An Operations Guide to Barren-ground Caribou Calving Ground Density, Dispersion and Distribution Surveys, Based on an Assessment of the June 2007 and 2008 Surveys, Northwest Territories and Nunavut

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ABSTRACT

In 2007 and 2008, Government of the Northwest Territories (GNWT) and Government of Nunavut (GN) staff conducted calving ground distribution surveys on all mainland migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) herds in the Northwest Territories (NWT) and Nunavut (NU) from the Mackenzie River to Hudson Bay. The objectives of these systematic reconnaissance surveys were to 1) systematically delineate the spatial distribution of breeding females on the calving grounds at or near the peak of calving, and 2) determine the relative density of breeding females on the calving grounds, including areas of concentrated calving. These surveys are not intended to estimate herd (population) size. Our objectives in this report were to 1) summarize the calving ground distribution surveys conducted in the NWT and NU during 2007 and 2008, 2) compile the attributes of calving distribution as an indicator for both caribou population management (i.e., trends in density) and land management (i.e., trends in caribou distribution), and 3) provide a template, in effect an operations manual, for the format and data to be collected and the terminology and definitions for future calving ground surveys.

Some surveys had extensive draft reports already compiled, while others had little or no written documentation. We were asked to ensure the survey data were reported in a standardized format. With the assistance of GNWT and GN staff, we compiled reports and spatial data from surveys conducted on the following herds in 2007 and 2008: Tuktoyaktuk Peninsula, Cape Bathurst, Bluenose-West, Bluenose-East, Bathurst, Beverly, Ahiak, and Qamanirjuaq. Almost all surveys used a standard transect grid at 5 or 10 km spacing, and surveyed a 400 m strip on each side of the aircraft. Survey data collection differed slightly among areas and years, but in general included the number of adults, hard-antlered cows, non-antlered cows, calves, yearling and bull observed within groups on transect. Incidental observations were also collected. Most survey reports summarized the number of adult (non-

calf) caribou and breeding females observed on and off transect. Data was summarized by 5-10 km segment along transect.

We summarize the dates, survey logistics (aircraft type, transect spacing, etc.), observations, and incidental sightings for each survey conducted in 2007 and 2008. We also provide a map of relative density of breeding females and non-breeders (where available) for each survey. Given the ecology of antler loss relative to peak of calving, we assume a group was a “breeding female” group based on the presence of hard-antlers or calves.

We suggest that future calving distribution surveys should provide clear objectives, should use standardized methodologies to more readily enable comparisons over time and among areas, and should quantify the density, dispersion, and distribution of breeding females on the calving ground. We suggest the following objectives be considered: 1) determine inter-year trend in estimated density of breeding females or adult (1+ year old) caribou on the calving ground; 2) describe the dispersion (the pattern of relative density) of breeding females or adult caribou on the calving grounds, including areas of concentrated calving; and 3) systematically delineate the distribution of breeding females or adult caribou on the calving grounds at or near the peak of calving – this will lead to determining boundaries. In our template we provide suggestions for survey design, field recording, and collection of incidental observations, post-flight analysis, report production, databases, and mapping products. Using standardized methodologies, distribution surveys can be used to monitor trends in caribou densities on calving grounds as an indicator for herd status.

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ACRONYMS AND DEFINITIONS USED IN THIS REPORT

Annual calving ground	The area occupied by parturient caribou from birth through the initiation of foraging by calves at about three weeks after birth (Russell et al. 2002).
Antlered cow	A cow with one or two hard antlers during or after calving.
Breeding females	A cow with hard antlers prior to or during peak of calving, or a non-antlered cow with calf at heel (see text for more discussion).
Calf	During calving ground surveys, calves are newly born individuals days old.
Calving ground	The area occupied by the parturient barren-ground caribou from calf birth through the initiation of foraging by calves (Russell et al. 2002).
Centroid	The centre of a 5 or 10 km segment on a transect. Survey data are often summarized at centroids.
Concentrated calving area	The area of relatively high use within an annual calving ground (Russell et al. 2002).
Delineate calving ground	To draw the boundary around the peak calving ground during a systematic reconnaissance survey.
Density	Number of caribou per unit area – in this report, caribou/km^2 (based on aerial survey observations during transect survey).
Dispersion	Pattern of spatial distribution (typically scale dependent as to whether clumped, random or uniform).
Distribution	The area occupied by the herd during a specific season – requires definition of boundaries.
DOE	Department of Environment, Government of Nunavut.
ENR	Environment and Natural Resources, Government of the Northwest Territories.
Extent of calving	The outer perimeter of all known annual calving grounds (Russell et al. 2002).
GNWT	Government of the Northwest Territories.
GN	Government of Nunavut.
Kriging	An interpolation mapping technique that employs the statistical properties of data points and their distribution and autocorrelation to produce a smooth, predictive surface.
Non-antlered cow	A cow with no hard antlers. Non-pregnant cows drop their antlers earlier in the spring, and depending upon nutrition, may have antler buds during the calving season. Parturient cows usually drop their antlers within one week after calving (Whitten 1995).
Parturient cows	Pregnant cows prior to parturition; can also refer to females that have recently calved (post-partum).

Parturition	The act of calving.
Peak of calving	The date (median) when approximately 50% of the cows have calved (Russell et al. 2002). Determination during surveys is based on observations of calves with parturient cows (e.g. Nishi et al. 2007); from satellite collar data it is determined from changes in movement rates by collared cows (Fancy and Whitten 1991).
Peak calving ground	The area used by parturient cows during calving in a particular year (Gunn et al. 2008).
Peak calving grounds	The outer perimeter of all known peak calving grounds (Gunn et al. 2008). Peak calving grounds are overlapped, but not enclosed in minimum convex polygon approach.
Segment	A 5 or 10 km section of a transect (usually 800 m wide) used to sum counts and densities of caribou observed on transect.
Stratification	A method of further defining areas of relatively similar densities (of breeding females) within the delineated calving ground, allowing additional survey effort in those strata to obtain more precise estimates.
Traditional calving grounds	The total cumulative area used for calving by a particular herd from the 1950s to 2004 (BQCMB 2005).
Transect	A line flown during the survey, generally spaced 5 or 10 km from the adjacent transect. A 400 m transect strip width is used for each side of the aircraft.
Yearling	During calving ground surveys, calves born the previous year are yearlings (12 months of age)

INTRODUCTION

Barren-ground caribou (*Rangifer tarandus groenlandicus*) herds across North America return annually to calving grounds in late May and June. Fidelity to distinct traditional calving grounds is high, and most herds are named and managed based on the location of these calving grounds (Skoog 1968, Thomas 1969). Calving ground location and size can vary to some extent among years, depending largely on environmental factors (e.g. Russell et al. 1993, 2002, Griffith et al. 2001, Gunn et al. 2007, 2008, Bergerud et al. 2008). While Aboriginal people have observed occasional shifts in calving ground locations over the longer term (Thorpe et al. 2001), Aboriginal people, co-management boards, and biologists have recognized that calving grounds are important to caribou ecology and health, and require careful management (Russell et al. 2002, BQCMB 2005, NTBCMS 2006, NBGCS 2007).

Most barren-ground caribou herds within northern Canada have been declining for the past 10-20 years (e.g. Adamczewski et al. 2009). During declines, management agencies and co-management boards often call for increased monitoring of caribou herd numbers, including calf survival and herd composition (BCMPC 2004, BQCMB 2005, NTBCMS 2006). Photographic censuses to estimate the number of breeding females on the calving grounds, which can be extrapolated to overall herd size, or photographic surveys of post-calving congregations are conducted more often during periods of decline, but these are costly to undertake. The photographic calving ground censuses are preceded by a systematic reconnaissance survey to delineate the distribution of calving, and to establish the relative composition and density of calving caribou. This information is then used to stratify the sampling effort for the photographic census.

Beginning in 2007 and again in 2008, surveys were conducted to map the distribution of the calving grounds of all the mainland migratory barren-ground caribou herds in the Northwest

Territories (NWT) and Nunavut (NU) at the same time. The simultaneous surveys had been recommended after concerns had been raised about herd identity and use of calving grounds (Fisher et al. 2009). Timed to occur at or soon after the peak of calving, NWT government (GNWT) biologists, NU government (GN) biologists and community observers surveyed the major migratory herds from the Mackenzie River to Hudson Bay: Tuktoyaktuk Peninsula[1], Cape Bathurst, Bluenose-West, Bluenose-East, Bathurst, Beverly, Ahiak, and Qamanirjuaq. In 2007, a photographic census of the Beverly herd was also planned, but was not carried out due to poor weather and low numbers of caribou on the calving ground (Johnson et al. 2007). In 2008, preparations were again made for a photographic census of the Beverly herd, but densities were not high enough (Johnson and Williams 2008). Also in 2008, a photographic census of the Qamanirjuaq herd was carried out following the calving distribution survey (Campbell et al. 2010).

Using standardized methodologies, distribution surveys can be used to measure trends in caribou densities on calving grounds as an indicator for herd status. Comparing inter-annual patterns of density has recently been made possible through GPS technology. Beginning in 2003, the use of GPS technology has contributed to improving and standardizing the recording and presentation of observations during calving ground surveys (Gunn et al. 2005). It is now relatively easy to standardize the presentation of densities as segments along transect lines, which also allows quantification of describing both dispersion and distribution of caribou on the calving grounds.

Examination of the various draft reports, summaries, databases, and maps produced following the 2007 and 2008 calving distribution surveys revealed a diversity of methods and reporting among surveys that has resulted in inconsistencies and inefficiencies in the

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[1] The status of the caribou/domestic reindeer on the Tuktoyaktuk Peninsula is uncertain, but the Inuvialuit have requested that they be managed separately from the nearby Cape Bathurst herd until their status is clarified.

methodology. Differences in mapping of results, from relatively straightforward density of breeding females by segment (5 or 10 km portion of a transect) to more advanced and technically challenging geostatistical techniques, varied over time and among regions. These differences can lead to difficulties comparing surveys among herds and among years, and may lead to inaccuracies in visual depiction of results and challenges in interpreting changes in calving ground distribution over time.

The main objectives of 2007 and 2008 calving distribution surveys were to:

1. Systematically delineate the spatial distribution of breeding females on the calving grounds at or near the peak of calving; and
2. Determine the relative density of breeding females on the calving grounds, including areas of concentrated calving.

(Note that most people use breeding female, breeding cow and calving female synonymously in these reports.)

These surveys were not intended to estimate herd (population) size for two reasons. Firstly, calving ground distribution surveys estimate the number of adult (1+ year old) caribou and to extrapolate that estimate to herd size requires accurate sex and age composition data (see below). However, during an aerial survey, reliably assigning adult caribou as breeding or non-breeding females is difficult – usually it is more accurately sampled using a helicopter to position ground observers. Secondly, bias is relatively high and variable during visual surveys over the calving grounds (Heard 1985). Several sources of bias mean that the number of caribou counted within a transect will always be less than the number actually present. These include sightability bias, where an observer does not see a group of caribou, and counting bias, where an observer miscounts (and generally undercounts) a group of caribou. Additional errors may occur when an observer incorrectly assigns caribou to inside or outside the transect strip.

However, trends in the abundance of total caribou or total breeding females on the calving grounds near peak calving can be determined (e.g. Boulanger 2010, Adamczewski et al. 2009). This can be done using standardized survey design and methodology, and examining the change in the mean number of caribou seen in each segment over time, or the change in the relative numbers of caribou on the calving ground (Boulanger 2010). Analysis of trends over time are greatly facilitated with standardized field techniques, databases, and reporting.

Photographic calving ground surveys estimate the number of adult (1+ year old) caribou present on the calving grounds. From this figure, a number of steps are required to produce an estimate of total herd size (Heard 1985). The proportion of breeding females in each survey strata is determined using composition surveys conducted immediately after the photographic census. The proportion of breeding females is combined with the herd sex ratio (generally determined during fall composition counts) and the pregnancy rate for 1.5+ year females to estimate total herd size.

The critical component of these calculations to estimate herd size is estimating the number of breeding females. Breeding females (pregnant and post-partum) are identified by the presence of hard antlers, a distended udder, or a calf at heel (Whitten 1995). Breeding females cannot be identified on photographs taken during photocensus, but can be identified during visual aerial surveys and more reliably, during ground composition surveys.

Our objectives in this report were firstly, to summarize the calving ground distribution surveys conducted in the NWT and NU during 2007 and 2008. Taken together for each year, they are a visual depiction of the summed survey coverage across the north. For each herd, they add to the historic data on calving ground distribution and dispersion/density over time. The broad methodology for each survey was similar, and we provided it as a generic methodology at the front of our report. We described the field conditions and methods for each survey, grouped by field operation, and noted any differences with the overall methodology. We have attempted to standardize the format for each survey, to enhance comparability among surveys and years. Much additional information can be gleaned and analyses can be conducted for each individual survey, and in some cases these are provided in draft reports. We have referenced all draft reports, but as we suspect many of these reports will remain unpublished, we have included more details from these draft reports if available. Similarly, knowledge of collar movements at calving contributed to all surveys, but original reporting, and hence our reporting, of collar movements was uneven.

Our second objective in this report was to compile the attributes of calving distribution as an indicator to monitor for both caribou population management (i.e., trends in density) and land management (i.e., trends in caribou distribution) for caribou protection measures. We note that the application of calving ground distribution as an indicator has only recently become practical largely due to GPS technology and mapping software. We also made suggestions on using the density segment information to quantify intra- and inter-annual calving density, dispersion, and distribution, and to examine distribution at different scales.

Given the potential importance of calving distribution as an indicator, we offer in this report a template, in effect an operations manual, to the format and data to be collected, terminology, and definitions for future calving ground distribution surveys. These surveys can provide data on the density, dispersion, and distribution of adult caribou or breeding females on the calving ground that can elucidate trends in numeric and spatial data. This template includes suggestions on what should be collected in the field, how it should be recorded, and what to report. We offer suggestions on the mapping techniques we believe should be used to fulfill objectives of both visual depiction and ease of temporal and spatial comparisons among years and herds.

While compiling the aerial survey data, we noted differences in the reporting of predator sightings. Given the importance of predation and the difficulties of estimating predation rates, we offer suggestions for collecting standardized information of predator sightings as an indicator to potential levels of predation on calving grounds.

METHODS

Survey areas

Survey areas were initially based on distribution of calving caribou from previous aerial surveys, as well as available collar data (satellite collars, and more recently GPS [global positioning system] collars with satellite uplink capability). Given that the herds were declining, survey coverage was generally expanded compared to previous years to ensure that concentrations of calving cows were not missed.

All surveys were carried out in June using fixed-wing aircraft, and were timed to occur at or soon after peak of calving. Timing depended to some extent on weather, field conditions, and aircraft availability. Most surveys began with reconnaissance flights to the expected calving grounds, guided by locations of collared caribou and previous information on the location of calving grounds, to help define the area to be flown and how far calving had progressed. For the surveys, a series of parallel straight-line transects spaced five (for Tuktoyaktuk, Cape Bathurst, and Bluenose-West) or 10 km apart oriented either north-south or east-west were flown over an area encompassing the predicted calving grounds. Transects were broken into 10 km segments (5 km segments for Tuktoyaktuk, Cape Bathurst, and Bluenose-West). To determine boundaries for the calving ground, methods varied. In some cases a pre-determined grid of transects was flown, and in others flight lines continued until no more cows with hard antlers or calves were seen for 10 km or along east-west or north-south border transects (Johnson et al. 2008), or transect lines were flown 20 km past the last breeding group and two lines were flown past the last line where a breeding group was found on transect (Davison et al. 2008). In many instances areas beyond the core survey area were searched with transect spacing increased to 10 or 20 km and up to 50 km. These systematic searches were designed to search for concentrations of breeding females beyond concentrated calving or traditional areas, and to determine if there was spatial separation between calving grounds near the peak of calving.

Most survey crews were equipped with laptop computers at base camps with OziExplorer (OziExplorer GPS Mapping Software, Newman 2006), a digital map of the survey area, and a digital data file of the waypoints for the ends of each transect. OziExplorer was used to upload the waypoints for the ends of each transect from the laptop to the GPS of the aircraft (Taylor 2009). The pilot used these waypoints to navigate to the start and end points of each transect.

Some of the survey areas (primarily Ahiak) were stratified into survey blocks that varied in coverage based on expected density of breeding females. Stratification was based on results of previous surveys and collar distribution, and on reconnaissance flights if conducted.

In-flight protocols

A systematic strip transect survey method was used. The surveys were based out of communities or camps as close to calving grounds as possible. Aircraft type varied among surveys. Depending upon aircraft type, wooden dowels or tape on the struts or tape on windows were used to delineate the outer boundary of an 800 m strip transect (400 m on either side of the aircraft) using the methodology of Norton-Griffins (1978). Transect width was checked by observers flying over a known distance. Caribou observed within the 400 m mark (and beyond the “blind” spot underneath the aircraft) were considered “on transect”, while those beyond were “off transect”. A pilot and two to three observers manned each aircraft, with one observer generally designated as the data recorder. All personnel participated in locating caribou. Aircraft were generally flown at 160 km/hr. at a height of 90–120 m above ground level, with lower aircraft height under more trying survey conditions (i.e., mottle snow background and low caribou density). A GPS was used to record flight track. No distance sampling (which corrects for the animals that were missed as a function of distance) was conducted during surveys (Buckland et al. 2004).

The location of groups of caribou was recorded using a waypoint saved into a handheld GPS. The number of caribou in each group was counted or estimated (by the 10s, 50s or 100s; Johnson et al. 2008), and the composition of the group determined. Classification of groups varied among surveys and between years. For example, for surveys of the Ahiak, Beverly, and Qamanirjuaq calving grounds, caribou were classified as cows with hard antlers, antlerless cows, calves, yearlings, and bulls based on body size and whether antlers were either light coloured and polished or in velvet (Johnson et al. 2008). For Inuvik-based surveys in 2007 (Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose-West), caribou were classified as cow, calf, bull, yearling, or unknown (Davison et al. 2007). In some surveys the yearling category was not recorded. Observations were recorded in-flight using data sheets, and tape recorders were used when caribou densities were high. On occasion pilots would deviate off the transect line to verify group counts or classification; transect flights were resumed at the point of departure off transect line. The waypoint and track files were downloaded to a laptop computer at the end of each day.

General weather information (air temperature, ceilings and horizontal visibility, wind speed and direction), percentage snow cover, and survey flight times were recorded at minimum daily, and generally more often. The criteria used to record flight times (ferry, on transect, off transect, on survey, off survey) varied among surveys, and it was difficult to know what was meant by “on survey”. In particular, it was unclear as to whether the flying time between transects was included as on survey or ferry. Observations of other wildlife species were recorded during all flights, although whether observations were collected during reconnaissance flights, systematic surveys, or during ferry flights, or were on or off transect was not always distinguished.

Summarizing observations and densities

Most surveys summarized the number of adult (non-calf) caribou (and breeding females) observed on and off transect, and often during ferry flights to and from survey. Many also provided counts of calves observed during the survey.

Mapping calving grounds

Distribution

Survey data were mapped into areas of higher and lower density of breeding females and calves seen on transect using two methods, density by 5 or 10 km by 800 m segment, and a geostatistical approach that translates locations and numbers of caribou seen using an interpolation technique called kriging.

Presentation by 5 or 10 km segment

All systematic transects were divided into 5 or 10 km segments and the average density of caribou for each segment was calculated. Five kilometre segments were used during surveys of the Tuktoyaktuk, Cape Bathurst and Bluenose-West herds (to match the 5 km transect spacing), and 10 km segments for all others. For display purposes and to aid in comparison among calving grounds, density was grouped into low, medium, and high-density cells of 0.01-0.99, 1.0-9.99, and ≥10.0 caribou per km^2, respectively. To aid visual interpretation, transect summaries were often represented by symbols that exaggerated the width of the transect to nearly fill the space to the adjacent transect.

Kriging

Kriging is a group of geostatistical techniques to interpolate the value of a random field (in this case, caribou observations) at an unobserved location from observations of its value at nearby locations. A description of the procedure is provided in Appendix 1.

During our review of the draft maps made for the various surveys it became evident that all the kriged maps may not have been built in a consistent manner. Some of the outputs suggest that the model and parameter selections used may not have been optimal, because of abrupt or jagged borders to the mapped densities and distribution. While kriging provides a visual overview of the main calving areas in relation to adjacent calving areas, incorrect mapping (in part because of the implications of differences among the semivariogram models selected; Johnson et al. 2008) may not benefit interpretation of results at finer scales. Because kriging creates maps of continuous caribou density, prediction maps do not encompass low densities separated from the main densities (Johnson et al. 2008). Prediction maps also generalize the density of transect segments, especially for transect centroids with isolated values. We suggest that the kriging methodology reported by Johnson et al. (2008) may not have been correctly applied to other surveys, resulting in output raster coverages that do not accurately reflect the observations. We did not conduct kriging for this report. In this report we present mapped outputs for each survey using symbols to represent 5 km (Inuvik herds) or 10 km segments for densities of breeding females (or total females, or total adults, as appropriate to the data). It may be more important to use a standard approach to mapping that can be followed by biologists in a consistent manner.

SPECIFIC SURVEY METHODS, RESULTS AND CONTEXT

During both 2007 and 2008, biologists conducted extensive flights to document the location of calving grounds, and perhaps more importantly, to document the presence or absence of breeding females in areas outside of the expected calving grounds (Table 1; Figures 1 and 2). Flight lines were extended in the immediate area of the calving grounds until no further groups of calving cows had been seen for 10 or 20 km (Davison et al. 2008, Johnson et al. 2008). Adjacent transect lines were extended by a minimum of the same distance. Additional lines were flown between calving grounds, primarily around the Bathurst, Ahiak, and Beverly herds, to be certain that breeding cows were not missed. In total 49,840 km and 67,462 km were flown in 2007 and 2008, respectively (A. D'Hont, personal communication, 2010).

Table 1. Summary of reported peak of calving, survey timing relative to peak of calving, classification data recorded, and references for calving ground distribution surveys conducted 2007 and 2008.

Survey	Peak of calving	Dates of main survey flights	Data recorded[1]	Reference
2007				
Tuktoyaktuk Peninsula	Unknown	25 June	All cows, calves	Davison et al. 2007
Cape Bathurst	~13 June	14–15 June	All cows, calves	Davison et al. 2007
Bluenose-West	~13 June	17, 21, 22 June	All cows, calves	Davison et al. 2007
Bluenose-East	11–14 June	14–16 June	All adults, calves	No report available
Bathurst	9–10 June	10 June	All adults, calves, with hard antlers, calves noted	No report available
Ahiak	14–15 June	14–18 June	HA cows, NA cows, calves, yearlings, bulls	Johnson et al. 2008
Beverly	~12 June	12 June	HA cows, NA cows, calves, yearlings, bulls	Johnson et al. 2007
Qamanirjuaq	13–14 June	11, 14 June	HA cows, NA cows, calves, yearlings, bulls	No report available
2008				
Tuktoyaktuk Peninsula	Unknown	25 June	HA cows, NA cows, calves, bulls	Davison et al. 2008
Cape Bathurst	~12 June	23–24 June	HA cows, NA cows, calves, bulls	Davison et al. 2008
Bluenose-West	~12 June	14–18 June	HA cows, NA cows, calves, bulls	Davison et al. 2008
Bluenose-East	~12 June	15–18 June	All adults, calves, with cow antlers/non-antlered noted.	Tracz 2008
Bathurst	10–11 June	9 June	All adults, calves, with antlers, calves noted	Adamczewski et al. 2009
Ahiak	13–14 June	13–18 June	HA cows, NA cows, calves, yearlings, bulls	Johnson et al. 2008
Beverly	~15 June	12, 18 June	HA cows, NA cows, calves, yearlings, bulls	Johnson and Williams 2008
Qamanirjuaq	Unknown	7–9 June	HA cows, NA cows, calves, yearlings, bulls	Campbell et al. 2010

[1] Adults refers to all non-calf caribou, also called 1+ caribou; HA = hard-antlered cows; NA = non-antlered cows.

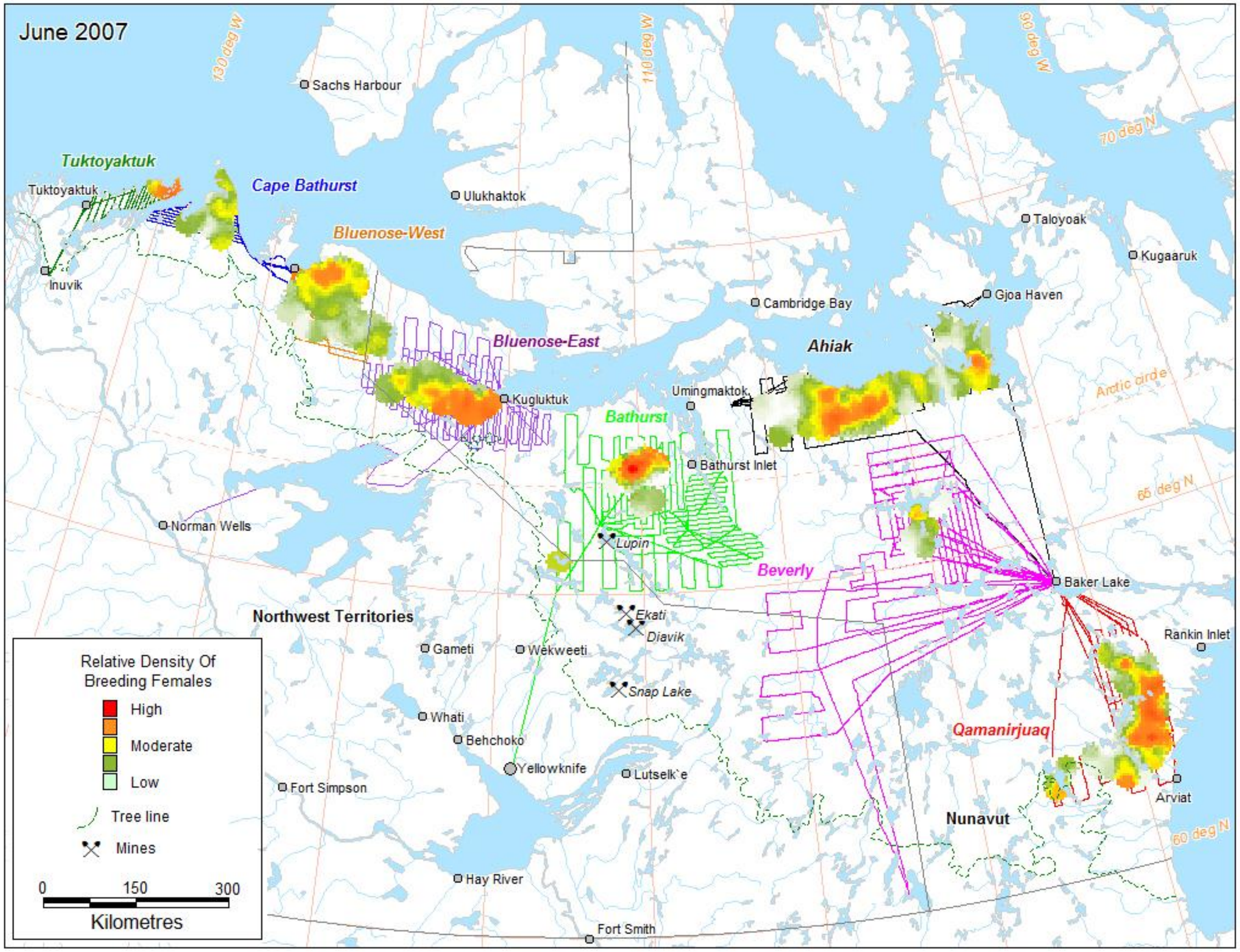

Figure 1. Relative density of breeding female caribou observed during surveys flown in June 2007 over calving grounds of eight barren-ground caribou herds calving on mainland NWT and NU. Relative density conducted using Inverse Distance Weighting (IDW) mapping interpolation using a 5x5 km pixel, exponent of 2, and a 20 km search radius (see template in this report). Flight lines associated with each survey are provided.

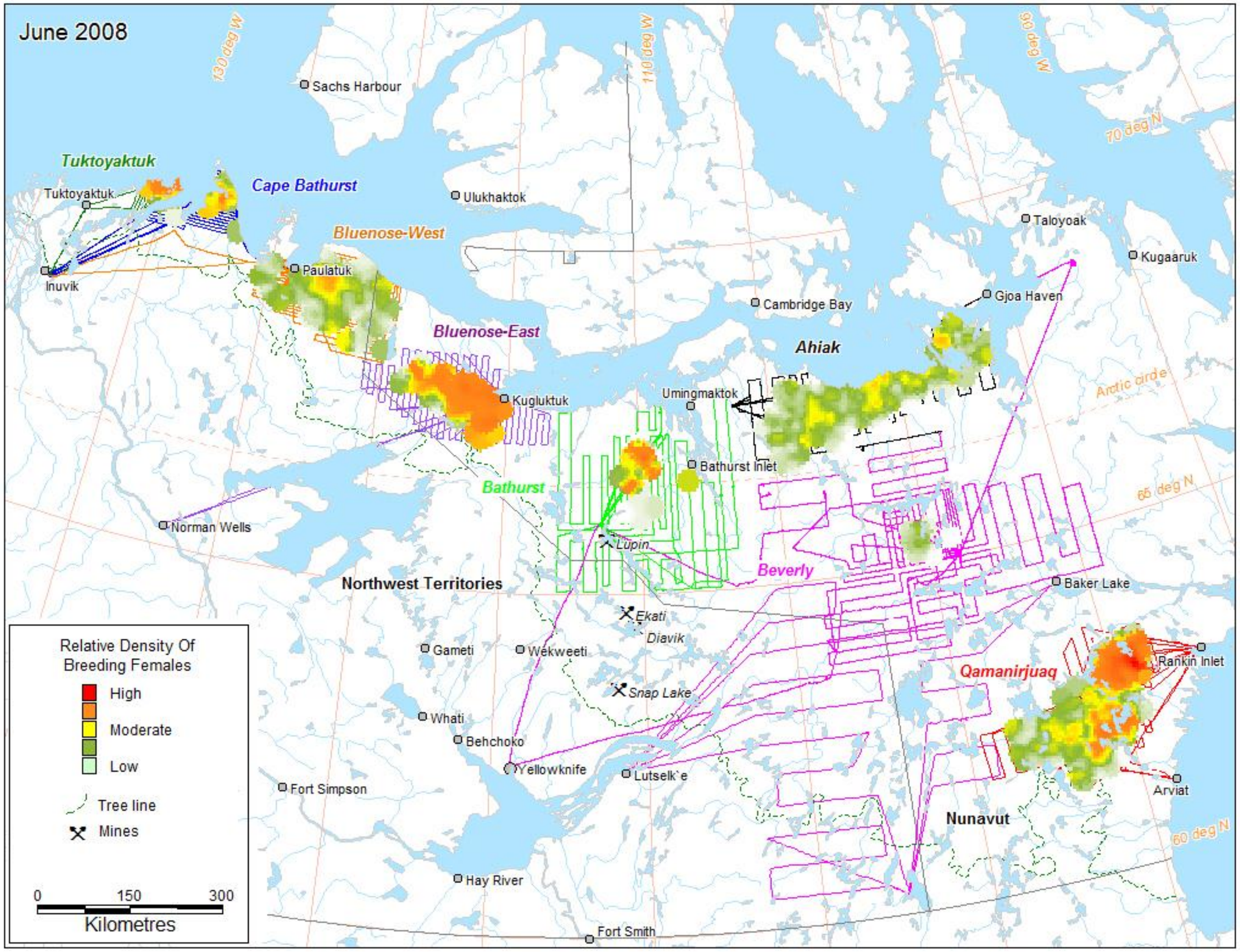

Figure 2. Relative density of breeding female caribou observed during surveys flown in June 2008 over calving grounds of eight barren-ground caribou herds calving on mainland NWT and NU. Relative density conducted using Inverse Distance Weighting (IDW) mapping interpolation using a 5x5 km pixel, exponent of 2, and a 20 km search radius (see template in this report). Flight lines associated with each survey are provided.

2007 Tuktoyaktuk Peninsula, Cape Bathurst and Bluenose-West herds

The Cape Bathurst and Bluenose-West herds were recognized as distinct herds in the late 1990s, after satellite collar location data showed that the former Bluenose herd had three distinct calving areas, now recognized as three separate herds (Cape Bathurst, Bluenose-West and Bluenose-East; Nagy et al. 2005). The objective of this survey of calving areas of the Cape Bathurst and Bluenose-West herds and on the Tuktoyaktuk Peninsula was to map the distribution and density of calving caribou (Davison et al. 2007). Weather conditions led to changes in the planned order of herds that were to be surveyed, and delays in starting and completing some areas.

On all three surveys the following classifications were obtained: adult (total non-calf), cow, calf, bull, and yearling. Thus with the exception of groups with calves, it is difficult to differentiate breeding from non-breeding females from the data, as the “cow” column would include non-breeding females (no distinction between hard-antlered and non-antlered cows). Identifying breeding females only as groups with calves would leave out parturient (hard-antlered) females prior to birth. This would have the greatest impact on the results from the Cape Bathurst survey, as this herd was surveyed earlier and likely had females that had not yet calved (T. Davison, personal communication, 2009). We mapped the density of adults where calves were present as “breeding females”, as not all groups had cows recorded when calves were present. Some pre-parturient cows may not have been mapped in this fashion and for Bluenose-West some cows had shed their antlers post-parturient as the survey was after the peak of calving. However, mapping all adults would have included a number of bulls and yearlings, and mapping of cows only would have missed groups with calves observed and only adults recorded.

Overall survey time: 57.6 hrs. were flown, 24.7 hrs. in pre-survey reconnaissance, ferry flights to and from communities, and flights between fuel caches and transects, and 32.9 hrs. on survey.

2007 Tuktoyaktuk Peninsula

Dates: 25 June 2007.

Snow cover: 0% (T. Davison, personal communication, 2013).

Aircraft: Cessna 206.

Transect spacing: 5 km, summed on 5 km segments, with 10 km transect spacing in peripheral areas – the outer edges of the Tuktoyaktuk Peninsula where numbers of observed caribou declined abruptly.

Survey time: 5.7 hrs. on survey.

Observations and discussion: A total of 1,871 adult caribou were observed on the Tuktoyaktuk Peninsula, including 572 caribou on transect. Calving was concentrated on the northeastern tip of the peninsula (Figure 3). This flight was carried out well past the presumed peak of calving.

This was the first calving survey for this area. Environment and Natural Resources, GNWT, first documented animals calving on the Peninsula in 2005 after post-calving census survey results were presented and reports from local hunters indicated that there were animals residing on the peninsula year round (Davison et al. 2007). A portion of this herd is considered to be feral reindeer escaped from a semi-domestic reindeer herd and, at the request of the Inuvialuit Game Council, is managed separate from the Cape Bathurst herd.

Incidental sightings: four grizzly bears. No wolves recorded.

2007 Cape Bathurst

Dates: 14–15 June 2007.

Snow cover: ~1% (T. Davison, personal communication, 2013).

Aircraft: Cessna 206.

Transect spacing: 5 km, summed on 5 km segments.

Survey time: 10.5 hrs. on survey.

Observations and discussion: A total of 624 adult (non-calf) caribou were seen in the Cape Bathurst area, including 260 on transect. Breeding females were distributed throughout the peninsula with no single concentration of calving (Figure 4). Peak of calving assumed to be approximately 13 June based on observations from the Bluenose-West survey.

Incidental sightings: four grizzly bears (all singles), ten moose (including two calves), and 317 muskoxen (including a minimum of 30 calves). No wolves recorded.

2007 Bluenose-West

Dates: 17, 21, and 22 June 2007, after some weather delays.

Snow cover: 1–15% (T. Davison, personal communication, 2013).

Aircraft: Cessna 206.

Transect spacing: 5 km, summed on 5 km segments, with 10 km transect spacing in peripheral areas – the outer edges of the Bluenose-West herd survey areas where numbers of observed caribou declined abruptly (Davison et al. 2007). However, the mapped data suggest that the flight lines did not extend beyond the breeding cow distribution (Figure 5).

Survey time: 16.7 hrs. on survey.

Observations and discussion: About 50% of the cows had newborn calves during a pre-survey reconnaissance flight of the Bluenose-West herd in Tuktut Nogait National Park (TNNP) on 13 June 2007, indicating that date as close to peak of calving. Thus, the calving ground distribution survey was conducted well after the peak of calving.

A total of 4,384 adult caribou were seen during the Bluenose-West survey, including 2,253 on transect. The main concentration of cows with calves was mostly east of Paulatuk and west of Bluenose Lake (Figure 5). Breeding females were observed in segments on the edge of survey coverage (e.g. eastern edge of transects east of Paulatuk), thus is it unclear whether the transects flown were extensive enough to cover all calving.

Incidental sightings: three grizzly bears (sow with two three-year olds), four wolves (all individual sightings), and 44 muskoxen (no calves noted).

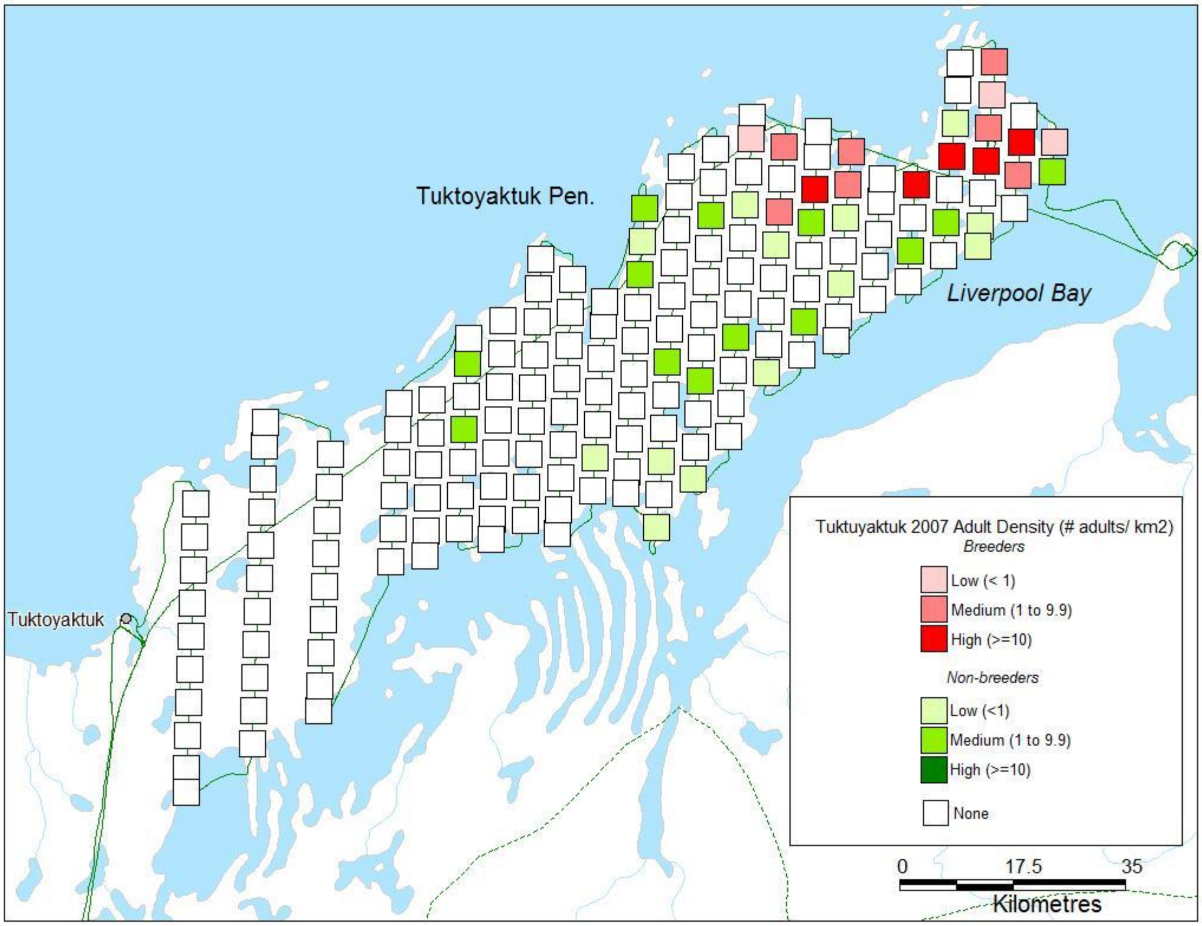

Figure 3. Distribution of breeding caribou and non-breeders observed on transect summarized by 5 km segment, Tuktoyaktuk Peninsula herd, June 2007. Here “breeders” include adults where calves were present, and “non-breeders” include adults where calves were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

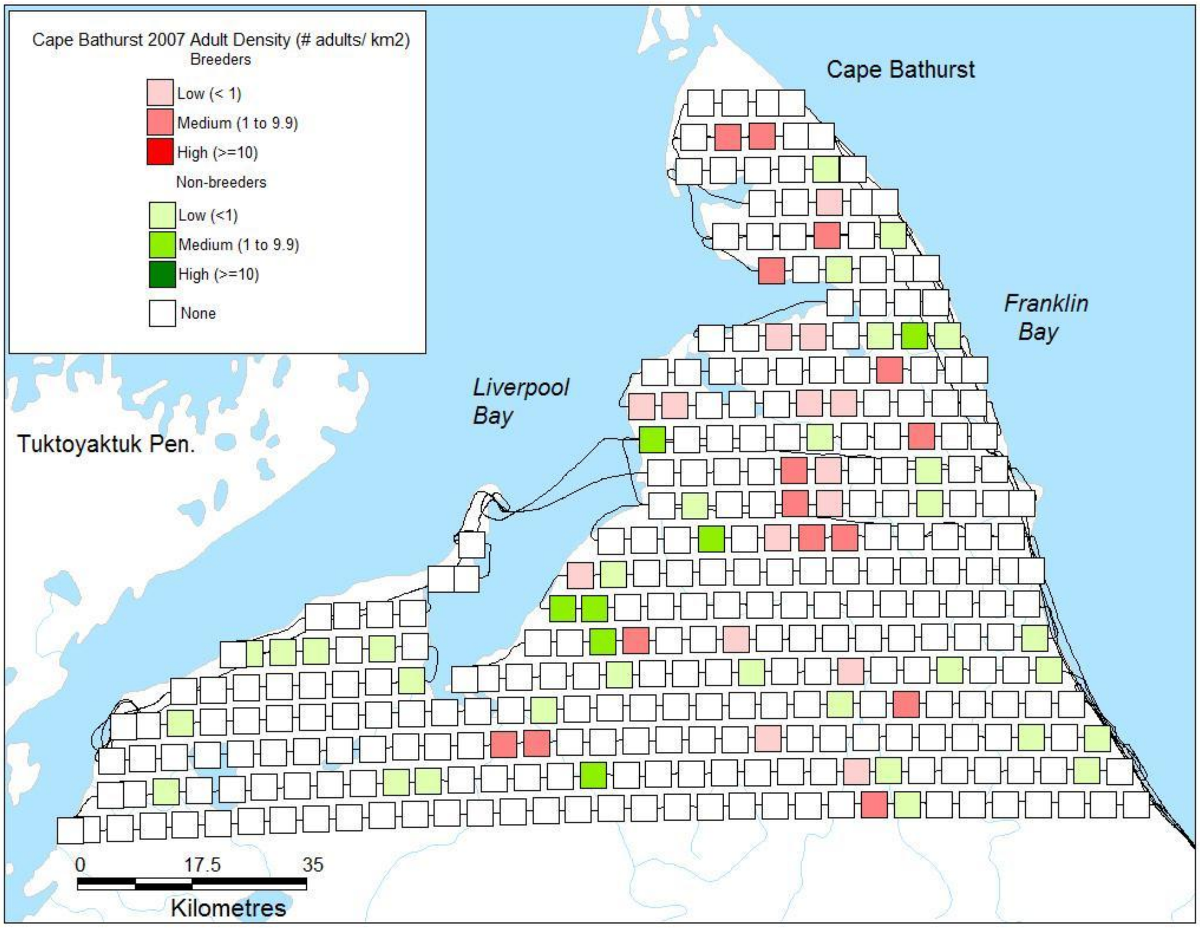

Figure 4. Distribution of breeding caribou and non-breeders observed on transect summarized by 5 km segment, Cape Bathurst herd, June 2007. Here “breeders” include adults where calves were present, and “non-breeders” include adults where calves were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

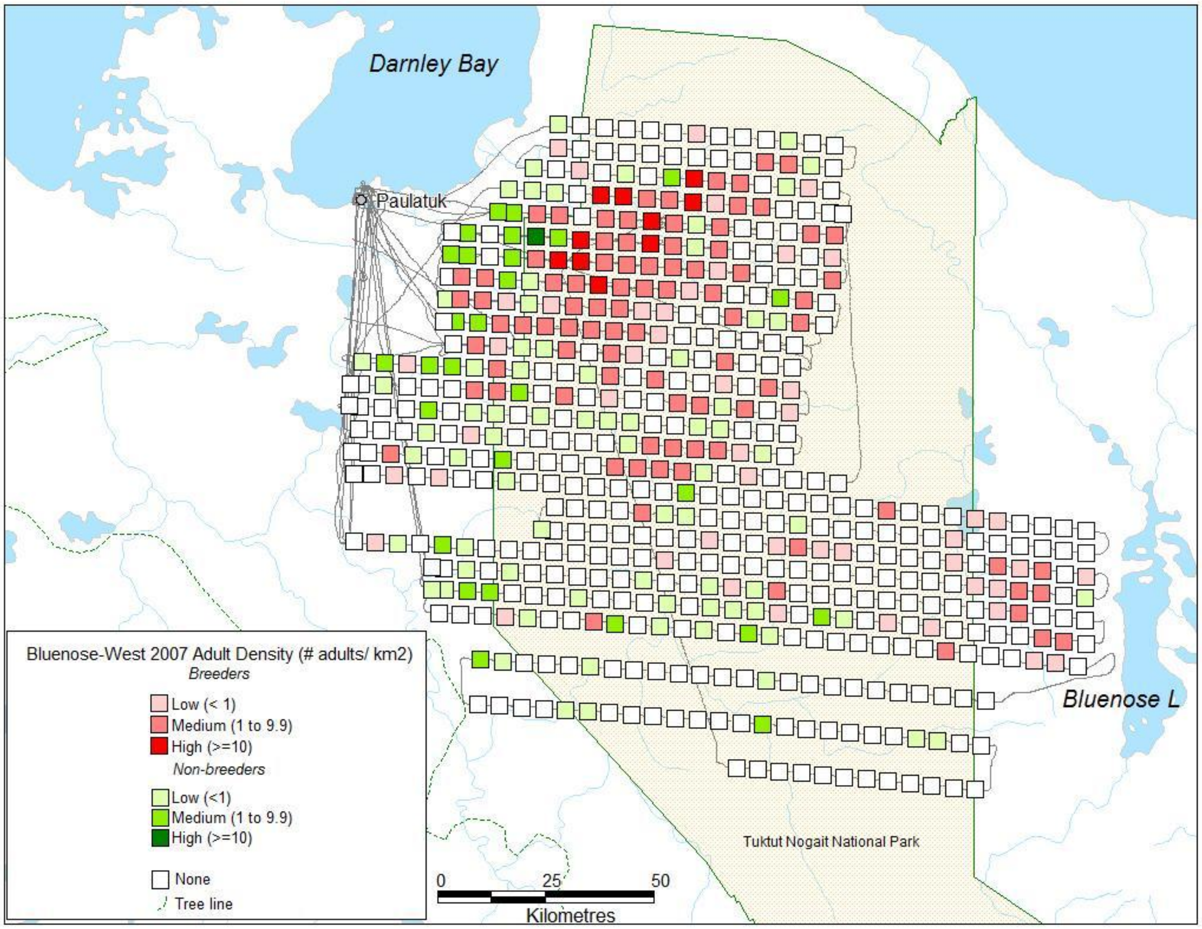

Figure 5. Distribution of breeding caribou and non-breeders observed on transect summarized by 5 km segment, Bluenose-West herd, June 2007. Here “breeders” include adults where calves were present, and “non-breeders” include adults where calves were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2007 Bluenose-East herd

We obtained background data for this survey from the 2007 summary by Adamczewski (2007). Calving ground distribution surveys of the type done in June 2007 have not been carried out for this herd since the 1980s. The survey was flown on 14, 15, 16 and 19 June. Peak of calving was estimated at 11-14 June.

Data recorded during the survey were non-calves and calves, making determination of breeding females difficult. Off transect sightings were recorded as adults/calves (e.g. 14/4 for 14 adults and four calves) in the database, making data summary difficult and time-consuming.

Here we mapped “breeding females” as all adults where calves were present, and “non-breeders” as adults from groups where no calves were present.

Dates: 12-20 June 2007, with some weather delays. A reconnaissance survey was flown over the potential calving area on 12 and 13 June.

Snow cover: Variable, but averaging perhaps 20-30%.

Aircraft: Cessna 185.

Transect spacing: A reconnaissance survey was flown over the potential calving area at 20 km spacing. The systematic survey was flown using 10 km spacing, summarized to 10 km segments, with flight lines running north-south.

Survey time: 54.8 hrs. for the whole survey.

Observations and discussion: A total of 4,381 adult (1+ year old) caribou were seen (Adamczewski 2007), including 3,366 on transect. Calving was concentrated west of Kugluktuk along the Rae-Richardson valleys, with the bulk of non-breeders southwest through southeast of Kugluktuk (Figure 6). We were unable to estimate the number or densities of breeding females on the calving ground because these data were not recorded.

Incidental sightings: Partial reporting from data sheets suggests ten muskoxen and one grizzly bear, but it is apparent these data are incomplete.

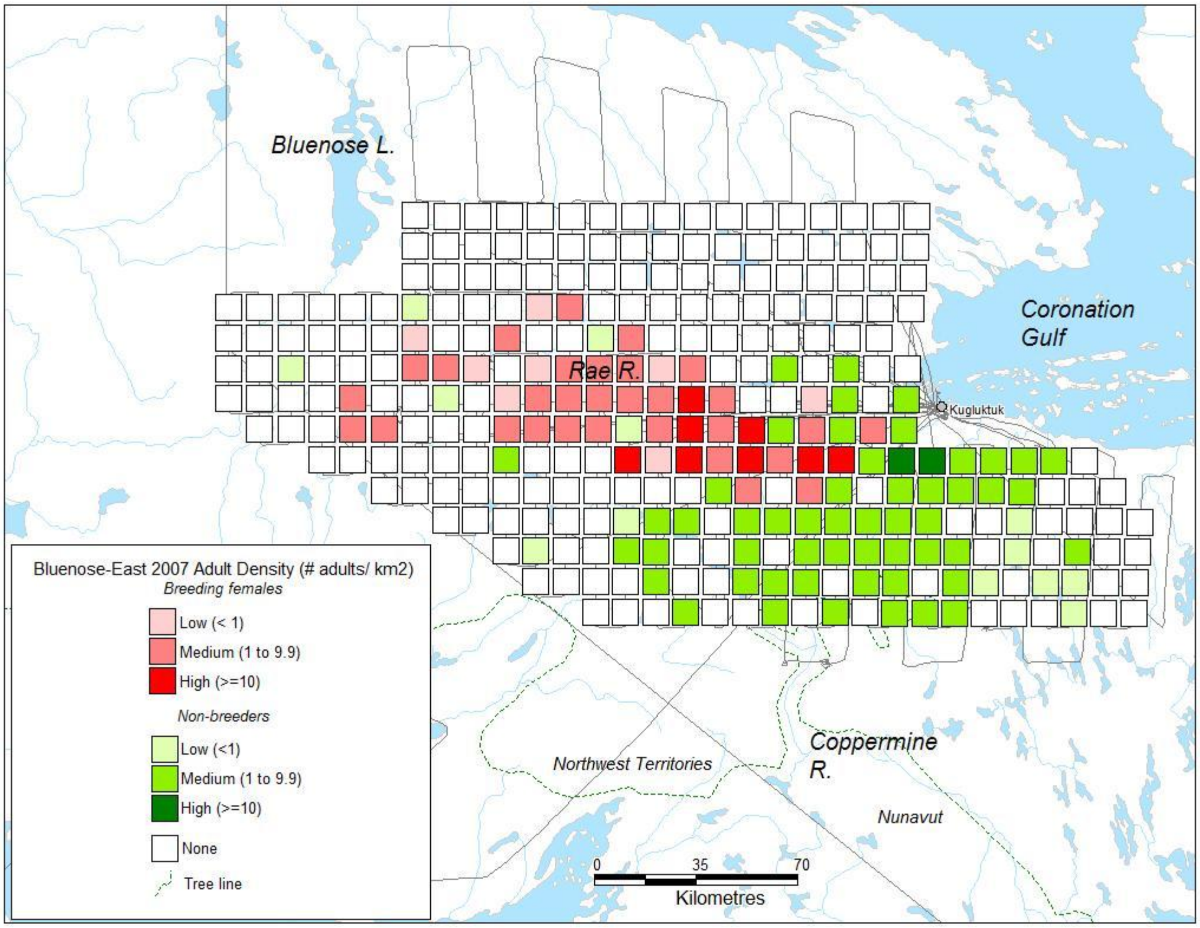

Figure 6. Distribution of breeding caribou and non-breeders observed on transect summarized by 10 km segment, Bluenose-East herd, June 2007. Here "breeding females" include adults where calves were present, and "non-breeders" include adults where calves were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2007 Bathurst herd

Calving ground information for the Bathurst herd from biologists' surveys and studies begins in 1965, when the herd calved to the east of Bathurst Inlet (Sutherland and Gunn 1996, Gunn et al. 2005, 2008), but oral history of Inuit people indicates that in the 1950s caribou calved on the western side of Bathurst Inlet. Beginning in the early 1990s, the herd has calved west of Bathurst Inlet (Gunn et al. 2005, 2008).

No report on this survey was written, but some data were presented in Adamczewski (2007), and clarified with B. Croft (personal communication, 2009). The objectives of this systematic aerial reconnaissance survey were to determine the relative composition and density of caribou and delineate the extent of the annual calving ground.

Recorded data were total number of adults (non-calves) with breeding females noted by the presence of calves or antlers. Non-breeders were unclassified groups with no visible calves and no hard antlers on cows.

Dates: 10-13 June 2007, with the calving ground covered on 10 June.

Snow cover: 75-90%.

Aircraft: Cessna 337.

Transect spacing: 10 km, with 20 km in suspected low-density blocks surrounding the main portion of the calving ground. Also used 8 km transect spacing (east-west oriented lines) flown for Dundee Precious Metals (George and Goose Lakes) and Sabina Silver, flown 11-12 June (Hackett Lake; K. Poole, unpublished data).

Survey time: 31.2 hrs. were flown (including ferry time from Hay River), 21.3 hrs. on survey, and 9.9 hrs. off survey and ferry. An additional 14.5 hrs. on survey were recorded during caribou survey flights south of Bathurst Inlet for Dundee Precious Metals and Sabina Silver.

Observations and discussion: A total of 2,370 caribou were seen on transect during the survey, with approximately 200 caribou observed off transect. The main concentration of calving caribou was along and south of the Hood River (Figure 7), and was consistent with the calving grounds documented from 1996 to 2006 (Gunn et al. 2008). A small concentration (<30 cows) of breeding caribou was observed south of the Burnside River. Extrapolating from density within segments to the entire calving ground, Adamczewski et al. (2009) estimated 23,175 breeding females within the calving ground. This estimate should track, but be consistently lower (because of no sightability correction) than estimates derived from aerial photocensus surveys (Adamczewski et al. 2009).

The estimated peak of calving was starting around 9 June, based on observations that roughly 40% of the cows had calves during the 10 June flight, and the assumption that observers normally underestimate the number of calves observed from the air (B. Croft, personal communication, 2009).

Incidental sightings: 28 muskoxen, seven grizzly bears, one wolf, and one wolverine.

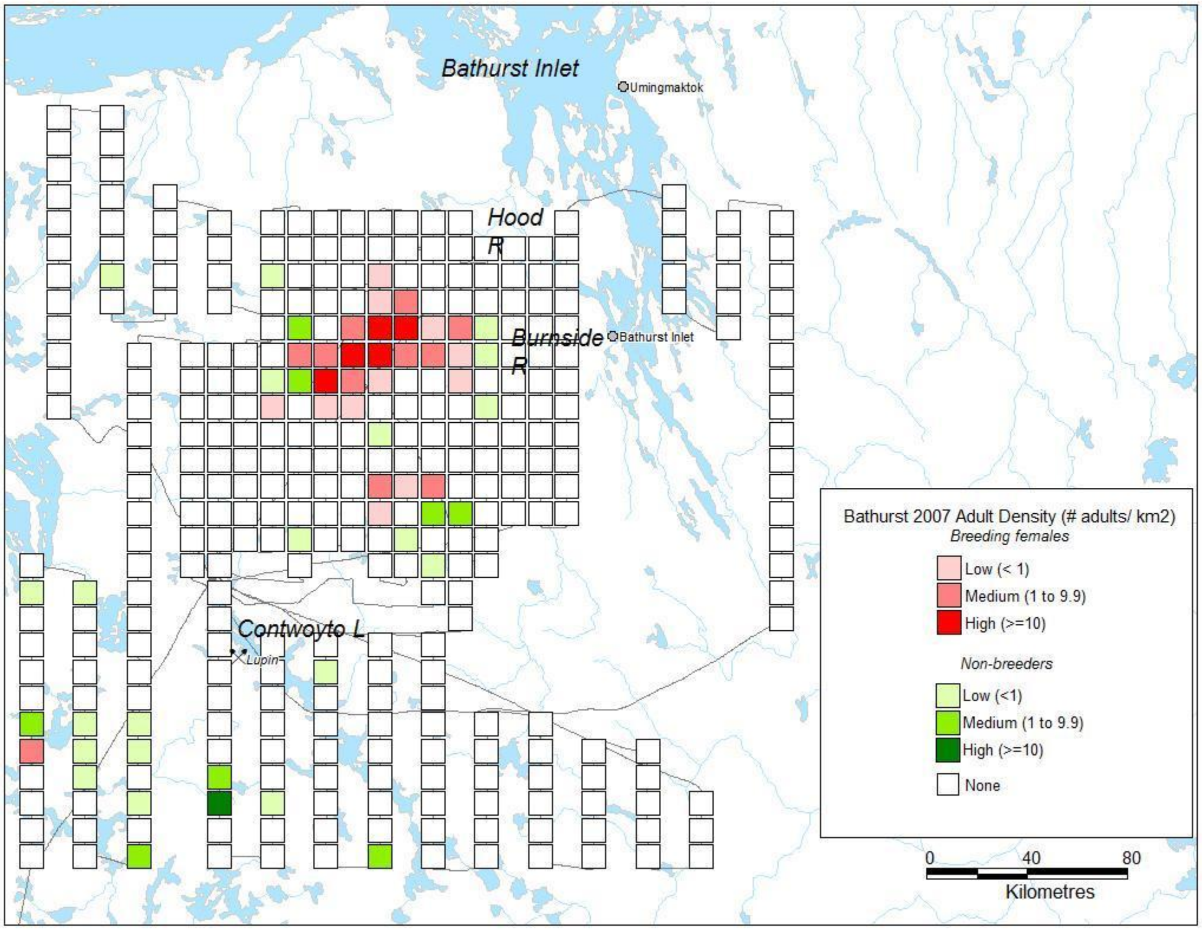

Figure 7. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Bathurst herd, June 2007. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2007 Ahiak herd[2]

A systematic survey of the entire Ahiak calving distribution was completed in 1986 and a partial aerial survey in 1996 (Gunn et al. 2000) but a systematic survey was not repeated until 2006 (Johnson et al. 2008). With the recent focus on the declines in the Bathurst and Beverly herds (Adamczewski et al. 2009), delineation of the calving grounds, assessments of trends in the population, and ultimately an estimate of herd size, are required. The Ahiak herd has been generally less monitored than other NWT herds, in large part due to its remote range and in part because it was thought to be rarely accessible to NWT hunters (Johnson et al. 2008).

Johnson et al. (2008) have detailed the 2006, 2007, and 2008 calving ground distribution surveys of the Ahiak herd in a draft report. Furthermore, an estimate of trends in the Ahiak herd based on calving ground distribution surveys from 2006-2009 has recently been conducted (Boulanger 2010). We will not duplicate the detailed analyses conducted by these authors, and refer readers to those reports for additional details.

The objectives for the Ahiak calving ground surveys were to 1) systematically delineate the spatial distribution of breeding females close to or near the peak of calving; 2) determine the relative density of breeding cows on the annual calving ground; and 3) predict (*sic*) and map annual calving areas of the Ahiak herd (Johnson et al. 2008). Stratification into three survey blocks was based on results from previous surveys during the calving period (Gunn et al. 2000, Gunn and D'Hont 2003, Johnson et al. 2008) and information on the past distribution of collared Ahiak cows during the calving period (GNWT unpublished data).

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[2] Naming of herds within the calving area known as the Ahiak in 2007 have changed subsequent to 2011. Campbell et al. (2012: Figure 2) used the name Beverly for the migratory herd calving west of Adelaide Peninsula that also used the traditional inland calving grounds near Beverly Lake, and used Ahiak for the tundra-wintering herd calving on the Adelaide Peninsula and east to the base of the Boothia Peninsula.

During the survey caribou were classified as cows with hard antlers, calves, antlerless cows, yearlings, and bulls. Groups of breeding females were considered all groups of adults where hard-antlered females or calves were observed. Observations were summed by 10 km segment during the flight, and not by waypoint and group.

Dates: 14-18 June 2007.

Snow cover: <20% near the coast to 70% farthest inland.

Aircraft: Helio Courier. In addition to the pilot, there were two rear-seat observers; no navigator was present during this survey.

Transect spacing: 10 km in the central block (approximately the area from the Ellice River east to the Simpson River), with 20 km in the generally low-density western block (east side of Bathurst Inlet to just west of the Ellice River) and eastern block (east of Simpson River to Chantrey Inlet).

Survey time: 37.3 hrs. were flown, 21.0 hrs. on survey, and 16.3 hrs. off survey.

Observations and discussion: Weather conditions during the survey were consistently poor with low ceilings, snowstorms, high winds and coastal fog. A total of 5,971 1+ year old caribou were observed on transect (4,431 cows [3,377 cows with hard antlers], 382 bulls, and 1,157 yearlings, and 2,508 calves. Three-quarters of hard antlered cows had calves. The calf:cow ratio for caribou observed was 57:100, which suggests that the 14-18 June survey was conducted during the peak of calving. The distribution of breeding females extended approximately 375 km between the Ellice River to Chantrey Inlet and southward from the Queen Maud Gulf coast to approximately 67°N, with the highest concentration of breeding cows south and east of the Perry River and on the east side of the Adelaide Peninsula (Figure 8). Nineteen satellite or GPS collared cows were present during the survey (Johnson et al. 2008). Twelve of the collared cows were within the medium and high density areas and four were within areas of low cow density. Two collared cows were location outside of the breeding cow density and most likely represent non-breeding cows, as they both exhibited late movement towards the Ahiak calving area.

The Ahiak calving distribution in 2007 was similar to the calving grounds delineated in 1986 and 1996 (Gunn et al. 2000, Gunn and D'Hont 2003), but was more dispersed and at lower density than in June 2006 (Johnson et al. 2008). Satellite telemetry data from cows in this herd has shown fidelity to a coastal calving range. While the calving distribution in June 2007 was very similar to the June 2006 survey (Johnson et al. 2008), trend analysis suggests a 10-15% decline in the number of caribou observed on transect (Boulanger 2010).

Incidental sightings: 106 muskoxen with ten calves and five wolves on transect, most of which were seen on the Adelaide Peninsula. No reports of incidental observations off transect.

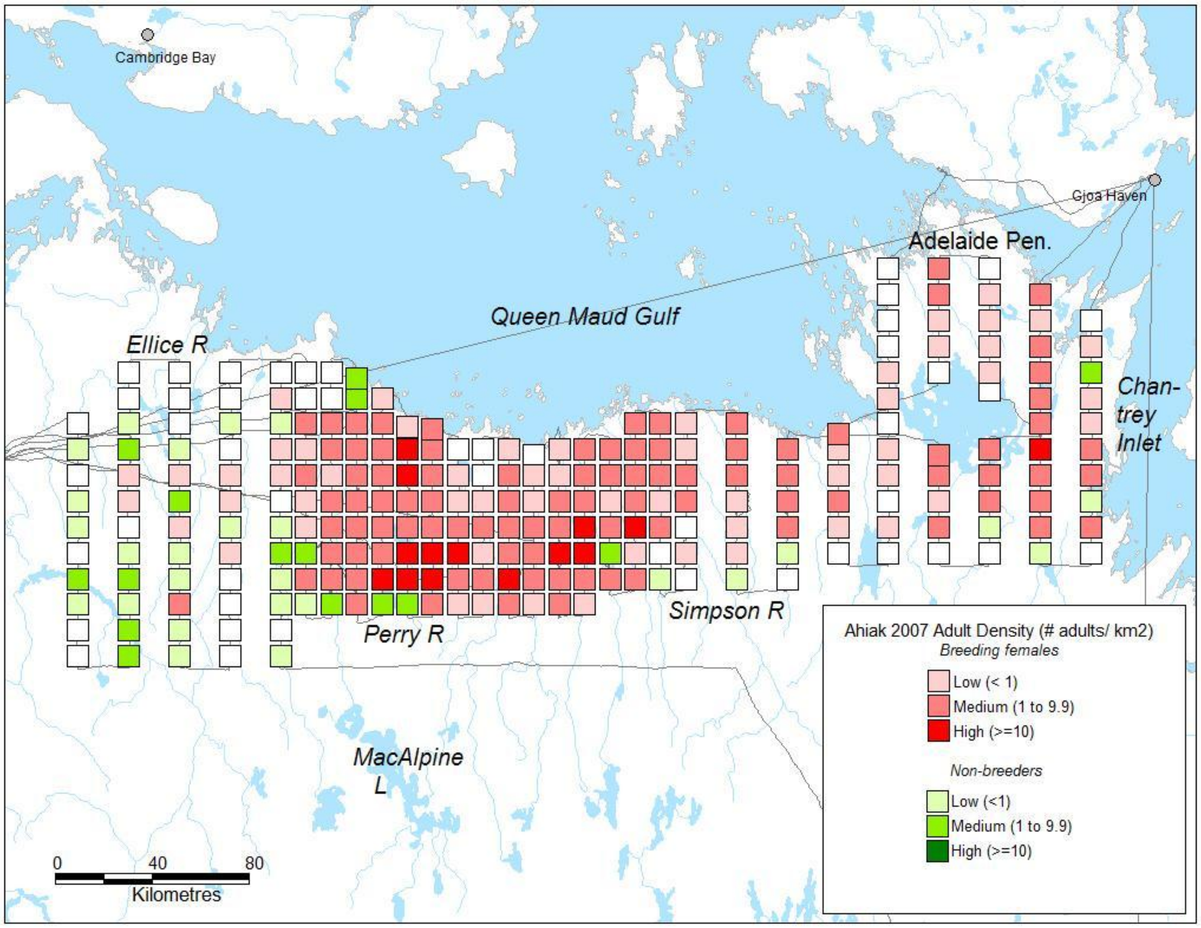

Figure 8. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Ahiak herd, June 2007. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2007 Beverly herd

The calving grounds of the Beverly herd were not documented since 1994 except for 2002 until 2007 (Johnson et al. 2007, Johnson and Mulders 2009). The last population estimate was conducted in 1994, an aerial photographic census which estimated 120,000±43,100 SE (standard error) breeding females, and 276,000±106,600 total herd size (Williams 1995). A calving ground distribution survey in 2002 found a reduced calving ground area and lower density of animals compared with previous surveys (Johnson and Mulders 2009).

The June 2007 survey was intended to be an aerial photographic census with the following objectives: 1) estimate the numbers of breeding females on the 2007 calving ground; 2) measure the trend in the number of breeding females on the Beverly calving ground between 1982 and 2007; and 3) measure the spatial extent of the 2007 annual calving ground relative to the previous years and the Caribou Protection Area (Johnson et al. 2007). However, because of poor weather conditions and the relatively few breeding cows observed on the Beverly calving ground during 2007, only the calving ground distribution survey was completed.

Two systematic reconnaissance surveys were flown. The first (4-5 June) was to roughly delineate the spatial distribution of breeding cows on the calving ground; provide anecdotal information on the movement behaviours of breeding females and timing of calving; to identify spatial separation of breeding cows on the Ahiak and Beverly calving grounds; and to ensure that breeding cow distribution was not missed. The second (12 June) was to delineate the spatial distribution of breeding cows on the calving ground near the peak of calving and to reassess the spatial separation of breeding cows on the Ahiak and Beverly calving grounds (Johnson et al. 2007). The 12 June survey was considered the main calving ground distribution survey (J. Williams, personal communication, 2009).

Caribou were classified as cows with hard antlers, calves, cows with no antlers, yearlings, bulls or unknown based on body size and whether antlers were either light coloured and polished (hard) or in velvet (Johnson et al. 2007). Groups of breeding females were considered all groups of adults where hard-antlered females or calves were observed.

Dates: 4-12 June 2007 (4-5 June within the traditional Beverly calving grounds; 7, 8, 10, and 12 June covering areas beyond the traditional area and including the pre-calving migration route; 12 June for the systematic survey of the calving grounds).

Snow cover: Snow cover prior to the 12 June survey ranged from 5-100% over the broader survey area (mostly >50%), and during the 12 June survey of the calving grounds ranged from 40-80%.

Aircraft: Helio Courier and Britton-Norman Islander.

Transect spacing: 10 km, with 10-20 km spacing during the first systematic reconnaissance survey.

Survey time: 95.4 hrs. flown, including 6.5 hrs. on survey, 43.0 hrs. on systematic and unsystematic reconnaissance surveys, and 45.9 hrs. on ferry.

Observations and discussion: Flights within the traditional Beverly calving grounds and surrounding areas conducted 4-12 June recorded just over 300 cows with hard antlers, ten calves, and less than 25 non-antlered cows (Johnson et al. 2007). Most cows were in the northern portion of the traditional calving grounds within 70 km of the boundary. Only six calves were observed on 4 June (<3% of antlered cows). Extensive flights that occurred east, south and southwest of the main calving areas (Figures 1, 9) detected almost no breeding cows.

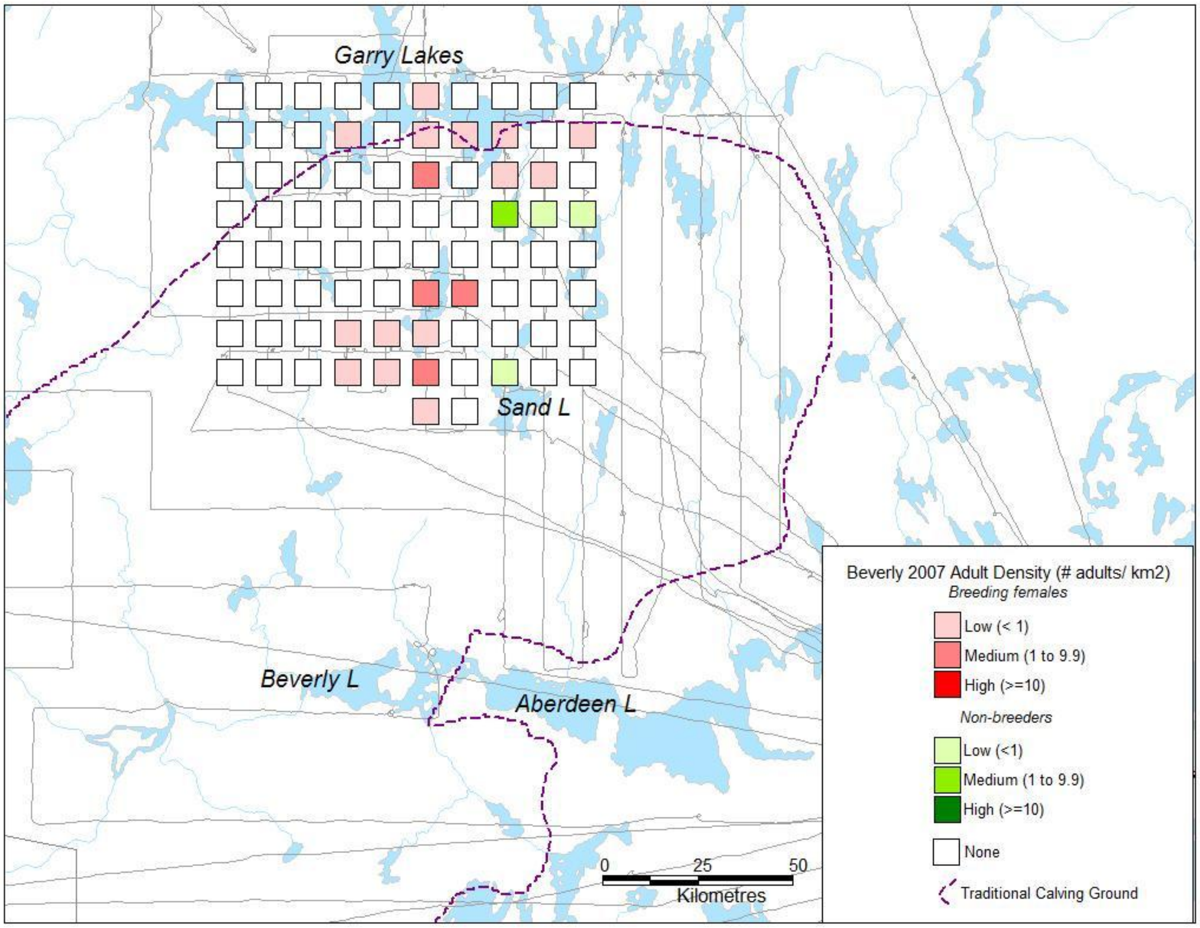

Figure 9. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Beverly herd, June 2007. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders. Only observations during the 12 June survey of the calving grounds are presented.

A total of 175 adult (non-calf) caribou were observed on the 12 July survey; 102 hard antlered cows, 12 non-antlered cows, and 61 non-breeding caribou (25 bulls and 36 yearlings), in addition to 33 calves (32% of hard-antlered cows). The eastern boundary of breeding females was approximately 15 km west of Sand Lake and was bounded to the west by the Upper Gary River, to the south by the southern latitude of Sand Lake and to the north by Gary Lakes (Figure 9). The area north of Gary Lakes was also systematically surveyed on 12 June (Figure 1), where only three breeding caribou were observed, demonstrating spatial separation between the Ahiak and Beverly herd calving grounds. The Beverly calving ground in 2007 occupied only a small portion of the traditional calving grounds of this herd, near its north end (Figure 9). Significant effort was used during reconnaissance flights beyond the calving ground to ensure that no Beverly calving areas were missed (Figure 1).

The numbers of calving caribou on the traditional Beverly calving grounds were much lower than had been found in the past, despite consistent survey methods. Surveys conducted in 1994, 2002, and 2007 observed 5,737, 2,629 and 175 adult caribou on transect, respectively (Gunn and Sutherland 1997, D. Johnson unpublished data, Johnson et al. 2007). Based on observations of cows with newborn calves, peak of calving was likely around 12 June.

Incidental sightings: During 4-12 June a total of 662 muskox and 25 calves in 62 groups (mean group size = 10.7±11.6 SD), two grizzly bears and one cub in two groups, five wolves in four groups, and one wolverine were observed both on and off transect over a total of 68.8 hrs. flown.

2007 Qamanirjuaq herd

The Qamanirjuaq caribou herd’s most recent calving ground photocensus was in 1994 until a survey was undertaken in 2008 (Campbell et al. 2010). In addition, the Qamanirjuaq calving ground has also not been delineated by systematic aerial reconnaissance surveys since 1994. In preparation for a full calving ground census scheduled for 2008, a calving distribution survey was conducted in 2007.

A report on the 2007 survey was not written. The same team that flew the 2007 Beverly and Ahiak surveys (Johnson et al. 2007, 2008) conducted the Qamanirjuaq survey, using similar methodologies. The objectives were likely to 1) systematically delineate the spatial distribution of breeding females close to or near the peak of calving; and 2) determine the relative density of breeding cows on the annual calving ground.

Caribou were classified as cows with hard antlers, calves, cows with no antlers, yearlings, bulls or unknown. Groups of breeding females were considered all groups of adults where hard-antlered females or calves were observed.

Dates: 11 and 14 June 2007.

Snow cover: Not available.

Aircraft: Helio Courier and Britten-Norman Islander.

Transect spacing: 10 km, with 20 km in suspected low-density blocks in the south of the calving ground.

Survey time: 26.1 hrs. were flown (includes ferry time).

Observations and discussion: A total of 6,082 1+ year old caribou, including 3,861 cows, were observed on transect during the Qamanirjuaq survey. The calf:cow ratio for caribou observed was 48:100, which suggests that peak of calving occurred around 13-14 June. The main distribution of breeding females occurred in the southern portion and to the south of the traditional Qamanirjuaq calving grounds defined from 1957-1994 survey data (Figure 10). A small pocket of breeding females (about 30 cows with hard antlers) was also observed around South Henik Lake. Information from radio collared cows indicates that from 2000 to 2007 there has been a southward trend in calving distribution (Gunn et al. 2007). A southward shift in calving distribution during 2007 may be related to early river break-up, which could have impeded the northward movement of cows during pre-calving migration (M. Campbell, personal communication, 2007 to D. Johnson).

Incidental sightings: Two lone wolves were observed on the southern portion of the calving grounds. A total of 142 muskoxen were observed in 12 herds, including 14 calves, primarily north of the calving grounds and during ferry flights south of Baker Lake.

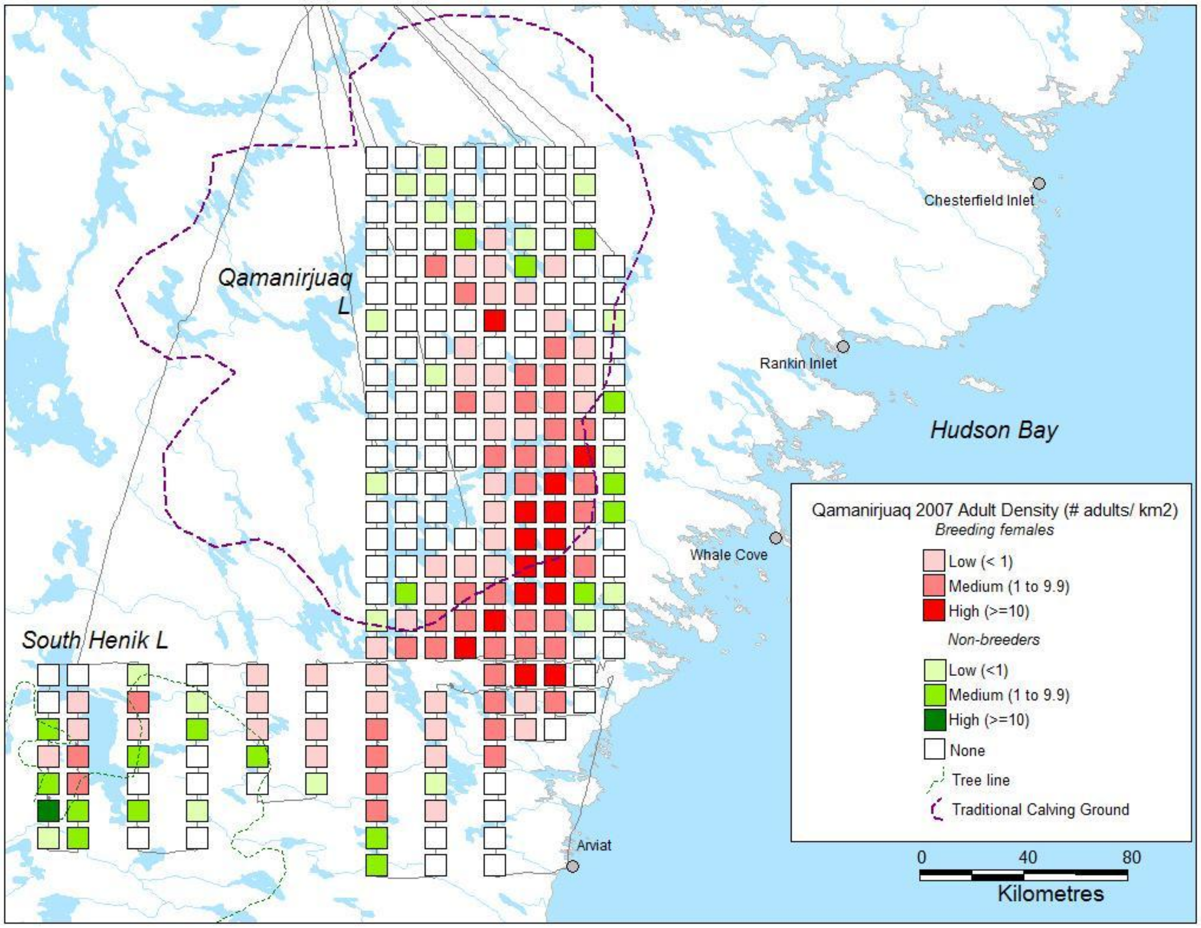

Figure 10. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Qamanirjuaq herd, June 2007. Here “breeding females” include adults where calves or females with hard antlers were present, and “non-breeders” include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Tuktoyaktuk Peninsula, Cape Bathurst and Bluenose-West herds

Similar to 2007, the objective of these surveys of the Cape Bathurst and Bluenose-West herds and on the Tuktoyaktuk Peninsula was to map the distribution and density of calving caribou (Davison et al. 2008).

On all three surveys the following classifications were obtained: adult (total non-calf), antlered cow, non-antlered cow, calf, and bull, with the greatest detail in classification was provided for caribou on transect. Groups of breeding females therefore included groups with calves or cows with antlers.

A pre-survey reconnaissance flight of the Bluenose-West herd in Tuktut Nogait National Park (TNNP) on 12 June 2008 indicated that just less than 50% of the cows had newborn calves, suggesting that this date was approximately peak of calving. Survey flight lines were adjusted slightly based on locations of GPS and satellite collared caribou (Davison et al. 2008).

Overall survey time: 75.7 hrs. were flown, 12.6 hrs. of these in pre-survey reconnaissance.

2008 Tuktoyaktuk Peninsula

Dates: 25 June 2008.

Snow cover: 0% (T. Davison, personal communication, 2013).

Aircraft: Cessna 207.

Transect spacing: 5 km, summed on 5 km segments, with 10 km transect spacing on western edges of the Tuktoyaktuk Peninsula herd survey areas where numbers of observed caribou declined. Transect lines were flown 20 km past the last breeding group and two lines were flown past the last line where a breeding group was found on transect.

Survey time: 6.1 hrs. (including ferry time).

Observations and discussion: A total of 1,402 caribou (non-calves) were observed during the survey, including 505 on transect. Breeding caribou were slightly less concentrated on the tip of the peninsula during 2008 (Figure 11) compared with 2007 (Figure 3). Similar to Cape Bathurst, the groups on Tuktoyaktuk Peninsula were larger and more aggregated in 2008 than 2007, possibly due to the warmer temperatures (Davison et al. 2007).

The percent of caribou seen on transect that were calves were 30% on the Bluenose-West range, 16% on Cape Bathurst Range and 25% on Tuktoyaktuk Peninsula. The low numbers of calves observed on the Cape Bathurst Range and Tuktoyaktuk Peninsula could have been due to observer bias when counting large groups. Calves could have been missed in some of the large, aggregated groups.

Incidental sightings: None observed.

2008 Cape Bathurst

Dates: 23-25 June 2008.

Snow cover: 0-2% (T. Davison, personal communication, 2013).

Aircraft: Cessna 207.

Transect spacing: 5 km, summed on 5 km segments. Transect lines were flown 20 km past the last breeding group and two lines were flown past the last line where a breeding group was found on transect.

Survey time: 16.3 hrs. (including ferry time).

Observations and discussion: A total of 944 caribou (non-calves) were observed during the survey, including 200 on transect.

The groups on Cape Bathurst were larger in 2008 than 2007 (Figures 12, 4; Davison et al. 2007), which may have been due to the later timing of the survey and corresponding warmer temperatures, which caused less than ideal survey conditions, as the caribou were beginning to form post-calving aggregations.

Incidental sightings: ten grizzly bears (including two “young”), one moose, and 115 muskoxen (including five calves) observed.

2008 Bluenose-West

Dates: 14-18 and 21 June 2008, after weather delays.

Snow cover: 10-20% (T. Davison, personal communication, 2013).

Aircraft: Cessna 206 and Cessna 207.

Transect spacing: 5 km, summed on 5 km segments, with 10 km transect spacing on southern edges of the Bluenose-West herd survey areas where numbers of observed caribou declined. Transect lines were flown 20 km past the last breeding group and two lines were flown past the last line where a breeding group was found on transect.

Survey time: 40.7 hrs. (including ferry time).

Observations and discussion: A total of 4,527 caribou (non-calves) were observed during the survey, including 1,693 on transect. Caribou were relatively dispersed, but with a concentration east and southeast of Paulatuk (Figure 13). Compared with 2007 (Figure 5), fewer breeding females were concentrated west of Bluenose Lake in 2008 (Figure 13).

Incidental sightings: 18 grizzly bears (including six “young”), one wolf, and three muskoxen (including two calves) observed.

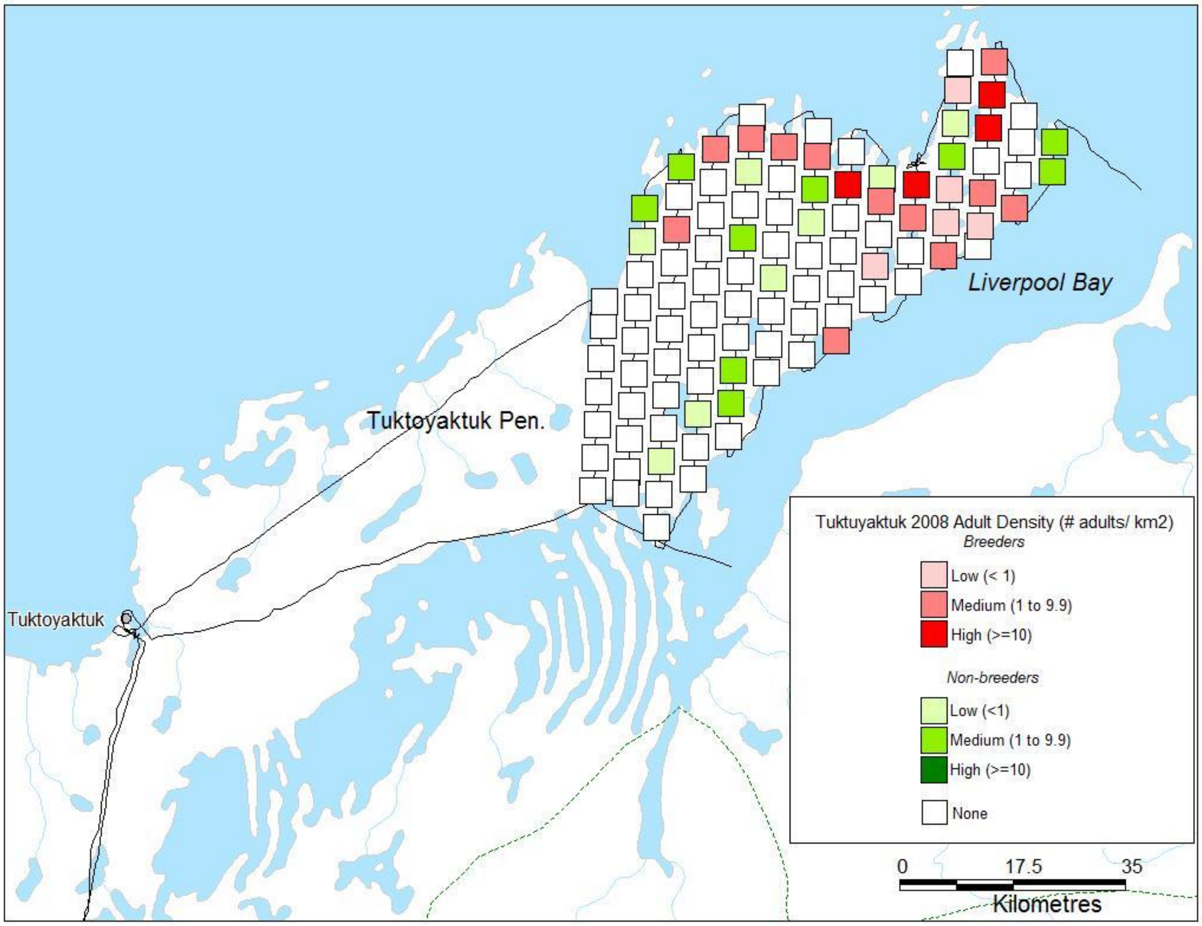

Figure 11. Distribution of breeding females and non-breeders observed on transect summarized by 5 km segment, Tuktoyaktuk Peninsula herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

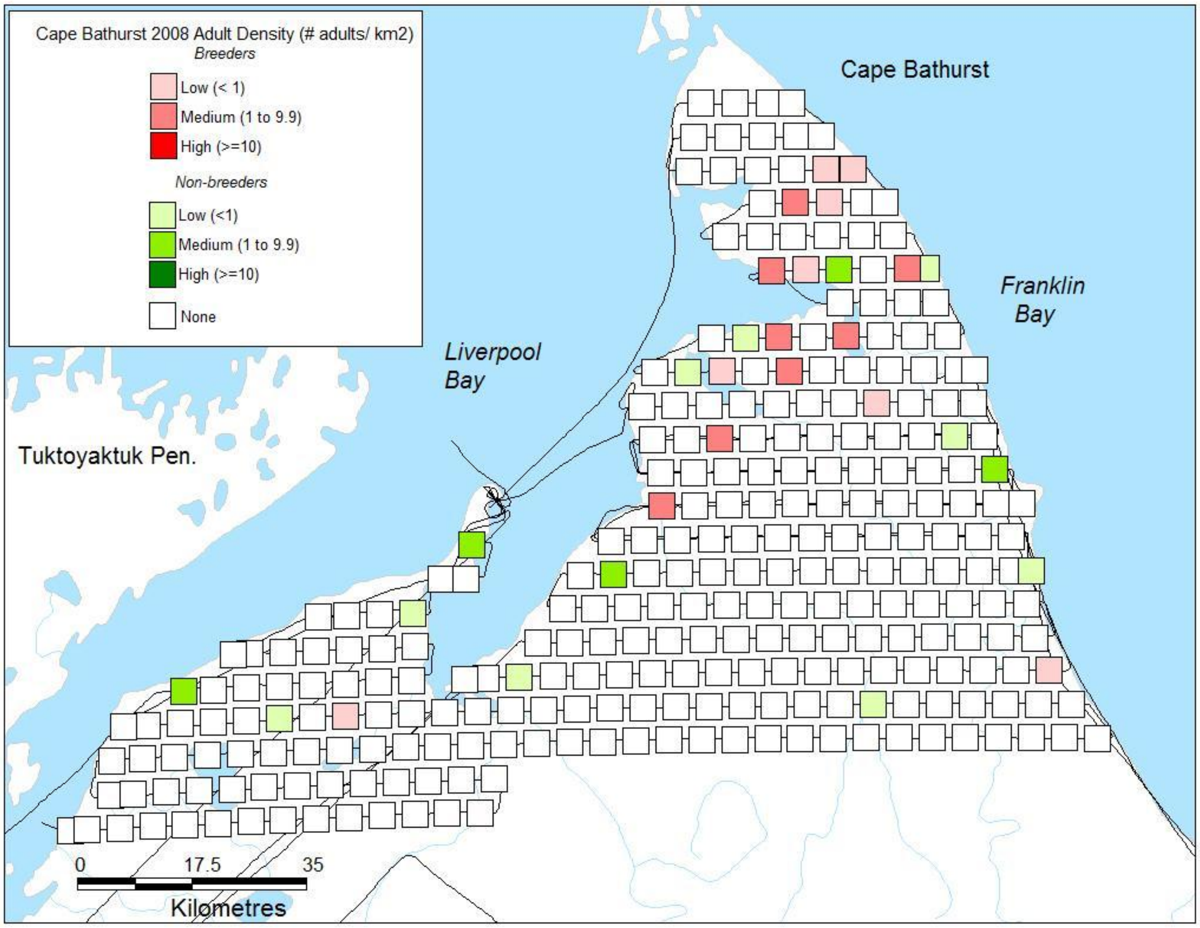

Figure 12. Distribution of breeding females and non-breeders observed on transect summarized by 5 km segment, Cape Bathurst herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

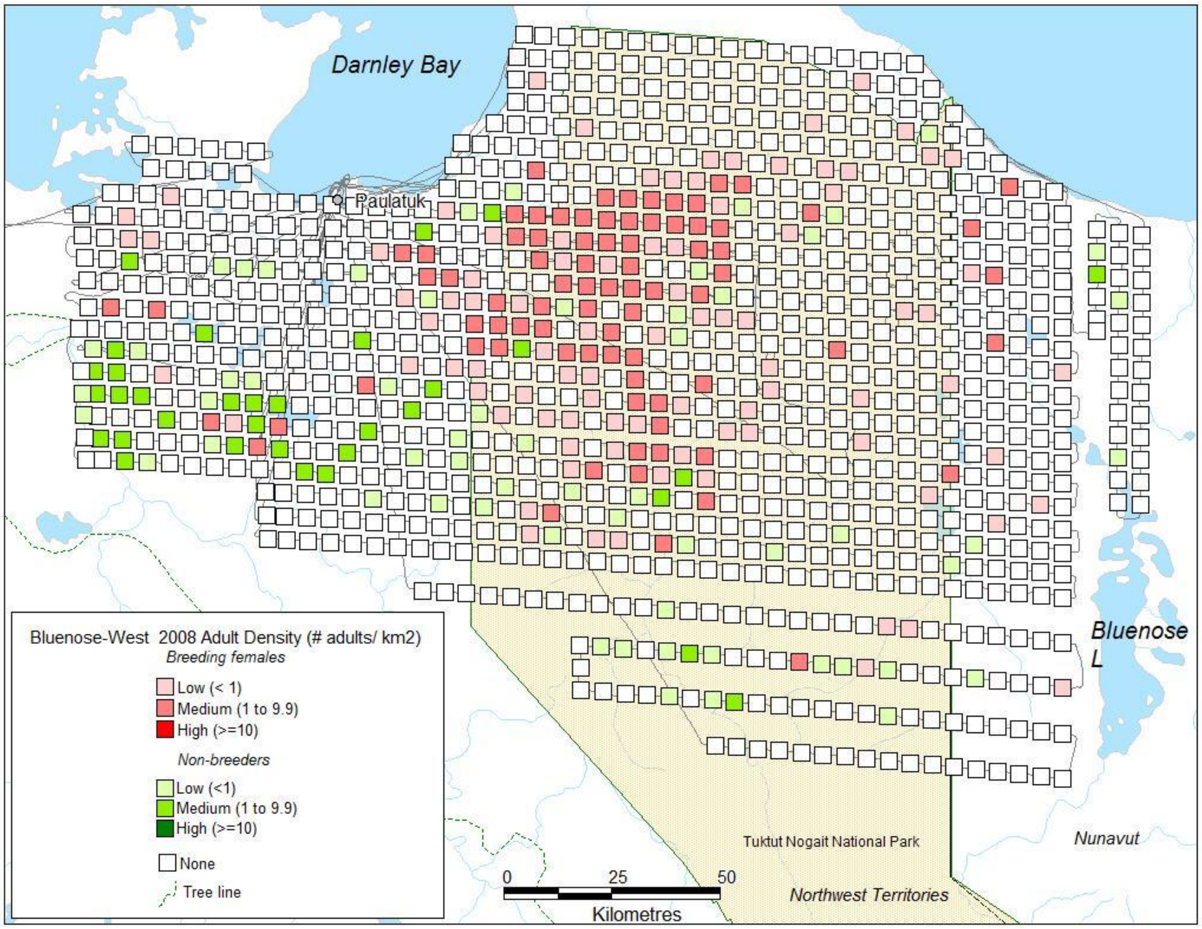

Figure 13. Distribution of breeding females and non-breeders observed on transect summarized by 5 km segment, Bluenose-West herd, June 2008. Here “breeding females” include adults where calves or females with hard antlers were present, and “non-breeders” include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Bluenose-East herd

Background to this survey was provided in Tracz (2008). The objective of the survey was to delineate the calving area. Prior to the survey, the movements and distribution of satellite and GPS radio collared female caribou were monitored as they approached their historic calving grounds. During the 12 June reconnaissance flight there were “just under 50 calves/100 cows” (Tracz 2008). Tracz (2008) noted that following the reconnaissance flight, the distribution survey was delayed for two days to allow the caribou to be closer to peak calving. The area flown in 2008 was based on the 2007 survey, observations from the reconnaissance survey (actual sightings, tracks), and recent data from satellite and GPS radio collars. In some instances, transects were shortened to prevent covering areas where there was no indication of any caribou (such as directly northwest of Kugluktuk).

Caribou were classified as either adult (non-calf) or calf, along with columns that noted the presence of antlers (antlered cows, non-antlered cows, bulls). Estimates of animals off transect (including presence/absence of calves) was also noted. For mapping of “breeding females” we selected adults in all locations where any calves were observed, in addition to two locations where antlered females were observed but no calves. “Non-breeders” were mapped as adults from groups where no calves were present.

Dates: 11-18 June 2008. Reconnaissance flight on 12 June over the potential calving area where the majority of satellite and GPS collars were located. Distribution survey occurred 15-18 June.

Snow cover: Minimal (“overall there was no snow on the ground”; Tracz 2008)

Aircraft: Cessna 206.

Transect spacing: Reconnaissance flight over the potential calving area on 12 June using 10 km spacing. Distribution survey 15-18 June also using 10 km transects.

Survey time: 43.6 hrs. were flown: 4.1 hrs. on reconnaissance flight, 29.2 hrs. on survey, and 10.3 hrs. on ferry.

Observations and discussion: A total of 4,669 non-calf caribou were observed on transect. In the database off transect sightings were recorded as non-numeric digits e.g. “14/4” (for 14 adults and four calves) or “100/Y” (for 100 adults with calves present), rendering total summaries difficult to compile.

A total of 3,276 breeding females were identified within the calving ground, which extrapolates to an estimated 40,950 breeding females. This is only slightly less than the 42,075 adult caribou (not just breeding females) estimated for the calving ground during the 2007 calving ground distribution survey. Extrapolating from all adult caribou observed on transect during 2008 (4,669), 58,350 adult caribou were present during the survey.

The area where animals calved in 2008 (Figure 14) is generally consistent with historic Bluenose-East calving ground data, and with the 2007 survey (Figure 7). In general, the greater Rae-Richardson river area is where caribou were expected to calve, and this is also consistent with traditional knowledge from the Kugluktuk area (Tracz 2008). There appeared to be a shift in calving from south of the Rae-Richardson valley in 2007, northward to encompass the valley to a greater extent (Figures 7, 14). The area east of the Coppermine River was not used for calving in either 2007 or 2008, and consisted mostly of bull caribou.

Incidental sightings: 23 grizzly bears (including five cubs, four yearlings, and one two-year old); eight wolves (five singles and a pack of three), approximately 308 muskoxen (minimum of 31 calves; most muskoxen observed east of the Coppermine River), and two cow moose (in the Rae-Richardson River area).

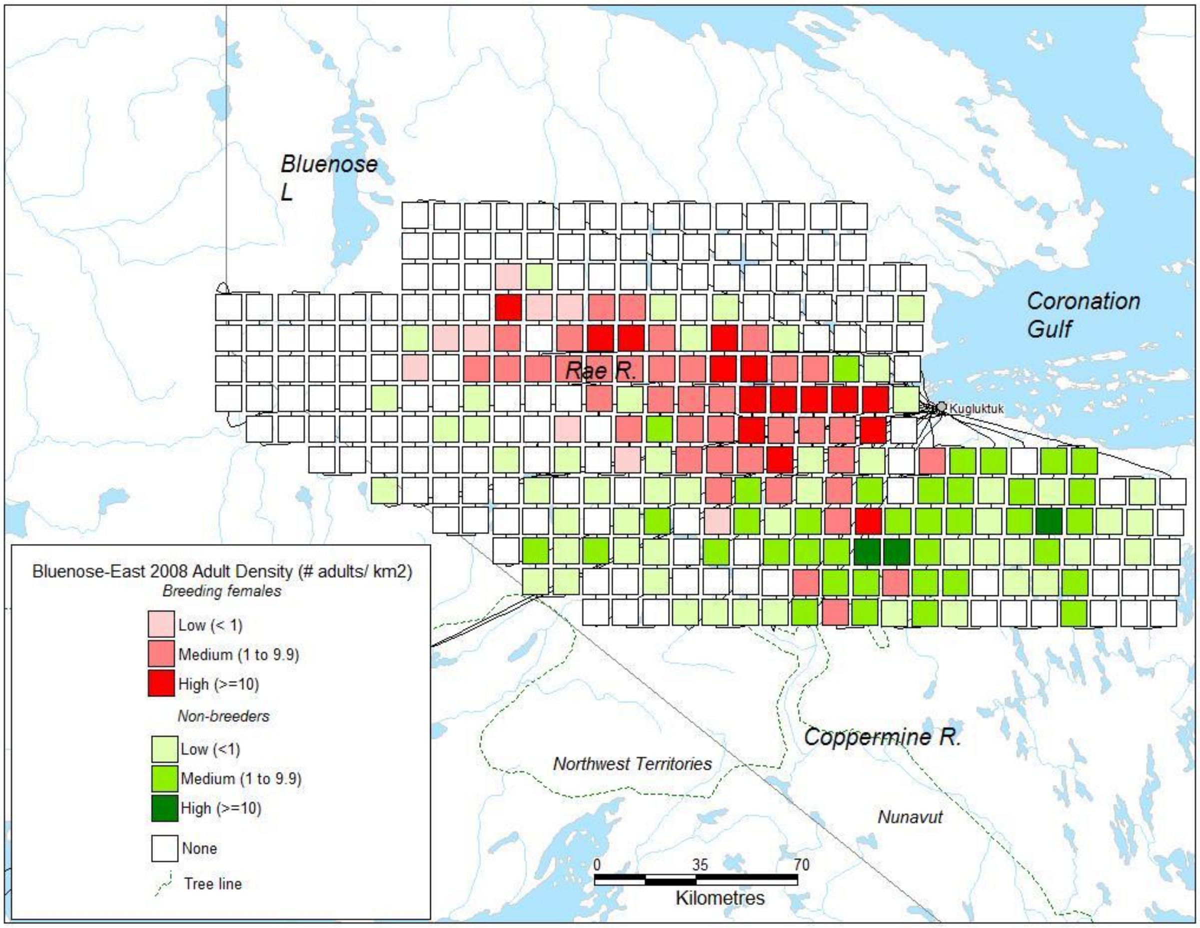

Figure 14. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Bluenose-East herd, June 2008. Here “breeding females” include adults where calves or females with hard antlers were present, and “non-breeders” include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Bathurst herd

Systematic aerial reconnaissance surveys of the Bathurst calving grounds were conducted in 2003 and 2006 (associated with calving ground photographic censuses; Gunn et al. 2005, Nishi et al. 2007), and in 2007 and 2008 (Adamczewski et al. 2009). The objectives of the 2007 and 2008 surveys were to determine the relative composition and density of caribou and delineate the extent of the annual calving ground.

Some information on this survey was obtained from Adamczewski et al. (2009), and data were clarified with B. Croft (personal communication, 2009). Data recorded during survey were number of adults (non-calves), whether calves were present within the group, and antlered status of cows observed.

Dates: 9-12 June 2008, with the calving ground covered on 9 June.

Snow cover: variable: 70-95% in the calving ground.

Aircraft: Cessna 337.

Transect spacing: 10 km, with 20 km in suspected low-density blocks surrounding the main portion of the calving ground. Three additional east-west oriented transects 30-40 km in length were flown through concentrated calving area on 9 June. The observations from these east-west transects are not included in the transect segment summaries.

Survey time: 31.5 hrs. were flown (includes ferry time from Hay River), 25.0 hrs. on survey, and 6.5 hrs. off survey.

A total of 2,437 caribou were observed, including 2,265 caribou observed on transect and 172 off transect. Calving was relatively concentrated, with some distribution of breeding females to the south (Figure 15). Based on observations during the flights (B. Croft, personal communication, 2009), peak of calving was estimated to be 10-11 June.

Extrapolated density estimates of breeding females from the 2007 (23,175) and 2008 (8,660) calving distribution surveys indicate a >60% decline in the number of breeding females on the calving grounds. This decline is broadly consistent with the decline in all adult (non-calf) caribou calculated by Adamczewski et al. (2009). An additional 5,850 breeding females can be estimated from observations during the non-standard east-west flights within the calving area.

Incidental sightings: 12 grizzly bears (including two cubs and one two-year old), nine wolves, 153 muskoxen (one calf noted), and five moose (two calves).

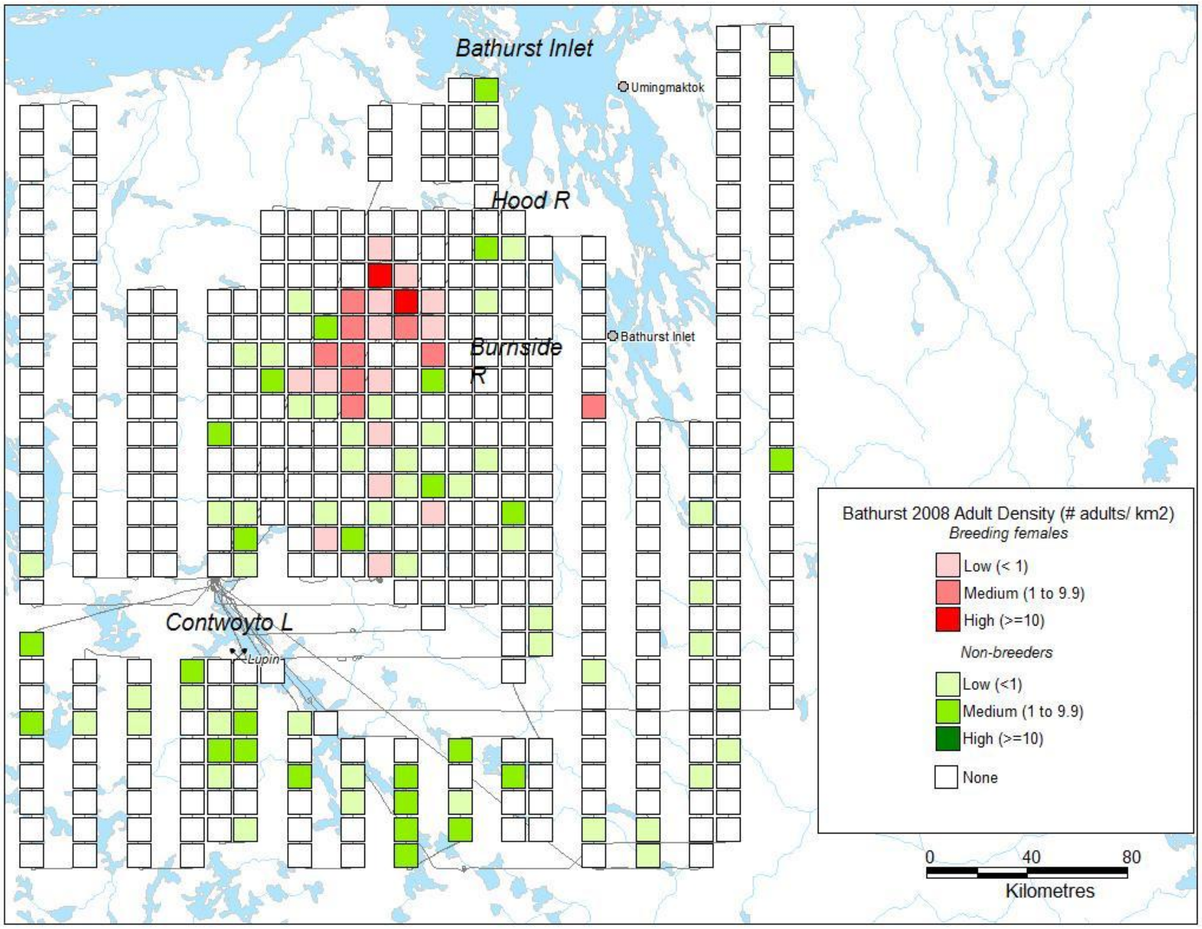

Figure 15. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Bathurst herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Ahiak herd

As noted earlier, the 2006, 2007, 2008 and 2009 calving ground distribution surveys of the Ahiak herd have been well documented in a draft report by Johnson et al. (2008), with trend analysis recently conducted by Boulanger (2010). We refer readers to these reports for additional details.

The objectives for the Ahiak calving ground surveys were to 1) systematically delineate the spatial distribution of breeding females close to or near the peak of calving; 2) determine the relative density of breeding cows on the annual calving ground; and 3) predict and map annual calving areas of the Ahiak herd (Johnson et al. 2008). Stratification into three survey blocks was based on results from previous surveys during the calving period (Gunn et al. 2000, Gunn and D'Hont 2003, Johnson et al. 2008) and information on the past distribution of collared Ahiak cows during the calving period (GNWT unpublished data).

Caribou were classified as cows with hard antlers, calves, antlerless cows, yearlings, and bulls. Groups of adults were considered breeding females where hard-antlered females or calves were observed.

Dates: 13-18 June 2008.

Snow cover: 30% near the coast to 100% inland.

Aircraft: Helio Courier.

Transect spacing: 10 km in the central block (approximately the area from the Ellice River east to the Simpson River), with 20 km in suspected low-density western block (east side of Bathurst Inlet to just west of the Ellice River) and eastern block (east of Simpson River to Chantrey Inlet).

Survey time: 32.0 hrs. were flown, 24.5 hrs. on survey, and 7.5 hrs. off survey.

Observations and discussion: Johnson et al. (2008) indicated that consistently bad weather conditions were again experienced during the 2008 survey. Spring conditions were late in the western portion of the survey area with 30% snow cover near the coast increasing to 100% inland; however the amount of lake ice was reduced from June 2007. Classification included 1,709 cows (732 cows with hard antlers) and 598 calves (82% of hard antlered cows with calves); and 1,144 non-breeders on transect during this survey, and 1,073 cows (346 cows with hard antlers) and 238 calves (69% of breeding females with calves); and 735 non-breeders off transect.

During 2008 all 24 collared cows assumed to be breeders (based on blood serum progesterone levels obtained from 30 cows captured in April 2008, and on movement rates of previously collared cows) were located within the distribution of breeding cows (Johnson et al. 2008). However, four of these collared cows were at the edge of the breeding cow distribution. Just over half of the 18 collared cows known to be non-breeders overlapped the distribution of breeding cows observed during the survey; however, most of these collared cows were at the southern extent of the breeding cow distribution.

Cows were dispersed over a larger area in June 2008 (Figure 16) compared to the previous two years (Figure 8; Johnson et al. 2008) and at lower density. No segments with a high density of total cows or breeding females (>10 animals/km^2) were observed (Figure 16). Medium density pockets of breeding females were observed between the Ellice and Perry rivers, and the Perry and Simpson rivers, as well as a few isolated transect segments on the Adelaide Peninsula. Considerably fewer cows were seen in June 2008 compared to June 2006 and 2007, especially the number of cows with hard antlers (Boulanger 2010). Peak of calving was assumed to be similar between 2007 and 2008, approximately 13-14 June. The low pregnancy rate in 2008 (57%) likely contributed to the fewer cows observed during the survey (Johnson et al. 2008).

Incidental sightings: 124 muskoxen and six calves in 15 groups on transect and 149 muskoxen with 20 calves in 13 groups off transect; five wolves in four groups on transect and three wolves in one group off transect; and one grizzly bear on transect. Muskoxen were distributed throughout the survey area, while wolves were seen around the Ellice and Perry rivers and the grizzly bear was observed along the coast between the Ellice and Perry rivers.

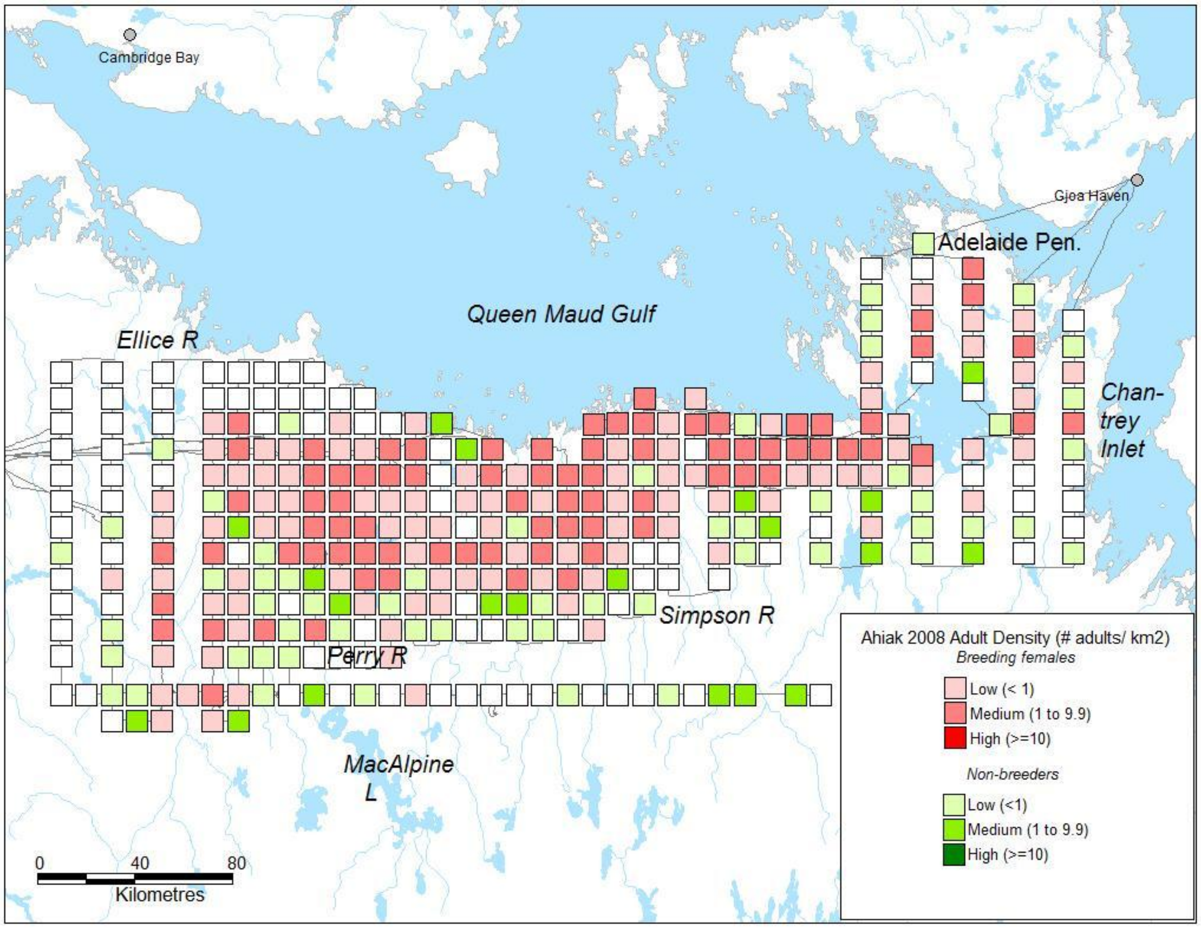

Figure 16. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Ahiak herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Beverly herd

Despite extensive coverage of the traditional Beverly calving grounds and much of the surrounding area in June 2007 (Johnson et al. 2007), concerns were raised that caribou may have been missed due to late spring conditions that may have delayed the migration of breeding cows onto the calving ground or shifted the calving ground outside of the documented traditional Beverly calving grounds (Johnson and Williams 2008). As a result, systematic aerial transect surveys of the Beverly calving ground were conducted in June 2008. A visual stratified transect survey was proposed if densities of caribou observed were low (approximately 1-2 caribou/km^2), while a photographic census was proposed if densities were higher. A transect survey of a large area south and west of the traditional Beverly calving grounds was also conducted to address concerns that the Beverly calving ground may have shifted to an area not previously documented. Johnson and Williams (2008) wrote a draft report on this survey.

As with 2007, the June 2008 survey was intended to be an aerial photographic census with the following objectives: 1) delineate the distribution and relative density of calving caribou on the Beverly calving ground; 2) based on the results, determine whether a population estimate can be completed in June 2008; 3) demonstrate that the Beverly calving ground has not shifted outside of the traditional Beverly calving grounds; 4) compare the spatial extent of the annual calving ground relative to the locations of the GPS collared cows and the Caribou Protection Area; and 5) demonstrate spatial separation between the Ahiak and Beverly calving grounds (Johnson and Williams 2008). However, again because of the relatively few breeding cows observed on the Beverly calving ground during 2008, no population estimate for the herd was completed.

A number of systematic reconnaissance surveys were flown, the first within the traditional Beverly calving grounds (4-10 June 2008) was to roughly delineate the spatial distribution and density of breeding cows on the calving ground; provide anecdotal information on the movement behaviours of breeding females and timing of calving; to identify spatial separation of breeding cows on the Ahiak and Beverly calving grounds; and to ensure that breeding cows were not missed. On 12 June the identified calving ground was flown at five and 10 km transect spacing, with the objective to delineate the spatial distribution of breeding cows on the calving ground near the peak of calving (Johnson and Williams 2008). The major distribution of breeding cows was re-surveyed on 18 June at 5 km transect spacing, again to delineate the spatial distribution of breeding cows on the calving ground. Extensive surveys also were flown between 6 and 20 June in a large area surrounding the traditional Beverly calving grounds, to demonstrate spatial separation between the Ahiak and Beverly calving grounds near the peak of calving, and to ensure that the Beverly calving ground had not shifted outside of the traditional calving grounds.

Caribou were classified as cows with hard antlers, calves, cows with no antlers, yearlings, bulls or unknown based on body size and whether antlers were either light coloured and polished (hard) or in velvet (Johnson and Williams 2008).

Dates: 4-18 June 2008 (systematic transect survey of the traditional Beverly calving grounds 4-10 June; systematic transect surveys of the observed breeding female distribution 12 and 18 June; systematic transect survey of a large area surrounding the Beverly calving ground 6-11, 13, and 20 June).

Snow cover: 4-10 and 13 June flights: snow cover ranged from 10-100% over the survey area with increasing snow cover to the north and east; 12 June survey: snow cover ranged from 20-100% from south to north; 18 June survey: snow cover ranged from 10-40% from south to north.

Aircraft: Helio Courier and Cessna 206

Transect spacing: 10 km, increased to 20 km on the edge of the traditional calving grounds; 5 km, increasing to 10 km in the area surrounding the area of observed breeding female distribution; 20 km in the area between the Ahiak and Beverly calving grounds; and 30-50 km in a large area surrounding the traditional Beverly calving grounds.

Survey time: 107.7 hrs. were flown: 70.3 hrs. total survey, and 37.1 hrs. on ferry.

Observations and discussion: As in previous surveys, the majority of the breeding cows observed during the surveys were in the northern portion of the traditional Beverly calving grounds (Figure 17).

Reconnaissance survey of the traditional calving grounds – 4-10 June 2008: During 4-10 June, breeding and non-breeding cows were primarily observed west of Sand Lake at low densities

(<1 caribou/km^2). A total of 48 and 88 cows (both hard antlers and non-antlered) were observed on and off transect, respectively. Only seven calves were observed (12% of all hard-antlered cows). Only five cows (all with hard antlers) and one calf were observed in the area between the Ahiak and Beverly calving grounds on 13 June. No cows with hard antlers or calves and only 14 non-antlered cows were observed during all surveys in the large area surrounding the traditional Beverly calving grounds.

First systematic survey - 12 June 2008: On transect observers found 93 cows (42 cows with hard antlers) and 14 calves (33% of hard antlered cows with calves; 15 calves:100 (all) cows); off transect, they observed 136 cows (82 cows with hard antlers) and 26 calves (32% of hard antlered cows with calves; 19 calves:100 (all) cows). The main distribution of breeding cows extended from the west side of Sand Lake westward to the Upper Garry River (Figure 17).

Second systematic survey - 18 June 2008: Johnson and Williams (2008) observed 64 cows (18 cows with hard antlers) and five calves (8 calves:100 cows) on transect, and 234 cows (18 cows with hard antlers) and 51 calves (22 calves:100 cows). Fewer breeding cows were observed on transect than during the 12 June flight.

Peak of calving was estimated to be approximately 15 June, as only 32% of hard antlered cows were with calves on 12 June.

Few breeding females were observed within the traditional Beverly calving grounds in 2008 (Johnson and Williams 2008), similar to observations from 2007 (Johnson et al. 2007), confirming that there has been a steep decline in the number of breeding females on the Beverly calving ground since 1994. Given the broad coverage of areas beyond the traditional calving grounds in both years (Figures 1, 2), it was highly unlikely that areas of concentrated calving in the vicinity of the traditional Beverly calving grounds had been overlooked. The low number of breeding cows observed on the calving grounds is in agreement with a 43%

pregnancy rate based on blood serum progesterone results from 30 cows captured in April 2008 in proximity to other collared Beverly caribou (Johnson and Williams 2008).

Incidental sightings: Johnson and Williams (2008) observed 392 muskoxen (calves not delineated) in 45 groups, seven single grizzly bears, 15 wolves in 12 groups, one wolverine, three single fox in three groups, and two moose in one group both on and off transect over a total of 84.7 hrs. flown.

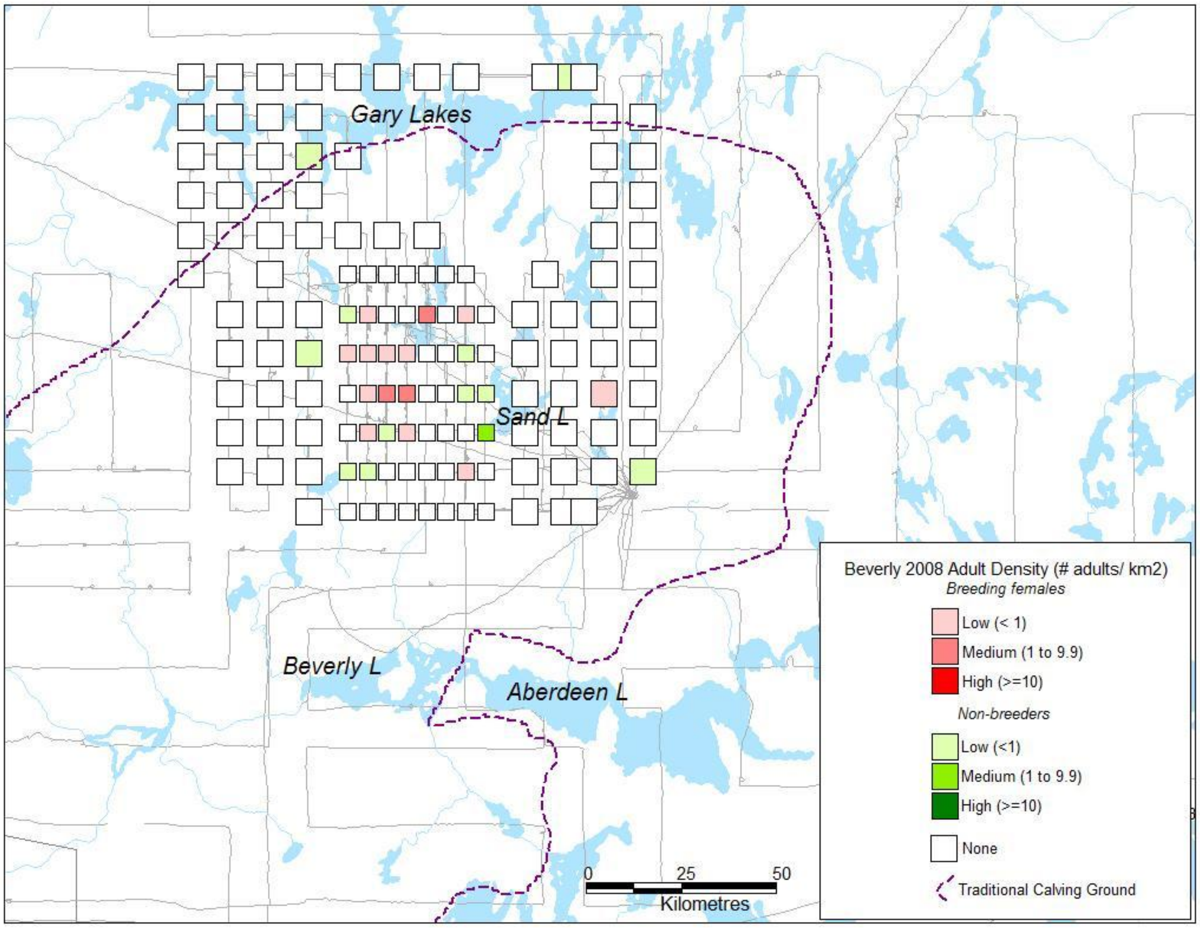

Figure 17. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Beverly herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

2008 Qamanirjuaq herd

The Qamanirjuaq caribou herd's previous calving ground photocensus was in 1994 (M. Williams, unpublished data, Campbell et al. 2010). In 2008, a photocensus was conducted (Campbell et al. 2010). Here we report on the calving ground distribution flights associated with that census, to provide a complete picture of barren-ground calving distribution across the mainland NWT and NU during 2008.

The objectives of the 2008 June photocensus were threefold: 1) to estimate the numbers of breeding females on the annual Qamanirjuaq calving ground; 2) to determine the trend in breeding female abundance on the traditional calving grounds among 1982, 1985, 1988, 1994 and 2008; and 3) to measure the spatial extent of the annual calving ground relative to previous survey findings, the Qamanirjuaq Caribou Protection Area, and relative to the locations of GPS collared cows (Campbell et al. 2010). The calving ground distribution survey (systematic reconnaissance survey) was an initial step to a full photocensus, and was used to delineate the distribution and density of breeding females to enable stratification for census. Thirty-three active collars on adult cows were used as an initial step in the survey, such that the location and breeding status of each collared animal was determined.

Caribou were classified as cows with hard antlers, calves, cows with no antlers, yearlings, or bulls (Campbell et al. 2010). Groups were assigned as breeding females if they contained at least one hard-antlered cow or one calf.

Dates: 6-12 June 2008 (collar reconnaissance 6 June, calving ground distribution surveys 7-12 June, with photo and visual census 9-10 June, and composition surveys 10-12 June).

Snow cover: Based on raw survey observations, 0-20%.

Aircraft: Cessna Grand Caravan.

Transect spacing: 10 km, with 20 km in suspected low-density blocks in the south of the calving ground. Note that transects and segments used in 2008 (based on UTM Zone 15; Campbell et al. 2010) did not align with the transects and segments used in 2007, which were an extension of the Beverly grid (J. Williams, personal communication, 2009), and were apparently based on UTM Zone 14.

Survey time: Not provided.

Observations and discussion: Twenty-five of the 33 collars active on Qamanirjuaq caribou on 6 June were within large aggregations of breeding females well within historically delineated extents of the Qamanirjuaq calving ground (Campbell et al. 2010). Two of the remaining collars were about 70 km south-southwest of the main aggregation, and the remaining six were associated with predominantly non-breeding females, yearlings, young bulls and mature bulls well south and south-southwest of the main collar aggregations.

Over 20,500 adult (non-calf) caribou and 3,000 calves were observed on transect during the calving ground distribution survey. Calving during 2008 was concentrated in a relatively tight aggregation in the central portion of the traditional Qamanirjuaq calving grounds in the main calving area (Figure 18; Campbell et al. 2010), further north than observed during 2007 (Figure 10). During 2008, a fairly concentrated area of breeding females was observed 70 km south of the main breeding female aggregation. Lower densities of breeding females (mostly hard-antlered cows within groups of non-antlered cows) were distributed throughout the southwestern and western portions of the traditional calving grounds.

Incidental sightings: During the systematic calving ground distribution survey, 13 wolves and five barren-ground grizzly bears were observed (Campbell et al. 2010).

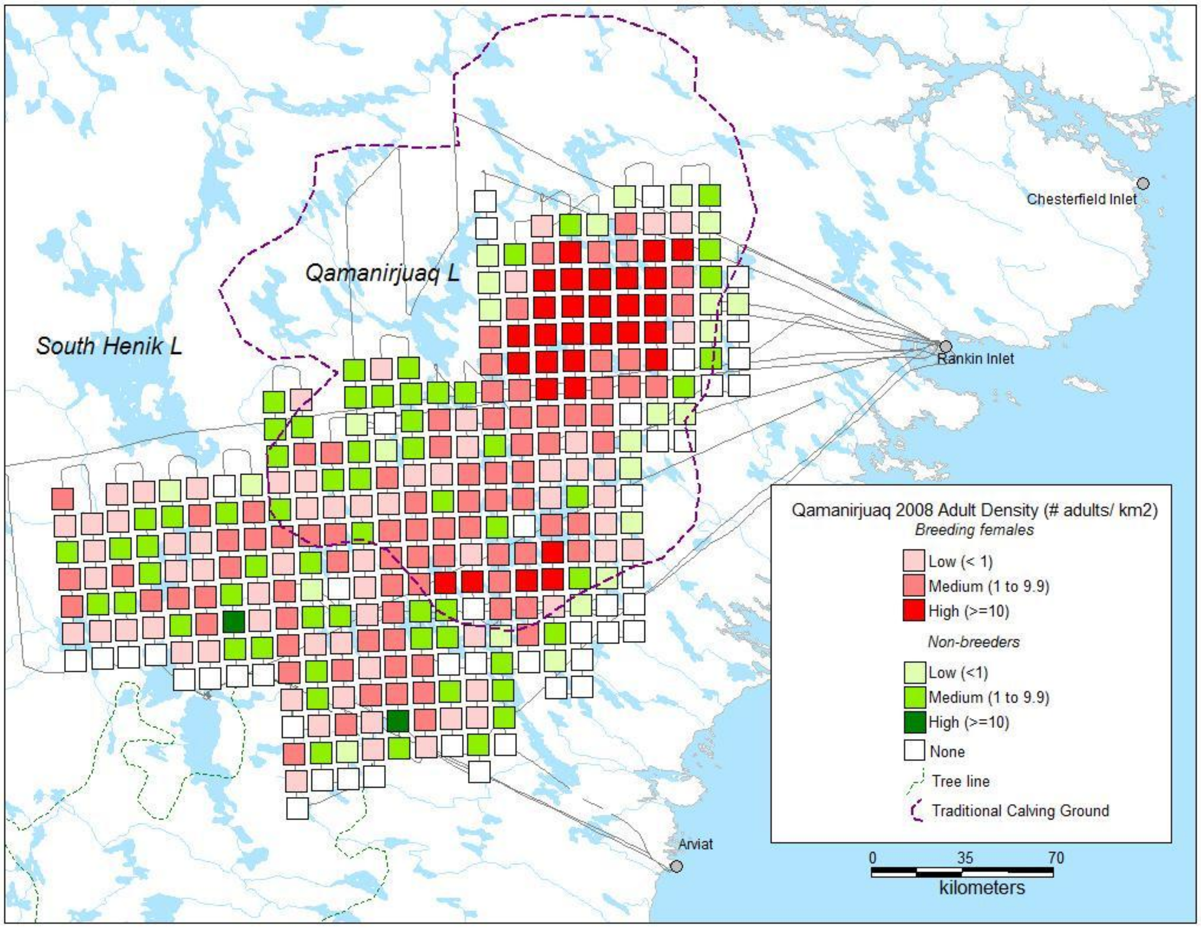

Figure 18. Distribution of breeding females and non-breeders observed on transect summarized by 10 km segment, Qamanirjuaq herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

Note: Our map looks different from the map in Campbell et al. (2010: Figure 14) primarily because we plotted the density of all segments with a minimum of one breeding female present (0.125 breeding females/segment). Campbell et al. (2010) plotted only densities ≥3 breeding females/km^2 (24 breeding females/segment). Plotting and interpretation of systematic surveys will vary with objectives, and the 2008 Qamanirjuaq systematic survey was conducted in preparation for a photocensus.

DISCUSSION

Describing the location of calving grounds, especially the dispersal and density of breeding cows on the calving grounds, underpins much of the caribou monitoring and management in NU and NWT. Since 2007, GNWT has switched to more frequent monitoring of the calving grounds in the face of recent declines of the major herds. The change to annual calving ground systematic reconnaissance aerial surveys (where conducted) and the approach to recording the data using GPS technology has considerably strengthened the available information from the calving ground surveys. The density and dispersion of breeding females can be relatively efficiently measured on calving grounds as an indicator for trends in densities. The annual surveys allow managers to track trends in densities of breeding females during the intervening years between full-scale calving ground photocensuses, including shifts in the number of density classes as well as overall numbers, and the patterns of density class changes (e.g. reductions in the number of segments of high density class). However, the precision and accuracy of calving ground distribution surveys will be affected by sightability and counting biases. These biases can be minimized using standardized survey methods and experienced and trained observers.

While acknowledging that sightability and counting biases can affect the accuracy of estimates, visual calving ground distribution surveys can index the trend in adults (or breeding females) on the calving grounds (Adamczewski et al. 2009). This can be conducted by comparing mean counts of caribou (adults, breeding females, etc.) observed in segments among years (Boulanger 2010), or by extrapolating density of caribou within segments to the area surveyed (Adamczewski et al. 2009).

The difficulty of using the mean count or density of caribou observed among years is that coverage and survey area may differ among years in response to changes in the distribution of breeding females. For example, if the mean count of caribou per segment was 8.0 within an 800 km^2 survey area in Year 1, and was 4.0 within a 1,600 km^2 survey area in Year 2, the mean count is half in Year 2, but the extrapolated estimates is the same between years. Therefore, the analysis of mean count would simply show great dispersion of animals, not a drop in numbers, which makes the point that comparison of mean counts or densities in segments among years, must be done with caution.

Recording the aerial observations as waypoints amalgamated into segment data (the centroids of the 10 km transect segments) allows the comparison of density and dispersion among years and among herds. Amalgamation after the fieldwork allows the more detailed waypoint data to be used for other objectives (as opposed to the survey method where all observations are recorded by segment not by waypoint). Additionally, managers can define and map the spatial extent of the annual concentrated calving area (high densities) and define and justify boundaries for annual calving grounds, which will also be useful for designing calving ground protection measures.

Where transects are conducted on 10 km spacing, centroid data “averages” data over a 10 km segment. With calving grounds that stretch over large areas this should not affect the accuracy of boundaries, but if calving ground size is reduced (e.g. Bathurst 2009: Adamczewski et al. 2009), averaging data along the boundaries of relatively small areas may reduce the resolution of the data. If these situations persist it may be prudent to adopt 5 km transects and segments for analysis, depending upon survey objectives.

Although some jurisdictions rely on locations of radio collared animals to delineate calving grounds, the information is quite different from that generated through aerial surveys. The locations of collared cows can be mapped using various mapping methods, for example the 95% or 99% fixed kernel utilization distribution of collared females (Kelleyhouse 2001, Caikoski 2009). Concentrated calving areas can also be mapped using similar methods. The rates of movements can be monitored, which can be used to determine the timing of arrival and departures from calving grounds as well as the peak of calving (e.g. Gunn and Poole 2010). Whether to use satellite telemetry or aerial surveys is dependent on the objectives for collecting the information and the two techniques generally serve quite different but often complimentary objectives.

The strength of using calving ground aerial systematic surveys as an index to breeding cow density, dispersion, and distribution depends on how standardized the surveys are in data collection and reporting. Given the importance of this and the difficulties we encountered while compiling the information in this report, we have included a template to increase the standardization of the surveys, which will reduce bias and increase comparability.

Predator indices

If collected in a rigorous and consistent manner, the sightings of grizzly bears and wolves during calving ground distribution surveys are an indication of relative densities and trends in predator numbers among areas and over time (e.g. Heard 1992). Using our understanding of hrs. flown during the 2007 and 2008 surveys, we summarized sightings of bears and wolves (Table 2). In general, more grizzly bears were sighted in 2008 compared with 2007 during the Cape Bathurst, Bluenose-West and East, and Bathurst surveys, and more wolves were observed in more eastern herds.

Comparisons with historic data are possible using this relatively simple index. For example, Heard (1992) reported an average of eight wolves seen per 100 hrs. during 500 hrs. of flying surveys in the Queen Maud Gulf area during the 1980s, lower than the 24-33 wolves/100 hrs. observed during surveys of the Ahiak herd in 2007 and 2008 (Table 1). This index requires consistency in reporting all observations of grizzly bears and wolves against a reported number of hrs. of flying (to clarify whether ferry flights, reconnaissance flights, etc. are included).

The distribution of predators in relation to caribou density and distribution can also be examined. We provide an example of the predator distribution in relation to caribou density on the Bluenose-East calving ground during 2008 (Figure 19). Here, observations of grizzly bears and to slightly lesser extent wolves correlated strongly with medium to high densities of breeding females.

Table 2. Summary of grizzly bear and wolf sightings during calving ground distribution surveys, NWT and NU, 2007 and 2008.

Survey	Hrs flown	Type[1]	Bears/100 hrs	Wolves/100 hrs	Comment
Tuktoyaktuk 2007	5.7	On survey	70	0	
Cape Bathurst 2007	10.5	On survey	38	0	
Bluenose-West 2007	16.7	On survey	18	24	
Bluenose-East 2007	54.8	Total flying			Incomplete data
Bathurst 2007	21.3	On survey	33	5	
Ahiak 2007	21.0	On survey	0	24	On transect
Beverly 2007	68.8	Stated	4	7	
Qamanirjuaq 2007	26.1	Total flying	0	8	
Tuktoyaktuk 2008	6.1	On survey	0	0	
Cape Bathurst 2008	16.3	On survey	61	0	
Bluenose-West 2008	28.1	On survey	64	4	
Bluenose-East 2008	33.3	Recon, survey	69	24	
Bathurst 2008	25.0	On survey	48	36	
Ahiak 2008	24.5	On survey	4	33	On and off transect
Beverly 2008	84.7	Stated	8	18	
Qamanirjuaq 2008	20.0	Assumed for 7–8 June	25	65	Apparently all observed 7–8 Jun; estimated hrs.

[1] Type refers to our interpretation of what flying hrs. the predator sightings were collected. Actual hrs. for which predator sightings were collected were reported for the Ahiak surveys.

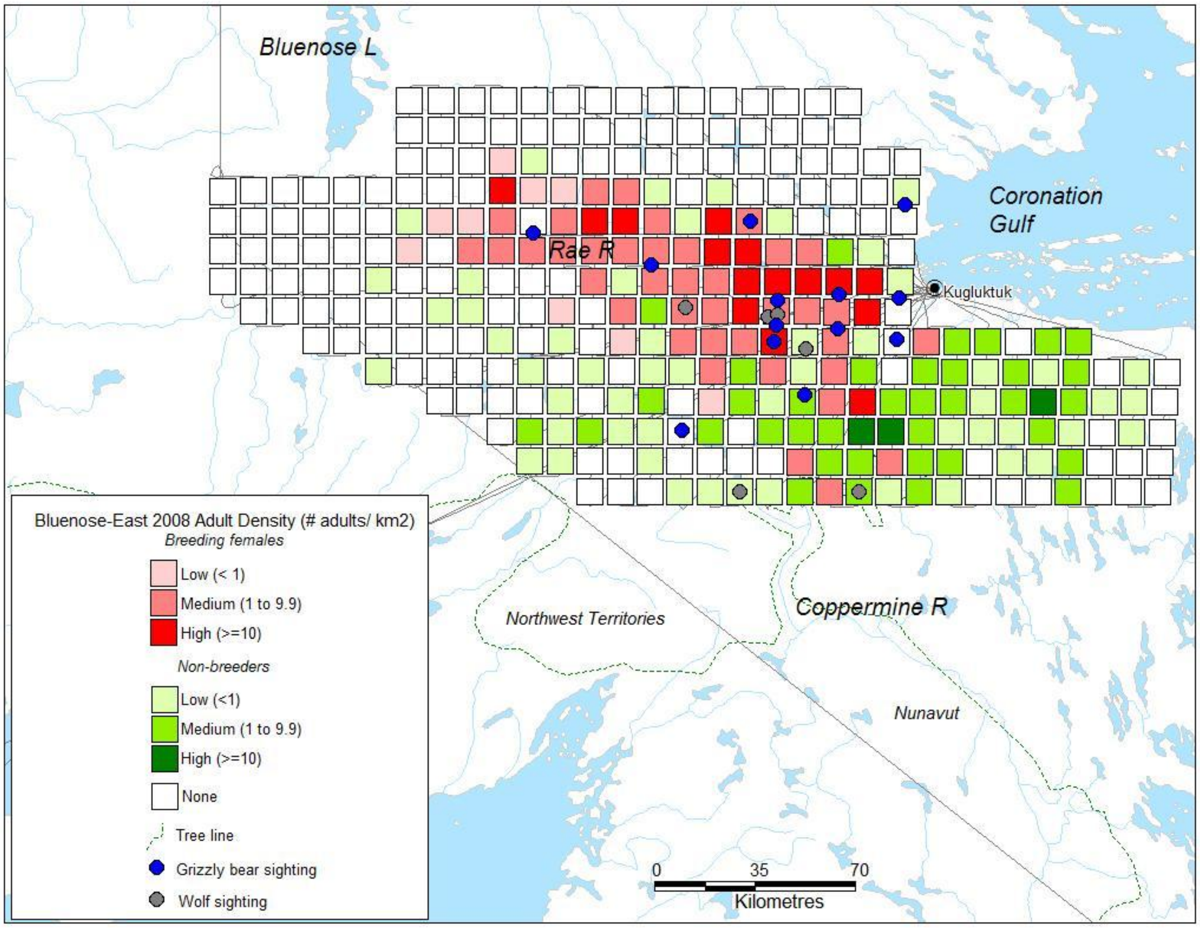

Figure 19. Distribution of grizzly bears and wolves observed in relation to breeding females and non-breeders observed on transect and summarized by 10 km segment, Bluenose-East herd, June 2008. Here "breeding females" include adults where calves or females with hard antlers were present, and "non-breeders" include adults where calves or hard-antlered cows were not present. Breeding density layer is placed on top of the non-breeding layer to show all observations of breeders.

A TEMPLATE FOR CALVING DENSITY, DISPERSION AND DISTRIBUTION SURVEYS

Here we provide an operation manual to conduct calving ground density, dispersion and distribution surveys on barren-ground caribou in the Northwest Territories (NWT) and Nunavut (NU). Our goals are to clarify objectives for the surveys and to standardize methodology to more readily enable comparisons over time and among areas. Such standardization facilitates more detailed geostatistical analyses if required (e.g. Gunn et al. 2008).

Background

Timing of arrival and movements on the calving grounds – The dates for the arrival on the calving ground annually vary as does the rate of travel. Most is known for the Bathurst herd based on analyses of satellite collared cows (Gunn et al. 2001, 2008, Gunn and Poole 2010). If cows arrive early, they may overshoot the northern boundary and return (Gunn et al. 2001).

Reproductive status – Breeding females (pregnant and a few days post-partum) are identified by the presence of hard antlers. Other indicators that persist for more than a few days are a distended udder, or a calf at heel (Whitten 1995; Figure 20). During aerial surveys, a distended udder is not visible, and thus breeding female status can only be positively indicated by hard antlers or a calf at heel. Calving is generally synchronous but may extend over a period of 10-14 days (Bergerud 1975, Bergerud et al. 2008) and breeding females generally shed their antlers within five days of parturition (Whitten 1995, Bergerud et al. 2008) Depending on the timing of a ground composition survey relative to the peak of calving, identification of breeding females include: a female with one or two hard antlers (with or without a calf at heel), or a female with no antlers and a distended udder (with or without a calf at heel) (Figure 20). Non-breeding females shed their antlers in April or early May, and during peak of calving may have about 10-15 cm of new antler growth and no distended udder (Williams 1994).

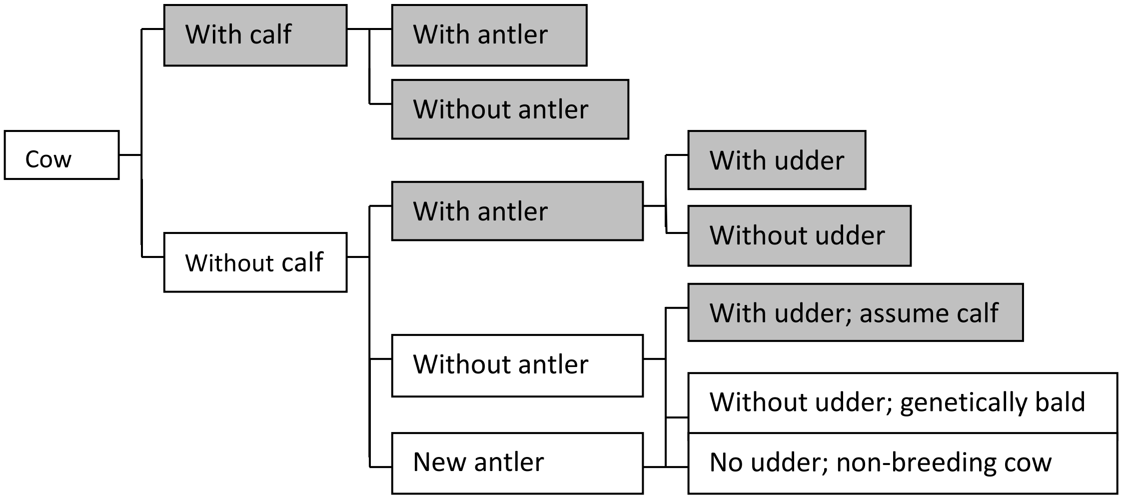

Figure 20. Female classification categories for determining pregnant and post-partum breeding females during peak of calving (after Gunn et al. 1997). Shaded boxes represent breeding females and white boxes represent non-breeding females. This level of detail is possible only during composition surveys from the ground, but represent the options available during aerial surveys.

Timing of antler drop in parturient cows likely varies among herds and phase of population increase or decline (Bergerud et al. 2008). In the Porcupine herd during the 1980s, 9% of parturient cows dropped both antlers before parturition, and 10% of parturient cows with antlers shed the second antler >1 week after calving, (Whitten 1995). The greatest degree of antler drop (both antlers) occurred within five days of parturition.

Small proportions of cows are annually unantlered either because they are genetically bald or were in poor condition the preceding summer (5% for the Porcupine herd during the 1980s; Whitten 1995). The proportion varies depending on summer condition. The percentage of adult females having no visible antlers increased from about 2-9% in the George River herd, concurrent with a decrease in body condition (Bergerud et al. 2008). The proportion of antlerless cows is determined during fall composition surveys. Thus a non-antlered cow without a calf observed during a calving ground distribution survey may be breeding female with a dissented udder that has lost her calf, or a non-breeding female with no distended udder that is genetically bald. The rate of genetic baldness also likely varies among herds.

During ground composition counts, a distended udder can reliably indicate a parturient cow up to about 10-11 days after calf loss (Whitten 1995).

OBJECTIVES

The main objectives of calving distribution surveys can vary depending upon the focus of the survey. In most cases we suggest the following objectives be considered:

1. Determine inter-year trend in estimated density of breeding females or adult (1+ year old) caribou on the calving ground.

2. Describe the dispersion (the pattern of relative density) of breeding females or adult caribou on the calving grounds, including areas of concentrated calving. (Dispersion is the most important objective and an essential step in preparation for photographic censuses).

3. Systematically delineate the distribution of breeding females or adult caribou on the calving grounds at or near the peak of calving – this will lead to determining boundaries.

The emphasis of the calving ground distribution surveys, including priorities for data collection, will vary with the objectives. However, standardization is a priority. For some, methodologies should be sufficient to enable trends in numbers to be calculated (Adamczewski et al. 2009, Boulanger 2010). These surveys also can be used as a basis for allocating sampling effort during subsequent calving ground surveys conducted to produce an estimate of breeding females present on the calving grounds, which can be extrapolated to an estimate of herd size (using composition data collected on the calving grounds and during fall composition counts (e.g. Nishi et al. 2007). If a photographic census is not possible because of weather, the visual survey will act as a contingency to provide a measure of the trend in breeding females or adult (1+ year old) caribou. Breeding females are the most biologically relevant metric that should be obtained, but when encountering problems with classification or with different objectives, adult caribou can be summarized.

PREPARATIONS

Pre-survey

Surveyors should consider contingency planning in the lead-up to the survey. These contingency options may include whether flights are being conducted too early or too late relative to the peak of calving, and the impacts of deep snow, late snowmelt, or prolonged bad weather on distribution of breeding females.

Survey area

The survey area should be based on distribution of calving caribou from previous aerial surveys, as well as available collar data (satellite collars, and more recently GPS [global positioning system] collars with satellite uplink capability). Survey areas can be stratified into survey blocks that vary in coverage based on expected density of breeding females; stratification can be based on results of previous surveys and collar distribution, and on preliminary reconnaissance flights if conducted.

A landscape level 10 km survey grid (5 km for Inuvik Region herds) has been established for all calving grounds in the NWT and NU. These grids are available in regional and headquarter offices, and generally align on the most appropriate UTM zone to the calving ground on the 10 km (or 5 km) lines. These grids (and the resulting segments) should be followed consistently over time, and can be loaded into the appropriate spreadsheet, mapping and GPS software. All herds have been flown using predominantly north-south oriented transect lines with the exception of Cape Bathurst and Bluenose-West, where the line are oriented east-west.

Survey timing

Calving ground density, dispersion and distribution surveys should be conducted at or as close to the peak of calving as possible. If surveys are conducted too early before the peak of calving, relatively rapid pre-calving movements often alter caribou distribution on a day-to-day basis, resulting in rapid changes to caribou distribution and density. Movements of breeding females will be least at birth and in the few days immediately after parturition (Fancy and Whitten 1991, Kelleyhouse 2001). Most females form post-calving congregations within 2-3 weeks of calving (herd and year specific) that are segregated by calf age. These often fast-moving congregations of breeding caribou will alter the relatively even distribution of caribou on the calving grounds and result in rapid changes to the density and distribution, resulting in greater bias and less precision in counts. In many cases researchers should conduct a reconnaissance flight prior to the systematic distribution survey to ensure that the survey is timed as close to the peak as possible.

Data to collect in the field

Survey setup

Surveys should use navigation and data management techniques that combine handheld GPS units with OziExplorer GPS mapping software (Newman 2006), digital maps of the survey area, the survey grid, and a digital data file of the waypoints for the ends of each transect installed. Observational data are compiled and analyzed in Microsoft Excel and OziExplorer (Appendix A in Gunn et al. 2005) to calculate densities of caribou classes within segments, and to produce maps. Taylor (2009) has provided detailed instructions and suggestions for using GPS units and associated software. It is prudent to practice the data handling between OziExplorer and Excel before the survey to ensure familiarity. Subsequent to the writing of this report, a touch screen tablet-based GPS/Access/ArcGIS interface has been used for entering data during surveys (e.g. Campbell et al. 2012).

Surveys have been standardized to use a total strip width of 0.8 km (400 m strip width per side), resulting in approximately 8% coverage at 10 km spacing, and approximately 16% coverage at 5 km spacing. Transect lines and labels should be loaded into GPS units following Taylor (2009). A limited number of waypoints can be stored in the commonly used Garmin

Map76 units, but waypoints can be freed up by loading survey points, fuel caches, camps, etc., as Points of Interest (POI).

Fixed-wing aircraft should generally fly at an altitude of about 120 m above ground level (AGL), and a ground speed of about 160 km/hr. Survey personnel may vary with objectives and aircraft type, but generally consist of a pilot and front-seat navigator-recorder, and two rear-seat observers.

The outer boundary of the 400 m transect strip should be established using wooden dowels (about 1.5 cm diameter, and about 50 cm long) taped with electrical or duct tape onto the wing struts on each side of the aircraft using the methods outlines by Norton-Griffins (1978). In the absence of struts a wire can be stretched from the tie-down bolt on the wing to the fuselage and marked with tape (verify the use of wire and tape or doweling with the pilot). Strip markers should be calibrated for all observers by having the pilot fly the aircraft at survey altitude along an axis perpendicular to a known 400 m distance on the ground. A blind zone directly below the aircraft will be present for all rear-seat observers. The edge of this blind zone represents the inner boundary of the 0-400 m on transect strip. During the on-transect flights, the observers should be directed to focus on the transect strip and not search for off-transect caribou.

Field recording

The type of flight being flown should be clearly identified on the field forms and in the database. For example, whether the flight is a ferry flight, systematic reconnaissance survey following transects, or any unusual flying (e.g. additional transects flown perpendicular to the main transects). Thus it should be clear that any particular observation can be assigned as 1) On transect (observations within the 400 m strip width on each side of the aircraft during a systematic flight on the transect line); 2) Off transect (observations beyond the 400 m strip width on each side of the aircraft during a systematic flight on the transect line), and 3) Ferry (flights to and from the start of systematic coverage of the transect lines, and during flights between 5 or 10 km spaced transect lines).

Observers should count caribou in smaller groups and estimate the numbers of caribou seen in larger groups both on and off transect (and during ferry flights), and classify caribou observed (especially for on-transect observations). The size of larger groups can be estimated by estimating blocks of caribou by the 10s, 50s and 100s. Where feasible (i.e., lower density of caribou, slow-moving aircraft [Helio Courier]), caribou should be classified as cows with hard antlers, antlerless cows, calves, yearlings, and bulls based on body size and whether antlers were either light coloured and polished or in velvet. This level of classification may not be possible at higher densities or in some situations with faster aircraft (Caravan) although calves should be noted. Depending upon the time since peak of calving, each group should be assigned as a "breeding female" group or not based on presence of hard antlers or calves (check mark in a column if at least one hard-antlered cow observed, and in a column if at least one calf observed), even if detailed classification is not conducted. Assignment of breeding female groups at the group/waypoint scale will facilitate more accurate mapping at the segment scale, since obvious non-breeding groups (yearlings, bulls) will not be counted as breeding females in a segment where there is evidence of breeding. An example of a field data form is provided in Appendix 2.

Observers should call their observations to the navigator who will record them as well as a waypoint number along with the transect segment label. We suggest that observations be recorded by waypoint number and not summarized and recorded only by segment number, since it is difficult to remove non-breeders from segment totals, and it is distracting during the survey for the observers to be focusing on segment boundaries. A navigator/recorder should always be on board to maximize the efficiency and accuracy of the survey, but if a navigator is not on board, the observers can consider either using a recording device to verbally record the waypoint number with the observational data, not focusing on segment number), be prepared to write quickly on data sheets (to minimize time away from surveying), or be efficient with tablet-based data entry methods. Observers may use recording devices to relocate caribou observations when large numbers of caribou are encountered (>10 caribou/km^2). Binoculars may help ensure that counts and classifications are accurate. The pilot may leave the transect line if an observer has difficulty counting or classifying a group of caribou, and then re-join the line at the same point to resume surveying. Sensitivity to concerns about circling calving groups is necessary.

Additional information that should be recorded on the datasheets during the survey (under the comment field) includes snow cover in various portions of the calving ground, and the magnitude and direction of recent tracks (if discernable). Track information may be useful to interpret movements within and outside of calving grounds.

Incidental observations

Incidental observations should include all predators (primarily grizzly bears and wolves, but also wolverine and eagles) as well as muskoxen and moose. The observations should include as much detail as feasible (especially cub, pup, or calf information). Incidental observations should be recorded to note on and off transect when flying transects, and when on ferry. The most rigorous indices would be to report all incidental sightings observed both on and off transect, and not during ferry flights; observers are often resting during ferry portions of surveys. The large and generally consistent number of hrs. flown during calving ground surveys allow indices of sightings (e.g. number of wolves observed per 100 hrs. or 1,000 hrs.) that can be used to examine long-term trends (e.g. Heard et al. 1990, Heard 1992). As calving ground surveys occur after muskox calving, they also indicate percent calves in the muskox population observed at 2-3 weeks of age.

Criteria to end transects

Criteria to end transects should be established prior to the survey, and may vary with specific survey objectives. Criteria may differ among boundaries of the calving grounds, as in many herds the southern edge may contain a trailing distribution of breeding females, whereas the northern (leading) edge may show a more abrupt break in caribou density. At the northern edge a criterion of no breeding females (antlered cows or calves; Johnson et al. 2008) or no caribou (Nishi et al. 2007) within a segment could be considered, while on the southern edge the criterion could be no caribou within a segment as a conservative approach, or <5-10 hard antlered caribou unless a calf was present (Nishi et al. 2007, Johnson et al. 2008). Among Inuvik herds in 2008 a criterion of flying 20 km past the last breeding group was used (Davison et al. 2008). On north-south oriented lines, criteria on eastern and western edges to terminate the survey could be the absence of breeding females along one or two entire transects (Davison et al. 2008, Johnson et al. 2008).

Suggestions to determine peak of calving

To estimate peak of calving, during all flights emphasis should be placed on determining the estimated proportion of calves in the concentrated calving area along with the estimated group size (tabulated either as breeding females or 1+-year-old caribou) (Nishi et al. 2007). If 1+ aged caribou (all non-calves) are recorded and further classification from the flight is not available, an estimate of the proportion of breeding females that had calved at that point can be determined if composition data are subsequently collected (Nishi et al. 2007). Data from any sequential flights within the concentrated calving area can be used to examine the trends in percent calves and percent females with hard antlers.

Flight time

Flight times are useful records of the total number of hrs. flown (for budgeting), and as a base indicator of effort (hrs. on transect). They should be recorded such that time used for positioning aircraft, reconnaissance surveys, time on ferry to and from transects, and time on transects can be calculated. Time on transect is the most consistent metric that can be used.

Post-flight analysis

At the end of each flight or day, waypoint and track log files should be downloaded to a laptop computer and backed up. Waypoint files can then be imported into a Microsoft Excel spreadsheet and the waypoint coordinate data (number, latitude and longitude or UTM coordinates, date and time) appended to the observation data. Latitude and longitude should be entered for ease of exporting to GIS (e.g. -121, not 121W). Care should be taken that day and month cannot be confused (e.g. 06-07-2011 could be 7 June or 6 July depending on format). Segment number can be associated with the waypoint observations at this time. It is essential to plot survey data (e.g. on National Topographic Series (NTS) 1:250,000 scale digital maps in OziExplorer or similar mapping program) to analyze patterns of caribou density and composition, and to plan work for the following day. Hard copy maps (1:250,000 or 1:500,000 scale) with transect lines, fuel caches, camps, etc. should be printed, along with a hard copy of the day's flight and previous observations. Details on summarizing and mapping observations are provided in Gunn et al. (2005) and Taylor (2009).

It is difficult to accurately and consistently identify breeding females during calving ground distribution surveys. There is no one perfect answer to summarize the actual number of breeding females observed, as the degree of classification from the air depends on prioritized survey objectives and on aircraft speed and caribou density, so will vary among surveys. Furthermore, the proportions of cows with hard antlers, non-antlered cows, and calves changes over the course of days relative to the timing of peak of calving, if indeed peak of calving can be accurately determined. Basing any counts of breeding females on number of calves seen is admittedly prone to large undercount bias.

We therefore suggest using all cows (hard antlered and non-antlered) when any hard antlered cows or calves are present. This is a simple rule, and relative to the phenology of antler drop and calf mortality, appears to be the best compromise to identify/quantify groups of "breeding females". Breeding females should be considered for each group observed rather than the segment summary. Examining past data, it is apparent that there will likely be a few cases where the number of "breeding females" might be inflated (e.g. a group with few hard-antlered cows, lots of non-antlered cows, no calves). There will also be some cases of groups with non-antlered cows but calves present, one reason why just using hard-antlered cows as an indication of breeding females is biased. This will therefore assign some non-breeders to the "breeding female" group and somewhat inflate numbers, but the other options appear to undercount and provide negatively biased estimates of breeding females.

Trends in adults (or breeding females) on the calving grounds can be conducted by comparing mean counts of caribou (adults, breeding females, etc.) observed in segments among years (Boulanger 2010), or by extrapolating density of caribou within segments to the area surveyed (Adamczewski et al. 2009). To approximate an estimate of breeding females on the calving ground based on the visual systematic reconnaissance surveys (with no bias correction), Adamczewski et al. (2009) multiplied density estimates for each transect segment (provided as caribou/km^2) by 100 to extrapolate the observed density within a transect segment to an expanded 10 km x 10 km cell surrounding the segment. These estimates were then summed for all 100 km^2 cells within the delineated calving ground. A similar formula could be used for 5 km segments at 5 km transect spacing (surrounding cell size 25 km^2; Inuvik herds), or when transect spacing is 20 km (10 km segments, thus 200 km^2 cell size).

In some cases, mainly recent surveys of the Beverly calving ground, a number of flights over potential calving grounds occur, and the actual calving ground may be surveyed twice in a single season. Which flights are used for analysis of breeding female distribution will depend upon the survey objectives, whether the flights were reconnaissance level or more intensive, and timing relative to peak calving.

Report production, databases, and mapping products

Report

At minimum, a summary report of each calving ground distribution survey should be completed. The report would provide enough detail for managers and researchers to interpret what was done, why it was done, and the essential results. Summary reports should be produced in a timely manner, while detailed analysis is reserved for more in-depth file reports if required. But the report should include sufficient detail to allow for interpretation and further analysis by others at some future date. Standardization of the information reported is necessary to enable long-term trend determination if desired. These reports can be completed in point form with tables where appropriate, and should include the following:

- Background, with objectives specified. Preparations for the survey should be noted (e.g. collar monitoring).
- Classification used during the survey, including specific clarification on whether 1+ adults or detailed composition were collected (hard antlered, non-antlered, calf, etc.; see Figure 20). It should be very clear what the surveyors considered groups with “breeding females”, as in some instances where detailed composition is not possible, data forms provide a “breeding female” column to be checked if calves are observed (but not counted), or if the presence or absence of calves were noted (but not counted). In some cases numbers of cows are noted (but not classified); these should be designated as a breeding group (hard antlers and/or calves observed) or not.
- Dates of the survey, broken down by what flying (reconnaissance, delineation survey, etc.) was done and when– this information could be in table format. To facilitate

interpretation, comments can added to clarify the cause of gaps in the survey period or partial flight days.

- Aircraft type(s) used.
- Transect spacing, and segment length. Rules used to terminate transect flights at the boundaries of the calving grounds should be clearly articulated.
- Flight times, summarized to total, and broken down to aircraft positioning, reconnaissance, on transect, and ferry (could be in table format).
- Weather conditions in general (with implications to the survey), but also recorded at minimum once per day at the start of survey or after drastic changes in conditions.
- Snow cover during the survey, at least generally described. Snow cover provides an indication of sightability and the progressions of melt and spring phenology.
- Indication of the peak of calving, and how this was determined.
- Observations should be summarized as on and off transect. Adult, 1+ year-old, and non-calf caribou should be considered synonymous terms.
- Clear, unambiguous terminology should be used (e.g. “approximately 300 breeding females were observed” rather than “major groups were observed”).
- Incidental sightings should be summarized (table form may be appropriate), and the number of flying hrs. used to collect incidental sightings should be clearly provided. Location data for incidental sightings should also be provided.
- Some discussion comparing the results with previous surveys could be presented.
- Maps showing at minimum flight lines and distribution of breeding female groups by segment should be provided. More detailed maps can also be provided (e.g. distribution

of calves, distribution of non-breeders, incidental sightings), but are not essential; these data can be obtained from the digital databases if required.

- Acknowledgments listing survey personnel, aircraft company and personnel, funding sources, and other support should be provided.

Databases

At a minimum two databases of observations should be provided for each survey, the second (data summed by segment) can be generated from the first (data by waypoint). Data entry errors can be minimized by ensuring that the datasheets and database are designed with the same order of columns for hand entry. Observation data should be entered in a spreadsheet (assuming waypoint data were collected, and observations were not summarized by segment during the survey) with at minimum the following data: Year, date (again clarifying day and month or spelling out the month), waypoint, latitude, longitude, segment (or designation of ferry flight or not on survey), species, observer side, and on and off transect sets of columns for numbers of hard antlered cows, non-antlered cows, calves, yearlings, bulls, unknown adults, etc. Summed columns may also be presented (e.g. total adults on transect, total breeding females on transect, etc.). Columns denoting a check for hard antlers and calves, or a breeding female group, or summing adults considered breeding females, at the waypoint level will facilitate data interpretation to the segment level. The waypoint database should include all incidental sightings. It is easier for summarizing to have the side (side of the aircraft of the observation) as a column with a L/R designation, rather than repeating all columns for the L and R sides. Do not use non-numeric data in spreadsheet columns [e.g. “14/4” (for 14 adults and four calves) or “100/Y” (for 100 adults with calves present)], as it is impossible to quickly summarize in Excel or export to any statistical package without further formatting.

The second database should summarize caribou data by segment in a file that either provides centroid locations, or can be linked to the centroid file for mapping. Non-caribou and caribou observed off transect or during ferry flights should not be included. Mapping will be made easier if density (number/km^2) calculations on the number of 1+ adults, or cows, or breeding females, are provided as columns.

A worksheet in each spreadsheet file should contain simple metadata (data about data; an explanation of the variables in the database and how they were derived) to aid in interpretation of the columns. It should be clearly stated in this metadata worksheet what each column heading means and how it was derived (e.g. if a breeding female column was built, which columns were summed).

Mapping products

All mapping products such as shapefiles and rasters should include associated completed metadata files. Metadata files allow the spatial product to be linked easily to the databases and reports. Metadata becomes especially important when shapefiles get modified for analysis, presentation, or other purposes.

There are a number of analyses and mapping techniques that can be used to quantify or illustrate the density, dispersion and distribution of breeding females observed during these surveys. Here we provide some suggested examples, but caution that more work is required to determine which techniques are most appropriate and can be used by researchers in all offices. We have strived to suggest mapping techniques that require a minimum of decision-making and background knowledge regarding mapping parameters. We suggest that examination of trends in density, dispersion, and distribution among years within each herd is more important than comparisons between or among herds. It is important that once standardized, labels and symbols should be similar among years.

Density

A simple comparison of density between years can be conducted by comparing the number and proportion of density classes over time (Table 3 for Ahiak and Bathurst as an example).

To portray changes in density over time, we suggest using the Kappa Index of Agreement (KIA) to examine agreement between years in where high, moderate, and low-density segments occur. This is a simple analysis requiring no assumptions or decisions. Further information is available at: www.spatialanalysisonline.com/output.

Table 3. Number and proportion of segments containing breeding females of low, moderate, and high density classes, Ahiak and Bathurst calving grounds, 2007 and 2008.

Herd	Segment density of breeding females	2007 segment density (% of occupied segments)	2008 segment density (% of occupied segments)
Ahiak	Low	57 (34%)	95 (53%)
	Moderate	95 (57%)	81 (46%)
	High	14 (8%)	0 (0)
	Total	166	178
Bathurst	Low	11 (41%)	14 (56%)
	Moderate	11 (41%)	9 (36%)
	High	5 (19%)	2 (8%)
	Total	27	25

The KIA is of the form:

$K = (Po - Pe)/(1 - Pe)$

where:

Po is the observed proportion of density classes that have not changed between 2007 and 2008. (In a cross-tabulation table Po is the sum of all the diagonal values - those that did not change- divided by the total number of cells).

Pe is the expected proportion of change due to chance.

Hence *Po* is simply the sum of the diagonal elements divided by the overall total number of cells, and *Pe* is computed in a similar manner to the expected values for a Chi-square calculation, with each element being summed. The Kappa index may be disaggregated into density classes by examining the row-wise expectations.

An example for the Ahiak surveys is provided (Table 4, Figure 21). This analysis was performed using Idrisi GIS software (Clark Labs, Worcester, MA), and was also computed using the SAS statistical package (SAS Institute Inc., Cary, NC). There is an extension for ArcView (ESRI, Redlands, CA) that will compute the Kappa statistic (www.jennessent.com/arcview/kappa_stats.htm), and we believe it can be calculated using more recent Arc software.

The overall KIA for the Ahiak surveys is 0.4913. The KIA for the "high" class in 2008 is zero because there were no high-density centroids. To judge the strength of the agreement, we used the classification by Landis and Koch (1977) (<0 - poor; 0 to 0.2 - slight; 0.21 to 0.4 - fair; 0.41 to 0.6 - moderate; 0.61 to 0.8 - substantial; 0.81 to 1.0 - almost perfect) to conclude there was moderate agreement between years.

Table 4. Example of use of Kappa Index of Agreement (KIA) for the 2007 and 2008 Ahiak surveys. The overall KIA is 0.4913.

Density class	2008 as the reference image	2007 as the reference image
None	0.699	0.648
Low	0.223	0.388
Moderate	0.414	0.350
High		0.0

Dispersion

We suggest using the Relative Richness Index (Turner 1989) to examine the dispersion of breeding females. The Relative Richness Index (R) is a fairly simple analysis:

$$R = n/n_{max}*100$$

where n = number of different classes present in the kernel

n_{max} = maximum number of classes in entire image

In our case we have four density classes (not observed, low, moderate and high), and we used a 3x3 and 5x5 kernel (30 km x 30 km, and 50 km x 50 km - for 10 km spaced grids) (Figure 22). This index gives us a measure of how patchy or variable density distribution is at different scales. Using the example of the Ahiak 2007 survey, three to four areas of high density can be seen in the calving ground at the 3x3 kernel scale, which blends to two main high-density areas at a 5x5 kernel scale (Figure 22). This mapping is available in ArcGIS.

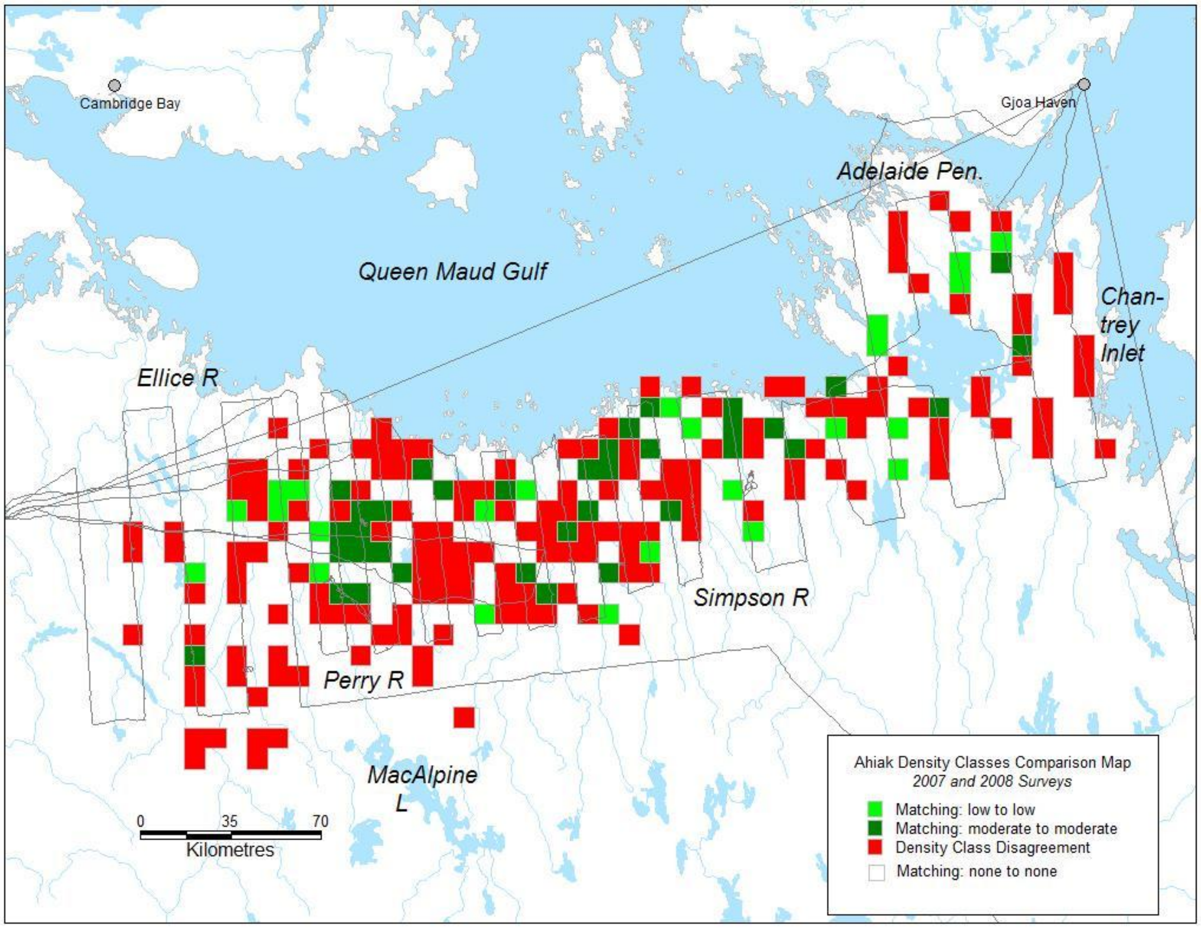

Figure 21. Comparison of breeding female caribou density classes per segment for Ahiak surveys during 2007 and 2008 using Kappa Index of Agreement.

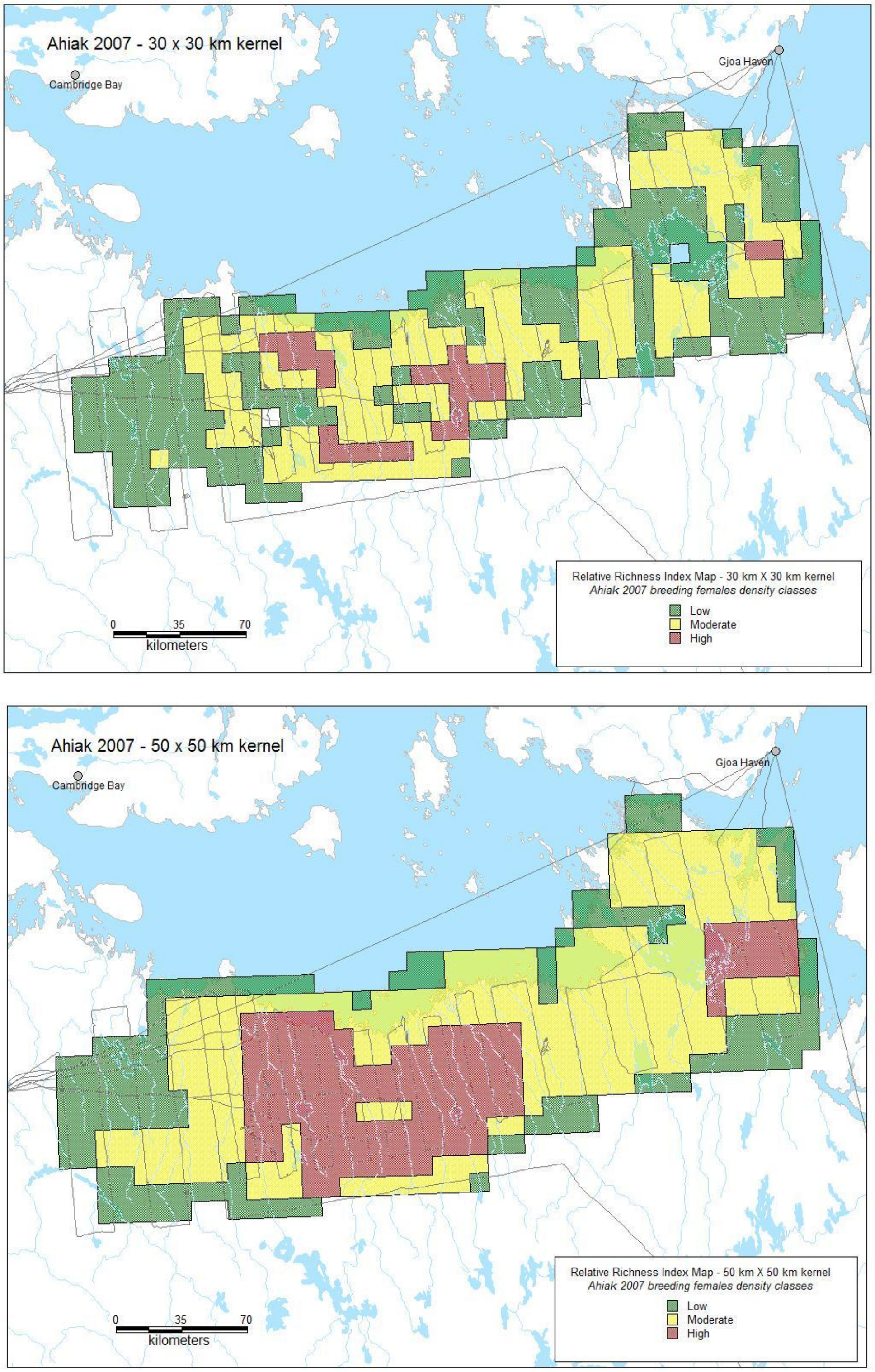

Figure 22. Relative Richness Index maps for the Ahiak 2007 survey, showing examples of a 30x30 km kernel (upper figure), and a 50x50 km kernel (lower figure).

Distribution

We suggest that Inverse Distance Weighted (IDW) interpolation is straight forward to use and has good success if the measured data have a tendency for autocorrelation (as is the case with observed caribou numbers), as it assumes that the variations in the surface being predicted (caribou density distribution) depend on, or are defined by the neighbouring density values. This link: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=How_Inverse_Distance_Weighted_(IDW)_interpolation_works, provides an excellent description of the technique. IDW produces predicted surfaces of similar quality, which is particularly true for caribou surveys as they are generally based on regularly spaced grids.

Although further experimentation may be required, the overall annual survey density maps (Figures 1, 2) and an example of the Ahiak 2007 survey (Figure 23) provides examples of the technique and output. For the cumulative annual survey maps we used an 5x5 km pixel (lowest common spatial denominator for all the surveys), exponent of two, and a search radius of 20 km that caused the surface to "bleed" slightly outside of the transects area. For the Ahiak 2007 map, we used a 10x10 km pixel, exponent of two, and a search radius of 15 km. The size of the pixel has a bearing on not only the spatial resolution of the map, but also influences the actual density values calculated; the greater the pixel size the smaller the overall density. By varying these parameters one has control on the level of generalization of the final density map.

Note that these IDW maps were created in MapInfo only for data visualization, and we were unable to generate contours based on these maps or calculate how much area a given density range occupies. These options are available in ArcGIS.

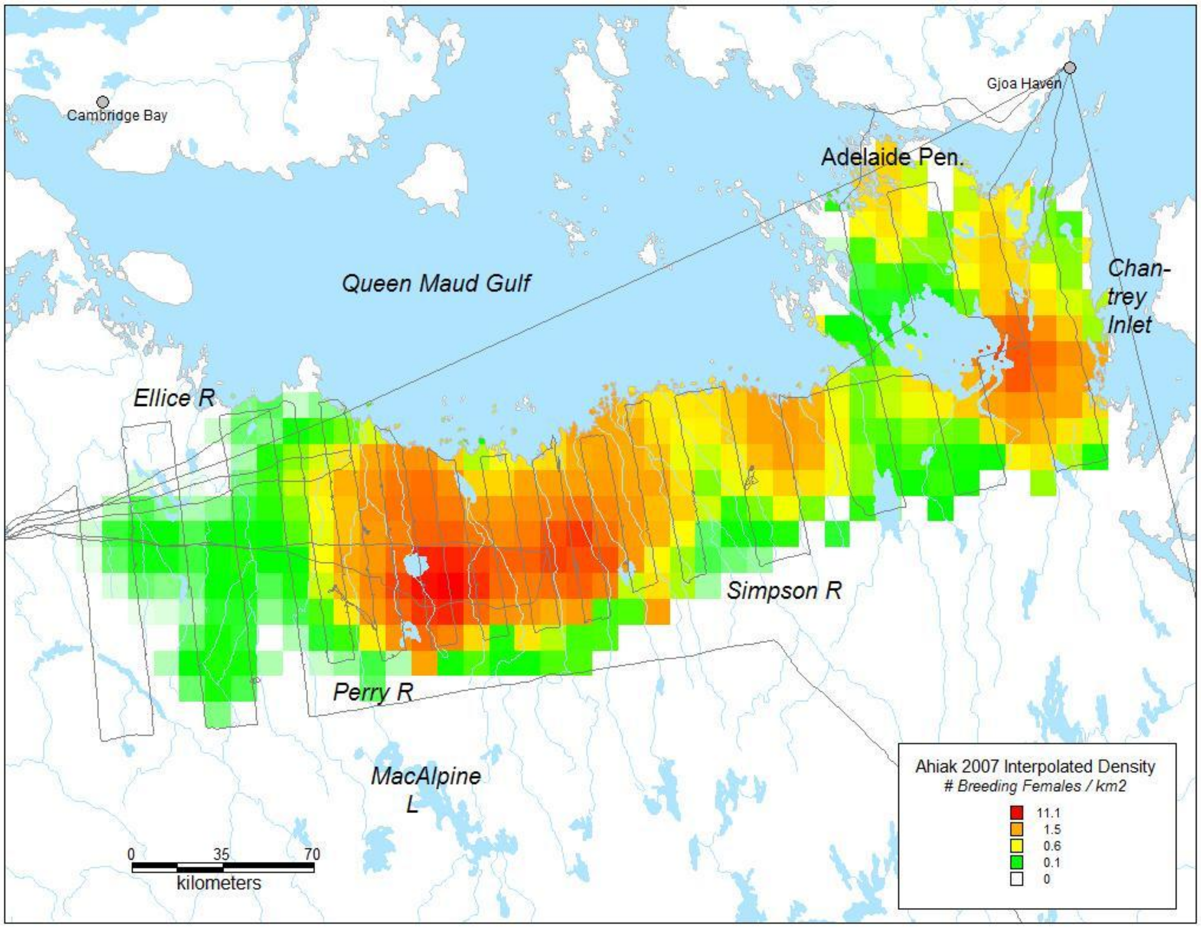

Figure 23. Distribution of breeding female caribou observed during the Ahiak survey flown in June 2007. Relative density conducted using Inverse Distance Weighting (IDW) mapping interpolation using a 10x10 km pixel, exponent of 2, and a 15 km search radius.

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LITERATURE CITED

Adamczewski, J. 2007. Summary: 2007 Barren-ground Caribou Calving Distribution Surveys, Northwest Territories & Nunavut. Environment and Natural Resources, Government of the Northwest Territories, unpublished report. 18pp.

Adamczewski, J., J. Boulanger, B. Croft, D. Cluff, B. Elkin, J. Nishi, A. Kelly, A. D'Hont, and C. Nicolson. 2009 *In prep*. Decline in the Bathurst caribou herd 2006-2009: a technical evaluation of field data and modeling. Environment and Natural Resources, Yellowknife, NWT.

BCMPC (Bathurst Caribou Management Planning Committee). 2004. A management plan for the Bathurst Caribou herd. Environment and Natural Resources Wildlife Division, Yellowknife. 51pp.

Bergerud, A.T. 1975. The reproductive seasons on Newfoundland caribou. Canadian Journal of Zoology 53(9):1213-1221.

Bergerud, A.T., S.N. Luttich, and L. Camps. 2008. The return of caribou to Ungava. McGill-Queen's University Press, Montreal, Québec. 656pp.

Boulanger, J. 2010. Estimates of trend for the Ahiak caribou herd 2006-2009. Unpublished report for Environment and Natural Resources, Yellowknife, NWT.

BQCMB (Beverly and Qamanirjuaq Caribou Management Board). 2005. Beverly and Qamanirjuaq caribou management plan 2005-2012. BQCMB Secretariat, Box 629, Stonewall, Manitoba. 17pp.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2004. Advanced distance sampling - estimating abundance of biological populations. Oxford Press.

Caikoski, J.R. 2009. Porcupine caribou herd calving and post-calving surveys, June-July 2009. Memorandum, Alaska Department of Fish And Game, Division Of Wildlife Conservation, Fairbanks, Alaska.

Campbell, M., J. Nishi, and J. Boulanger. 2010. A calving ground photo survey of the Qamanirjuaq migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) population - June 2008. Technical Report Series 2009 - No. 1-10. Department of Environment, Nunavut Wildlife Service, Arviat, NU.

Campbell, M., J. Boulanger, D.S. Lee, M. Dumond, and J. McPherson. 2012. Calving ground abundance estimates of the Beverly and Ahiak subpopulations of barren-ground caribou (*Rangifer tarandus groenlandicus*) - June 2011. Technical summary to be replaced by Technical Report Series - No: 03-2012, Government of Nunavut. 111pp.

Davison, T., R. Popko, and W. Wright. 2007. An aerial survey of barren-ground caribou calving grounds Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose-West herds, June 2007. Environment and Natural Resources, Inuvik region, Inuvik, unpublished report. 8pp.

Davison, T., B. Milakovic, and W. Wright. 2008. An aerial survey of barren-ground caribou calving grounds: Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose-West herds, June 2008. Environment and Natural Resources, Inuvik region, Inuvik, unpublished report. 11pp.

Fancy, S.G., and K.R. Whitten. 1991. Selection of calving sites by Porcupine herd caribou. Canadian Journal of Zoology 69:1736–1743.

Fisher, J.T., L.D. Roy, and M. Hiltz. 2009. Barren-ground caribou management in the Northwest Territories: an independent peer review. Alberta Research Council, Sustainable Ecosystems Unit, Ecological Conservation Management Program, Vegreville, Alberta, Canada.

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.

Gunn, A., and M. Sutherland. 1997. Surveys of the Beverly caribou calving grounds, 1957-1994. Resources, Wildlife and Economic Development, Government of the Northwest Territories. File Report. No. 120. 119pp.

Gunn, A., and A. D’Hont. 2003. Extent of calving for the Bathurst and Ahiak caribou herds June 2002. Resources, Wildlife and Economic Development, Government of the Northwest Territories. Manuscript Report No. 149. 35pp.

Gunn, A., and K.G. Poole. 2010. Environmental trends across the range of the Bathurst caribou herd and timing of the arrival of cows on their calving ground 1996-2009. Unpublished report for Environment and Natural Resources, Government of the Northwest Territories, NT, Canada. 34pp.

Gunn, A., J. Dragon, and J. Nishi. 1997. Bathurst calving ground survey 1996. Resources, Wildlife and Economic Development. Government of the Northwest Territories. File Report No. 119. 80pp.

Gunn, A., B. Fournier, and J. Nishi. 2000. Abundance and distribution of the Queen Maud Gulf caribou herd, 1986-98. Resources, Wildlife and Economic Development, Government of the Northwest Territories. File Report. No. 126. 76pp.

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.

Gunn, A., J. Nishi, J. Boulanger, and J. Williams. 2005. An estimate of breeding females in the Bathurst herd of barren-ground caribou, June 2003. Northwest Territories Department of Resources, Wildlife and Economic Development. Manuscript Rep. 164. 75 pp.

Gunn, A., K.G. Poole, J. Wierzchowski, and M. Campbell. 2007. Assessment of caribou protection measures. Unpublished report for Indian and Northern Affairs Canada, Gatineau, Québec. 41pp.

Gunn, A., K.G. Poole, and J. Wierzchowski. 2008. A geostatistical analysis for the patterns of caribou occupancy on the Bathurst calving grounds 1966-2007. Unpublished report prepared for Indian and Northern Affairs Canada, Yellowknife, NWT. 50pp.

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

Heard, D.C. 1992. The effect of wolf predation and snow cover on musk-ox group size. American Naturalist 139:190-204.

Heard, D.C., F.J. Jackson, and T.M. Williams. 1990. Beverly calving ground survey 2-14 June 1987. Renewable Resources, Government of the Northwest Territories. File Report No. 22. 118pp.

Johnson, D., and J. Williams. 2008. Beverly herd of barren-ground caribou: calving ground survey, June 2008. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, unpublished draft.

Johnson, D., J. Nagy and J. Williams. 2008 *In prep*. Calving ground surveys of the Ahiak herd of barren-ground caribou June 2006-2008. Environment and Natural Resources, Government of the Northwest Territories.

Johnson, D., and R. Mulders. 2009. Beverly calving ground survey June 2002. Environment and Natural Resources, Government of the Northwest Territories. Manuscript Report No. 188. 63pp.

Johnson, D., A. Gunn, J. Nagy, and J. Williams. 2007. Beverly herd calving ground survey, June 2007. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Manuscript Report (unpublished).

Johnson, D., J. Nagy, and J. Williams. 2008. Calving ground surveys of the Ahiak herd of barren ground caribou June 2006-2008. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, draft.

Kelleyhouse, R.A. 2001. Calving ground habitat selection: Teskekpuk Lake and Western Arctic caribou herds. MS thesis, University of Alaska, Fairbanks, Alaska. 140pp.

Landis, R.J., and G.G. Koch. 1977. The measurement of observer agreement for categorical data. Biometrics 33:159-174.

Nagy, J.A., W.H. Wright, T.M. Slack, and A.M. Veitch. 2005. Seasonal ranges of the Cape Bathurst, Bluenose-West, and Bluenose-East barren-ground caribou herds. Environment and Natural Resources, Government of the Northwest Territories. Manuscript Report No. 167. 43pp.

NBGCS (Northwest Territories Barren-ground Caribou Summit). 2007. Caribou forever – our heritage, our responsibility. Meeting in Inuvik, January 23-26, 2007. Environment and Natural Resources, Government of the Northwest Territories. 51pp.

Newman, D. 2006. OziExplorer GPS Mapping Software, v. 3.95.5g [Online] URL: http://www.oziexplorer.com/ Accessed 10 Jan 2010.

Norton-Griffiths, M. 1978. Counting animals: Serengeti Ecological Monitoring Program Handbook No. 1. African Wildlife Leadership Foundation, Nairobi, Kenya. 110pp.

Nishi, J., B. Croft, J. Williams, J. Boulanger, and D. Johnson. 2007. An estimate of breeding females in the Bathurst herd of barren-ground caribou, June 2006. Environment and Natural Resources, Government of the Northwest Territories. File Report No. 137. 117pp.

NTBCMS (Northwest Territories Barren-Ground Caribou Management Strategy). 2006. Caribou forever – our heritage, our responsibility. A barren-ground caribou management strategy 2006-2010. Environment and Natural Resources, Government of the Northwest Territories. 38pp.

Russell, D.E., A.M. Martell, and W.A.C. Nixon. 1993. Range ecology of the Porcupine caribou herd in Canada. Rangifer Special Issue 8 168pp.

Russell, D.E., G. Kofinas, and B. Griffith. 2002. Barren–Ground caribou calving ground workshop: report of proceedings. Canadian Wildlife Service, Ottawa, Ontario. Technical Report Series No. 390. 39 pp.

Skoog, R. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph.D. thesis. University of California, Berkley. 699p.

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

Taylor, D. 2009. Survey procedures. Revision 1.0. Unpublished report for Environment and Natural Resources, Yellowknife, NWT.

Thomas, D. 1969. Population estimates and distribution of barren-ground caribou in MacKenzie District, NWT, Saskatchewan and Alberta- March to May, 1967. Canadian Wildlife Service. Report Series No. 9.

Thorpe, N., N. Hakongak, S. Eyegetok, and the Kitikmeot Elders. 2001. Thunder on the tundra: *Inuit Qaujimajatuqangit* of the Bathurst caribou. Generation Printing, Vancouver, British Columbia. 208pp.

Tracz, B. 2008. Summary of an aerial survey delineating the Bluenose-East barren-ground caribou herd calving grounds, June 2008. Unpublished report. 7pp.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics 20:171-197.

Whitten, K.R. 1995. Antler loss and udder distension in relation to parturition in caribou. Journal of Wildlife Management 59:273-277.

Williams, T.M. 1994. Manual for conducting photographic calving ground surveys in the N.W.T. Unpublished report. Renewable Resources, Government of the Northwest Territories.

Williams, M. 1995. Beverly calving ground surveys, June 5-16, 1993 and June 2-13, 1994. Renewable Resources, Government of the Northwest Territories. File Report No. 114. 36pp.

APPENDIX 1: KRIGING

Johnson et al. (2008) provided the following description of kriging:

“The ordinary kriging prediction map method using the Geostatistical Analyst extension in ArcGIS 9.1 was used to model the distribution of breeding females and calves on the calving grounds near peak of calving. We used a heuristic approach to select the best-fit semivariogram model (circular, spherical, tetraspherical, pentaspherical, exponential, gaussian, rational quadratic, hole effect, K-Bessel, J-Bessel, stable). Kriging as a predictor does not require that data have a normal distribution (Johnston et al. 2003). When considering only predictors that are formed from weighted averages, kriging is the best unbiased predictor of whether or not your data is normally distributed (Johnston et al. 2003). Ordinary kriging has remarkable flexibility as it can use either semivariograms or covariances, it can use transformations and remove trend, and can allow for measurement error (Johnston et al. 2003).

Kriging was carried out using the estimated breeding female and calf density values (number of cows or calves per km^2) at the centroids of the 10km transect segments; transect segments that were not flown were coded as “9999”. We used a second order trend removal for all models. Lag size was set at one-third of the largest distance between the data points divided by the number of lags (lag number was set at 12). This consideration was based on a rule of thumb that states that the lag size times the number of lags should be less than one half of the largest distance in the database (Johnston et al. 2003, Sarangi et al. 2005, 2006). The corresponding sill, nugget, and range values were observed for the different model types. The presence of isotropy and anisotropy in the data were observed in the variogram fitting (Sarangi et al. 2005, 2006). We used a search neighbourhood of five data points, with a minimum of two included, and an eight sector circular neighbourhood.

Generally, the best model was selected as the one that had the standardized mean nearest to zero, the smallest root-mean-square prediction error, the average SE nearest the root-mean-square prediction error, and the root-mean-square standardized prediction error nearest to one (Johnston et al. 2003).

We used a cell size of 1000 m to create the output raster, as once the semivariogram is estimated (i.e., the best model), a smaller cell size can be used in creating the actual output raster (ESRI 2007). The output raster was then reclassified into the following density classes (calves or breeding females per km^2): cells with density values of <0.125 cow or calf per km^2 were given a value of 0, low, medium, and high density cells were labeled as cow/calf densities of 0.125-1.0, 1.0-10.0, and >10.0 cow or calf per km^2, respectively. We applied a spatial mask to limit these analyses to the boundaries of the survey area."

ESRI (Environmental Systems Research Institute). 2007. How krige and variogram work. ArcGIS 9.2 Desktop Help. 5 pp.

Johnston, K., Hoef, J.M.V., Krivoruchko, K., and Lucas, N. 2003. Using ArcGis geostatistical analyst, GIS user Manual by ESRI, New York. 306pp.

Sarangi, A., C.A. Cox, and C.A. Madramootoo. 2005. Geostatistical methods for prediction of spatial variability of rainfall in a mountainous region. Transactions of the American Society of Agricultural Engineers 48:943-954.

Sarangi, A., C.A. Madramootoo, and P. Enright. 2006. Comparison of spatial variability techniques for runoff estimation from a Canadian watershed. Biosystems Engineering 95:295-308.

APPENDIX 2: SUGGESTED FIELD DATA FORM

Survey:	Altitude: m agl	Strip width:	Jun 20__
A/C:	Pilot:		
Weather:			Page of
Recorder:		Location:	
Observers: L		Entered as file:	
R			

Transect	Way point	Obs L/R	ON/ OFF	*Ad*	Ca	CA √	HA	HA √	Non Ant	Yrlg	Bull	SC	*Unkwn*	*Comments, Time, Predator, M-ox, etc*

Transect (or segment or ferry); Obs L/R (left or right observer); For ON/OFF transect: use N (on) or F (off); Ad (Adult); Ca (calves); HA/CA (hard antlered females/calves) √: To signify observed if not counted (breeding female); Non Ant (non-antlered females); Yrlg (yearling); SC: snow cover (%); Unkwn (unknown adult); Clearly note *Bear*, *Wolf*, *M-ox*, etc. in Comment field.