AN ESTIMATE OF BREEDING FEMALES IN THE BATHURST HERD OF BARREN-GROUND CARIBOU, JUNE 2009

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ABSTRACT

We used the calving ground photographic survey technique to estimate abundance and distribution of breeding females in the Bathurst herd of barren-ground caribou *(Rangifer tarandus groenlandicus)* in June 2009. In late May 2009, we started monitoring movements and locations of satellite-collared Bathurst cows (n= 11). We used Tahera Mine, located by the northwest end of Contwoyto Lake as our base of operations and started systematic aerial surveys on the 4 June. The distribution of satellite-collared cows provided the means of distributing survey effort during the initial systematic surveys and then we used observations of relative caribou density and composition (presence of hard antlered cows and/or newborn calves) to define the annual calving ground. Due to concerns regarding the declining trend of the Bathurst herd, we ensured that our systematic coverage was extensive so that we did not miss any large groups of breeding females. On the 7 June, we delineated the annual calving ground a second time and stratified it into one high density (photographic) stratum, one medium density (photographic) strata and three low density (visual) strata. We initiated the photographic survey of the high density stratum on the 8 June and completed photography of the medium density stratum on the 9 June. Visual surveys of low density strata were flown with a fixed wing aircraft on the 8 June. We used a helicopter to complete the composition surveys in high, medium and low density strata from the 8-11 June. Based on the combined results of visual surveys in the low density strata and photographs of transects in the medium and high density strata, we estimated that there were 23,273 ± 2,788 (SE) 1^{+}-year-old caribou on the annual calving ground. After adjusting this estimate by the proportion of breeding females observed during the composition surveys, we estimated that there were 16,605 ± 2,176 (SE) breeding females in the survey area. The high density stratum contributed 76% of the estimated number of total caribou and 72% of the breeding females. The proportion of breeding females in the high density strata was *ca.* 68% ± 4% (SE). The estimate of breeding females in June 2009 was relatively precise (CV = 13%), and substantiates results of the June 2006 Bathurst caribou survey. The June 2009 survey confirms that the abundance of breeding females in the Bathurst herd has significantly declined since 1986; it also suggests an accelerated rate of decline since the June 2006 survey. If the observed rate of decline continues over the next several years, the estimated number of breeding females may decline to ca. 8,300 animals by June 2012, i.e., 50% of the June 2009 estimate. We suggest that conservation and recovery of the Bathurst herd will require immediate development, implementation, and effective monitoring of co-management actions.

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INTRODUCTION

The Bathurst herd is a population of migratory barren-ground caribou *(Rangifer tarandus groenlandicus)* that has traditionally calved near Bathurst Inlet in the Kitikmeot Region of Nunavut (Sutherland and Gunn 1996). The annual range of the Bathurst herd occurs mostly within the Northwest Territories and Nunavut, but also extends into northern Saskatchewan (Figure 1). There are ten aboriginal communities on or near the range that rely on Bathurst caribou as a source of country food (Bathurst Caribou Management Planning Committee 2004). The Bathurst herd has also provided important economic opportunities for commercial harvesting and the guide/outfitting industry (Ashley 2000), and has been used extensively by resident hunters. Due to the proximity of Yellowknife to the winter range of Bathurst caribou and ready access from all-weather and winter roads, the Bathurst herd has been one of the most heavily hunted barren-ground caribou herds in the Northwest Territories (Case *et al.* 1996).

Regular calving ground surveys are a core monitoring action for Bathurst caribou, and survey frequency is tied to status and trend of the herd (Bathurst Caribou Management Planning Committee 2004). The most recent surveys of the Bathurst herd were completed in June 2003 (Gunn *et al.* 2005) and June 2006 (Nishi *et al.* 2007) and showed that the estimated number of breeding females had declined significantly since 1986. Because of the declining trend and ongoing management concern regarding the low population status of the Bathurst herd, the Government of the Northwest Territories has committed to

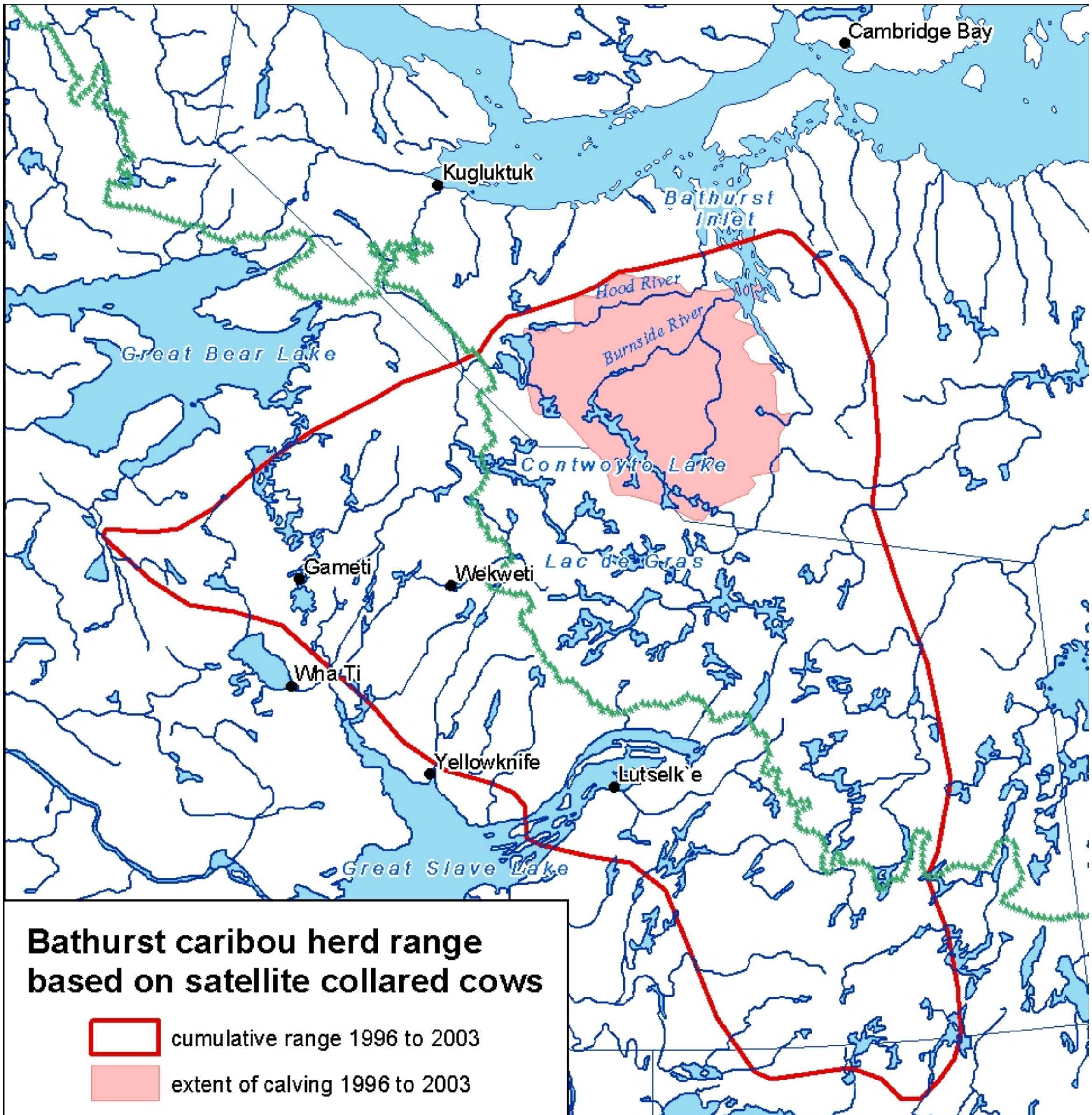

Figure 1. Herd range of Bathurst caribou based on satellite collared cows from 1996 to 2003 (p.8 in Bathurst Caribou Management Planning Committee 2004)

conducting calving ground surveys at three-year intervals (Government of the Northwest Territories 2006).

In this report, we describe the calving ground survey of the Bathurst herd in June 2009. To maintain comparability with previous surveys, we used the calving ground photographic survey method to estimate the number of breeding females on the annual calving ground. This technique was developed and tested since the early 1980s (Heard 1985, Heard and Williams 1990, Williams 1994) for barren-ground caribou herds in the Northwest Territories. The rationale for using aerial photography was to reduce bias and increase accuracy of survey estimates. Mowat and Boulanger (2000) highlighted more recent discussions and recommendations to improve precision of calving ground surveys, and Gunn *et al.* (2005) described and implemented changes to survey design for improved precision starting with the June 2003 photographic survey of the Bathurst herd.

Our objectives for the survey in June 2009 were:

1) obtain an estimate for the number of breeding females on the annual calving ground with a coefficient of variation (CV) of ≤ 15%;
2) determine the trend in number of breeding females on the calving grounds since 1986;
3) estimate the ratio of breeding females to total females at the peak of calving as an indicator to pregnancy rates comparable to previous years; and
4) describe the spatial extent of the annual calving ground relative to previous years.

METHODS

Study area

The study area was defined by the extent of calving for the Bathurst caribou herd over the past 10 years (Figure 1). Since 1996, the seasonal movements and annual range of the Bathurst caribou herd have been monitored using radio collars with satellite transmitters. Telemetry studies summarized by Gunn *et al.* (2001), Griffith *et al.* (2001), and Gunn and D'Hont (2002) as well as aerial surveys by Gunn (1996), Gunn *et al.* (1997 and 2005) and Nishi *et al.* 2007, have shown that the extent of calving has occurred west of Bathurst Inlet (Figure 1) since the mid 1990s.

Monitoring satellite collars and mobilization of field crews

We anticipated that the annual calving ground would be in or near the same area as in recent years – generally between the Hood and Burnside Rivers, and west of Bathurst Inlet. Starting in early May 2009, we closely monitored the movements and observed locations of 11 satellite-collared Bathurst caribou cows to track their progress relative to the known extent of calving over the past 13 years (Figure 2).

On the 3 June 2009, we mobilized field crews (JA, JB, BC, FC, ND, RF, GM, JN; see Appendix A) from Yellowknife using a Cessna Caravan (Appendix B). Our base of operations for the survey was Tahera Mine (66° 01.2' N 111° 28.2' W). A second survey aircraft – a Turbo Beaver – and additional field crew members (JB, KC, AK; see Appendix A) arrived on the 6 June (Appendix B).

Aerial systematic reconnaissance surveys

We used a standardized methodology for visual strip-transect aerial surveys of barren-ground caribou; survey altitude was 120 m above ground level, survey speed was *ca.* 160 kph, and total transect width was 0.8 km (400 m strip width per side). We used 50 cm lengths of wooden doweling (*ca.* 1.5 cm diameter) as markers to demarcate the outer edge of the strip-transect on the wing struts of survey aircraft. We used the methods outlined by Norton-Griffiths (1978) to position the strip markers and attached the dowelling to aircraft wing struts using black electrical tape and duct tape. We marked out 400 meters from the southern end of the Tahera mine airstrip and had a service van park temporarily at the marked distance after the survey aircraft was airborne. We checked the strip markers by having the pilot fly at survey altitude along a perpendicular axis to the airstrip with the aircraft positioned so that the southern end of the runway marked the inside of the transect and observers determined whether the parked van aligned with the strip markers on the wing struts. Left and right observers verified the strip marker positions on the wing struts against the distance markers on the ground, or adjusted them as necessary after the plane was back on the ground.

We used a systematic aerial survey design within the extent of calving to achieve three objectives:

1) delineate the annual calving ground based on relative densities and composition of caribou;

2) stratify the annual calving ground for a photographic survey of high and medium density strata and a visual survey of low density strata; and

3) survey an extensive area *ca.* 100 km beyond the annual calving ground to confirm that we did not miss any large groups of breeding females.

We used the methodology described by Gunn *et al.* (2005) and adapted from Williams (1994), in which a landscape level 10 km survey grid was applied to the known extent of calving for the Bathurst herd since the mid 1990s. Using the 10 km survey grid, we flew north-south transects with a coverage of *ca.* 8% (*i.e.,* transects spaced at 10 km intervals).

We used navigation and data management techniques that combined portable Global Positioning System units with ESRI ArcView mapping software (http://www.esri.com). Observational data were compiled and analyzed in Microsoft Excel (http://office.microsoft.com) to calculate densities within 10 km segments, and displayed in ArcView to produce maps that showed relative caribou densities, as well as the presence of antlered cows and/or calves for each segment. On a daily basis we plotted survey data on digital maps of the study area to analyze observed patterns of caribou density and composition, and to plan subsequent survey tasks.

Because of the concern that the Bathurst herd was declining, our overall strategy for the systematic survey was to cover the known calving distribution since 1996, and also include a large peripheral buffer to demonstrate clearly that we found the annual concentrated calving area – the area of relatively high use within an annual calving ground (*sensu* Russell *et al.* 2002) – and did not miss any substantial groups of calving caribou.

We started the systematic reconnaissance survey on the 4 June 2009 with the Cessna Caravan, and conducted the initial flight so that it encompassed the distribution of nine satellite-collared cows that were located within the extent of calving. This allowed us to survey the area that we initially thought would encompass the annual calving ground, and apply criteria on observed densities and relative composition of caribou to complete an initial delineation of the calving ground.

We selected the initial flight to cover the most recent locations of the satellite-collared cows, and adapted the criteria described by Gunn *et al.* (2005) to end transects lines. As the northern distribution of the annual calving ground would have been a leading edge, our main criterion for ending a transect was the absence of caribou in the northern-most segment of a transect. As the southern 'edge' was more likely to reflect a trailing distribution, the absence of caribou in a 10 km segment was likely a less useful criterion because we expected to observe groups of non-breeders following the breeding females towards the calving grounds. Consequently, we used the criterion of < 10 hard-antlered caribou within a southern-most segment unless a calf was present. However, during the actual survey, we often continued flying south along a transect until we saw no caribou in a 10 km segment; this conservative approach ensured that there was a clear break in the distribution of caribou.

We continued the systematic survey to progressively cover a larger portion of the extent of calving. From the 6-8 June, a Turbo Beaver was also used to conduct the systematic survey. To determine whether we were approaching the peak of calving, we also estimated the proportion of calves in the concentrated area of calving, relative to observations from the systematic survey on the 4 June. On the 6 and 7 (AM) June, we reflew some transect segments that had been surveyed on the 4 June; observers counted or estimated the proportion of calves along with the group size of all 1^+-year-old caribou. Based on those observations we used two fixed wing aircraft to resurvey and delineate the annual calving ground on the afternoon of the 7 June so that we could subsequently design the stratified photographic and visual survey.

Concomitant with the start of the photographic and visual survey of the calving ground, we used the Turbo Beaver to continue the systematic survey in the area northwest of the annual calving ground on the 8 June. The Cessna Caravan resumed the systematic survey on the 9-10 June to extend coverage to the south and east to Bathurst Inlet. On the 17 June, the Cessna Carvan was used to extend coverage of the systematic survey to the area directly south and southeast of Kugluktuk. The purpose of the survey was to ensure continuous systematic coverage between the eastern edge of the Bluenose East calving ground distribution and the western extent of calving for the Bathurst herd, and to confirm that there were no large aggregations of breeding females between the two expected calving grounds.

Stratification of the annual calving ground **for photographic and visual surveys**

On the evening of the 7 June, we delineated a single high density stratum with an adjacent medium density survey stratum. We also delineated three low density strata. Our stratified survey design for the annual calving ground was based on a combination of photographic survey methods for high and medium density strata, and standard visual aerial survey methods for low density strata. We used spatial patterns of breeding females and relative caribou densities within 10 km segments from aerial systematic reconnaissance surveys to delineate and stratify the annual calving ground. We delineated strata by enclosing adjacent segments that comprised breeding females (*i.e.,* hard antlered females with or without calves and non-antlered females with newborn calves) of similar densities classes. We used density classes of high, $\geq$ 10 caribou/km^2; medium, 1.0 – 9.9 caribou/km^2; and low, 0.1 – 0.9 caribou/km^2).

As outlined by Gunn *et al.* (2005), we also specifically considered five issues in designing the survey and delineating strata on the annual calving ground:

1) Variance among observed caribou densities of transect segments within a stratum should be minimal.
2) In addition to observed densities, the presence of newborn calves and hard antlered cows within 10 km grid segments and the spatial dispersion of those segments were important factors in delineating survey strata.

3) Strata should be large enough to accommodate the anticipated movements of caribou between the time when the systematic reconnaissance survey and stratification are completed, to the time when transects in the strata are actually photographed by the photo plane.

4) The stratum baseline should be sufficiently long enough to allow for a minimum of 10 transects as a sample size.

5) Transect lines should be of similar length to minimize variance.

To minimize variance between numbers of caribou photographed / counted on transects, we oriented transects to run north-south so that we sampled along the predominant density gradient. We initially determined the allocation of survey effort, i.e., the number of available photographs, by estimating mean population size and variances for each stratum (Heard 1987). However, because of the small combined areas of the high and medium strata, we allocated effort to ensure that there were at least 10 transects in the medium strata (*ca.* 20% coverage), and maximized effort in the high density strata to achieve *ca.* 40% coverage, which required 22 transects.

Aerial photographic survey for estimation of caribou in high and medium density strata

We contracted Geographic Air Survey Ltd., Edmonton, AB, to conduct the aerial photography. The survey aircraft was an Aero-commander equipped with a belly mounted camera (Wildle RC40 camera with forward motion compensator) and radar altimeter, and the crew consisted of a pilot and camera-man. The camera system was linked to a GPS navigation system that would fly the plane in an auto-pilot mode and permit the camera to take geo-referenced aerial photographs while on transect. In order for the pilot and cameraman to run their survey aircraft and camera, the aircraft GPS navigation needed to be pre-programmed with transect coordinates.

After completing the survey design, *i.e.,* delineation of strata and allocation of effort, we sent electronic files with stratum boundaries and start / end coordinates for all transects in the high and medium density strata to Geographic Air Survey's office in Edmonton on the evening of the 7 June. On the morning of 8 June, the aerial photography survey crew arrived at Tahera Mine to start the photographic survey. To ensure a proper sun angle (25-30°), aerial photography was conducted between 0800h – 1830h. The intended scale of the aerial photography was 1:4000, necessitating an approximate altitude of 1100 m agl. Approximate speed of the photo plane was 260 kph.

Aerial survey for visual estimation of caribou in low density strata

On 8 June, we used a Cessna Caravan with a pilot, navigator, left and right observers to survey the two low density strata and obtain a visual estimate of caribou numbers. Survey altitude was 120 m agl, survey speed was 160 kph, and total strip width was 0.8 km (400 m strip width per side).

Sex and age composition survey

We started composition surveys on the 8 June to estimate the proportion of breeding females within the high, medium, and low density strata. Due to time limitations on the helicopter, and the importance of collecting composition data on the same days of the photo and visual surveys, our main priority was to collect composition data from high and medium photographic strata initially. Remaining time was allocated for adjacent low density visual strata on the 11 June. We used the midpoints of the 10 x 10 km segments within a stratum to distribute our search effort.

We used an Aerospatiale AStar (AS350) helicopter with a three or four person crew (pilot, navigator, and observer(s)) to spot groups of caribou for classifying. The pilot approached caribou groups in a manner that minimized aircraft noise and landed 100-500 m away. A two (or three) person field crew would approach the caribou on foot. One person would classify caribou using binoculars or a spotting scope and the second person would record the data. To avoid double counting, the observer would scan and classify progressively from one side of their field of view to the other. The intent was to classify caribou as animals walked away slowly because this presented the observer with an optimal view of the hind end by which they could readily observe key characteristics of breeding females, i.e., vulva patch and udder. In low density strata where groups were scattered and group sizes were usually smaller than 20, the front seat observer would classify caribou from the helicopter. For groups larger than 30, the helicopter would land and field crews would use the same ground-based techniques as those used in the high and medium strata.

We classified caribou into the following categories: breeding females, non-breeding females, yearlings, bulls, and calves (see p. 6 in Gunn *et al.* 1997). We identified breeding females (pregnant and post-partum) by the presence of hard antler(s) and/or a distended udder. Cows without hard antlers and without a calf at heel but with a distended udder were considered breeding females that had probably lost their calves. Non-breeding females were characterized by the absence of a distended udder and usually had new antler growth (although it is possible to observe a genetically bald cow that would not have any antler growth). Yearlings were distinguished based on their relatively small body size and short faces. Bulls were easiest to classify consistently because of their relatively large antlers in velvet, large body size, and broad faces and muzzles.

Data analyses

Data from satellite-collared cows

Location data from most satellite-collared cows were available multiple times a day. We used successive locations at *ca.* 1500h to calculate daily distance travelled using the great circle distance (D):

$$\cos D = (\sin a \sin b) + (\cos a \cos b \cos|\delta\lambda|),$$

where *a* and *b* are the geographic latitudes of the two locations and $|\delta\lambda|$ is the absolute value of the difference in the two geographic longitudes (Robinson *et al.* 1995). We calculated daily distance travelled, by the distance between successive locations at 24 hour intervals (Appendix C). We then calculated the average distance travelled by all collared cows for which we had locations.

We used the Hawth's AnalysisTools © 2002-2006 Version 3.26 (Beyer n.d.) in ArcGIS to create minimum convex polygons (MCP) by date for the satellite-collared cow locations.

Data from aerial surveys

We compiled observations of caribou for each transect within low density strata. Depending on whether transect lengths were the same, we used either the Jolly 1 or Jolly 2 method (Jolly 1969) for equal and unequal sample units, respectively. We used the program Aerial (Krebs 1992, Program 3.5) to calculate population estimates and variances.

We contracted Paul Roy (H.P. Roy, Ottawa, ON) to count all 1^+-year-old caribou on the photographs using a stereoscope. Caribou counts within each photograph were summed across all the photographs along a transect. We checked that the intended scale of 1:4000 for the aerial photographs was correct by comparing distances on 1:250 000 scale maps to distances on the photographs. Population estimates for the High and Medium density strata were calculated using the Jolly methods in the program Aerial.

Data from composition surveys

We calculated the mean proportion (and variance) of breeding females within each stratum by analyzing composition data using Cochran's (1977) jackknife method in a Microsoft Excel spreadsheet (Appendices H – J). We estimated the number of breeding females on the calving ground by multiplying the mean population estimate for each of the strata by the mean proportion of breeding females calculated for each respective stratum. We were not able to collect compositional data from one low density strata (Low-N) due to scarcity of caribou and time restrictions. Due to low densities of caribou in the Low-SW and Low-SE, we calculated the proportion of breeding females based on group observations pooled across the two strata, and also extrapolated that estimate to the Low-N stratum.

Trend analyses

We incorporated the population estimate of breeding females from the 2009 survey into a longer term trend analysis on the Bathurst herd. We used three methods to estimate the trend in the estimated number of breeding females from 1986 to 2009 (see Appendix K):

1) For the two most recent surveys, we used methods described in Section 4.2.1.4 of Gasaway *et al.* 1986 to conduct a one-tailed t-test and determine whether the number of breeding females had declined since the last survey, i.e., was the estimate of breeding females in 2009 significantly lower than the 2006 estimate?
2) A weighted least squares analysis was used to estimate trend from the full time series of data.
3) Monte Carlo simulation techniques were used to estimate the variance in trend that resulted from individual variances of each of the surveys since 1986.

RESULTS

Satellite collared caribou cows

We monitored movements and locations of 11 satellite-collared Bathurst caribou cows (Figure 2, Appendix C) from May through June. Cow # 212 was considered to be a non-breeder based on her location west of Contwoyto Lake and comparatively high rate of movement throughout the calving period (see Figure 2, Appendix C), and it was not included in subsequent analyses.

The average daily movement rates of collared cows ranged from ~ 6-16 km/day during the first three weeks in May (Figure 3). Mean daily rate of movement increased and remained elevated (ranged from ~ 14.2 – 20.1 km/day) through the last 10 days of May, and then showed a constant rate of decline through early June. Average daily movement rates were less than 5.0 km/day from the 8-15 June, with the lowest rate of movement, 2.0 ± 2.7 km/day (SD), observed on the 11 June 2009 (Figure 3 and Figure 5). Subsequently, from mid June to the end of June, daily movement rates increased steadily.

The trend in dispersion of collared caribou was represented by the change in area of the minimum convex polygon (MCP) that enclosed 10 satellite-collared cows on any given day from 1 May to the 30 June (Figure 4 and Figure 5). Aggregation of breeding cows increased as area of MCP decreased; this spatial trend showed that the MCP enclosing the collared animals was steadily getting smaller as caribou cows travelled to and congregated on the annual calving ground. The first week of June showed a marked reduction in area occupied by the 10 satellite-collared cows, and MCP was strongly influenced by the location

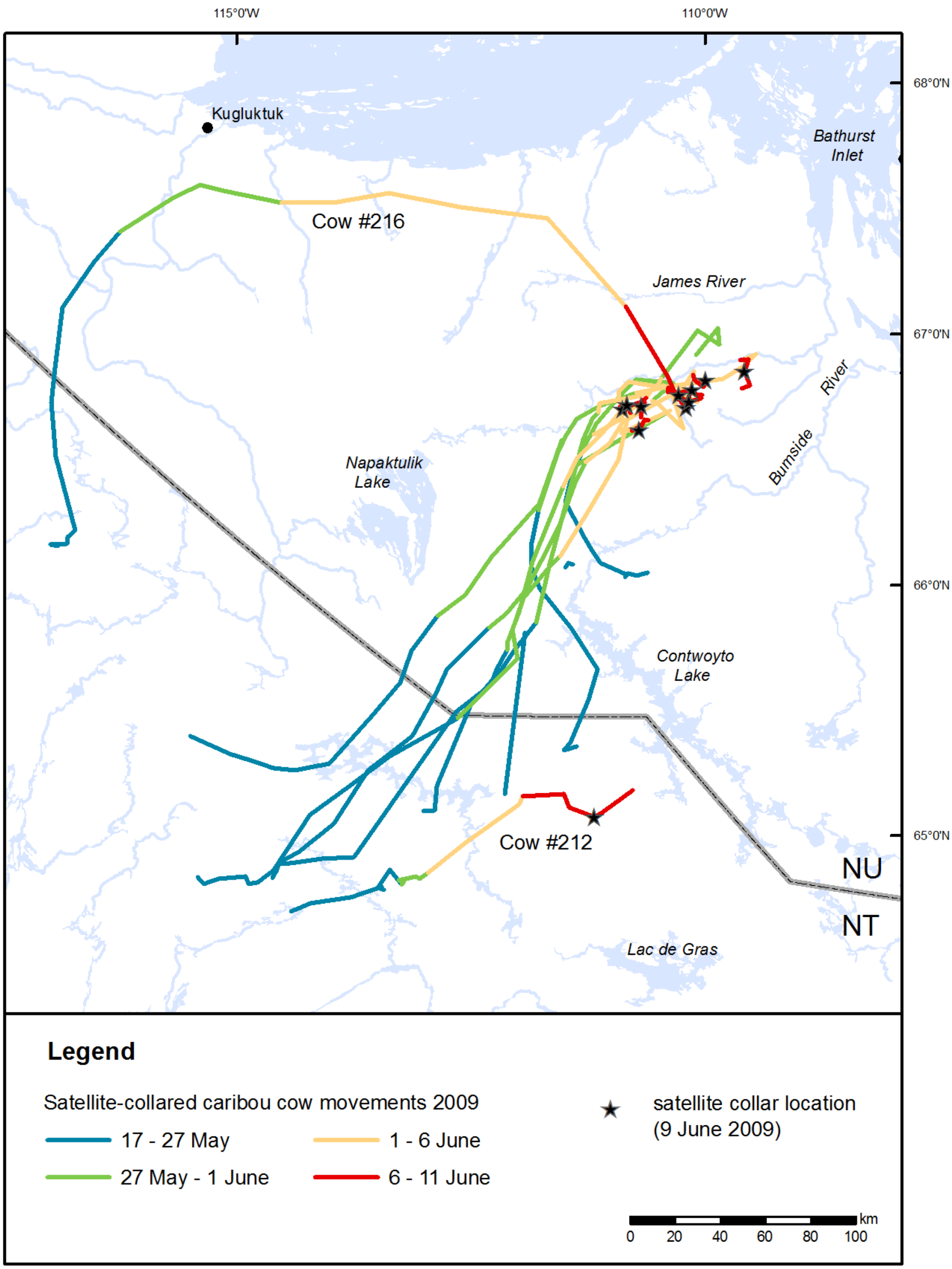

Figure 2. Movements of satellite collared Bathurst caribou cows from 17 May to 30 June 2009.

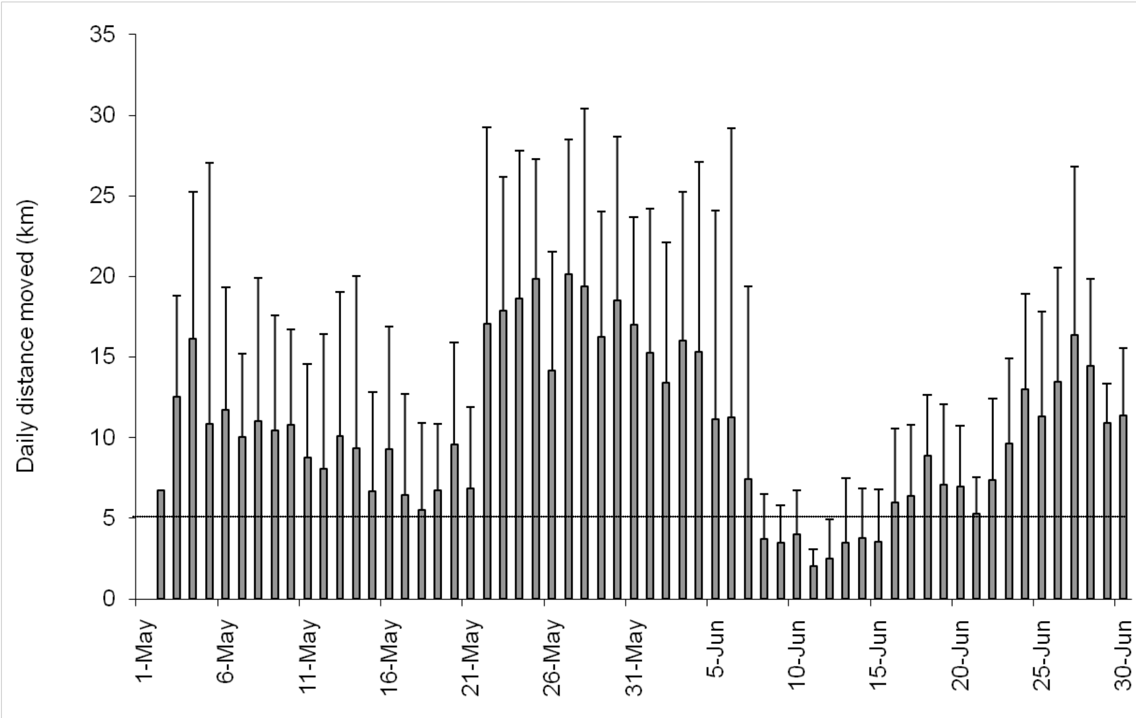

Figure 3. Average daily distance (km + 1 standard deviation) moved by satellite-collared Bathurst caribou cows (presumed to be breeding animals) during May and June 2009.

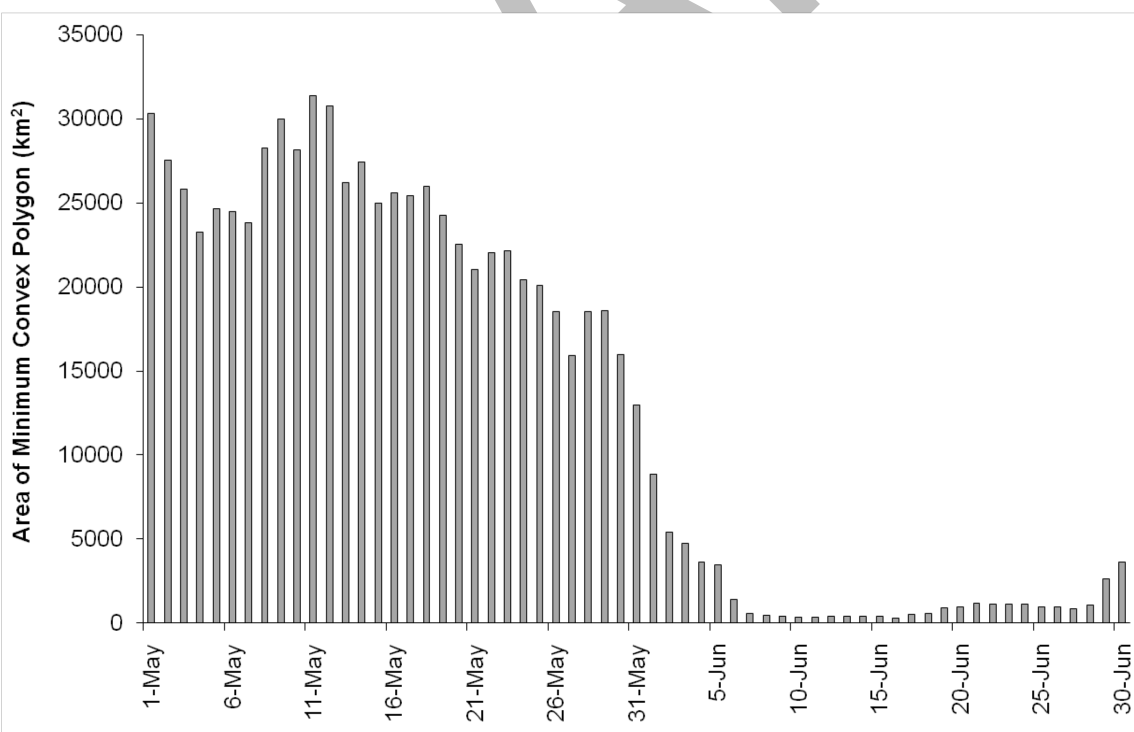

Figure 4. Area (km^2) of minimum convex polygons (MCP) for satellite-collared Bathurst caribou cows (presumed to be breeding females) from May through June 2009.

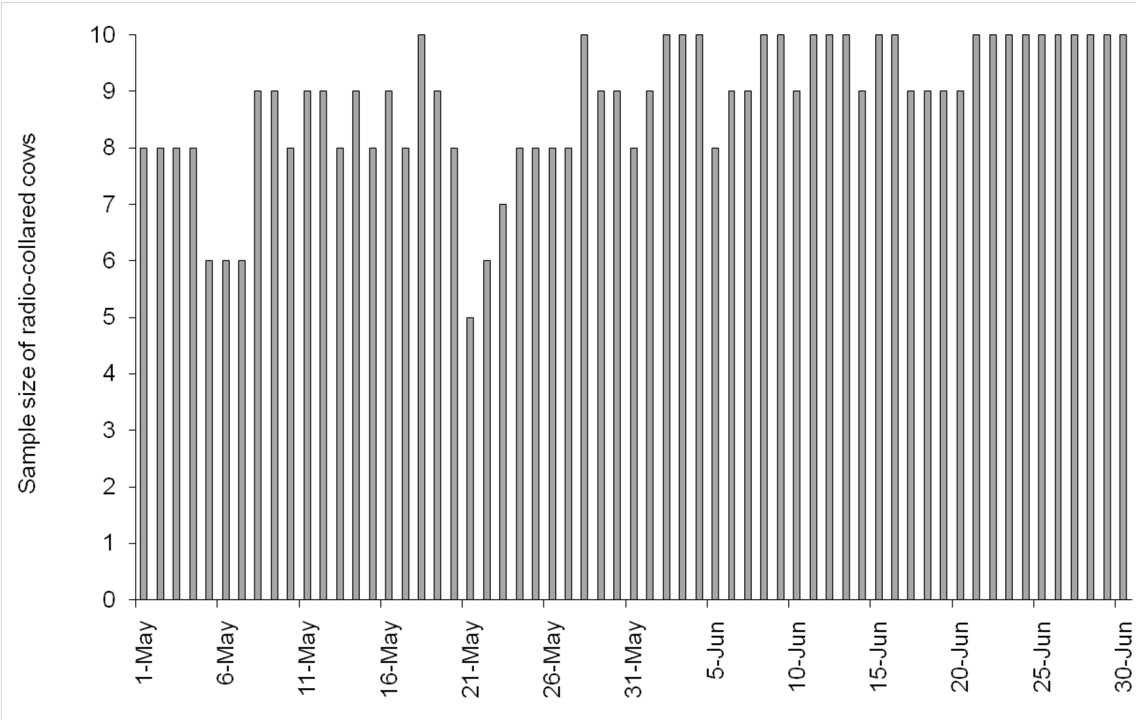

Figure 5. Sample sizes of satellite-collared Bathurst caribou cows used to calculate daily movement rates and minimum convex polygons from May through June 2009. All cows presumed to be breeding females (see Appendix C).

and movement pattern of cow #216 (Figure 2, Appendix C). Cow #216 showed a dramatic pattern of movement because she appeared to be displaying a movement pattern consistent with the spring migration of the Bluenose East herd: in late May, it was *ca*. 20 km south of Kugluktuk but then over a six day period (2-8 June), she travelled quickly to the east and south and was on the concentrated annual calving ground of the Bathurst herd at about the peak of calving (Figure 2).

By 7 June the MCP of the 10 collared cows had declined to 568 km^2, from a high of 31,400 km^2 on the 11 May (Figure 4). From the 8-16 June, the collared cows were enclosed by the smallest MCP values, which ranged from 282-465 km^2 (Figure 4).

Aerial systematic reconnaissance surveys

During the initial survey on 4 June, we covered an area that included the locations of nine satellite-collared cows; cows 212 and 216 were not in the surveyed area (Figure 6). We flew 1140 km of transects and counted 510 caribou and 25 calves (5%) across the surveyed area (Figure 7 and Figure 8). Of the 114 10-km transect segments, 1 (0.9%) was high density, 17 (14.9%) were medium density and 27 (9%) were low density (Figure 7, Appendix D). The high and medium density segments represented 17.5% and 68.0% respectively of all the caribou observed (Appendix D). The highest densities of caribou were within the central portion of the surveyed area somewhat above but mostly below the Hood River and along the Wright River valley (Figure 7).

The aggregated distribution of caribou was well circumscribed within the initial surveyed area on the 4 June, and there was a clear break in distribution along the western, southern, and eastern boundaries (Figure 7). A single high density transect segment was located in the north-central area of the aggregated caribou distribution, with medium and low densities of caribou observed in adjacent transect segments (Figure 7). Breeding females, *i.e.,* cows with hard antlers, and cows with a newborn calves, were dispersed throughout the observed distribution of caribou (Figure 8).

In subsequent days (5-7 June), we extended the systematic survey to progressively cover the areas to the south, east, and north (Figure 9). We extended the survey south and southwest to determine whether breeding females may have been dispersed and travelling along the spring migratory corridor and to ensure that continuous systematic coverage was extended out to

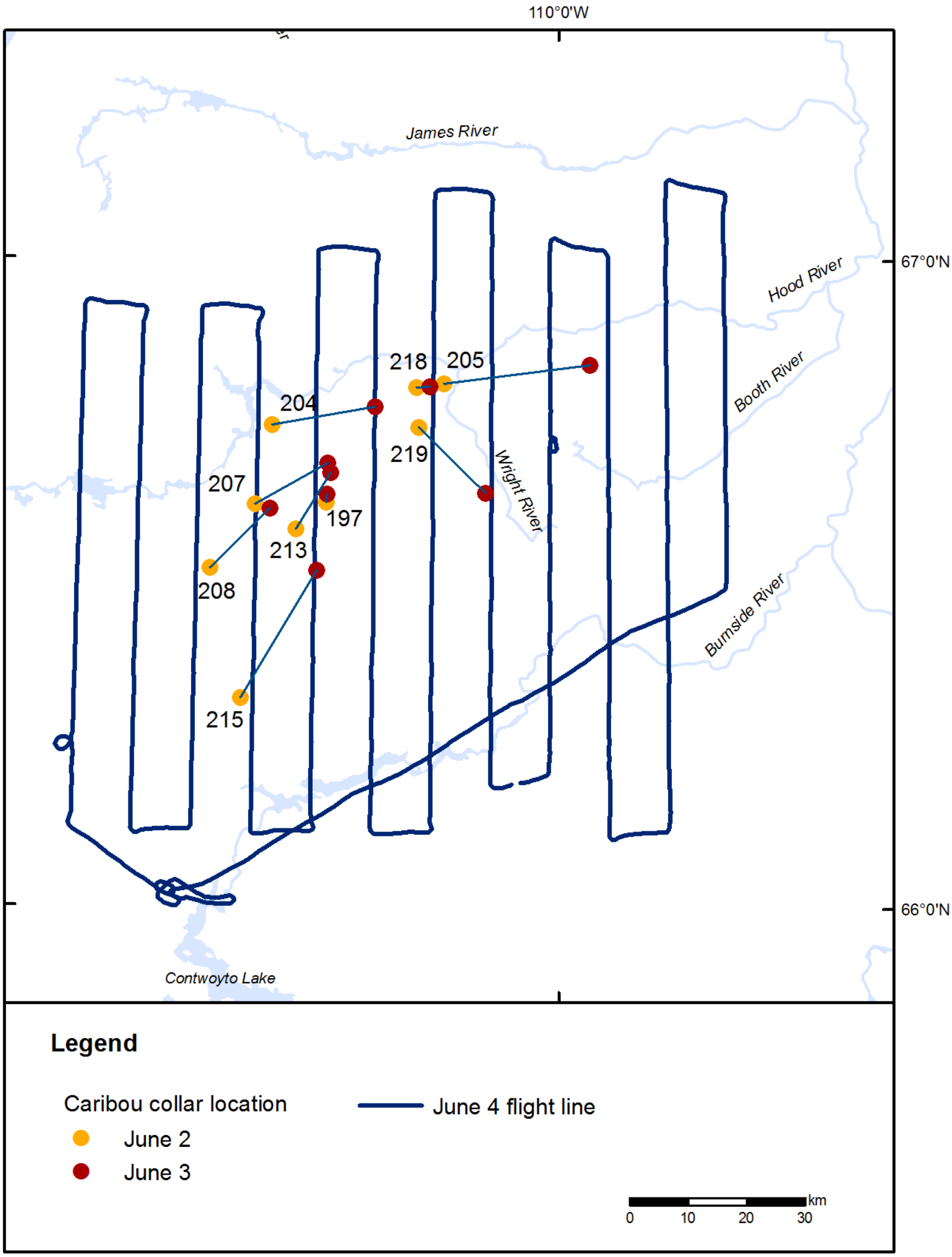

Figure 6. Locations of nine satellite-collared caribou cows (presumed to be breeding females) in early June, prior to a systematic aerial survey that was flown on 4 June 2009 to delineate the annual calving ground of the Bathurst herd.

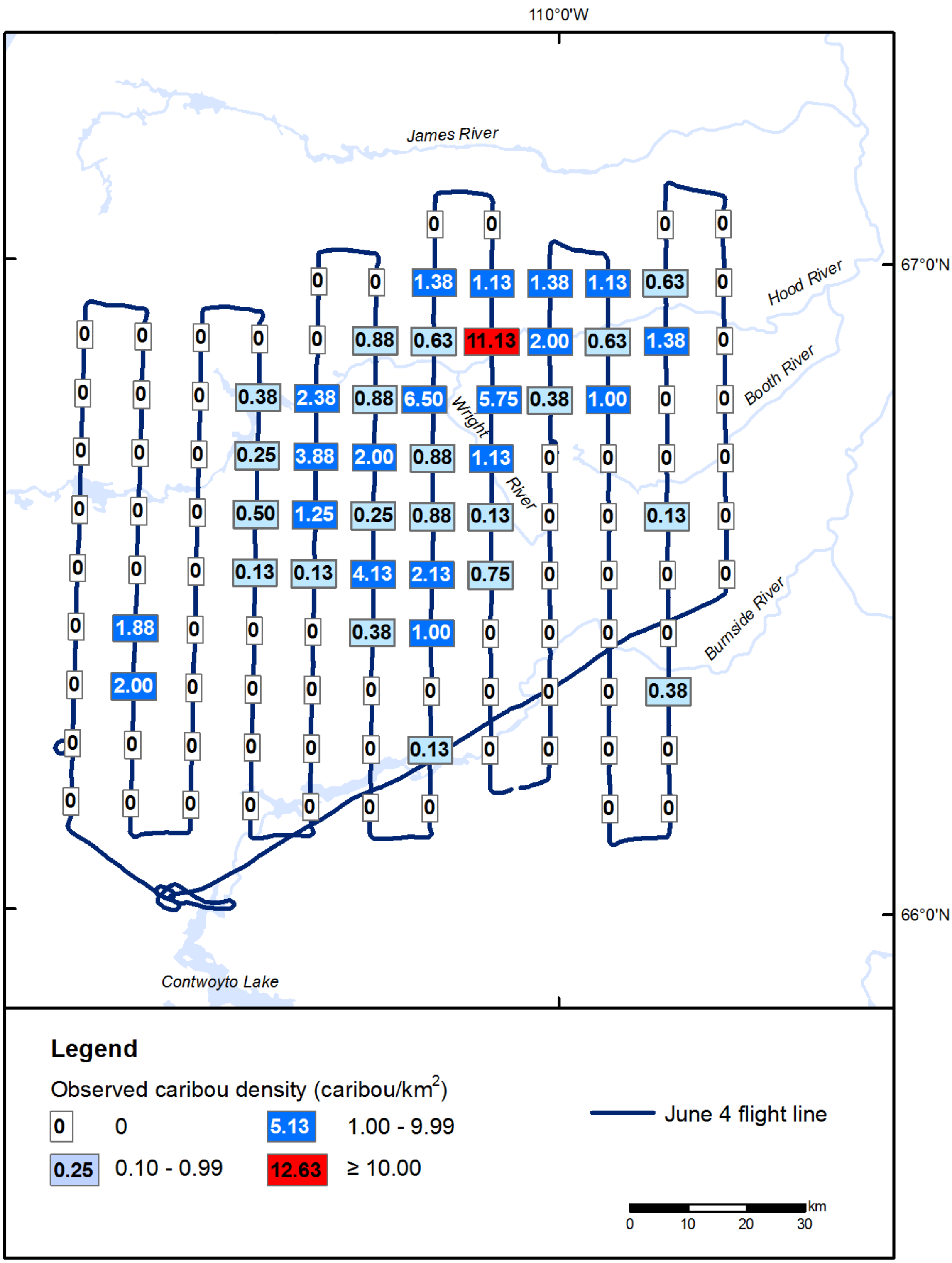

Figure 7. Observed densities of caribou within adjacent 10-km transect segments from a systematic aerial survey of caribou on the Bathurst calving ground, 4 June 2009. Label colours represent density classes: White = flown and no caribou observed, Light blue = 0.1-0.99 caribou/km^2, Dark blue = 1.0- 9.9 caribou/km^2 and Red = ≥10 caribou/km^2. Numbers within cell represent actual caribou densities for each 10 km segment.

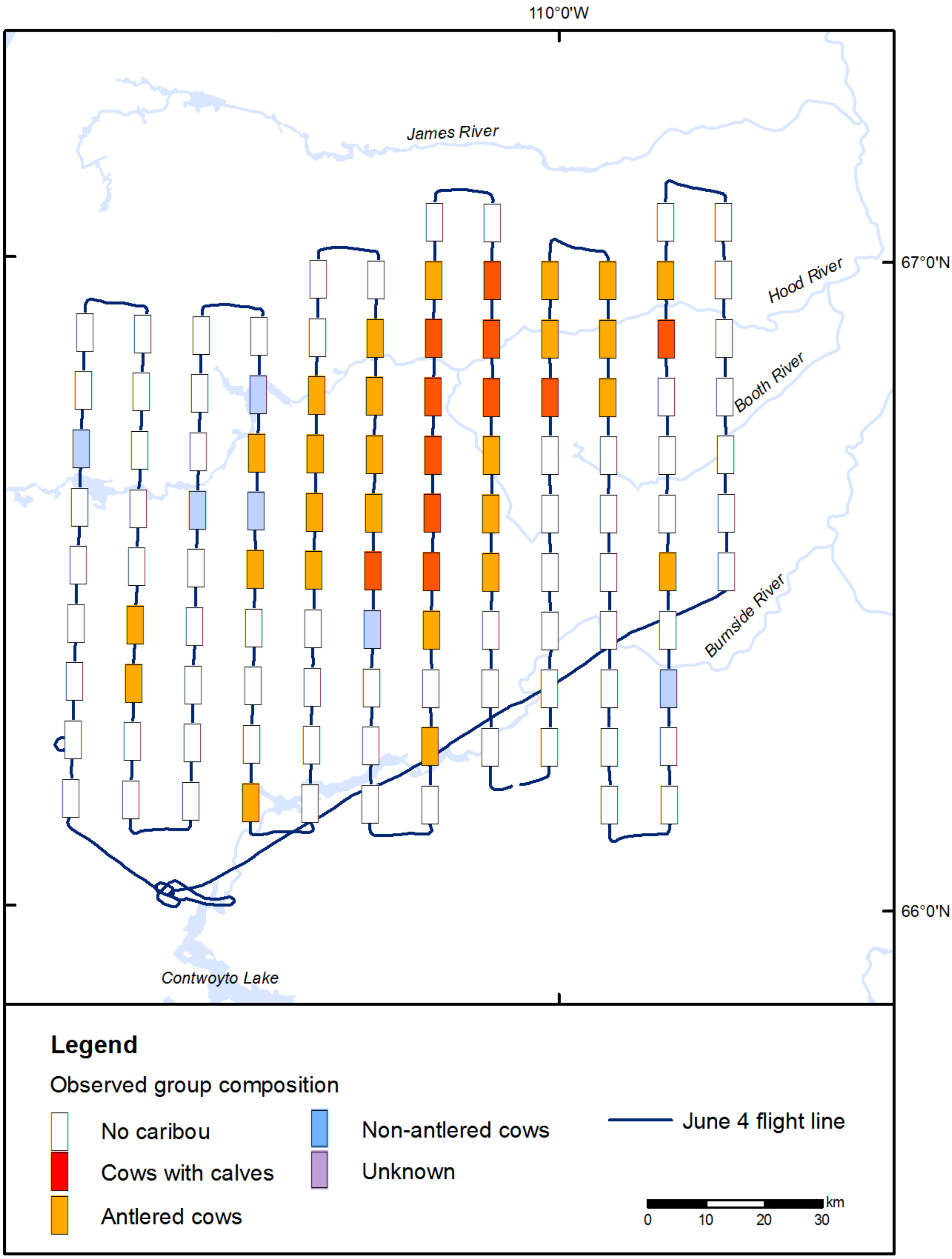

Figure 8. Observed composition of caribou groups during an initial systematic survey of Bathurst calving ground on 4 June 2009. Each cell represents an adjacent 10-km segment length (8 km^2) within a survey transect and cell colours represent composition classes: White = flown and no caribou observed; Red = cow-calf groups; Orange = cows with hard antlers; Blue = non-antlered caribou; Purple = unclassified groups.

a previous location of a single satellite-collared cow in vicinity of Point Lake (Figure 9). Survey coverage was also extended south to include all of Contwoyto Lake, east to the southern extent of Bathurst Inlet, and north to the coastline of Coronation Gulf (Figure 9). Although 10 segments – that had at least one antlered female – were outside of the core aggregation of antlered cows and cows with calves, those peripheral segments were dispersed and isolated, and we did not observe any large aggregations of breeding females during subsequent survey flights outside the concentrated area observed on the 4 June (Figure 10 and Figure 11).

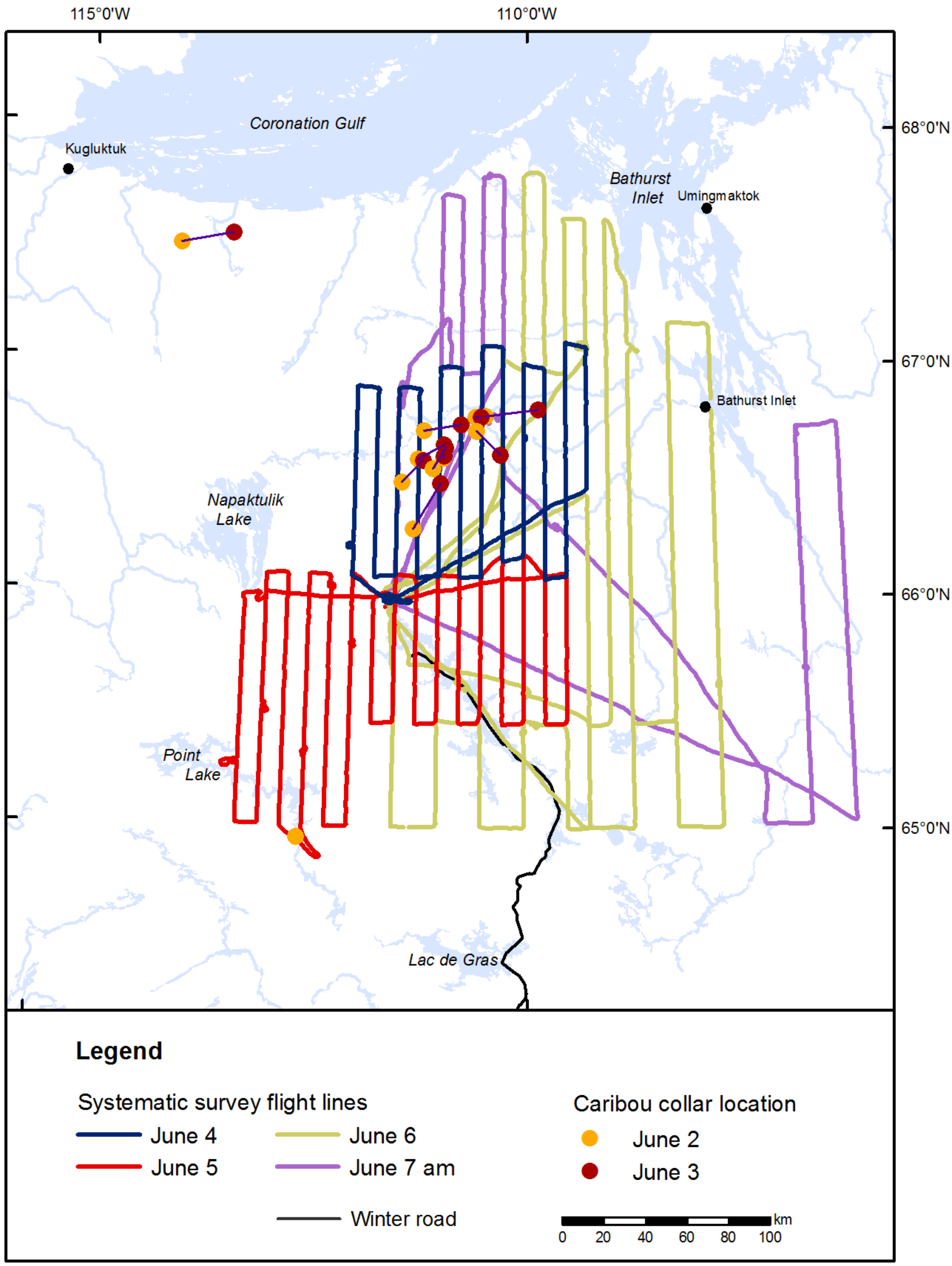

Figure 9. Flight lines from initial systematic survey to delineate annual calving ground for Bathurst caribou herd on 4 to 7 June 2009. Locations of satellite-collared cows (n = 10) on the 2 and 3 June are shown by orange/red circles. Cow #216 is located north of Napaktulik Lake and about 20-30 km from the coastline of Coronation Gulf.

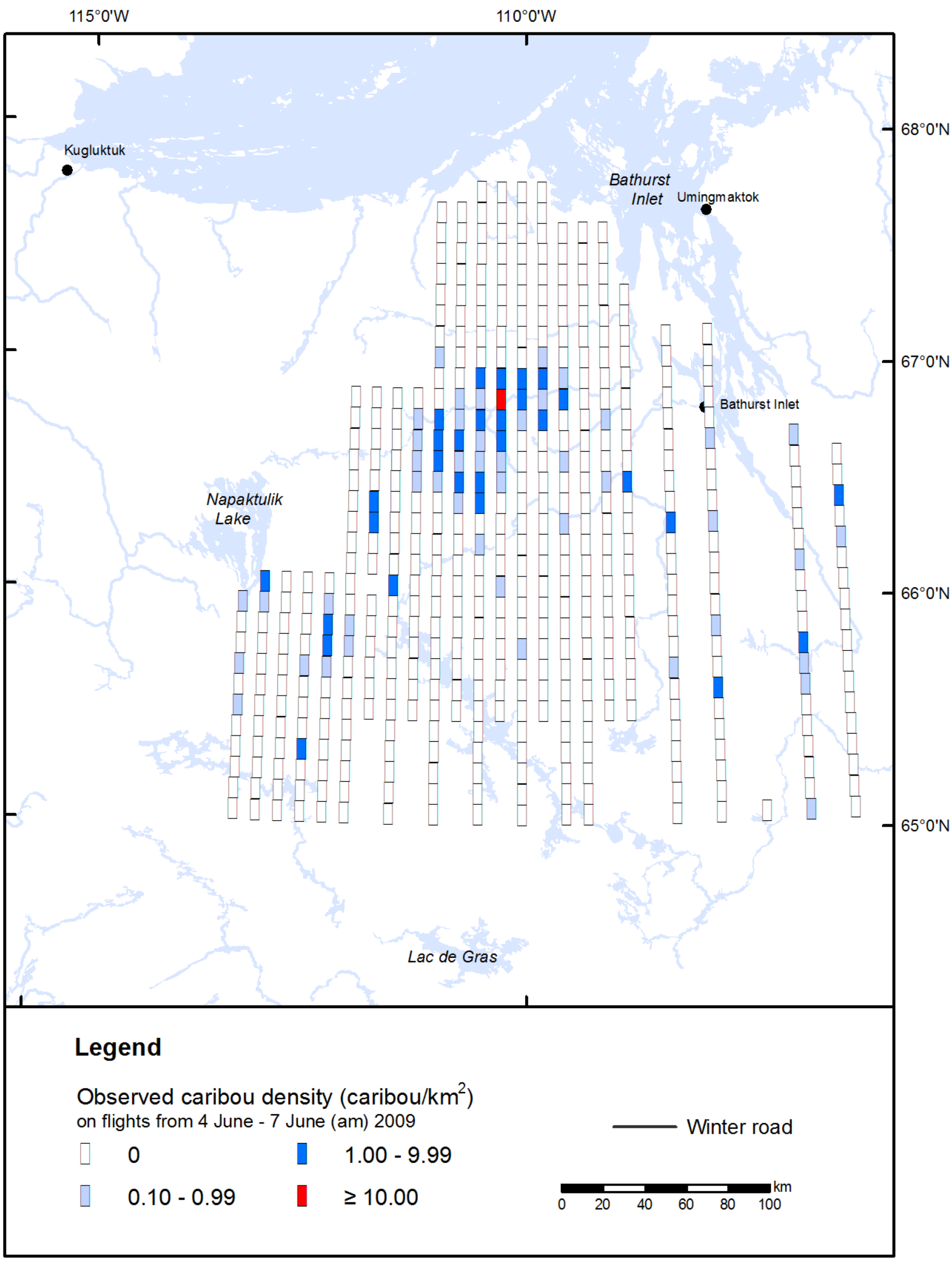

Figure 10. Observations of caribou densities within 0.8 km^2 transect segments, from systematic surveys of Bathurst calving grounds, 4 to 7 (am) June 2009. Label colours represent density classes: White = flown and no caribou observed, Light blue = 0.1-0.99 caribou/km^2, Dark blue = 1.0-9.9 caribou/km^2 and Red = ≥10 caribou/km^2.

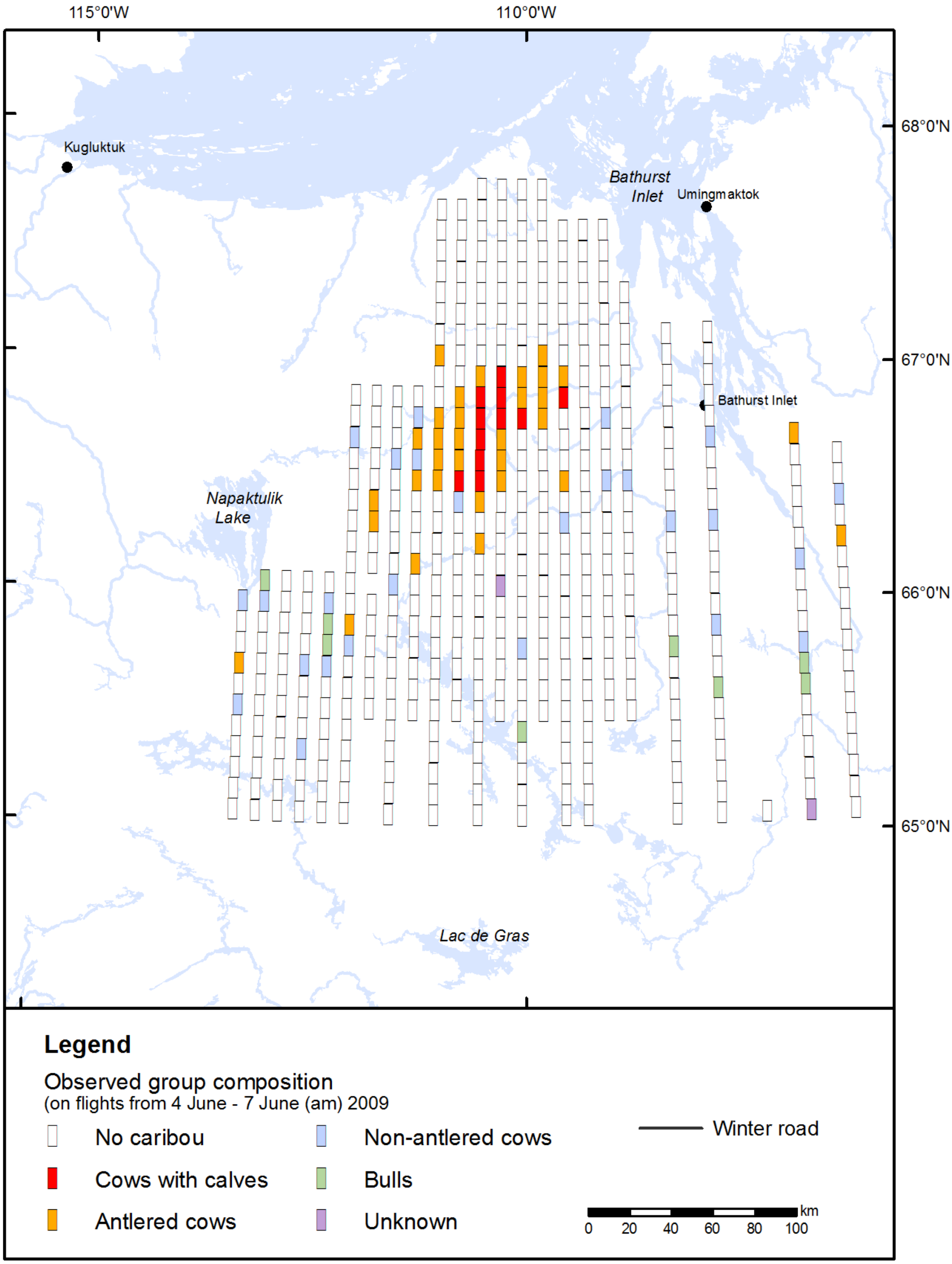

Figure 11. Observed composition of caribou within 0.8 km^2 transect segments, from systematic surveys of Bathurst calving grounds, 4 to 7 (am) June 2009. Each cell represents a 10-km segment of a survey transect and cell colours represent composition classes: White = flown and no caribou observed; Red = cow-calf groups; Orange = cows with hard antlers; Blue = non-antlered caribou; Green = Bulls; Purple = unclassified groups.

During the systematic survey on the 6 and 7 (am) June, we also flew some transect segments that had been previously flown on the 4 June to determine whether there may have been any observable changes in the proportion of calves, or a horizontal shift of the western boundary of the previously observed caribou distribution (Figure 12). A comparison of caribou observed on the same five transect segments showed that the proportion of newborn calves went from *ca.* 5.6% to 27.1% in a 48 hour period (Table 1).

While returning back to Tahera Mine after surveying on the morning of the 7 June, the survey crew in the Cessna Caravan checked the high density area previously observed on the 4 June, and observed three groups of caribou (see round symbols in Figure 12D), which totaled 29 caribou plus 16 calves. Additional unrecorded observations confirmed that the ratio of calves to 1+-year-old caribou was *ca.* 50%; the pilot was instructed to gain elevation and return to base in order to minimize potential disturbance through the concentrated area of calving as it would be resurveyed later in the day.

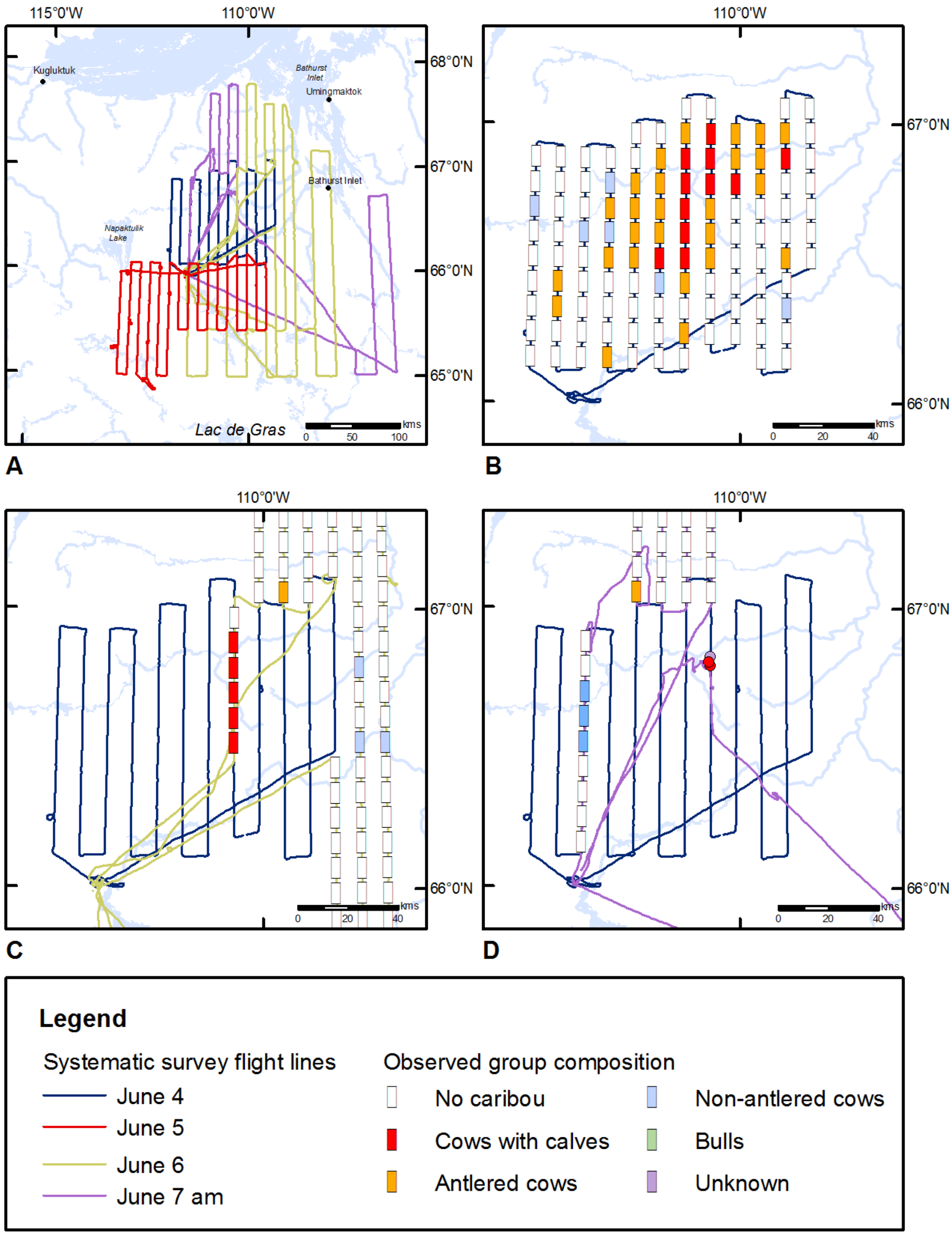

Figure 12. Comparison of systematic surveys flow on identical transect segments in subsequent days: A) all systematic transects flown from 4 to 7 (am) June; B) relative group composition of caribou observed within 8 km^2 segments on 4 June; C) composition of caribou observed on transect segments (557-562) on 6 June; and D) composition of caribou observed on transect segments during a morning flight on 7 June along the western edge of the breeding female distribution.

Table 1. Survey of five (8.0 km^2) transect segments on the 4 and 6 June 2009, to assess changes in proportion of caribou calves within the concentrated area of calving based on systematic reconnaissance surveys of the Bathurst calving ground.

Segment #	Caribou	# Calves	Density (caribou/km^2)	Density class
4 June				
562	9	1	1.13	Medium
561	89	3	11.13	High
560	46	5	5.75	Medium
559	9	0	1.13	Medium
558	1	0	0.13	Low
557	6	0	0.75	Low
	160	9		
	% Calves	5.6%		
6 June				
562	0	0	0.00	No Caribou
561	1	1	0.13	Low
560	52	14	6.50	Medium
559	13	2	1.63	Medium
558	3	1	0.38	Low
557	1	1	0.13	Low
	70	19		
	% Calves	27.1%		

Delineation and stratification of annual calving ground

On the afternoon of the 7 June (PM), we re-surveyed the main area occupied by breeding females during the initial systematic survey area on the 4 June (Figure 13). We flew 920 km and counted 633 caribou and 106 calves (16.7%) on transect (Appendix D). We observed two horizontally adjacent high density segments in the west central portion of the annual calving ground, with segments of medium density caribou around the periphery interspersed with

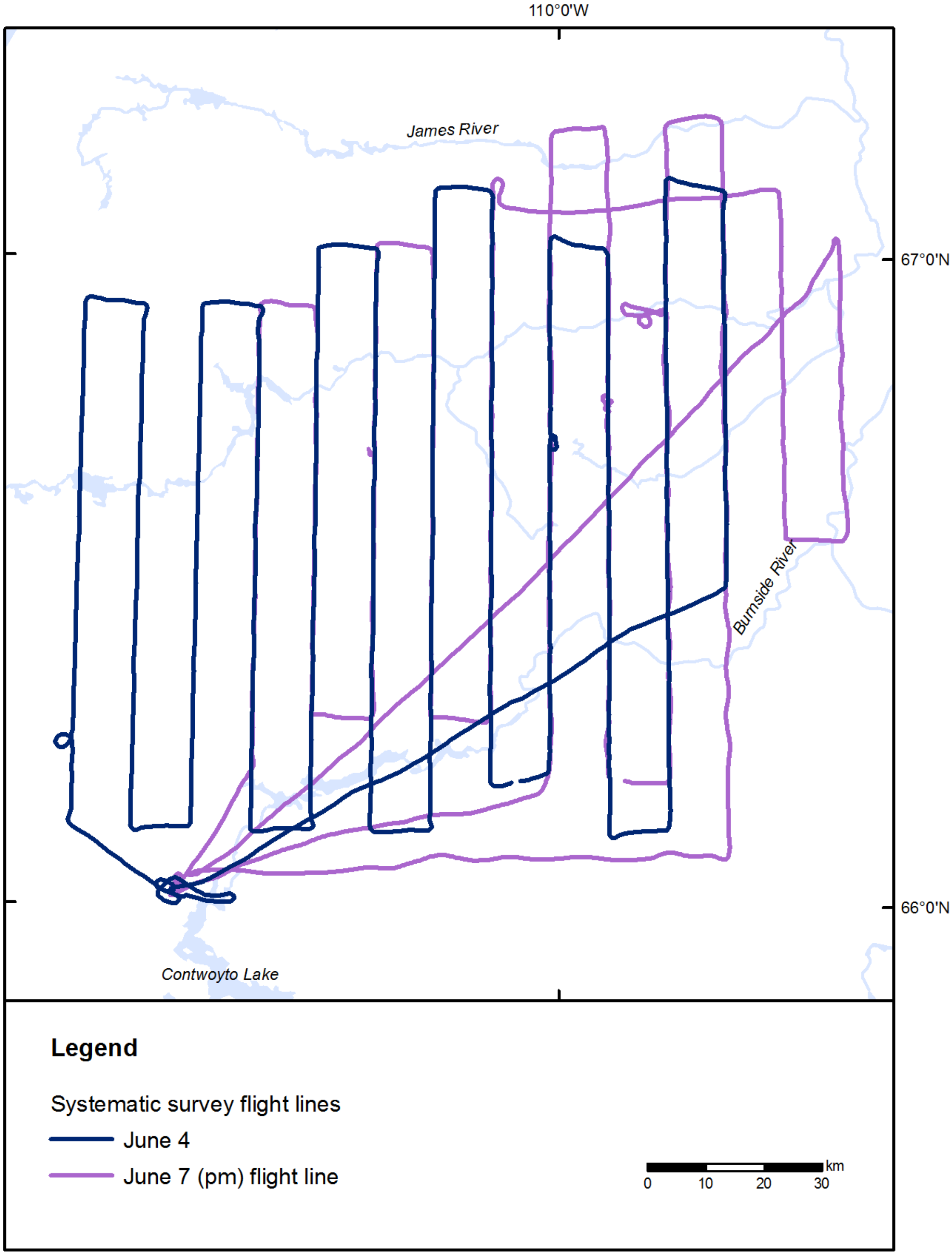

Figure 13. Flight lines from a) initial systematic survey to delineate annual calving ground and b) second systematic survey to delineate survey strata for combined photographic survey and visual survey of annual calving ground for Bathurst caribou herd, June 2009.

some low density segments (Figure 14). The pattern of segments that had at least one calf were dispersed more frequently in the east-central portion of the surveyed area, and associated more with medium and low density segments (Figure 15).

Based on the pattern of density and composition (Figure 14 and Figure 15), we delineated the annual calving ground and stratified it in to five survey blocks: a high (2601.8 km^2) and medium density strata (2113.1 km^2) for the photographic survey, and three low-density strata (Low N, Low SW and Low SE were 1310.9, 882.0, and 1077.7 km^2, respectively) for estimation of 1+-year-old caribou based on standard visual strip transect survey techniques (Figure 16).

We initially partitioned effort for the high and medium density strata based on the allocation formula by Heard (1987), but then re-adjusted the allocation to ensure a minimum sample size of 10 transects in the medium density strata (19.1% coverage), and allocated sampling effort in the high density stratum to achieve *ca.* 40% coverage (n = 22 transects; 40.6% coverage). For visual strata, we maintained coverage of *ca.* 17-18%, which ensured that we sampled at least 10 transects in each of the smaller strata (Figure 16).

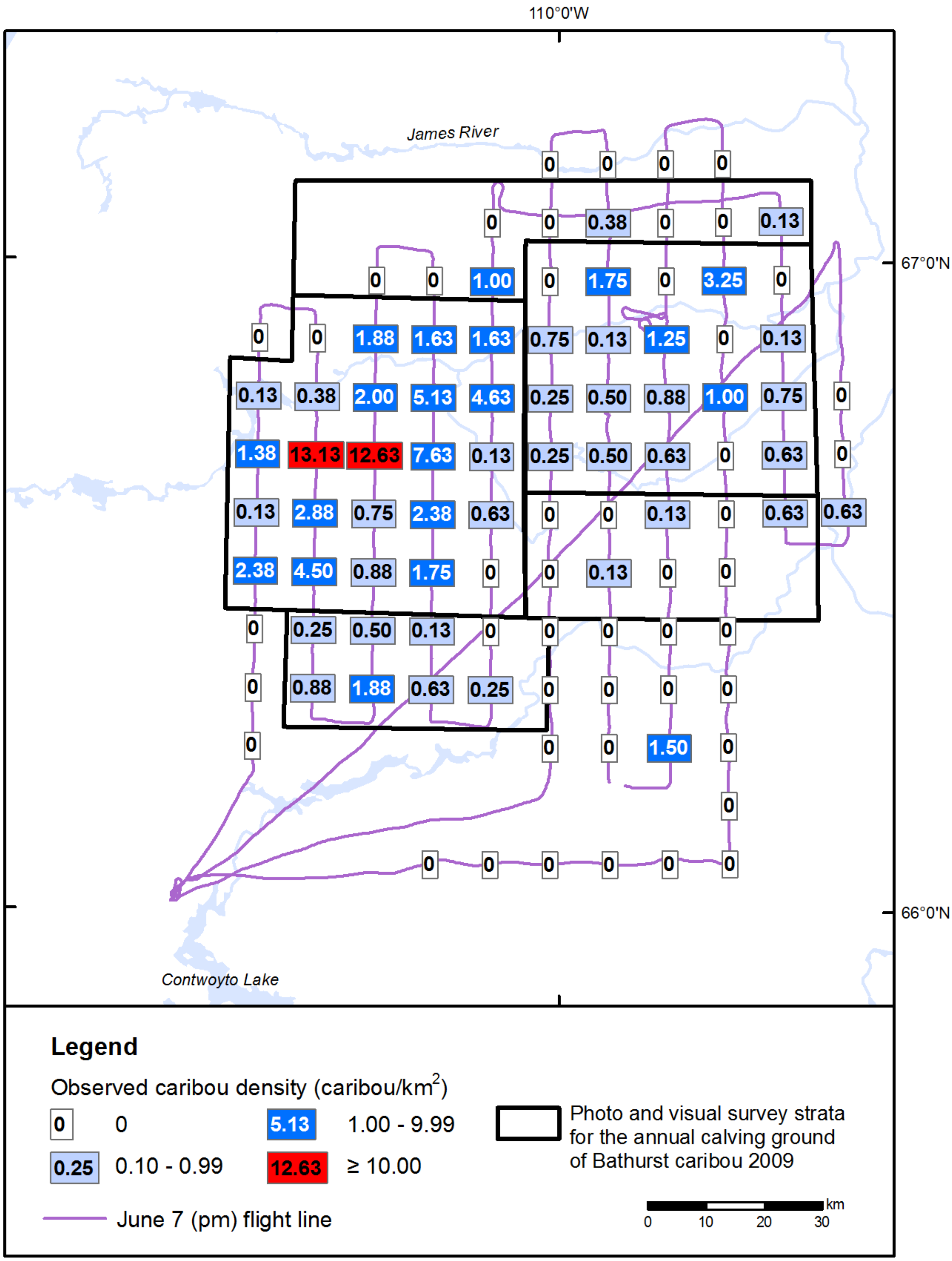

Figure 14. Flight lines and observed caribou densities within adjacent transect segments to delineate and stratify the annual calving grounds of Bathurst caribou, June 2009. Label colours represent density classes: White = flown and no caribou observed, Light blue = 0.1- 0.99 caribou/km^2, Dark blue = 1.0- 9.9 caribou/km^2 and Red = ≥10 caribou/km^2.

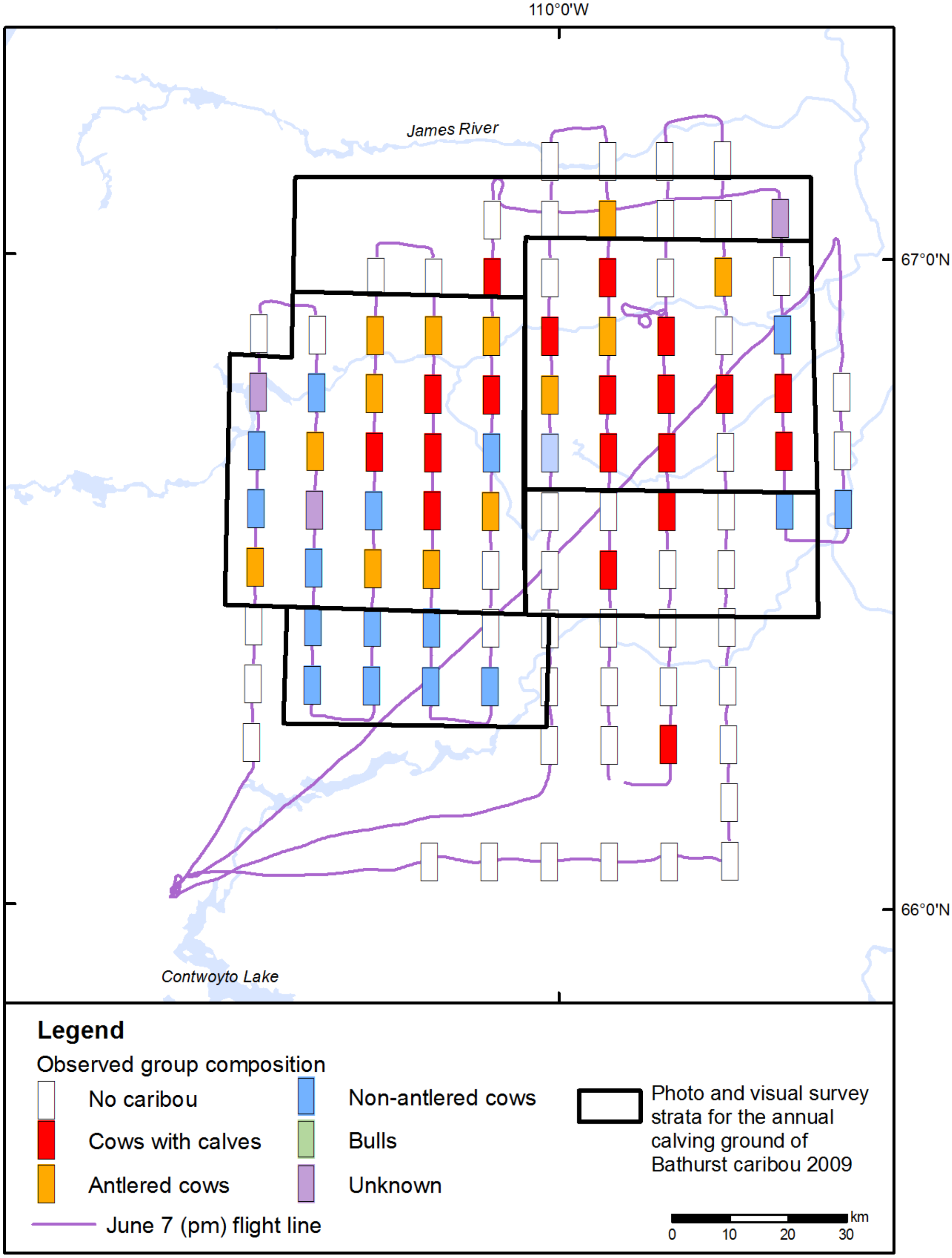

Figure 15. Observed caribou composition within adjacent transect segments flown to delineate and stratify annual calving grounds of Bathurst caribou, June 2009. Each cell represents a 10-km segment of a survey transect and cell colours represent composition classes: White = flown and no caribou observed; Red = cow-calf groups; Orange = cows with hard antlers; Blue = non-antlered caribou; Purple = unclassified groups; Green = Bulls.

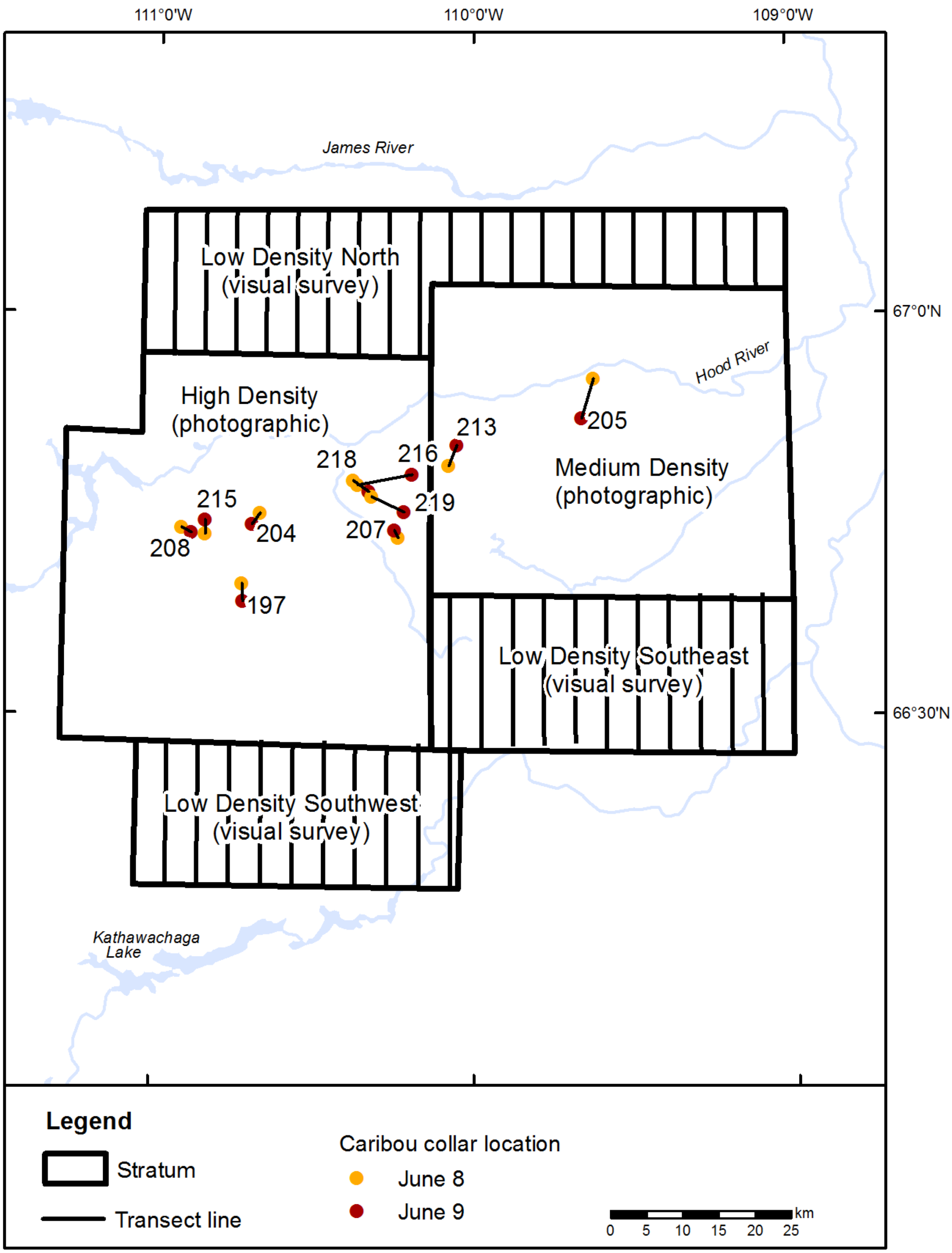

Figure 16. Final stratification for annual calving ground of Bathurst caribou herd, June 2009. The photo plane surveyed the high and medium density strata. Standard visual strip transect surveys were conducted on the low density strata. Eight of 10 satellite-collared cows were located in the high density stratum, and two collared cows were in the medium density stratum. Transect numbers were sequential with number one starting in the west.

Survey of the annual calving ground

Photographic survey

The photographic survey of the calving ground was initiated on the 8 June. Due to favorable weather and photographic conditions – morning temperature was 8^{o}C with excellent visibility and high scattered clouds (> 8000 feet above ground level) with 50% snow cover – the photo plane completed the high density strata on the first day of the photographic survey. However, due to the large number of transects in the high density stratum (n=22), we knew that the photographic aircraft would not be able to complete photography of the stratum during the morning flight, so we assigned priority to the first 9 long lines (from west to east) followed by every other line until the aircraft had to return to base for fuel. The remaining lines were photographed on a second sortie later in the afternoon. The medium density stratum was photographed completely on the 9 June. At the time of the photographic survey (8-9 June), we had excellent visibility. We encountered high scattered to high overcast conditions (8000 – 10,000 feet agl) which provided good contrast and lighting for aerial photography (D. Evans pers. comm.). The weather and snow conditions for the photographic survey were good for subsequent photo interpretation.

In the high density stratum, Paul Roy counted 7140 1^{+}-year-old caribou, which resulted in an estimate of 17,593 ± 2413 (SE) and a density of *ca*. 6.76 caribou / km^2 (Table 2, Appendix E). In the medium density strata, Paul Roy counted 1007 caribou. Caribou density in the medium strata was 2.49 caribou /

km^2 and the estimate was 5267 ± 1390 (SE) 1^+-year-old caribou (Table 2, Appendix F).

Visual survey

We surveyed all three low density strata on the 8 June. We counted a total of 5, 53, and 15 1^+-year-old caribou in the Low N, Low SW and Low SE strata respectively. This resulted in a combined estimate of 413 caribou for low density visual strata (Table 2, Appendix G). Densities within the low density strata ranged from 0.02 – 0.34 caribou / km^2. Of all the low density strata, stratum Low SW, which was adjacent to the southwestern boundary of the high density stratum, accounted for 299 ± 127 (SE) (72%) of all caribou within the three low density strata (Table 2). These observations likely reflected a trailing distribution of non-breeder caribou on to the calving ground.

Based on the combined photographic and visual survey estimates, the total number of 1^+-year-old caribou estimated on the calving ground was 23,273 ± 2788 (SE) (Table 2).

Table 2. Analysis of data from an aerial survey of the Bathurst calving ground, June 2009.

	Photographic		Visual			
	High	**Medium**	**Low N**	**Low SW**	**Low SE**	**Total**
Maximum number of transects (N)	57	55	112	57	63	
Number of transects surveyed (n)	22	10	20	10	11	
Stratum area, km2 (Z)	2,601.8	2,113.1	1,310.9	882.0	1,077.7	
Transect area, km2 (z)	1,055.9	404.0	234.2	156.4	188.3	
Number of 1+-year-old caribou counted (y)	7,140	1,007	5	53	15	
Caribou density, caribou/km2 (R)	6.76	2.49	0.02	0.34	0.08	
Population estimate (Y)	17,593	5,267	28	299	86	23,273
Population variance (Var Y)	5,822,120	1,931,054	624	16,100	1,088	7,770,986
Standard error (SE Y)	2,413	1,390	25	127	33	2,788
Coefficient of variation (CV)	0.137	0.264	0.892	0.425	0.384	0.120
95% Confidence interval	5,019	3,143	52	283	33	
% Coverage	40.6%	19.1%	17.9%	17.7%	17.5%	

Sex and age composition surveys

We flew 28.4 hours in a helicopter (Appendix B) and classified 2033 1^+-year-old caribou in 91 groups to estimate sex and age composition of caribou within high, medium, and low density strata (Table 3, Appendices H – J). We sampled 65 groups in the high density stratum which accounted for 71% of our total number of groups classified; seventeen groups classified in the medium density photographic strata accounted for *ca.* 19% of sampling effort (Table 3).

Table 3. Sample sizes and proportion of breeding females in high, medium and low density strata of the Bathurst caribou calving ground, June 2009.

Stratum	Number of groups sampled	Number of breeding females	Number of 1^+-year-old caribou	Proportion of breeding females	Standard Error	CV
High density – photo	65	1,248	1,847	0.678	0.043	0.063
Medium density – photo	17	760	866	0.879	0.017	0.019
Low density - visual (South)	9	25	226	0.113	0.048	0.423
Sum	91	2,033	2,939			

Estimate for number of breeding females on annual calving ground

We adjusted the overall estimate of the number of 1^{+}-year-old caribou (summarized in Table 2) by the proportion of breeding females observed in each stratum during the composition surveys (Table 3). Due to low densities of caribou in the Low N strata, we collected and pooled composition data from only the two low density strata in the south and extrapolated the observed proportion of breeding females (0.113) to all three low density strata. In summary, we estimated that there were a total of 16,605 ± 2176 (SE) breeding females in the survey area (Table 4).

Table 4. Estimated number of breeding females in all high, medium and low density strata of the Bathurst calving ground, June 2009 based on composition counts and stratum population estimates.

Stratum	Estimated number of 1+-year-old caribou on calving ground	Proportion of breeding females	Estimated number of breeding females	Variance	Standard Error	CV
High	17,593	0.678	11,928	3,236,450	1,799	0.151
Medium	5,267	0.879	4,630	1,499,906	1,225	0.265
Low N[a]	28	0.113	3	10	3	0.988
Low SW	299	0.113	34	410	20	0.599
Low SE	86	0.113	10	31	6	0.571
Total	23,273		16,605	4,736,807	2,176	0.131

[a] Composition data were not collected for stratum. Due to small sample sizes, composition data from stratum Low SW and Low SE were combined and the one estimate was used to derive the number of breeding females for all low density strata.

Trend of breeding females in Bathurst caribou herd, 1986-2009

The trend in estimates of breeding females since calving ground photographic surveys of the Bathurst herd were initiated in 1986 (Heard and Williams 1991) indicates that the herd has been declining (Figure 17). The estimate from June 2009 suggests an accelerated rate of decline between 2006 and 2009.

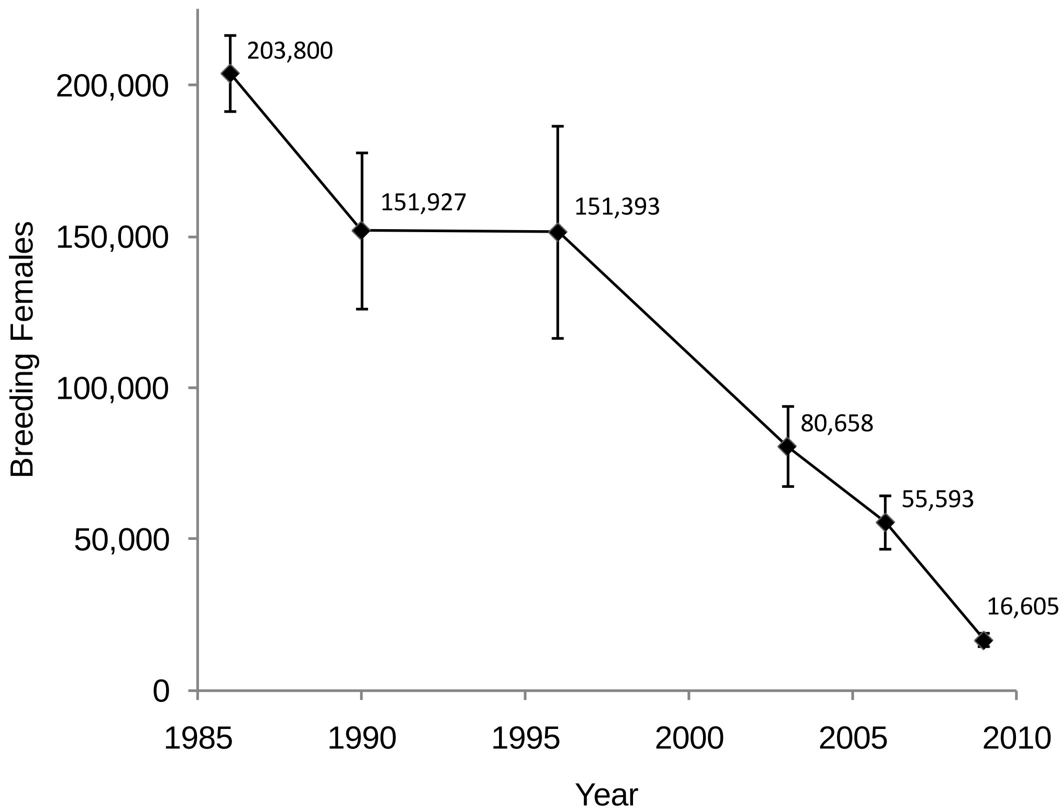

Figure 17. Trend in breeding females (estimate ± Standard Error) in Bathurst caribou herd, 1986-2009.

One-tailed t-test

Based on a one-tailed t-test, the estimate of breeding females in 2009 was significantly lower than the calving ground survey in 2006 ($t = 4.27$, $df = 21$, $P < 0.005$). The exponential rate of increase[i] between the 2006 and 2009 estimates of breeding females was $r = -0.403$ (0.068 Standard Deviation) (Appendix L). The magnitude of this rate of decline corresponds to a halving time of *ca.* 1.7 years.

Weighted least squares regression

Model selection results suggested that a nonlinear trend best approximated by a cubic polynomial term was most supported (Table 5). This model showed strong support as indicated by an AIC weight of 0.95. A model with linear trends was not supported by the data.

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[i] The exponent *(r)* is the power to which *e* (the base of natural "Naperian" logs, taking the value of 2.71828) is raised such that $e^r = \lambda$; *r* is the exponential rate of increase. According to Caughley (1977), the exponential rate of increase is a more useful expression of population increase than λ for three reasons: 1) *r* is centered at zero, hence a rate of increase measured as *r* has the same value as an equivalent rate of decrease, apart from reversal of sign; 2) *r* converts easily from one unit of time to another, i.e., when *r* per year equals *x*, *r* per day equals *x* / 365; and 3) doubling or halving time of a population can be easily calculated from *r* by 0.6931 / *r.* For example 0.6931 / -0.403 equals a halving time of 1.7 years. Halving time refers to the number of years in which a population would be half of its size if it continued to decline at its present rate. Conversely, doubling time is the time in which a population would double its size if it continued to increase at its present rate.

The finite rate of increase (also termed the growth multiplier) is the simplest measure of a population's rate of increase; it is the ratio of numbers in two successive years. The Greek symbol lambda (λ) is used to represent the finite rate of increase. When λ is greater than 1 the population has increased between successive years; when less than 1 the population has declined.

Table 5. Model selection results for Bathurst trend analysis. Akaike Information Criteria (AIC_c), the difference in AIC_c values between the i^{th} and most supported model (ΔAIC_c), Akaike weights (w_i), and number of parameters (K) are presented.

model	AICc	ΔAICc	wi	logl
yr^3	2.82	0	0.995	2.59
$yr+yr_{>06}$	8.12	5.30	0.005	4.94
yr^2 yr^3	11.58	8.76	0.000	3.21
yr yr^3	12.50	9.68	0.000	2.75
yr yr^2	17.68	14.86	0.000	0.16
$yr+yr_{>03}$	20.59	17.77	0.000	-7.29
yr	34.91	32.09	0.000	-13.46
yr yr^2 yr^3	37.04	34.22	0.000	5.48
intercept	322.72	319.90	0.000	-159.86

Parameter estimates for the most supported model suggested that both the intercept and yr^3 terms were significant (Table 6).

Table 6. Regression model parameter estimates

Parameter	Estimate	S.E	C.I. low	C.I.high	t	P-value
Intercept	12.208	0.075	12	12.417	162.72	0
yr^3	-0.0002	0.000015	-0.0002	-0.0001	-13.45	0.0002

Figure 18 shows a plot of the regression line (back transformed to population size units). The 95% confidence intervals around the predicted trend are irregular because they reflect different levels of variance at each of the point estimates. For example, the 1986, 2003, and 2006 and 2009 surveys had the best precision and therefore the confidence intervals are narrowest around those points.

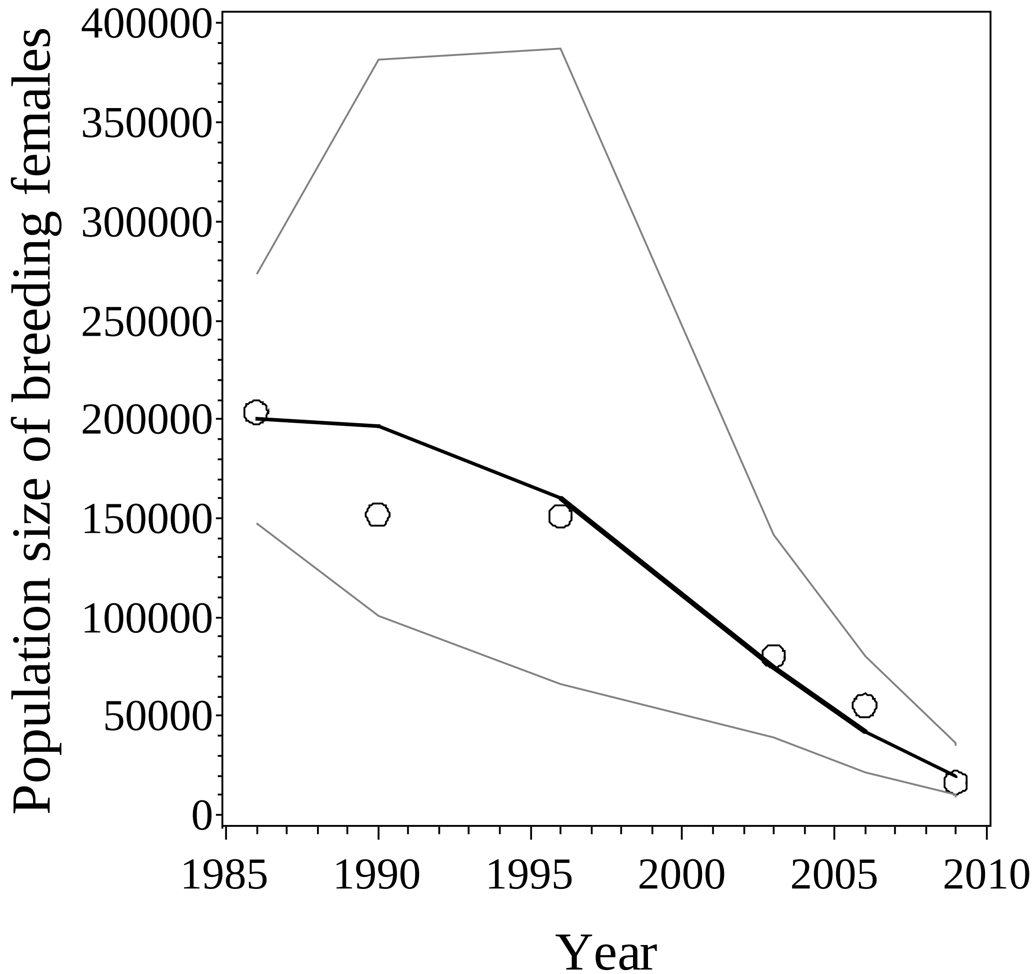

Figure 18. Predicted trend for breeding females of the Bathurst caribou herd using weighted least squares regression analysis. Grey lines are the 95% confidence intervals around the predicted trend. Circles are estimates of breeding females from calving ground surveys.

Monte Carlo simulation

Monte Carlo simulation results suggested that the trend was increasingly negative (*i.e.,* indicative of a progressively faster rate of decrease) as shown by lower λ estimates for each year (Figure 19). The λ of 1 at the beginning of the simulations was an artifact of the fact that this was the first point in the simulation and therefore the most applicable estimates were for the latter part of the time series (*i.e.* after 2000).

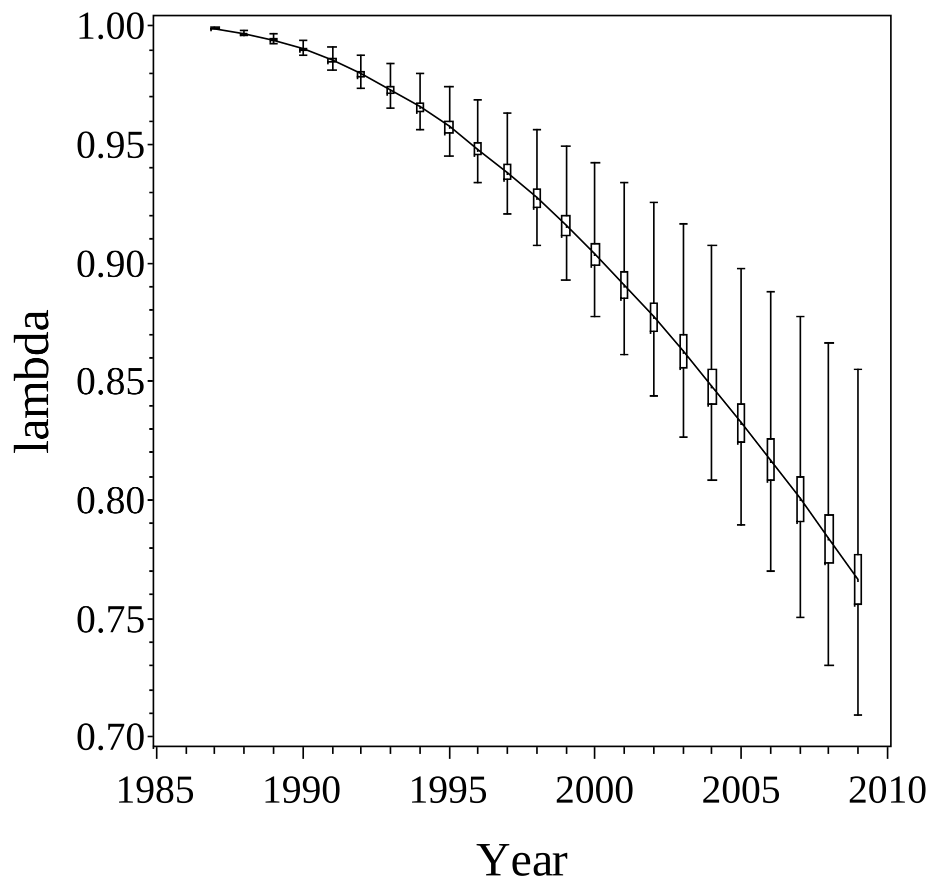

Figure 19. Simulated estimates of λ as a function of year from Monte Carlo simulation analysis.

A histogram of *λ* estimates for 2009 shows that none of the values overlapped 1 suggesting there was no statistical chance that the population was stable (Figure 20).

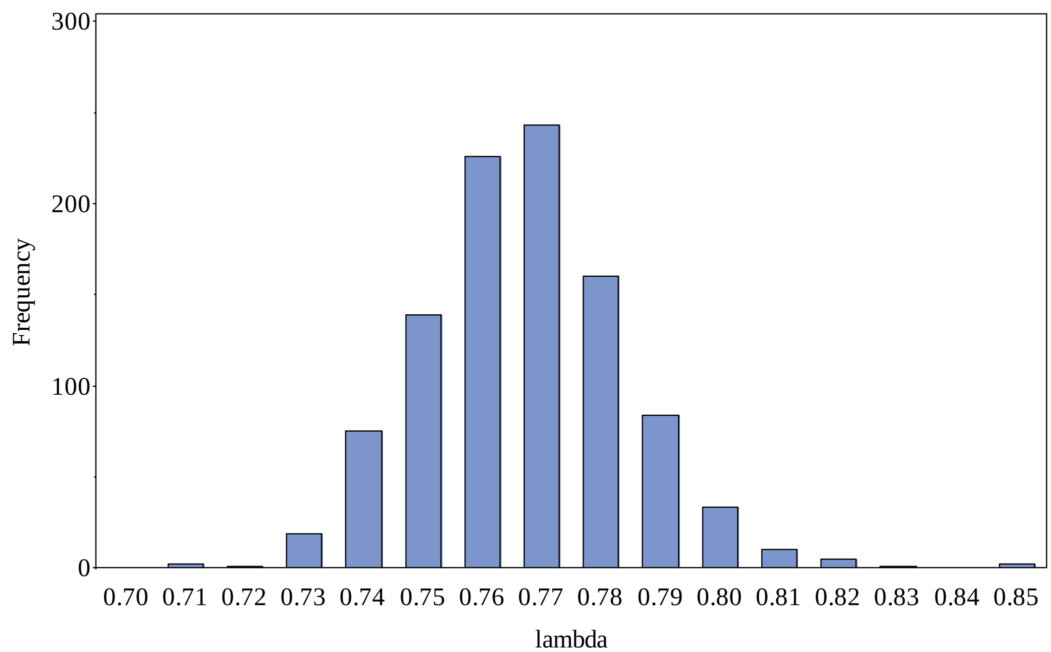

Figure 20. Distributions of population rate of change (λ) for 2009 generated using Monte Carlo simulation trials.

Estimates of λ from the Monte Carlo analysis for 2009 is 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). The magnitude of this rate of decline corresponds to a halving time of *ca.* 2.7 years.

Additional systematic surveys

Once the photographic and visual surveys of the annual calving ground were initiated, we resumed the systematic survey to extend survey coverage and determine whether additional aggregations of breeding females may have been missed in adjacent areas. We completed the systematic survey on the 8, 9, and 10 June (Figure 21). On June 17, we also surveyed the area west of Napaktulik Lake and northwest to Kugluktuk (Figure 21) and observed low and medium densities of caribou that were mostly bulls and non-breeding females (Figure 22 and Figure 23, Appendix D).

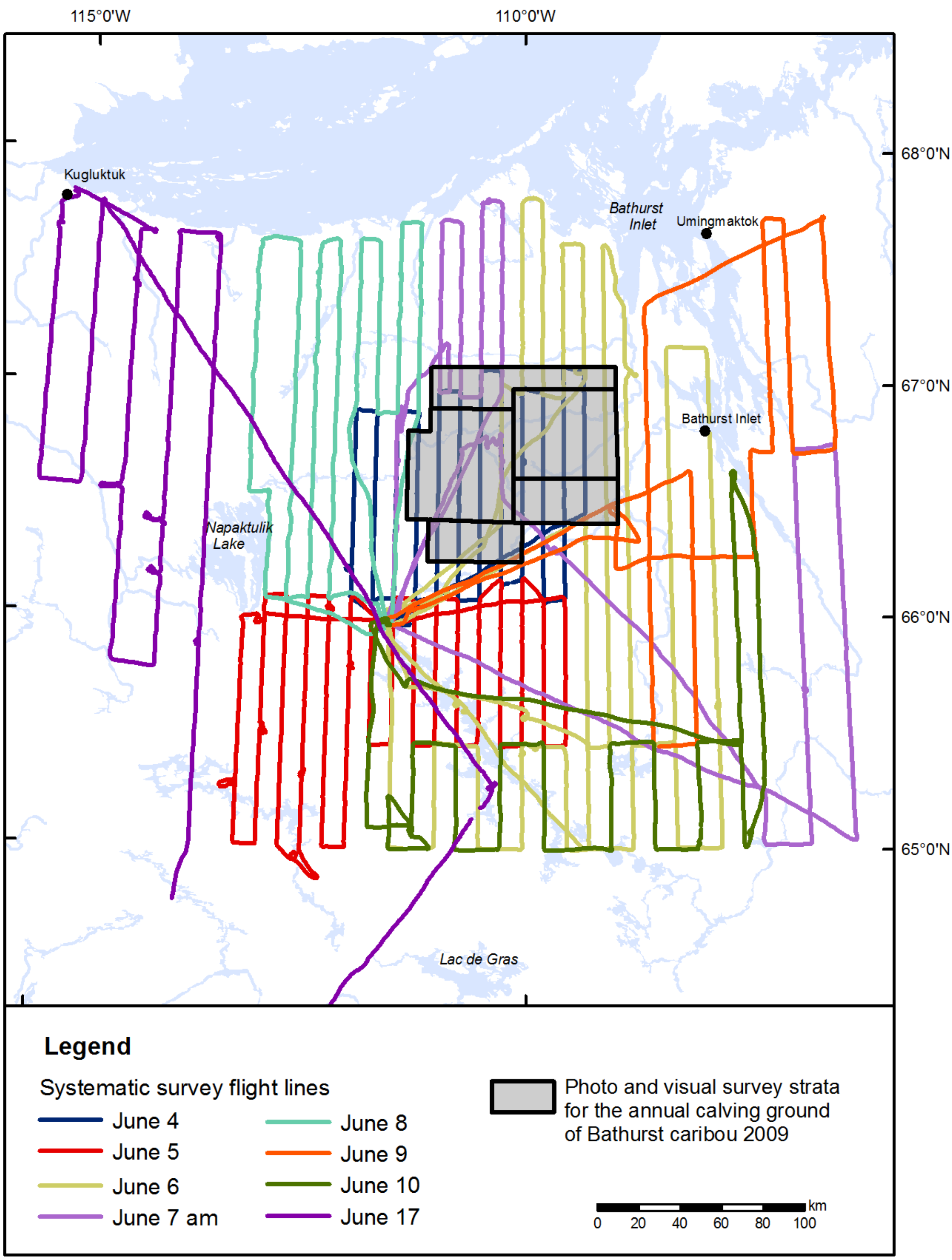

Figure 21. Cumulative coverage of extensive systematic surveys that were used to delineate the annual calving ground and determine final stratification for the Bathurst calving ground survey in June 2009.

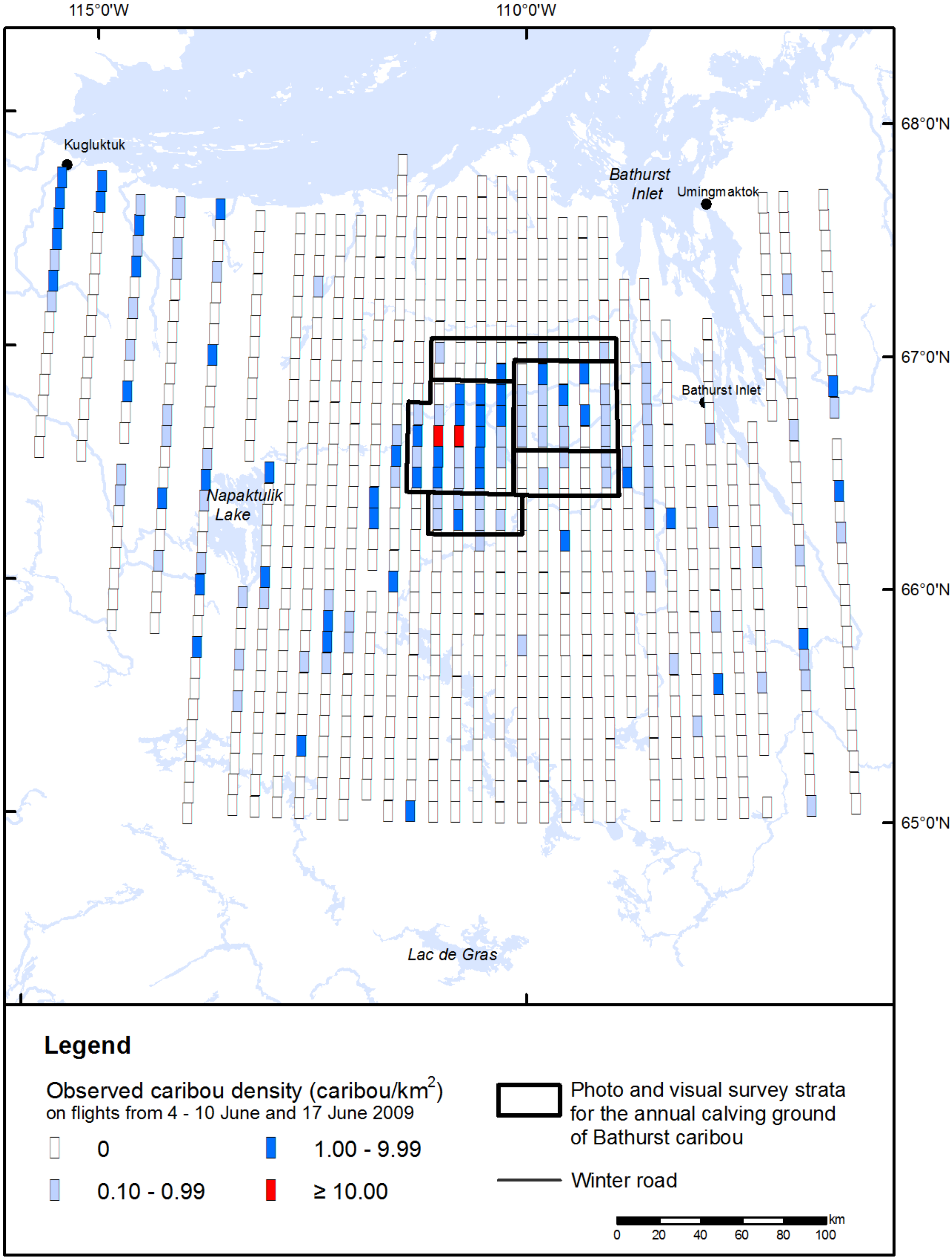

Figure 22. Observed caribou densities from extensive systematic survey of Bathurst caribou calving grounds, June 2009. Label colours represent density classes for 10-km transect segments: White = flown and no caribou observed, Light blue = 0.1 – 0.99 caribou/km^2, Dark blue = 1.0 – 9.9 caribou/km^2 and Red = ≥10 caribou/km^2.

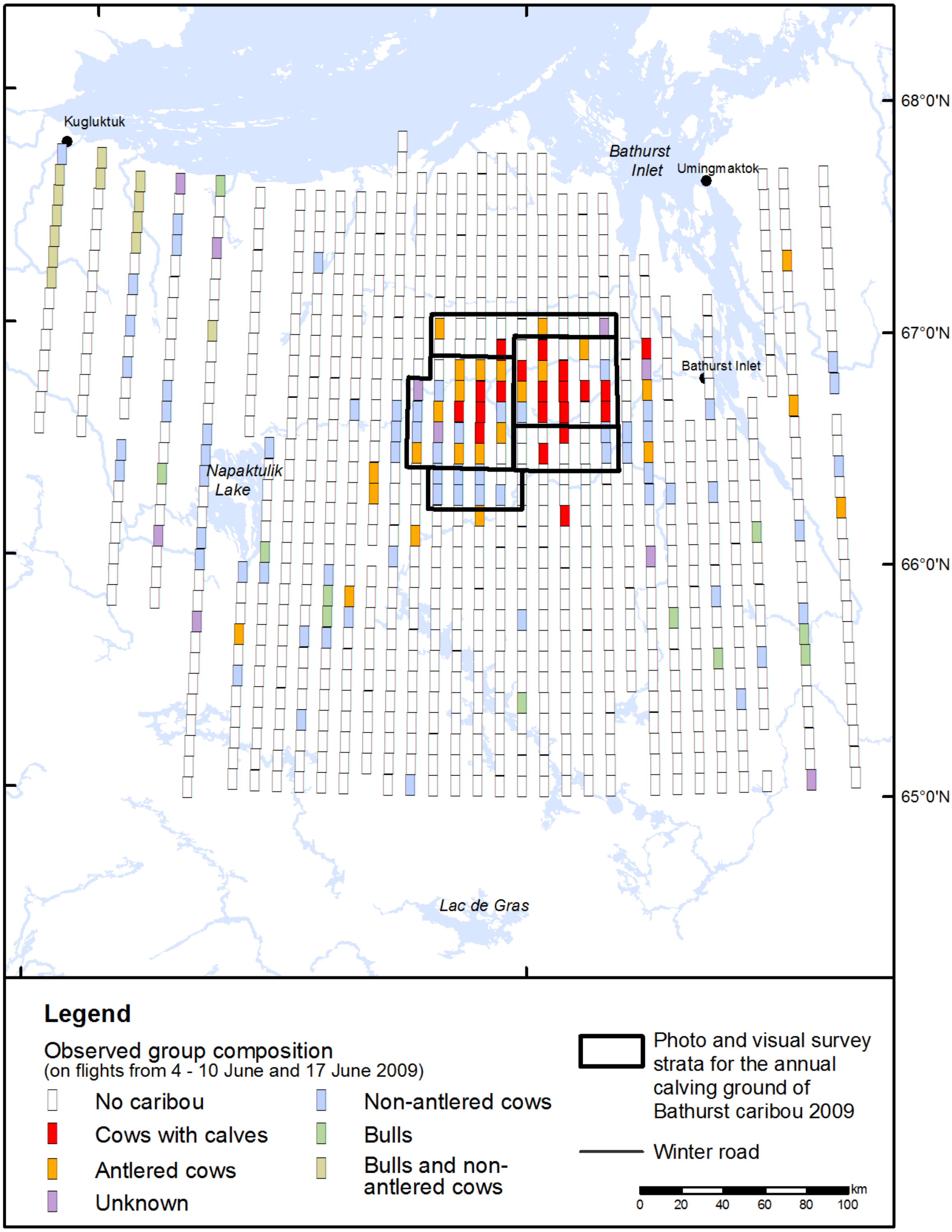

Figure 23. Observed caribou composition from extensive systematic survey of Bathurst caribou calving grounds, June 2009. Label colours represent composition classes for 10-km transect segments: White = flown and no caribou observed; Red = cow-calf groups; Orange = cows with hard antlers; Blue = non-antlered caribou; Purple = unclassified groups; Green = Bulls.

Extrapolating the estimate of breeding females to total herd size

An estimate of breeding females can be used to extrapolate an estimate of total herd size, with the inclusion of two additional parameters: i) the proportion of females in the population (i.e., sex ratio); and ii) the pregnancy rate of breeding females (Heard 1985). Thus, depending on the numerical estimates used for these two parameters, the derived estimate of total herd size can differ even though the estimate of breeding females is the same. Table 7 shows extrapolated population estimates for the Bathurst herd based using the same pregnancy rate, but with two different estimates of sex ratios. An extrapolated total population estimate of 38,283 ± 7,382 caribou is calculated (Table 7) when the average sex ratio of 66 males per 100 females is used (Heard and Williams 1991, p. 35 in Gunn *et al.* 1997). If the sex ratio of 38.3 males per 100 females is used, which is based on fall 2008 composition surveys (GNWT unpublished data; B. Croft pers. comm.), than the derived total population estimate is 31,895 ± 5,293 (Table 7).

Table 7. Extrapolation of breeding female estimate to total herd size.

Population Parameter	Parameter Value	Standard Error	Coefficient of Variation
a) Assumed proportion of females = 0.602 (66 bulls / 100 cows from Heard and Williams 1991, p. 35 in Gunn et al. 1997)			
Estimate of 1+ Yr Old Caribou	23,273	2,788	0.120
Estimate of Breeding Females	16,605	2,176	0.131
Proportion of Females in Population	0.602		0.100 *
Pregnancy rate of Breeding Females#	0.720		0.100 *
Extrapolated Population Estimate	38,283	7,382	0.193
b) Assumed proportion of females = 0.723 (38.3 bulls / 100 cows, 2008 composition data, p. 42 in Adamczewski et al. 2009, CV = 0.019 B. Croft unpub. data)			
Estimate of 1+ Yr Old Caribou	23,273	2,788	0.120
Estimate of Breeding Females	16,605	2,176	0.131
Proportion of Females in Population	0.723		0.019
Pregnancy rate of Breeding Females	0.720		0.100 *
Extrapolated Population Estimate	31,895	5,293	0.166

* no data, value is only a guess

pregnancy rate from Heard and Williams 1991, p. 46 in Gunn et al. 1997

DISCUSSION

Results of the June 2009 calving ground photographic survey of the Bathurst caribou herd were robust, relatively precise, and met the survey's objectives. The estimate of breeding females was 16,605 ± 2176 SE with a coefficient of variation of 0.131. The June 2009 estimate of breeding females was significantly lower ($p < 0.005$) than the June 2006 estimate of 55,593 (± 8813 SE) (Nishi *et al.* 2007). The estimate of breeding females in June 2009 substantiates the results of the June 2006 Bathurst caribou survey, and confirms the declining trend in abundance of breeding females since 1986.

A direct comparison of the June 2009 estimate with the estimate of breeding females in June 2006, suggests that the number of breeding females has declined dramatically over the 3 year interval. The rate of decline (r = -0.403 (0.068 Standard Deviation) corresponds to a halving time of less than 2 years. A statistically rigorous Monte Carlo trend analysis suggested that the rate of decline has accelerated over the last few surveys, and that the abundance of breeding females is currently declining at a rate (r estimate of –0.26, SE = 0.027, CI = -0.31 to -0.22), which corresponds to a halving time of less than 3 years. This means that if the number of breeding females continues to decline at the same rate (r = -0.26), by 2012 the there may only by *ca.* 8,300 breeding females on the calving grounds (*i.e.,* 50% of 16,605). Both analyses suggest a rapid rate of decrease that has accelerated during the most recent surveys, which suggests that reversal of the declining trend and recovery of the Bathurst herd will require immediate development and implementation of co-management conservation actions (see Adamczewski *et al.* 2009).

A retrospective view of the pattern of movement and aggregation by 10 satellite-collared cows on to the survey strata suggests that our delineation of the annual calving ground and timing of the survey were effective (Figure 24). The design and execution of the June 2009 calving ground survey was efficient, and we did not incur any major problems that could have seriously affected credibility of survey results. We also suggest that timing of the stratified photographic and visual survey coincided well to the peak of calving, which based on our observations during the systematic survey on the 7 June, may have occurred by the 8 June at the earliest. Reduced daily movement rates of satellite collared Bathurst caribou cows from the 8-15 June coincided, with the initiation of the photographic survey. Data from composition surveys suggested that the peak of calving had occurred by the 11 June; thus we conclude that peak of calving occurred from the 8-11 June.

There were no logistic or weather-caused delays in timing between various phases of the calving ground survey including the systematic reconnaissance, stratification and completion of the photographic survey (and visual survey strata) and composition surveys on the annual calving ground. As the photographic survey was completed within two days following stratification, there was low potential for movements of breeding females across survey strata to bias the calving ground estimate. Occurrence of nine collared cows within the high and medium strata (Figure 16Figure 6) also supports our assertion that we had effectively delineated the annual calving ground and did not miss a substantial portion of breeding females outside the surveyed area.

In June 2009, we used two aircraft and flew 59.1 hours on survey (with an addition 33.6 hours of ferrying time) to complete extensive systematic surveys for delineating the annual calving ground and extending coverage well beyond it (Appendix B). In comparison, 35.0 hours (plus an additional 11.1 hours of ferry time) were flown in two aircraft to conduct the systematic survey in June 2006 (Appendix B in Nishi *et al.* 2007) and 22.2 hours were flown in one aircraft during the systematic surveys in June 2003 (Appendix B in Gunn *et al.* 2005). In summary, the relatively small area in which we observed breeding females, combined with the extensive area searched during systematic surveys, and the movement and distribution patterns of collared cows suggested that we accurately defined the Bathurst annual calving ground in June 2009.

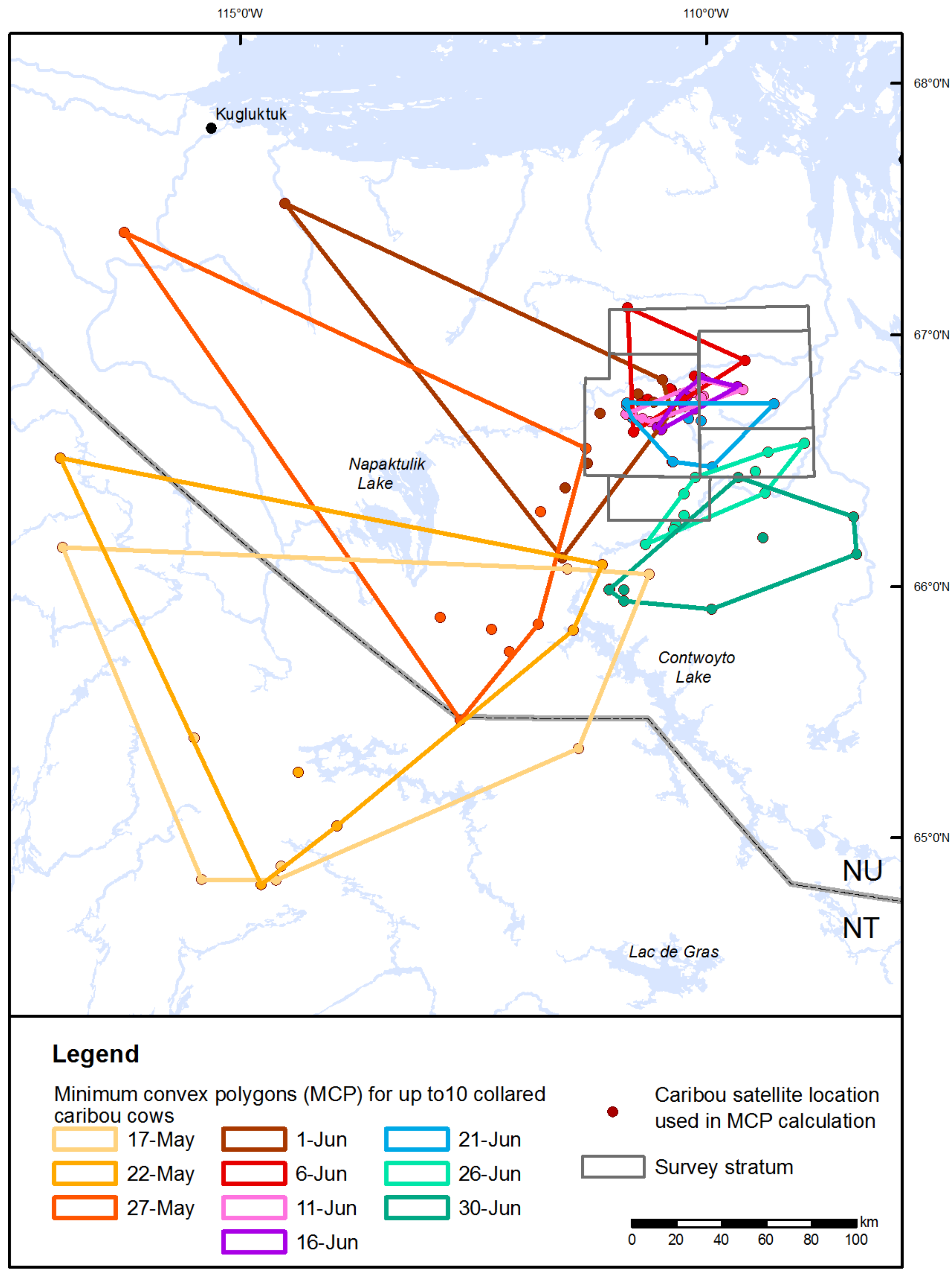

Figure 24. Minimum convex polygons enclosing locations of 10 satellite collared Bathurst caribou cows at five day intervals from 17 May to 30 June 2009.

Extrapolation of breeding females to total herd size.

An extrapolated population estimate is calculated based upon variability across four parameters including 1) the estimate of 1^{+}-year old caribou on the annual calving ground, 2) the proportion of breeding females on the calving ground, 3) population sex ratio, and 4) population pregnancy rate. Estimates for the first two parameters are addressed as specific objectives for calving ground photographic surveys. However, as shown earlier in this report, extrapolated population estimate will differ depending on the estimates used for the third and fourth parameters, even though they are based on the same estimate of breeding females. It is also important to note that calving ground photographic surveys were developed to meet one objective: tracking the trend in abundance of breeding females over time. Extrapolating the estimate of breeding females to a rough estimate of total herd size is a secondary aspect to calving ground surveys; "… in spite of explicit statements that this technique produces only rough estimates of total herd size, total numbers are calculated and often given more emphasis than warranted" (Heard 1985, p. 234).

The initial approach for extrapolating a calving ground survey to total herd size was to use long-term average ratios (across multiple herds in the Northwest Territories) with estimated CVs of 10% for population sex ratio and pregnancy rate (Heard 1985). This approach essentially applied constant means and CVs for sex ratio and pregnancy rate to derive total herd size. Consequently, population estimates calculated in this manner were largely a reflection of the precision of the calving ground photographic survey. However, this method of extrapolation also introduces additional uncertainty, because in any given year the true estimates of herd specific parameters for sex ratio and pregnancy rate may vary up to 10% relative to long term average rates (see Thomas 1998). Thus, if management objectives become linked to estimates of total population size, which have been derived from estimates of breeding females from calving ground surveys, then additional work is required – within the framework of quantitative risk assessment methods (Voise 2000) – to investigate the sensitivity of extrapolated population estimates to variability and uncertainty in herd-specific annual, versus long-term average estimates (across multiple herds) for sex ratio and pregnancy rate respectively. This would be a first step towards addressing Thomas's (1998) contention that extrapolation from photographic estimates of caribou on calving grounds is not justified due to unknown or poor accuracy and precision of population parameters*, i.e., sex* ratio and pregnancy rate. A thorough evaluation of uncertainty and variability in the parameters used to derive total herd size from calving ground surveys should also lead to development of appropriate standards and better alignment between survey methods and objectives, and information needs for wildlife co-managers.

Recommendations for calving ground survey design

Based on our experience from the June 2009 survey and in considering the issues discussed by Williams 1994, Mowat and Boulanger 2000 and Gunn *et al.* 2005, we provide the following revised recommendations for photographic calving ground surveys:

1) A stratum should be designed so that variance among observed caribou densities of transect segments (from the systematic survey) is minimal.
2) In addition to similar density values (in 1 above), the presence of newborn calves and hard antlered cows within 10 km grid segments and the spatial dispersion of those segments should be considered in delineating survey strata. A survey strata should be delineated so that it is comprised predominantly of breeding females (hard antlered cows, or cows with newborn calves), based on observed composition of transect segments from the systematic survey.
3) Based on observed caribou densities within 8 km^2 segments of the systematic survey, transects within a delineated stratum should be oriented along the predominant gradient of density to minimize variation among transect counts.
4) Whenever possible, stratum areas should be delineated as even sided rectangular polygons so that transect lines are of similar length to minimize variance. Jolly 1 analysis methods should be used for those strata that are intended to be designed with even length transects. Accordingly, GIS delineation of stratum boundaries and area should precisely meet the criteria for even sided polygons, so that calculated transect lengths are in fact identical *i.e.,* to the nearest 10 meters, and consistent with the intended design of survey strata.

5) The stratum baseline should be sufficiently long enough to allow for a minimum of 10 transects as a sample size at the prescribed level of survey coverage and sampling intensity.

6) Photographic strata should be large enough to accommodate the anticipated movements of caribou between the time when the systematic reconnaissance survey and stratification are completed, to the time when transects in the strata are actually photographed by the photo plane.

7) Photographic strata should be small enough to facilitate complete coverage by the photoplane in one sortie (*ca.* 4.5 hrs), or within a duty day of flying, at the prescribed level of survey coverage. This will increase the likelihood that a photographic stratum is sampled completely within an 8 hour period.

- This approach minimizes the risk of partially photographed strata at the end of a day which may not be completed sampled within 24 hours due to inclement and variable weather conditions. For larger strata with high coverage that may require up to two sorties of the photoplane, a two pass method whereby every other transect is photographed on the first pass and then the remainder are photographed on the second pass should be considered.
- A potential source of bias with a two pass method is double counting, so to be conservative, all sampling within a stratum should be completed within 4-8 hours (see Figure 25). Since average daily

movement rates were < 5 km / day from the 8-15 June (see Figure 3), 50% coverage likely represents the upper limit for survey sampling intensity at the peak of calving. A more conservative threshold would be 40-45% coverage to reduce the likelihood of double counting within a stratum during an 8 hour period (Figure 25).

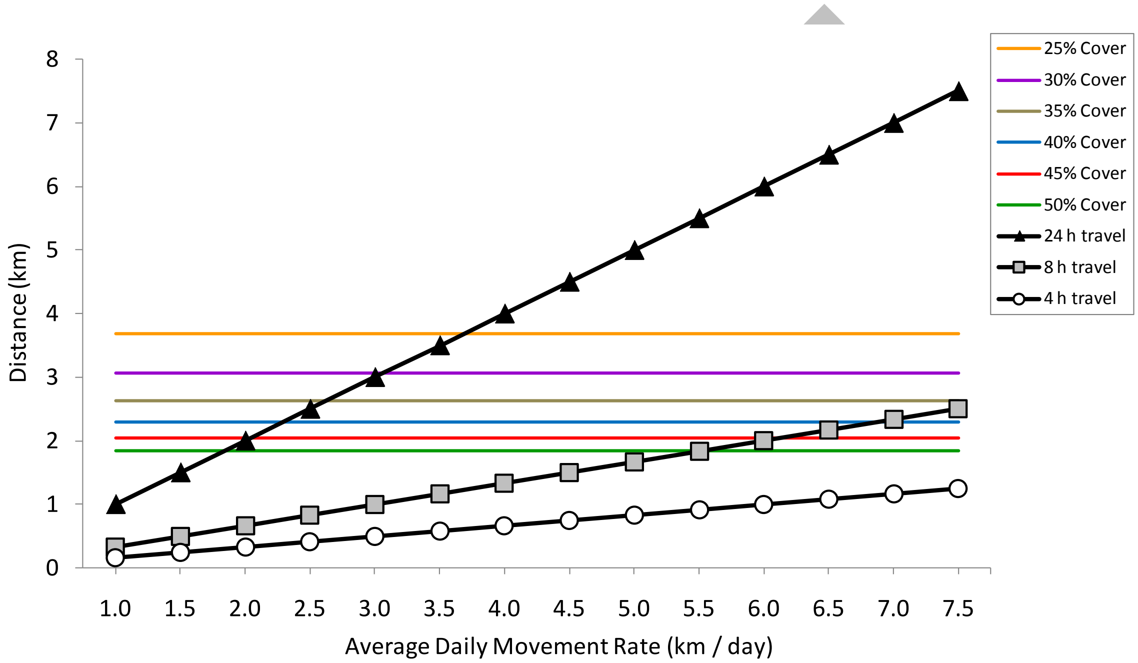

Figure 25. Relationship between transect spacing distances (horizontal lines) and distance travelled (oblique lines) relative to average daily movement rates for 4, 8, and 24 hours. Horizontal lines show distances between equal-length transects for different sampling intensities, ranging from 25% - 50% coverage, and where photographic transect strip width is 0.92 km. The intersection between horizontal and oblique lines, represents occurrences where distance between transects equals potential distance moved by an animal for a given movement rate over a defined time period. For example, the intersection of the green horizontal line with the line with square symbols suggests that an animal that has an movement rate of 5.5 km / day, would have travelled the straight-line distance between transects (spaced at 1.8 km intervals to achieve 50% coverage) in 8 hrs.

Systematic surveys of calving grounds

Systematic aerial reconnaissance surveys represent the first phase of a calving ground survey; they are used to i) determine the relative composition and density of caribou on a traditional calving ground, ii) delineate the extent of an annual calving ground, and iii) develop stratification strategies for subsequent photographic survey of the annual calving ground. When used as a monitoring protocol, systematic surveys are much less expensive than photographic surveys and may still provide a useful comparative dataset to track trend in size of an annual calving ground, as well as relative caribou densities on the calving ground. Our cursory evaluation of densities on the Bathurst calving grounds from systematic reconnaissance surveys shows that those data also indicate a dramatic decline in caribou density since 2003 (Figure 26, Appendix M).

We suggest that systematic reconnaissance surveys provide a useful and comparatively economic way of monitoring trend of caribou on an annual calving ground, and allow managers to anticipate trend of breeding females during the intervening years between full-scale calving ground photographic surveys. In addition to monitoring abundance of 1^+-year-old caribou, results from systematic reconnaissance survey of caribou calving grounds can provide insight on trend in spatial extent of the annual concentrated calving area and associated spatial patterns and changes in caribou densities. However, observer bias associated with sightability and counting error will be a source of uncertainty and variability that will affect precision and accuracy of this visual survey technique; counting error will increase especially as overall densities on the annual calving grounds increase. Therefore, careful and consistent standardization of survey methods and rigorous training of observers will help to improve the value of systematic reconnaissance surveys. Systematic reconnaissance surveys may be a particularly important annual monitoring tool when caribou populations (such as the Bathurst herd) decline to low numbers and management actions are implemented to assist in recovery.

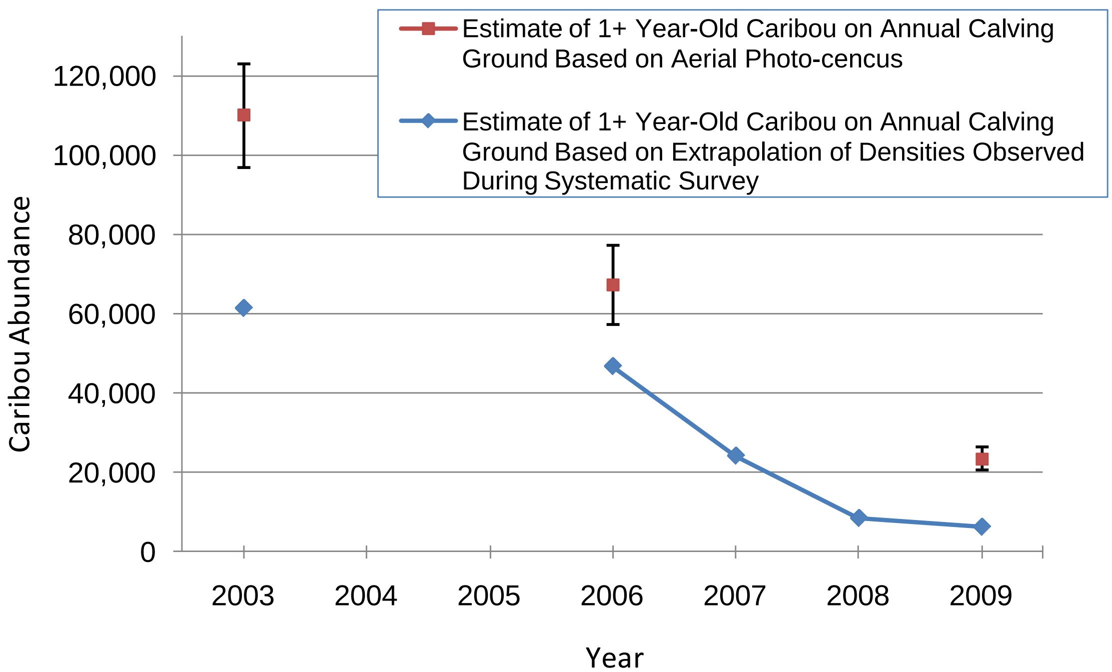

Figure 26. Relationship between trend in estimates of 1^{+}-year-old caribou on annual calving grounds based on i) stratified photographic survey and ii) visual extrapolations from systematic surveys.

Summary

We met the survey objective of obtaining a relatively precise estimate of the number of breeding females in the Bathurst herd (CV $\leq$ 15%). Optimal lighting conditions and use of aerial photography to count the number of caribou means that the estimate is accurate. Since the photographic estimate from the high and medium density strata represented over 98% of the total number of 1+-year-old caribou on the calving ground, the overall contribution of observer bias (from the low density visual strata) to the survey results was inconsequential.

Our systematic reconnaissance covered an extensive area to reduce the likelihood of missing aggregations of breeding females. Indeed, we extended systematic coverage for approximately 100 km from the delineated boundary of the annual calving ground and extended our survey coverage west to the calving extent of the Bluenose East herd, and east to the western calving extent of the Ahiak herd (Figure 4.8 in Adamczewski *et al.* 2009). Concomitant systematic surveys of the traditional calving grounds of the Ahiak and Beverly caribou herds further reduce the likelihood that large groups of breeding females from the Bathurst herd would have been missed (see Adamczewski *et al.* 2009). Furthermore, 8 of 10 satellite-collared cows (that were presumed to be breeding females) were concentrated in the high density stratum; the other two animals were located in the medium density strata, which also supports our assertion that we had included the entire distribution of breeding females. The 11th collared female, which was considered a non-breeder was located west of Contwoyto Lake (Figure 2, Appendix C) during the peak of calving and was associated with bulls, yearlings, and non breeding females.

Based on our observations of caribou distribution, density and composition from extensive systematic reconnaissance, combined with locations and movement rates of collared cows, we suggest that the timing of the 2009 calving ground survey coincided well with the peak of calving, which likely occurred between the 8 and 11 June. Finally, we experienced no major delays or technical challenges in conducting the calving ground photographic survey of the Bathurst herd in June 2009.

CONCLUSIONS

1. Results from the calving ground survey of the Bathurst caribou herd in June 2000 were robust and relatively precise.

2. The estimate of breeding females in June 2009 (16,605 $\pm$ 2176 SE) substantiates the results of the June 2006 Bathurst caribou survey (55,593 $\pm$ 8813 SE), and confirms that the abundance of breeding females has significantly declined since 1986.

3. The estimate of breeding females in June 2009 suggests that the number of caribou has declined significantly since 2006. If the observed rate of decline continues over the next several years, the estimated number of breeding females may decline to ca. 8,300 animals by June 2012*, i.e.,* 50% of the June 2009 estimate. Conservation and recovery of the Bathurst herd will require immediate development, implementation, and effective follow-up monitoring of co-management actions.

ACKNOWLEDGEMENTS

Funding for the calving ground survey was provided by ENR, Wildlife Division, Yellowknife, NT. The staff at Tahera Mine, Tahera Diamond Corporation generously provided us with a staging area and use of their airstrip along with meals, accommodations, flight services and office space at their site north of Contwyoto Lake.

Steve Blanchette and Adam Bourque (Air Tindi, Yellowknife) safely flew the survey crews in the Turbo Beaver and Cessna Caravan. Chuck Burke (Great Slave Helicopters, Yellowknife, NT) piloted the A-Star for the composition surveys. We thank Geographic Air Service Ltd. (Edmonton, AB) for their excellent collaboration on the photographic survey; Wally Fiesel (pilot) flew the photo plane and Doug Evans (cameraman) took the photographs; Hilke Krey (Manager) was patient and accommodating in our late night calculations of end points to photo lines. Beverly Archibald (True North Weather Services, Edmonton, AB), provided daily weather reports and forecasts which assisted us with planning field activities and anticipating weather conditions.

The data recording approach and data translations were developed by David Taylor and we appreciate his expertise. We thank Karin Clark (WRRB) for her participation and capable assistance throughout the survey. Adrian D'Hont (ENR, Yellowknife, NT) provide timely updates on locations of collared cows, and helped with various logistics. Jennifer Bailey (ENR North Slave) provided assistance with GIS data and presentation, while Mika Sutherland (EcoBorealis Consulting Inc.) analysed satellite collar locations, and drafted all figures. Paul Roy counted caribou from all the aerial photographs. We thank George Mandeville, Ron Fatt, Frank Camsel, and Noel Doctor for participating in all aspects of the field work and for sharing their insights on caribou. We thank Anne Gunn for advice on various aspects of survey design.

Funding for writing this report was provided to EcoBorealis Consulting Inc. under contract to ENR, North Slave Region, Yellowknife, NT. Integrated Ecological Research was also contracted by ENR, North Slave Region to conduct initial statistical analyses of data.

The reader will note that there are some slight differences in calculated values, from initial analyses conducted in Appendix K, compared to the final data analyses presented in the report. These minor differences are attributed to differences in rounding of numerical values in the main report. All survey estimates presented in the main report are based on the raw data from the photographic, visual, and composition surveys that are presented in Appendices E – J.

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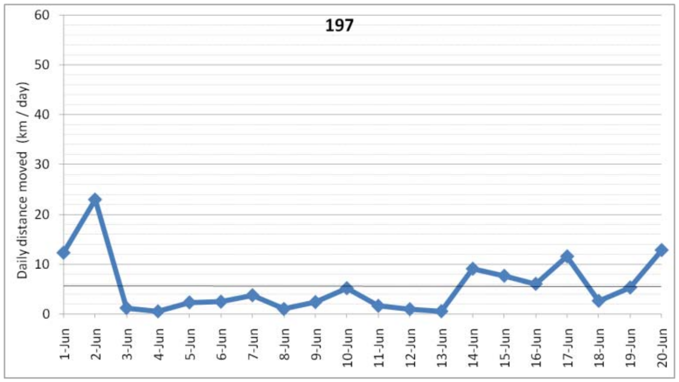
APPENDIX A. Field crew for a calving ground survey of the Bathurst caribou herd, June 2009.

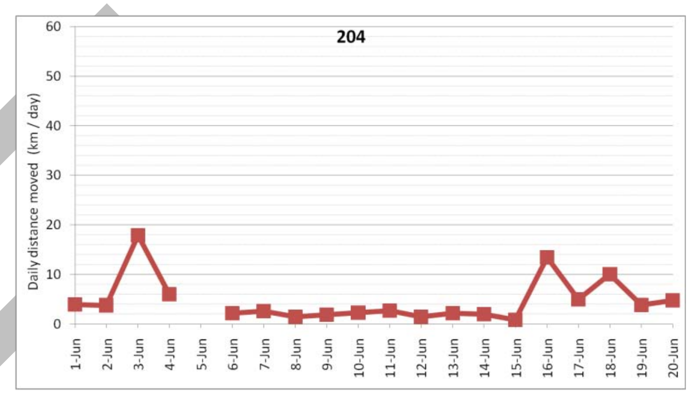
Team Member	Role	Affiliation
Jan Adamczewski (JA)	Biologist	Government of the Northwest Territories
Jennifer Bailey (JB)	GIS Technician	Government of the Northwest Territories
John Boulanger (JB)	Biometrician	Integrated Ecological Research
Steve Blanchette (SB)	Pilot (Turbo Beaver C-FOPE)	Air Tindi
Adam Bourque (AB)	Pilot (Cessna Caravan C-GATY)	Air Tindi
Frank Camsel (FC)	Observer & Community Representative	Tlicho Government
Karin Clark (KC)	Biologist	Wek'èezhìi Renewable Resources Board
Bruno Croft (BC)	Biologist	Government of the Northwest Territories
Noel Doctor (NC)	Observer & Community Representative	Yellowknife Dene First Nation
Doug Evans (DE)	Photographer (Challenger C-GEOS)	Geographic Air Survey Ltd.
Ron Fatt (RF)	Observer & Community Representative	Lutsel K'e Wildlife Lands & Environment Department
Wally Feisal (WF)	Pilot (Challenger C-GEOS)	Geographic Air Survey Ltd.
Allicia Kelly (AK)	Biologist	Government of the Northwest Territories
Chuck Burke (CB)	Pilot (A-Star G-ABX)	Great Slave Helicopters
George Mandeville (GM)	Observer & Community Representative	North Slave Metis Alliance
John Nishi (JN)	Biologist	EcoBorealis Consulting Inc.

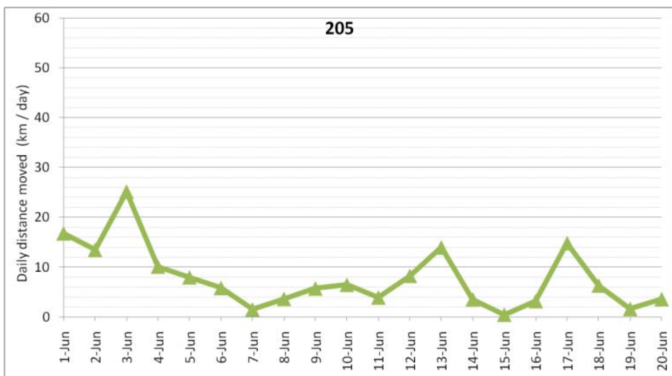
APPENDIX B. Daily flight log during reconnaissance, systematic, and composition surveys of Bathurst calving ground, 3 - 17 June 2009

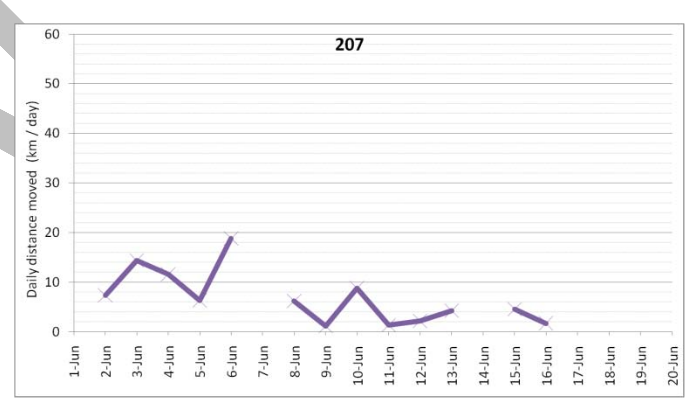
	Caravan		Turbo Beaver		A-Star Helicopter		
Date	Ferry time (hr)	Survey time (hr)	Ferry time (hr)	Survey time (hr)	Ferry time (hr)	Survey time (hr)	
03-Jun	8.0						
04-Jun	0.7	5.9					
05-Jun	1.0	8.0					
06-Jun	2.1	7.0	3.3	2.7			
07-Jun	2.9	5.5	2.2	5.8	3.0		
08-Jun	0.9	5.8	3.6	4.7		8.3	
09-Jun	2.0	4.2				8.9	
10-Jun	1.1	5.3				5.6	
11-Jun					3.0	5.6	
17-Jun	5.8	4.2					
Sum	24.5	45.9	9.1	13.2	6.0	28.4	
Total by Aircraft		70.4		22.3		34.4	127.1

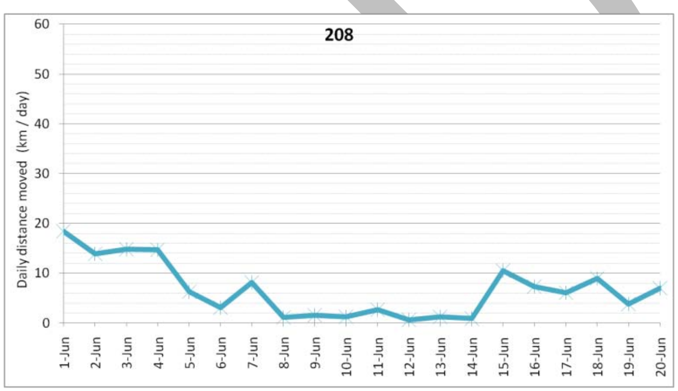
APPENDIX C. Daily movements of 11 radio- collared Bathurst cows from the 1-20 June 2009.

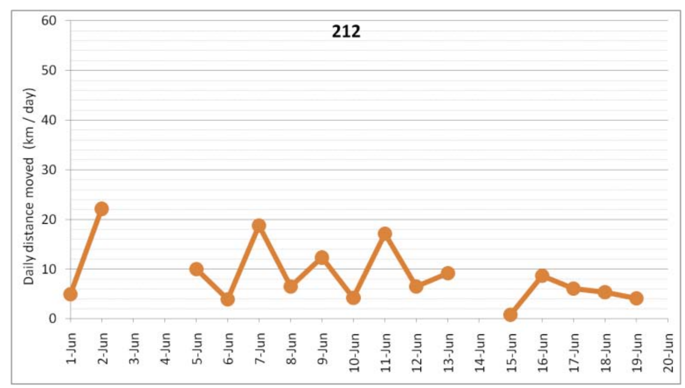


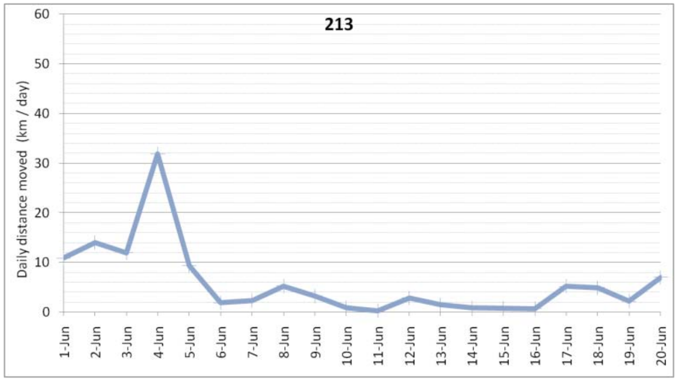











213
Daily distance moved (km / day)
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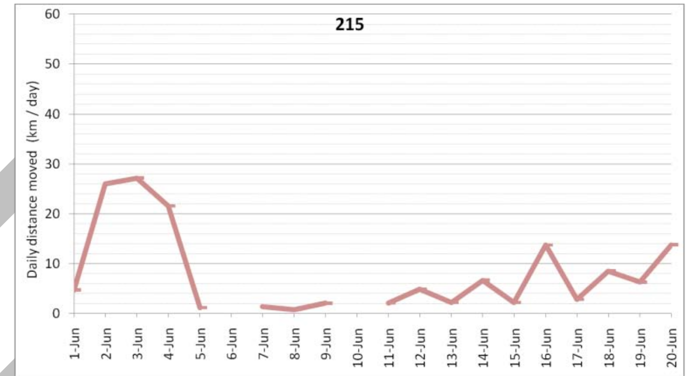
60
1-Jun 2-Jun 3-Jun 4-Jun 5-Jun 6-Jun 7-Jun 8-Jun 9-Jun 10-Jun 11-Jun 12-Jun 13-Jun 14-Jun 15-Jun 16-Jun 17-Jun 18-Jun 19-Jun 20-Jun


215
Daily distance moved (km / day)
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Daily distance moved (km / day)
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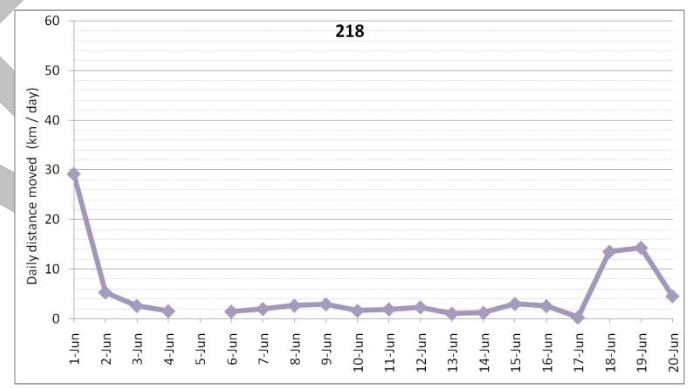
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Daily distance moved (km / day)
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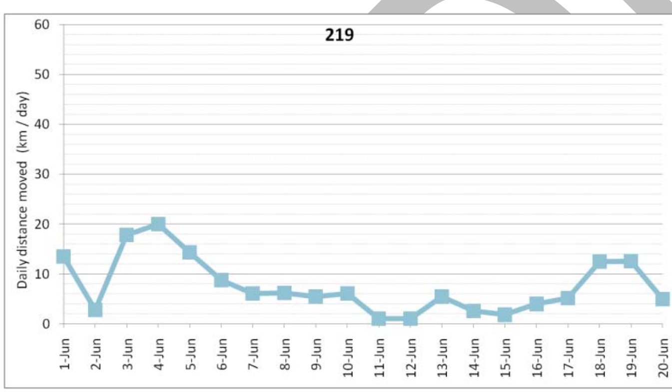
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Daily distance moved (km / day)
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1-Jun 2-Jun 3-Jun 4-Jun 5-Jun 6-Jun 7-Jun 8-Jun 9-Jun 10-Jun 11-Jun 12-Jun 13-Jun 14-Jun 15-Jun 16-Jun 17-Jun 18-Jun 19-Jun 20-Jun

APPENDIX C. continued.

Table C1. Likely breeding status of 11 radio-collared Bathurst caribou cows based on location and trends in daily movement rates.

ID #	PTT #	Collar Type	On Annual Calving Ground	Daily distance < 2-3 km, for at least 2 consecutive days	Likely Breeding Status
197	73253	ARGOS	yes	yes	calved
204	73373	GPS	yes	yes	calved
205	73374	GPS	yes	no	uncertain
207	73376	GPS	yes	yes	calved
208	73377	GPS	yes	yes	calved
212*	73381	GPS	no	no	non-breeder
213	73382	GPS	yes	yes	calved
215	73384	GPS	yes	yes	calved
216	73385	GPS	yes	yes	calved
218	73387	GPS	yes	yes	calved
219	92147	GPS	yes	yes	calved

* Cow 212 was considered to be a non-breeder because it was a) located in an area east of Contwoyto Lake and away from the calving ground through the calving period, and b) it had a variable and comparatively high rate of movement. Cow 212 was not included in subsequent analyses of movement rates and dispersion of collared cows presumed to be breeders.

APPENDIX D. Caribou densities observed during systematic survey of the Bathurst calving ground, 4-17 June 2009.

Table D1. Transect segments surveyed and caribou counted during systematic reconnaissance surveys of the Bathurst calving ground, 4-17 June 2009.

4 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	74	64.9%	0	0.0%	0	0.0%
Low	20	17.5%	74	14.5%	8	32.0%
Medium	19	16.7%	347	68.0%	14	56.0%
High	1	0.9%	89	17.5%	3	12.0%
Sum	114	100.0%	510	100.0%	25	100.0%

5 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	126	88.7%	0	0.0%	0	0.0%
Low	11	7.7%	33	28.4%	0	0.0%
Medium	5	3.5%	83	71.6%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	142	100.0%	116	100.0%	0	0.0%

6 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	159	145.9%	0	0.0%	0	0.0%
Low	11	10.1%	27	55.1%	3	15.8%
Medium	5	4.6%	93	189.8%	16	84.2%
High	1	0.9%	99	202.0%	0	0.0%
Sum	176	161.5%	219	446.9%	19	100.0%

7 June (AM)	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	69	84.1%	0	0.0%	0	0.0%
Low	10	12.2%	21	35.6%	0	0.0%
Medium	3	3.7%	38	64.4%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	82	100.0%	59	100.0%	0	0.0%

7 June (PM)	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	52	56.5%	0	0.0%	0	0.0%
Low	22	23.9%	78	12.3%	3	2.8%
Medium	16	17.4%	349	55.1%	85	80.2%
High	2	2.2%	206	32.5%	18	17.0%
Sum	92	100.0%	633	100.0%	106	100.0%

8 June (PM)	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	100	98.0%	0	0.0%	0	0.0%
Low	1	1.0%	3	27.3%	0	0.0%
Medium	1	1.0%	8	72.7%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	102	100.0%	11	100.0%	0	0.0%

9 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	60	83.3%	0	0.0%	0	0.0%
Low	11	15.3%	32	62.7%	1	100.0%
Medium	1	1.4%	19	37.3%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	72	100.0%	51	100.0%	1	100.0%

10 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	66	94.3%	0	0.0%	0	0.0%
Low	3	4.3%	10	47.6%	0	0.0%
Medium	1	1.4%	11	52.4%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	70	100.0%	21	100.0%	0	0.0%

17 June	10-km Segments		1+ yr-old Caribou		Calves	
Density class	(n)	(%)	(n)	(%)	(n)	(%)
No Caribou	1	2.6%	0	0.0%	0	0.0%
Low	18	47.4%	60	9.5%	0	0.0%
Medium	19	50.0%	569	90.5%	0	0.0%
High	0	0.0%	0	0.0%	0	0.0%
Sum	38	100.0%	629	100.0%	0	0.0%

APPENDIX E. Number of 1+-year-old caribou observed during an aerial transect survey of high density photographic strata (High), Bathurst calving ground, 8 June 2009.

High Density Photographic Stratum - High

Transect No.	Transect Length (km)	Transect Area (km^2)	1+ yr-old Caribou Counted
1	43.55	39.82	71
2	43.55	39.82	39
3	43.50	39.78	51
4	43.45	39.73	51
5	54.49	49.82	81
6	54.49	49.82	79
7	54.49	49.82	158
8	54.49	49.82	130
9	54.49	49.82	192
10	54.49	49.82	391
11	54.49	49.82	220
12	54.49	49.82	580
13	54.49	49.82	494
14	54.49	49.82	661
15	54.49	49.82	479
16	54.49	49.82	643
17	54.49	49.82	624
18	54.49	49.82	1039
19	54.49	49.82	276
20	54.49	49.82	266
21	54.49	49.82	426
22	54.49	49.82	189
Total	1154.80	1055.95	7140

APPENDIX F. Number of 1+-year-old caribou observed during a photographic transect survey of a medium density stratum, Bathurst calving ground, 9 June 2009

Medium Density Photographic Stratum – Med

Transect No.	Transect Length (km)	Transect Area (km^2)	1+ yr-old Caribou Counted
1	44.18	40.40	118
2	44.18	40.40	296
3	44.18	40.40	195
4	44.18	40.40	30
5	44.18	40.40	68
6	44.18	40.40	113
7	44.18	40.40	97
8	44.18	40.40	63
9	44.18	40.40	17
10	44.18	40.40	10
Total	441.82	404.00	1007

APPENDIX G. Number of 1+-year-old caribou observed during a visual strip transect survey of three low density strata (Low N, Low SW, and Low SE), Bathurst calving ground, 8 June 2009.

Low Density Visual Stratum - Low N

Transect No.	Transect Length (km)	Transect Area (km^2)	1+ yr-old Caribou Counted
1	19.63	15.70	5
2	19.69	15.75	0
3	19.75	15.80	0
4	19.81	15.85	0
5	19.88	15.90	0
6	19.94	15.95	0
7	20.00	16.00	0
8	20.06	16.05	0
9	20.12	16.10	0
10	9.92	7.94	0
11	10.01	8.01	0
12	10.09	8.08	0
13	10.18	8.15	0
14	10.27	8.21	0
15	10.36	8.28	0
16	10.44	8.35	0
17	10.53	8.42	0
18	10.62	8.49	0
19	10.70	8.56	0
20	10.79	8.63	0
Total	292.79	234.23	5

APPENDIX G. Continued

Low Density Visual Stratum - Low SW

Transect No.	Transect Length (km)	Transect Area (km^2)	1+ yr-old Caribou Counted
1	19.90	15.92	7
2	19.82	15.86	4
3	19.74	15.79	1
4	19.67	15.73	4
5	19.59	15.67	7
6	19.51	15.61	26
7	19.43	15.55	0
8	19.36	15.49	0
9	19.28	15.42	4
10	19.20	15.36	0
Total	195.50	156.40	53

Low Density Visual Stratum - Low SE

Transect No.	Transect Length (km)	Transect Area (km^2)	1+ yr-old Caribou Counted
1	21.40	17.12	0
2	21.40	17.12	2
3	21.40	17.12	2
4	21.40	17.12	0
5	21.40	17.12	3
6	21.40	17.12	0
7	21.40	17.12	2
8	21.40	17.12	0
9	21.40	17.12	6
10	21.40	17.12	0
11	21.40	17.12	0
Total	235.42	188.34	15

APPENDIX H. Composition of 1+-year-old caribou classified in the high density photo stratum, Bathurst calving ground, 8 -11 June 2009

Waypoint	Observation Number	Antlered With Udder	Antlerless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
141	1	0	0	1	1	0	9	0	11	1	11	0.0909	0.67919	0.45146
142	2	0	1	1	3	1	6	0	12	2	11	0.1818	0.67865	0.48632
143	3	1	0	0	6	0	6	0	13	1	13	0.0769	0.67993	0.40406
144	4	0	1	5	3	5	11	2	27	6	22	0.2727	0.68055	0.36480
147	5	5	2	2	0	7	0	0	16	9	16	0.5625	0.67668	0.61239
148	6	9	7	1	0	16	0	0	33	17	17	1.0000	0.67268	0.86850
149	7	27	11	15	0	36	2	0	91	53	55	0.9636	0.66685	1.24130
150	8	3	0	1	2	2	4	0	12	4	10	0.4000	0.67719	0.57964
151	9	8	8	3	1	14	3	0	37	19	23	0.8261	0.67379	0.79706
152	10	0	0	1	2	0	9	0	12	1	12	0.0833	0.67956	0.42777
153	11	0	0	1	2	0	14	0	17	1	17	0.0588	0.68142	0.30894
154	12	0	0	0	16	0	33	0	49	0	49	0.0000	0.69410	-0.50282
155	13	0	0	0	6	0	16	0	22	0	22	0.0000	0.68384	0.15439
157	14	0	1	0	15	1	13	0	30	1	29	0.0345	0.68592	0.02108
158	15	0	1	0	3	1	6	1	12	1	11	0.0909	0.67919	0.45146
160	16	12	6	3	1	19	0	0	41	21	22	0.9545	0.67233	0.89083
161	17	80	25	15	15	101	10	0	246	120	145	0.8276	0.66275	1.50389
162	18	30	20	5	1	31	0	0	87	55	56	0.9821	0.66611	1.28894
163	19	16	10	9	1	26	4	0	66	35	40	0.8750	0.67128	0.95805
164	20	18	6	3	0	23	2	0	52	27	29	0.9310	0.67162	0.93637
165	21	6	2	2	0	7	0	0	17	10	10	1.0000	0.67392	0.78868
166	22	8	3	6	1	11	3	0	32	17	21	0.8095	0.67415	0.77420
167	23	12	4	11	5	15	4	0	51	27	36	0.7500	0.67421	0.77023
168	24	26	12	10	2	35	0	0	85	48	50	0.9600	0.66778	1.18197
169	25	13	1	3	1	14	0	0	32	17	18	0.9444	0.67305	0.84497
170	26	4	1	4	0	5	0	0	14	9	9	1.0000	0.67410	0.77732

APPENDIX H. Continued

Waypoint	Observation Number	Antlered With Udder	Antlerless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
171	27	6	5	3	0	13	0	0	27	14	14	1.0000	0.67321	0.83422
172	28	16	9	8	0	22	3	0	58	33	36	0.9167	0.67090	0.98227
173	29	32	5	4	1	39	2	0	83	41	44	0.9318	0.66944	1.07572
175	30	37	13	9	7	46	2	0	114	59	68	0.8676	0.66835	1.14528
176	31	48	6	1	5	42	4	0	106	55	64	0.8594	0.66910	1.09766
177	32	46	20	11	5	64	5	0	151	77	87	0.8851	0.66534	1.33805
179	33	4	1	5	0	4	13	0	27	10	23	0.4348	0.67873	0.48127
181	34	6	4	6	1	10	4	0	31	16	21	0.7619	0.67470	0.73915
182	35	3	1	1	14	3	16	0	38	5	35	0.1429	0.68598	0.01700
184	36	10	4	4	2	16	2	0	38	18	22	0.8182	0.67397	0.78562
186	37	0	0	2	5	0	6	0	13	2	13	0.1538	0.67939	0.43895
187	38	12	3	1	3	13	5	0	37	16	24	0.6667	0.67581	0.66809
188	39	19	3	3	4	22	3	0	54	25	32	0.7813	0.67383	0.79480
189	40	13	0	0	0	11	12	0	36	13	25	0.5200	0.67783	0.53897
191	41	5	0	10	5	5	7	0	32	15	27	0.5556	0.67747	0.56163
193	42	8	1	4	5	8	7	0	33	13	25	0.5200	0.67783	0.53897
195	43	28	8	24	2	31	8	0	101	60	70	0.8571	0.66854	1.13315
196	44	22	8	14	7	19	5	1	76	44	57	0.7719	0.67263	0.87183
199	45	1	0	1	5	0	7	0	14	2	14	0.1429	0.67976	0.41523
200	46	7	0	6	5	11	6	0	35	13	24	0.5417	0.67745	0.56277
201	47	6	7	0	3	19	0	0	35	13	16	0.8125	0.67449	0.75220
202	48	4	0	4	0	5	0	0	13	8	8	1.0000	0.67428	0.76598
203	49	10	3	8	1	14	2	0	38	21	24	0.8750	0.67307	0.84362
204	50	3	1	3	5	3	3	0	18	7	15	0.4667	0.67740	0.56616
205	51	19	4	25	3	21	7	0	79	48	58	0.8276	0.67077	0.99086
207	52	7	8	2	3	14	3	0	37	17	23	0.7391	0.67489	0.72689
208	53	5	0	5	0	3	1	0	14	10	11	0.9091	0.67429	0.76519
209	54	3	0	2	4	3	10	0	22	5	19	0.2632	0.67998	0.40127

APPENDIX H. Continued

Waypoint	Observation Number	Antlered With Udder	Antlerless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
210	55	0	0	0	3	0	7	0	10	0	10	0.0000	0.67937	0.44028
212	56	0	0	0	9	0	0	1	10	0	10	0.0000	0.67937	0.44028
213	57	0	0	0	9	0	5	0	14	0	14	0.0000	0.68085	0.34540
214	58	2	0	1	8	2	7	0	20	3	18	0.1667	0.68070	0.35508
215	59	0	0	2	2	0	9	0	13	2	13	0.1538	0.67939	0.43895
217	60	0	2	6	16	2	4	0	30	8	28	0.2857	0.68169	0.29150
218	61	8	1	4	2	10	0	0	25	13	15	0.8667	0.67413	0.77577
219	62	7	1	5	0	10	0	0	23	13	13	1.0000	0.67339	0.82281
220	63	9	2	6	8	13	4	0	42	17	29	0.5862	0.67712	0.58434
221	64	1	1	3	2	1	10	0	18	5	17	0.2941	0.67923	0.44883
224	65	16	6	3	2	23	0	0	50	25	27	0.9259	0.67198	0.91328

n=	65				
Sum Breeding Females	1248	Sum Calves	892	Sum all caribou	2732
Sum 1+ Yr Old Caribou	1847	Ratio Calf:cow	0.7147		
Overall proportion Breeding Females	0.6757				

Tukey's Jacknife Method
(Cochran 1977, p. 178;
Krebs 1989, p. 464,
Sokal & Rohlf 1981, p. 796)

mean	0.678
variance	0.118
SD	0.343
SE	0.043
CV	0.063

Øi = nS - (n-1) St

Where:

Øi = Pseudovalue for jacknife estimate

n = Original sample size

S = Original statistical estimate

St = Statistical estimate when original value i has been discarded from sample

i = Sample number (1,2,3,…. n)

APPENDIX I. Composition of 1+-year-old caribou classified in the medium density photo strata (Med), Bathurst calving ground, 8 -11 June 2009

Waypoint	Observation Number	Antlered With Udder	Antlerless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
225	1	1	1	39	6	3	4	0	54	41	51	0.8039	0.88221	0.80383
226	2	11	4	7	2	22	0	0	46	22	24	0.9167	0.87648	0.89542
227	3	15	3	2	2	16	1	0	39	20	23	0.8696	0.87782	0.87409
228	4	84	12	15	6	98	7	0	222	111	124	0.8952	0.87466	0.92456
229	5	7	9	3	2	16	2	0	39	19	23	0.8261	0.87900	0.85511
230	6	7	21	3	2	25	2	0	60	31	35	0.8857	0.87726	0.88307
231	7	30	30	1	8	60	1	0	130	61	70	0.8714	0.87814	0.86892
232	8	85	74	10	12	148	10	0	339	169	191	0.8848	0.87556	0.91028
233	9	22	28	2	0	47	1	0	100	52	53	0.9811	0.87085	0.98559
235	10	0	0	0	4	0	6	0	10	0	10	0.0000	0.88785	0.71356
236	11	0	3	2	1	3	1	0	10	5	7	0.7143	0.87893	0.85630
237	12	53	3	11	6	60	0	0	133	67	73	0.9178	0.87390	0.93682
238	13	21	18	1	3	32	2	0	77	40	45	0.8889	0.87698	0.88750
239	14	19	7	1	3	25	6	0	61	27	36	0.7500	0.88313	0.78905
240	15	12	10	5	0	19	2	0	48	27	29	0.9310	0.87575	0.90722
241	16	34	11	8	0	45	0	0	98	53	53	1.0000	0.86962	1.00527
242	17	10	1	4	0	10	4	0	29	15	19	0.7895	0.87957	0.84597

n=	17				
Sum Breeding Females	760	Sum Calves	629		
Sum 1+ Yr Old Caribou	866	Ratio Calf:cow	0.8276	Sum all caribou	1495
Overall proportion Breeding Females	0.8776				

APPENDIX I. Continued

Tukey's Jacknife Method
(Cochran 1977, p. 178;
Krebs 1989, p. 464,
Sokal & Rohlf 1981, p. 796)

mean	0.879
variance	0.005
SD	0.070
SE	0.017
CV	0.019

Øi = nS - (n-1) St

Where:
Øi = Pseudovalue for jacknife estimate
n = Original sample size
S = Original statistical estimate
St = Statistical estimate when original value i has been discarded from sample
i = Sample number (1,2,3,…. n)

APPENDIX J. Composition of 1+-year-old caribou classified in the low density strata (Low-SW and Low-SE), Bathurst calving ground, 8-11 June 2009.

Waypoint	Observation Number	Antlered With Udder	Antlerless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
243	1	0	0	0	8	0	15	0	23	0	23	0.0000	0.12315	0.01035
244	2	0	0	0	12	0	10	1	23	0	23	0.0000	0.12315	0.01035
245	3	3	7	2	14	2	18	2	48	12	46	0.2609	0.07222	0.41780
246	4	2	1	0	29	0	18	0	50	3	50	0.0600	0.12500	-0.00442
247	5	0	0	0	7	0	8	0	15	0	15	0.0000	0.11848	0.04771
248	6	3	2	0	12	3	1	0	21	5	18	0.2778	0.09615	0.22634
249	7	3	2	0	13	2	3	0	23	5	21	0.2381	0.09756	0.21509
250	8	0	0	0	15	0	4	0	19	0	19	0.0000	0.12077	0.02939
251	9	0	0	0	7	0	4	0	11	0	11	0.0000	0.11628	0.06534

n=	9				
Sum Breeding Females	25	Sum Calves	7		
Sum 1+ Yr Old Caribou	226	Ratio Calf:cow	0.2800	Sum all caribou	233
Overall proportion Breeding Females	0.1106				

Tukey's Jacknife Method
(Cochran 1977, p. 178;
Krebs 1989, p. 464,
Sokal & Rohlf 1981, p. 796)

mean	0.113
variance	0.021
SD	0.143
SE	0.048
CV	0.423

Øi = nS - (n-1) St

Where:

Øi = Pseudovalue for jacknife estimate

n = Original sample size

S = Original statistical estimate

St = Statistical estimate when original value i has been discarded from sample

i = Sample number (1,2,3,…. n)

APPENDIX K. Bathurst caribou breeding female trend analysis 2009 - DRAFT

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This short paper details analysis of trend for breeding females in the Bathurst caribou herd. It eventually will be incorporated into a larger more comprehensive report.

METHODS

Data set used for analysis

The data set of population estimates for breeding females is shown in Table 1 and Figure 1. I note that this is the most applicable data set for trend estimation since breeding females are the most biologically meaningful segment of the population. In addition, all parameters (i.e. counts of caribou and composition) are directly estimated for each year surveyed and therefore breeding female counts should most directly reflect changes in population size.

Table 1: Breeding female population estimates used for trend analysis

year	N	SE	CV	t df	CI min	CI max
2009	16604	2176.42	0.13	29	12153	21056
2006	55593	8813	0.16	19	37147	74039
2003	80658	13149.1	0.16	17	52916	108400
1996	151393	35144.0	0.23	13	75469	227317
1990	151927	25805.0	0.17	10	94430	209424
1986	203800	12695.7	0.06	43	178197	229403

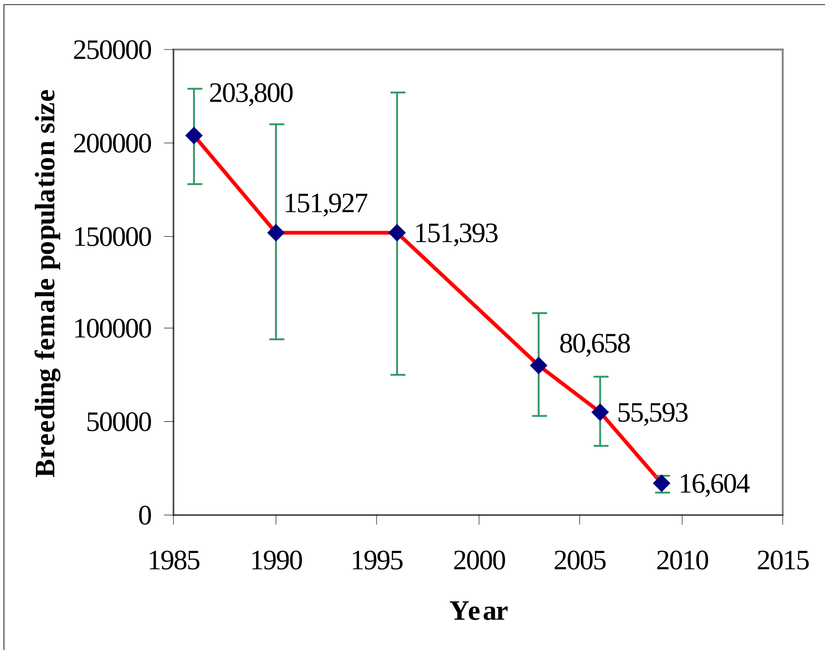

Figure 1: Population estimates of breeding females for surveys conducted in 1986, 1990, 1996, 2003, 2006, and 2009 Ninety five percent confidence intervals for estimates are shown as error bars.

Weighted regression

Weighted least squares analysis was used to estimate trend from the time series of data (Brown and Rothery 1993). Each population estimate was weighted by the inverse of its variance to account for unequal variances of surveys, and to give more weight in the estimation to the more precise surveys.
Unlike previous surveys, there was evidence of potential non-linear population trends as indicated by the substantially lower 2009 calving ground estimate. Given this, I conducted substantial testing for non-linear population trends using the sample-size-corrected Akaike Information Criterion (AICc) index of model fit (Burnham and Anderson 1998). The model with the lowest AICc score was considered the most parsimonious, thus optimizing the tradeoff between bias and precision (Burnham and Anderson 1998). The difference between any given model and the most supported (ΔAICc) was used to evaluate the relative fit of models when their AICc scores were similar. In general, any model with a ΔAICc score of ≤ 2 is 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). Unlike previous analysis, it was not possible to estimate rates of change from λ given potential non-linear trends in the data set. However, λ could still be estimated using the ratio of successive predicted population sizes from the regression model. The per capita growth rate can be 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. If λ is less than 1 then the population is decreasing, and if λ is greater than 1 then the population is increasing.

Monte Carlo simulation

I used a Monte Carlo simulation technique to allow another estimate of the variance in trend that resulted from individual variances of each of the surveys (Manly 1997) and provide confidence interval for λ. The basic question this simulation asked was: "If these studies were repeated many times, would the estimated trends and associated variances be observed given the levels of precision of each of the surveys?" 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 estimation. For a given estimate the 95% confidence interval is the population estimate $\pm\ t_{(\alpha=0.05,2,df)}$*standard error. 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 standard error and then 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 confidence intervals. 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 population sizes was generated for each of the 5 sampling occasions using the procedure documented in point 1 and the parameters listed in Table 1. The most supported AIC regression model was used for estimation. This procedure was repeated for 2000 pseudo data sets that resulted in 2000 estimates of trend. The most supported trend model was used to produce trend estimates.

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

Basically, 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.

RESULTS

Weighted regression

Model selection results suggested that a nonlinear trend best approximated by a cubic polynomial term was most supported (Table 2). This model showed strong support as indicated by a AIC weight of 0.95. A model with linear trends was not supported by the data.

Table 2: Model selection results for Bathurst trend analysis. Akaike Information Criteria (AIC_c), the difference in AIC_c values between the *i*th and most supported model (ΔAIC_c), Akaike weights (w_i), and number of parameters (*K*) are presented.

model	AICc	ΔAICc	wi	logl
yr^3	2.82	0	0.995	2.59
$yr+yr_{>06}$	8.12	5.30	0.005	4.94
$yr^2\ yr^3$	11.58	8.76	0.000	3.21
$yr\ yr^3$	12.50	9.68	0.000	2.75
$yr\ yr^2$	17.68	14.86	0.000	0.16
$yr+yr_{>03}$	20.59	17.77	0.000	-7.29
yr	34.91	32.09	0.000	-13.46
$yr\ yr^2\ yr^3$	37.04	34.22	0.000	5.48
intercept	322.72	319.90	0.000	-159.86

Parameter estimates for the most supported model suggest both the intercept and yr^3 terms are significant (Table 3).

Table 3: Regression model parameter estimates

Parameter	Estimate	S.E	C.I. low	C.I.high	t	P-value
Intercept	12.208	0.075	12	12.417	162.72	0
yr^3	-0.0002	0.000015	-0.0002	-0.0001	-13.45	0.0002

A plot of the regression line (back transformed to population size units) is shown in Figure 2. The gray lines are 95% confidence interval around the trend line. The circles are data points. The confidence intervals are irregular since they are accounting for varying degrees of variance in each of the point estimates. For example, the 1986, 2003, and 2006 and 2009 surveys had the best precision and therefore the confidence intervals are tightest around these points.

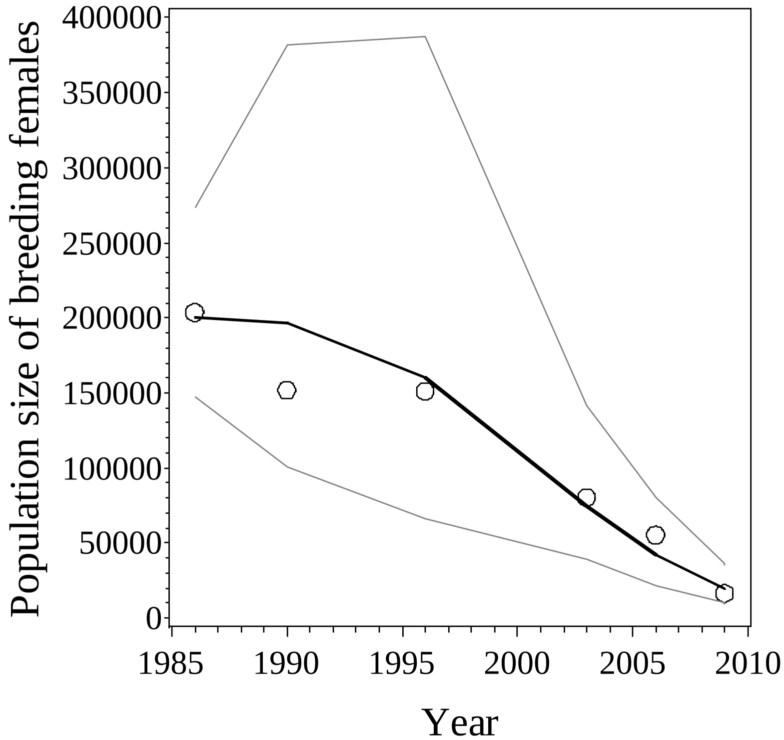

Figure 2: Predicted trend for breeding females from weighted least squares regression analysis. Grey lines are confidence interval on predictions. Circles are estimates for each years.

Monte Carlo simulation

Monte Carlo simulation results (Figure 3) suggested that the trend was increasingly negative as shown by lower λ estimates for each year. The λ of 1 at the beginning of the simulations was an artifact of the fact that this was the first point in the simulation and therefore the most applicable estimates were for the latter part of the time series (i.e. after 2000).

A histogram of λ estimates for 2009 (Figure 4) shows that none of the values overlapped 1 suggesting there was no statistical chance that the population was stable.

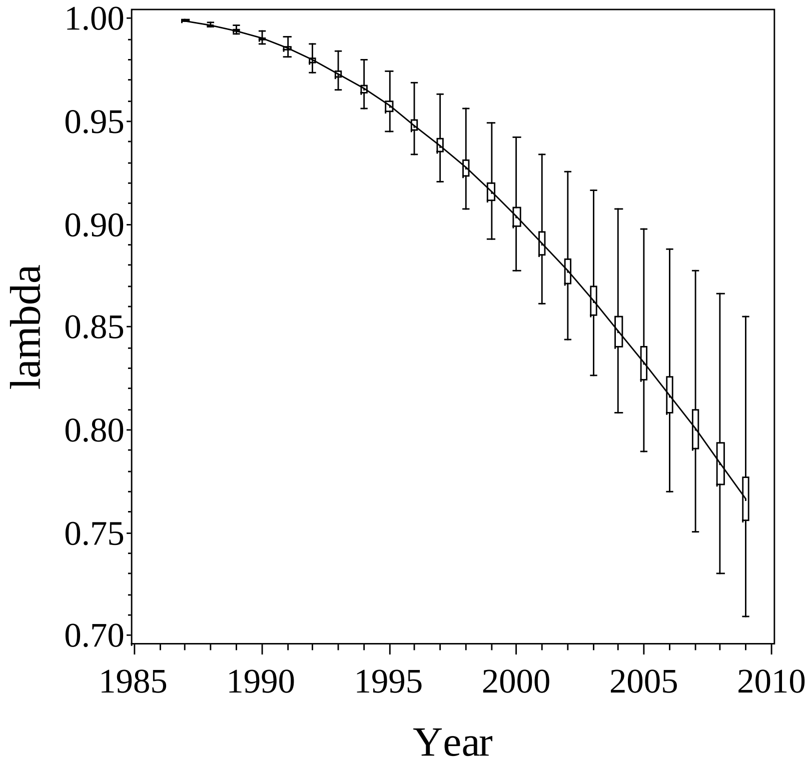

Figure 3: Simulated estimates of λ as a function of year from Monte Carlo simulation analysis.

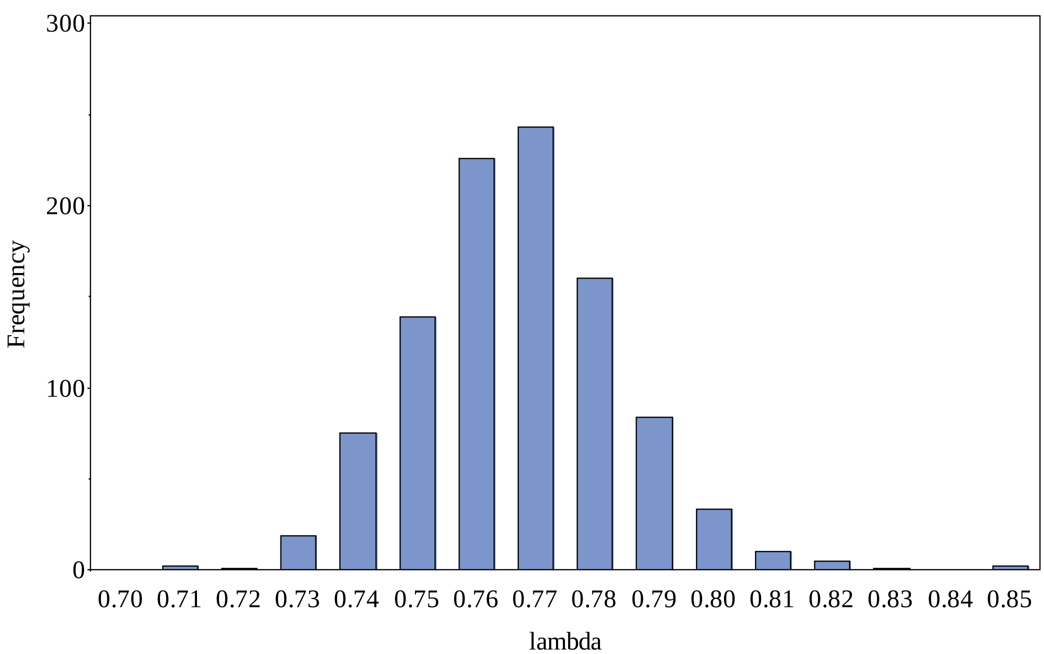

Figure 4: Distributions of population rate of change (λ) for 2009 generated using Monte Carlo simulation trials.

The estimates of λ from the Monte Carlo analysis for 2009 was 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)

DISCUSSION

Both analyses suggest an increasing negative trend in the population size of breeding females in the Bathurst caribou herd. From inspection of Figure 1 it might be surmised that the population may have declined between 1986 and 1990 and then stabilized from 1990 to 1996 and then declined from 1996 to 2006 and then declined further from 2006 to 2009. The cubic polynomial trend model is the "best approximating model" in that it best summarizes the trends in population size using the least number of parameters as displayed in Table 2. Regression methods that utilize multiple years of data provide potentially more inference regarding population trend and status compared to 2 sample t-tests of sequential population estimates. For example, regression-based estimates of r and λ express population change in yearly units. In comparison, t-tests of sequential estimates are will be influenced by the arbitrary period of time between successive surveys. For example, a 2 sample t-test will be more likely to detect a change in population size between surveys that are conducted at longer time intervals even if the population is changing at a constant rate. Estimates from regression are not influenced by survey interval, and they utilize data from all surveys conducted leading to higher overall power to detect change in population size. For this reason I recommend reporting trend estimates in terms of λ and r-values rather than the results of t-tests of sequential estimates.

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APPENDIX L. Exponential rate of increase between estimates of breeding females on 2006 and 2009 Bathurst caribou calving ground surveys.

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Rate of increase *(r)* between T_{2006} and T_{2009}

The rate of increase between the 2003 and 2006 estimates of breeding females was calculated in a spreadsheet using the formulas and methods in Section 4.3.1 of Gasaway *et al.* 1986. I estimated the value of *r* as well as the standard deviation and 95% confidence intervals for this parameter.

		T_{2006}	T_{2009}	Halving Time (years)
	Year (t)	2006	2009	
	Population Size (Nt)	55593	16605	
	Variance	77667712	4736807	
	$\log_e$ (Nt)	10.9	9.7	
	Δt	3		
	df	19	30	
a) Exponential Rate of increase *(r)* =	$\log_e (T_{2009}) - \log_e (T_{2006}) / \Delta t$			
	r =		-0.403	1.7
b) Variance of the Exponential Rate of Increase				
	Var(L1)=		0.025	
	Var(L2)=		0.017	
	Var (r) =		0.00465	
	Std Dev =		0.068	
	Degrees Freedom =		42	
c) 95% Confidence Intervals	Upper		-0.265	2.6
	Lower		-0.541	1.3

APPENDIX M. Potential for systematic surveys of Bathurst caribou calving grounds to contribute to herd monitoring

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INTRODUCTION

In this Appendix, I describe a trend analysis of data from systematic surveys of the Bathurst caribou calving grounds. I initiated the analysis in May 2009, prior to the June 2009 calving ground photographic survey. My goal was to review the systematic surveys that had been flown annually in 2007 and 2008, since the last photographic survey in 2006 (Nishi *et al.* 2007), in order to understand trend in area and density of the annual calving grounds, and anticipate those conditions for June 2009.

My rationale for the analysis was based on the premise that systematic surveys of traditional calving grounds are designed to delineate the annual calving ground based upon relative composition and density of caribou observed within 10 km long (or 8 km^2) segments of systematic transects. My objective was to delineate annual calving grounds retrospectively from systematic surveys in 2006, 2007, and 2008, and extrapolate observed densities within the delineated areas to area-weighted estimates of 1^+-year old caribou. I thought this assessment would provide a directly comparable time series of data, which I could use to evaluate general trends, anticipate size of the calving ground and densities of caribou on the calving ground in June 2009.

Following the 2009 survey, I subsequently added the systematic surveys from 2003 and 2009 to graphically evaluate trends and review implications of this assessment. I have integrated these findings in to the larger survey report.

METHODS

Data used for analyses

Estimates of 1+ year-old caribou were available for systematic surveys and from completed calving ground photographic surveys in 2003 (Gunn *et al.* 2005b), 2006 (Nishi *et al.* 2007), and 2009 (this report). Systematic aerial reconnaissance surveys of the Bathurst calving grounds were conducted in 2007, 2008 (GNWT unpublished data), and 2009 (this report).

Data from systematic visual surveys were reported as caribou densities within adjacent transect segments (10 km long segments by 0.8 km wide) oriented along north-south oriented linear transects, within a systematic grid of transects spaced at 10 km intervals. For the 2003, 2006, and 2009 systematic survey data, I simply used the segment data from within the final stratification designs of the calving ground surveys. For 2007 and 2008 survey data, I delineated the annual calving ground based upon: i) relative distribution and density of breeding females (with and without calves) from the composition categories, and ii) density values assigned to each of the 10 km segments during the systematic survey. Within the delineated annual calving ground, I extrapolated each observed density to an estimate of 1^+-year old caribou in a 100 km^2 area (or adjusted it based on transect spacing) by multiplying the density value of a segment by 100. The sum of caribou counts within all 100 km^2 cells provided a coarse extrapolated estimate of 1+ year-old caribou on the annual calving ground based on the systematic reconnaissance surveys.

RESULTS

The extrapolated estimates of 1+ year-old caribou on the Bathurst calving ground were consistently lower, but showed a similar declining trend to that depicted by the caribou estimates derived from aerial photographic surveys (Figure 1M). Extrapolated estimates based on observed caribou densities from systematic reconnaissance surveys showed the decline from 2006 to 2009 on an annual time step.

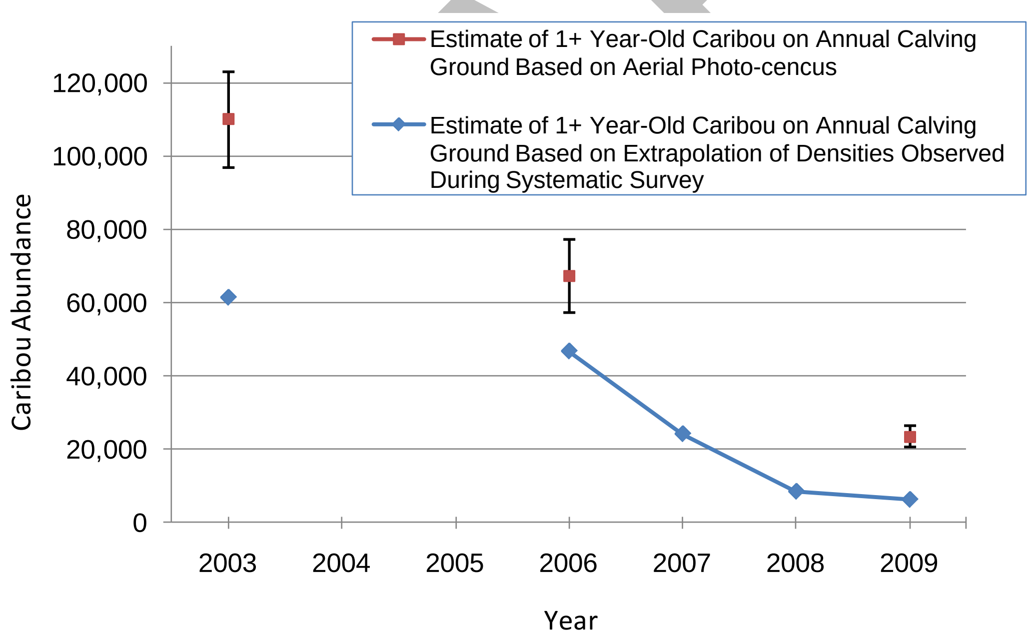

Figure 1M. Trend in estimates of 1+ year-old caribou on Bathurst calving grounds based on aerial photographic survey results and extrapolation of caribou densities observed during systematic reconnaissance surveys.

DISCUSSION

Recent systematic reconnaissance surveys of the annual Bathurst caribou calving grounds are consistent with results from calving ground photographic surveys and show a continued and dramatic decline in numbers of caribou on the calving grounds.

Systematic reconnaissance surveys provide a potentially useful and comparatively economic way of monitoring trend of caribou on an annual calving ground, and allow managers to anticipate trend during the intervening years between full-scale calving ground photographic surveys. In addition to monitoring abundance of 1^{+}-year-old caribou, results from systematic reconnaissance survey of caribou calving grounds can provide insight on trend in spatial extent of the annual concentrated calving area and associated spatial patterns of dispersion and changes in caribou densities.

However, observer bias associated with sightability and counting error will be a source of uncertainty and variability that will affect precision and accuracy of this visual survey technique; counting error will increase especially as overall densities on the annual calving grounds increase. Therefore, careful and consistent standardization of survey methods and rigorous training of observers will help to improve the value of systematic reconnaissance surveys. Systematic reconnaissance surveys may be a particularly important annual monitoring tool when caribou populations (such as the Bathurst herd) decline to low numbers and management actions are implemented to assist in recovery.

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