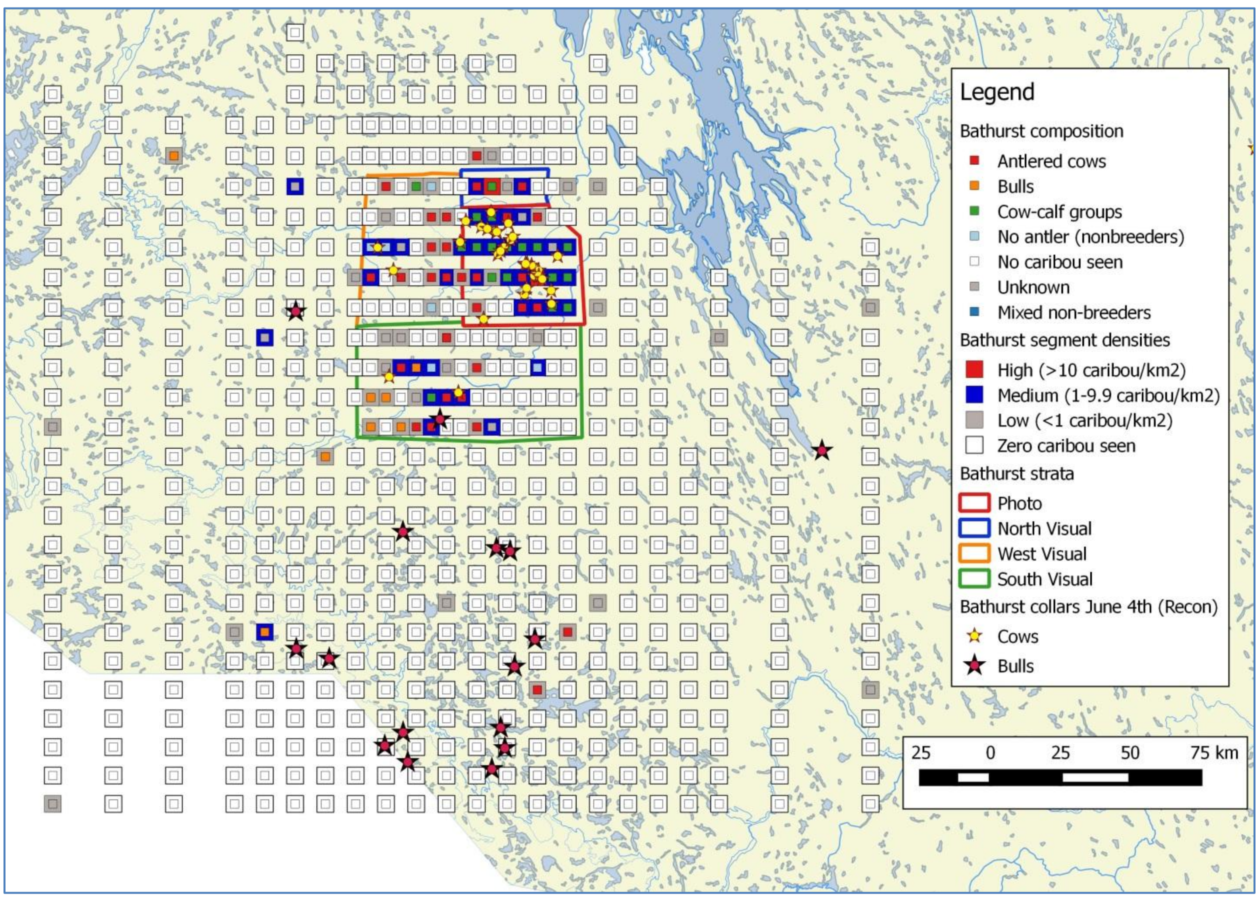

Figure 1: Full reconnaissance coverage of the Bathurst herd calving area and surrounding areas. Locations of female collared caribou during the core calving ground reconnaissance survey (June 4th) is also shown.

The locations of collared caribou, densities and composition of segments indicated that the core calving area occurred in a 40x40 kilometer area with scattered groups in areas to the north, west and south. The locations of collared females were highly aggregated around areas of higher segment densities. The majority of collared bulls did not occur in the core area with all but 1 bull in areas to the south.

A closer view of the core calving area (Figure 2) with segment densities displayed suggest that higher densities of caribou only occurred in the core area with one segment with a density of 32.1 caribou per square kilometer. One segment with 10 caribou per square kilometer was observed in the northern stratum (Figure 2). This was a caused by observation of a single group of 80 caribou just south of the high density segment indicator near the Hood River.

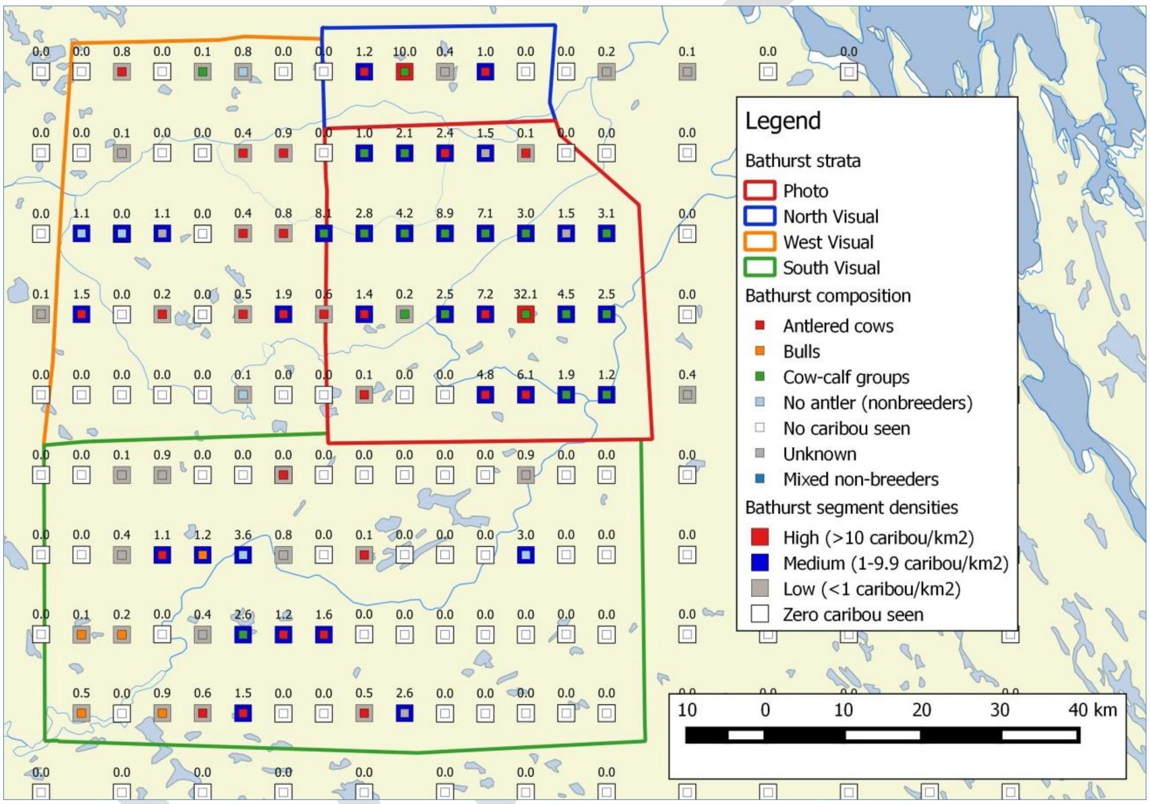

Figure 2: Estimates of segment based densities and composition on the Bathurst calving ground from the 2015 survey. Densities of caribou in each segment are displayed above each segment.

Using the reconnaissance data based estimates of caribou in each stratum, survey effort was allocated to a single photo stratum and 3 visual strata. Survey effort for the visual stratum was allocated using reconnaissance estimates to ensure that 3 visual planes could fly all strata within a single survey day. This constraint was essential given variable weather patterns and fog experienced prior to the reconnaissance survey, as well as the longer transit times from Kugluktuk base to the Bathurst core area.

Survey effort for the photo stratum was based upon the number of photos available (due to budgetary constraints). In addition, the number of lines was drawn to ensure that the photo planes could fly the photo stratum within a single survey day. One potential issue was that a single photo plane might take up to 8 hours to fly the photo stratum. Therefore, an additional design was considered in which both photo planes would fly the photo stratum to ensure that the survey was done within a single day. The strip width from the digital cameras in the photo planes was slightly different. To accommodate this, the planes flew every other survey line therefore ensuring that variable coverage was systematic throughout the photo stratum therefore mitigating any bias due to unequal coverage of transect lines.

Table 1: Dimensions of strata and transects for the 2015 Bathurst calving ground survey

Strata	Area (km^2)	Transects Number	Strip width (km)	Area sampled (km^2)	coverage
Photo	1492.5	20	1.057 (0.715-1.35) [A]	817.0	0.55
North Visual	339.9	12	0.8	115.7	0.34
South Visual	2906.5	15	0.8	464.2	0.16
West Visual	1623.6	18	0.8	475.0	0.29

[A]Mean strip width and the range of strip widths sampled are given for the photo stratum (given fog issues).

Photo and visual surveys

On June 5th, the day after the reconnaissance, a survey was attempted over the survey area. However, low cloud and fog prevented the survey from occurring. On June 6th, the fog lifted in the afternoon therefore allowing both photo planes to fly the survey. The planes encountered low cloud in the southern portion of the photo stratum but were still able to fly at a lower altitude (and smaller strip width). Cloud was encountered in one photo line which resulted in 0.6 kilometers not being surveyed (1.6% of the line length). All three visual survey planes were also able to fly the visual surveys with variable survey conditions. Movement of collared caribou from the 4th to 6th indicates that there was no movement across strata boundaries between the reconnaissance and visual/photo surveys. However, there was some movement south from the northern border towards the center of the photo stratum (Figure 3).

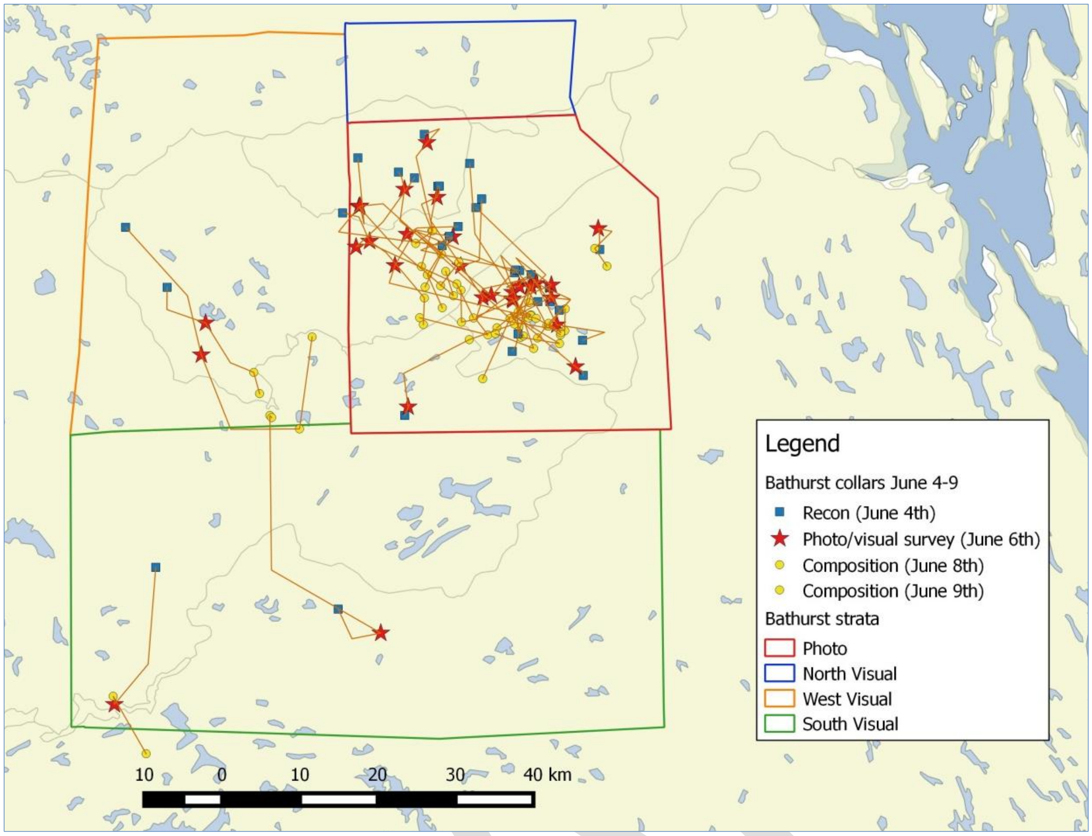

Figure 3: Movements of collared female caribou during the main Bathurst survey relative to survey strata. The locations of collared females during the primary reconnaissance survey (June 4th) and photo/visual survey (June 6th) and composition surveys are displayed. Lines connect the locations of individual caribou.

Figure 4 illustrates the results of the photo and visual surveys as indicated by individual points for caribou in the photo survey area and points colored relative to group size for the visual surveys. It can be seen that the majority of caribou in the photo survey occurred in the middle of the stratum in a relatively large single cluster with scattered groups to the northwest and one aggregation to the northeast. Group sizes were small and intermittent in the visual strata. Post-processing of the data revealed that the airplane that flew the northern stratum flew at a lower altitude than 120 meters required for the 800m strip width. The strip width for this airplane was re-estimated based upon GPS based altitudes at 539 meters which was used for the north stratum estimates. This adjustment reduced the coverage of the north stratum to 22.9%.

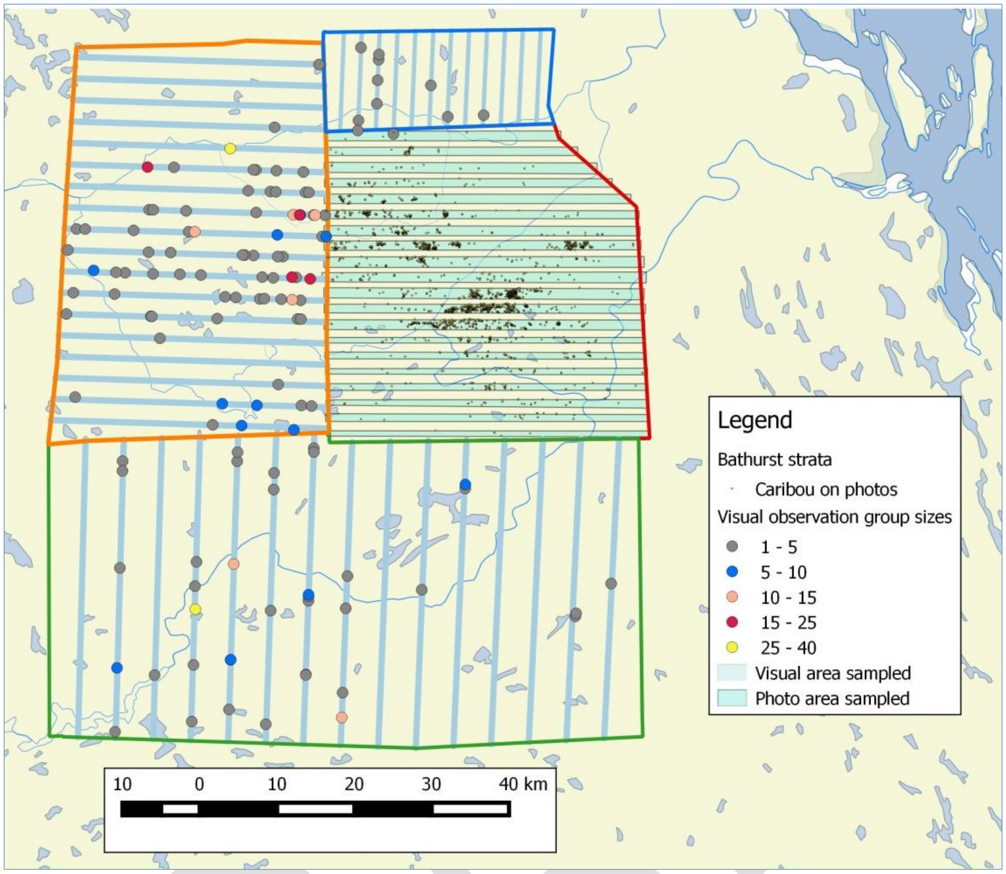

Figure 4: Results of the photo and visual survey as indicated by individual waypoints of caribou identified on photos for the photo stratum and locations of groups for the visual strata. The width of survey lines indicates the area sampled (strip width) for photo and visual surveys.

For visual surveys, the majority of observations were for groups of 5 or less caribou (Figure 5). A proportion of observations in smaller group size (<5 caribou) categories were observed by only one observer.

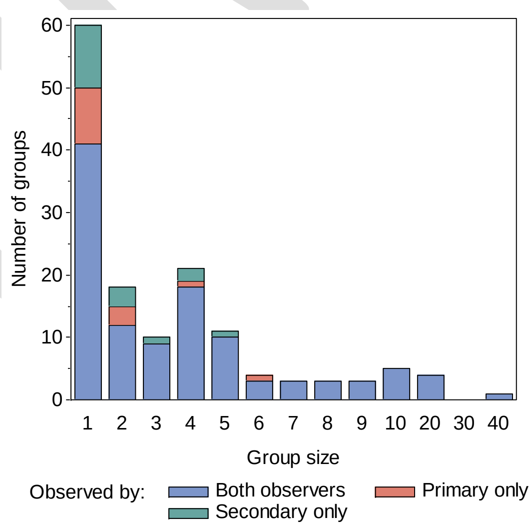

Figure 5: Distribution of group sizes from pooled visual surveys as categorized by double observer outcome

Composition surveys

Composition surveys occurred from June 6th to June 9th. A storm front enveloped the survey area on June 7th therefore grounding all aircraft in Kugluktuk. A single helicopter continued the survey on June 8th. Two helicopters (one from Yellowknife and one from Kugluktuk) completed the composition survey on June 9th. Movement of collared caribou suggested that they were relatively sedentary between the Photo/visual and composition surveys therefore minimizing any bias due to the delay in photo/visual estimates and composition surveys (Figure 3).

Estimates of breeding females

As seen in Figure 4, the photo stratum had variable coverage with smaller strip width transects in the south compared to central and norther sections of the stratum. If uncorrected, this could potentially bias estimates since caribou in the south would have a lower chance of being sampled given the smaller strip widths. To mitigate this issue, a method was used that estimated population size by equally weighting densities of caribou on each transect line regardless of strip width. More precisely, population size within a stratum is usually estimated as the product of the total area of the stratum (*A*) and the mean density $(\overline{D})$ of caribou observed within the strata $(\widehat{N} = \overline{D}A)$ where density is estimated as the sum of all caribou counted on transect divided by the total area of transect sampling ($\overline{D}$=caribou counted/total transect area). An equivalent estimate of mean density can be derived by first estimating transect-specific densities of caribou ($\widehat{D}_i = caribou_i/area_i$) were $caribou_i$ is the number of caribou counted in each transect and $area_i$ is the transect area (as estimated by transect length X strip width). Each transect density is then weighted by the relative length of each transect line (w_i) to estimate mean density ($\overline{D}$) for the stratum. More exactly, $\overline{D} = \sum_i^n \widehat{D}_i w_i / \sum_i^n w_i$ where the weight (w_i) is the ratio of the length of transect line (l_i) i to the mean length of all transect lines ($w_i = l_i/\overline{l_i}$.) and *n* is the total number of transects sampled. Using this weighting term accommodates for different lengths of transect lines within the stratum therefore ensuring that each transect line contributed to the estimate in proportion to its length. Population size is then estimated using the standard formula ($\widehat{N} = \overline{D}A$).

Using the alternative formula to estimate mean stratum density and the resulting stratum population size negates bias caused by differential strip width by allowing each transect line to contribute independently of strip width to estimates of stratum population. If strip widths are similar for each transect then this method will yield the same estimate as standard formulas. Variance was estimated using formulas (Jolly 1969, Krebs 1989) for unequally sized sample units (which account for transects of varying size).

Double observer modelling revealed variation in sightability due to snow, cloud and observers. However, the overall sightability of caribou was high and therefore the increase in estimates with double observer sightability correction was minimal.

Table 2 provides estimates of caribou on the calving ground strata, proportion breeding caribou, and the resulting estimate of breeding females. Composition sampling was not conducted for the northern stratum due to lack of caribou. Therefore, the photo stratum composition estimates were used to estimate breeding females for this stratum. Overall, estimates were marginally precise which was mainly due to lower precision of the photo stratum estimate as well as lower precision of some of the composition survey estimates. Estimates of breeding females were largely based upon the photo stratum given low numbers of caribou and low proportions of breeding caribou on the visual strata. The estimate of breeding females was 8,075 (CI=4,608-11,542).

Table 2: Estimates of total caribou on the calving ground, proportions of breeding females (from composition surveys) and the resulting estimates of breeding females.

Strata	Caribou	Total caribou on calving ground				Proportion Breeding Females			Breeding Females		
	Counted	Density	N	SE(N)	CV	Proportion	SE	CV	N	SE(N)	CV
Photo	7,843	8.76	13,076.9	2571.2	19.7%	0.594	0.047	7.9%	7,768	1646.4	21.2%
North	17	0.22	74.1	31.6	42.6%	0.594	0.047	7.9%	44	19.1	43.4%
South	180	0.39	1,135.8	351.2	30.9%	0.010	0.006	60.0%	11	7.4	67.5%
West	311	0.67	1,082.6	327.6	30.3%	0.233	0.076	32.6%	252	112.1	44.5%
Total			15,369.4	2615.9	17.0%				8,075	1650.3	20.4%

Lower precision of the photo stratum can be partially attributed to the large degree of aggregation within the stratum. Transect line specific densities illustrate that the majority of the caribou were contained within 3-4 lines of the 20 transect lines with much lower densities of caribou observed on the peripheral lines (Figure 6). I suspect that this distribution was partially caused by increased aggregation of caribou that occurred between the recconsance and photo surveys (Figure 3). Regardless, this result illustrates the challenge of surveying highly aggregated species that still exist across larger spatial scales. Basically, it is challenging to sample the core aggregations with a larger number of transect lines while still keeping strata large enough to minimize biases due to movement across stratum between reconnisance and photo/visual surveys. In addition, the large degree of aggregation challenges interpretation of reconnisance-based surveys that have wider transect spacing.

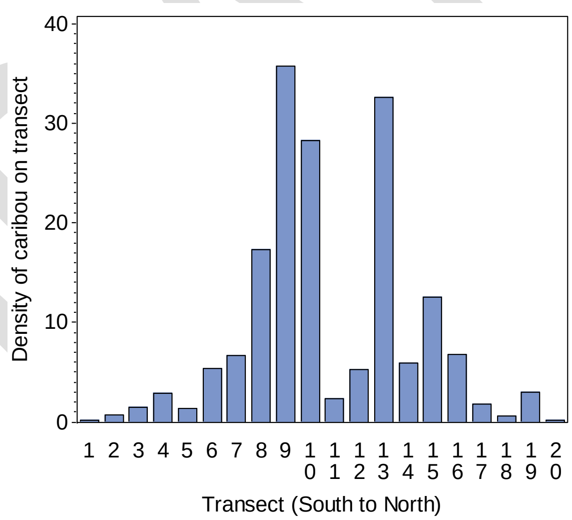

Figure 6: Transect-specific densities for the photo stratum.

Trends in breeding females

A comparison of the breeding female estimate with estimates from the 2009 survey (Nishi et al. 2010) and 2012 survey (Boulanger et al. 2014) shows a decline in breeding females since the 2012 survey (Figure 7). Despite slightly lower precision of the 2015 estimate, the difference in estimates is significant as indicated by non-overlap of confidence limits.

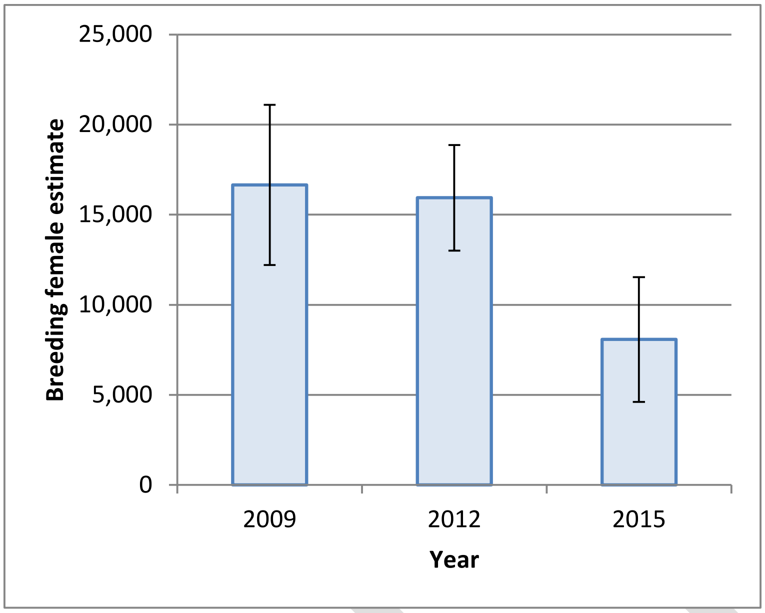

Figure 7: Comparison of 2015 breeding female estimate with estimates from the 2009 and 2012 calving ground surveys.

One important point to note was that the proportion adult females that were breeding was lower in 2015 compared to previous which potentially further reduced breeding female estimates. Using composition data it is possible to estimate the proportion of adult females ((breeding + non-breeding adult females)/total 1+ year old caribou) (Boulanger et al. 2011) on the calving ground and from this derive an estimate of adult females (Figure 8) which will contain both breeding and non-breeding caribou (Figure 8). It can be seen that the decline in adult females is less than breeding females and that there was a higher proportion of non-breeding females in 2015 compared to 2009 and 2012.

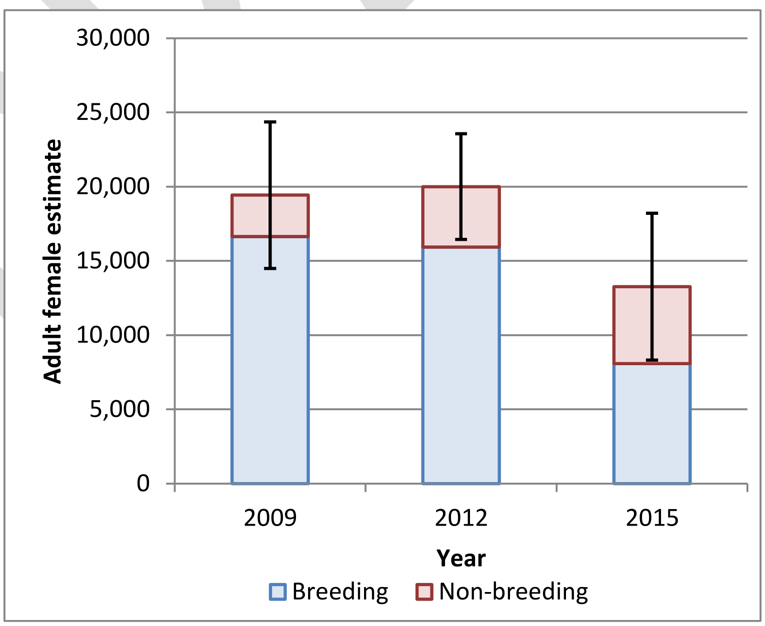

Figure 8: Estimates of total adult females subdivided by breeding status for 2009, 2012, and 2015. Confidence limits are for the total adult female estimate.

Future reports will consider alternative methods to asses trend as well as include OLS demographic analyses which will estimate and model trends in base demographic parameters

Extrapolated herd size estimates

Fall composition surveys were conducted on October 22, 2014. Overall, 34 groups were observed amounting to 2,502 adult caribou. Of these, 823 were bulls and 1,679 were cows which resulted in proportion cow and bull cow ratios as listed in Table 3. Bootstrapping was used to obtain standard error and confidence limits. The bull-cow ratio decreased relative to 2011 and 2012 therefore resulting in an increase in proportion cows.

Table 3: Results of fall composition surveys from 2008 to 2014 for the Bathurst herd

Year	Proportion cows					Bull-cow ratio			
	Estimate	SE	Conf. Limit		CV	Estimate	SE	Conf. Limit	
2008	0.723	0.013	0.697	0.750	0.018	0.383	0.025	0.334	0.435
2011	0.631	0.013	0.606	0.655	0.021	0.585	0.033	0.526	0.651
2012	0.638	0.014	0.610	0.664	0.022	0.567	0.035	0.505	0.640
2014	0.671	0.011	0.648	0.693	0.017	0.490	0.025	0.444	0.544

In terms of extrapolated estimates of herd size, if the proportion cows from 2014 is used with a fixed pregnancy rate (0.72, CV=10%) then the overall herd size estimate is 16,714 1.5+ year old caribou (SE=3813.1, CV=22.8%, CI=8,703-24,725). The assumption of a fixed pregnancy rate for 2015 is questionable given the lower observed relative number of breeding females (Figure 8).

An alternative extrapolated herd size estimate was developed as a means to explore the effect of variable pregnancy rates as part of the 2014 Qamanirjuaq caribou herd survey (Mitch Campbell, Government of Nunavut, and John Boulanger IER, in prep). This estimator first uses data from the composition surveys to estimate total proportion of adult females, and adult females in each of the survey stratum. The estimate of total adult females (as displayed in Figure 8) is then divided by the proportion adult females (cows) in the herd from fall composition surveys (Table 3). Using this approach, the fixed pregnancy rate is eliminated from the estimate procedure. For the Bathurst herd in 2015, the estimate of total adult females in the core calving area was 13,265 (SE=2359.5, CV=17.8%, CI=8,308-18,222). The resulting estimate of herd size (13,265 divided by 0.671 from Table 3) is 19,769 (SE=3531.8, CV=17.9%, CI=12,349-27,189) 1.5+ year old caribou. This estimate assumes that all adult female caribou (breeders and non-breeders) as classified in composition surveys occurred within the core calving area as delineated by the survey strata (Figure 1). It does not make any assumptions about the distribution of yearling or bull caribou. The distribution of female collared caribou observed in 2015 suggests that this assumption may be reasonable given that all 31 collared females were contained within the survey strata (Figure 1).

The applicability of the adult female based herd size estimator depends greatly upon the extent of the survey (to estimate all adult females) as well as the degree of aggregation of adult during the given survey year. It is likely that it is less applicable to all survey years given that the Bathurst herd has been less aggregated relative to survey efforts. Figure 9 compares estimates using the adult female and pregnancy rate-based estimates for 2006, 2009, 2012 and 2015 (Nishi et al. 2007, Nishi et al. 2010, Boulanger et al. 2014). It can be seen that the pregnancy-rate based estimator was higher in 2006, 2009 and 2012 and then lower than the adult female based estimate in 2015.

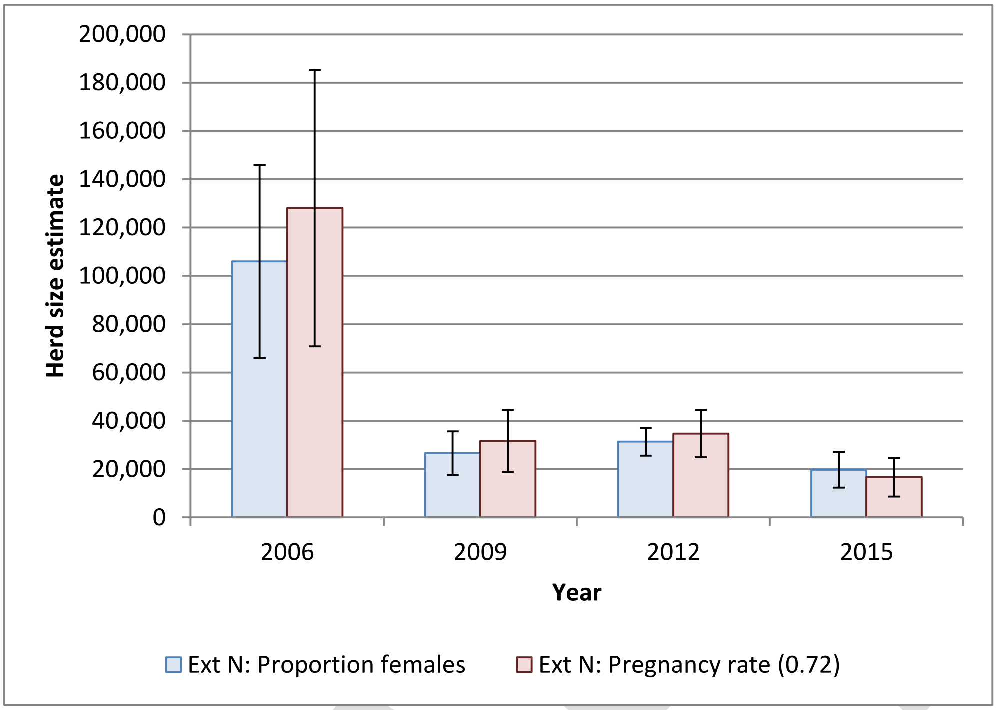

Figure 9: Extrapolated herd estimates using the pregnancy rate and adult female based estimation methods for 2009, 2012, and 2015.

There are a few potential reasons for the differences between pregnancy-based and adult female based extrapolated herd estimates (beyond simple sampling variation). First, pregnancy rate was higher in 2006, 2009 and 2012 and therefore the pregnancy-rate based estimates were less likely to be negatively biased due to differences between the fixed pregnancy rate (0.72) and actual pregnancy rate. Second, it is likely that the degree of aggregation of caribou relative to the calving ground has increased from 2009 to 2015. For example, 81.8% (n=11 collared females), 83.3% (n=18), and 100% (n=31) of collared females were contained within survey strata for the 2009, 2012, and 2015 calving ground surveys. Estimates of the number of collared females on the core for the 2006 survey were not readily available and will be included in future reports. If the collars represent distribution of females overall then it is more likely that the majority of adult females were contained within the survey strata in 2015 compared to other years which would reduce bias with the adult female based extrapolation method. The comparison based on collared females is compromised by low sample sizes of collared caribou (especially for 2009 and 2012). Future analyses will estimate aggregation indices based upon reconnaissance data to further test the aggregation assumption.

Discussion

In point form:

- Overall, the coverage of the survey area, minimal movements of collared caribou in the time period between reconnaissance and visual/photo surveys indicate that the survey was reasonably efficient in estimating caribou on the calving ground. Therefore, the apparent decline in the Bathurst herd cannot be attributed to survey or sampling issues.
- Note that the likely lower pregnancy rate in 2015 will also reduce the estimate of breeding females. Therefore, as previously discussed, trend estimates based solely on breeding females may overestimate

the rate of overall herd decline compared to trend in adult females (Figure 8). Despite lower pregnancy rates there was no evidence of females not showing up on the calving ground as indicated by the distribution of collared females (Figure 1).

- The adult female based extrapolated herd size is larger than the pregnancy rate based method in 2015, whereas in 2009 and 2012 the pregnancy-rate based estimator was higher. I speculate these differences are due to aggregation of females relative to survey strata as well as variation in the true biological pregnancy rate of females. The key assumption of the adult female-based method is that all or the vast majority of adult females occur within the surveyed calving ground area. The increase in collared caribou for the Bathurst herd provides a way to assess this assumption more precisely. Future reports will provide more details and further investigation of the effects of variable pregnancy rates on estimates.
- Future analyses will consider other indicators such as collar-based survival rates, and spring composition surveys to assess potential demographic mechanisms for the decline in the Bathurst herd.

Literature cited

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