AN ESTIMATE OF BREEDING FEMALES IN THE BATHURST HERD OF BARREN-GROUND CARIBOU, JUNE 2006

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ABSTRACT

We used the calving ground photo-census technique to estimate abundance and distribution of breeding females in the Bathurst herd of barren-ground caribou *(Rangifer tarandus groenlandicus)* in June 2006. In late May 2006, we started monitoring movements and locations of satellite-collared Bathurst cows (n= 8-14). We used Lupin Mine at Contwoyto Lake as our base of operations and started systematic aerial surveys on the 6 and 7 June. The distribution of satellite-collared cows was the means of centering survey effort during the initial systematic surveys. Then, we used observations of relative caribou density and composition (presence of hard antlered cows and/or newborn calves) to define our survey extents. 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 breeding females. We conducted another systematic aerial survey on the 8 June, and delineated the annual calving ground based on the systematic surveys. We initially stratified the calving ground into one high density (photographic) stratum, two medium density (photographic) strata and two low density (visual) strata. Although we initiated the photo-census of the high density stratum on the 9 June, poor weather prevented completion of the photography on the 10 June. We flew the boundaries of the high density stratum on the afternoon of the 10 June, and re-aligned the boundaries of the high and medium density strata to reflect changes in caribou distribution. We added additional low density strata to ensure complete coverage of the calving ground. The aerial photography of one high and two medium density strata was completed on the 11 and 12 June. Visual surveys of six low density strata were flown with a fixed wing aircraft on the 9 and 11 June. We used a helicopter to complete composition surveys in high, medium and low density strata from the 11-15 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 67,246 ± 9904 (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 55,593 ± 8813 (SE) breeding females in the survey area. The high density stratum contributed 92% of the estimated number of total caribou and 98% of the breeding females. The proportion of breeding females in the high density strata was 88% ± 3% (SE). The estimate of breeding females in June 2006 was relatively precise (CV = 16%), and substantiates the results of the June 2003 Bathurst caribou survey. The June 2006 survey confirms that the abundance of breeding females in the Bathurst herd of barren-ground-caribou has significantly declined since 1986.

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INTRODUCTION

The Bathurst caribou herd is named after Bathurst Inlet, near where calving has traditionally occurred. The annual range of the Bathurst herd is extensive, occurring mostly within the Northwest Territories and Nunavut, but also extending into northern Saskatchewan (Figure 1). Ten aboriginal communities, on or near the range, rely on the herd as a source of country food (Bathurst Caribou Management Planning Committee 2004). The Bathurst herd also provides important economic opportunities for commercial harvesting and the guide/outfitting industry (Ashley 2000), and is 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 is one of the most heavily hunted barren-ground caribou herds in the Northwest Territories (Case *et al.* 1996).

In addition to harvest management, issues and concerns regarding the cumulative effects of land use on sensitive habitats and industrial development within the annual range, and the broader implications of environmental contaminants and climate change necessitate a coordinated approach among a broad group of users and stakeholders, government agencies, and co-management boards. Although the current structure and consultation process among governments and co-management boards is under review (Government of the Northwest Territories 2006), core monitoring actions are necessary to continually update information and assist with developing management options.

The current framework for developing coordinated management of the Bathurst herd is directed by the Bathurst Caribou Management Planning Committee. The Bathurst Caribou Management Plan (Bathurst Caribou Management Planning Committee 2004) provides the current *de facto* guideline document to monitor and manage the herd.

One of the fundamental monitoring actions for the Bathurst herd is to determine the size of the herd every six years when the population is considered stable. The survey interval is reduced to four years when the herd has started to decline in size, and reduced to three years when the population is considered low and unlikely to increase in size without management intervention (Bathurst Caribou Management Planning Committee 2004).

The most recent survey of the Bathurst herd was completed in June 2003 (Gunn *et al.* 2005), and showed that the estimated number of breeding females had declined significantly since 1986. Because of the declining trend and concern regarding the low population status of the Bathurst herd, the management plan recommends a three year survey interval and the Government of the Northwest Territories committed to doing a survey in June 2006 (Government of the Northwest Territories 2006).

Calving ground surveys of barren-ground caribou

A defining characteristic of migratory barren-ground caribou *(Rangifer tarandus groenlandicus)* is the annual return of breeding females to a calving ground (Thomas 1969, Skoog 1968, Gunn and Miller 1986). An annual calving ground is defined as the area occupied by parturient caribou in a particular year from calf birth through the initiation of foraging by calves, which occurs at about three weeks of age (Russell *et al.* 2002). The return of barren-ground caribou cows to an annual calving ground is a predictable migratory behavior at the seasonal and landscape scale; although predictability of the timing of calving and spatial extent of an annual calving ground is lost at finer scales of temporal and spatial resolution. For example, we can predict that an annual calving ground will likely occur within the extent of calving[1] defined from the previous 10 years, but we are not able to predict exactly where the annual concentrated calving area[2] will occur. Similarly, we can predict that cows from a herd will be calving in early to mid-June with reasonable accuracy and repeatability, but we are not able to predict that peak of calving will occur on the 8-9 June, versus the 11-12 June in a given year. Consequently, the combined uses of aerial surveys and satellite telemetry have provided essential techniques for monitoring the movement and distribution of breeding females during the calving period, and for improving our understanding of the spatial and temporal dynamics of barren-ground caribou calving grounds.

Although the annual calving ground from subsequent years may overlap spatially, over decadal periods the annual calving grounds may shift across the landscape (see Sutherland and Gunn 1996, Gunn and Sutherland 1997, Russell *et al.* 2002). Nevertheless, the traditional use of a calving ground has facilitated development of the calving ground survey as a logistically feasible and

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[1] "The outer perimeter of all known annual calving grounds" (p. 31 in Russell *et al.* 2002)
[2] "The area of relatively high use within an annual calving ground" (p. 31 in Russell *et al.* 2002)

biologically relevant inventory method (Heard 1985, Heard 1987a and 1987b). The feasibility of the calving ground survey technique is due to the gregarious behavior of breeding females and their fidelity to a traditional calving ground. Those behaviors result in high densities of caribou within a small area, relative to the annual range of the caribou herd. The relevance of the calving ground survey technique is linked to the assertion that the abundance of breeding females is a meaningful index of total herd size, from which we can infer where the herd is within its long-term population cycle (e.g. increasing/high, declining, or low).

In this report, we describe the calving ground survey of the Bathurst herd in June 2006. To ensure comparability with previous surveys, we estimated the number of breeding females on the annual calving ground using the calving ground photo-census method. This technique was developed and tested since the early 1980s (Heard 1985, Williams 1994). The motivation for the application of photography was to reduce bias (increase accuracy). As well as reducing bias, effort has been made to increase the precision of estimates. The 2003 census of the Bathurst herd describes the changes made to survey design to increase precision (Gunn et al. 2005).

Our objectives for the survey in June 2006 were:

1) obtain an estimate for the number of breeding females on the annual calving ground with a coefficient of variation of ≤ 15%;
2) determine the trend in number of breeding females on the calving grounds since 1986;

3) estimate the ratio of breeding females : total females at the peak of calving as an indicator of pregnancy rates comparable to previous years; and

4) describe the spatial extent of the annual calving ground relative to previous years.

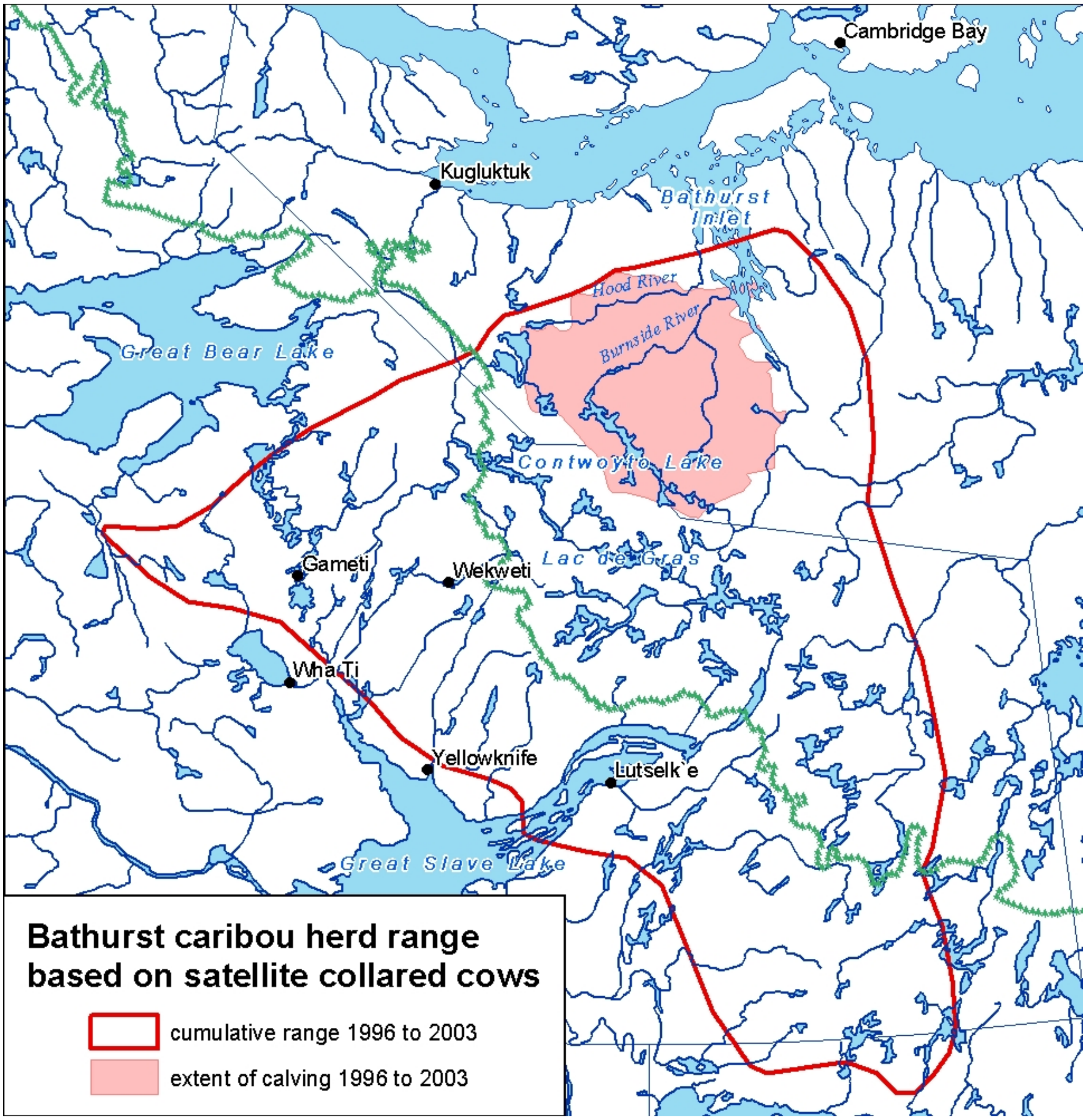

Figure 1. Herd range of Bathurst caribou based on satellite collared cows from 1996 to 2003 (p.8 in Bathurst Caribou Management Planning Committee 2004)

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), and Gunn *et al.* (1997 and 2005), have shown that the extent of calving has occurred west of Bathurst Inlet (Figure 1) since the mid- 1990s.

Satellite collars and early reconnaissance

We anticipated that the annual calving ground would be in or near the same area as in recent years – west of Bathurst Inlet and south of the Hood River. However, starting in mid-May 2006, we specifically monitored the movements and observed the locations of the 14 satellite-collared Bathurst caribou cows to track their progress relative to the extent of calving.

In addition to monitoring the satellite collars, we communicated with another biologist who was conducting aerial surveys as part of a baseline monitoring program for caribou in the High Lake Project study area[3] for Wolfden Resources Inc. (K. Poole pers. comm., Wolfden Resources Inc. 2006). On the 31 May, we conducted an initial reconnaissance flight in a Cessna Caravan using

[3] The study area is located west of Bathurst Inlet, an area *ca.* 75 km wide between 110° W and 112° W, and bounded by the arctic coast in the north and the Hood River in the south (see Figure 21 in this report, and Figure 3.3-1 in Wolfden Resources Inc. 2006).

standard parameters for visual aerial surveys for caribou; survey altitude was 120 m above ground level (agl), survey speed was *ca.* 160 kph, and total strip width was 0.8 km (400 m strip width per side). We mobilized crews and positioned survey aircraft based on the distribution of satellite-collared cows and observations of antlered caribou cows from these initial reconnaissance surveys. Our base of operations for the survey was Lupin Mine, Echo Bay Mines Ltd. (65° 45.2' N 111° 14.2' W). A Cessna 185 and survey crew arrived at Lupin Mine on the 3 June, while the second aircraft – a Cessna 206 – and additional crew members arrived on the 6 June.

Aerial systematic reconnaissance surveys

We used pieces of wooden doweling (*ca.* 1.5 cm diameter, and *ca.* 50 cm long) on the wing struts of the respective survey aircraft to demarcate the outer edge of the strip. These strip markers were positioned, using the methods outlined by Norton-Griffiths (1978), and fixed to the wing struts using black electrical tape and duct tape. We checked the strip markers by having the pilot fly the aircraft at survey altitude along an axis perpendicular to a known distance on the ground. Left and right observers verified the strip marker positions on the wing struts against the known distance markers on the ground, or adjusted them as necessary after the plane was back on the ground. At Lupin Mine, the distance between the western edge of the northern runway apron and the eastern edge of the radio operator's office building was approximately 400 m.

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

1) delineate the annual calving ground based on relative densities and composition of caribou; and
2) stratify the annual calving ground for a photo-census of high and medium density strata and a visual survey of low density strata.

We used the approach described by Gunn *et al.* (2005), 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%.

We used navigation and data management techniques that combined handheld Global Positioning System units (Garmin GPS 76) with OziExplorer GPS mapping software (Newman 2006). Observational data were compiled and analyzed in Microsoft Excel and OziExplorer (see Appendix A, p. 55 in Gunn *et al.* 2005) to calculate densities within 10 km segments, and 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 National Topographic Series (NTS) 1:250 000 scale digital maps to analyze patterns of caribou density and composition, and to plan work for the following day.

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, including a 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 calving caribou. Due to inclement weather on the 4 and 5 June, the systematic survey was delayed until the 6 June. 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.

On the 7 June, we extended the western and eastern coverage of the surveyed area to confirm that we did not miss breeding females. On the 8 June, we resurveyed the central portion of the surveyed area that included the high density calving area. Our first aim was to evaluate changes in density and distribution, and to delineate and stratify the concentrated calving area observed on the 6 June. Our second aim was to complete the northern coverage of several lines (transects 14-18) that, in retrospect, appeared to be truncated prematurely based on observations from 6 June of caribou in the northern-most segments of transects 13 and 14. Although it was unlikely that we had missed antlered caribou or calves along the northern area, we thought it was equally important to carefully assess the potential presence of a gap in coverage.

To determine whether the peak of calving had occurred, we also estimated the proportion of calves in the concentrated area of calving, as determined by observations from the systematic survey on the 6 June. On the 7 and 8 June, while surveying transect 14, sections 8 to 11, observers recorded the estimated proportion of calves along with the estimated group size of all 1^+-year-old caribou. Those data were used at the time to evaluate whether we had observed 50% or more calves per 1^+-year-old caribou. To estimate the proportion of breeding females that had calved, we later adjusted the observed group sizes of 1^+-year-old caribou using the composition data from the high density strata.

Stratification of the annual calving ground for photographic and visual surveys

Our survey design for the annual calving ground was based on a combination of photo-census techniques for high and medium density strata, and standard visual aerial survey techniques for low density strata. Our primary basis for stratification was caribou densities observed within the 10 km segments during the aerial systematic reconnaissance surveys. We delineated strata by enclosing adjacent segments 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 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.

We oriented transects perpendicular to the long axis of the stratum and parallel to the observed gradient in caribou density. This orientation maximized the sample size of transects for a given stratum size, and also acted to minimize variance between transects because they were oriented along the density gradient. We determined the allocation of survey effort, i.e., the number of available photographs, by estimating mean population size and variances for each stratum (Heard 1987a, and see Appendix C). We used data from the systematic reconnaissance surveys to estimate density of caribou on transects, population size ($\hat{N}$) and precision (Coefficient of Variation, CV) for each of the strata. Optimal allocation was estimated using estimated population size ($\hat{N}$) and the estimated standard error (SE) of population size (Appendix C).

On the evening of the 8 June, we delineated a single high density stratum with two adjacent medium density survey strata for photographic surveys. We also delineated two low density strata. Our assessment of density estimates indicated that the optimal allocation would place the majority of photographs into the single large high density stratum (18 transects), with 9 transects in each of the two medium density strata (Appendix C).

Aerial systematic survey for visual estimation of caribou in low density strata

On 9 June, we used a Cessna 206 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).

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

We contracted Geographic Air Survey Ltd, Edmonton, AB, to do the photographic survey. 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 cameraman. 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. 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.

On the evening of the 8 June, after completing the survey design (delineation of strata and allocation of effort), we sent electronic files with stratum boundaries and start / end coordinates for all transects in each of the high and medium density strata to Geographic Air Survey's office in Edmonton. On the morning of 9 June, the survey crew arrived at Lupin Mine to start the photo-census. 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.

Due to the weather delay of a day in the photo-census, we flew additional reconnaissance flights on 10 June to confirm the original stratification. We flew boundaries of the high density strata in a step-wise manner, whereby we alternatively flew perpendicular and parallel to the survey boundary. Each length of a perpendicular and parallel 'step' was 10 km long, thereby allowing us to compare observed caribou densities with those from the 10 km segments in the systematic surveys. We used the observed densities along each 'step' to adjust the boundaries of the high density stratum and a medium density stratum, i.e., boundaries were extended where we observed higher densities and reduced where densities were lower. Following these minor adjustments of the high and medium density strata, the complete photo-census was conducted and completed on the 11 and 12 June.

As a result of the weather-related delay and the small-scale shifts we observed in caribou distribution, we also added four additional low density survey strata to ensure that we would account for any movements of caribou out of the high and medium density strata. Three (L-I, L-III, and L-IV) of the four strata we added were adjacent to high and/or medium density strata. We added the fourth low density strata (L-VI) to extend coverage to the east in the unlikely event that caribou moved east of L-V (see Figure 17). On the 11 June, we used two fixed-wing aircraft to survey the remaining low density strata. On the 12 June, we used the survey aircraft (C-185) to fly systematic surveys of the areas lying to the south of Bathurst Inlet and east of the photo and visual strata.

Sex and age composition survey

In the early evening of the 11 June, we started composition surveys 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 within a few days of the photo and visual surveys, our main priority was to collect composition data from high and medium photographic strata on the 11-13 June. Remaining time was allocated for adjacent low density visual strata on the 14-15 June. We used the midpoints of the 10 x 10 km segments within a stratum to distribute our search effort. We used a Bell Jet Ranger 206B 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 approached the caribou on foot. One person classified caribou using binoculars or a spotting scope and the second person recorded 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 classified caribou from the helicopter. For groups larger than 30, the helicopter would land and field crews used 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

<u>Data from satellite-collared cows</u>

Location data from satellite-collared cows were available every five days. During the period for which we wanted to measure the daily distance traveled (22 May – 30 June), location data for three of the collared cows became available daily from 31 May.

We calculated distance travelled between successive locations 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).

To calculate daily distance travelled, we divided the great circle distance by the number of days elapsed between successive locations (usually five days, but one day for three caribou for some dates). 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.

<u>Data from aerial surveys</u>

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. 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 three low density strata (L-II, L-III, and L-IV) due to time restrictions. Since the estimates of total 1+-year-old caribou for L-II and L-III were less than 100, we did not use those data in the estimate of breeding females. We used the proportion of breeding females calculated from composition data in L-VI to estimate the number of breeding females in L-VI.

Trend analyses

We incorporated the population estimate of breeding females from the 2006 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 2006 (see Appendix D):

1) weighted least squares analysis was used to estimate trend from the time series data;
2) Monte Carlo simulation techniques were used to estimate the variance in trend that resulted from individual variances of each of the surveys; and
3) a one-tailed t-test was used to determine whether the population of breeding females had declined since the last survey, i.e., was the estimate of breeding females in 2006 (T_{2006}) significantly lower than the 2003 estimate (T_{2003})? We also conducted a power analysis of the one-tailed t-test (Appendix E).

To understand implications of different population trends on the design of the next calving ground survey in 2009, we also simulated different values of *r* on future population trend (Appendix E). We developed recommendations for the next survey based on the simulations and power analysis.

RESULTS

Satellite collars and early reconnaissance survey

The locations of satellite-collared Bathurst cows from mid- to late May showed that 10 out of 14 collared cows traveled north into the Hood River drainage and then by early to mid-June, 13 of 14 collared cows were moving towards the Burnside River (Figure 2). An aerial survey of the High Lake Project study area on the 24 May and a ferry flight on the 26 May (Appendix A) confirmed that widespread calving had not occurred in the vicinity of the satellite-collared cows (K. Poole pers. comm., Table A2.5-1 and Figure A2.5-12 in Wolfden Resources Inc. 2006). An aerial reconnaissance survey on the 31 May provided additional information on the distribution of caribou and the timing of calving – of 2237 caribou observed, only 35 newborn calves were observed (Figure 3, and see Appendix B for flight times and schedules of survey aircraft).

The average daily movement rates of satellite-collared cows showed a marked reduction during the last two weeks in May. The reduced daily movement rates continued through early June with the nadir, 3.2 ± 2.7 km (SD), occurring on the 11 June (Figure 4). Average daily movements increased constantly from the 16 June to the end of the month (Figure 4).

Changes in the area of minimum convex polygons (MCP) for satellite-collared cow locations on a particular day showed the spatial dispersion of the cows from late May through June (Figure 5). In late May, the MCP was 4878 km^2. During the first two week in June, the MCP was reduced to *ca.* 25% of the area observed in late May. The MCP varied between 154 and 526 km^2 from 11 – 26 June, and increased to 902 km^2 during the last week in June (Figure 5).

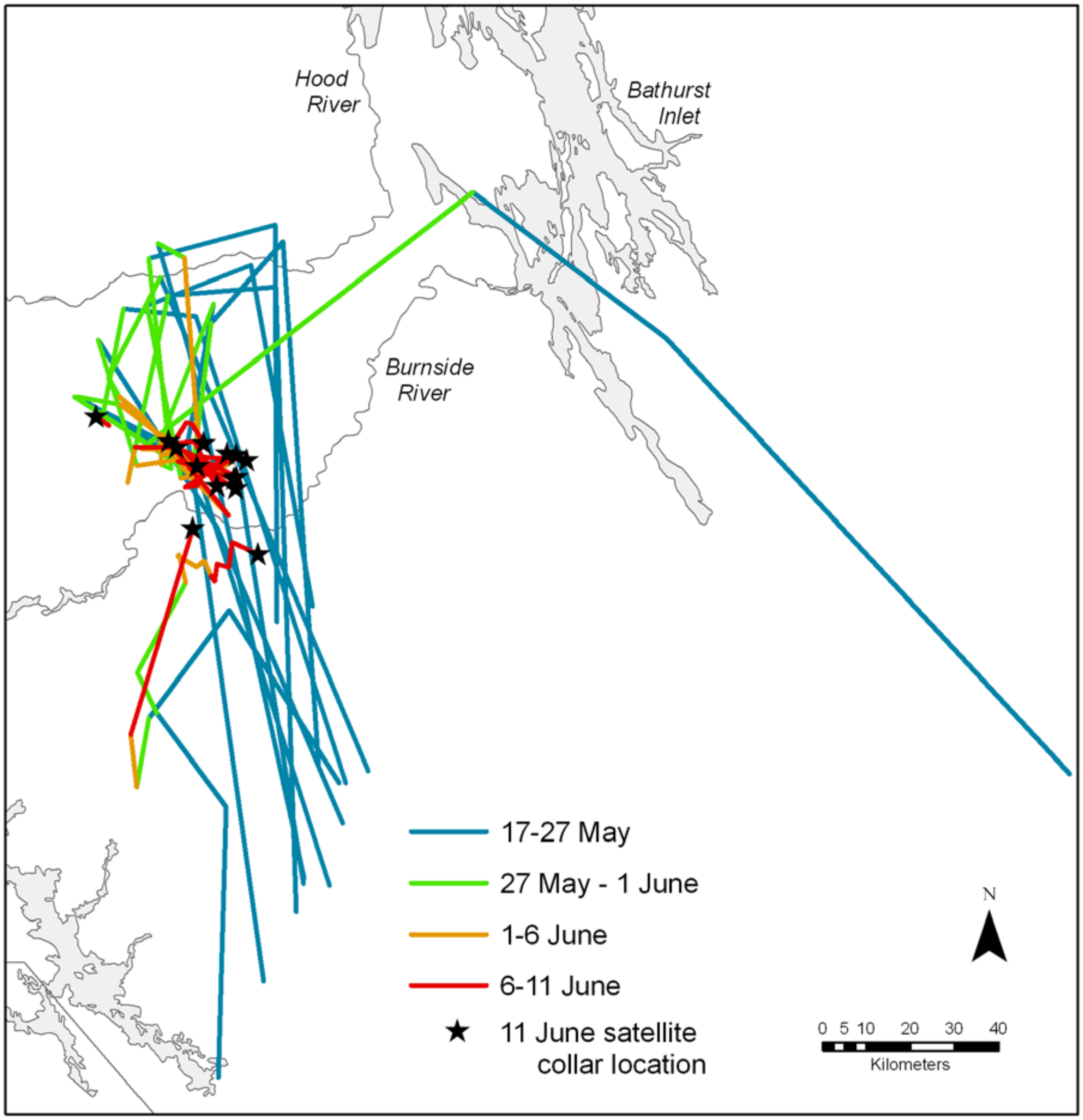

Figure 2. Movements of satellite collared Bathurst caribou cows from 17 May to 11 June 2006.

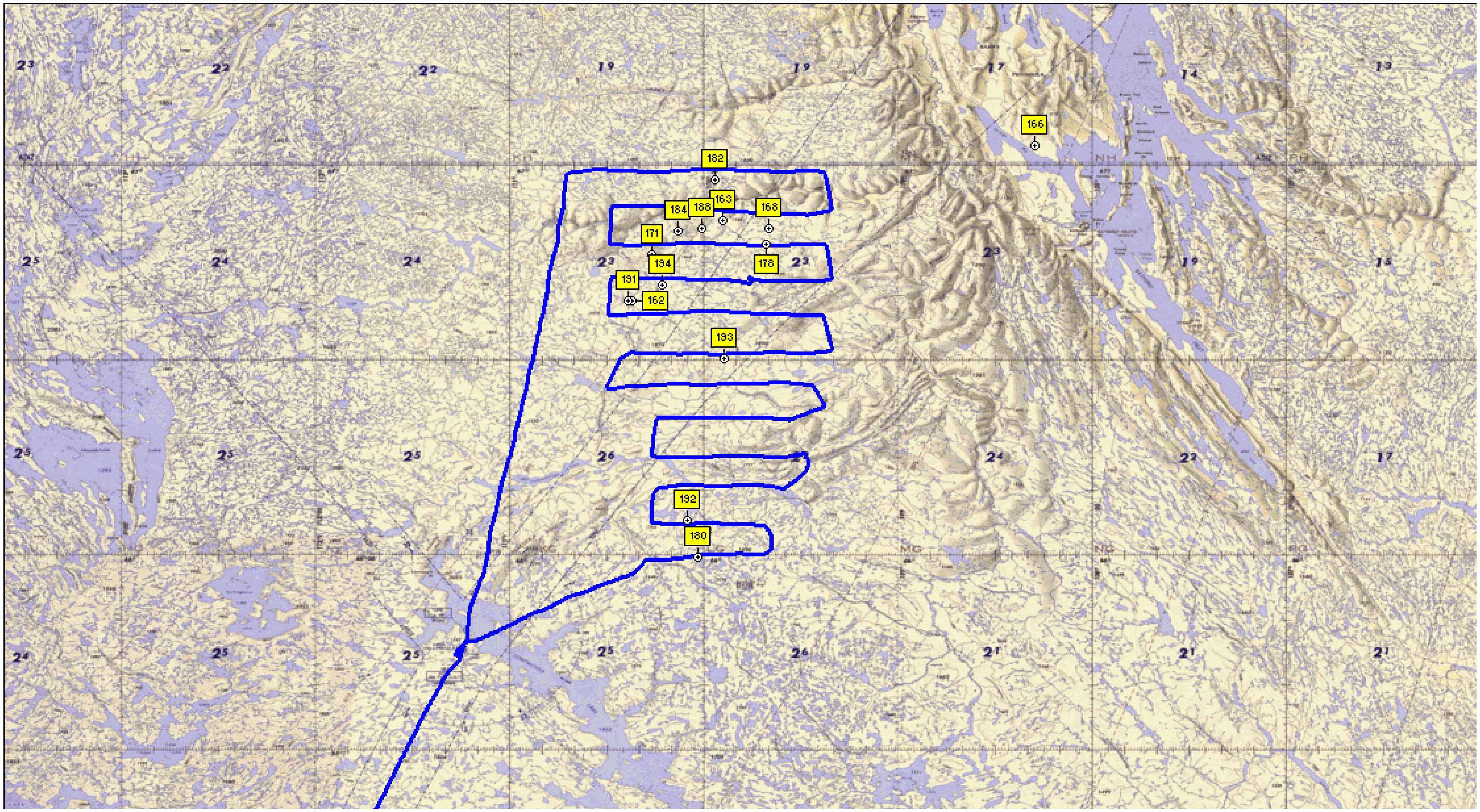

Figure 3. Flight path from a reconnaissance survey on the 31 May 2006. Survey coverage was based on locations of satellite-collared Bathurst caribou cows. Collar locations were from the 27 May 2006, except collars 192, 193, and 194 which were locations from the 31 May 2006. A total of 2237 1^{+}-year-old caribou and 37 calves were observed.

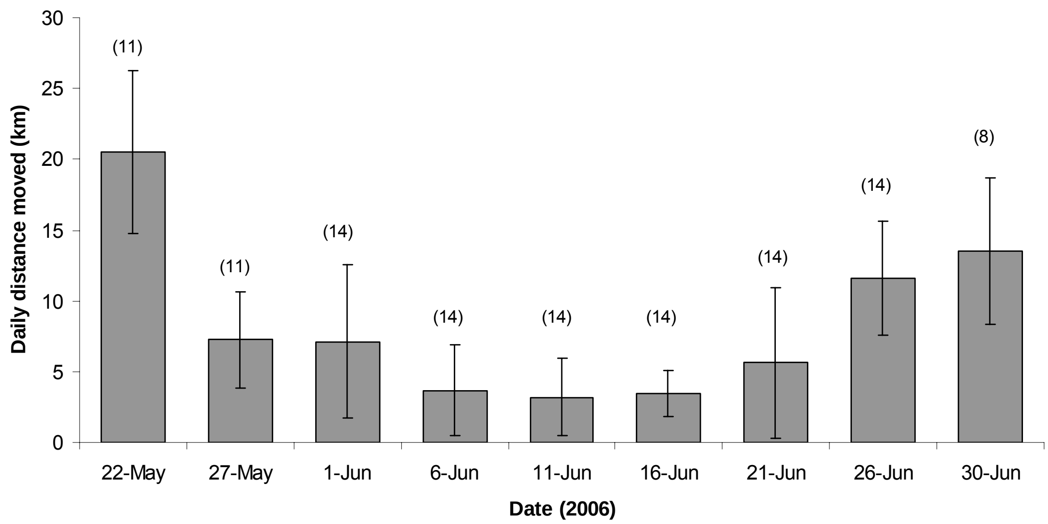

Figure 4. Average daily distance (km ± 1 standard deviation) moved by satellite-collared Bathurst caribou cows during late May and June 2006. Sample sizes shown in parentheses.

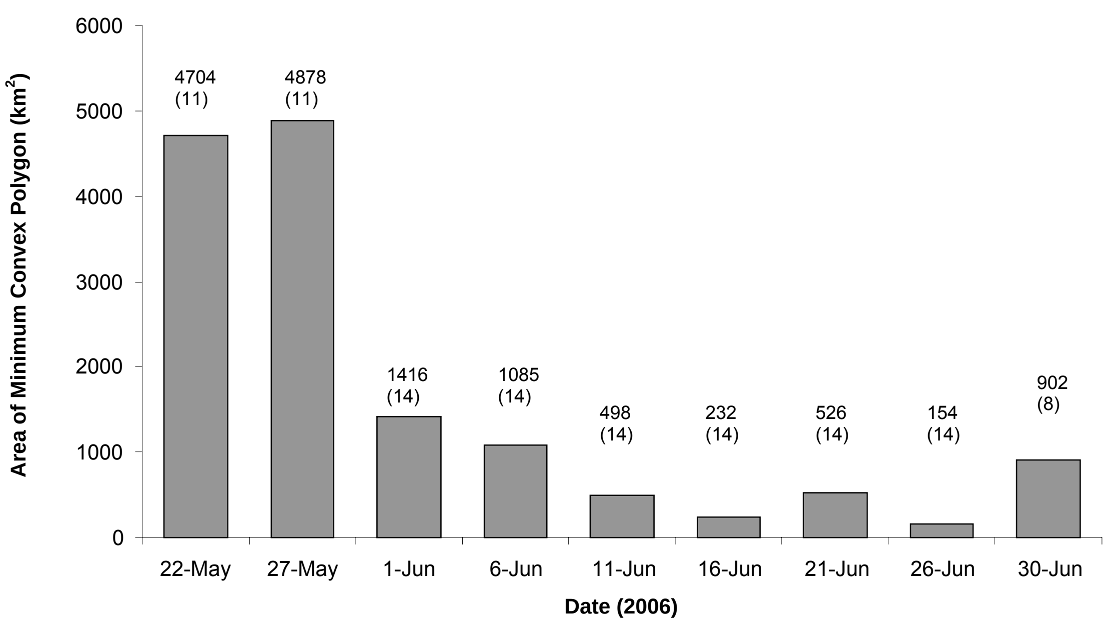

Figure 5. Area (km^2) of minimum convex polygons (MCP) for satellite-collared Bathurst caribou cows from late May through June 2006. Calculated MCP areas shown above bars with sample sizes in parentheses.

Aerial systematic reconnaissance surveys (6 -7 June and 8 June 2006)

On the 6 and 7 June 2006, we flew 2990 km of transects and counted 961 caribou and 43 calves (5%) across the surveyed area (Figure 6). Of the 299 10 kmtransect segments, 3 (1%) were high density, 15 (5%) were medium density and 27 (9%) were low density (Table 1). The high and medium density segments represented 47% and 44% respectively of all the caribou observed. The highest densities of caribou were within the central portion of the surveyed area, along the Burnside River between Bellanca Rapids to the west and Kuuvik Lake to the east (Figure 7). The locations of the high density segments were associated with the distribution of most of the satellite-collared caribou cows (Figures 6 and 7). The spatial distribution of 10 kmsegments that had at least one newborn calf was also clumped and closely associated with the high density segments and the locations of the satellite-collared cows (Figures 6, 7 and 8). The distribution of antlered cows was comparatively sporadic and dispersed through the surveyed area (Figure 8). On the 7 June, while resurveying density segments (8-11) on transect 14[4], we observed over 559 1^{+}-year-old caribou in 17 groups and estimated that there were *ca.* 22% (± 4% SE) calves (Appendix L).

On the 8 June, we reflew the central portion of the initial systematic survey area (flown on the 6 and 7 June) to confirm the extent of the concentrated calving area and to monitor changes in distribution (Figure 9). We flew a total of 1040 km of

[4] Transect 14 can be seen on Figure 7; it has three high density segments shown in red. Segment 11 is the northern-most high density segment. Segments 10 through 8 are located sequentially to the south.

transects and counted 3840 caribou and 15 calves[5] (Table 1, Figure 9). Although only six of the 104 (6%) 10 kmsegments were classified as high density, they represented *ca.* 88% of the total caribou observed (Table 1, Figure 10).

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[5] In order to minimize counting errors, we only counted calves when the densities were approximately $\leq$ 5 caribou / km^2. We did not attempt to count calves in the higher density segments but instead estimated proportions of cows with calves.

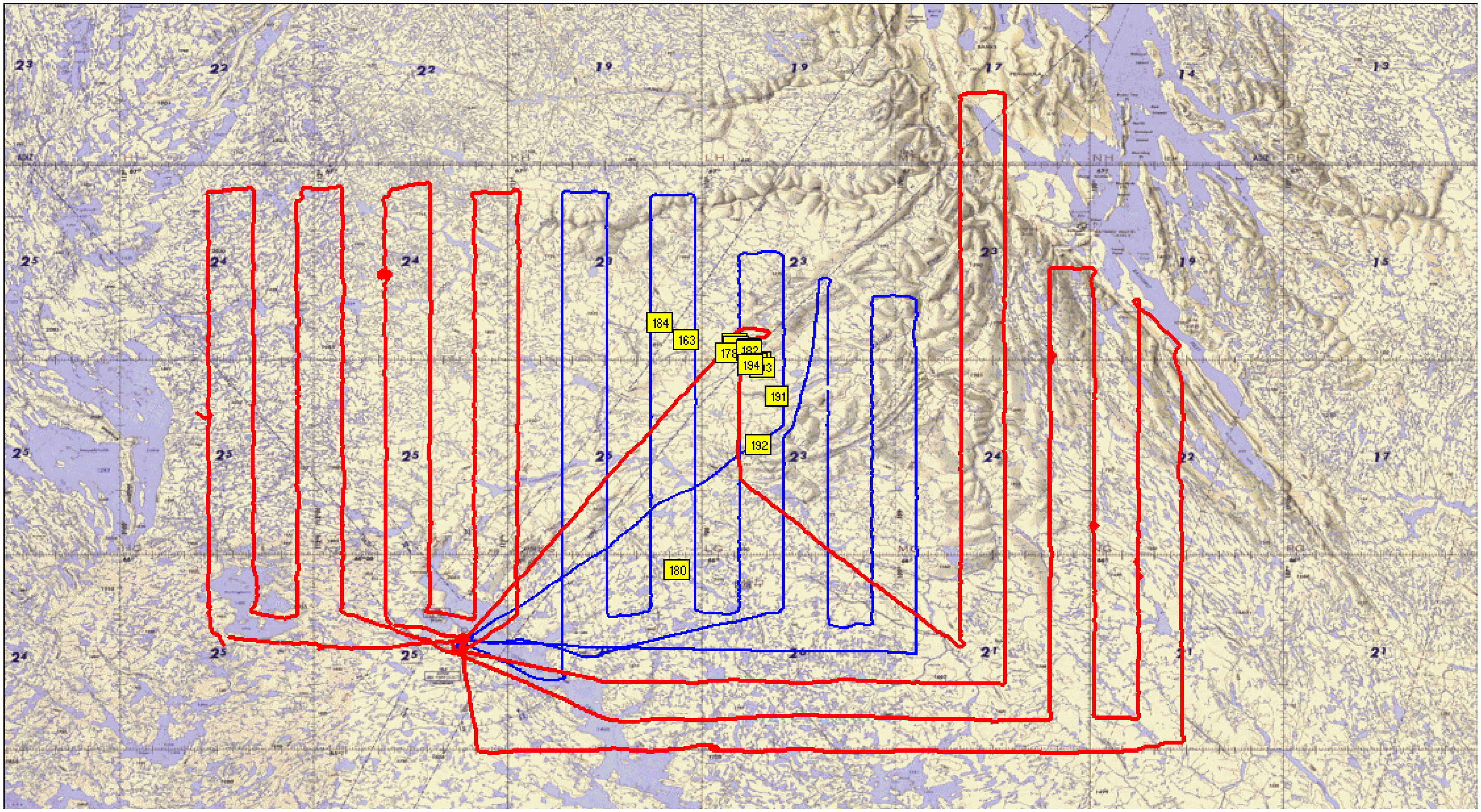


Figure 6. Flight lines from initial systematic survey to delineate annual calving ground for Bathurst caribou herd on 6 (blue) and 7 (red) June 2006. Locations of satellite-collared cows (n = 14) on the 6 June are shown by yellow boxes.

The spatial distribution of newborn calves was centered on the high density segments with a slight northward extension beyond the highest densities of caribou (Figures 10 and 11). When we reflew the high density segments (8-11) on transect 14[6], we counted over 456 caribou in 11 groups and estimated that there were 37% (± 3% SE) calves (Appendix L). We observed that most cows with calves had hard antlers. Compared to the 6 and 7 June, the number of high density segments increased from three to six on the 8 June (Table 1, Figures 10 and 12). Similarly, the average density within high density segments increased from 18.8 caribou / km^2 (451 caribou / 3 segments) to 70.2 caribou / km^2 (3368 caribou / 6 segments) caribou (Table 1, Figures 10 and 12).

Table 1. Transect segments surveyed and caribou counted during systematic reconnaissance surveys of the Bathurst calving ground, June 2006.

Date	Density Class	10-km Segments (n)	10-km Segments (%)	Caribou Counted (n)	Caribou Counted (%)
6 & 7 June	No Caribou	254	84.9%	0	0.0%
	Low	27	9.0%	87	9.1%
	Medium	15	5.0%	423	44.0%
	High	3	1.0%	451	46.9%
	Sum	299	100.0%	961	100.0%
8 June	No Caribou	59	56.7%	0	0.0%
	Low	29	27.9%	94	2.4%
	Medium	10	9.6%	378	9.8%
	High	6	5.8%	3368	87.7%
	Sum	104	100.0%	3840	100.0%

[6] Transect 14 can be seen on Figure 10; it has three high density segments shown in red. Segment 11 is the northern-most high density segment. Segments 10 through 8 are located sequentially to the south.

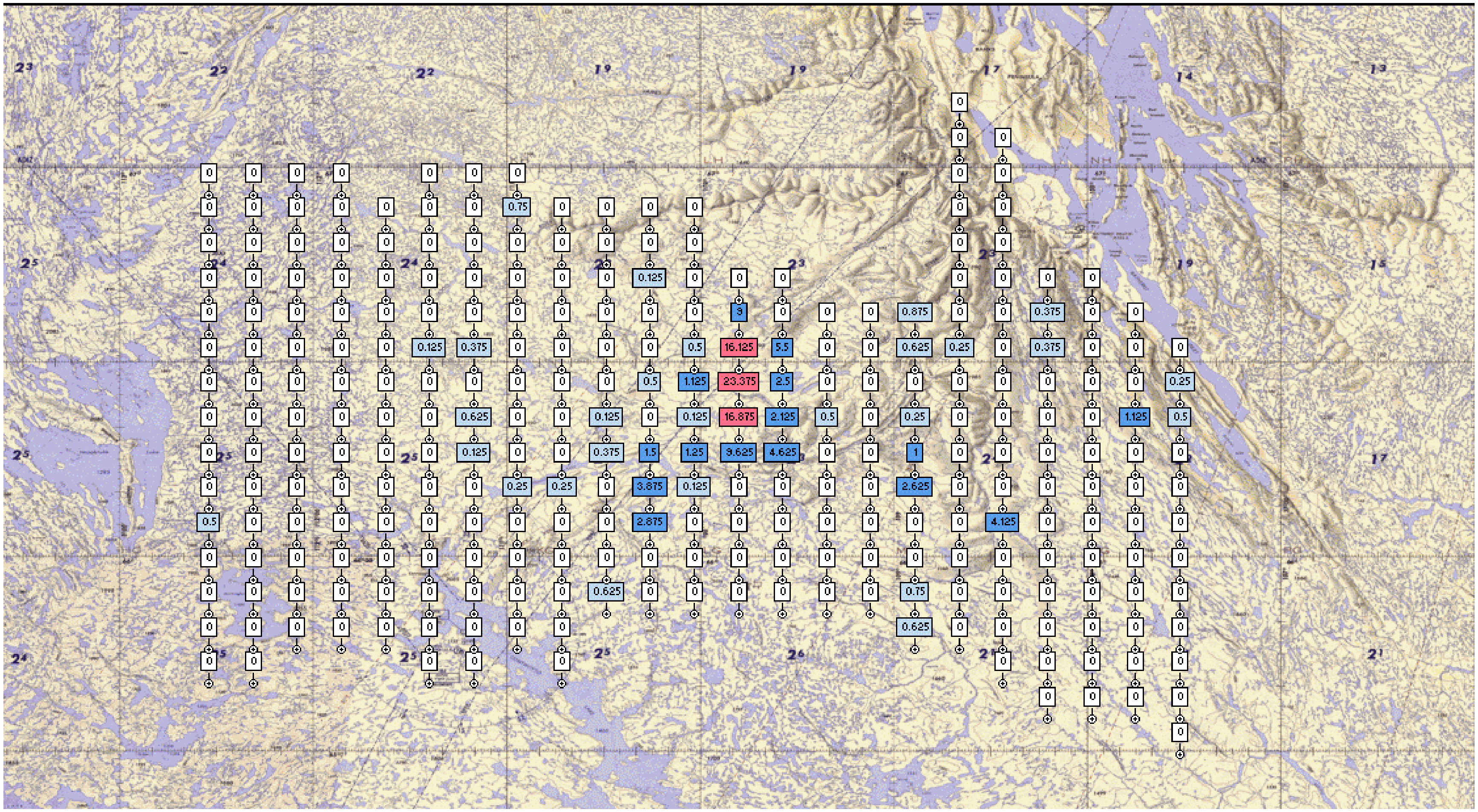


Figure 7. Observed densities of caribou (>1 year old) during an initial systematic survey on 6 and 7 June 2006. Each cell represents a 10 km segment of a survey transect. Label colors represent density classes: White = flown and no caribou observed, Light blue = 0.1 – 0.99 caribou/km^2, Dark blue = 1.0 – 9.9 caribou/km^2 and Red = ≥10 caribou/km^2. Numbers within cell represent actual caribou densities for each 10 km segment.

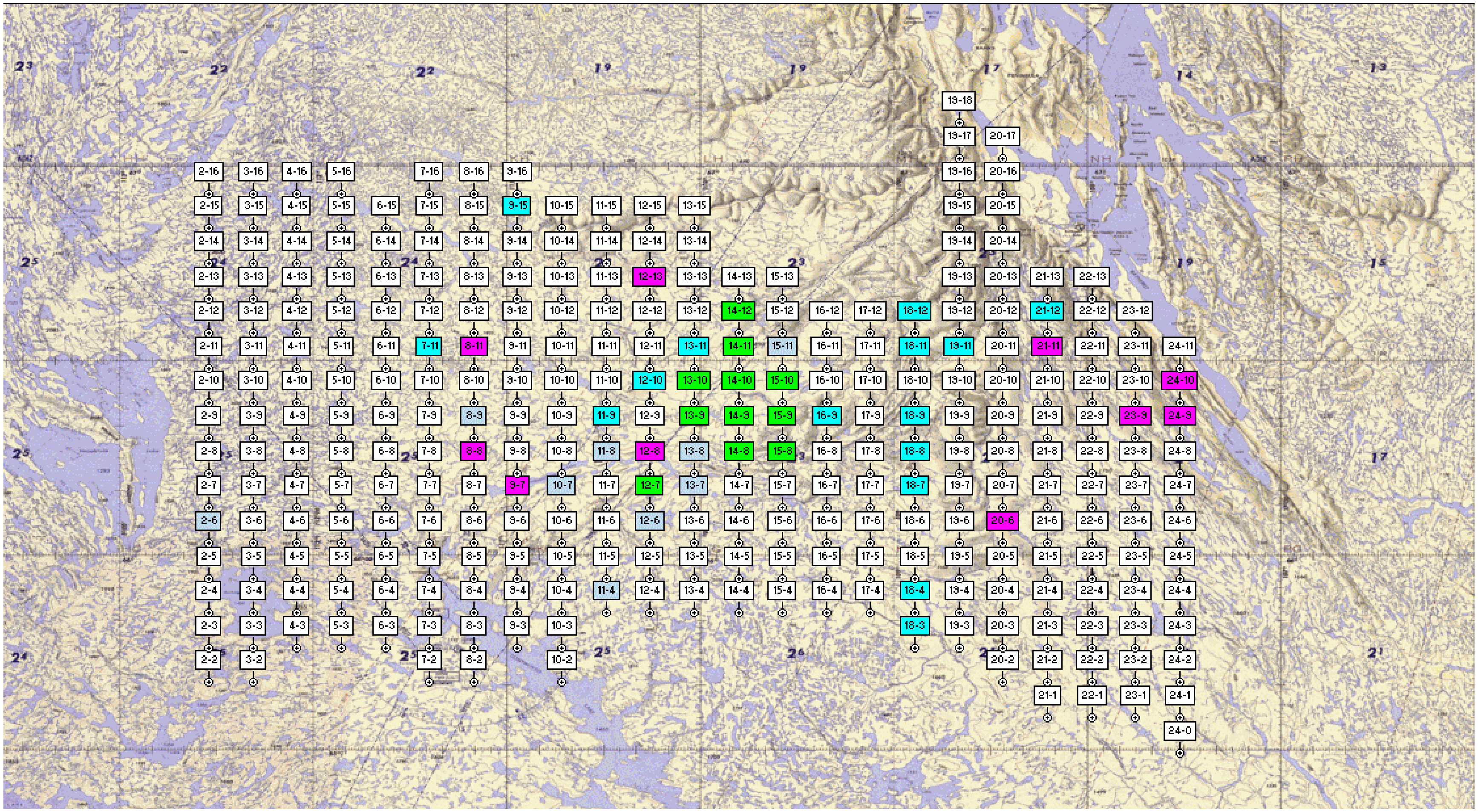


Figure 8. Observed composition of caribou groups during an initial systematic survey on 6 and 7 June 2006. Each cell represents a 10 km segment of a survey transect and cell values indicate transect and segment numbers. Label colors represent composition classes: White = flown and no caribou observed; Aqua = cows with hard antlers; Lime = cow-calf groups; Purple = non-antlered caribou; Light Blue = unclassified groups.

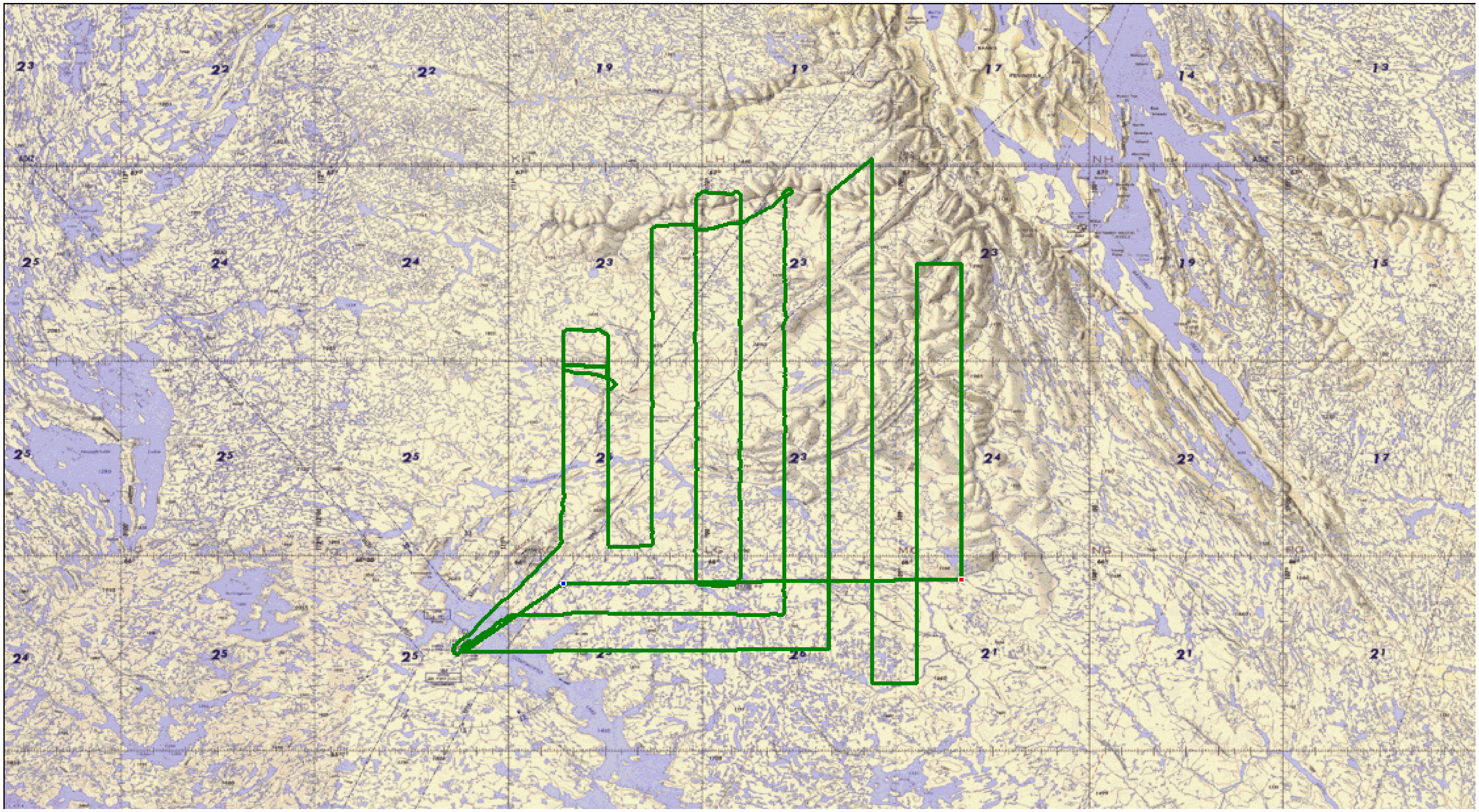


Figure 9. Flight lines from systematic survey to confirm extent of the annual calving ground for Bathurst caribou herd on 8 June 2006.

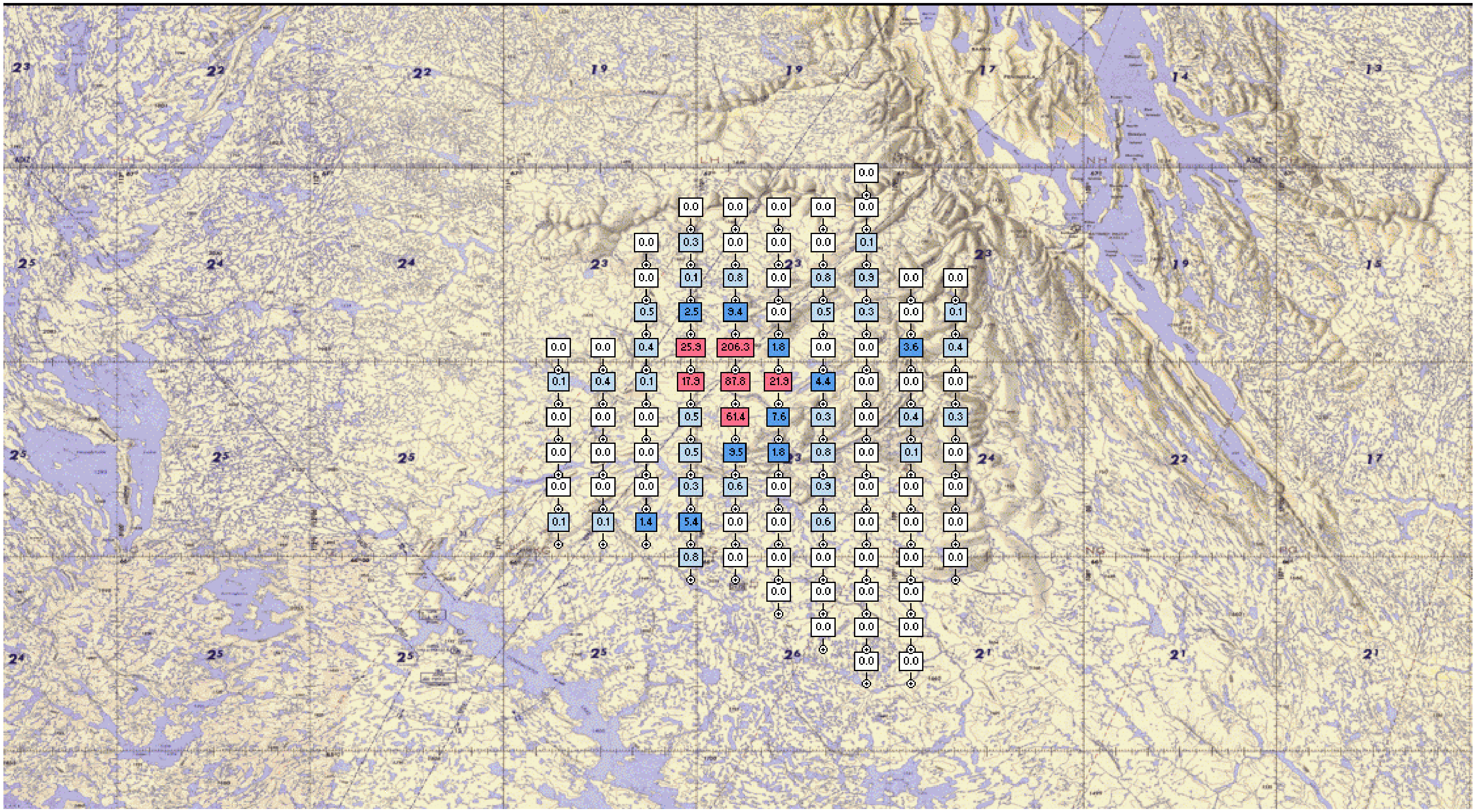


Figure 10. Observed densities of caribou (>1 year old) during a systematic survey on 8 June 2006. Each cell represents a 10 km segment of a survey transect. Label colors represent density classes: White = flown and no caribou observed, Light blue = 0.1 – 0.99 caribou/km^2, Dark blue = 1.0 – 9.9 caribou/km^2 and Red = ≥10 caribou/km^2. Numbers within cell represent actual caribou densities for each 10 km segment.

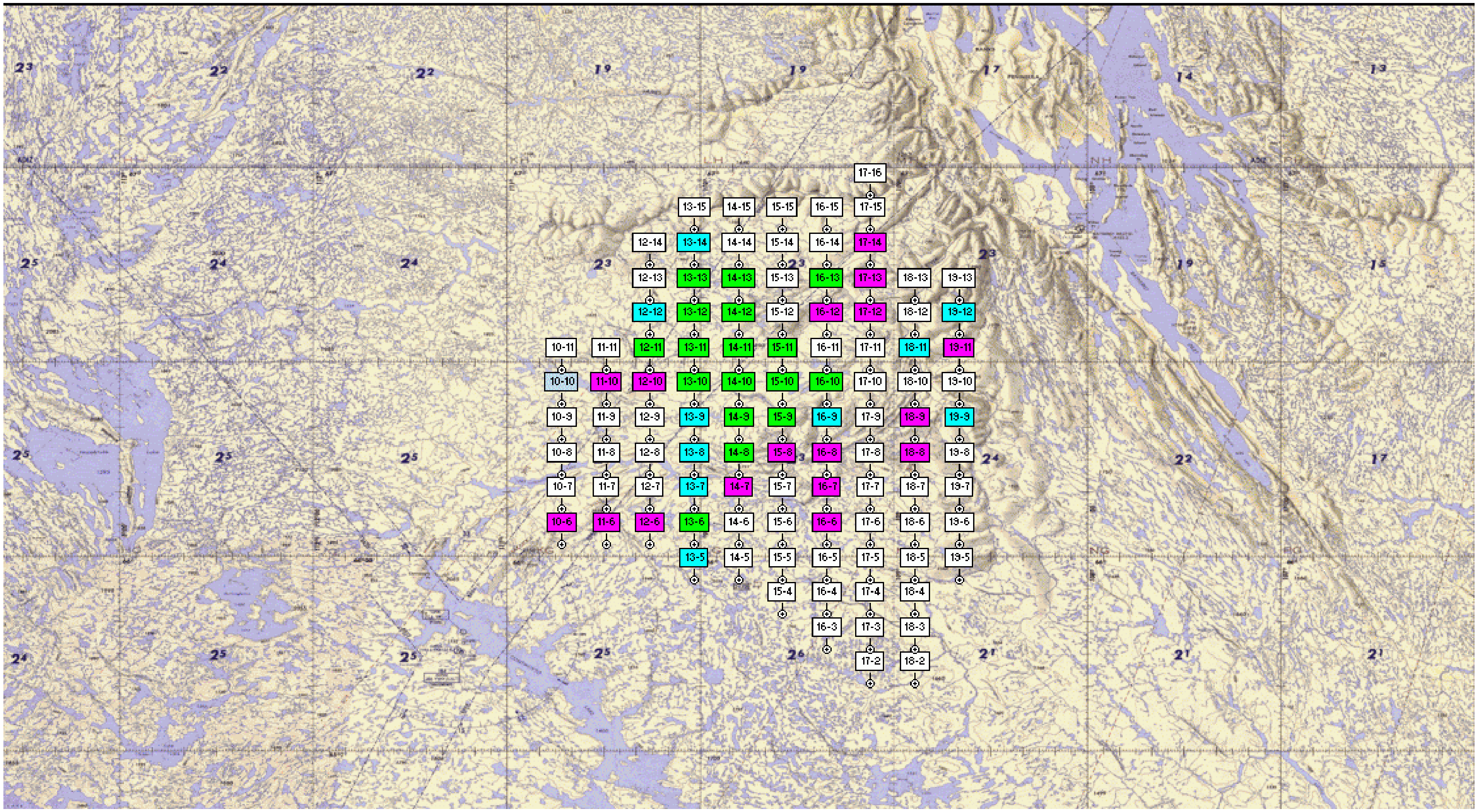


Figure 11. Composition of caribou groups observed during a systematic survey on 8 June 2006. Each cell represents a 10 km segment of a survey transect and cell values show the number of caribou (≥1 year old) per km^2. Label colors represent composition classes: White = flown and no caribou observed; Aqua = cows with hard antlers; Lime = cow-calf groups; Purple = non-antlered caribou; Light Blue = unclassified groups.

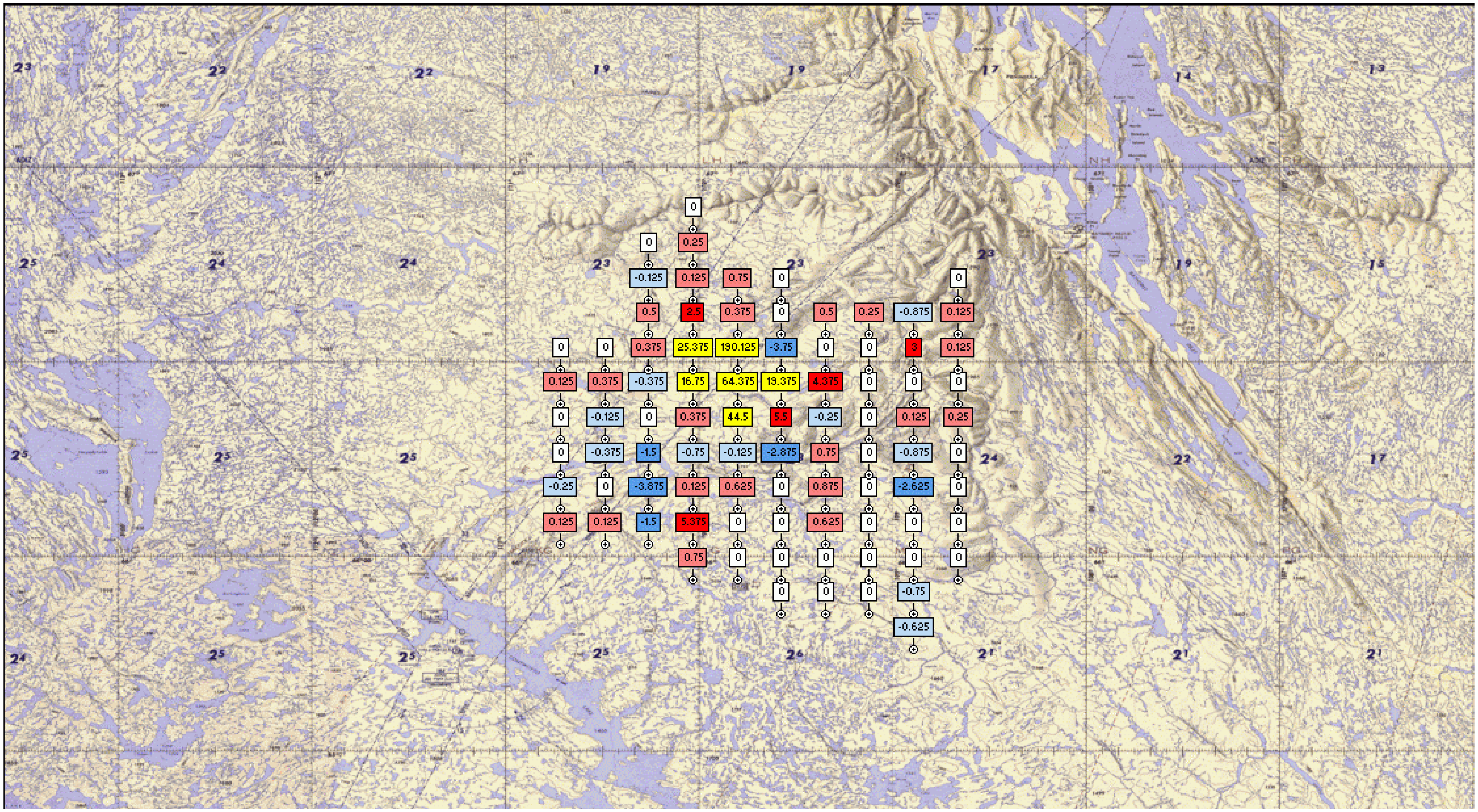
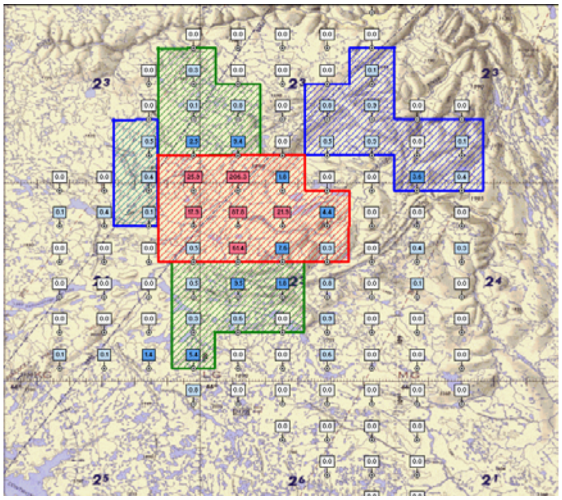


Figure 12. Change in caribou density within 10 km transect segments between 6/7 June and 8 June 2006. White = no change, Light blue = decreasing density (-0.1 – -0.9 caribou/km^2) Dark blue = decreasing density (-1.0 – -10.0 caribou/km^2), Pink = increasing density (0.1 – 0.9 caribou/km^2), Red = increasing density (1.0 – 9.9 caribou/km^2), Yellow = increasing density (10$^+$ caribou/km^2).

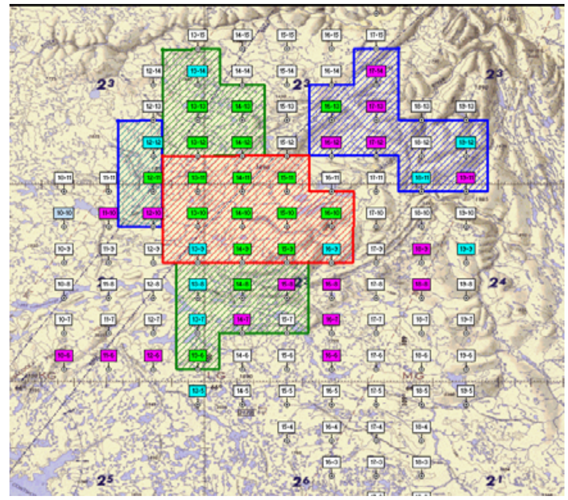
Stratification of the annual calving ground

Based on the two systematic reconnaissance surveys, we delineated the annual calving ground and then stratified it into one high density stratum (1203 km^2), two medium density strata (709 and 590 km^2, respectively), and two low density strata (906 and 297 km^2, respectively). The strata were defined mainly on the basis of observed caribou densities and relative composition; comparative density changes between systematic surveys as well as locations of satellite-collared cows provided additional rationale for the stratification (Figure 13). We initially partitioned effort for the high and medium density strata based on allocation formula results (Appendix C), and then adjusted the allocation to maximize sampling effort in the high density stratum (n = 18 transects; 55% coverage) with remaining photographic effort assigned to the medium density strata (n = 9 transects; 13% and 16% coverage respectively).

The photographic survey was initiated on the 9 June; the photo-plane surveyed over half of the high density strata while a field crew surveyed the two low density visual strata in a fixed wing aircraft (Figure 14). Due to low cloud cover on the 10 June, the photo-plane was unable to photograph remaining transects in the high density stratum. Consequently, we conducted another reconnaissance flight in a step-wise manner along the perimeter of the high density stratum (Figure 15). We readjusted the boundaries of the high density stratum to reflect a shift in caribou densities; the northern boundary was extended 7 km to the north and the eastern boundary was truncated 10 km to the west (Figures 15 and 16). Two additional transects were added to the high density stratum and survey coverage was *ca.* 53%. The western boundary of the southern medium stratum (M-1) was shifted 3 km to the west to include medium densities of caribou (*ca.* 8 caribou / km^2) observed during the reconnaissance survey on the 10 June (Figure 15). Given the observed shifts in distribution and availability of two fixed wing aircraft, we added four low density strata to ensure complete and seamless coverage of the entire calving area (Figures 16 and 17).



A



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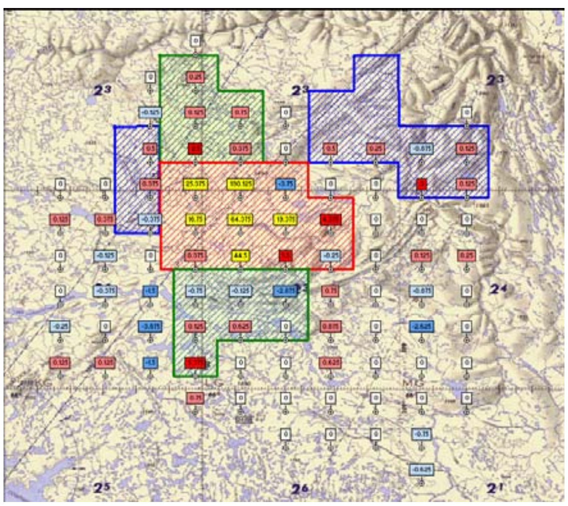

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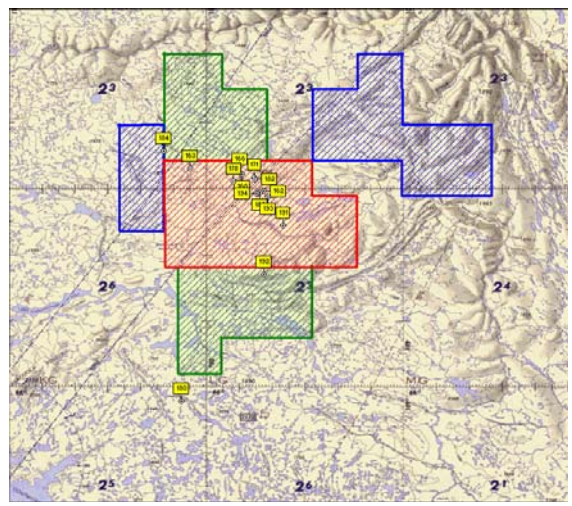

D

Figure 13. Initial stratification of the annual calving ground for the Bathurst caribou herd. Orientation and delineation of a high density photo-census stratum (red), medium density photo-census strata (green), and low density visual strata (blue) were based on systematic stratification flights on the 6, 7, and 8 June 2006. Survey strata are overlaid on caribou densities (A) and relative composition (B) observed on the 8 June, and the comparative density changes observed from the 6/7 June, to the 8 June (C), and the locations of collared cows (D) (locations are from the 6 June). See Figures 10-12 for figure legends that apply to A, B, and C.

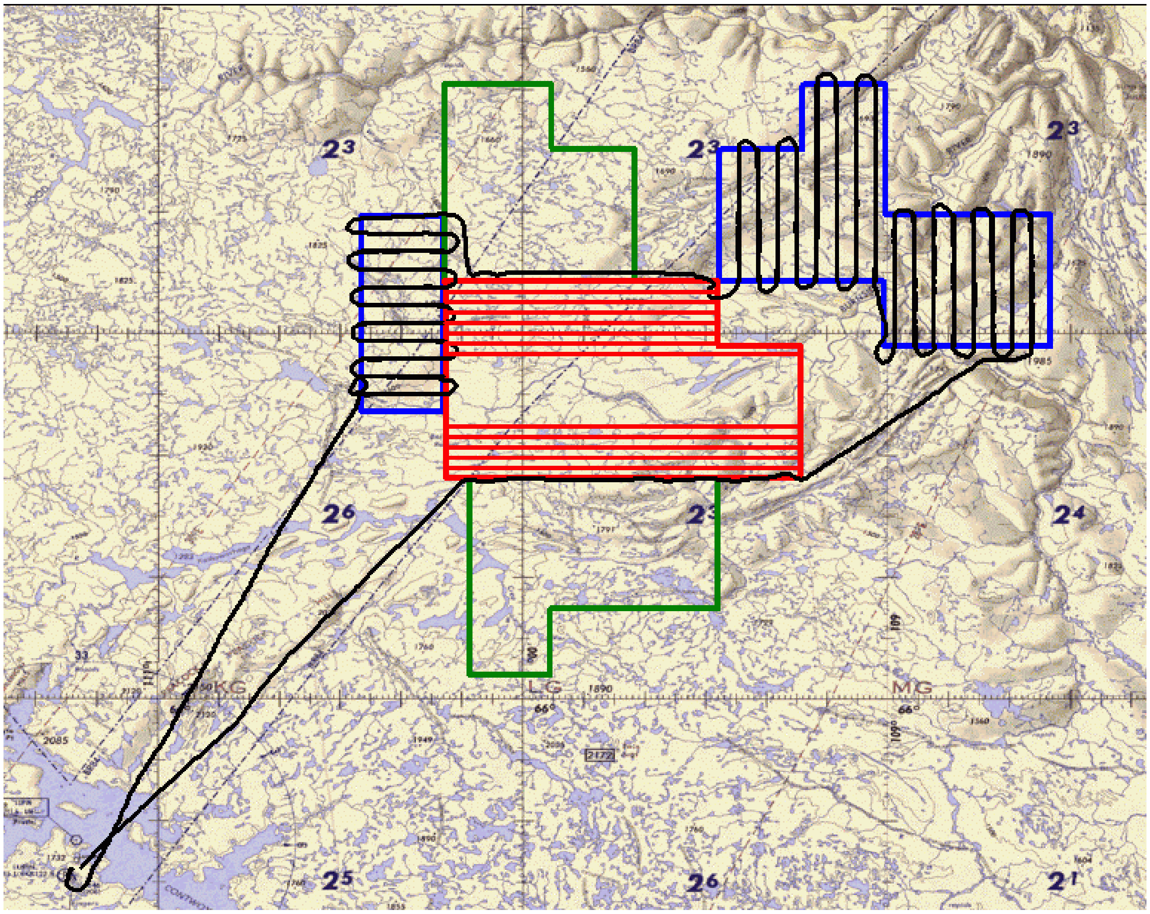

Figure 14. Strata and transects surveyed on Bathurst calving ground, 9 June 2006. Lines in red show transects in the high density stratum that were surveyed by a photo-plane. Lines in black show transects surveyed by a fixed-wing aircraft in the low density visual strata.

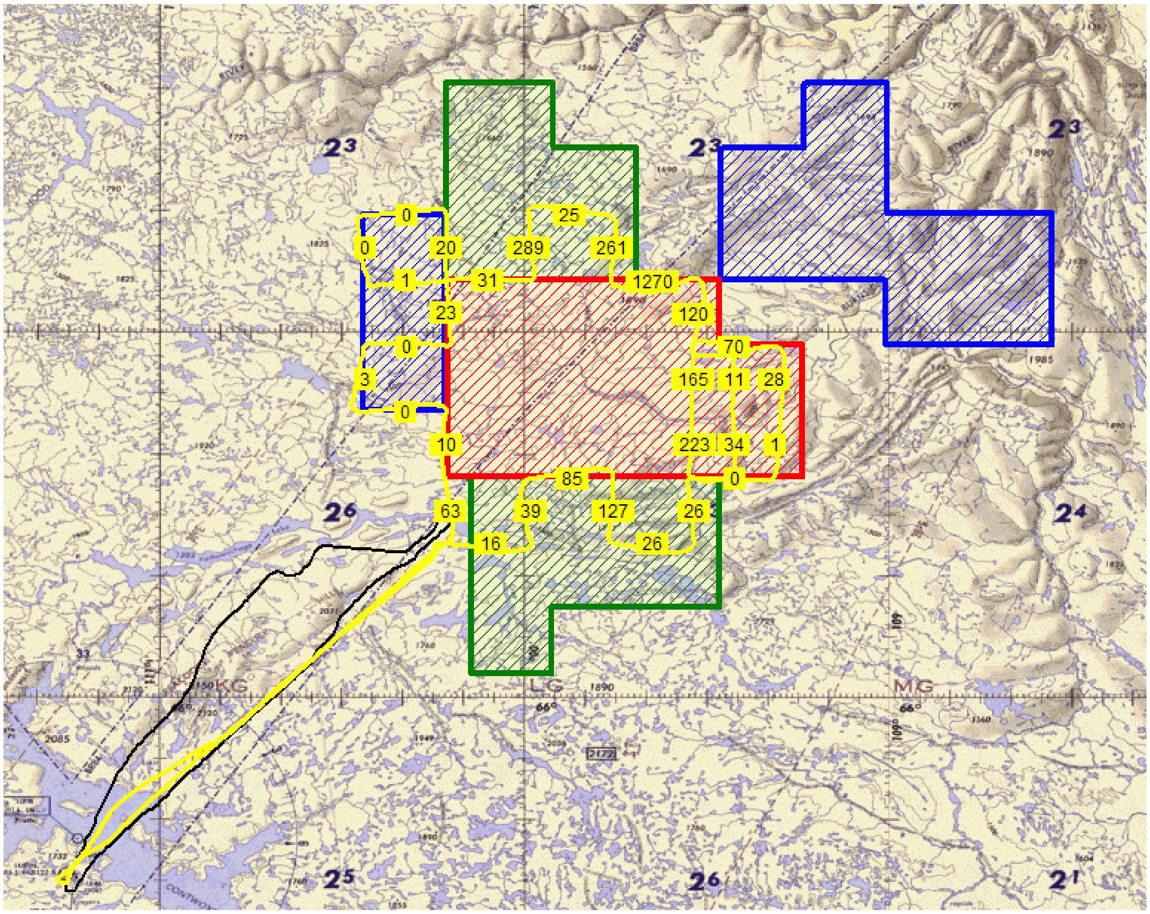

Figure 15. Flight lines from reconnaissance survey on 10 June 2006 to check initial stratification of annual calving ground for Bathurst caribou herd. The black line shows the morning flight path, which required the survey aircraft to return due to low cloud cover. The yellow line shows the afternoon flight path, which allowed the survey crew to fly the boundaries of the proposed high density stratum (shown in red). Values represent total numbers of 1^+- year-old caribou seen on transect within 10 km segments.

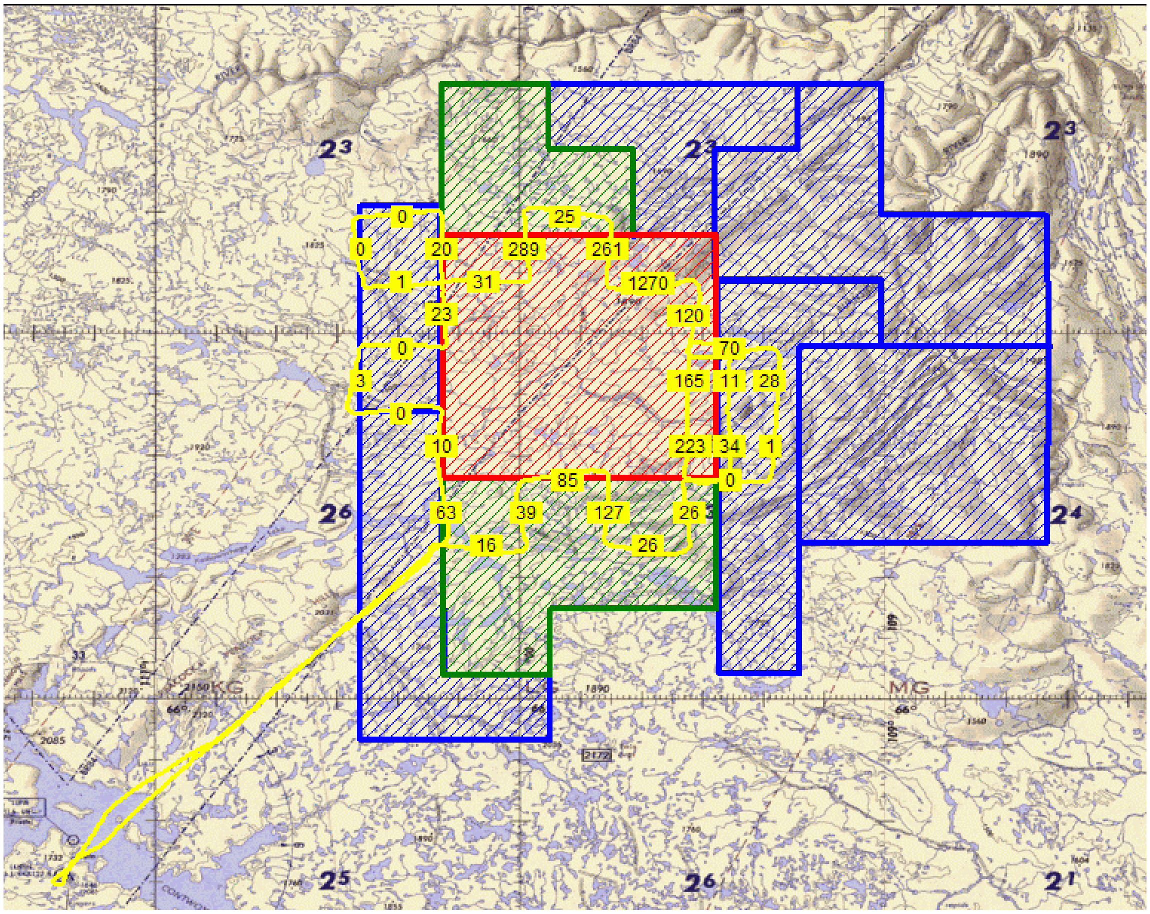

Figure 16. Flight lines from reconnaissance survey on 10 June 2006 and final stratification of annual calving ground for Bathurst caribou herd. The final stratification was adjusted to reflect the densities of caribou observed during the afternoon flight (yellow line). Values represent total numbers of 1^{+}- year-old caribou seen on transect within 10 km segments.

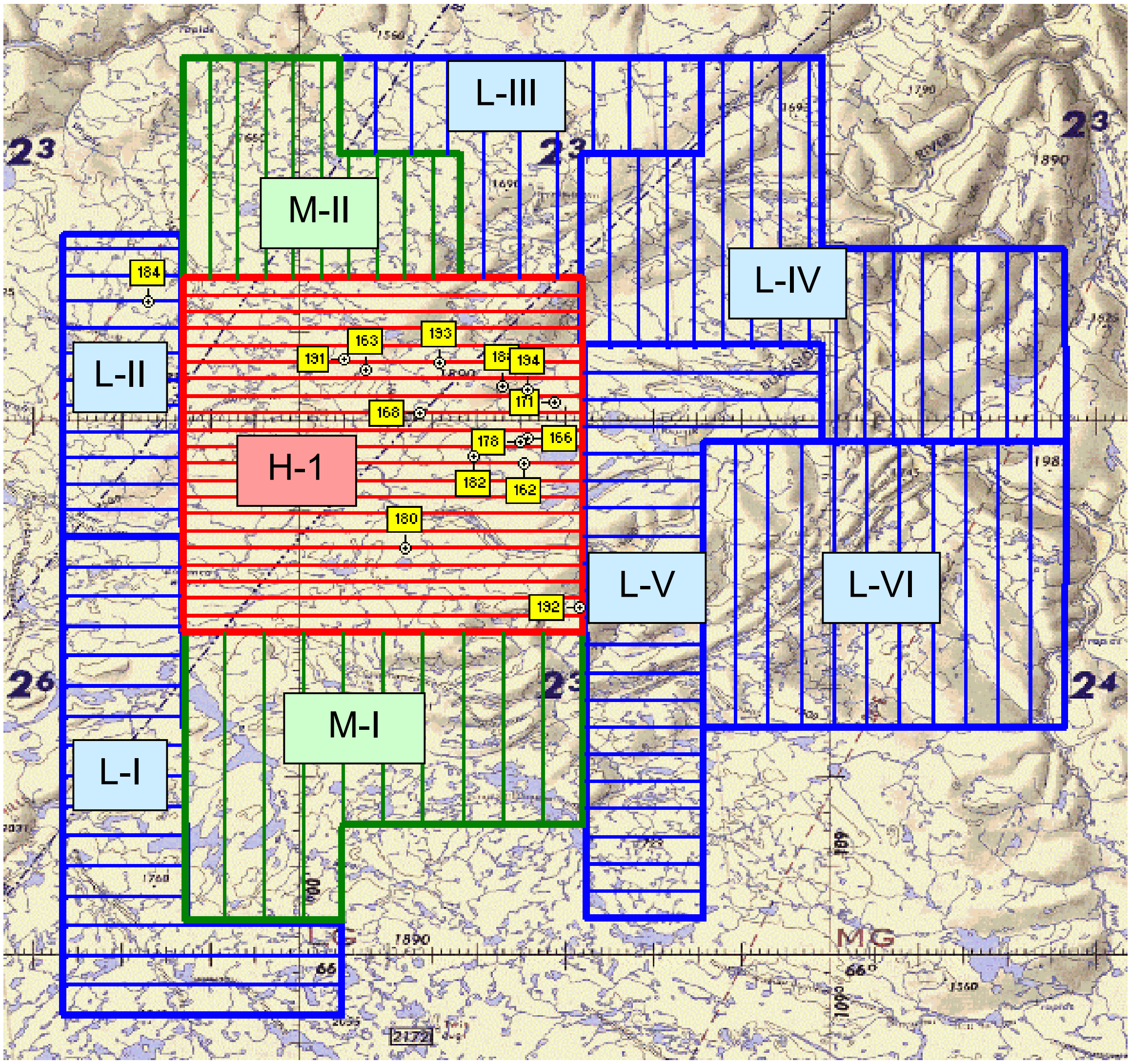

Figure 17. Final stratification for annual calving ground of Bathurst caribou herd. The photo-plane surveyed the high (H) (red), and medium (M) (green) density strata. Standard visual strip transect surveys were conducted on the low (L) (blue) density strata. Locations of satellite-collared cows (11 June 2006) are overlaid on survey strata; 13 of 14 collared cows were located in the high density stratum. Transects are numbered sequentially and depending on orientation, number one starts at the south or west.

Visual survey

We surveyed strata L-II and L-IV on the 9 June, and strata L-I, L-III, L-V, and L-VI on the 11 June. We counted a total of 905 caribou on transects within the six low density strata, which resulted in a combined estimate of 3302 caribou for those strata (Table 2, Appendix F). Densities within the low density strata ranged from 0.04 – 3.09 caribou / km^2. Of all the low density strata, stratum L-V, which was adjacent to the eastern boundary of the high density stratum, accounted for 2175 ± 916 (SE) (66%) of all caribou within the low density strata (Table 2). These observations reflected an eastward extension of caribou from the high density stratum, which was most striking along a 1.8 km length of transect 18 where 305 caribou were observed on-transect west of Kuuvik Lake (Figure 17, Appendix F).

Photographic survey

Following the partial survey of the high density stratum on the 9 June and the modification of stratum boundaries on the 10 June, the photo aircraft reflew and completed the photographic survey of the high density stratum on the 11 June. The two medium density strata were photographed on the 12 June. At the time of the photo-census (11-12 June), we had unlimited visibility. The sky was clear with few and scattered high cumulus clouds. There was very little wind and snow cover over the high and medium density strata was < 1%. The weather and snow conditions for the photo-census were optimal for subsequent photo interpretation.

In the high density stratum, Paul Roy counted 32,944 1+-year-old caribou which resulted in an estimate of 61,781 ± 9846 (SE) and a density of ca. 49 caribou / km^2 (Table 2, Appendix G). In the medium density strata M-I and M-II, Paul Roy counted 495 and 29 1+-year-old caribou, respectively. Densities in the two medium strata M-I and M-II were 2.57 and 0.19 caribou / km^2, which resulted in estimates of 2082 ± 492 and 81 ± 24 (SE) caribou, respectively (Table 2, Appendix H). Based on photographic and visual survey techniques, the total number of 1+-year-old caribou estimated on the calving ground was 67,246 ± 9904 (SE) (Table 2).

Table 2. Analysis of data from an aerial survey of the Bathurst calving ground, June 2006.

	STRATA									
	High	Medium I	Medium II	Low I	Low II	Low III	Low IV	Low V	Low VI	Total
Maximum number of transects (N)	40.7	37.0	25.6	62.5	41.0	37.5	50.0	75.1	37.5	406.9
Number of transects surveyed (n)	20	9	9	15	11	9	16	20	10	119
Stratum area, km^2 (Z)	1253.7	811.1	431.5	632.1	326.1	431.7	907.9	703.2	913.3	6410.6
Transect area, km^2 (z)	668.5	192.8	154.4	153.6	88.0	103.2	288.0	184.0	240.0	2072.5
Number of 1+-year-old caribou counted (y)	32 944	495	29	30	24	4	246	569	32	34 373
Caribou density, caribou/km^2 (R)	49.30	2.57	0.19	0.20	0.27	0.04	0.85	3.09	0.13	10.50
Population estimate (Y)	61 781	2082	81	123	89	17	776	2175	122	67 246
Population variance (Var Y)	96 932 891	241 789	594	1645	1226	72	77322	839 691	2005	98 097 235
Standard error (SE Y)	9846	492	24	41	35	9	278	916	45	9904
Coefficient of variation (CV)	0.16	0.24	0.30	0.33	0.39	0.50	0.36	0.42	0.37	0.15
95% Confidence interval	20 607	1134	56	87	78	20	593	2622	101	
% Coverage	53.3	23.8	35.8	24.3	27.0	23.9	31.7	26.2	26.3	32.3

Sex and age composition survey

We classified 6393 1+-year-old caribou in 101 groups to estimate sex and age composition of caribou within high, medium, and low density strata (Table 3, Appendices H – J). We allocated most of our effort into classifying caribou in the high density stratum (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 2006.

Stratum		Number of groups sampled	Number of breeding females	Number of 1^{+}-year-old caribou	Proportion of breeding females (± SE)
High density – photo estimate	H-1	43	3474	3957	0.8798 (± 0.0252)
Medium density – photo estimate	M-I	13	8	391	0.0184 (± 0.0211)
	M-II	12	345	479	0.7199 (± 0.0691)
Low density - visual estimate	L-I	4	1	59	0.0146 (± 0.0178)
	L-II	ns*	-	-	-
	L-III	ns	-	-	-
	L-IV	ns	-	-	-
	L-V	14	456	1027	0.4465 (± 0.1005)
	L-VI	15	89	480	0.1875 (± 0.0775)
Sum		101	4373	6393	

* not sampled

Survey estimates – number of breeding females

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). We did not collect composition data from three low density strata because we ran out of available helicopter time. We estimated that there were a total of 55,593 ± 8813 (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 2006 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	61 781	0.8798	54 355	77 447 343	8800	0.16
Medium I	2082	0.0184	38	1999	45	1.17
Medium II	81	0.7199	58	340	18	0.32
Low I	123	0.0146	2	5	2	1.26
Low II	89	[a]	0	0	0	0
Low III	17	[a]	0	0	0	0
Low IV	776	0.1875[a b]	146	2718	52	0.36
Low V	2175	0.4465	971	215 148	464	0.48
Low VI	122	0.1875	23	160	13	0.55
Total	**67 246**		**55 593**	**77 667 712**	**8813**	**0.16**

[a] Composition data were not collected for stratum.
[b] Composition data from stratum Low VI were used to calculate the number of breeding females (146) in stratum Low IV.

Trend of breeding females in Bathurst caribou herd, 1986-2006

Weighted least squares regression

Results of a weighted least squares regression on the five estimates of breeding females from 1986 to 2006 (Table 5) suggested a significant negative exponential rate of increase[7] *(r)* of -0.059 (Table 6). This translated into a finite rate of increase[8] (λ) of 0.942 ($\lambda = e^{-0.059}$), which indicated that the number of breeding females was approximately 94% of its size in each successive year from 1986 to 2006. The trend for the weighted least squares regression is shown in Figure 18.

Table 5. Breeding female population estimates used for trend analysis, Bathurst caribou calving ground.

Year	n	Variance ($x10^7$)	SE	CV	Df (*t*)	CI low	CI high
2006	55593	7.767	8813	0.16	19	37147	74039
2003	80756	17.337	13167	0.16	17	52916	108400
1996	151393	123.510	35144	0.23	13	75469	227317
1990	151927	66.590	25805	0.17	10	94430	209424
1986	203800	16.118	12696	0.06	43	178197	229403

[7] 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 time of a population can be easily calculated from *r* by 0.6931 / *r.* For example 0.6931 / -0.059 equals a halving time of 11.8 years.

[8] 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 6. Weighted least square regression results.

Parameter	Estimate	Standard error	CI low	CI high	*t*	*P*-value
Intercept	12.29	0.058	12.106	12.473	213.30	<0.001
Slope (*r*)	-0.059	0.006	-0.079	-0.039	- 9.51	0.002
Rate of change (*λ*)	0.942	1.006	0.924	0.961		

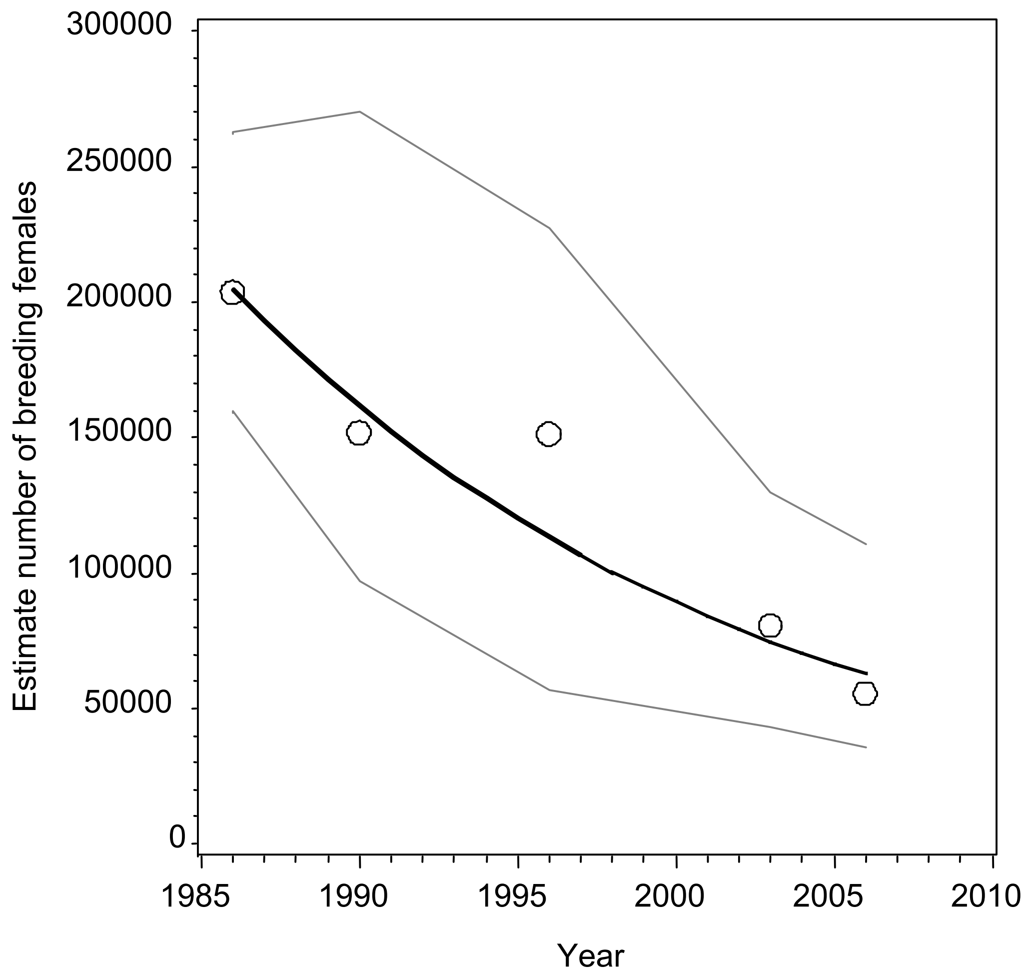

Figure 18. Predicted trend for breeding females of the Bathurst caribou herd using weighted least squares regression analysis. Grey lines are confidence interval on predictions. Circles are estimates of breeding females from calving ground surveys.

Monte Carlo simulation

Monte Carlo simulations showed that the trend in number of breeding females was negative when the sampling variance associated with each of the surveys was directly accounted for. The estimate of the exponential rate of increase *(r)* was –0.060 with 95% confidence limits of –0.078 to –0.045. The estimate for the finite rate of increase *(λ)* was 0.941 with 95% confidence limits of 0.924 to 0.956. As the confidence limits of *r* did not overlap zero and the confidence limits of *λ* did not overlap one, the observed population decline could not be attributed to sampling variation. The distribution of *r* and *λ* values in the simulations suggested that r was always less than zero, and that *λ* was always less than one (Figure 19).

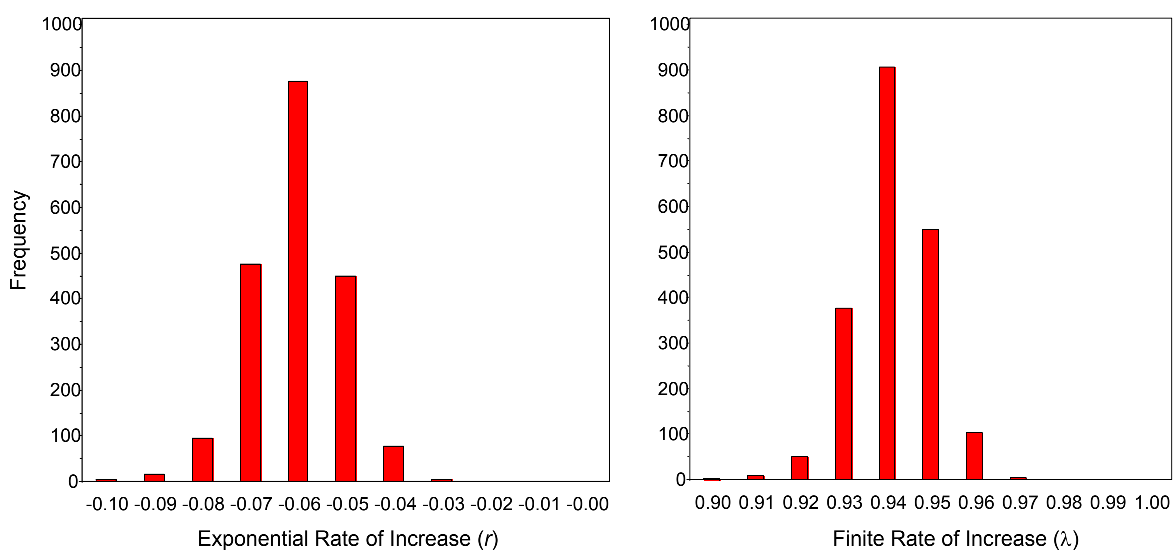

Figure 19. Frequency distributions of finite rate of increase (λ) and exponential rate of increase (r) generated using Monte Carlo simulation trials (n = 2000) on population estimates of breeding females (n = 5 calving ground surveys) in the Bathurst caribou herd, 1986 – 2006.

<u>One-tailed t-test</u>

Based on a one-tailed t-test, the estimate of breeding females in 2006 was not significantly different from the calving ground survey in 2003 at the $\alpha = 0.05$ confidence level ($t = 1.59$, $df = 30$, $p = 0.06$). However, the one-tailed test interpreted at the $\alpha = 0.05$ level of significance suffers from an associated high probability of a Type II error (> 20%), and low power (<80%) to detect a population change of less than 50% (Appendix E). The power analysis also showed that an increase in the acceptable level for a Type I error from $\alpha = 0.05$, to $\alpha = 0.10$ resulted in decreased Type II error rates and correspondingly increased the power of the t-test. (Appendix E).

The intrinsic rate of increase between the 2003 and 2006 estimates of breeding females was $r = -0.124$ (0.075 Standard Deviation) (Appendix E). The magnitude of this decline was *ca.* two times greater than the estimates derived from the longer term dataset (1986-2006) using Monte Carlo simulation techniques and weighted least squares regression where $r = -0.0604$ (0.009 SD) and $r = - 0.059$ (0.010 SD) respectively (Appendix E). Because the two estimates of r calculated by Boulanger (Appendix E) were virtually identical, they produced very similar simulation estimates when projected forward at each annual time step from 2003 to 2009 (Appendix E – Table 1). The simulated estimate of breeding females in 2009 was 39,032 (9668 SD) when using $r = -0.124$ which was ca. 30% less than the simulations derived using $r = -0.060$ and $r = -0.059$, which were 56,328 and 56,676 respectively (Appendix E - Table 1). The simulations suggested that a significant population decline could be detected in

2009 if the rate of increase between 2003 and 2009 was r = -0.124 or lower. Conversely, if the rate of increase between 2003 and 2009 was r = -0.060 or greater, then a statistically significant trend would be less likely.

DISCUSSION

The results from the calving ground survey of the Bathurst caribou herd in June 2006 were robust and relatively precise and met the survey's objectives. The estimate of 55,593 ± 8813 (SE) breeding females in June 2006 substantiates the results of the June 2003 Bathurst caribou survey, and confirms that the abundance of breeding females has declined since 1986. A one-tailed t-test of the 2006 estimate with the estimate of breeding females in 2003, suggests that the number of breeding females has declined over the 3 year interval between surveys ($p=0.06$). Results of the one-tailed t-test emphasize the importance of understanding the trade-offs between Type I and Type II errors when interpreting statistical results of trend data.

The survey's design and execution were efficient and faced no substantial problems that could reduce the credibility of the results. The timing of the survey coincided with the peak of calving. We flew extensive systematic surveys to delineate the calving ground. Compared to the 2003 survey in which 22.2 hours were flown during the systematic surveys to define the calving ground (Appendix B in Gunn *et al.* 2005), we used two aircraft and flew a total of 35.0 hours (plus an additional 11.1 hours of ferry time) to conduct the systematic survey (Appendix B). The distribution of caribou and the distribution of the collared cows suggested that the calving ground was correctly delineated. The 1-day delay between stratification and photography was not a problem as a reconnaissance survey was used to check for caribou movements across stratum boundaries.

Trend in numbers of breeding females

Both the weighted least squares regression and Monte Carlo simulations revealed a negative trend in the abundance of breeding females in the Bathurst caribou herd. Similarity in these results is a function of the large difference in estimates and comparatively tight confidence intervals from the surveys conducted in 1986, 2003, and 2006 (Table 5 and Figure 18). The confidence intervals on these surveys do not overlap, and the 2003 and 2006 estimates are statistically lower than the 1986 survey. These points "anchor" the relationship and compensate for the relatively low precision of surveys in 1990 and 1996. Although the plot of breeding female estimates (Figure 18) suggests that the population may have declined between 1986 and 1990, stabilized from 1990 to 1996, and then declined from 1996 to 2006, the low number of surveys (n=5) makes it impossible to test for non-linear trends. Regardless of the shape of the trajectory, the population of breeding females has declined between 1986 and 2006.

The regression and Monte Carlo analyses clearly show the declining trend of breeding females and provide estimates (and associated confidence intervals) of the negative rates of increase. The similarity in results between the Monte Carlo simulation procedure and the weighted least squares analysis suggests that both methods are efficient ways to estimate trend while accounting for variance of surveys. The approaches should be used to estimate trend and compare estimates when more than two estimates are available. Furthermore, estimates from regression are not influenced by survey interval, and utilize data from all surveys. This results in higher power to detect change in population size, which is an essential step for management decisions. In comparison, t-tests of sequential estimates are influenced by the arbitrary period of time between successive surveys. All else being equal, if a population is changing at a constant rate, a 2-sample t-test is more likely to detect a change in population size between surveys that are conducted at longer time intervals.

Nevertheless, results of the one-tailed t-test between T_{2003} and T_{2006} strongly suggested that there was a real decline in the number of breeding females over the 3-year survey interval. The comparison between the two estimates showed that the rate of increase between 2003 and 2006 was r = -0.124 (0.075 SD), and the reduction (*i.e.,* consequential difference) in number of breeding females over the three year period was 25,163 or 31% of T_{2003} (Appendix E). Although the results are not significant at $\alpha = 0.05$ because p = 0.06, the one-tailed t-test would have only had a 45% probability (*i.e.*, power) of detecting a 31% reduction in the 2003 estimate. Thus if we accept H_o at the 5% significance level for a Type I error[9], we also accept a corresponding Type II error[10] rate of ca. 55% (Table 1 in Appendix E). It is important to consider that the 5% level of significance is only a convention. Interpretation of the test result requires an evaluation of acceptable levels of Type I and Type II error because there is a trade-off between the two.

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[9] α - The acceptable probability of error (from a practical point of view) if you were to conclude that a change in numbers had occurred when in fact it had not changed, i.e., a Type I error.
[10] β - The acceptable probability of error (from a practical point of view) if you were to conclude that no change in numbers larger than the consequential (expected) difference had occurred when in fact it had changed, i.e., a Type II error. Power is calculated by 1- β.

Thus, there are two reasons why it is more appropriate to reject the null hypothesis H_o ($T_{2003} \leq T_{2006}$) and accept the alternative hypothesis H_a that the 2003 estimate is significantly greater than the 2006 estimate and to conclude that number of breeding females has significantly declined. Firstly, if we use the α = 0.05 level of significance and accept the null hypothesis, then we also accept a 55% probability that we have falsely concluded that there is no difference between estimates, when in fact the trend is declining. By accepting a higher probability of Type I error, at say α = 0.10, we conclude with 90% confidence that the 2006 estimate is lower than the 2003 estimate.

The second reason for rejecting H_o and accepting H_a is that from a biological perspective, the implications of a Type II error may have more serious implications to recovery and conservation of a population that is low or declining, than a Type I error (Taylor and Gerodette 1993). The rationale behind this logic is that a declining and low population has less of a margin to recover from incorrect management decisions.

Although the relative weighting of Type I and Type II errors appear technical in nature, weighting of these sources of error are grounded in the values and perspectives of managers and stakeholders who will interpret the results of the analyses and use them in formulating management options and decisions (Mapstone 1995). For example, commercial harvesters of a wildlife population may be more concerned with minimizing Type I error in population trend – that is, with minimizing the probability of deciding that trend is declining when in reality it is not. The result of this incorrect conclusion may be the additional loss of harvest opportunities due to management restrictions. A biologist would also want to minimize a Type I error, but for a different reason: loss of scientific credibility (Taylor and Gerodette 1993). However, from a wildlife conservation perspective, a Type II error on trend of a low or declining population poses greater risks because this incorrect conclusion would fail to diagnose a true decline and may lead to poor management decisions, which could in turn accelerate an existing declining trend and reduce overall population resilience.

Further work should be done on trend and power analysis as it pertains to caribou surveys. In particular, it is likely that the consequential difference of interest (or effect size) that is important from a management perspective needs to be further discussed and understood among a larger group of managers and stakeholders. If caribou managers are concerned about trend of breeding females, than relationships between detectable effect size, rates of increase, survey frequency, and linkages with management options requires further discussion (see for example Heard and Williams 1990, and Appendix E).

Delineation of the annual calving ground

We used a hierarchical spatial approach for defining the annual calving ground to reduce the likelihood of missing a large portion of breeding females from the Bathurst herd. At the coarsest spatial scale, we used the known extent of calving that had been defined by satellite telemetry and aerial surveys over the past 10 years to focus on the area west of Bathurst Inlet and approximately between the Hood and Burnside Rivers. We then used the locations of satellite-collared cows during the pre-calving period, supplemental information from an independent biologist, and our own aerial reconnaissance in late May to refine the survey area. Once we initiated the systematic aerial reconnaissance in early June, we were able to reduce the spatial extent and define the annual calving ground using adaptive criteria based on observed patterns of density and composition. The locations of 13 of 14 satellite-collared cows were within the high density stratum, which is support for the effectiveness of the high density stratum (Figure 17). The 14th collared cow was adjacent to the high density stratum and was within low density stratum L-II; we did not get a visual observation of that cow and were not able to confirm whether enjoy she was a breeding female or not.

One of our criteria for defining the annual calving ground was based on observing a continuous distribution of breeding females at a finer spatial scale (i.e., 10 km). Figure 20 shows the extent of systematic reconnaissance that we flew, while Figure 21 shows the extent of systematic aerial survey that was undertaken by another biologist in the High Lake study area for Wolfden Resources. The lines flown and the marked absence of breeding females outside of the photographic and visual survey strata are additional evidence against the contention – even at the courser spatial scale, i.e., 100 km – that a large aggregation of breeding females would have been missed because they were not on the calving ground during the survey. In addition, our observations of mature bulls and yearlings to the south and east of the calving area makes it unlikely that breeding females from the Bathurst herd would have been outside the total area survey.

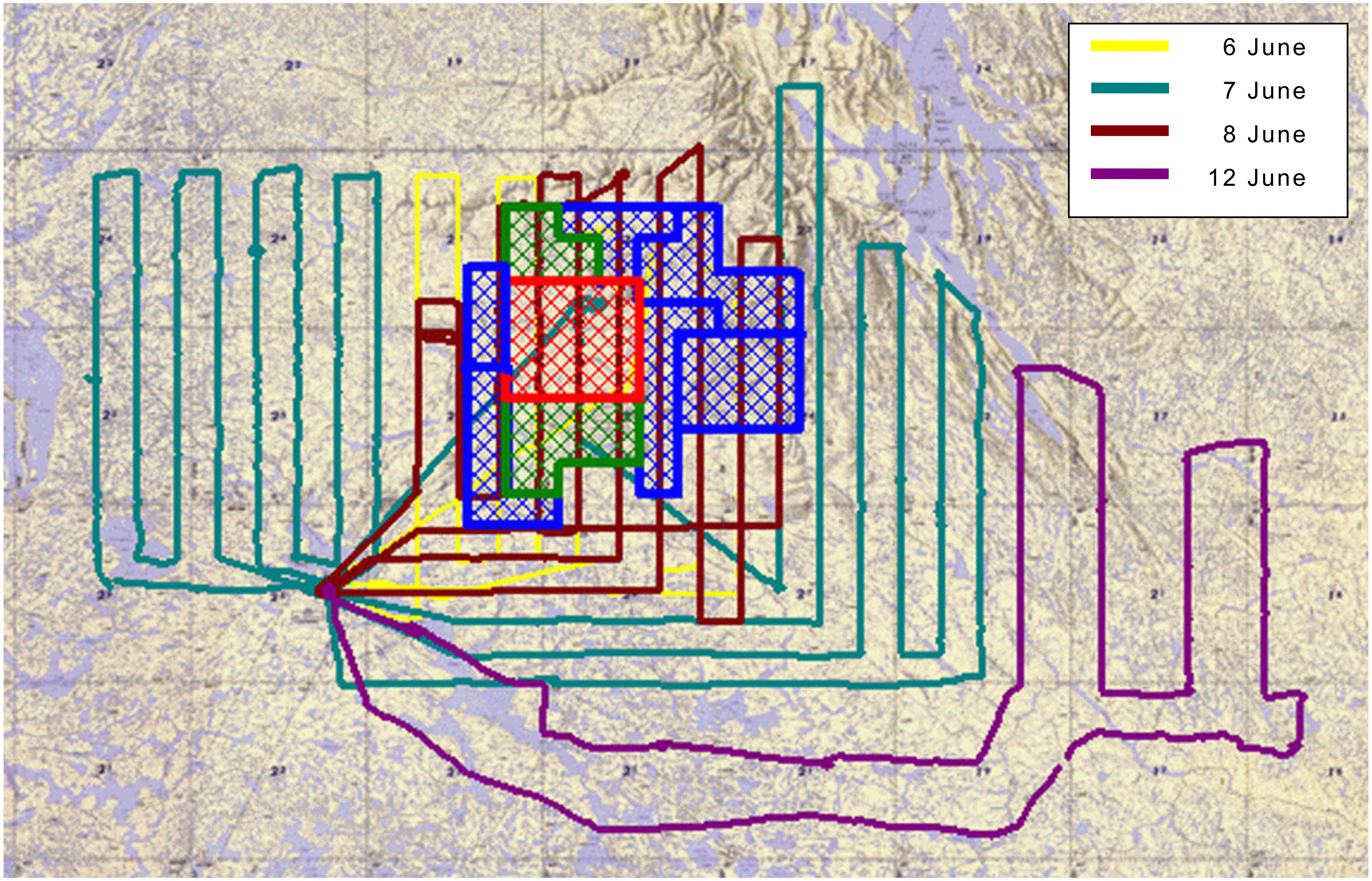

Figure 20. Cumulative coverage of systematic surveys that were used to delineate the annual calving ground and final stratification for the Bathurst calving ground survey in June 2006. Survey strata shown as cross-hatched polygons: high density photographic stratum (red); medium density photographic strata (green); low density visual strata (blue).

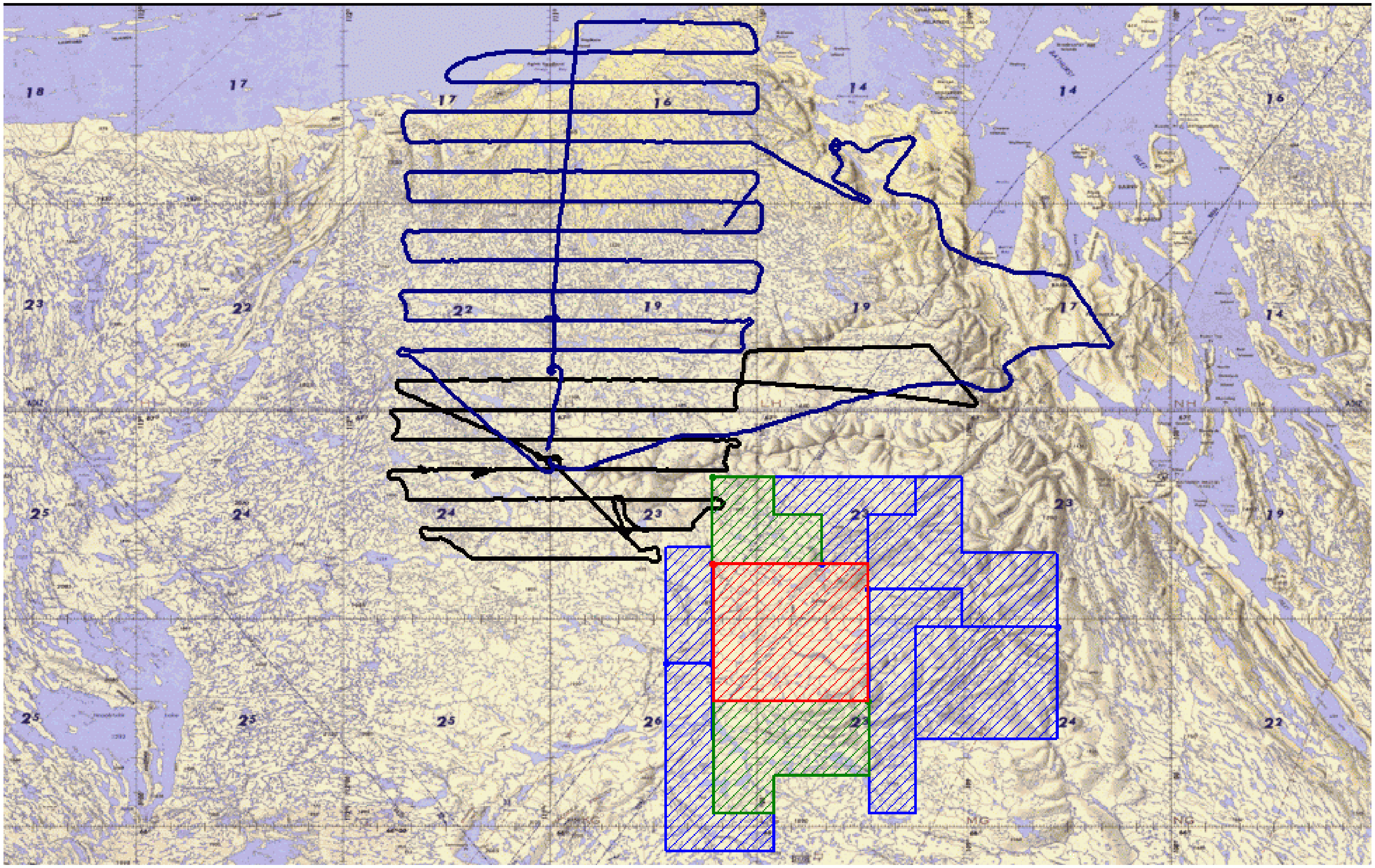

Figure 21. Flight lines from systematic surveys of High Lake study area for Wolfden Resources on 10 (black lines) and 11 (dark blue lines) June 2006 (K. Poole unpub. data), relative to final stratification of annual calving ground for Bathurst caribou herd. During that survey 17 caribou and two calves were observed on transect (see Table A2.5–1 and Figure A2.5– 3 in Wolfden Resources Inc. 2006).

Survey timing relative to peak of calving

The satellite-collared cows were helpful for monitoring movements and distribution of caribou cows during the pre-calving and calving periods. Data on the spatial distribution of satellite-collared cows through the calving period and the average daily rates of movement provided information that helped frame the temporal window on the peak of calving (Figure 5). Trends in the area of the minimum convex polygon for collared cows showed a marked increase in aggregation from late May to early June which coincided with our observations from aerial surveys on the 6 - 9 June (Figure 12). A marked decrease in average daily movement rates, i.e., fewer than 5 km / day from the 6 to 16 June suggested that most collared cows had calved in that period. This interpretation is consistent with the patterns observed by Griffith *et al.* (2001) and Gunn *et al.* (2001) on Bathurst cows in the late 1990s, and by Russell *et al.* (1993) who observed that the period of calving for the Porcupine herd was characterized by a reduction in the rate of movement and proportion of time spent walking.

We conclude that the visual and photographic surveys were well-timed with respect to the peak of calving, which most likely occurred between the 9 and 11 June 2006. From aerial surveys on the 7 and 8 June, we estimated that *ca.* 22% and 37% of the breeding females in the highest density segments had a calf at heel, and most cows still had hard antlers. The observed proportion of calves was clearly an underestimate because the ability of observers to accurately differentiate and count calves and 1^{+}-year-old caribou simultaneously from a fixed wing aircraft is limited. Nevertheless, by estimating group sizes of 1^{+}-year-old caribou and the relative proportion of calves in the groups, the method produced a repeatable index and showed that the proportion of calves had increased from the 7 to the 8 June. By the 8 June, we suspect that the true proportion of calves was quickly approaching 50%, if it had not already. On the 12 and 13 June during composition surveys of the high density stratum, the proportion of calves to breeding females was 63% (± 4% SE) (Appendix I). This observed proportion confirmed that the peak of calving would have occurred before the 12 June, despite sources of potential error such as lower sightability of calves and unknown numbers of neonate mortalities. During the composition survey of the high density stratum, we also observed that *ca.* 85% of the breeding females were antlerless (see Appendix I), which suggested that most cows had calved a few days previously.

The use of digital photography presents another approach that could be developed for a robust field technique to document timing of calving. During systematic surveys of the calving ground, a minimum of three to five digital photographs of representative groups of caribou could be taken by the navigator (within the 400m strip width) in a high density area. Cows and calves could be counted from the photos to determine relative frequencies for that day. By repeating the photography of caribou in the same area of the calving ground at three or more times over subsequent days, the change in frequencies of calves and cows could be analyzed with methods described by Caughley and Caughley (1973) to define peak of calving, i.e., median date of birth.

Efficacy of stratification

The ability to detect trend in population size is affected largely by the precision of the population estimates. In general, population estimates with higher precision, i.e., lower variances, provide better statistical power to detect numerical change. The precision of a calving ground survey is largely a function of how well the survey area was stratified and how efficiently the survey was conducted relative to the stratification.

We adopted the survey objective outlined by Gunn *et al.* (2005, p. 14) to obtain an estimate for the number of breeding females on the annual calving ground with a CV < 15%; a CV level of 10 – 15% is considered appropriate for management purposes (Mowat and Boulanger 2000). In this calving ground survey, the CV for the total number of caribou estimated on the calving ground was 15%, while the CV for the estimated number of breeding females was 16%. Although we may consider that this survey met the objective for precision, it is important to understand the major sources of variance in the survey to consider areas for potential improvement.

The high density stratum contributed 92% of the estimated number of total caribou and 98% of breeding females on the calving ground (Tables 2 and 4). Accordingly, the contribution of the high density stratum to the overall variance of those estimates was *ca.* 99%. The overall variance is a reflection of the variance in numbers of caribou counted from photographs of transects (n = 20) within the high density stratum, which ranged from 123 – 5401 (Appendix G). Transects 5-9 in the high density stratum were lower density and suggest a spatial gradient in density from south to north (Appendix G). However, without empirically testing whether there was also a density gradient along an east-west axis, it is not possible to determine whether the stratification could have been improved, nor the relevant spatial scale for improvement. Consequently, the photographs of the high density stratum from this survey represent a useful dataset to i) better understand spatial patterns, i.e., grain and gradient, of animal density on a calving ground, and ii) evaluate whether post-stratification techniques (e.g. Anganuzzi and Buckland 1993) may be a valid and useful approach to improve survey precision.

There may be ways of further reducing variance through improved stratification, but a practical perspective of survey logistics requires a realistic approach to balancing finer scale stratification techniques with the probabilities for animal movement between strata and the likelihood of receiving good weather for completing a photo-census. For example, between the time when we completed the initial stratification on the 8 June and when we flew reconnaissance along the boundary of the initial high density stratum on the 10 June, we started to observe a small-scale northward movement of caribou (<10 km) along the northern boundary of the initial high density stratum. After adjusting the northern boundary to account for the shift in distribution, and the addition of four low density strata – in particular L-V which was adjacent to the eastern edge of the high density stratum – we observed that several hundred caribou had moved *ca.* 3-5 km west out of the high density stratum and in to L-V. Although, an evaluation of improved stratification designs and post-stratification techniques may help improve the calving ground survey methodology to consistently achieve a CV of $\leq$ 15%, the precision of a survey will always be subject to the movements of caribou across stratum boundaries.

In retrospect, a potential problem that was linked to the stratification was the fact that we were not able to collect composition data from each of the six low density strata. Due to limited helicopter time, we were only able to collect composition data from three of the six strata. However, as the summed estimate of 1+-year-old caribou from the three low density strata was 882 and represented *ca* 1.3% of the total estimate, the contribution of the three low density strata to the total estimate of breeding females was minimal.

Summary

In summary, we met the survey objective of obtaining a relative precise estimate of the number of breeding females in the Bathurst herd. The use of aerial photography to count the number of caribou means that the estimate is accurate. As the photographic estimate from the high and medium density strata represented *ca.* 95% 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 minimal.

Our systematic reconnaissance covered a large area to reduce the chances of missing concentrations of breeding females. In addition, the satellite-collared cows were concentrated in the high density stratum which also supports the contention that we had included the entire distribution of breeding females. The timing of the survey coincided with the peak of calving, which is when the cows move the least and are relatively concentrated. Both conditions improve the applicability of the survey design including stratification. Finally, we experienced no major delays or technical challenges in estimating the number of breeding females in the Bathurst herd in June 2006.

CONCLUSIONS

1. Results from the calving ground survey of the Bathurst caribou herd in June 2006 were robust and relatively precise.

2. The estimate of breeding females in June 2006 substantiates the results of the June 2003 Bathurst caribou survey, and confirms that the abundance of breeding females has significantly declined since 1986.

3. The estimate of breeding females in June 2006 suggests that the number of caribou has declined since 2003. The observed decline translates in to an exponential rate of increase of $r = -0.124$ and should be interpreted as a statistically significant decline, at the $\alpha = 0.10$ level of significance.

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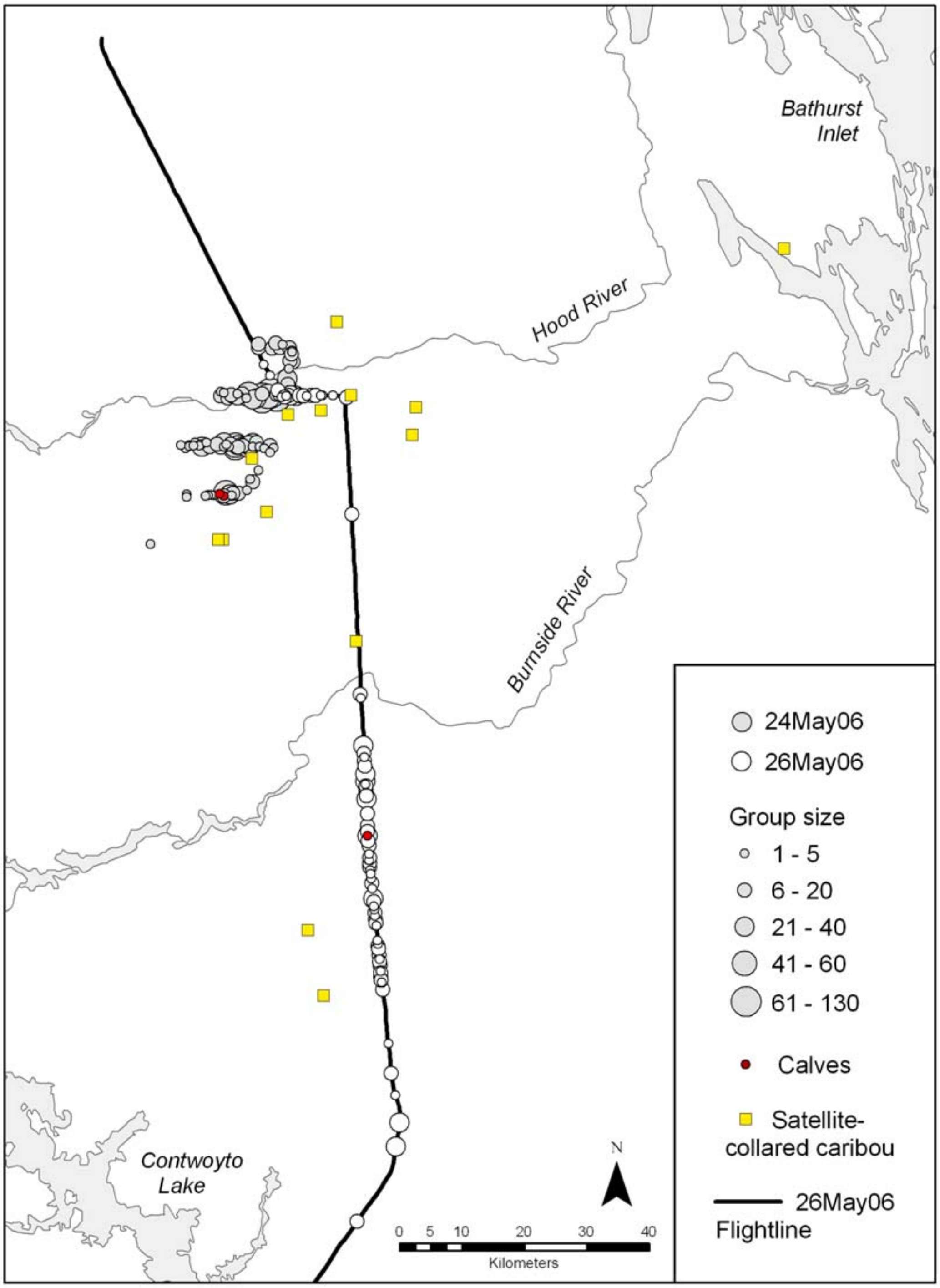
APPENDIX A. Observations of caribou during an aerial survey of the High Lake Project study area and ferry flight to Yellowknife, NT in late May 2006 (K. Poole unpub. data, Wolfden Resources Inc. 2006). A total of 1310 caribou plus 1 calf, and 814 caribou with 2 calves were observed on the 24 and 26 May, respectively. Locations of satellite collared Bathurst caribou cows are shown from the 27 May 2006, except collars 192, 193, and 194 which were locations from the 31 May 2006.



APPENDIX B. Daily flight log during reconnaissance, systematic, and composition surveys of Bathurst calving ground, 31 May - 16 June 2006

		HOURS FLOWN								
		Systematic Recon				Low Density Visual				
DATE	**PURPOSE**	Ferry		Survey		Ferry		Survey		Composition
		C185	C206	C185	C206	C185	C206	C185	C206	Helicopter
31-May	Reconnaissance survey to assess % calves and densities of caribou			5.4						
03-Jun	Survey crew (B. Croft, D. Johnson, J. Williams) arrive at Lupin Mine (Cessna 185)	**1.9**								
04-Jun	Weather day									
05-Jun	Weather day									
6 June am	Ferry (Cessna 185)			1.1						
6 June am	Systematic survey (C185): Navigator – B. Croft, Left Observer – D. Johnson, Right Observer – J. Williams			3.7						
6 June pm	Additional survey crew arrive (K. Clark, J. Nishi) arrive at Lupin Mine (Cessna		**2.0**							
6 June pm	Ferry (C185)	1.5								
	Systematic survey (C185): Navigator – B. Croft, Left Observer – D. Johnson, Right Observer – J. Nishi			1.7						
07-Jun	Ferry (C185)	1.0								
	Systematic survey (C185): flew west transects 9 to 2 (segments 2 to 16); Navigator – B. Croft, Left Observer – D. Johnson, Right Observer – J. Nishi			6.0						
07-Jun	Ferry (C206)		4.1							
	Systematic survey (C206): flew east lines 19 to 24; Left Observer – K. Clark, Right Observer – J. Williams				4.5					
08-Jun	Ferry (C206)		1.9							
	Systematic survey (C206)				5.6					
09-Jun	Ferry (C206)						1.6			
	Survey (C206): surveyed strata L-II and L-IV: Navigator – K. Clark, Left Observer – D. Johnson, Right Observer – J. Nishi								3.5	
09-Jun	Photo plane flew 12 of 18 transects in high density stratum - 6 not flown due to rain clouds in middle of stratum.									
10-Jun	Weather poor with low ceilings - photo plane could not complete high density stratum									
10-Jun	Ferry (C206)		1.5							
	Systematic reconnaissance flight (C206) to check strata boundaries				1.7					
11-Jun	Ferry (C185)					1.3				
	Survey (C185): surveyed strata L-V and L-VI							3.7		
	Ferry C206						1.5			
	Survey C206 (L-I and L-III)								2.8	
	Helicopter (Composition survey)									4.7
	Photographic survey – high density stratum									
12-Jun	Helicopter (Composition survey)									7.3
	Photographic survey – north & south medium density strata (am)									
	Ferry (C185)	1.1								
	Systematic survey (C185)			3.8						
13-Jun	Helicopter (Composition survey)									6.2
	Ferry (C206): K. Clark and J. Nishi return to Yellowknife)		**2.0**							
14-Jun	Helicopter (Composition survey)									9.4
15-Jun	Helicopter (Composition survey)									7.2
16-Jun	Helicopter (Elders visit)									7.2
	TOTAL	5.5	11.5	21.7	11.8	1.3	3.1	3.7	6.3	42.0

*Note: Figures in bold within the “Ferry” column of “Systematic Recon” are hours flown to position aircraft. The C185 was used in a subsequent survey, so there was no positioning time associated to it at the end of the survey.

APPENDIX C. Population estimates and allocation for 2006 Bathurst survey

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This short report outlines allocation efforts for the 2006 Bathurst Survey.

1. POPULATION ESTIMATES FROM RECONNAISSANCE SURVEYS.

Strata were initially defined by NWT personnel (Bruno Croft, John Nishi, Judy Williams) as shown in Figure 1.

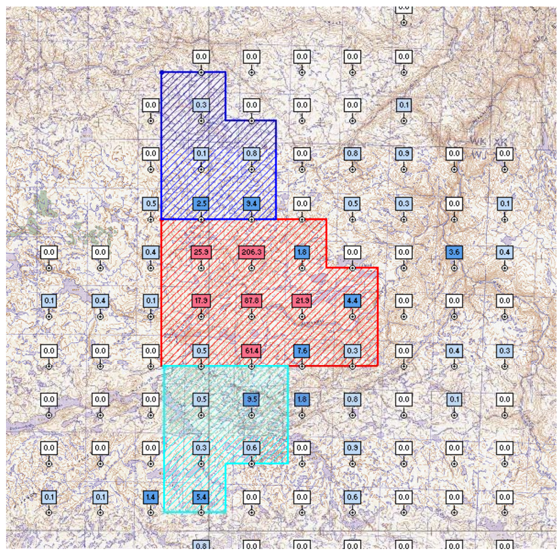

Figure 1: Strata boundaries with density for each section surveyed. Strata were medium north (dark blue), high (red) and medium south (light blue).

Reconnaissance data were used to estimate density of caribou on transects, population size ($\hat{N}$) and precision (coefficient of variation (CV)) for each of the strata. Calculations assumed that the medium strata were flown in a north-south direction and the high stratum was flown in an east-west direction. Areas of strata, average transect width (W_i), and length (L_i) were approximated using a weighted mean formula (given that strata shape was uneven) so these estimates will be approximate also.

Table 1: Strata summary and population estimates from reconnaissance surveys

Stratum	N	n	Area (km2)	W_i	L_i	Density	$\hat{N}$	SE ($\hat{N}$)	CV
High	28	3	1052	41.4	22.9	39.6	41649	12759	0.30
Medium N	23	2	538	25.4	18.6	2.6	1398	865.9	0.62
Medium S	30	2	589.6	23.9	24.6	3.3	1916	840.5	0.44

Density estimate and population estimates suggest that there are approximately 15 times more caribou in the high stratum than the medium strata.

2. OPTIMAL ALLOCATION USING ESTIMATES OF N AND SE (N).

Optimal allocation formulas were used to estimate the optimal number of transects for each stratum (to maximize overall estimate precision). Optimal allocation was estimated using estimated population size ($\hat{N}$) and the estimated standard error (SE) of population size (Norton-Griffiths 1978, Thompson 1992). The actual number of transects allocated was based on average transect width (w_i) and the total number of transects kilometres available (925). Percent effort was simply a measure of the proportion of effort that should be allocated to each stratum.

Table 2: Optimal allocation of transects from reconnaissance surveys

Stratum	Optimal No. of transects		Optimal km transects		Percent effort	
	Using SE	Using $\hat{N}$	Using SE	Using $\hat{N}$	Using SE	Using $\hat{N}$
High	20.2	20.4	838.32	843.278	91%	91%
Medium N	1.4	1.44	35.971	36.375	4%	4%
Medium S	2.1	1.9	50.709	45.346	5%	5%

Allocation formula results suggested that the majority of effort should be put in the high stratum. This is due to the fact that the population size/density in the high stratum is much higher than the medium strata. For example, in 2003 there were approximately 6 times as many caribou in the high strata than medium strata. This year the difference is 15 fold.

Ideally, there should be at least 5 (preferably 10) transects per stratum (Norton-Griffiths 1978, Heard 1987). The original plan was to do 10 transects in the medium strata and 15 in the high stratum. I suggest that the number of transects in the medium strata is reduced slightly (i.e. 8-9 transects) and the number of transects in the high strata increase (to approach 20 transects). Due to the difference in densities it is likely that the precision of the high stratum will be the prime determinant of overall precision of the survey. Therefore, allocating more effort to this stratum is warranted.

Literature Cited

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APPENDIX D. Bathurst caribou breeding female trend analysis 2006

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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	Variance	SE	CV	CI low	CI high
2006	55593	77667712	8813.0	0.160	37147	74039
2003	80756	173372522	13167.1	0.163	52916	108400
1996	151393	1235100000	35144.0	0.232	75469	227317
1990	151927	665900000	25805.0	0.170	94430	209424
1986	203800	161180000	12695.7	0.062	178197	229403

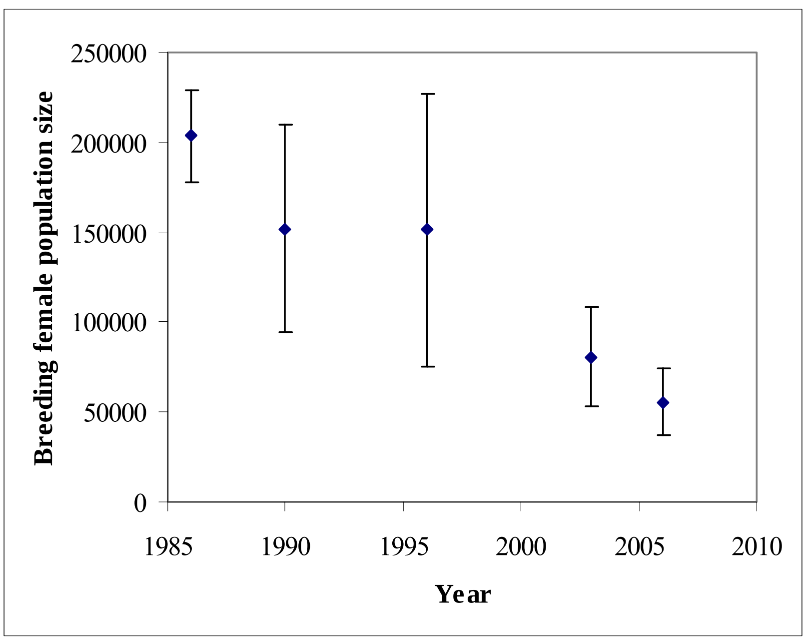

Figure 1: Population estimates of breeding females for surveys conducted in 1986, 1990, 1996, 2003, and 2006. Ninety five percent confidence intervals for estimates are shown as error bars.

Trend in population size was estimated using two methods.

Weighted least squares 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. The population size was log transformed to allow direct estimation of the per-capita rate growth rate (r) (Thompson 1998). More exactly, the estimated slope from the regression was an estimate of *r,* the per capita growth rate. 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 λ=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

Second, 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). 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 4 sampling occasions using the procedure documented in point 1 and the parameters listed in Table 1. As in the previous analysis, population estimates were log-transformed and a regression analysis was

conducted. This procedure was repeated for 2000 pseudo data sets that resulted in 2000 estimates of trend.

3. *Estimates of trend from the pseudo data sets were analyzed.* Mean estimates and percentile-based confidence intervals 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.

T-test comparison of 2003 and 2006 surveys

I also used a t-test to compare the 2003 and 2006 surveys to determine if a statistical difference had occurred between surveys. As discussed later, this method is less powerful in that it only considers 2 of 5 surveys that have been conducted. We used the methods documented in Gasaway *et al.* (1986) for this test.

RESULTS

Weighted least squares regression

The weighted least squares regression results suggested a significant negative per capita growth rate (r) of -0.059 in population size from 1986 to 2006. This translates to a population rate of change (λ) of 0.942 ($\lambda = e^{-0.059}$). This can be interpreted to mean that the caribou population was approximately 95% of its size each of the successive years from 1986 to 2006.

Table 2: Weighted least square regression results

Parameter	Estimate	S.E	C.I. low	C.I.high	t	P-value
Intercept	12.29	0.058	12.106	12.473	213.30	<0.001
slope (r)	-0.059	0.006	-0.079	-0.039	-9.51	0.002
Rate of change (λ)	0.942	1.006	0.924	0.961		

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 surveys had the best precision and therefore the confidence intervals are tightest around these points.

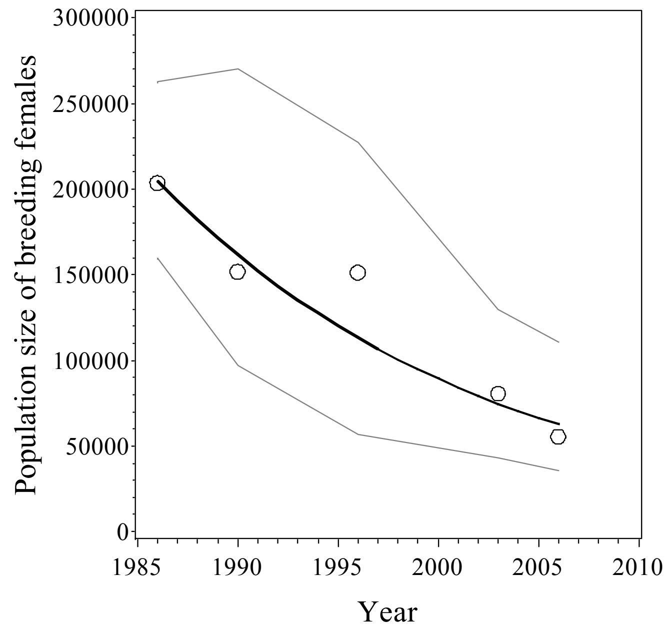

Figure 2: Predicted trend for breeding females from weighted least squares regression analysis. Grey lines are confidence interval on predictions. Circles are estimates for each year.

Monte Carlo simulation

Monte Carlo simulation results suggested that the trend was negative when the sampling variance associated with each of the surveys was directly accounted for. Estimates of per capita growth rate (r) was -.0604, with associated percentile-based 95% confidence limits of –.078 to –.045. Estimates of rate of population change (λ) were 0.941 with associated percentile-based 95% confidence limits of 0.924 to 0.956. The fact that the confidence limits of *r* do not overlap 0 and the confidence limits of λ do not overlap 1 suggest that the population was declining, and that the observed decline could not be attributed to sampling variation. The distribution of r and λ values suggests that λ never was equal to or greater than 1, and r was never equal or greater than 0 in simulations.

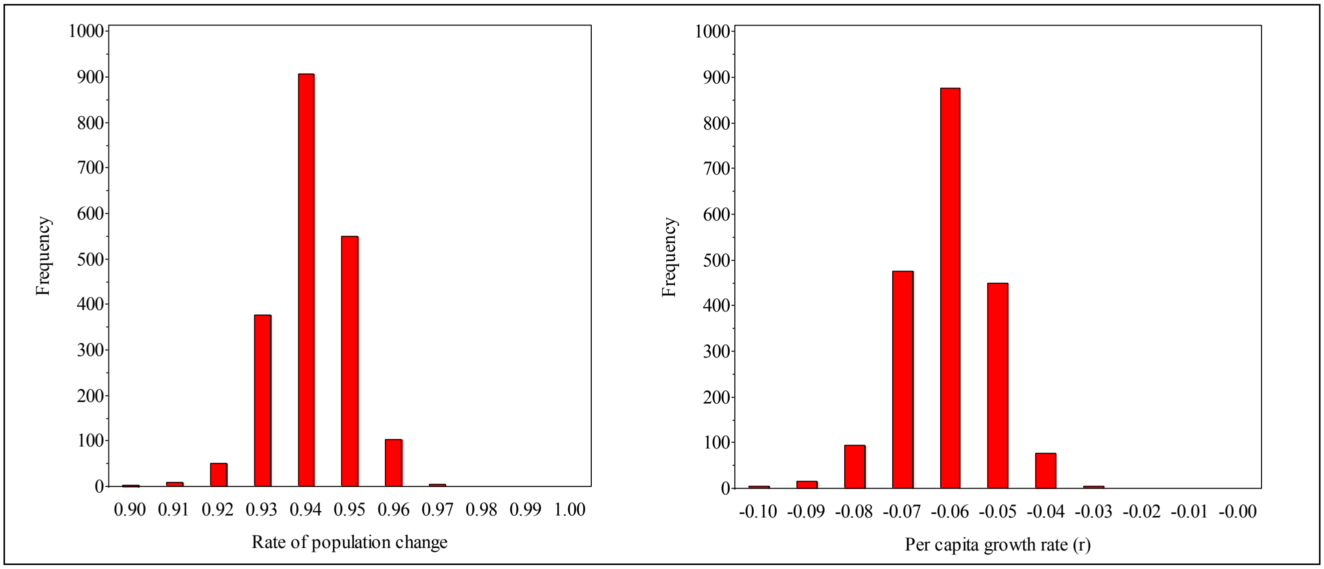

Figure 3: Distributions of population rate of change (λ) and per-capita growth rate (r) generated using Monte Carlo simulation trials.

T-test to compare 2003 and 2006 surveys

There was not a statistical difference in the 2003 and 2006 estimates ($t=1.59$, $df=30$, $p=0.12$) at $\alpha=0.05$. This was probably due to the relatively short period between surveys. As discussed later, the best method to interpret survey data is the regression analysis presented in this report rather than comparison of sequential estimates.

DISCUSSION

Both analyses suggest a negative trend in the population size of breeding females in the Bathurst caribou herd. The similarity in results of these analyses should not be surprising given the large difference in estimates and comparatively tight confidence interval bands on the surveys conducted in 1986, 2003, and 2006 (Table 1 and Figure 1). The confidence intervals on these surveys do not overlap, and therefore it can be concluded that the 2003 and 2006 estimates are statistically lower than the 1986 survey. These points "anchor" the relationship and compensate for the relatively low precision of surveys in 1990 and 1996.

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. It was not possible to test for non-linear trends given the low number of surveys. However, it can be concluded that the population has declined between 1986 and 2006 regardless of the shape of the trajectory.

The similarity in estimates between the Monte Carlo simulation procedure and the weighted least squares analysis suggest that each method is an efficient way to estimate trend while accounting for variance of surveys. It is suggested that these approaches be used to estimate trend and compare estimates when more than 2 estimates have been undertaken for a given population. In addition, they provide biologically useful estimates of population rate of change.

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 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 E. Trend and power analysis of Bathurst caribou breeding females, 2003 – 2006, with simulations to 2009 and implications for subsequent survey

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INTRODUCTION

In this Appendix, I describe the analysis of trend for breeding females in the Bathurst caribou herd based on the 2003 and 2006 survey data. I conducted this analysis after Boulanger's trend analyses (Appendix D) where he used Monte Carlo (MC) and weighted least squares (WLS) regression analyses to estimate trend of breeding females using data from 1986 to 2006. I did this analysis to specifically consider the results of the 2006 Bathurst caribou calving ground survey relative to the 2003 survey, and the implications of these analyses for the next survey. I have integrated these findings in to the larger survey report.

Although trend analysis methods that utilize multiple years of population data provide potentially more inference regarding trend compared to two sample t-tests of sequential estimates, an evaluation of trend patterns using both techniques is important when considering design of the next survey. Also, since management options are often evaluated in light of the most recent population data – especially when a population is considered to be low or declining – it is important to evaluate recent survey results to develop objectives and criteria for the next census.

My objectives were fourfold:

1) Conduct a one-tailed t-test of the 2003 and 2006 estimates of breeding females. The null hypothesis was that the 2006 estimate was not significantly lower than the 2003 estimate.

2) Conduct a power analysis of the one-tailed t-test.

3) Calculate the exponential rate of increase *(r)* and its variance between the 2006 and 2003 estimates of breeding females.

4) Simulate different values of *r* on future population trend, and explore the implications of different population trends on the design of the next survey in 2009.

METHODS

Data used for analyses

The data set of population estimates for breeding females in 2006 is presented in this larger report. The data for 2003 are presented in Gunn et al. 2005. The data are also summarized by Boulanger in Appendix D.

I designed spreadsheet models in Microsoft Excel (http://office.microsoft.com) using the methods and formulas described by Gasaway et al. 1986 in Chapter 4 of their monograph on moose survey analyses. I used these spreadsheets to calculate critical t-values (Section 4.2), evaluate survey precision and power to detect numerical changes in results from aerial surveys (Section 4.2), and estimate the exponential rate of increase *(r)* between two surveys (Section 4.3). In conjunction with Excel, I used @RISK software (http://www.palisade.com) to simulate estimates of breeding females in 2009. The simulations were based on the 2003 estimate of breeding females and three different estimates of *r* calculated from:

a) the 2006 and 2003 estimates of breeding females;

b) the Monte Carlo analysis of trend using data from 1986 to 2006, conducted by Boulanger in Appendix D; and

c) the weighted least squares regression analysis of trend using data from 1986 to 2006, conducted by Boulanger in Appendix D;

One-tailed t-test

I used the methods described in Section 4.2.1.4 of Gasaway *et al.* 1986 to conduct the t-test between the 2003 and 2006 estimates. I used a one-tailed t-test to specifically test whether the 2006 estimate was lower than the 2003 estimate. The relevant hypotheses were:

> $\mathbf{H_o}$ (null hypothesis): The estimate of breeding females has not decreased, *i.e.,* T_{2003} is equal to or less than T_{2006}, and
>
> $\mathbf{H_a}$ (alternate hypothesis): The estimate of breeding females has decreased, *i.e.,* T_{2003} is greater than T_{2006}
>
> where: T_{2003} is the estimate of breeding females in 2003, and
> T_{2006} is the estimate of breeding females in 2006.

In this case, the one-tailed t-test was more relevant and powerful than the two-tailed test case because a declining trend had been previously determined and reported by Gunn *et al.* 2005. From a management perspective, concerns that the Bathurst herd size was low and the trend was declining had resulted in implementation of additional monitoring and management actions.

Power analysis

Power analyses of the student t-test was also done using the procedures outlined in Section 4.2 of Gasaway *et al.* 1986. In order to calculate values for *β* (the acceptable probability of a Type II error), I designed a spreadsheet to calculate and incorporate:

a) the degrees of freedom for each respective survey;
b) total degrees of freedom for the t-test;
c) user defined entry of the estimate of breeding females and associated Coefficients of Variation (CV) for the respective surveys; and
d) user entry for the Consequential Difference of interest (CD) or effect size, as a percentage of the 1st survey.

The spreadsheet allowed me to determine the power of a t-test if the null hypothesis was rejected. Since the parameters that are used to calculate the critical value for β (Type II error rate) also include the CV's for the respective population surveys, the CD of interest, and the t-value to the corresponding value for α (Type I error rate), the spreadsheet allows one to iteratively explore *post hoc* power analyses by changing the parameters singly or in combination.

Rate of increase *(r)* between T_{2003} and T_{2006}

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 for this parameter, so that it could be used in subsequent simulations of population trend.

Simulation of population trend in 2009

I used Monte Carlo simulation techniques to generate estimates of breeding females to 2009, *i.e.,* when the next calving ground survey is scheduled. I conducted the simulations using the 2003 estimate of breeding females as a starting point, and simulated the number of breeding females on an annual time step through to 2009. I conducted three scenarios, which differed only in the exponential rate of increase (*r*) to simulate annual population growth:

a) r_{GAS}: the value of *r* (and associated variance) determined by comparing the two most recent estimates of breeding females (T_{2003} and T_{2006}). The method is described by Gasaway et al. 1986 (see above).

b) r_{MC}: the value of *r* (mean, standard deviation) estimated by Boulanger using Monte Carlo simulation techniques on all estimates of breeding females form 1986 – 2006 (see Appendix D).

c) r_{WLS}: the value of *r* (mean, standard deviation) estimated by Boulanger using weighted least squares regression on all estimates of breeding females form 1986 – 2006 (see Appendix D).

RESULTS

One-tailed t-test and Power analysis

Based on a one-tailed t-test, the estimate of breeding females in 2006 was not significantly different from the calving ground survey in 2003 at the $\alpha = 0.05$ confidence level ($t = 1.59$, $df = 30$, $p = 0.06$). However, the one-tailed test interpreted at the $\alpha = 0.05$ level of significance suffers from an associated high probability of a Type II error, and low power (<80%) to detect a population change of less than 50%. Table 1 shows the corresponding power of the one-tailed t-test of T_{2003} and T_{2006} with consequential differences expressed as an expected change in T_{2003} after 3 years at different rates of increase.

For example, if the exponential rate of increase for breeding females since 2003 was $r = -0.125$, by 2006, the 2003 estimate would have declined by *ca.* 31%; the t-test had a power of 45% to detect the 31% reduction in population size. In this example, if we accept H_o using the 5% significance level for a Type I error, we also accept a corresponding Type II error rate of ca. 0.55. Alternatively, if we consider that an acceptable level for a Type II error is 0.20, Table 1 shows that the one-tailed test could reliably detect a population change of 50% at a 3 year interval with 80% power. Table 1 also shows that a population that declines by half in 3 years has an exponential rate of increase of ca. -0.225.

The analysis of power raises two general points. Firstly, an increase in the acceptable level for a Type I error from $\alpha = 0.05$, to $\alpha = 0.10$ results in decreased Type II error rates and correspondingly increases the power of the t-test. In the previous example above, an increase in α to 0.10 increases the power of a test (with CD of 31%) from 45% to 61%. The second point arising from the power analysis shows that an increase in survey interval increases the power of the test at corresponding rates of increase. The main reason for this is that if the population trend (i.e., a decline) is continued for another three years, there is a larger change in the population. As in the previous example from Table 1, a population with a rate of increase of -0.125 over a 6 year period has a 53% reduction in size, the corresponding power to detect that change increases to 84% at $\alpha = 0.05$, and 91% when $\alpha = 0.10$.

Table 1. Power analysis of a one-tailed t-test between the 2003 (T_{2003}) and 2006 (T_{2006}) estimates of breeding females. The expected change in population size (relative to T_{2003}) is shown as the consequential difference of interest, and is linked to the rate of increase that would cause the proportionate change in the population.

				Constant rate of decline for 3 years			Constant rate of decline for 6 years		
Average Annual Intrinsic Rate of Increase +/- (r)	Doubling / Halving time (years)	Annual Finite Rate of Increase Lambda (-)	Annual Finite Rate of Increase Lambda (+)	Change in Population after 3 years (Consequential Difference)*	Power** (alpha = 0.05)	Power (alpha = 0.10)	Change in Population after 6 years (Consequential Difference)	Power (alpha = 0.05)	Power (alpha = 0.10)
0.025	27.7	0.98	1.03	7%	10%	17%	14%	17%	28%
0.050	13.9	0.95	1.05	14%	17%	28%	26%	36%	51%
0.075	9.2	0.93	1.08	20%	25%	39%	36%	55%	70%
0.100	6.9	0.90	1.11	26%	36%	51%	45%	72%	83%
0.125	5.5	0.88	1.13	31%	45%	61%	53%	84%	91%
0.150	4.6	0.86	1.16	36%	55%	70%	59%	90%	95%
0.175	4.0	0.84	1.19	41%	65%	78%	65%	94%	97%
0.200	3.5	0.82	1.22	45%	72%	83%	70%	96%	98%
0.225	3.1	0.80	1.25	49%	78%	88%	74%	97%	99%
0.250	2.8	0.78	1.28	53%	84%	91%	78%	99%	99%

* The consequential difference of interest (i.e., the minimum change in population size that would probably cause some change in management strategy) was related to constant rates of decline for either a 3 or 6 year period.

** Power calculations were conducted relative to the 2003 and 2006 estimates (and variances) of breeding females. Student's t distribution (30 df) was used to calculate critical values.

Rate of increase *(r)* between T_{2003} and T_{2006}
The intrinsic rate of increase between the 2003 and 2006 estimates of breeding females was r_{GAS} = -0.124 (0.075 Standard Deviation) (Table 2). This was *ca.* two times lower than the estimates derived from the longer term dataset (1986-2006) using Monte Carlo simulation techniques and weighted least squares regression which were r_{MC} = -0.0604 (0.009 SD) and r_{WLS} = - 0.059 (0.010 SD) respectively (Appendix D and Table 3).

Table 2. Rate of increase between subsequent surveys.

	T_{2003}	T_{2006}
Year (t)	2003	2006
Population Size (Nt)	80756	55593
Variance	173370258	77667712
$\log_e$ (Nt)	11.30	10.93
Δt	3	
df	17	19
a) Exponential Rate of Increase (r)		
	r =	$\log_e$ (Nt2) - $\log_e$ (Nt1) / Δt
	r =	-0.124
b) Variance of the Exponential Rate of Increase		
	Var(L1)=	0.026
	Var(L2)=	0.025
	Var (r) =	0.006
	std dev=	0.075

Simulation of population trend in 2009
The estimates of r_{MC} and r_{WLS} calculated by Boulanger (Appendix D) were virtually identical and therefore produced very similar simulation estimates at each annual time step through to 2009 (Table 1). The rate of decline represented by r_{GAS} was approximately twice the estimates of r_{MC} and r_{WLS} calculated by Boulanger, and therefore resulted in a lower simulation of breeding females in 2009. The simulation of breeding females was 39,032 (9668 SD) using r_{GAS}, which was ca. 30% less than the simulations derived using r_{MC} and r_{WLS} which were 56,328 and 56,676 respectively (Table 1).

Figure 1 shows the sampled distributions of the 2003 and 2006 estimates compared to simulated estimates for 2006 and 2009 using r_{GAS} and r_{MC}. When r_{GAS} is applied, the 2009 simulation shows a clear separation in its statistical distribution to the 2003 sampled distribution (Figure 1A). When r_{MC} is applied, there is almost a complete overlap between the 2005 sampled estimate and the 2009 simulated estimate.

Table 3. Summary of Monte Carlo simulations for breeding females from 2003 to 2009.

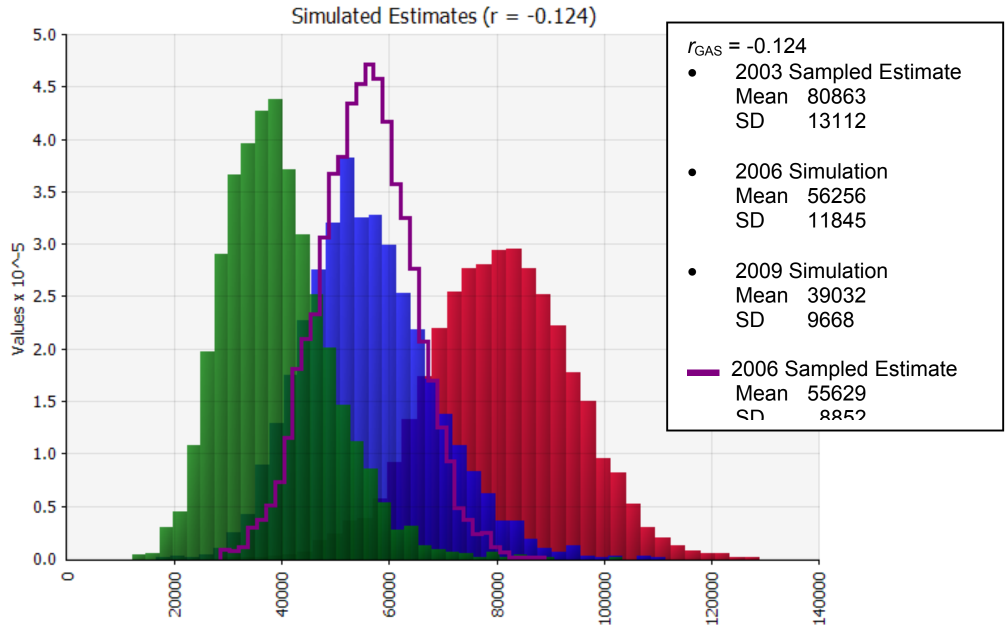
a) Simulated estimates of breeding females based on 2003 calving ground estimate. Simulations generated with an annual time step using Monte Carlo sampling (5000 iterations) of population estimates and *r.*

Derivation	*r* value	Year	2003	2004	2005	2006	2007	2008	2009
r_{GAS} *(Gasaway)*	-0.124	Simulated Estimate	80863	71558	63359	56256	49825	44058	39032
2003 & 2006	0.075 (SD)	SD	13112	12407	12407	11845	11255	10414	9668
		CV		0.173	0.196	0.211	0.226	0.236	0.248
r_{MC} *(Monte Carlo)*	-0.060	Simulated Estimate	80863	76020	71605	67429	63503	59797	56328
1986-2006	0.009 (SD)	SD	13112	12450	11749	11078	10438	9839	9280
		CV		0.164	0.164	0.164	0.164	0.165	0.165
r_{WLS} *(Weighted Least Squares)*	-0.059	Simulated Estimate	80863	76095	71737	67630	63767	60122	56676
1986-2006	0.010 (SD)	SD	13112	12476	11794	11147	10529	9954	9401
		CV		0.164	0.164	0.165	0.165	0.166	0.166

b) Estimates of breeding females from calving ground surveys

Year	2003	2006	2009
Estimate	80756	55593	?
SE	13167	8813	?
CV	0.163	0.159	?

*Note: Values highlighted in blue indicate inputs for simulations



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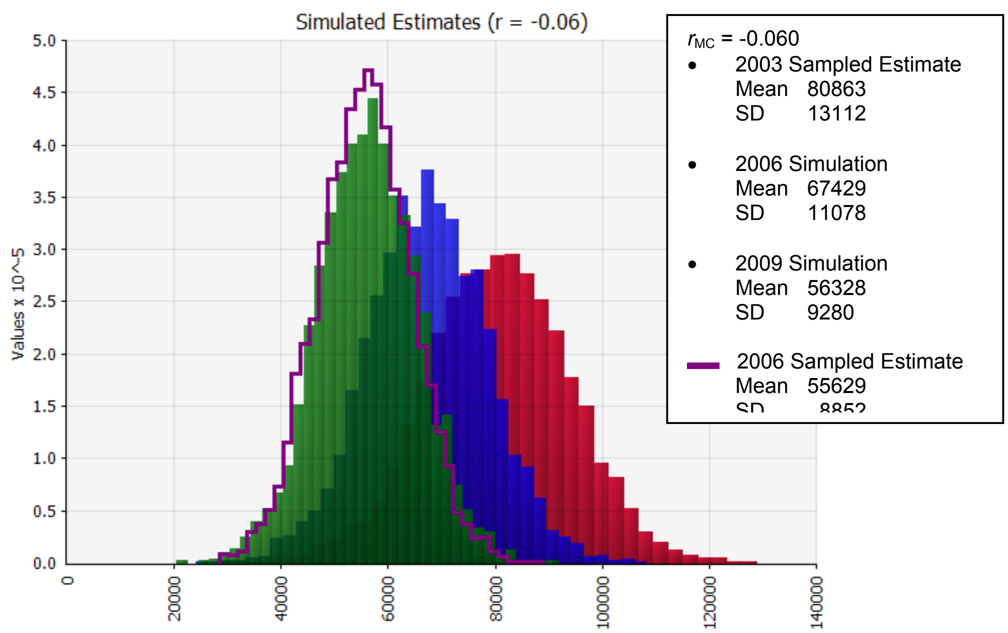

B

Figure 1. Monte Carlo simulations of breeding females, generated from a common starting value (2003 estimate of breeding females) and forecasted with two different estimates for rate of increase *(r)*: -0.124 (0.075 SD) (A), and -0.060 (0.009 SD) (B).

DISCUSSION

The one-tailed t-test between T_{2003} and T_{2006} is based on a more appropriate null hypothesis than a two-tailed test, because there was prior information to suggest that the herd may be declining. Results of the two-tailed test showed that there was not a statistical difference between T_{2003} and T_{2006} ($t=1.59$, $df=30$, $p=0.12$) (Appendix D). As expected the probability associated with the one-tailed test was half that of the two-tailed test ($t = 1.59$, $df = 30$, $p = 0.06$). A cursory evaluation of the associated probabilities would suggest that the differences between T_{2003} and T_{2006} are not statistically significant because both t-tests have probabilities that are greater than the conventional test of statistical significance which commonly sets the probability of a Type I error[11] at $\alpha=0.05$. However, the 5% level of significance is only a convention, and needs to be considered with respect to the probability of making a Type II error[12] because there is a trade-off between the two sources of error. For example, lowering the Type I error (α) will always increase the likelihood of a Type II (β) error. Therefore, it is important to consider the consequences of making each type of error.

In the one-tailed test between T_{2003} and T_{2006}, Type I error refers to the likelihood of making the false conclusion that the number of breeding females is declining, i.e., $T_{2006} < T_{2003}$, when in fact the two estimates are not different $T_{2006} \geq T_{2003}$. In statistical terminology (see Methods for one-tailed test above), H_o is falsely rejected in favor of H_a, when H_o is true. An interpretation of this type of error is that the trend in breeding females may actually be stable or increasing, yet we have falsely concluded that the trend is declining. An implication of this error is that additional conservation actions and harvest restrictions may be imposed unnecessarily.

Conversely, a Type II error is the false conclusion that the number of breeding females is not declining, i.e., $T_{2006} \geq T_{2003}$, when in fact the breeding females are declining, $T_{2006} < T_{2003}$. In statistical terms, H_o is falsely accepted, when in fact H_a is true. An interpretation of a Type II error in this case is that the breeding females are declining, yet we have falsely concluded that the trend is stable or possibly increasing slightly. An implication of this error is that management and monitoring efforts may be reduced or relaxed, whereas in reality there is continued need for conservation actions. From a biological perspective, the implications of a Type II error may have more serious implications to recovery and conservation of a population that is low or declining, than a Type I error (Taylor and Gerodette 1993).

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[11] α - The acceptable probability of error (from a practical point of view) if you were to conclude that a change in numbers had occurred when in fact it had not changed, i.e., a Type I error.
[12] β - The acceptable probability of error (from a practical point of view) if you were to conclude that no change in numbers larger than the consequential difference had occurred when in fact it had changed, i.e., a Type II error. Power is calculated by $1- \beta$.

Thus with respect to the results of the one-tailed t test between T_{2003} and T_{2006}, H_o should be tested at $\alpha = 0.10$. This means that a significant results requires that the risk of a Type I error must be 1-in-10 or lower to be acceptable. Thus I reject H_o and accept H_a, and conclude that the estimate of breeding females in 2006 was significantly less than the 2003 estimate ($p = 0.06$).

As Boulanger suggests in Appendix D, trend analyses that include more than two data points are more powerful and meaningful, than single t-tests on two subsequent surveys. However, information needs of wildlife managers and stakeholders require us to consider the contribution of knowledge that each subsequent population survey provides as it is completed. The use of t-tests has practical use because management options are often considered based on the most recent survey results. In this context, it is also important to consider how the next survey will contribute to information needs, and to develop criteria which may help us anticipate and interpret those survey results.

Since the next calving ground survey is recommended to occur in 2009 (GNWT 2006), results from the survey should be used to test whether the trend of breeding females is declining. As shown in Table 1 and Figures 1A and 1B, a test of whether the breeding females are declining is linked to the expected rate of decline and the likelihood, i.e., power, of being able to detect a significant change with the next calving ground survey. As reflected in Table 1, if one assumes that the 2009 survey will be similar to the 2003 and 2006 surveys in so far as precision (variance and Coefficient of Variation) and effort (degrees of freedom) are concerned, we should expect that a statistical comparison of the 2006 survey to the 2009 results would have 80% power to detect only a relatively a large change between estimates, *i.e.,* 40% or more.

In considering power of t-tests, it is important to understand how the rate of increase and survey interval affects how well a survey can detect or at the very least, provide an early indication of a change in longer term population trend (Heard and Williams 1990). Figures 1A and 1B show a simplistic example of simulating two different yet very plausible rates of increase to the 2003 estimate of breeding females. If an exponential rate of increase of -0.060 is applied annually to T_{2003} for a period of six years (Figure 1B and Tables 2), it is reasonable to expect that a calving ground estimate of breeding females in 2009 will not be statistically different from either T_{2003}, or T_{2006}, thereby making it difficult to distinguish a declining trend from a stable trend. However, if an exponential rate of increase of -0.124 is applied to T_{2003}, than it is much more likely for a survey in 2009 to detect a true decline (Figure 1A).

Therefore, a useful test of the 2009 survey result would be to conduct trend analyses using data from the three recent surveys (2003, 2006, and 2009), and compare the recent trend to the overall trend determined by Monte Carlo and regression analysis of the long term data (1986-2009). This comparative analysis may distinguish whether the rate of increase (r = -0.124) indicated by the comparison between the 2006 and 2003 surveys, has continued.

In this Appendix, I conducted an initial and cursory assessment of power analyses for a simple one-way t-test, and an exploration in to the issues of trend analyses for caribou calving ground surveys. Further work is required. In particular, the consequential difference of interest (or effect size) that is important from a management perspective needs to be further developed and understood among a larger group of managers and stakeholders. If caribou managers are concerned about trend of breeding females, than relationships between detectable effect size, rates of increase, survey frequency, and linkages with management options requires further discussion.

Although the relative weighting of Type I and Type II errors appear technical in nature, weighting of these sources of error are grounded in the values and perspectives of managers and stakeholders who will interpret the results of the analyses and use them in formulating management options and decisions (Mapstone 1995). For example, in their survey design and power analysis of a monitoring program for fisher and American marten, Zielinski and Stauffer (1996) set Type I error rate at 20% because they felt that the environmental cost of a Type II error was much larger than that of a Type I error. Similarly, Heard and Williams (1990) suggested that Type II error should set at 0.10 (90% power) because it was important to avoid the error of concluding there was no trend when in fact there was one. As, an initial recommendation for interpreting results from the upcoming 2009 survey, I suggest that the following levels of significance be considered: α = 0.10, and β = 0.20. However, this suggestion should be evaluated more rigorously.

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APPENDIX F. Number of 1+-year-old caribou observed during an aerial transect survey of low density visual strata (Low I - VI), Bathurst calving ground, 9 and 11 June 2006.

Low Density Visual Stratum - Low I

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	24	19.2	2
2	24	19.2	7
3	24	19.2	0
4	10	8.0	0
5	10	8.0	8
6	10	8.0	0
7	10	8.0	0
8	10	8.0	6
9	10	8.0	0
10	10	8.0	3
11	10	8.0	0
12	10	8.0	0
13	10	8.0	4
14	10	8.0	0
15	10	8.0	0
Total	192	153.6	30

Low Density Visual Stratum - Low II

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	10	8.0	0
2	10	8.0	2
3	10	8.0	2
4	10	8.0	0
5	10	8.0	2
6	10	8.0	0
7	10	8.0	10
8	10	8.0	1
9	10	8.0	7
10	10	8.0	0
11	10	8.0	0
Total	110	88.0	24

APPENDIX F. Continued

Low Density Visual Stratum - Low III

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	10	8.0	0
2	10	8.0	0
3	10	8.0	1
4	23	18.4	1
5	23	18.4	0
6	23	18.4	0
7	10	8.0	2
8	10	8.0	0
9	10	8.0	0
Total	129	103.2	4

Low Density Visual Stratum - Low IV

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	20	16.0	3
2	20	16.0	1
3	20	16.0	2
4	20	16.0	2
5	30	24.0	1
6	30	24.0	0
7	30	24.0	0
8	30	24.0	4
9	20	16.0	1
10	20	16.0	2
11	20	16.0	10
12	20	16.0	75
13	20	16.0	74
14	20	16.0	39
15	20	16.0	32
16	20	16.0	0
Total	360	288.0	246

APPENDIX F. Continued

Low Density Visual Stratum - Low V

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	10	8.0	0
2	10	8.0	0
3	10	8.0	0
4	10	8.0	6
5	10	8.0	0
6	10	8.0	0
7	10	8.0	3
8	10	8.0	3
9	10	8.0	7
10	10	8.0	13
11	10	8.0	27
12	10	8.0	84
13	10	8.0	21
14	10	8.0	5
15	10	8.0	6
16	10	8.0	40
17	10	8.0	19
18	20	16.0	305
19	20	16.0	28
20	20	16.0	2
Total	230	184.0	569

Low Density Visual Stratum - Low VI

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	30	24.0	0
2	30	24.0	0
3	30	24.0	0
4	30	24.0	6
5	30	24.0	0
6	30	24.0	0
7	30	24.0	3
8	30	24.0	3
9	30	24.0	7
10	30	24.0	13
Total	300	240.0	32

APPENDIX G. Number of 1+-year-old caribou observed during a photographic transect survey of a high density stratum, Bathurst calving ground, 11 June 2006

High Density Photographic Stratum

Transect No.	Transect Area (km2)	Transect Length (km)	1+-yr-old Caribou Counted
1	33.56	36.70	1062
2	33.56	36.70	1055
3	33.56	36.70	1174
4	33.62	36.77	1444
5	33.68	36.83	768
6	33.68	36.83	175
7	33.62	36.77	123
8	33.56	36.70	211
9	33.62	36.77	831
10	33.62	36.77	3255
11	33.38	36.51	5401
12	33.38	36.51	4481
13	33.21	36.32	3188
14	33.21	36.32	3678
15	33.21	36.32	1146
16	33.21	36.32	1595
17	33.21	36.32	1114
18	33.21	36.32	1298
19	33.21	36.38	451
20	33.21	36.32	494
Total	668.52	731.18	32 944

APPENDIX H. Number of 1+-year-old caribou observed during a photographic transect survey of medium density strata (Med I, II), Bathurst calving ground, 12 June 2006

Medium Density Photographic Stratum – Med I

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	30.12	27.54	47
2	30.12	27.54	5
3	29.99	27.42	123
4	20.11	18.39	31
5	20.11	18.39	108
6	20.11	18.39	15
7	20.11	18.39	10
8	20.11	18.39	99
9	20.11	18.39	57
Total	210.89	192.84	495

Medium Density Photographic Stratum – Med I

Transect No.	Transect Length (km)	Transect Area (km^2)	1+-yr-old Caribou Counted
1	23.22	21.23	1
2	23.22	21.23	4
3	23.28	21.29	2
4	23.28	21.29	4
5	23.22	21.23	5
6	13.16	12.03	0
7	13.16	12.03	11
8	13.16	12.03	0
9	13.16	12.03	2
Total	168.86	154.39	29

APPENDIX I. Composition of 1+-year-old caribou classified in the high density photo stratum, Bathurst calving ground, 11-12 June 2006

Waypoint	Lat	Long	Sample no. in segment	Antlered With Udder	Antleless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
99	66 19 33	110 04 49	1	0	2	0	14	2	1	0	19	2	17	0.1176	0.88122	0.74016
101	66 20 06	109 59 13	1	0	4	0	13	0	0	0	17	4	17	0.2353	0.88071	0.76148
103	66 18 22	109 52 31	1	13	36	0	13	46	0	0	108	49	62	0.7903	0.87933	0.81936
104	66 18 42	109 45 50	1	48	108	3	0	117	0	0	276	159	159	1.0000	0.87283	1.09256
5	66 21.833	109 37.131	1	9	29	3	12	33	1	4	91	41	58	0.7069	0.88048	0.77108
6	66 20.969	109 41.027	1	3	19	1	12	15	13	0	63	23	48	0.4792	0.88283	0.67228
7	66 20.67	109 41.42	1	29	65	0	16	57	2	0	169	94	112	0.8393	0.87906	0.83065
8	66 20.95	109 39.19	1	1	37	0	4	12	1	5	60	38	48	0.7917	0.87900	0.83344
9	66 21.65	109 36.13	1	23	231	0	6	114	6	0	380	254	266	0.9549	0.87239	1.11085
11			1	7	84	0	11	61	0	0	163	91	102	0.8922	0.87756	0.89374
12	66 19.776	109 32.317	1	10	209	0	0	92	0	6	317	219	225	0.9733	0.87219	1.11949
13	66 21.42	109 33.72	1	0	0	0	23	0	2	3	28	0	28	0.0000	0.88419	0.61516
14	66 25.657	109 35.096	1	5	75	0	18	18	1	0	117	80	99	0.8081	0.87973	0.80265
15	66 26.905	109 31.867	1	15	166	0	0	136	0	0	317	181	181	1.0000	0.87209	1.12368
16	66 27.915	109 25.226	1	21	144	1	3	103	0	0	272	166	169	0.9822	0.87328	1.07340
17	66 28.700	109 29.345	1	16	118	0	0	74	0	0	208	134	134	1.0000	0.87366	1.05763
19	66 29.276	109 30.709	1	22	203	0	0	146	0	0	371	225	225	1.0000	0.87058	1.18702
20	66 29.077	109 35.299	1	13	191	0	4	95	0	0	303	204	208	0.9808	0.87223	1.11756
21	66 26.313	110 04.829	1	0	9	0	1	1	0	0	11	9	10	0.9000	0.87788	0.88029
22	66 27.793	109 57.221	1	0	14	0	0	14	0	0	28	14	14	1.0000	0.87750	0.89614
23	66 26.397	109 59.339	1	0	1	0	10	0	2	0	13	1	13	0.0769	0.88058	0.76705
24	66 23.862	109 50.730	1	11	126	0	0	72	0	0	209	137	137	1.0000	0.87356	1.06180
25	66 34.011	109 50.352	1	4	25	0	2	11	1	1	44	29	33	0.8788	0.87793	0.87824
26	66 23.965	109 45.885	1	3	21	0	12	3	1	2	42	24	39	0.6154	0.88055	0.76817
27	66 24.066	109 41.833	1	6	41	6	5	0	0	6	64	53	64	0.8281	0.87876	0.84354
28	66 25.275	109 39.508	1	2	43	0	11	6	0	0	62	45	56	0.8036	0.87901	0.83310
29	66 26.961	109 48.109	1	9	43	1	41	40	6	0	140	53	100	0.5300	0.88696	0.49906
30	66. 26.682	109 40.447	1	15	70	0	10	72	3	0	170	85	98	0.8673	0.87821	0.86664
31	66 28.733	109 37.234	1	16	101	1	14	99	1	0	232	118	133	0.8872	0.87762	0.89149
32	66 29.676	109 35.442	1	15	26	0	3	39	0	0	83	41	44	0.9318	0.87733	0.90338
33	66 30.827	109 36.676	1	29	85	0	1	114	1	0	230	114	116	0.9828	0.87477	1.01089
34	66 31.134	109 28.024	1	1	13	0	41	3	2	3	63	14	60	0.2333	0.88786	0.46110
150	66 36 10	109 49 01	1	22	83	0	13	65	2	0	185	105	120	0.8750	0.87803	0.87408
			1	12	28	0	4	35	0	0	79	40	44	0.9091	0.87759	0.89265
			1	45	65	0	7	90	1	0	208	110	118	0.9322	0.87627	0.94799
154	66 32 50	109 41 47	1	30	57	0	13	55	0	0	155	87	100	0.8700	0.87814	0.86929
155	66 31 00	109 38 17	1	21	90	0	4	102	0	0	217	111	115	0.9652	0.87533	0.98766
156	66 30 28	109 34 29	1	9	29	0	7	37	0	0	82	38	45	0.8444	0.87832	0.86176
157	66 30 19	109 30 14	1	14	93	0	3	95	1	0	206	107	111	0.9640	0.87546	0.98222
158	66 32 57	109 35 28	1	5	26	0	7	0	21	0	59	31	59	0.5254	0.88327	0.65384
159	66 39 05	109 45 06	1	6	16	1	24	2	0	0	49	23	47	0.4894	0.88261	0.68176
160	66 41 25	109 58 15	1	1	7	0	1	5	0	0	14	8	9	0.8889	0.87791	0.87899
161	66 36 13	109 54 18	1	5	108	0	1	108	0	0	222	113	114	0.9912	0.87458	1.01909

APPENDIX I. Continued

n=	43
Sum Breeding Females	3474
Sum 1+ Yr Old Caribou	3957
Overall proportion Breeding Females	0.8779

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

mean	0.8798
variance	0.0273
SD	0.1652
SE	0.0252
CV	0.0286

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 medium density photo strata (Med I, II), Bathurst calving ground, 12-13 June 2006

Medium Density Photo Stratum – Med I

Waypoint	Lat	Long	Sample no. in segment	Antlered With Udder	Antleless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
174	66 15 43	109 49 31	1	0	0	0	10	0	0	6	16	0	16	0.0000	0.02133	0.00998
175			1	0	0	8	0	0	0	0	8	8	8	1.0000	0.00000	0.26598
176	66 17 24	109 37 33	1	0	0	0	36	0	0	16	52	0	52	0.0000	0.02360	-0.01720
178	66 14 26	109 30 57	1	0	0	0	3	0	2	51	56	0	56	0.0000	0.02388	-0.02058
179			1	0	0	0	16	0	21	0	37	0	37	0.0000	0.02260	-0.00520
180	66 15 35	109 34 25	1	0	0	0	15	0	1	33	49	0	49	0.0000	0.02339	-0.01472
182			1	0	0	0	0	0	1	20	21	0	21	0.0000	0.02162	0.00653
183			1	0	0	0	0	0	1	25	26	0	26	0.0000	0.02192	0.00297
184	66 12 19	109 43 12	1	0	0	0	10	0	1	11	22	0	22	0.0000	0.02168	0.00582
186			1	0	0	0	0	0	0	7	7	0	7	0.0000	0.02083	0.01598
187			1	0	0	0	4	0	2	10	16	0	16	0.0000	0.02133	0.00998
189	66 17 03	109 33 56	1	0	0	0	15	0	4	52	71	0	71	0.0000	0.02500	-0.03402
190			1	0	0	0	0	0	4	6	10	0	10	0.0000	0.02100	0.01402

n=	13
Sum Breeding Females	8
Sum 1+ Yr Old Caribou	391
Overall proportion Breeding Females	0.0205

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

mean	0.0184
variance	0.0058
SD	0.0759
SE	0.0211
CV	1.1429

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. Continued

Medium Density Photo Stratum – Med II

Waypoint	Lat	Long	Sample no. in segment	Antlered With Udder	Anterless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Bree Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
158			1	26	5		0	21	0	0	52	31	31	1.0000	0.70089	0.93318
159			1	6	16	1	34	3	0	0	60	23	57	0.4035	0.76303	0.24964
162			1	1	8	0	3	5	0	0	17	9	12	0.7500	0.71949	0.72866
164			1	7	16	0	8	20	0	0	51	23	31	0.7419	0.71875	0.73676
165			1	10	38	0	0	44	0	0	92	48	48	1.0000	0.68910	1.06296
166			1	15	42	0	18	32	0	0	107	57	75	0.7600	0.71287	0.80142
167			1	8	35	0	20	28	3	0	94	43	66	0.6515	0.73123	0.59942
168			1	4	4	0	24	6	0	0	38	8	32	0.2500	0.75391	0.34994
169			1	1	10	0	3	7	0	0	21	11	14	0.7857	0.71828	0.74193
170			1	9	33	0	0	27	0	0	69	42	42	1.0000	0.69336	1.01600
171			1	0	8	0	8	9	0	0	25	8	16	0.5000	0.72786	0.63653
172			1	3	39	0	12	40	0	1	95	42	55	0.7636	0.71462	0.78216

n=	12
Sum Breeding Females	345
Sum 1+ Yr Old Caribou	479
Overall proportion Breeding Females	0.7203

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

mean	0.7199
variance	0.0583
SD	0.2415
SE	0.0697
CV	0.0969

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. Composition of 1+-year-old caribou classified in the low density strata (Low I, V & VI), Bathurst calving ground, 15 June 2006.

Low Density Stratum – Low I

Waypoint	Lat	Long	Segment	Sample no. in segment	Antlered With Udder	Anterless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
1	66 00 48	110 19 00		1	0	0	0	12		3	2	17	0	17	0.0000	0.02381	-0.00363
2	66 04 12	110 24 41		1	0	0	0	8		3	4	15	0	15	0.0000	0.02273	-0.00039
3	66 11 24	110 17 30		1	0	1	0	4	1	2	2	10	1	9	0.1111	0.00000	0.06780
4	66 16 6	110 12 00		1	0	0	0	7		3	8	18	0	18	0.0000	0.02439	-0.00537

n=	4
Sum Breeding Females	1
Sum 1+ Yr Old Caribou	59
Overall proportion Breeding Females	0.0169

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

mean	0.0146
variance	0.0013
SD	0.0355
SE	0.0178
CV	1.2165

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. Continued

Low Density Stratum – Low V

Waypoint	Lat	Long	Sample no. in segment	Antlered With Udder	Anterless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breed Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
195	66 22 29	109 27 19	1	12	25	0	9	34	0	10	90	37	56	0.6607	0.43151	0.60648
196	66 22 27	109 27 19	1	1	1	0	12	0	1	9	24	2	24	0.0833	0.45264	0.33182
197			1	0	0	0	15	0	0	10	25	0	25	0.0000	0.45509	0.30000
199	66 23 03	109 19 07	1	0	0	0	8	0	0	12	20	0	20	0.0000	0.45283	0.32937
200	66 23 03	109 19 07	1	0	0	0	20	0	0	24	44	0	44	0.0000	0.46389	0.18564
201	66 23 43	109 22 46	1	0	0	0	38	0	4	14	56	0	56	0.0000	0.46962	0.11112
202	66 25 39	109 24 32	1	0	45	0	117	28	2	8	200	45	172	0.2616	0.48070	-0.03296
203	66 29 25	109 21 57	1	4	59	0	39	47	3	0	152	63	105	0.6000	0.42625	0.67495
204			1	0	2	12	0	2	8	0	24	14	22	0.6364	0.43980	0.49875
	66 27 14	109 24 11	1	1	22		30	15	7	1	76	23	61	0.3770	0.44824	0.38904
205	66 27 29	109 20 34	1	25	65	0	7	79	0	0	176	90	97	0.9278	0.39355	1.10003
206	66 29 00	109 26 29	1	3	108	0	25	108	2	0	246	111	138	0.8043	0.38808	1.17117
209	66 23 37	109 19 59	1	0	13		93	13	6	2	127	13	114	0.1140	0.48521	-0.09161
210	66 31 35	109 20 39	1	2	56	0	35	38	0	0	131	58	93	0.6237	0.42612	0.67655

n=	14
Sum Breeding Females	456
Sum 1+ Yr Old Caribou	1027
Overall proportion Breeding Females	0.4440

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

mean	0.4465
variance	0.1413
SD	0.3759
SE	0.1005
CV	0.2250

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. Continued

Low Density Stratum – Low VI

Waypoint	Lat	Long	Sample no. in segment	Antlered With Udder	Antleless With Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
224	66 17 19	108 45 14	1	1	0	0	18	0	2	18	39	1	39	0.0256	0.19955	-0.01240
225	66 15 46	108 43 11	1	0	0	0	18	0	1	2	21	0	21	0.0000	0.19390	0.06665
226	66 11.4	110 17.5	1	0	0	0	16	0	0	15	31	0	31	0.0000	0.19822	0.00619
227	66 16.1	110 12.0	1	0	0	0	14	0	1	7	22	0	22	0.0000	0.19432	0.06073
228	66 13 07	108 36 43	1	0	0	0	27	0	7	41	75	0	75	0.0000	0.21975	-0.29529
229			1	0	0	0	12	0	0	18	30	0	30	0.0000	0.19778	0.01236
230			1	0	0	0	5	2	2	4	13	0	11	0.0000	0.18977	0.12453
231			1	0	0	0	24	0	0	5	29	0	29	0.0000	0.19734	0.01850
217	66 26 08	109 12 26	1	2	31	0	24	27	3	0	87	33	60	0.5500	0.13333	0.91458
218	66 25 02	109 12 13	1	1	12	0	19	14	1	0	47	13	33	0.3939	0.17002	0.40094
219	66 26 42	109 11 14	1	2	20	0	19	29	1	0	71	22	42	0.5238	0.15297	0.63970
220	66 25 23	109 04 47	1	0	2	0	8	2	0	0	12	2	10	0.2000	0.18511	0.18976
221	66 27 46	108 54 38	1	1	16	0	26	8	5	0	56	17	48	0.3542	0.16667	0.44792
222	66 26 46	108 54 38	1	1	0	0	5	0	1	1	8	1	8	0.1250	0.18644	0.17108
223			1	0	0	0	11	0	1	9	21	0	21	0.0000	0.19390	0.06665

n=	15
Sum Breeding Females	89
Sum 1+ Yr Old Caribou	480
Overall proportion Breeding Females	0.1854

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

mean	0.1875
variance	0.0901
SD	0.3001
SE	0.0775
CV	0.4134

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 L. Estimated proportion of calves observed during systematic reconnaissance flights on the 7 and 8 June 2006.

07-Jun-06 Systematic Survey

Segment	WPT	Estimated 1+ Yr Caribou Observed On Transect	Estimated % Calves	Adjusted 1+ Yr Caribou	Breeding Females 1+ Yr Caribou	Adjusted % Calves	**p**	**St**	**Pseudovalue**
14-11	99	unk	40						
14-11	101	100+	30	100	88	26	0.30	0.204	0.497
14-11	102	75	30	75	66	20	0.30	0.209	0.417
14-11	103	10	40	10	9	4	0.40	0.218	0.273
14-11	104	40	0	40	35	0	0.00	0.238	-0.051
14-11	105	5	60	5	4	3	0.60	0.217	0.276
14-10	106	100	30	100	88	26	0.30	0.204	0.497
14-10	109	50	20	50	44	9	0.20	0.223	0.188
14-10	111	50	10	50	44	4	0.10	0.233	0.031
14-10	112	14	0	14	12	0	0.00	0.226	0.130
14-10	113	11	0	11	10	0	0.00	0.225	0.150
14-09	115	2	0	2	2	0	0.00	0.222	0.208
14-09	116	12	33	12	11	3	0.33	0.218	0.259
14-09	117	6	33	6	5	2	0.33	0.220	0.240
14-08	119	20	30	20	18	5	0.30	0.218	0.268
14-08	121	9	0	9	8	0	0.00	0.224	0.163
14-08	122	50	10	50	44	4	0.10	0.233	0.031
14-08	124	5	40	5	4	2	0.40	0.219	0.247
			406	559	492	109			

High Density Strata Proportion Breeding Females
0.8798235

n=	17
Sum Calves	109
Sum Breeding Females	492
Overall proportion Calves	0.2208

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

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
i = Sample number (1,2,3,…. n)

mean	0.2248
varian	0.0228
SD	0.1511
SE	0.0366
CV	0.1630

08-Jun-06 Systematic Survey

Segment	WPT	Estimated 1+ Yr Caribou Observed On Transect	Estimated % Calves	Adjusted 1+ Yr Caribou	Breeding Females 1+ Yr Caribou	Adjusted % Calves	**p**	**St**	**Pseudovalue**
14-8		6	50	6	5	3	0.50	0.367	0.386
14-9		30	50	30	26	13	0.50	0.359	0.461
14-9		30	10	30	26	3	0.10	0.387	0.179
14-10		30+	45	30	26	12	0.45	0.363	0.426
14-10		30+	40	30	26	11	0.40	0.366	0.391
14-10		30+	45	30	26	12	0.45	0.363	0.426
14-10		30+	20	30	26	5	0.20	0.380	0.250
14-11		30+	35	30	26	9	0.35	0.370	0.355
14-11		50+	50	50	44	22	0.50	0.352	0.530
14-11		100+	35	100	88	31	0.35	0.374	0.317
14-11		90	35	90	79	28	0.35	0.373	0.323
				456	401	148			

n=	11
Sum Calves	148
Sum Breeding Females	401
Overall proportion Calves	0.3684

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

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
i = Sample number (1,2,3,…. n)

mean	0.3677
varian	0.0097
SD	0.0985
SE	0.0297
CV	0.0807