AN ESTIMATE OF BREEDING FEMALES IN THE BATHURST HERD OF BARREN-GROUND CARIBOU, JUNE 2003

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ABSTRACT

Prior to 2003, the most recent survey of the number of breeding females in the Bathurst herd of barren-ground caribou *Rangifer tarandus groenlandicus* was conducted in June 1996. At that time, the estimate of breeding females was 151 000 ± 35 200 (Standard Error). To determine the trend in the number of breeding females – a key indicator for herd health - we followed the standardized method for an aerial photographic survey to determine relative abundance and distribution of breeding cows in June 2003. We flew systematic visual reconnaissance surveys in a fixed-wing aircraft on 4 and 5 and again on 7 June 2003 to delineate the annual calving ground and determine relative caribou densities. We used those observations to delineate high density and moderate density strata for the photographic survey. A blizzard delayed the photography for 5 days and we flew another systematic reconnaissance survey on 13 June to re-align stratum boundaries. The photography of the high and moderate density strata was completed 14 and 15 June and we also completed a visual survey of the low density strata on 13 and 14 June. To estimate sex and age composition of caribou on the annual calving ground, we used a helicopter to position observers on the ground to classify caribou. We estimated the proportion of caribou that were breeding cows to be 6%, 47% and 82% in low, medium, and high density stratum. The spatial extent of the annual calving ground we observed in spring 2003, was similar to 2002. The distribution of pre and post parturient caribou occurred south of the Hood River. Based on the combined estimates from the low density visual stratum, and two photo strata, we estimated that there were 109 983 ± 15 990 (SE) 1+ year old caribou on the calving ground. After adjusting this overall estimate by the proportion of breeding females observed in each stratum during composition surveys we estimated that there were a total of 80 756 ± 13 167 (SE) breeding females. The 2003 estimate is relatively precise and reveals a significant decline in the number of breeding females since 1996.

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INTRODUCTION

People from 11 communities in the Northwest Territories and Nunavut regularly depend on harvesting the Bathurst herd of barren-ground caribou (*Rangifer tarandus groenlandicus)*. In the late 1990s extensive exploration and the construction of three diamond mines on the Bathurst herd's range has piqued interest in the Bathurst Herd at the Territorial, national and international levels. For example, the Circumpolar Arctic Flora and Fauna's 2001 Overview featured the Bathurst herd, diamond mining and traditional knowledge. Non-government organizations (Canadian Arctic Resources Committee and World Wildlife Fund Canada) are emphasizing the major caribou herds in their programs and this will be increased given the feasibility study for the deep-sea port and roads on the Bathurst herd's calving and post-calving ranges. A warming trend in weather, the construction of winter roads that would increase hunting access, and changes to winter range through forest fires and overlap with other caribou herds could all change the Bathurst herds' annual range and cumulatively affect the herd.

The Bathurst Caribou Management Planning Committee's Plan (2004) will need an updated estimate of the trend in herd size to determine which suite of management activities is appropriate. Without understanding the current trend in herd size, uncertainty is added to any environmental assessments and monitoring of cumulative effects of current activities on the range. The Nunavut Planning Commission also requires data on the spatial extent and dynamics of the Bathurst calving grounds in order to effectively implement the Mobile Caribou

Protection Measures as outlined in the 2004 draft West Kitikmeot Land Use Plan (Nunavut Planning Commission 2004).

Prior to 2003, we last estimated the size of the Bathurst herd of barren-ground caribou in 1996 (Gunn *et al.* 1997). The trend in the size of the herd is an overall measure of a caribou herd's health and we estimate herd size by extrapolating from the number of caribou counted on the calving ground. Since 1980, the estimates of breeding females suggested that the Bathurst herd had increased between 1980 and 1986 (four surveys) and was stable from 1986 to 1996 (two surveys).

Barren-ground caribou cows annually return to their traditional calving grounds, which largely overlap between consecutive years although they do shift over the timescale of decades (Sutherland and Gunn 1996). The Bathurst herd used to calve east of Bathurst Inlet (Sutherland and Gunn 1996) but since the early 1990s, it has calved west of Bathurst Inlet (Figure 1). In 2002, we used an aerial survey and satellite collared cows to determine that the Ahiak and Bathurst herds' calving distributions were east and west of Bathurst Inlet, respectively (Gunn and D'Hont 2003). In this report, we describe a calving ground survey of the Bathurst herd in June 2003.

To ensure compatibility with previous surveys, and the ability to repeat the survey method, we followed the methods developed and tested since the early 1980s (Heard 1985). We updated sections of the methods to include the use of global positioning system (GPS) technology and mapping software [OziExplorer (Newman 2003)] to compile and display survey data during the survey.

The calving ground photographic census starts with a systematic aerial reconnaissance to delineate the boundaries of the annual calving ground and to determine the relative densities of caribou. We used the caribou densities to divide the annual calving ground into high, medium and low density strata and allocated sampling effort for the photographic coverage in proportion to the relative densities in high and medium strata. Effective stratification is a critical step for improving the precision of an estimate.

The precision of previous calving ground photographic surveys (expressed as a Coefficient of Variation, CV) has ranged from 6.2% (1986) to 23% (1992 and 1996). The Department of Resources, Wildlife and Economic Development and Nunavut's Department of Sustainable Development hosted a workshop for biologists and statisticians in November 2000 to discuss steps to improve the precision of calving ground surveys. The following recommendations from the workshop were incorporated into the design for the 2003 survey:

- We improved allocation effort between strata by considering variance within strata as well as density when allocating survey effort;
- We planned to verify sampling effort by using a spotter plane to check strata boundaries just before photo flights were done to correct for major movements of large aggregations;
- We used the locations of the satellite–collared cows to plan the reconnaissance survey of the annual calving ground and delineate strata boundaries;

- We planned to use a small number of relatively large non-rectangular strata to help minimize the effects of within strata movements and ensure that transects are orientated against the density gradient; and
- We aimed to improve precision of the estimate by increasing photographic coverage for high density strata and using the less costly line transect sampling with visual observers for lower density strata.

In this report, we present results from the June 2003 aerial and photographic survey. Our objectives for the survey were:

1. Obtain an estimate for the number of breeding females on the annual calving ground with a coefficient of variation <15%.
2. Determine the trend in the number of breeding females on the calving grounds and the trend in herd size since 1986.
3. Estimate the ratio of breeding females:total females at the peak of calving as an indicator to pregnancy rates comparable to previous years.
4. Describe the spatial extent of the annual calving ground relative to previous years.

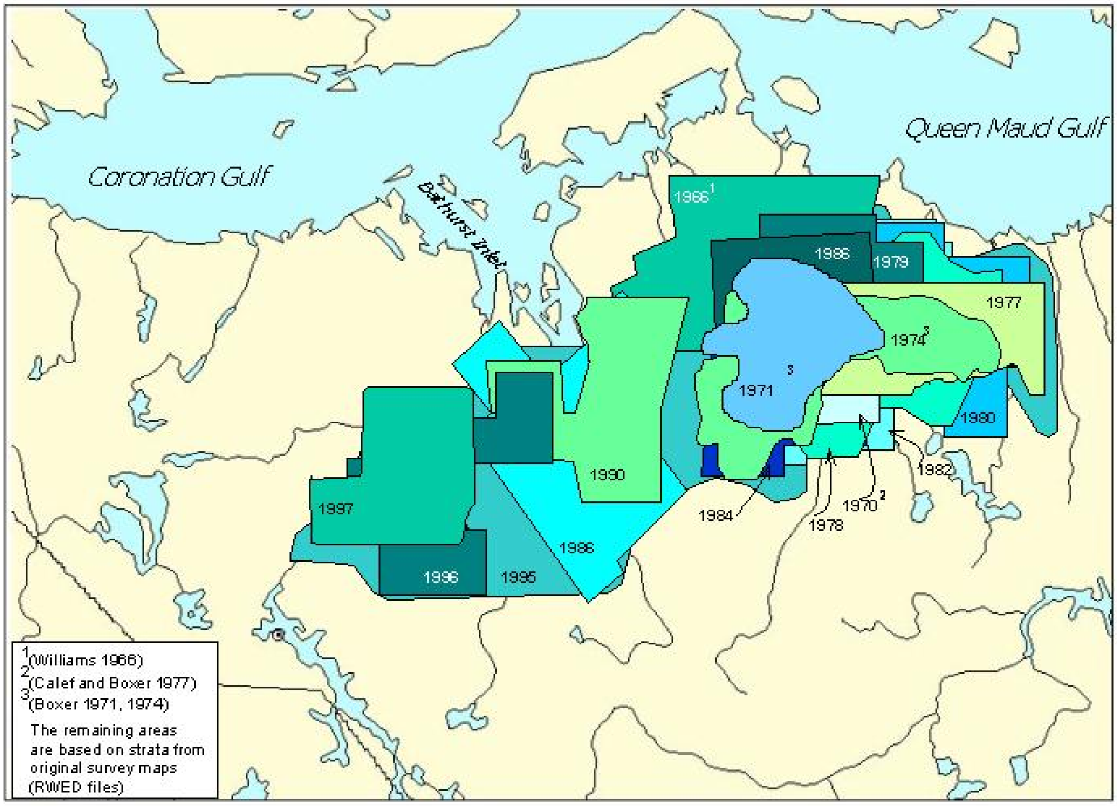


Figure 1. Distribution of caribou at or close to the peak of calving for the Bathurst caribou herd based on aerial surveys 1966 to 1997.

METHODS

Study Area

We delineated the survey area from the distribution of calving caribou from 1996 – 2002 based on satellite collar data and aerial surveys. Over this period, the annual calving ground occurred west of Bathurst Inlet and mostly south of the Hood River (Gunn *et al.* 1997, Gunn *et al.* 2001, Griffith *et al.* 2001).

Aerial systematic reconnaissance survey

For the systematic strip transect surveys, we used a Helio Courier aircraft on tundra tires. The survey crew was the pilot (PL), navigator (JW), and left (JN) and right (AG) observers. Survey altitude was 120 m above ground level, survey speed was *ca.* 160 kph, and total strip width was 0.8 km (0.4 km strip width per side). Lupin Mine was our base of operations.

We attached a nylon cord on an eyebolt on the underside of the wing to a bracket bolted on the fuselage to delimit strip markers on each side of the Helio Courier. We used the methodology described by Norton Griffiths (1978) to determine the position of the strip markers (black plastic tape with bright orange duct tape) on the nylon cord, which would provide the appropriate strip width at survey altitude. Observers checked their strip markers by having the pilot fly at survey altitude, along an axis perpendicular to a known distance on the ground. At the Lupin Mine airport, the ground distance between the western edge of the northern runway apron and the eastern edge of the radio operator's office was approximately 400 m.

Our objective for the systematic survey objective was to delineate the spatial distribution of calving caribou and to determine the pattern of caribou density as a basis for allocating sampling effort (number of photographs and survey transects). We applied a landscape-level 10 km survey grid that covered the known calving distribution of the Bathurst herd since the mid-1990s. Each 10x10 km grid segment was sequentially labelled with the transect number and a letter a-x (for example 10 b was due west of 11b) and these were stored in OziExplorer as both points and waypoints (Appendix A). We took the north-south grid lines and flew them as transects to systematically cover the expected distribution from the west to the east with a coverage of about 8%.

The navigator used the ‘distance to waypoint function’ on a hand-held Global Positioning System to identify which 10 km segments the aircraft was flying over. The observers called their observations to the navigator who recorded them, as well as the waypoint and the segment number. When there was no navigator (13 and 14 June) the observers used tape-recorders for the waypoint number and observation.

After the flights, we managed the observations in OziExplorer and Excel software (Appendix A) to tally the observations and to print maps showing the relative caribou densities and presence of antlered cows or calves for each 10 km segment.

We started our initial systematic survey on the 4 June as Sutherland and Gunn (1996) showed that the earliest dates for the peak of calving for the Bathurst herd were the 4-6 June. We selected the western boundary of the reconnaissance survey using the movement patterns of 11 satellite-collared cows and previous aerial surveys (Gunn *et al.* 1997, Gunn *et al.* 2001, Griffith *et al.* 2001). The criteria to end a transect on 4 and 5 June 2003 was either the absence of caribou, low density of caribou (<7 caribou/10 km grid segment), or low numbers of antlered cows (<5).

We re-flew the systematic reconnaissance on 7 June 2003 as few calves had been born by 5 June and we saw groups of caribou moving north and east on 4-5 June. The survey coverage, altitude and speed were similar to what we used on 4-5 June. We did not repeat the two western-most transects (transects 6 and 7) as we had only observed non-antlered caribou on 4-5 June on that area. On the eastern edge, Transect 19 was shortened as densities were low and only two 10 km segments had antlered cows on 4-5 June. The criteria to end a transect was different for the northern and southern distribution as we were observing cows traveling north and east. The leading edge of the calving distribution would have been on the northern and eastern fronts. We expected to see more pre-parturient cows (with hard antlers & no calves) on the leading edge than in the trailing distribution. As such, on the northern end of transects, we used the criteria of no antlered cows or calves, and for southern ends we used <10 caribou unless a calf was present.

We shortened the eastern most transect which on 4/5 June had had mostly low densities and relatively few antlered cows. On 7 June, we extended the southern end of the transects for south central transects to better define the edge of the extent of calving.

Poor weather from 8-12 June (low cloud ceilings, snow and blowing snow) delayed the photographic survey (Appendix B). The 6-day interval between stratum delineation based on the systematic surveys 4-5 and 7 June, and the photographic survey raised questions about caribou movements between strata. Thus on 13 June, we flew in the Helio-Courier to systematically determine relative densities and composition of caribou to evaluate the stratum boundaries for the photographic strata and we also counted caribou in the North East visual stratum.

Allocation of effort and rationale for stratification in the calving ground photographic and visual survey

We decided previously that the photographic survey would cover the High and Medium density strata so as to increase the photographic coverage of these strata and thereby improve precision. Caribou numbers in the low density strata would be estimated using a systematic visual survey – most of the caribou in the low density strata were not breeding females and those strata would then contribute very little to the overall estimate. The caribou densities were recorded during the systematic reconnaissance survey. The breaks in the cumulative frequency of caribou densities recorded during the second systematic visual survey were used as the rationale for the density classes (high = >10 caribou/km^2; medium = 1.1 –9.9 caribou/km^2 and low = 0.1 – 0.9 caribou/km^2). Then we mapped the density classes and delineated three provisional strata (Appendix C) to enclose similar densities. In delineating these strata we gave consideration to the following issues: i) variance of observed density classes within a strata was minimal; ii) the presence of calves and breeding females, *i.e.,* antlered cows, and spatial dispersion of grouped 10 km^2 grid segments of similar density of caribou were used in addition to observed density, to provide a basis for delineating survey strata, iii) the strata were large enough to accommodate possible movements of caribou between the time the reconnaissance and stratification were completed to the time the strata were actually photographed, iv) the stratum baseline had to be long enough to allow for a minimum of 10 transects as a minimum sample size, and v) transect lines needed to be of relatively similar length.

We oriented the transects to parallel the gradient in density and to be perpendicular to the long axis of the stratum. We then refined the allocation of survey effort (number of photographs) based on estimating mean population size and variance of population size for each strata (Heard 1987a; Appendix C). The analyses indicated the optimal allocation would be a high density stratum with transects to be flown east-west and a pooled medium density stratum to be flown north-south. The allocated effort for the photographic survey was approximately 15 transects for high density stratum and 7 transects for medium density stratum. We allocated survey effort to two low-density visual strata so that they were sampled at ca. 25% coverage (14 and 16 transects respectively).

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

On 13 June 2003, we surveyed the low density North East stratum and on 14 June 2003, we surveyed the low density South West stratum. The survey aircraft was a Helio-Courier on tundra tires. Survey altitude was 120 m above ground level, survey speed was *ca.* 160 kph, and total strip width was 0.8 m (0.4 m strip width per side).

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

We contracted Geographic Air Survey Ltd. for the photographic survey. The survey aircraft was an Aero-commander equipped with a radar altimeter. The GPS navigation system on the survey aircraft was directly linked to a belly-mounted camera (a Wilde RC30 camera with forward motion compensator). In order to pre-program the aircraft navigation system, we sent stratum boundaries and transect coordinates for the high and medium density strata to Geographic Air Survey's main office in Edmonton the night before the planned survey flight. Their technical staff created the navigation data files and emailed the data to the flight crew on the morning of the survey. The photo aircraft covered the High Density stratum on 14 June and the Moderate Density stratum on 15 July.

Sex and age composition survey

On 15 June 2003, we started composition surveys to determine the proportion of breeding females on the calving ground within the one visual and two photographic strata. We used the 10x10 km segments to disperse the sampling points across the strata as we flew to the center of each segment and searched for no more than 15 minutes or 5 caribou groups. In high and moderate density strata, we first located groups of caribou from a Bell Jet Ranger 206B. We landed 100-500 m away from the caribou and the observers made their final approach on foot using rises in the terrain and rocks as cover. One observer watched and classified the caribou through a spotting scope; the second observer recorded the data. To avoid selecting individual caribou, observers attempted to systematically observe all animals within visual range and classified the caribou as they walked away. In low density strata, where caribou were in groups of <20-30, the front seat observer classified caribou from the helicopter. For larger groups, we landed and used the same procedure as in the high and medium density strata.

We classified caribou into three categories: breeding females, non breeding females and yearlings or bulls (see p. 6 Gunn *et al.* 1997). Breeding females (pregnant and post-partum) were identified by the presence of hard antler and/or a distended udder. Cows with distended udders and without hard antlers were probably breeding cows which had lost their calf. Non breeding cows had new antler growth and no udder or had no udder and no new antler growth (genetically bald). Cows with hard antlers and without an udder or calf may have either lost their calf or not yet given birth. Yearlings were identified by their shorter face and smaller body size, while bulls were easily identified by their relatively large antlers in velvet.

Data analyses

We contracted Paul Roy of H.P. Roy and Associates (Ottawa, Ontario) to count the caribou on the photographs using a stereoscope. We checked to confirm that the scale was 1:4000 by comparing distances on the 1:250 000 scale map to distances on the photographs. By comparing the counts of caribou on each line to the 1:250 000 map showing the photographic survey lines, we were able to adjust the boundaries of the stratum to include only those areas which actually contained caribou. This ensured that the population estimate for each stratum was not inflated by extrapolation of the density to large areas that did not contain caribou. Population estimates for each stratum were calculated using the Jolly 2 Method for unequal sample units (Jolly 1969) in the program Aerial (Krebs 1992, Program 3.5).

The proportion of breeding females in each stratum was multiplied by the population mean estimate for that stratum to obtain an estimate of the number of breeding females on the calving ground. Total herd size was estimated by dividing the number of breeding females by the sex ratio of the population (60 males: 100 females) and by the pregnancy rate of female caribou (72%). We analysed composition data using Cochran's (1977) Jackknife method to calculate the mean proportion of breeding females in each stratum. The variances of the number of breeding females and the total herd estimate were calculated as suggested by Heard (1987b).

We used two methods to estimate the trend in population size.

a) Weighted least squares regression (Brown and Rothery 1993) weights each population estimate 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) (Caughley 1977). 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 $\lambda=1$ then a population is stable. If λ is less than 1 then the population is decreasing, and if λ is greater than 1 then the population is increasing.

b) Monte Carlo simulation allows another estimate of the variance in trend that resulted from individual variances of each of the surveys (Manly 1997). The basic question we asked through this simulation 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?". To answer this question, we first simulated the sampling procedure for each year. We used the estimated mean and variance 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 variable with associated degrees of freedom for each survey was generated. This random variable was then multiplied by the standard error, then added to the population estimate. The resulting random population size 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.

1. *The sampling procedure was simulated and trend was 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 b (above) and the parameters listed in Table 5. As in the weighted least squares regression analysis (outlined in point b above), 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.
2. *Estimates of trend from the pseudo data sets were analyzed.* Mean estimates and percentile-based confidence intervals were estimated using the pseudo data sets. This analysis determined the maximal and most likely range of trend estimates that could be observed from this data set when the variance of each of the surveys was accounted for.

RESULTS

Systematic Reconnaissance Surveys (4-5 June and 7 June 2003)

Fog and a low and variable ceiling (60 to 120 m above ground at Lupin Mine), restricted us to flying 4.3 hours on the afternoon of 4 June 2003. We completed transects 6-9 which were started 10 km west of the western most satellite collared cow location for 30 May 2003 (cow 78). We continued the systematic reconnaissance on the 5 June 2003 when we flew 6.5 hours and transects 10 – 19 (Figure 2).

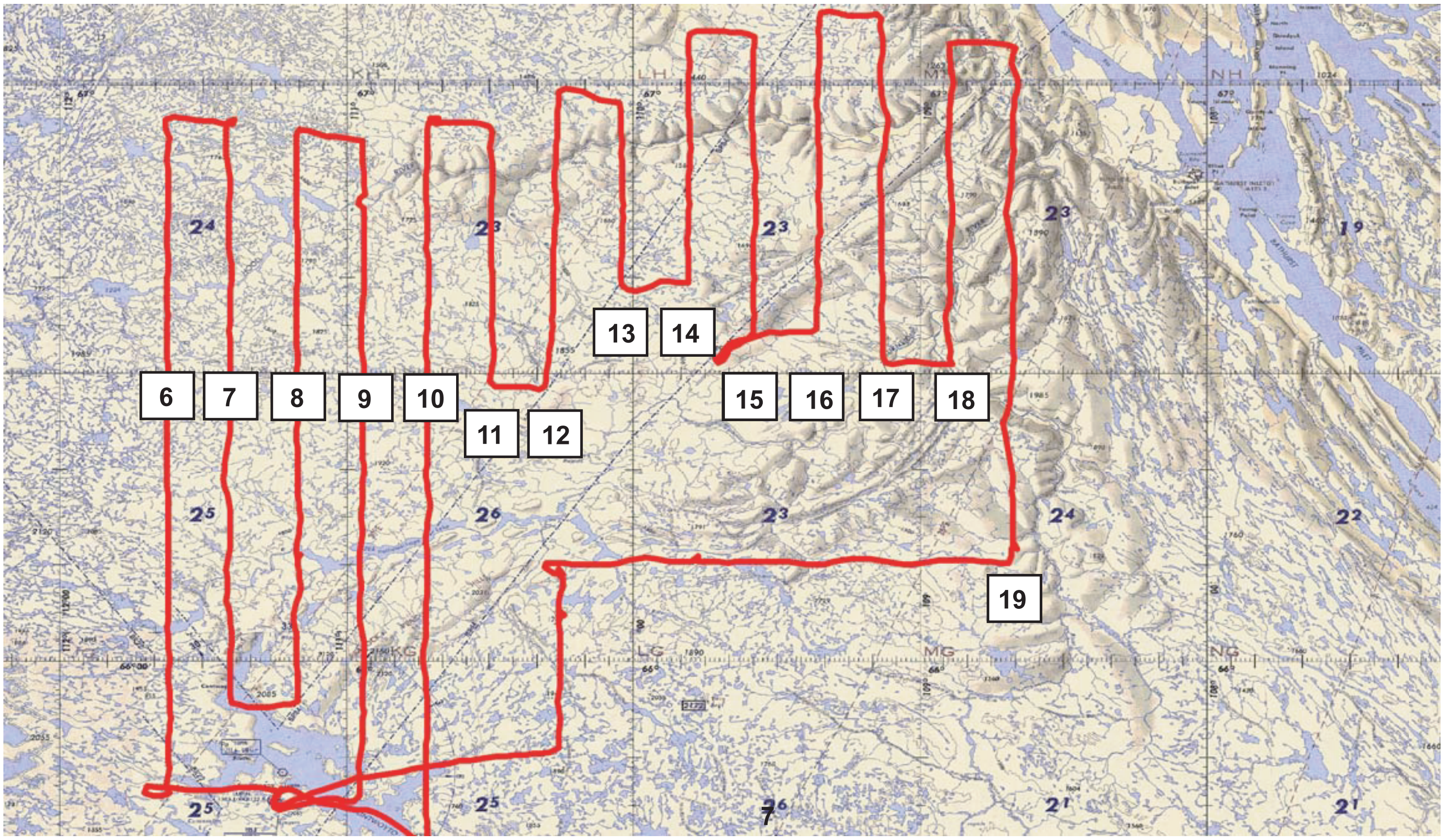
On 4 and 5 June 2003, we counted 5407 caribou and 88 calves (2%) across the survey area. We flew 123 10-km grid segments and 10% were high density (10+ caribou/km^2); 46% were medium density (1.0-9.9 caribou/km^2), 18% were low density (0.1-0.9 caribou/km^2) and 27% had no caribou (Figure 3). We classified 47% of 10-km grid segments as having caribou with hard antlers compared to 22% of grid segments having caribou without hard antlers (Figure 4).

The breeding cows (antlered cows and calves) were spread as an arch from Kathawashago Lake extending north to the Wright and Hood River before bending south west of the Booth River. Within that arch there was one smaller (90 km^2) and one larger (1000 km^2) cluster of high density caribou (10+ caribou/km^2). The western most grid segments had low densities and no antlered cows.

We re-flew the systematic survey on 7 June 2003 (Figures 2-4), and counted 5074 caribou and 1243 calves (20%) on transects 9-19. We flew 80 10-

km grid segments and 15% were high density (10+ caribou/km^2); 32% were medium density (1.0-9.9 caribou/km^2), 21% were low density (0.1-0.9 caribou/km^2) and 18% had no caribou. We classified 45% of 10-km grid segments as having caribou with hard antlers and 20% of grid segments having caribou without hard antlers .

The distribution on 7 June compared to 4/5 June was similar in that the breeding cows were still distributed as an arch from Kathawashago Lake extending north to the Wright and Hood River. A comparison of the densities of caribou in the segments flown during both surveys reveals an increase in densities in the centre south of the Hood River and a tendency for decreasing densities north of the Hood River. On the western edge, movement of non-breeding caribou increased the density in half the segments (Figure 5). Although we had confidence that we had defined the western and eastern boundaries on 4/5 June, we were less sure about the central areas (Table 1, Figures 3 and 4). When we re-flew the second systematic reconnaissance survey (7 June), we were more stringent in applying criteria to decide when to end transects and we were able to more clearly define the central southern and central northern boundaries for the extent of calving.



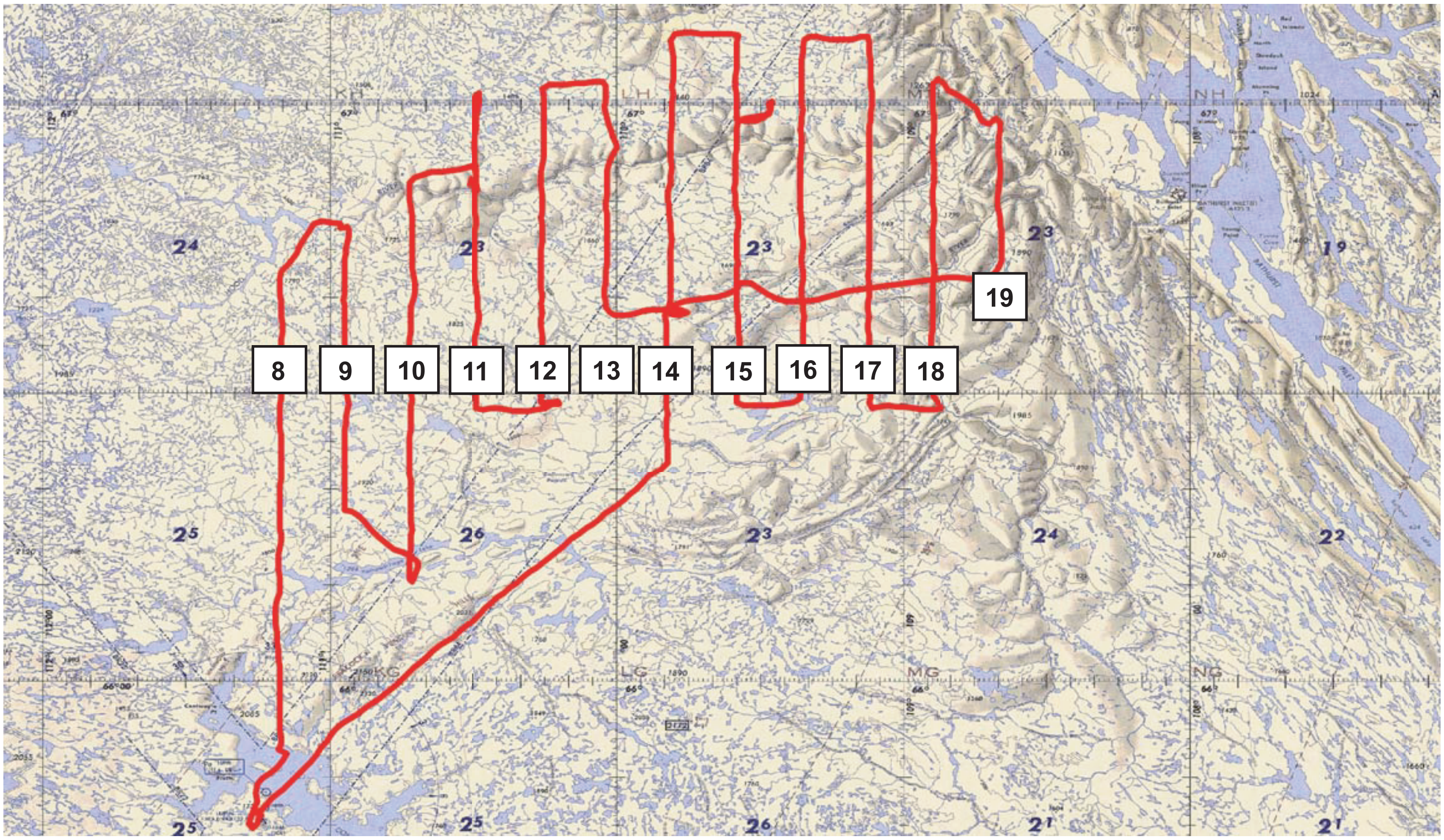
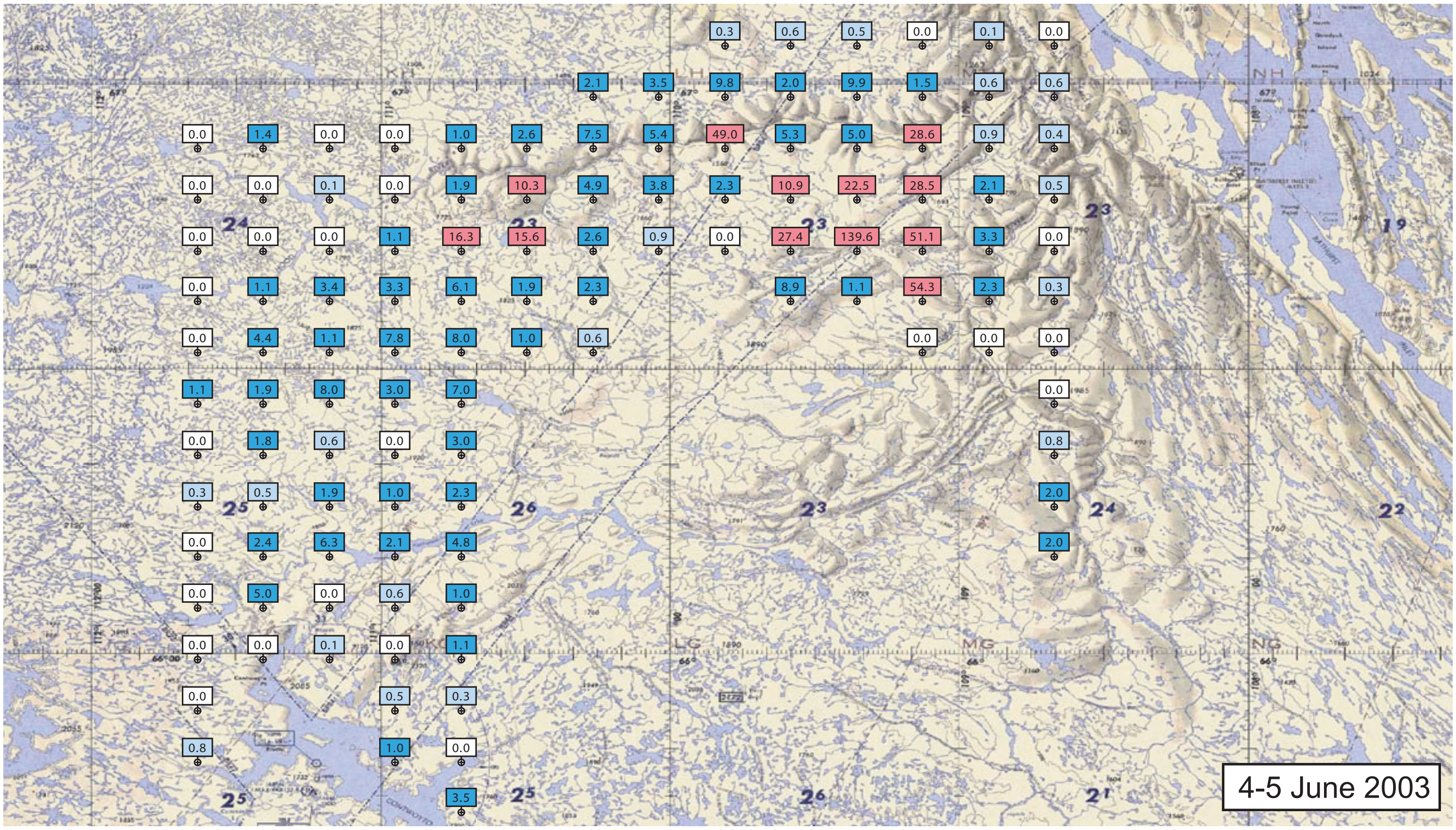


Figure 2. Flight lines for systematic reconnaissance survey conducted on 4-5 June 2003 (upper) and 7 June 2003 (lower).



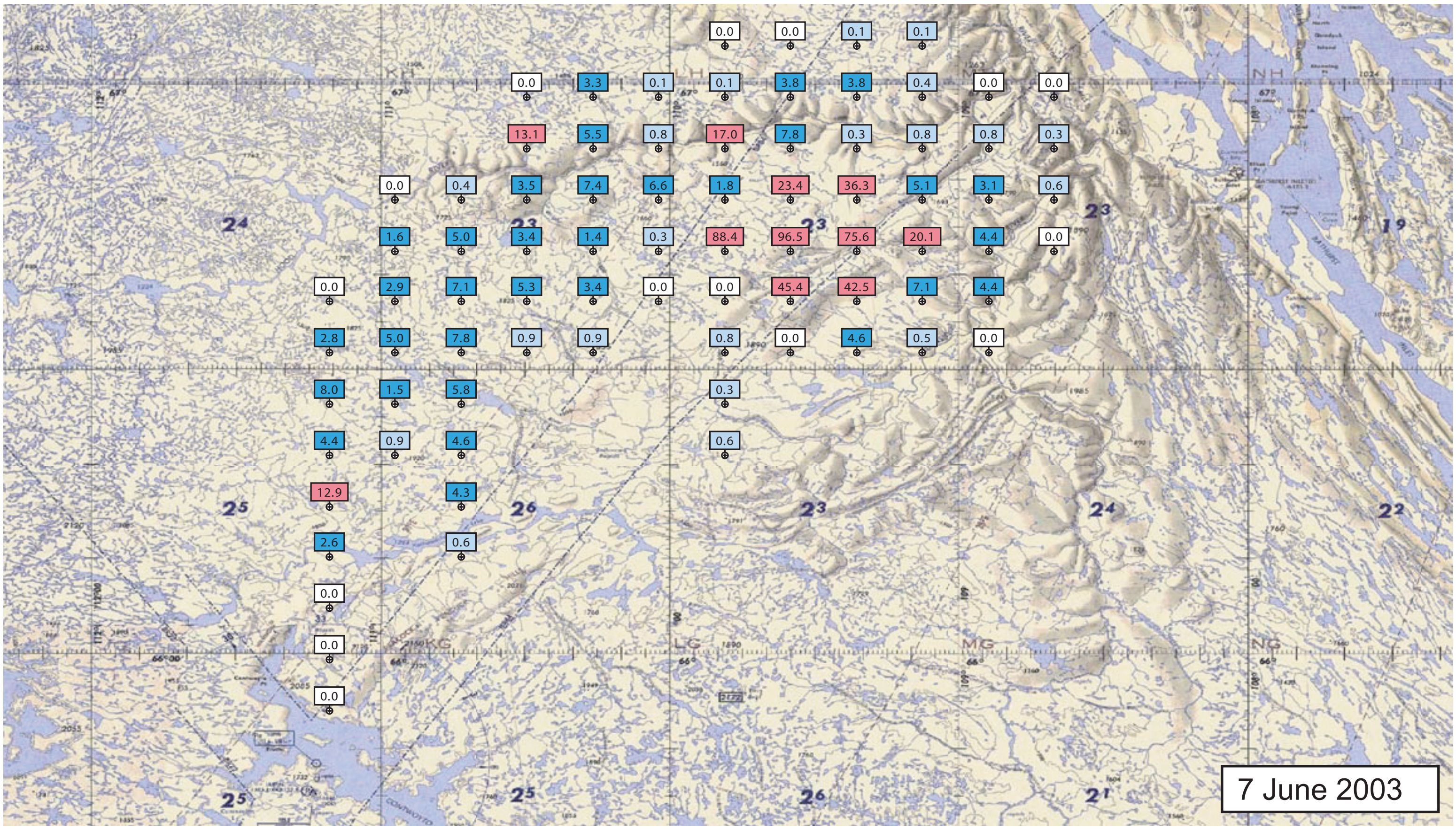
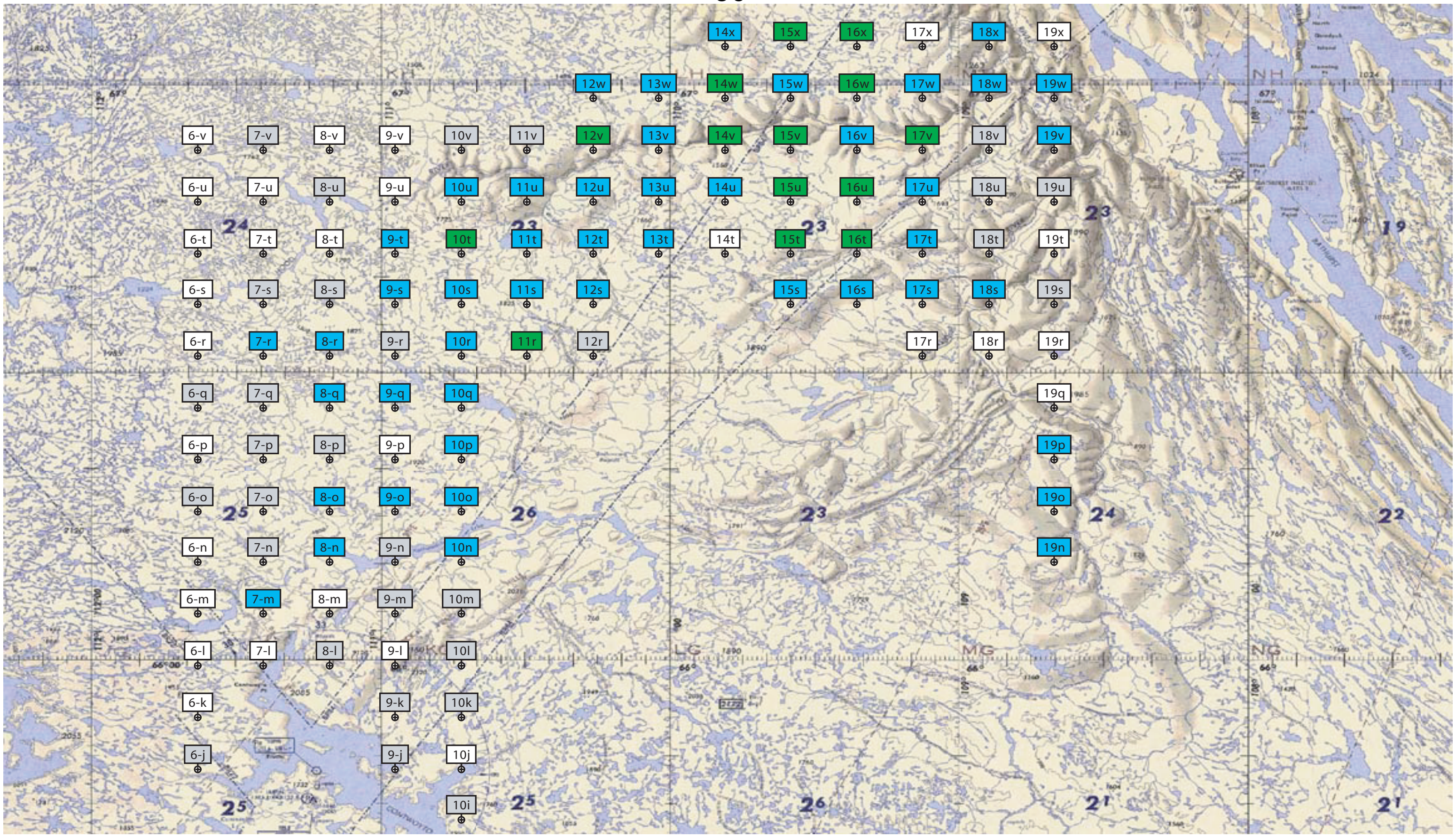


Figure 3. Comparison of density classes from systematic reconnaissance surveys conducted on 4-5 June (upper) and 7 June 2003 (lower).
White = no caribou, Light blue = low density (0.1-0.9 km2), Dark blue = medium density (1.0-9.9 km2), Red = high density (10+ km2).



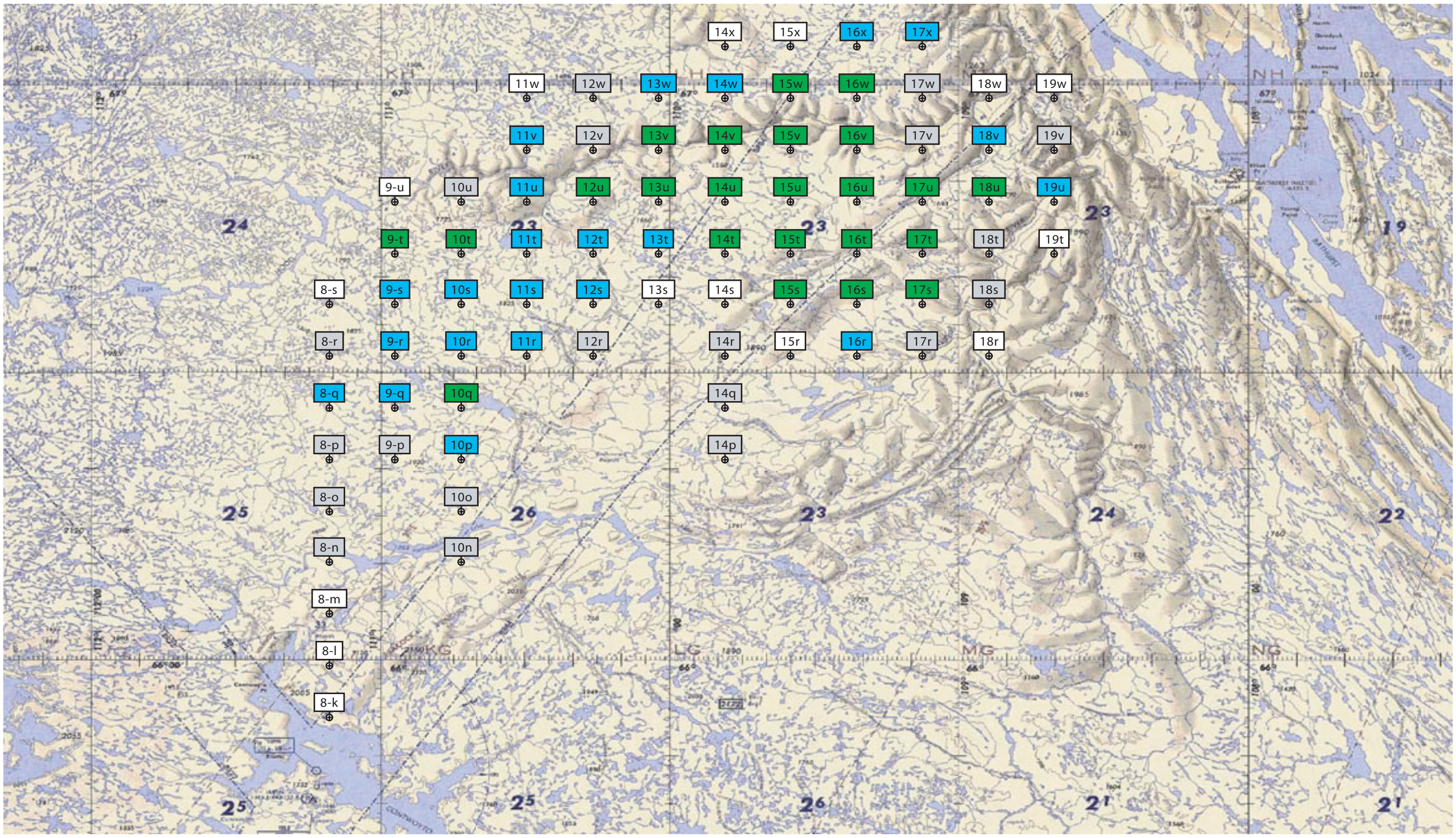


Figure 4. Transect numbers and segments with comparison of cow-calf classes from systematic reconnaissance surveys conducted on 4-5 June (upper) and 7 June 2003 (lower). White = no caribou, Aqua = with antler, Lime = cow calf groups, Grey = no antler.

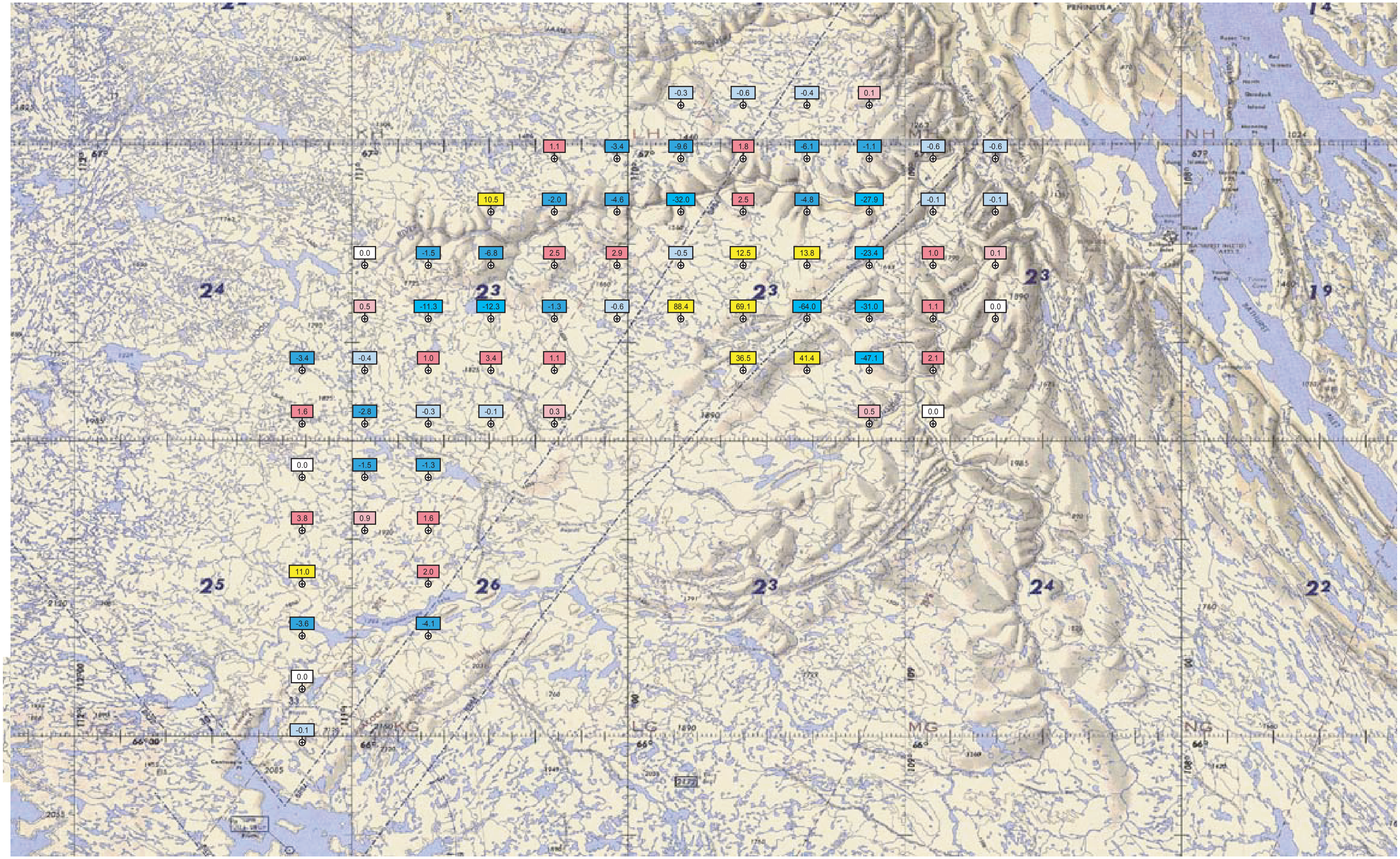


Figure 5. Change in density class between 4-5 June and 7 June 2003 reconnaissance surveys.
White = not change, Light blue = decreasing density (-0.1-0.9 km2), Dark blue = decreasing density (-1.0 km2), Pink = increasing density (0.1-0.9 km2), Red = increasing density (1.0-9.9 km2), Yellow = increasing density (10+ km2).

Table 1. Percentage of transect end grid segments categorized by breeding status and caribou density compared between systematic aerial surveys on 4-5 June and 7 June, 2003, west of Bathurst Inlet, Nunavut.

		4-5 June % (south and north nos. of grid segments)	**7 June % (south and north nos. of grid segments)**
Breeding status	No caribou	46 (6 and 7)	50 (5 and 7)
	Non-antlered	18 (3 and 2)	29 (5 and 2)
	Antlered	29 (4 and 4)	18 (2 and 3)
	Calf	7 (1 and 1)	0
Density	No caribou	46 (6 and 7)	50 (5 and 7)
	Low	21 (3 and 3)	42 (6 and 4
	Medium	32 (5 and 4)	8 (1 and 1)
	High	0	0

		4-5 June % (south and north nos. of grid segments)	**7 June % (south and north nos. of grid segments)**
Density	No caribou	32% (4 and 5)	50% (5 and 7)
	Low	29% (4 and 4)	42% (6 and 4
	Medium	39% (6 and 5)	8% (1 and 1)
	High	0%	0
Breeding status	No caribou	32% (4 and 5)	50% (5 and 7)
	Non-antlered	29% (5 and 3)	29% (5 and 2)
	Antlered	29% (4 and 4)	21% (2 and 3)
	Calf	11% (1 and 2)	0%

Allocation of effort and stratum location and boundaries

After analysis of the survey data from 7 June 2003, we had designated the high density strata as a relatively large block (40x50 km = 2000 km^2) with 18 transect lines (900 km x 0.92 km photo width = 830 km^2) to give 41% coverage. We also had outlined a Medium and two low density visual strata (Figure 6). However, the partially photographed survey on 8 June reduced the number of photographs available and so we adjusted the stratification. We only had enough photos for 700 km for the High Density so we re- designated it with two optional areas (east, and west) to take into account possible movements (when flying the photo survey, lines and end sections can be dropped but no sections can be added as the coordinates have to be digitised in Edmonton and then emailed back to be fed into the photo aircraft's computer). We chose to omit the southern-most line from the High stratum because we had initially included that line as a buffer against southern movements. The reallocation was to increase the coverage for the Medium stratum relative to the proposed coverage for the low density strata (which being visual surveys has not been included in the allocation analysis for the photographic survey). We increased the allocation effort for the Medium stratum to approximately 20% by dropping the southernmost line from the High Density stratum and adding those photos to the Medium stratum. We anticipated that the breeding females in the Low density and Medium density strata would continue moving northeast so we abutted the High and Medium density strata. We had designated two low density visual strata and as a third option for a visual strata, we delineated a stratum to the east of the High density stratum (Figure 7).

A blizzard caused delays between the systematic survey and the photo survey, so we modified the High density and Medium density strata again. We flew with the Helio-Courier to assess the boundaries of the High Density stratum (Figure 8). We observed 10s to 100s of antlered cows and newborn calves in the area immediately north and south along the Hood River (Figure 8) and adjacent to the northwest boundary of the High density stratum boundary - on the 7 June we observed only low to medium densities of caribou in this area. Consequently we enlarged the north western boundary by adding three transects to the High density stratum (Figure 9). We also dropped the four southern most transects as on 13 June we only found low to moderate densities of non-breeders. In addition, the moderate densities that we saw along north south Transect 13 led us to add that segment to the Moderate density strata (Figure 9).

Aerial visual survey

We counted 2702 caribou on transect in the North East low density stratum on 13 June but almost all the caribou were close to the Hood River (Figure 7) and were within the area that we added to the High Density photographic stratum. We counted only six scattered groups (101 caribou in total) across the remainder of the stratum, which included three groups with calves.

In the low density South West stratum, we counted 467 caribou on 14 June and the resulting estimate (2639 $\pm$ 581 SE) was relatively imprecise (Table 2). The low precision was the consequence of the uneven caribou distribution as most caribou were on the northern transects.

Photographic survey

The photo aircraft started the survey at the southern end of the High Density stratum on 8 June but after 5 lines had been flown, low cloud forced postponement. Weather remained unsuitable for flying and photography for 5 days. After the additional fixed-wing reconnaissance on the 13 June and our modification to the original stratification, the photo aircraft covered the High Density stratum on 14 June and the Moderate Density stratum on 15 June. The photos from 8 June were not counted. Paul Roy counted 35 323 caribou on the 1480 photos from the High Density stratum and counted 5572 caribou on the 754 photos from the Medium Density stratum (Table 2).

Sex and age composition survey

We determined sex and age composition at 32 locations (10x10 km grid segments) across the three strata. At those locations we sampled a total of 6417 caribou in 56 groups (Table 3).

Survey estimates – number of breeding females

Observed mean densities from the visual low density stratum, and the medium and high density photographic stratum were 1.5, 22.8, and 71.8 caribou/km^2 respectively. Based on the combined estimates from the low, medium, and high density strata, we estimated that there were 109 983 ± 15 990 (SE) 1+ year old caribou (Table 2). After adjusting this overall estimate by the proportion of breeding females observed in each stratum during composition surveys (Appendix D), we estimated that there were a total of 80 756 ± 13 167 (SE) breeding females in the survey area (Table 4).

Population trend 1986-2003

The weighted least squares regression results suggested a significant negative trend (r= -0.052 in the number of breeding females from 1986 to 2003 (Tables 5 and 6 and Figures 10-12). This translates to a population rate of change (λ) of 0.9496 ($\lambda = e^{-0.0517}$), suggesting that the caribou population was approximately 95% of its size each of the successive years from 1986 to 2003

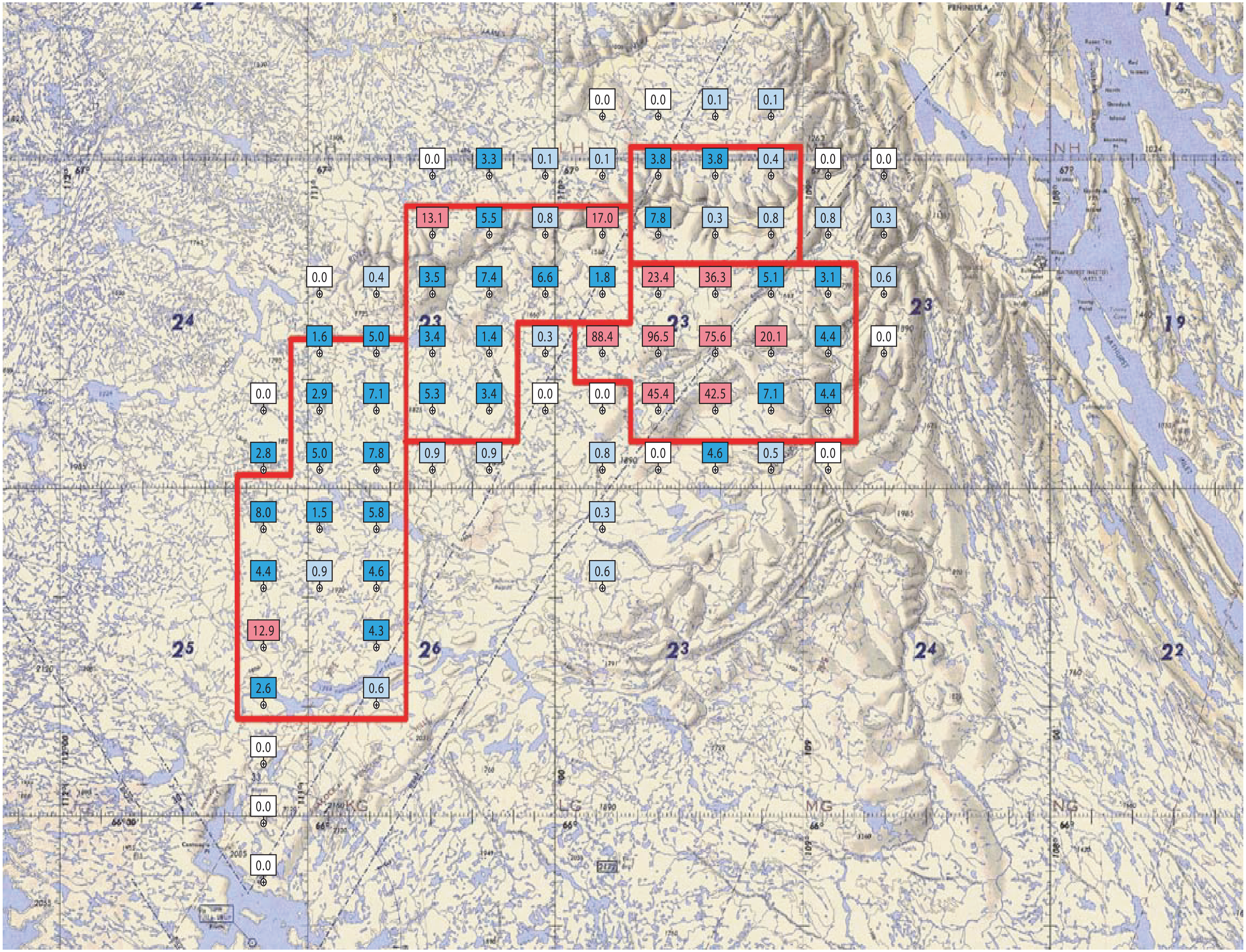


Figure 6. Proposed stratification for photographic (high and medium strata) and two visual strata based on densities (caribou/km2) observed on 7 June 2003.

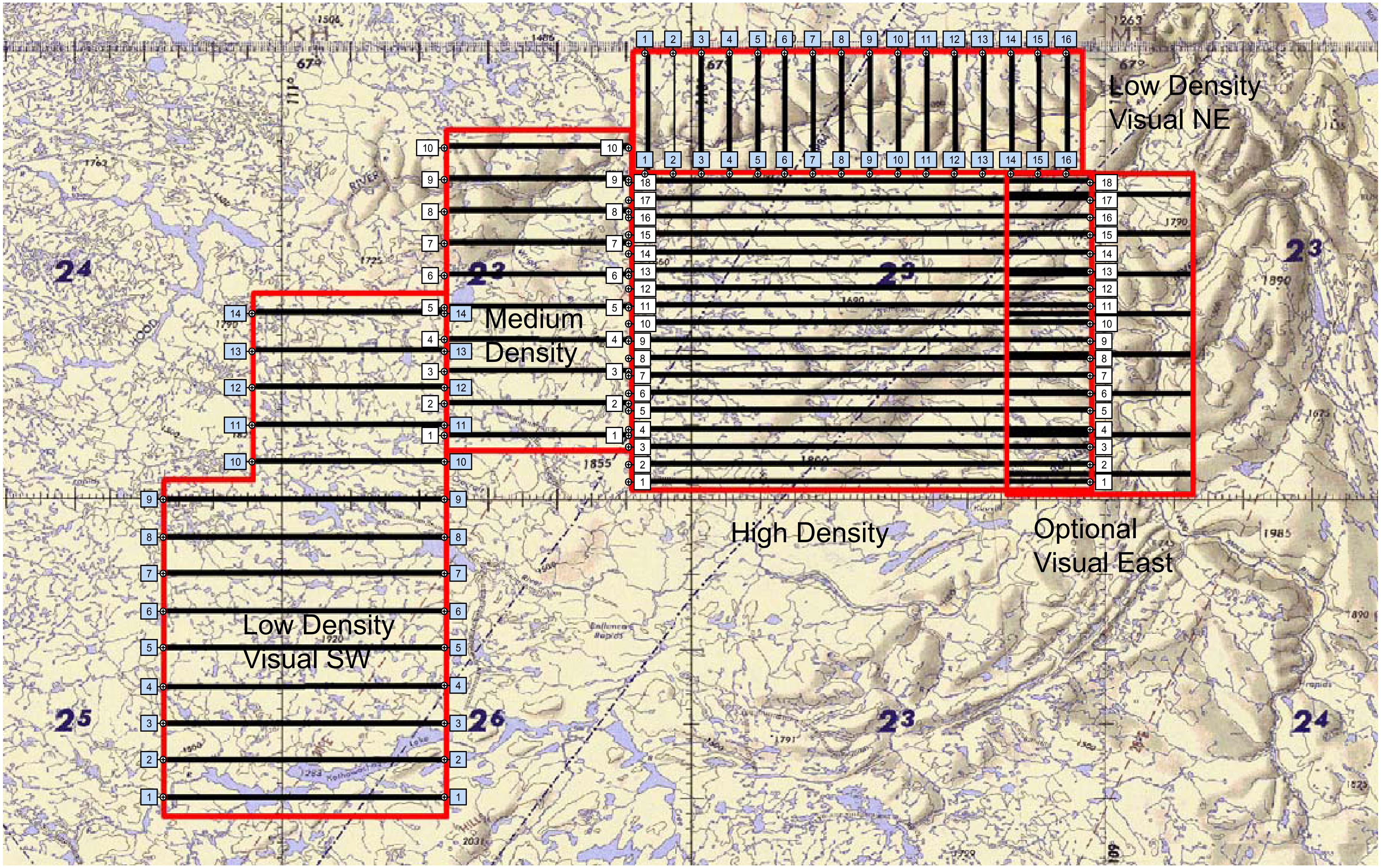


Figure 7. Stratum boundaries and transect lines for a stratified photo census and visual strip transect survey of the Bathurst caribou calving grounds (June 2003).

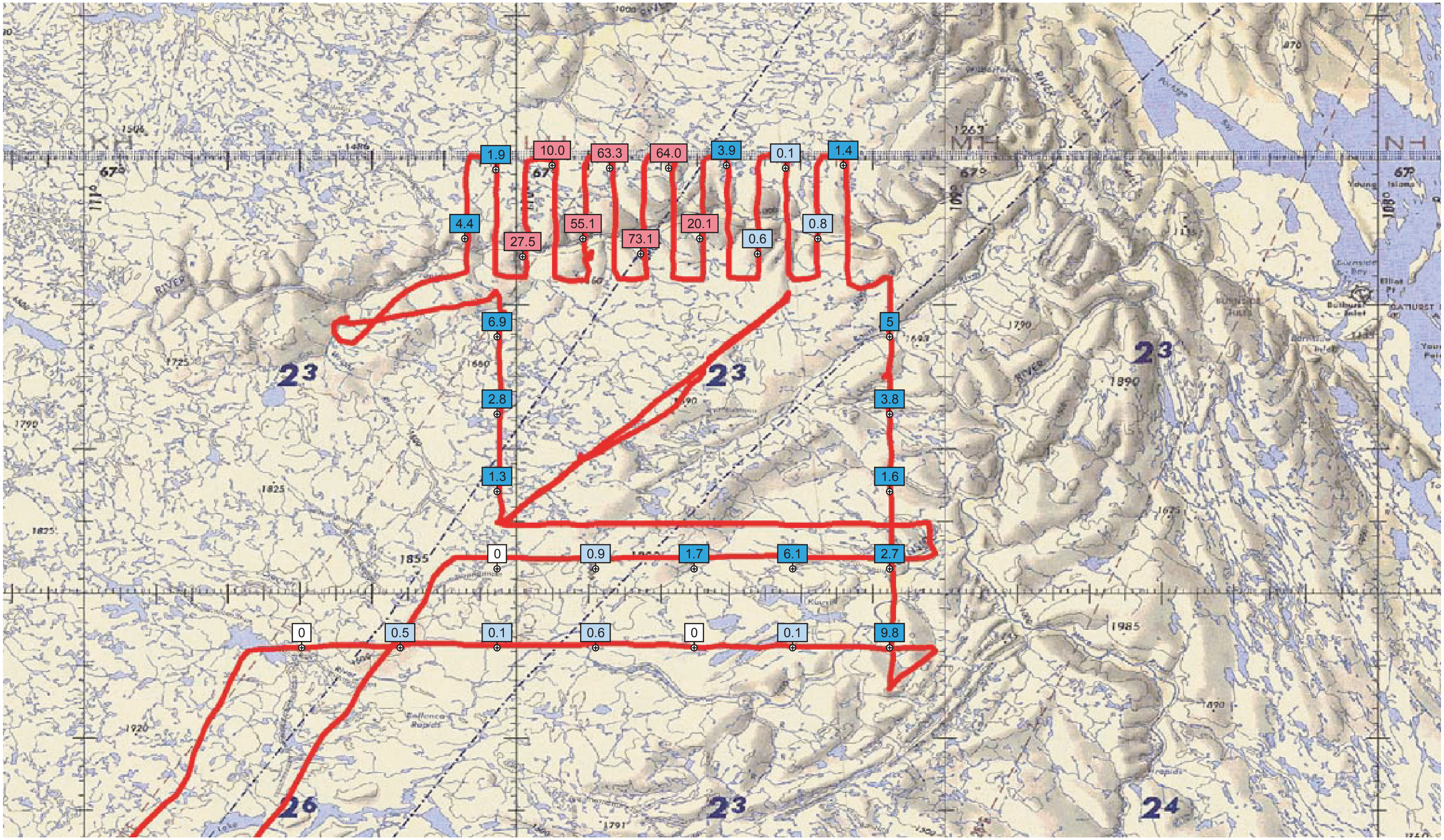


Figure 8. Visual survey of possible high density photo strata and low density NE strata showing density classes, 13 June 2003. White = no caribou, Light blue = low density (0.1-0.9 km2), Dark blue = medium density (1.0-9.9 km2), Red = high density (10+ km2).

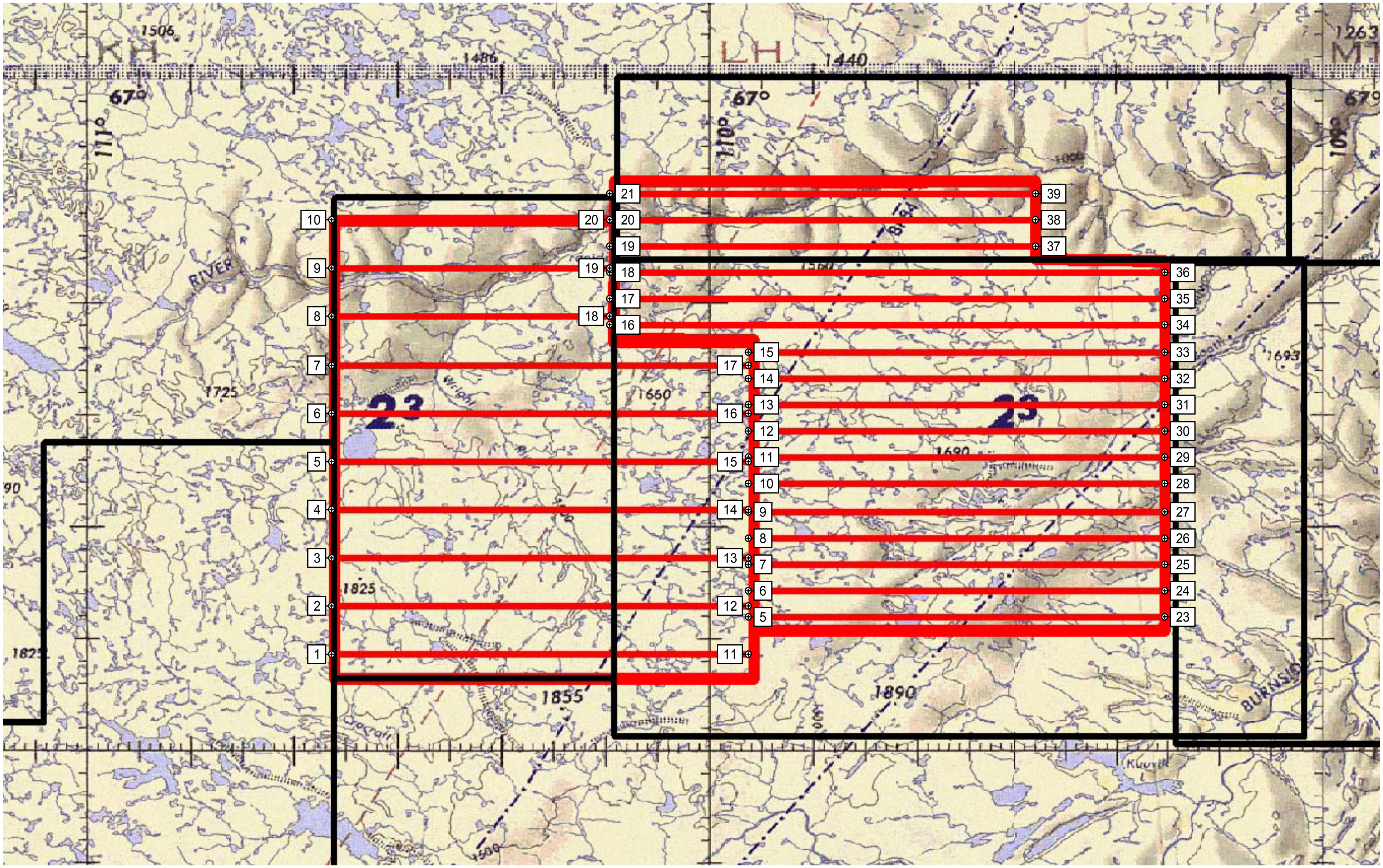


Figure 9. Transects flown by photo aircraft 14-15 June, 2003 and earlier stratum boundaries.

Table 2. The number of caribou estimated in the high, medium and low density strata based on a visual and photographic strip transect survey of the Bathurst calving ground, June 2003.

Stratum	**Stratum Area (km^2)**	**Survey Coverage**	**Estimate**	**Density caribou/km^2**	**Variance**	**Standard Error**	**CV**
Low Density Visual	1757.0	17.7	2 639	1.5	338 116	581	0.22
Medium Density Photo	1027.8	23.7	23 385	22.8	18 529 666	4305	0.18
High Density Photo	1169.5	42.0	83 959	71.8	236 816 435	15 389	0.18
Total	3954.3		109 983		255 684 217	15 990	0.15

Table 3. Sample size and proportion of breeding females in the three strata, 16-18 June 2003.

Stratum	**Number 10x10 km segments sampled**	**Number groups sampled**	**Number breeding females**	**Number 1+year caribou**
Low density Visual	11	33	34	462
Medium density Photo	9	56	813	1735
High density Photo	12	67	3547	4220

Table 4. Estimated number of breeding females in high, medium and low density strata of the Bathurst calving ground, June 2003 based on composition counts and stratum population estimates.

Stratum	Estimated number of caribou on calving ground	Proportion of breeding females	Estimated number of breeding females	Variance	Standard Error	CV
Low Density Visual	2 639	0 .0620	164	1919	44	0.27
Medium Density Photo	23 385	0.4725	11 049	4 797 948	2190	0.20
High Density Photo	83 959	0.8283	69 543	168 569 737	12 983	0.19
Total	109 983		80 756	173 369 604	13 167	0.16

Table 5. Breeding female population estimates used for trend analysis

Year	N	Variance	SE	CV	Df (t)	CI low	CI high
2003	80756	173369604	13167	16.3%	17	52916	108400
1996	151393	1235100000	35143.99	23.2%	13	75469	227317
1990	151927	665900000	25805.04	17.0%	10	94430	209424
1986	203800	161180000	12695.67	6.2%	43	178197	229403

Table 6. Weighted least square regression results

Parameter	Estimate	S.E	C.I. low	C.I.high	t	P-value
Intercept	12.27	0.051	12.05	12.49	240.1	<0.001
slope (r)	-0.0517	0.008	-0.085	-0.019	-6.8	0.0212
Rate of change (λ)	0.9496	1.008	0.919	0.981		

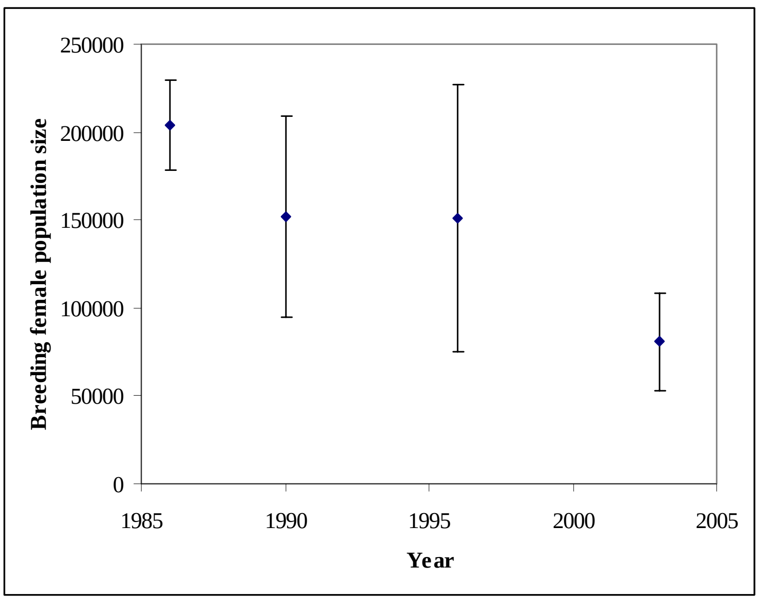


Figure 10. Population estimates of breeding females for surveys conducted in 1986, 1990, 1996, and 2003. Ninety five percent confidence intervals for estimates are shown as error bars.

A plot of the regression line (back transformed to population size units) shows (Figure 11) that the confidence intervals are irregular, which is because they are accounting for varying degrees of variance in each of the point estimates. For example, the 1986 and 2003 surveys had the best precision and therefore the confidence intervals are tightest around these points.

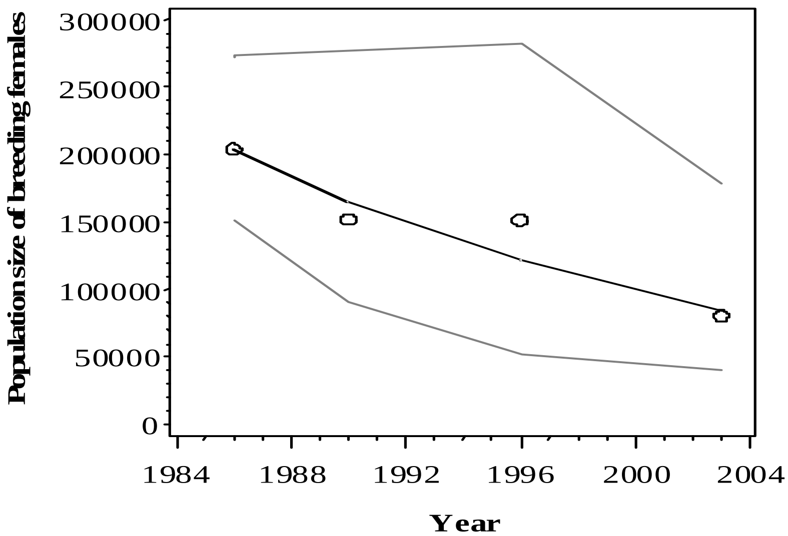


Figure 11. Predicted trend for breeding females from weighted least squares regression analysis. Grey lines are confidence interval on predictions. Circles are estimates for each years.

Monte Carlo simulation results (Figure 12) also reveal 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 -.0504 with associated percentile-based 95% confidence limits of –.0709 to –.0277. Estimates of rate of population change (λ) were 0.951 with associated percentile-based 95% confidence limits of 0.926 to 0.972. 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 to or greater than 0 in simulations.

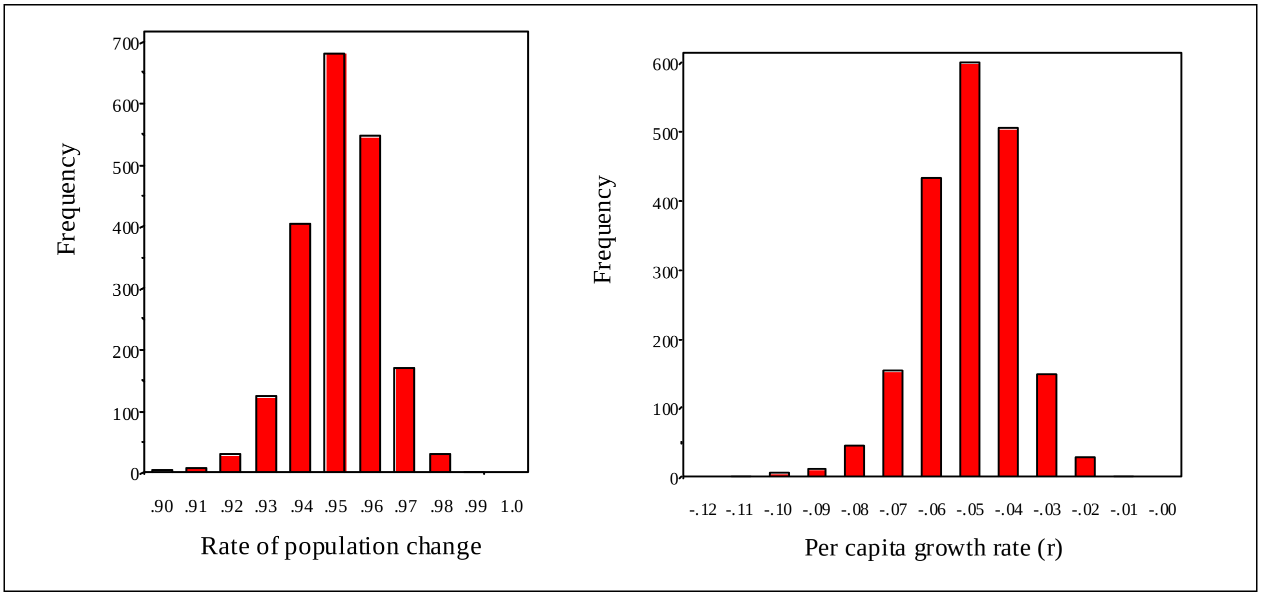


Figure 12. Distributions of population rate of change (λ) and per-capita growth rate (r) generated using Monte Carlo simulation trials.

DISCUSSION

Trend in numbers of breeding females

We estimated 80 756 ± 13 167 (SE) breeding females in June 2003. Using a sex ratio of 100 females:60 males (based on Heard unpublished data, 1978) and a pregnancy rate of 0.72 (Heard 1985), we can extrapolate that estimate of breeding females to a total herd size of 186 000 ± 40 100 Standard Error (Coefficient of Variation of 0.27) (Table 7).

The estimated number of breeding females has statistically significantly declined since 1986. The similarity in results between the Monte Carlo simulation procedure and the weighted least squares analysis is expected given the large difference in estimates and comparatively tight confidence interval bands on the surveys conducted in 1986 and 2003 (Table 5 and Figure 10). The confidence intervals on these surveys do not overlap, and we conclude that the 2003 estimate is statistically lower than the 1986 survey. These two points “anchor” the relationship and compensate for the relatively low precision of surveys in 1990 and 1996.

The number of breeding females may have declined between 1986 and 1990 and then stabilized from 1990 to 1996 and then declined from 1996 to 2003. It was not possible to test for non-linear trends given the low number of surveys (Figure 10). Regardless of the shape of the trajectory, the number of breeding females has declined between 1986 and 2003. 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

Table 7. Extrapolation of the 2003 calving ground survey data to estimate of total herd size.

Survey Data	**Estimate**	**Standard Error**	**CV**
Number of caribou on the calving ground	109 983	15 990	0.15
Number of breeding females on the calving ground	80 756	13167 [c]	0.16
Proportion of females in the entire herd	0.603		0.1[a]
Proportion of 1.5 year old and older caribou pregnant	0.72		0.1[a]
Total population estimate[b]	186 005	40 146	0.216

[a] no data, value only a guess

[b] total population = number of breeding females/proportion of females in the population*proportion of females pregnant.

[c] Variance of the number of breeding females = (No Breeding Females)^2 [(CV of Estimate)^2 + (CV of % Breeding Female)^2] from Heard 1987b

Variance of total population estimate = (Total pos estimate)^2 [(cv of % females)^2) + (cv of % pregnant)^2 + (cv of total number of breeding females)^2]

Variance of total pop = (186005)2 [(0.1)2 + (0.1)2 + (0.163046575)2]

V = (34597860025) [0.0466]

V = 1611713129

SE = 40146.1, CV = 0.215833699

trend while accounting for variance of surveys. We suggest that these approaches be used to estimate trend and compare estimates when more than 2 estimates have been undertaken for a given population. When compared to 2 sample t-tests, these methods provide potentially more powerful tests for differences in estimated population sizes between 2 surveys and, also allow us to estimate rate of change.

Implications for designing calving ground surveys

A key question about the June 2003 survey is whether the weather-caused delay between the systematic reconnaissance survey and the photographic survey affected the survey results. Movements of caribou could reduce the applicability of stratum boundaries and decrease the estimate's precision. However, we had budgeted for enough fixed-wing flying that we could resurvey the boundaries of the photographic strata and were able to adjust the boundaries immediately prior to the photographic survey. If the peak of calving in 2003 was 8-11 June based on our observation of 20% calves on 7 June, the photographic survey was within the period before when we could expect rapid and extensive movements. Barren-ground caribou cows and calves are relatively stationary for 3-4 days after the peak of calving (based on daily satellite-collar locations (Gunn *et al.* 2001). In 2003, the movement rates of the satellite-collared cows was based on locations at 5-day intervals. At the time of the photographic survey, 11 collared cows were in the three strata (Figure 13) and one cow which was close to Contwoyto Lake and was probably a non-breeder.

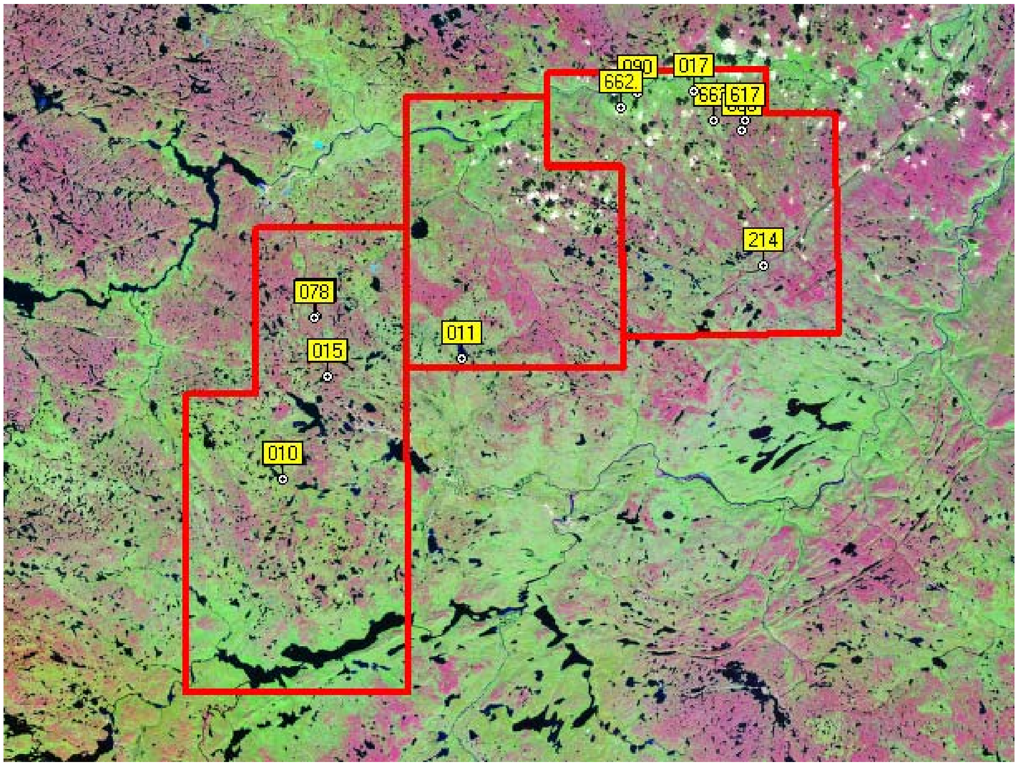


Figure 13. Locations of satellite-collared Bathurst caribou cows (n= 11) and stratum boundaries for a calving ground survey, 14-15 June 2003.

A tacit assumption of the calving ground photo-census, is that within the annual extent of calving, the area of highest caribou density comprises the majority of breeding females whereas the periphery consists mostly of non-breeding caribou. As density and composition of caribou are correlated, the challenge of delineating the periphery and spatial trends within the calving distribution is that there may be no clear demarcation along either a density or composition gradient across the calving ground. A flexible and adaptive approach is required to define *a priori*, the criteria which would be used to determine cut-off points along strip transects within a systematic survey design. We suggest that using a 10km grid and way points labelled with density or composition (antlered cow, calf) will contribute over several surveys to predicting and testing criteria.

Caution is needed with applying set uniform criteria for delineating spatial patterns within calving grounds. Currently, we have limited knowledge about the ecological variance in calving strategies. We cannot, for example, rule out the possibility that not all cows on the edge of the calving ground were ‘late’ reaching the calving ground and calved before they reached the high density calving. Instead, some cows may have an evolutionary strategy of dispersed and more solitary calving which we detected in the low density strata.

We agree with Davis *et al.* (1986) who cautioned caribou biologists about rigid adherence to a limited number of models of caribou behaviour. Davis *et al.* (1986) drew attention to Bergerud’s (1974) emphasis on the adaptability of caribou’s use of space, and commented that caribou may have alternate behavioural strategies. We suspect that some caribou cows may disperse to calve rather than gregariously as an evolutionary strategy.

The visual surveys of low density strata should remain an important component of the overall calving ground survey technique because it compliments the photo-census. When compared to photo-census techniques, visual surveys allow us to estimate caribou in low density areas economically. In addition, precision and accuracy of visual surveys are less affected by observer bias in low-density areas. Finally, the proportion of caribou that would occur in low density strata likely represents only a small fraction to the overall estimate of caribou on an annual calving ground . However, we think that the proportion of low density (dispersed) calving may vary over time and between herds. As a practical recommendation, we suggest that the budget has to include adequate funds to allow for coverage of possibly relative large low density areas as well as contingency funding to systematically re-fly stratum boundaries if there is a delay between stratification and photography.

CONCLUSIONS

1. Abundance of breeding females in the Bathurst caribou herd has significantly declined since 1986.
2. Our ability to detect changes in numbers based on calving ground photography was improved by increasing the estimate's precision by effective use of survey effort through improved stratification, higher photographic coverage on high and medium density strata, and the use of visual surveys on low density strata.

ACKNOWLEDGEMENTS

The census was funded through West Kitikmeot Slave Society with contributions from Indian and Northern Affairs Canada, Government of Nunuvut and Government of Northwest Territories. We also had support in-kind from Inmet Mining Corporation (av gas) and we thank Ian Piriei for his help. At the Kinross Lupin mine, Gary Aubin, Gary Garner, Dave Hohnstein and Wayne Grudzinski were all helpful in arranging accommodation, fuel and office space. We have a large debt to David Taylor (RWED). Dave's efforts in teaching us the intricacies of GPS, OziExplorer and Microsoft Excel made a huge difference to the survey. We are also grateful to the help from David Abernethy (RWED) and Adrian D'Hont (RWED) who handled requests for information and logistical details. Perry Linton (Northwright Air Services Ltd) piloted the Helio-Courier with his customary skill. Dale Weir and Walter Feisel (Geographic Air Service Ltd) shared the waiting for weather at Lupin with us before completing the photography and we appreciate their patience and diligence. Hilke Krey (Geographic Air Survey Ltd) was patient over the changes to the photo lines. Paul Ray has done the counts of the caribou on the photographs for the surveys since 1986 and we appreciate his accuracy and skill once again in 2003. We also thank Mark Williams for his contribution to calving ground surveys as we continued to use his detailed 1994 manual. Lastly, we thank Ray Case for all his administrative support and for reviewing this report and Gina Elliott for her help in producing it.

LITERATURE CITED

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley & Sons, New York. 234pp.

Bathurst Caribou Management Planning Committee. 2004. A Management Plan for the Bathurst Caribou Herd. Yellowknife, NWT. 51 pp. Copies available from Bathurst Caribou Management Planning Committee Secretariat, Box 1320, Yellowknife, NT, X1A 3S8.

Bergerud, T. 1974. 1974*d*. The role of the environment in the aggregation, movement, and disturbance behavior of caribou. Pages 552-584 *in* V. Geist and F. Walters, eds. The behavior of ungulates and its relation to management. Vol. 2. IUCN New Ser. Publ. 24, Morges, Switzerland. 940 pp.

Brown D., and P. Rothery. 1993. Models in biology: Mathematics, statistics, and computing. John Wiley and Sons. New York. 687 p.

Circumpolar Flora and Fauna. 2001. Arctic flora and Fauna: status and conservation. Edita, Helsinki, Finland. 272 pp.

Cochran, W.G. 1977. Sampling techniques. 3rd. Edition. J. Wiley and Sons Ltd., 423 pp.

Davis, J. L., P. Valkenburg, and R. D. Boertjy. 1986. Empirical and theoretical considerations toward a model for caribou

Gasaway W.C., S.D. Dubois, D.J. Reed, and S.J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska No 22:1-108.

Gunn, A, and A. D'Hont. 2003. Extent of calving for the Bathurst and Ahiak Caribou herds June 2002. Department of Resources, Wildlife and Economic Development. Manuscript Rep. 149. 35pp.

Gunn, A., J. Dragon and J. Nishi. 1997. Bathurst calving ground survey 1996. Northwest Territories Department of Resources, Wildlife and Economic Development. File Rep. No. 119. 70 pp.

Gunn, A., J. Dragon and J. Boulanger. 2001. Seasonal movements of satellite-collared caribou from the Bathurst herd. Final Report to the West Kitikmeot Slave Study Society, Yellowknife, NWT.80pp.

Griffith, B, A. Gunn, D. Russell, J. Johnstone, K. Kielland, S. Wolfe,and D. C. Douglas, 2001. Bathurst caribou calving ground studies: Influence of nutrition and human activity on calving ground location. Final report submitted to West Kitikmeot Slave Study Society. Yellowknife, NWT. 90pp

Heard, D.C. 1985. Caribou census methods used in the Northwest Territories. McGill Subarctic Research Papers. 40:229-238.

Heard, D.C. 1987a. Allocation of effort in a stratified survey design. Department of Renewable Resources Manuscript Report. 9pp.

Heard, D.C. 1987b. A simple formula for calculating the variance of products. Department of Renewable Resources Manuscript Report. 5pp.

Jolly, G.M. 1969. Sampling method for aerial census of wildlife populations. East African Agricultural and Forestry Journal 34:46-49

Krebs, C.J. 1992. Version 3.0 FORTRAN programs for “Ecological Methodology” Exeter Software, Setauket, NY. 156 pp.

Manly B.F.J. 1997. Randomization and Monte Carlo Methods in Biology. Chapman and Hall. New York. 281 pp. p.

Newman, D. 2003. Ozi Explorer GPS Mapping Software v. 3.95.3.b. [Online] URL: http://www.oziexplorer.com

Norton-Griffiths M. 1978. Counting Animals. African Wildlife Leadership Foundation. Nairobi. 110 p.

Nunavut Planning Commission. 2004. West Kitikmeot Land Use Plan (2004 draft). Nunavut Planning Commission, Cambridge Bay, NU.

Sutherland, M. and A. Gunn. 1996. Bathurst calving ground surveys, 1965-1996. Northwest Territories Department of Resources, Wildlife and Economic Development File Report No. 118. 97 pp.

APPENDIX A. PROCEDURES AND FILE MANAGEMENT USING GPS, OZIE EXPLORER AND EXCEL (DEVELOPED BY DAVID TAYLOR)

Starting Files:
Load these two files into the GPS's at the start of the survey (or reduce in Ozi to a single day's flying):
Surveyroute.rte
Transectendpoints.wpt

The following files were used to print maps and are not loaded into the GPS:
Sectionlabels.pnt
Sectionlabels.wpt
Extents.trk

<u>After day of flying:</u>

1. Save GPS way points and track file
Download waypoints and track log from the GPS into Ozi

- .
- Save waypoints as <ddL.wpt>

2. Transcribe observations

- Low density – check all observations on transect sheets are referenced by section label and check against Ozie map
- Back seat recorders transcribe data onto data sheet and sum observations for each transect section.
- Combine Right and Left observer data onto another data sheet and sum observations for each transect section.

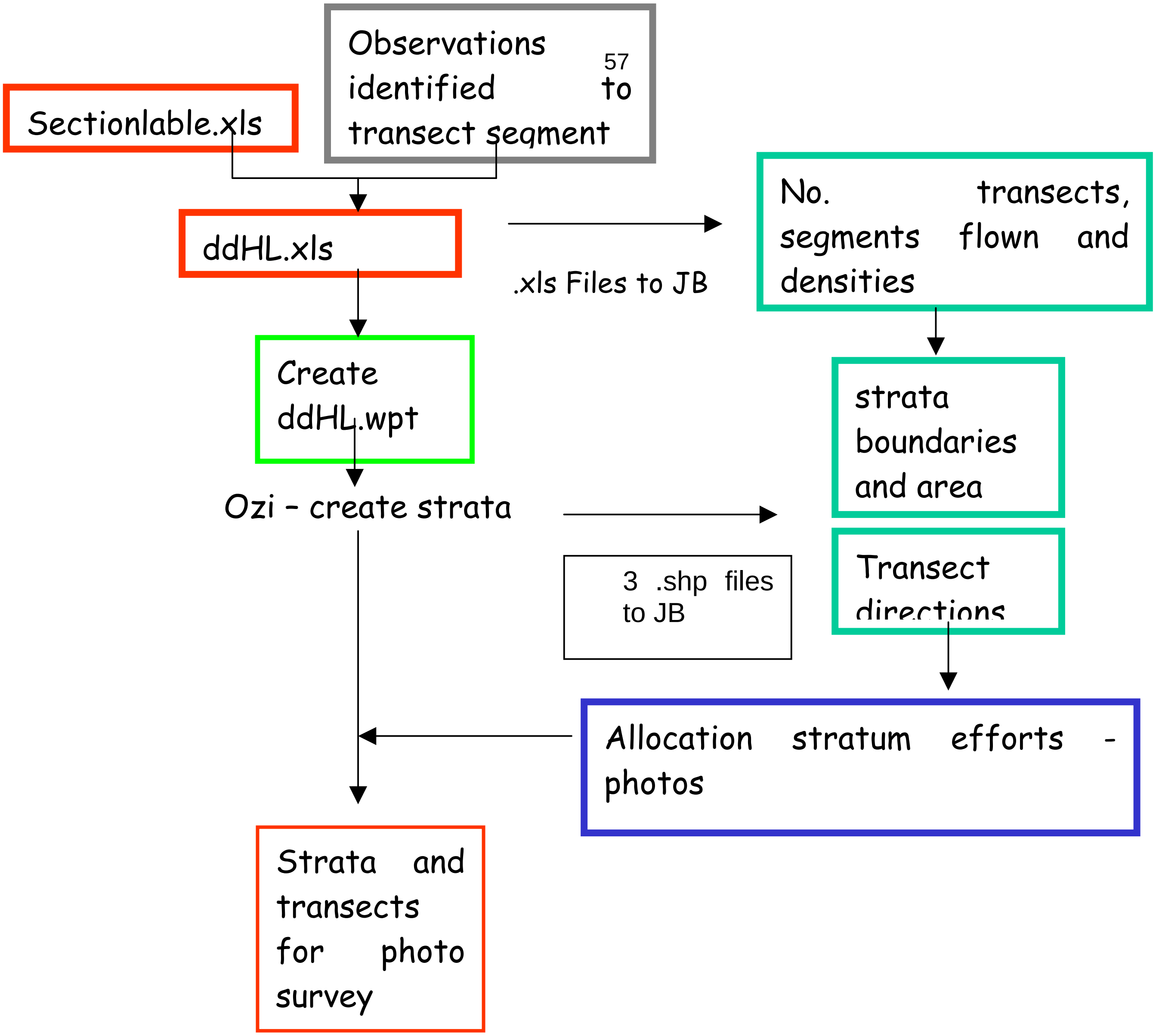
3. Create Excel file for observations (to assign strata and send to Boulanger)

- Open <Sectionlable.xls>
- Save as <ddHL.xls>
- Add observation columns to the right hand end of data and enter observations from data sheets (You might find it handy to hide the columns you are not using for data entry. Select columns and then right click - hide).
- Enter zeros for those section labels that we flew but did not have observations for.
- Sections we did not fly can be deleted (Select all and sort on data column).
- Unhide the columns – select and unhide
- Sort by observation class size (10's, 100's, 1000's).

- Change waypoint characteristics (colour) to code observations as high, medium, low and zero using colour codings from key.xls.
- You must resequence the final Excel spreadsheet of observations and put the sequential number in column O. Check the section label in the column B. O is the Altitude column in Ozi. (In ArcView the column AUX 3 will have these resequenced numbers that will link to column E of the JB version of the spread sheet).
- Add a column with High, Low and Medium Density info (H, L or M).
- Add as text box the total number of segments flown/stratum and the area of each stratum.
- Save. This is your working ddHL_DENSITY.xls file and the file you will send to JBoulanger
- To make a map showing actual segment densities, go to entered data file (ddHL_DENSITY.xls); copy and paste density column into column B replacing labels (Ta etc); save as ddHL_DENSITY_LABEL.xls.

4. To bring this Excel file back into Ozi (to see the density pattern and draw strata boundaries) :

- Open any Ozi way point file into Excel: cut and paste Ozi fields into ddHL.xls (except Column J which the way point color and has been changed to code for relative density classes).
- Delete all observation columns and save as type csv with the name <"ddHL.wpt"> (remember the quotes)
- Open <ddHL.wpt> in Notepad and add four Ozi lines (found in oziheader.txt) to top of data and save.
- Open Ozie and open ddHL.wpt Bring into Ozi.
- Create stratum using Ozi's Area Calculator to draw the strata. Delete way points leaving the track line; save track file as a shape file (line to polyline); add corner points as waypoints and save as shape file (way points to points) and send both track and point files to send both files to John Boulanger.
- Send .jpg file of survey area with segments labeled to density
- Saving to shape file: Datum = WGS 84 Position format = lat/long


Sectionlable.xls
Observations identified to transect segment
ddHL.xls
.xls Files to JB
No. transects, segments flown and densities
Create ddHL.wpt
strata boundaries and area
Ozi – create strata
3 .shp files to JB
Transect directions
Allocation stratum efforts - photos
Strata and transects for photo survey

APPENDIX B. DAILY FLIGHT LOG DURING RECONNAISSANCE AND SYSTEMATIC SURVEYS OF BATHURST CALVING GROUND, 2 –18 JUNE 2003.

Date	Purpose	Hours flown
2 June	Ferry (Twin Otter): J. Williams to Lupin Mine with field gear	
3 June	Ferry (Helio Courier): Norman Wells – Yellowknife (P. Linton)	
	Yellowknife – Lupin Mine (P. Linton, A. Gunn, J. Nishi)	
4 June	Systematic survey: Transects 6 – 9	3.6
5 June	Systematic survey: 10-19	6.2
6 June	Entering, tabulating data	
7 June	Systematic survey: Transects 8-19	7.2
8 June	Photo plane arrived Lupin	
9 June	Overcast, snow, reduced visibility	
10 June	Overcast, snow, reduced visibility	
11 June	Snow, blowing snow	
12 June	Overcast, snow, reduced visibility	
13 June	Systematic survey to check stratum boundaries	5.2
14 June	Photo plane High density; Helio Courier surveys low density SW stratum	4.1
15 June	Photo plane medium density; Helio Courier surveys high density stratum	5.7
16 June	Helicopter survey composition	3.0
17 June	Helicopter survey composition	2.8
18 June	Helicopter survey composition	3.7
	Finish composition; Helio-Courier to check satellite collar west of calving ground, then to Yellowknife	8.6

APPENDIX C. SAMPLING DESIGN AND ALLOCATION OF EFFORT FOR BATHURST CARIBOU SURVEY 2003

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This short report outlines the procedure used to allocate effort for photographic transects based upon reconnaissance surveys for the 2003 Bathurst Caribou survey. It will eventually be included with the final report for this project.

METHODS

Preliminary systematic reconnaissance surveys were conducted by NWT personnel. Waypoint data and preliminary strata boundaries (based upon grouping of similar caribou densities) were provided. From this, I calculated the mean population size and variance of population size for each strata based upon preliminary surveys using formulas for unequal size transects as documented in Krebs (1998). Transects within strata were constructed by sub-setting the larger reconnaissance transects segments based upon strata boundaries. Strata area, mean photographic transect length, and width of strata were also estimated from preliminary data using ArcView. Widths of irregular shape strata were estimated by the weighted mean of width (weighted by opposing strata length for segments of each strata).

The optimal orientation of transect was chosen based upon two criteria. First, transects were oriented towards the long axis of strata to maximize the number of replicate samples. If densities occurred in linear bands then deviations from this orientation were considered to minimize between transect variance (by orienting transects with the density gradient).

Allocation for strata was estimated two ways which are briefly described.

1. *Allocation using standard error from population* (n_{SE})- This type of allocation assumes that the standard error of preliminary surveys is a suitable predictor of the standard error of photographic surveys. The sample effort was expressed as the number of transects for each strata (Norton-Griffiths 1978) and the proportion of effort for each strata (Thompson 1992). The proportion of effort calculation considers a kilometer of photo transect as the sample unit. It provides a method to cross check effort calculations when strata are non-uniform shaped.
2. *Allocation using population estimates* (n_N)- This type of allocation assumes that the population size for each strata from reconnaissance surveys is proportional to the standard error of photo surveys (Norton-Griffiths 1978). This formula has been used in previous caribou surveys (Heard 1987).

Allocation that used direct estimates of standard error was given priority for use unless the estimates of standard error from preliminary surveys were judged to be unreliable. There are some scenarios where estimates of standard error may not be reliable from reconnaissance transects. First, low numbers ($n<5$) of transects for any strata would make estimation of standard error problematic. Second, a long time period between reconnaissance and photo surveys (due to poor survey weather) could cause the distribution and dispersion of animals within a strata to change therefore making the estimate of standard error from the reconnaissance transects a poor estimator of standard error for the photo transects. Third, if reconnaissance surveys were flown with a different orientation than photo transects (to minimize between transect variance) then the estimate of standard error from reconnaissance surveys could overestimate the standard error of photo transect surveys. In each case, allocation estimates based upon population size would be more reliable than estimates based on standard error. It was assumed that 925 km of photo transects was available for all strata. All calculations were done using SAS statistical package.

RESULTS

Defining strata

NWT personnel surveyed the Bathurst herd on June 7, 2003. From this, they suggested that three strata be used to sample the herd using aerial photos (Figure 1). The medium strata would be flown in an north-south direction whereas the high strata would be flown in a east-west direction (to minimize variance between strata lines). Flying the high strata transects in an east west direction is contrary to the recommendation of Norton-Griffiths (1978) that transects should be flown perpendicular to the long axis of the strata. However, the main reason for this recommendation was to maximize sample size of transects to minimize variance. If photo transects were flown north-south, the variance of estimates would most likely be inflated by the east-west gradient in density (i.e. low densities on east side of strata). Therefore, it was decided that flying east west would most likely reduce variance estimates more than a slight increase in sample size that would be gained by flying transects north and south.

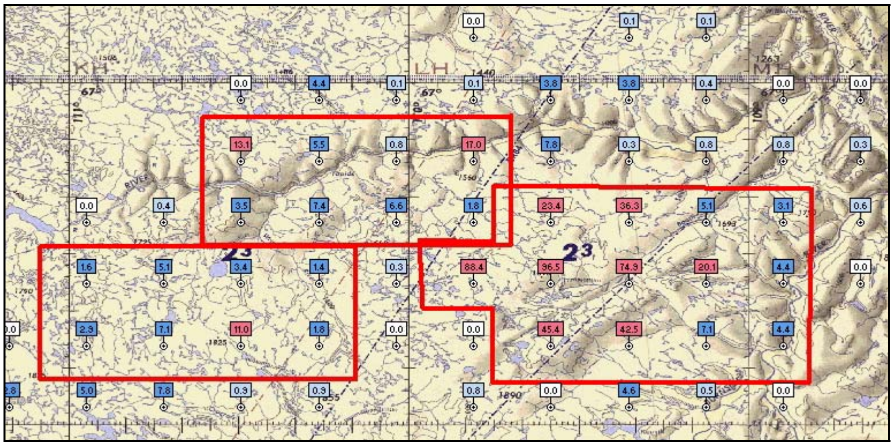

Figure 2: Proposed photo strata for Bathurst caribou herd surveys. The eastern strata was high density. The northern and western strata were defined as medium density. The rest of the areas were surveyed using visual transects. Each box represents a density estimate of caribou based upon north-south aerial transects segments of 8 km^2

Population and variance estimates from reconnaissance surveys

Population and variance estimates were estimated by sub-setting each north-south reconnaissance transect segment based upon inclusion in each strata (Table 1). In Table 1, transect estimates correspond to the sample of transect taken in each strata. The transect estimates were then extrapolated to the whole strata.

Table 1: Strata population, density, and variance estimates based upon reconnaissance surveys with 3 strata.

Strata	Area	Transect estimates					Whole Strata estimates		
	(km^2)	N^A	n^B	$\hat{N}$	Area	$\hat{D}$	$\hat{N}$	S.E. ($\hat{N}$)	CV
High	1407	66	5	3612	104	34.73	48866	17112	35.0%
Medium-N.	815	52	4	445	64	6.95	5667	996	17.6%
Medium-S	918	53	4	274	64	4.28	3930	1138	28.9%

[A]total number N-S transects possible
[B]number of transects sampled

From Table 1 it can be seen that the density of caribou ($\hat{D}$) is approximately five to six times greater in the high strata when compared with the medium strata. In addition, the degree of variation (as indicated by the CV) is also higher in the high strata. The two medium strata display nearly identical densities of caribou. Given the similarity of density for the medium strata, estimates were also considered with medium strata pooled (Table 2).

Table 2: Strata population, density, and variance estimates based upon reconnaissance surveys with the medium strata pooled.

Strata	**Area**	**Transect estimates**					**Whole Strata estimates**		
	(km^2)	**N**[A]	**n**[B]	$\hat{N}$	**Area**	$\hat{D}$	$\hat{N}$	**S.E. ($\hat{N}$)**	**CV**
high	1407	66	5	3612	104	34.73	48866	17112	35.0%
med	1733	80	6	719	128	5.62	9735	1713	17.6%

[A]total number N-S transects possible
[B]number of transects sampled

Estimates with medium strata pooled suggest an increase in precision of estimates of the pooled medium strata compared to the separate medium strata. The areas of pooled medium and high strata were roughly similar.

Strata allocation estimates

One important point to note is that the estimate of variance for the high strata was based upon reconnaissance surveys that flew a north-south direction whereas photo transects were flown east-west (to minimize between transect variance). Given this it was likely that estimates of standard error from photo transects would be lower than those from reconnaissance surveys for the high strata. Therefore, allocation of survey effort using estimates of standard error from reconnaissance surveys of the high strata was problematic.

Three sampling scenarios were considered in terms of allocating survey effort. Each is now considered and discussed.

1) Three strata sampling design

With this design each of the medium strata would be sampled individually (flying north-south) and the high strata would be flown east-west.

Table 3: Effort allocation using 3 strata

Strata		Allocation (# of transects)		Relative effort
	Mean transect length	Using $\hat{N}$	Using SE($\hat{N}$)	Using SE($\hat{N}$)
High	48 km	14.9	17.1	92.3%
Medium N	21 km	5.9	2.3	3.6%
Medium-S	21km	4.1	2.6	4.0%

Allocation estimates that use estimated population size and the standard error of estimated population size both suggest that the majority of effort be placed in the high strata. One potential issue with this design is that there should be at least 5 transects for any strata and therefore the number of transects in the high strata would have to be reduced to allow sufficient number of transects for the medium strata.

2) Medium strata pooled and photo transects flown north-south

Similar estimates in terms of allocation for the high strata resulted if medium strata were pooled. The number of transects for the pooled medium strata is 7 (using estimates of N to allocate effort) which was above the minimal sample size requirement of 5. As stated earlier, allocation estimates using N may be more reliable than estimates using standard error given the different orientation of reconnaissance and photo transects for the photo surveys.

Table 4: Allocation using 2 strata and flying medium strata N-S

Strata	Mean transect length	Allocation (# of transects) Using $\hat{N}$	Using SE($\hat{N}$)	Relative effort Using SE($\hat{N}$)
High	48 km	15.2	16.3	88.1%
Medium	27.25 km	7.1	5.1	11.9%

3) Medium strata pooled and transects flown east-west.

One potential issue with flying the pooled medium strata transects in a north and south direction was uneven size of transects. This could potentially cause a slight increase of variance between transects. Another strategy that was suggested was to fly the medium strata transects east and west therefore making transect lengths roughly equal. However, this

sampling design substantially increases transect length and goes against the general recommendation that transects should be perpendicular to the long axis of strata. The main issue of concern was if a suitable number of transects could be flown in both high and medium transects given the limited kilometers of photo transect (925 km).

Table 5: Allocation using 2 strata and flying medium strata E-W

Strata	Mean transect length	Allocation (# of transects) Using $\hat{N}$	Using SE($\hat{N}$)	Relative effort Using SE($\hat{N}$)
High	48 km	15.9	16.3	85.5%
Medium	43 km	3.7	3.2	14.5%

Allocation estimates suggested a similar number of transects for the high strata but a reduced number for the medium strata (due to the longer length of transects if they were to be flown east and west). This allocation would have to be adjusted to meet the minimal sample size requirements of 5 transects by reducing the number of transects in the high strata. For example, the number of high strata transects could be reduced so that 12 transects were flown in the high strata and 7 transects were flown in the medium strata.

DISCUSSION

The sampling design in which high strata transects were flown east west and the pooled medium strata were flown north and south was decided to be the optimal design allocation. Using this design it was possible to allocate effort without any adjustments to meet minimal sample size requirements. It also allowed a higher proportion of effort to be expended in the high strata, a reasonable strategy given the significantly higher population size and variability within this strata.

Allocations that used estimates of population size (approximately 15 transects for high strata and 7 transects for medium strata) were judged to be optimal for allocation given issues with obtaining a reliable estimate of standard error for the high strata given that reconnaissance surveys were flown north-south and photo transects were flown to be west-east. The main concern was that estimates of standard error for the high strata would be biased high from reconnaissance surveys therefore resulting in over allocation to the high strata.

LITERATURE CITED

Heard D.C. 1987. Allocation of effort in a stratified survey design. Yellowknife NWT: Department of Renewable Resources, Government of Northwest Territories.

Krebs C.J. 1998. Ecological Methodology (Second edition). Benjamin Cummins. Menlo Park, CA. 620 p.

Norton-Griffiths M. 1978. Counting Animals. African Wildlife Leadership Foundation. Nairobi. 110 p.

Thompson S.K. 1992. Sampling. John Wiley and Sons. New York.

APPENDIX D. NUMBER OF 1+ CARIBOU OBSERVED DURING A VISUAL TRANSECT SURVEY IN THE NORTH EAST LOW DENSITY STRATUM, 14 JUNE 2003, BATHURST CALVING GROUND

Transect no.	Transect area (km^2)	Transect length (km)	1+ year old caribou counted
1	25.76	32.2	0
2	24.80	31.0	0
3	24.80	31.0	22
4	24.96	31.2	3
5	25.60	32.0	6
6	24.64	30.8	26
7	25.12	31.4	41
8	24.88	31.1	63
9	25.04	31.3	34
10	16.40	20.5	31
11	17.60	22.0	46
12	17.36	21.7	61
13	17.28	21.6	71
14	17.04	21.3	63
Total	**311.28**	**389.1**	**467**

APPENDIX E. NUMBER OF 1+ CARIBOU OBSERVED DURING A PHOTOGRAPHIC TRANSECT SURVEY OF A MEDIUM DENSITY STRATUM, 15 JUNE 2003, BATHURST CALVING GROUND.

Transect no.	Transect area (km^2)	Transect length (km)	1+ year old caribou counted
1	27.37	29.93	201
2	27.37	29.93	134
3	27.37	29.93	639
4	26.91	29.43	704
5	26.91	29.43	536
6	26.91	29.43	1299
7	26.85	29.36	854
8	18.11	19.81	812
9	18.11	19.81	366
10	18.11	19.81	27
Total	**244.02**	**266.87**	**5572**

APPENDIX F. NUMBER OF 1+ CARIBOU OBSERVED DURING A PHOTOGRAPHIC TRANSECT SURVEY OF A HIGH DENSITY STRATUM, 14 JUNE 2003, BATHURST CALVING GROUND.

Transect no.	Transect area (km^2)	Transect length (km)	1+ year old caribou counted
1	27.37	29.93	177
2	27.30	29.86	203
3	27.30	29.86	994
4	27.37	29.92	4928
5	27.30	29.86	2184
6	27.30	29.86	365
7	27.30	29.86	1752
8	27.30	29.86	1045
9	27.37	29.93	615
10	27.30	29.86	1402
11	27.18	29.73	1013
12	36.40	39.81	3956
13	36.40	39.81	2593
14	36.22	39.61	7584
15	27.54	30.12	5683
16	27.54	30.12	659
17	27.54	30.12	170
Total	**492.03**	**538.12**	**35 323**

Appendix G. Composition of 1+ year old caribou classified in the low density south west visual stratum, Bathurst calving ground, 18 June 2003.

Waypoint	Segment	Sample no. in segment	Antlered W/ Udder	Anterless W/ Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
45	10t	1	0	0	0	6	0	3	0	9	0	9	0.0000	0.05286	0.02262
46	10t	2	0	0	0	7	0	15	0	22	0	22	0.0000	0.05607	-0.02233
47	10t	3	0	0	0	2	0	1	0	3	0	3	0.0000	0.05150	0.04168
48	10t	4	1	1	0	4	1	9	1	17	2	16	0.1250	0.04545	0.12635
49	9s	1	0	1	0	9	1	8	0	19	1	18	0.0556	0.05046	0.05629
50	9s	2	1	0	0	8	1	9	3	22	1	21	0.0476	0.05116	0.04643
51	9s	3	0	0	0	5	0	3	0	8	0	8	0.0000	0.05263	0.02587
52	8r	1	0	0	0	3	0	7	6	16	0	16	0.0000	0.05455	-0.00092
53	8r	2	0	0	0	2	0	6	0	8	0	8	0.0000	0.05263	0.02587
54	8r	3	0	0	0	2	0	3	4	9	0	9	0.0000	0.05286	0.02262
55	10r	1	0	2	0	12	1	18	0	33	2	32	0.0625	0.04902	0.07644
56	10r	2	3	2	0	10	3	10	2	30	5	27	0.1852	0.03349	0.29381
57	10r	3	1	0	0	13	0	14	3	31	1	31	0.0323	0.05366	0.01149
59	9p	1	0	0	0	4	0	4	0	8	0	8	0.0000	0.05263	0.02587
60	9p	2	0	0	0	4	0	4	0	8	0	8	0.0000	0.05263	0.02587

n=	15
Sum Breeding Females	12
Sum 1+ Yr Old Caribou	236
Overall proportion Breeding Females	0.0508

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

mean	0.0519
variance	0.0057
SD	0.0752
SE	0.0194
CV	0.3744

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 H. Composition of 1+ year old caribou classified in the medium density visual stratum, Bathurst calving ground, 16-18 June 2003.

	Waypoint	Segment	Sample no. in segment	Antlered W/ Udder	Anterless W/ Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
16-Jun-03	2	13s	1	0	0	1	5	0	1	0	7	1	7	0.1429	0.46991	0.39601
	3 & 4	13s	2	1	0	2	8	0	4	0	15	3	15	0.2000	0.47093	0.33976
	5	13s	3	0	0	0	2	0	1	0	3	0	3	0.0000	0.46940	0.42395
	6	13s	4	1	0	0	7	1	8	0	17	1	16	0.0625	0.47237	0.26070
	7	13s	5	0	0	1	3	0	2	5	11	1	11	0.0909	0.47100	0.33605
	8	13s	6	1	0	2	3	0	3	0	9	3	9	0.3333	0.46929	0.42980
	9	13t	1	1	6	2	6	7	7	0	29	9	22	0.4091	0.46935	0.42656
	10	13t	2	1	4	0	9	4	7	0	25	5	21	0.2381	0.47141	0.31327
	11	13t	3	1	0	0	10	1	5	0	17	1	16	0.0625	0.47237	0.26070
	12	13t	4	3	5	0	1	8	3	0	20	8	12	0.6667	0.46721	0.54446
	13	13t	5	4	0	1	2	4	2	0	13	5	9	0.5556	0.46813	0.49353
	14	13t	6	4	2	4	4	4	7	1	26	10	22	0.4545	0.46877	0.45867
	15	13u	1	10	12	0	7	16	3	1	49	22	33	0.6667	0.46475	0.67982
	16	13u	2	5	0	2	5	0	3	0	15	7	15	0.4667	0.46860	0.46767
	17	13u	3	15	18	0	4	26	4	0	67	33	41	0.8049	0.46045	0.91625
	18	13u	4	14	17	1	7	20	7	0	66	32	46	0.6957	0.46240	0.80871
	19	13u	5	12	25	0	15	24	4	0	80	37	56	0.6607	0.46218	0.82103
	20	13u	6	1	5	0	15	5	4	0	30	6	25	0.2400	0.47193	0.28478
	21	13u	7	1	2	0	6	3	2	1	15	3	12	0.2500	0.47011	0.38486
18-Jun-03	1	11s	1	1	11	0	10	8	16	0	46	12	38	0.3158	0.47201	0.28040
	2	11s	2	2	14	0	8	8	11	2	45	16	37	0.4324	0.46938	0.42526
	3	11s	3	0	0	1	5	0	6	0	12	1	12	0.0833	0.47127	0.32102
	4	11s	4	10	40	0	4	32	11	1	98	50	66	0.7576	0.45716	1.09712
	5	11s	5	1	3	0	11	2	6	1	24	4	22	0.1818	0.47227	0.26602
	6	11s	6	2	16	0	4	13	1	0	36	18	23	0.7826	0.46437	0.70062
	7	12s	1	6	18	0	17	13	19	5	78	24	65	0.3692	0.47246	0.25589
	8	12s	2	8	16	0	6	16	11	1	58	24	42	0.5714	0.46604	0.60891
	9	12s	3	11	31	0	8	35	12	2	99	42	64	0.6563	0.46140	0.86390
	10	12s	4	8	17	0	12	16	7	2	62	25	46	0.5435	0.46655	0.58077
	12	12s	5	4	14	0	11	14	5	0	48	18	34	0.5294	0.46737	0.53545
	13	12t	1	2	8	0	15	5	14	2	46	10	41	0.2439	0.47403	0.16949
	14	12t	2	15	45	0	11	38	8	3	120	60	82	0.7317	0.45554	1.18648
	15	12t	3	13	34	1	8	29	10	0	95	48	66	0.7273	0.45836	1.03122
	16	12t	4	2	16	0	4	12	3	0	37	18	25	0.7200	0.46491	0.67075
	17	12t	5	17	50	0	16	52	15	1	151	67	99	0.6768	0.45599	1.16146
	18	11t	1	3	3	0	14	2	8	1	31	6	29	0.2069	0.47304	0.22392
	19	11t	2	4	10	0	25	11	28	1	79	14	68	0.2059	0.47930	-0.12081
	20	11t	3	12	40	0	27	35	16	5	135	52	100	0.5200	0.46544	0.64153
	21	11t	4	3	48	0	41	49	21	7	169	51	120	0.4250	0.47183	0.29046
	22	11t	5	2	16	0	15	12	7	3	55	18	43	0.4186	0.46986	0.39872
	25	12u	1	6	6	0	6	5	7	0	30	12	25	0.4800	0.46842	0.47776
	26	12u	2	3	0	0	2	1	3	0	9	3	8	0.3750	0.46902	0.44474
	27	12u	3	0	0	0	11	0	9	0	20	0	20	0.0000	0.47405	0.16804
	xx	12u	4	0	4	1	15	0	6	0	26	5	26	0.1923	0.47279	0.23741
	xx	12u	5	1	0	0	12	0	6	0	19	1	19	0.0526	0.47319	0.21528
	33	12v	1	2	6	0	15	4	5	0	32	8	28	0.2857	0.47159	0.30361
	34	12v	2	0	0	1	0	0	1	1	3	1	3	0.3333	0.46882	0.45570
	36	11v	1	0	0	5	0	0	3	0	8	5	8	0.6250	0.46786	0.50844
	37	11v	2	0	0	3	0	0	1	0	4	3	4	0.7500	0.46794	0.50435
	38	11v	3	1	0	0	3	0	4	1	9	1	9	0.1111	0.47045	0.36607

Appendix H. Composition of 1+ year old caribou classified in the medium density visual stratum, Bathurst calving ground, 16-18 June 2003.

Waypoint	Segment	Sample no. in segment	Antlered W/ Udder	Anterless W/ Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
39	11v	4	0	0	0	1	0	2	0	3	0	3	0.0000	0.46940	0.42395
40	11v	5	0	2	0	1	1	0	0	4	2	3	0.6667	0.46824	0.48746
41	11u	1	3	3	0	2	3	6	0	17	6	14	0.4286	0.46891	0.45068
42	11u	2	0	1	0	8	1	13	0	23	1	22	0.0455	0.47402	0.16970
43	11u	3	0	0	0	9	0	7	3	19	0	19	0.0000	0.47378	0.18323
44	11u	4	0	0	0	4	0	7	0	11	0	11	0.0000	0.47158	0.30415

n=	56
Sum Breeding Females	813
Sum 1+ Yr Old Caribou	1735
erall proportion Breeding Females	0.4686

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

mean	0.4703
variance	0.0698
SD	0.2642
SE	0.0353
CV	0.0751

Øi = nS - (n-1) St

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

Appendix I. Composition of 1+ year old caribou classified in the high density photo stratum, Bathurst calving ground, 16-17 June 2003.

	Waypoint	Segment	Sample no. in segment	Antlered W/ Udder	Anterless W/ Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
16-Jun-03	22	13v	1	1	1	0	1	2	1	0	6	2	4	0.5000	0.84084	0.81920
	23	13v	2	0	1	0	3	0	0	0	4	1	4	0.2500	0.84108	0.80354
	24	13v	3	5	66	0	0	54	0	0	125	71	71	1.0000	0.83779	1.02064
	25	13v	4	2	2	0	0	0	0	0	4	4	4	1.0000	0.84037	0.85051
	26	13v	5	40	95	0	4	117	8	0	264	135	147	0.9184	0.83771	1.02595
	28	13v	6	1	10	0	0	9	1	0	21	11	12	0.9167	0.84030	0.85485
	29	14v	1	4	18	0	1	19	1	0	43	22	24	0.9167	0.84009	0.86927
	30&31	14v	2	2	56	0	2	57	1	0	118	58	61	0.9508	0.83890	0.94729
	32	14v	3	7	34	0	8	26	6	0	81	41	55	0.7455	0.84178	0.75767
	33	14v	4	29	74	0	0	98	3	0	204	103	106	0.9717	0.83714	1.06359
	34	14v	5	14	52	0	0	56	2	0	124	66	68	0.9706	0.83839	0.98111
	34	14v	6	35	56	0	0	34	0	0	125	91	91	1.0000	0.83701	1.07250
	35	15v	1	19	47	0	2	49	1	0	118	66	69	0.9565	0.83859	0.96778
	36	15v	2	27	33	0	0	53	0	0	113	60	60	1.0000	0.83822	0.99233
	36	15v	3	29	67	0	1	83	1	0	181	96	98	0.9796	0.83721	1.05874
	37	15v	4	11	25	0	0	28	1	0	65	36	37	0.9730	0.83935	0.91785
	38	15v	5	48	86	0	0	133	0	0	267	134	134	1.0000	0.83529	1.18571
17-Jun-03	1	15s	1	0	0	14	0	0	0	0	14	14	14	1.0000	0.83999	0.87556
	2	15s	2	3	5	0	1	6	3	0	18	8	12	0.6667	0.84102	0.80780
	3	15s	3	12	57	0	0	34	0	0	103	69	69	1.0000	0.83787	1.01548
	4	15s	4	10	5	0	0	12	0	0	27	15	15	1.0000	0.83995	0.87807
	5	15s	5	9	41	0	10	24	0	0	84	50	60	0.8333	0.84063	0.83368
	6	15s	6	0	0	0	3	0	1	0	4	0	4	0.0000	0.84132	0.78789
	7	16s	1	0	0	0	4	0	0	0	4	0	4	0.0000	0.84132	0.78789
	8	16s	2	0	1	0	11	0	0	0	12	1	12	0.0833	0.84268	0.69801
	9	16s	3	0	0	0	3	0	2	0	5	0	5	0.0000	0.84152	0.77472
	10	16s	4	0	0	0	3	0	7	4	14	0	14	0.0000	0.84332	0.65587
	11	16s	5	0	0	0	2	0	4	2	8	0	8	0.0000	0.84212	0.73516
	12	16s	6	1	4	0	1	1	9	1	17	5	16	0.3125	0.84253	0.70789
	14	16t	1	49	78	0	1	112	4	2	246	127	134	0.9478	0.83700	1.07264
	14	16t	2	103	134	0	2	211	3	0	453	237	242	0.9793	0.83208	1.39789
	16	16t	3	7	11	0	1	15	0	0	34	18	19	0.9474	0.84004	0.87242
	17	16t	4	18	35	0	13	41	10	1	118	53	77	0.6883	0.84335	0.65381
	17	16t	5	9	83	0	2	65	0	0	159	92	94	0.9787	0.83737	1.04833
	18	16t	6	6	22	0	0	22	2	0	52	28	30	0.9333	0.83986	0.88438
	20	16t	7	18	96	0	2	101	4	1	222	114	121	0.9421	0.83752	1.03852
	20	16t	8	28	149	0	0	167	2	1	347	177	180	0.9833	0.83416	1.26047
	22	15t	1	22	125	0	0	125	2	0	274	147	149	0.9866	0.83518	1.19334
	23	15t	2	9	27	0	1	31	1	0	69	36	38	0.9474	0.83955	0.90460
	24	15t	3	2	2	1	12	2	14	3	36	5	34	0.1471	0.84615	0.46878
	25	15t	4	14	76	0	0	85	1	0	176	90	91	0.9890	0.83725	1.05651
	26	15t	5	3	6	0	5	4	7	1	26	9	22	0.4091	0.84278	0.69130
	27	14t	1	32	31	0	0	51	1	1	116	63	65	0.9692	0.83851	0.97341
	29	14t	2	20	20	0	3	27	3	0	73	40	46	0.8696	0.84020	0.86165
	30	14t	3	4	9	0	0	10	1	0	24	13	14	0.9286	0.84023	0.85986
	31	14t	4	7	66	0	2	59	3	0	137	73	78	0.9359	0.83873	0.95906
	32	14t	5	19	37	0	5	49	4	0	114	56	65	0.8615	0.84019	0.86222
	33	16u	1	11	42	0	7	43	5	1	109	53	66	0.8030	0.84112	0.80121
	34	16u	2	6	27	0	3	24	7	0	67	33	43	0.7674	0.84127	0.79087
	35	16u	3	1	0	0	14	0	6	1	22	1	22	0.0455	0.84469	0.56552

Appendix I. Composition of 1+ year old caribou classified in the high density photo stratum, Bathurst calving ground, 16-17 June 2003.

Waypoint	Segment	Sample no. in segment	Antlered W/ Udder	Anterless W/ Udder	Antlered No Udder	Antlerless No Udder	Calves	Yearlings	Bulls	Sum All	Sum Breeding Females	Sum 1+ Yr Old Caribou	p	St	Pseudovalue
37	16u	4	0	1	0	9	0	7	0	17	1	17	0.0588	0.84368	0.63185
38	16u	5	4	38	0	21	24	7	2	96	42	72	0.5833	0.84499	0.54588
39	15u	1	10	76	0	23	55	19	14	197	86	142	0.6056	0.84870	0.30071
39	15u	2	14	64	0	14	43	15	5	155	78	112	0.6964	0.84445	0.58124
40	15u	3	17	81	0	2	87	4	0	191	98	104	0.9423	0.83795	1.01026
41	15u	4	18	49	1	4	54	2	0	128	68	74	0.9189	0.83912	0.93287
42	15u	5	15	37	0	1	45	0	0	98	52	53	0.9811	0.83873	0.95856
x	14u	1	13	40	0	0	46	0	0	99	53	53	1.0000	0.83849	0.97440
43	14u	2	12	76	10	1	75	1	1	176	98	101	0.9703	0.83734	1.05054
44	14u	3	14	95	0	4	79	2	2	196	109	117	0.9316	0.83792	1.01198
45	14u	4	38	114	0	27	120	29	14	342	152	222	0.6847	0.84917	0.26941
46	14u	5	29	43	0	8	67	7	1	155	72	88	0.8182	0.84100	0.80912
48	14s	1	5	2	0	12	6	12	4	41	7	35	0.2000	0.84588	0.48697
49	14s	2	0	1	0	13	0	11	0	25	1	25	0.0400	0.84529	0.52566
50	14s	3	0	1	0	14	1	36	1	53	1	52	0.0192	0.85077	0.16426
51	14s	4	1	2	0	8	3	12	0	26	3	23	0.1304	0.84441	0.58369
52	14s	5	0	2	0	8	2	9	3	24	2	22	0.0909	0.84445	0.58125

n=	67
Sum Breeding Females	3547
Sum 1+ Yr Old Caribou	4220
Overall proportion Breeding Females	0.8405

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

mean	0.8415
variance	0.0520
SD	0.2281
SE	0.0279
CV	0.0331

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)