A Calving Ground Photo Survey of the Qamanirjuaq Migratory Barren-Ground Caribou (*Rangifer tarandus groenlandicus*) Population – June 2008

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ABSTRACT

We estimated abundance of breeding females in the Qamanirjuaq migratory barren-ground caribou population with a calving ground photographic survey in June 2008. We used a systematic survey to delineate and stratify the annual calving ground based on observed densities and relative composition of caribou within strip transects. Aerial photography was then used to estimate 1^{+}-year-old caribou on strip transects in high and medium strata, whereas visual counts of caribou on transect were used to estimate abundance in low density strata. We used data from composition surveys conducted on the calving ground to estimate the proportion of breeding females in each stratum. The estimates of all 1+-year-old caribou from photographic and visual strata (Yh) was multiplied by the respective breeding proportions to obtain estimates of breeding females for each stratum.

The estimate of breeding females is the best indicator of population size since all necessary parameters are estimated directly during the calving ground surveys. However, for management purposes a total population estimate is also desired. To estimate the total population size the number of breeding females (155,154; SE = 13,558; CV = 0.0874) was divided by the proportion of females in the population and the proportion of females that were pregnant. The proportion females in the population (including yearlings (assuming a 50:50 sex ratio of yearlings) was estimated from fall composition surveys. A total of 348,661 (SE = 44,861; CV = 0.129) were estimated The proportion females pregnant is not immediately known and the same proportion was used as in past Bathurst caribou surveys (Gunn et al. 2005).

Key words: Calving ground photographic survey, Caribou calving ground, Kivalliq region, Barren-ground caribou, Qamanirjuaq herd, Nunavut, *Rangifer tarandus groenlandicus*, , population survey.

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1.0 INTRODUCTION

The Qamanirjuaq barren-ground caribou population is the largest population of caribou in Nunavut. There are no records of a delineated calving ground for the Qamanirjuaq Herd prior to 1947 (Fleck and Gunn, 1982). The first reports of a possible calving ground in the vicinity of Qamanirjuaq Lake came in 1947 when Turner observed many dead newborn calves in the area (Banfield, 1951). Further evidence collected by Lawrie (1948) from local hunters as well as observations of pregnant females made by McEwen (1960) in the vicinity of Carr Lake suggested a calving area between Qamanirjuaq and Maguse Lakes. It was not until 1963 that a survey, flown by Malfair (1963), defined the first extents of the Qamanirjuaq calving ground.

The first Qamanirjuaq calving ground photographic survey was flown June 1983 and estimated 230,000 (SE = 59,000; 90% CI = 126,000 to 334,000; CV = 0.258) animals in the population (Heard & Jackson, 1990a; Williams, 1995; Heard & Jackson,1990b; Crete *et al*., 1991; Couturier *et al*., 1996). Two years later in June 1985 the population was similarly estimated at 272,000 (SE2 = 142,000; 90% CI = 22,000 to 522,000; CV = 0.523) (Heard & Jackson, 1990a; Williams, 1995; Heard & Jackson,1990b; Crete *et al*., 1991; Couturier *et al*., 1996). In June 1988 a third photo survey estimated 221,000 caribou (SE2 = 72,000; 90%CI = 94,000 to 349,000; CV = 0.328) (Heard & Jackson, 1990a; Williams, 1995; Heard & Jackson,1990b; Crete *et al*., 1991; Couturier *et al*., 1996).) . Prior to the present survey the last calving ground photo survey was flown in June 1994 and estimated 496,000 caribou (SE2 = 105,000; 90%CI = 310,000 to 682,000; CV = 0.213) (Unpublished). All of the above surveys were flown using photographic and visual stratified strip transect methods.

There was concern at the time of these surveys that the estimates generated between 1982 and 1994 were imprecise and thus inadequate for management

(Thomas, 1998). Since this time, several annual meetings had been held by the Beverly and Qamanirjuaq Caribou Management Board (BQCMB) and a focused meeting "Barren-ground caribou calving ground photography work shop" held in Yellowknife November 2000 to address this imprecision. All participants in these strategic meetings concluded that; 1) the deployment of more collars on caribou prior to a survey were necessary in order to increase the precision of these surveys; 2) more wide spread reconnaissance surveys were required to capture and quantify numbers of breeding females not making it to the calving grounds; and 3) photographic coverage of high and medium density stratums should be increased. All these recommendations are now followed when conducting calving ground photo surveys in the Northwest Territories and Nunavut.

Our goal was to incorporate recommended modifications into the 2008 Qamanirjuaq Calving Ground Photographic survey to improve accuracy and precision to a point where trend analysis could be undertaken. In addition, collar distributions were examined up to and including the calving periods through collar reconaissance surveys to determine reliability of collars in locating breeding females.

The objectives of the 2008 June calving ground photographic survey were three fold:

1. estimate the numbers of breeding females on the annual Qamanirjuaq calving ground maintaining a coefficient of variation less than or equal too fifteen percent;
2. determine the trend in breeding female abundance on the traditional calving grounds between 1982, 1985, 1988, 1994 and 2008; and
3. 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.

2.0 STUDY AREA

Using annual location data collected from satellite and GPS collars between 1993 and 2008 we estimated the Qamanirjuaq caribou herd range to cover 310,000 km^2, (Figure 1). The study area was large and extends from the southern shores of Baker Lake and Chesterfield Inlet in the north to latitude 57 degrees north from northeastern Saskatchewan through northern Manitoba to the Hudson Bay coast. West to East the range extends from longitude 105 degrees west, east to the coast of Hudson Bay. The annual range covers four jurisdictions and includes seven communities; Manitoba (Brochet, Tadoule Lake), Saskatchewan (Black Lake, Wollaston), Northwest Territories (NWT) and Nunavut (Arviat, Whale Cove, Rankin Inlet, Baker Lake, Chesterfield Inlet). Most of the annual range including the calving, post-calving range, as well as the spring and fall migration corridors, lie entirely within Nunavut while the early mid and late winter range spreads across all four jurisdictions.

The Qamanirjuaq caribou annual range extends from the northern Arctic ecozone at its northeastern edge through the southern Arctic ecozone into its largest expanse in the taiga shield ecozone and ending with its southern tip within the boreal shield ecozone and at its southeastern tip within the Hudson plain ecozone (Environment Canada, 2001, Figure 2).

Qamanirjuaq caribou rarely range into the Northern Arctic Ecozone and are commonly seen within the Southern Arctic Ecozone during spring and summer. Within the Southern Arctic Ecozone, the Dubwant Lake Plain/Upland ecoregion forms the northwestern extents of the herds range and is primarily used by post calving caribou during the months of July and August (Environment Canada 2001, Figure 3) annual temperatures of approximately -10.5 ^{0}C with a summer mean of 6^{0}C and a winter mean of -26.5^{0}C. Mean annual

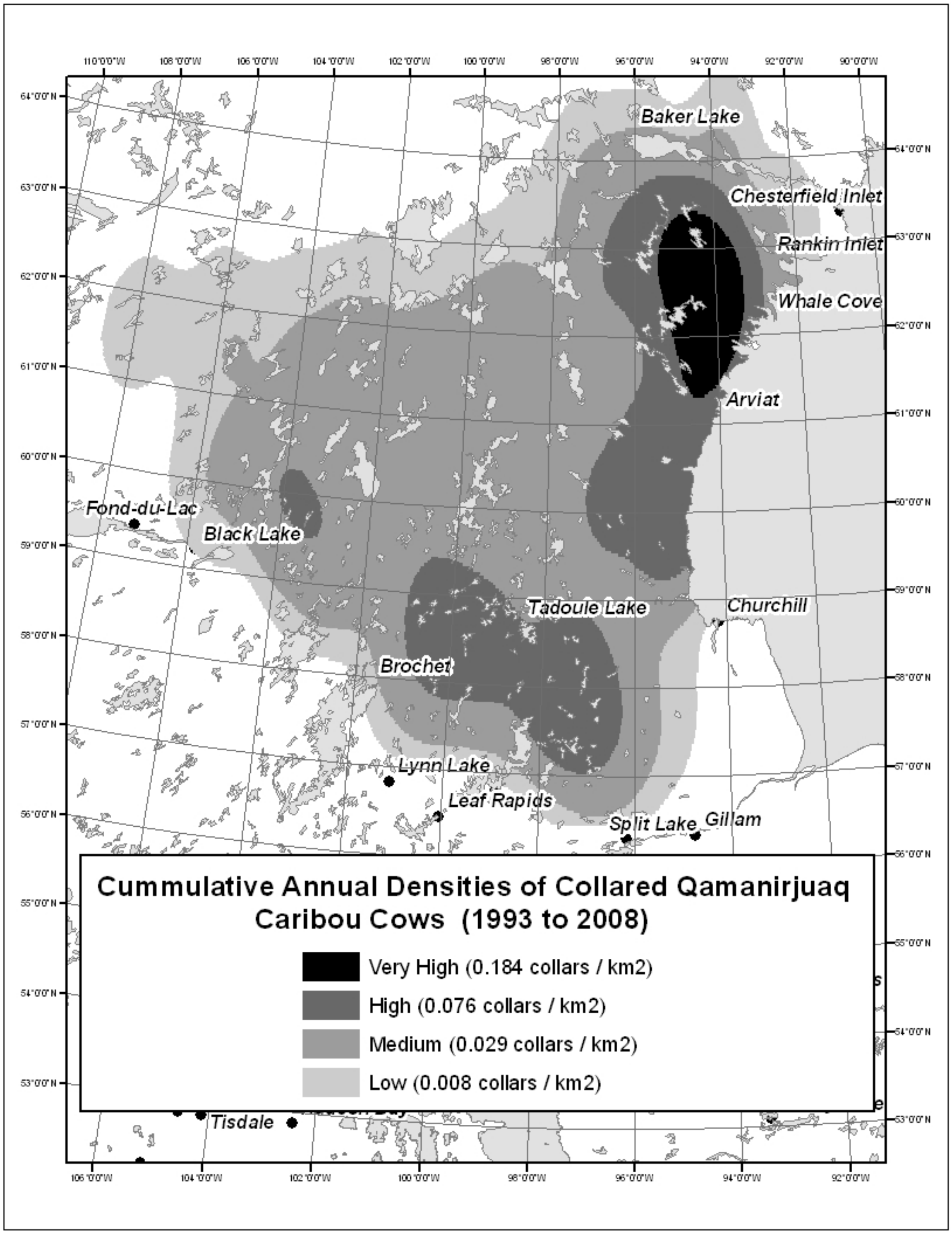

Figure 1 The range extents and annual densities of the Qamanirjuaq barren-ground caribou herd. Range extents were calculated using a kernel analysis of satellite and GPS collar data collected between November 1993 and April 2008.

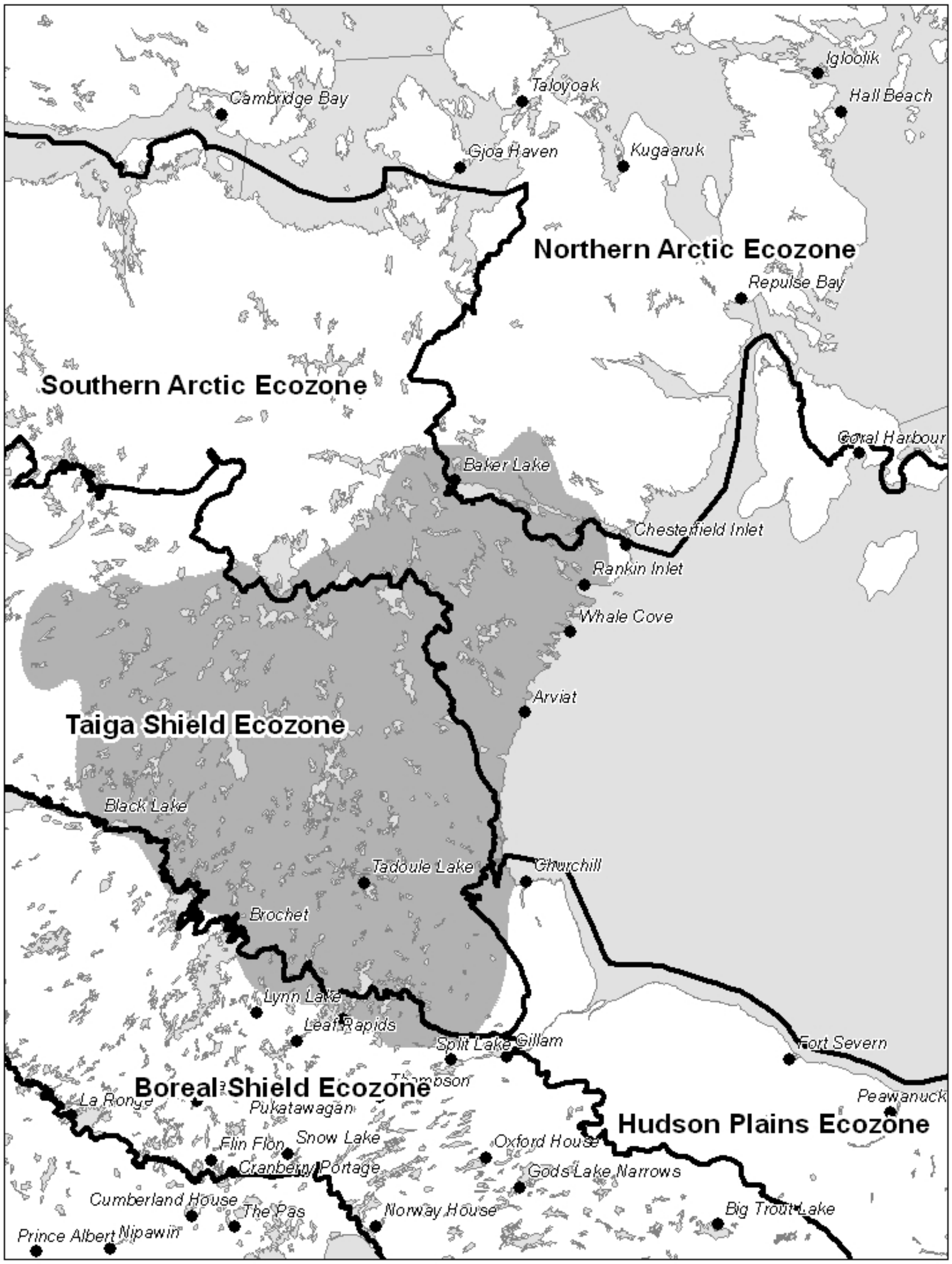

Figure 2 Ecozones of the Qamanirjuaq caribou herd annual range (1993 to 2008) (Environment Canada, 2009).

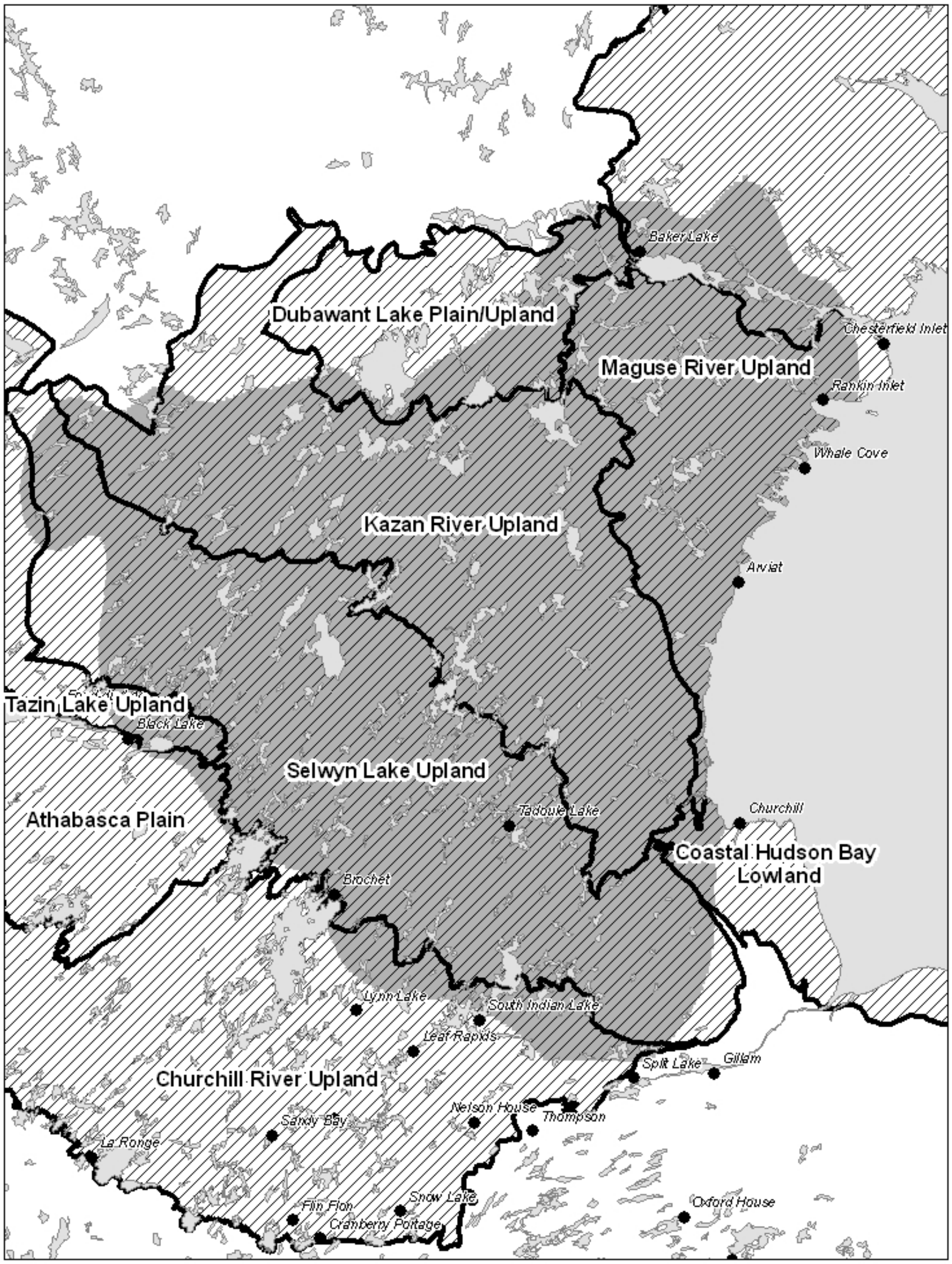

Figure 3 Ecoregions of the Qamanirjuaq caribou Herd annual range extents.

precipitation varies from 225-300mm. The Dubwant Lake Plain/Upland ecoregion is classified as having a low shrub arctic ecoclimate. It is characterized as having a nearly continuous cover of tundra vegetation, consisting of *Betula nana* (dwarf birch), *Salix* spp (Willow), *Ledum decumbens* (Labradoor tea), and *Vaccinium* spp. Tall shrubs including *Betula* spp (Birch), *Salix* spp and *Alnus crispa* (Alder) occur on warm sites while wet sites are dominated by *Salix* spp, *Carex* spp (Sedges) and moss. Sandy flats sparsely covered by vegetation characterize most of the surface of this region. Permafrost is continuous with low to medium ice content in the eastern extents of the region.

The Maguse River Upland Ecoregion is the dominant ecoregion making up much of the northern extents of the herds range through May, June, July and August. Traditional Calving grounds of the herd are entirely within this ecoregion including much of the post-calving range and spring migration corridor. The ecoregion is characterized by mean annual temperatures ranging from -8^{0}C in the south to -11^{0}C in the north. A mean summer temperature of 6^{0}C and a winter mean of -24^{0}C occur across the region. Mean annual precipitation varies from 250-400mm. The coastal climate is moderated by the open waters of the Hudson Bay during late summer and early fall. The ecoregion is classified as having a low arctic ecoclimate. It is characterized as having a cover of shrub tundra vegetation. *Betula nana*, *Salix* spp and *Alnus crispa* occur on warm dry sites while poorly drained sites are dominated by *Salix* spp, *Sphagnum* spp (Sphagnum moss) and *Carex* spp. The region is associated with areas of continuous permafrost with medium ice content. Hummocky bedrock outcrops covered with discontinuous, acidic, sandy, granitic tills are dominant. Prominent fluvialglacial ridges (eskers) and beach ridges occur. Wetlands make up 25% to 50% of the land area and are characterized by low and high centered polygon fens.

There are three ecoregions within the Taiga Shield ecozone; the Kazan River Upland, the Selwyn Lake Upland and Tazin Lake Upland. The Kazan River

Upland ecoregion roughly covers the middle third of the Qamanirjuaq caribou herd annual range. The eastern and southeastern portions of this ecoregion are used by the Qamanirjuaq herd primarily for post-calving (August), fall migration and rut (September and October). The western extents are used during most years as rutting habitat and during some years as early winter range. The Kazan River Upland is characterized by a mean annual temperature of approximately -8^{0}C with a mean summer temperature of 8^{0}C and a mean winter temperature of -24.5^{0}c. Mean annual precipitation ranges between approximately 200mm in the north to over 400mm in the south. This ecoregion is classified as having a high subarctic ecoclimate. It is part of a broad tract of taiga (tundra and boreal forest transition) extending from Labrador to Alaska. Dominant plants include stands of *Picea mariana* (Black spruce), *Picea glauca* (White spruce), *Larix laricina* (Tamarak) with a lower canopy of *Betula nana*, *Salix* spp, ericaceous shrubs and a ground cover of *Carex* spp, *Eriophorum* spp, fruticose lichens and moss. Drier sites are usually dominated by *Picea glauca*, ericaceous shrubs with a ground cover of moss and lichen while poorly drained sites largely support *Carex* spp, *Eriophorum* spp, and *Sphagnum* moss. In more open areas a low shrub tundra of *Betula nana* and *Salix* spp is more common. Ridged to hummocky bedrock outcrops covered with discontinuous sandy, granitic till are characteristic. Predominant eskers and small to medium sized lakes are common. Permafrost is mostly continuous with low to medium ice content grading to mostly discontinuous in the southern extents.

The Selwyn Lake Upland ecoregion dominates the southern extent of the ecozone and is used by caribou primarily during the late fall, winter and early spring (November through April). This ecoregion forms the southern extents of the Qamanirjuaq annual range. Mean annual temperatures are approximately -5^{0}C with a mean summer temperature of 11^{0}C and a mean winter temperature of -21.5^{0}C. The ecoregion is classified as having a low subarctic ecoclimate. As in the Kazan River Upland the Selwyn Lake Upland is part of the same broad tract of taiga (tundra and boreal forest transition) extending from Labrador to Alaska.

Stands of *Picea maraina* and *Picea glauca* are common and support ground covers of largely fruticose lichens and moss. Bog-fen communities are common and dominated by a *Picea glauca* canopy and ericaceous shrub and moss ground cover. Wetlands cover approximately 25% to 50% of the southeastern extents of the ecoregion largely consisting of moss, *Sphagnum* moss, *Salix* spp and graminoide communities including *Carex* spp.. Ridged to hummocky massive rocks form broad sloping uplands and lowlands and are covered with discontinuous acidic sandy tills. Prominent sinuous esker ridges and lakes are common throughout the region. Permafrost is extensive though discontinuous with low to medium ice content and sporadic ice wedges grading into sporadic discontinuous with low ice content into the regions southern extents. Qamanirjuaq caribou rarely extend their range into the Tzin Lake Upland ecoregion and then only during late winter.

Within the Boreal Shield ecozone Qamanirjuaq caribou have seldom used the Athabasca Plain and Churchill River upland ecoregions since 1993. The two ecoregions represent the southern and southwestern extremes of Qamanirjuaq winter range. The Coastal Hudson Bay lowland ecoregion within the Hudson Plains ecozone is most commonly used during late winter and at times during late fall. This ecoregion represents the southeastern extent of the Qamanirjuaq herd annual range receiving little use in some years and no use over most years.

3.0 METHODS

The 2008 Qamanirjuaq Caribou Herd Photographic calving ground survey was based entirely out of Rankin Inlet, Nunavut with periodic refueling stops in the community of Arviat, 300 km south of Rankin. The survey was structured into six main components: 1) Collar reconnaissance survey, 2) Systematic reconnaissance survey, 3) Photographic survey, 4) Visual Survey, 5) density stratum based composition surveys and 6) fall composition surveys. The collar, and systematic reconnaissance surveys were designed to determine the timing and distribution of calving as well as to stratify effort based on observed relative densities. The photographic, visual and composition surveys were used to estimate the number of breeding females on the annual calving ground while the fall composition survey was used to extrapolate the breeding female estimate to an estimate of the entire population by estimating the proportion of males to females.

Potential reconnaissance survey transects were distributed systematically over the northeastern third of the Qamanirjuaq caribou annual range covering an area of approximately 152,500 km² and encompassing the known extent of the annual concentrated calving area (Russell *et al,.* 2002) for the herd (Figure 4). This yielded a total of 40 transects spaced 10 kilometers apart. The transects were oriented north to south and were each 490 kilometers long, with the exception of those shortened where they intersected the coast line. Each transect had associated transect station points that were located at 10 kilometer intervals along the lines. Each station had an alpha-numeric identifier (i.e., S22) allowing each location to be easily referenced. The 10 kilometer segment between any two transect stations is termen a transect segment. Each transect segment was named for the transect station marking its northern extent. Transects were created using ESRI ArcMap GIS software and were based on the UTM zone 15

WGS 1984 coordinate system. The starting coordinate for the first transect was 200,000 east and 7,140,000 north.

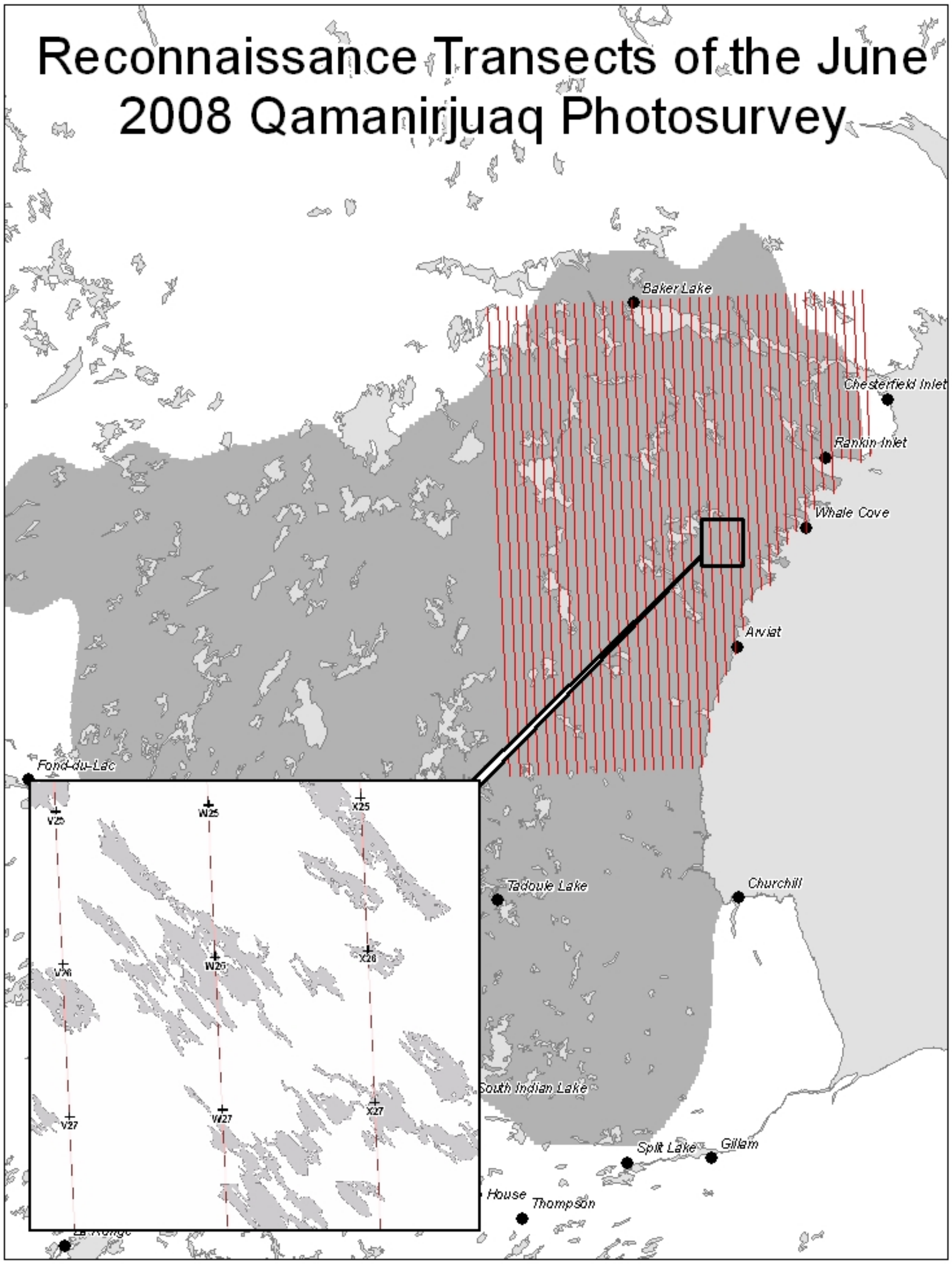

Figure 4 Potential reconnaissance transects and transect stations designed to cover the known extent of calving for the Qamanirjuaq barren-ground caribou herd. Not all lines were flown during the 2008 survey.

A Cessna Grand Caravan was used for the collar, calf, systematic, and visual surveys. Strip widths were established using streamers attached to the wing struts (Figure 5). Strip width (w) was calculated using the formula of Norton-Griffiths (1978):

$$w = W * h/H$$

where:

W = the required strip width**;**

h = the height of the observer's eye from the tarmac; and

H = the required flying height

Strip width calculations were confirmed by flying perpendicularly over runway distance markers. The strip width was 400 m out each side of the aircraft, for a total transect width of 800 m. Off-transect observations were recorded for the purposes of establishing minimum counts where applicable.

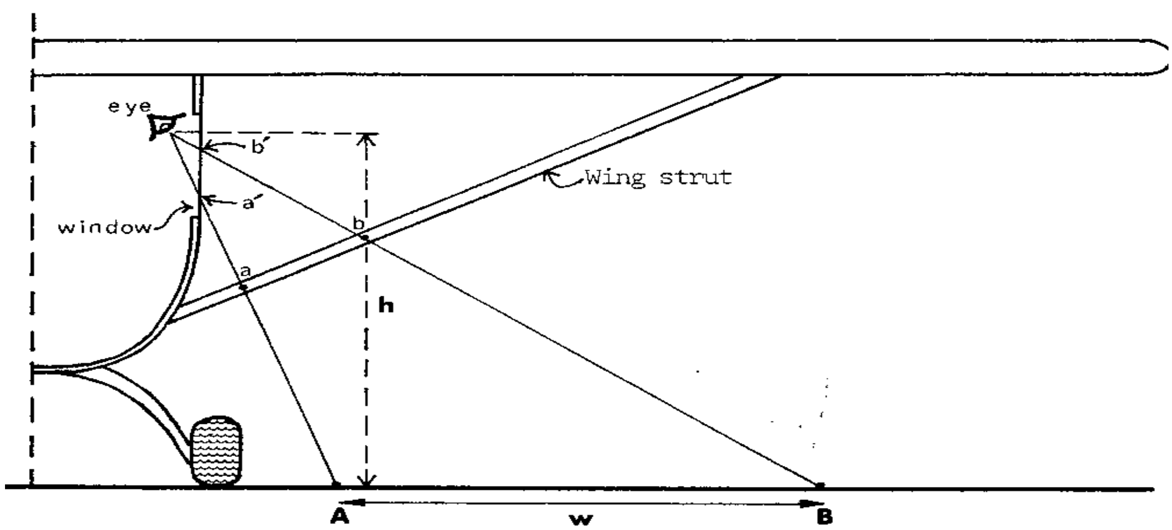

Figure 5 Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). W is marked out on the tarmac, and the two lines of sight a' – a – A and b' – b – B established. The dowels are attached to the struts at a and b, whereas a' and b' are the window marks.

During all survey phases altitudes were maintained as close as possible to 122 m (400 ft) above ground level (agl) using a radar altimeter. Ground speed was maintained at approximately 160 kph (100 mph) but ranged between 140 (90 mph) and 180 kph (110 mph). The survey crew included the pilot (front left seat), the data recorder/navigator (front right seat), the left rear seat observer and the right rear seat observer. The pilot's responsibilities were to monitor air speed and altitude while following a route pre-programmed into Garmin 176C Geographic Positioning System (GPS) units mounted on the dash of the aircraft. The data recorder/navigator was responsible for monitoring a second identically programmed GPS unit for the purposes of double-checking the position and to record the waypoints and numbers of adult and calf caribou groups on data sheets. The responsibilities of the left and right rear observers were to monitor their 400 m strips and call out numbers observations of caribou, distinguishing between cows with and without hard antlers. Adult bulls and yearlings were generally obvious and separated out from the other observations. Newborn calves were recorded whenever observed.

To minimize observer fatigue the observers rotated between four individuals throughout the survey while the navigator rotated between two individuals. The caravan pilot remained constant throughout the survey. All observers went through identification training as well as in the air training prior to filling the observer position. Training included an overview of theory and a review of techniques used to effectively search their strip area. A series of photographs taken from a fixed wing aircraft and with known numbers of caribou were used to train all observers to estimate groups.

3.1 Collar Reconnaissance

Photographic calving ground surveys are based on the observation that most breeding females within large migratory populations return to traditional calving areas (Heard 1985; Russell *et al.* 2002). Extensive reconnaissance surveys combined with movement rates and movements of radio-collared cows provide useful information to determine the spatial distribution of breeding females relative to peak of calving in any one year.

In April 2006, twenty Telonics GPS Generation IV GPS (Geographic Positioning System) collars were affixed to Qamanirjuaq caribou on their migratory corridor. An additional 15 collars were deployed one year later. These collars were equipped with a UHF (Ultra High Frequency) beacon to allow for satellite relay of daily locations of each collared animal once every three to four days. In addition, each collar was also equipped with a VHF (Very High Frequency) transmitter so that precise locations of animals could be attained at any time using an aircrapt equipped with associated receiving equipment. By June 2008, thirty three of the original thirty five collars were still active and used to initiate the collar reconnaissance of the 2008 survey.

The collar reconnaissance involved a flight to each active collar to visually locate the collared caribou and determine its breeding status (Figure 6).

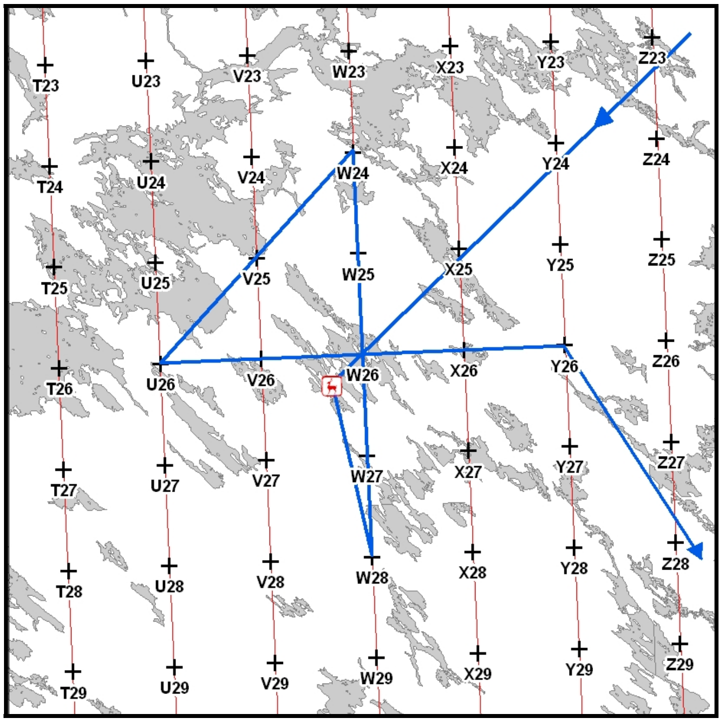

Figure 6 The reconnaissance of a collared caribou using a fixed wing in early June 2008.

A Cessna Grand Caravan with VHF antennas mounted to each of the left and right wing struts was used for collar reconnaissance. A Telonics TR50 VHF receiver/scanner was connected to each antenna through a switch box allowing for the isolation of each antenna as required. A preplanned flight route to each of the most recent satellite provided collar locations initiated the reconnaissance. Through the alternate isolation of the left and right antennas the survey plane was steered toward the target collar. The process would continue until the collared caribou was sighted and evidence of its breeding status (antlered or non-antlered) observed. Once the collared cow was observed, the survey plane, using the closest transect station as a reference point, flew two 40 km sample transects the first in a north/south orientation and the second in an east/west orientation (Figure 6). Information from the collar reconnaissance was used to verify the breeding status of collared cows that were further away from the calving ground and determine the location of breeding females that were travelling to the annual calving ground. Collars known to be within groups of breeding females were carefully tracked and used in the planning of the systematic reconnasance survey.

3.2 Systematic Reconnaissance Survey

The systematic reconnaissance survey were designed to estimate relative densities and delineate aggregations of breeding females (hard antlered cows or cow/calf pairs) for the purposes of stratifying the calving ground for the subsequent photocensus. The same aircraft configuration method was used as in previous reconnaissance. We used the observed locations of hard-antlered cows, newborn calves and aggregations of bulls and yearlings to delineate the spatial extent of the annual calving ground (Russell *et al*. 2005). The systematic reconnaissance survey of the annual calving ground was flown on June 7th and 8th, 2008. To ensure breeding female aggregations along know migratory corridors were not missed, we continued the reconnaissance through June 9th, and completed the survey on June 12th, 2008.

As described earlier in this report, the reconnaissance survey was based on a systematic array of transects running north-south (Figure 4) and spaced at 10 kilometer intervals. Each transect was divided in continuous 10 kilometer transect segments, with each segment identified by a unique alpha-numeric code assigned to the transect station defining its northern extent. The reconnaissance survey used these pre-determined transect segments (defined as one 10 km segment between two transect stations) to bin caribou observations for the purposes of calculating relative density within the segment. A rigid set of criteria governed when the 10 kilometer transect segments were flown. Criterion controlling when and where transect segments would be flown varied slightly across the calving distribution.

As the historic distribution of the Qamanirjuaq Herd consistently displayed a distinct northern boundary along the leading edge of known migratory movements while the southern, eastern and western extents showed more interannual variability based on known annual spring movements of the Qamanirjuaq herd representative of the trailing edge of these movements. As a result the criterion on the northern extent of the distribution was modified from that of the southern, eastern and western. Consecutive transect segments were flown north until no breeding females (Hard antlered cows or cow/calf pairs) were observed within the ten kilometer segment. Two additional ten kilometer transect segments would be flown north of the last observed breeding female and two parallel ten kilometer transect segments to the east and west of the transect segment with the last observed breeding female. Along the more southerly “trailing edge” of the observed caribou distribution, the reconnaissance survey continued two full transect segments (including those segments directly east and west) beyond any surveyed segment where fewer than 2 breeding females were observed. On the western extents where caribou densities were in excess of 5 animals per ten kilometer transect segment and/or breeding female densities below 2 per transect segment, additional western transects would be flown at 20 km spacing between transects rather then ten, to increase area coverage and to ensure aggregations of breeding females were not missed.

Following the systematic reconnaissance but prior to the initiation of the visual and photographic surveys, all observations were entered in to ESRI GIS software to calculate relative densities of breeding females using a tool utility. The relative density tools were built in ESRI’s Model Builder (v9.1) utility and loaded into ArcToolbox. The tools allowed us to calculate the relative density of observed caribou locations along the sample transects and display these results on a map. We used vector-based analysis methods based on the following steps:

1. The survey transect segments were buffered by a user-specified width (i.e., 800 meters) yielding polygons that were 8 km^2 (i.e., 0.80 km wide x 10 km long).
2. The survey observations points were intersected with the derived buffer polygons.

3. The density was calculated for each polygon by dividing the number of 1+ year-old caribou by the area of the buffer polygon (#1+ year old caribou/km²).
4. The relative density (#obs/km²) is then thematically displayed on a map based on pre-defined classes or bins.

The resulting graphics were then used to stratify the breeding female distribution into High, Medium and low density strata.

3.3 Visual and Photographic Surveys

The visual survey was conducted within four low density stratum located entirely within the breeding female distribution identified using reconnaissance survey results. ESRI GIS software was used to visually display reconnaissance survey results including both numbers of animals and breeding status. A "low density stratum" was a distribution of breeding females with a relative density of 0 to 10 caribou/km^2. Stratum boundaries would be visually aligned with the relative density graphic to capture transect segments of similar density (Figure 14). Four low density strata, low-1, low-2, low-3 and low-4 were delineated using this method. All low density strata were surveyed June 10, 2008, two days following the completion of the systematic reconnaissance of breeding female distributions. We continued the reconnaissance along known spring migratory corridors to ensure distributions of breeding females were not missed. The low density visual survey followed the same methods discussed in the systematic reconnaissance survey with the exception of transect allocation and alignment. Transects within each of four low density stratum were aligned at right angles to the longitudinal axis of the stratum to maximize the total number of transects (N). Transect spacing was allocated based on a pre-set minimum coverage of 25 percent (Norton-Griffiths, 1978). All low density visual transects were systematically placed 3.17 kilometers apart following an initial randomly placed transect, which yielded an actual percent coverage of 27.9 percent. Observation methods and survey equipment were identical to those used during the reconnaissance surveys.

Visual survey data collected within each of the four low density stratums were analyzed using Jolly's Method 2 for unequal sample sizes (Jolly 1969 *In* Norton-Griffiths 1978). Only counts of adults were used for the final population estimates. Lake areas <u>were not</u> subtracted from the total area calculations used in density calculations as they remained frozen and therefore accessable to caribou over the survey period. To determine if there was an increase in Qamanirjuaq numbers between June 1994 and June 2008 a comparison of the two surveys was conducted using equation 5.3 of Thompson *et al*. (1998):

$$z = \frac{Y_{1991} - Y_{1999}}{\sqrt{Var(Y_{1991}) + Var(Y_{1999})}}$$

where:

z = z statistic;

$\boldsymbol{Y}_x$ = population estimate for year x

$Var(\boldsymbol{Y}_x)$ = variance of the population estimate.

Estimates for both visual and photographic surveys were developed after Jolly (Jolly 1969 *in* Norton-Griffiths). Aerial photography provides more accurate estimates of breeding females because observer bias (the number of animals missed by observers during visual surveys) is considerably reduced. This is due to the ability of the interpreter to count caribou under controlled conditions.

Geographic Air Services was contracted to fly the photographic component of the survey. The plane used was a Aero Commander low wing turbine aircraft. The aircraft was equipped with a radar altimeter and a Wilde RC30 camera with forward motion compensator. The aircraft was positioned from Edmonton to Rankin Inlet just prior to the completion of the reconnaissance. All portions of the photographic survey were flown at an altitude of 600 meters (AGL) yielding a scale of 1:4000. Photographs were only taken between 0800 hrs and 1830 hrs to ensure proper sun angle (25^0 to 30^0). The coverage of each photo-transect was continuous and 0.92 km wide. Approximately 2800 photos were taken representing approximately 1200 linear kilometers of flying.

The photographic component of the calving ground survey was designed to photograph relative density strata of breeding females in excess of ten caribou per kilometer squared as close to the completion of the systematic reconnaissance survey as possible. The systematic reconnaissance survey over breeding female distributions was completed June 8th, 2008 though we continued the reconnaissance along known spring migratory corridors to ensure distributions of breeding females were not missed. High, medium and Medium/low strata were delineated using the methods described for the visual survey on June 9th, 10th and 11th respectively. Survey resources were, based on those used during similar calving ground photo surveys, above minimum requirements. The extra resources were used to increase overall effort and within each of the high and medium stratum, allocated based on relative densities and loosly based on the following formula after (Heard 1987):

$$N_i = (Y_i\ (M)) \,/\, (TL_i)\ (\int TL_i)\ (\sum(Y_i \,/\, TL_i)$$

Where:

Y_i = Stratum Population Estimate.

M = Total number of line kilometers available for photography.

TL_i = Mean length of transect in stratum I.

Transects within each of high and medium and medium/low density stratum were aligned at right angles to the longitudinal axis of the stratum to maximize the total number of transects (N). In both strata an initial transect was randomly placed perpendicular to the longest stratum boundary and the remaining transects systematically placed at regular intervals according to the allocation of survey effort. Transect spacing was allocated based on proportional densities and available resources (Heard, 1987). Within the medium density stratum transects were placed three kilometers apart providing approximately 30% coverage while in the high stratum transects were placed 2.28 kilometers apart yielding approximately 40% coverage of the strata. Transect spacing for the medium/low density stratum was five kilometers providing a coverage of approximately 20% in the strata.

3.4 Composition Surveys

Composition surveys of the High, medium, Medium/low photographic strata and low density visual strata were flown as close to the photocensus as logistically possible. The purpose of the composition surveys was to determine the proportions of breeding females within each of the survey strata.

All caribou were classified from the air using a Bell 206-B Jet Ranger helicopter with one dedicated observer (front left seat), a data recorder (rear left seat) and the pilot. Caribou observed were classified into one of eleven categories (Table 1).

Table 1 Caribou classification categories used during the composition phase of the 2008 Qamanirjuaq calving-ground photo survey.

Cow with Calf			Cow with Udder			Udderless Cow			Yearling	Bull
2 Antlers	1 Antler	0 Antler	2 Antlers	1 Antler	0 Antler	2 Antlers	1 Antler	0 Antler		

Composition survey effort was allocated proportionally to the relative densities observed within each stratum. Within each photographic strata, composition sampling points were placed half way between each pre-determined reconnaissance survey transect station (e.g. Y-25) along the main transect (e.g.

Y). Selection of sampling points to be surveyed was made using a graphic overlay of adult distributions within each strata developed from the systematic reconnaissance survey. In the field, all sampling points were searched within a 10 km radius or until a minimum of four groups of caribou were classified. When group size was very large, waypoints of the start and finish of a composition run were marked, while for smaller groups' one waypoint marking the point of contact was recorded. We found that caribou had moved very little over the time between the reconnaissance and composition surveys. When caribou could not be located around a sampling point, we searched adjacent points within the strata. A northern movement of breeding females in the Medium/Low density stratum required additional sampling sites in the northern portion of the strata to be sampled.

Due to the low densities of animals encountered within the four low density visual strata, the sampling method was modified from that used within the high, medium and medium/low strata. Sampling began at the end of the stratum with the highest recorded densities and proceeded along its longitudinal axis completely through its length. Due to fuel and time constraints search patterns were restricted to five kilometers to the left or right of the starting point's longitudinal axis classifying all groups encountered.

The purpose of the Qamanirjuaq fall-rut composition survey was to determine the proportion of females in the population at a time of year when all age and sex classes come together into large mixed groups. Though the estimates of breeding females are the best indicator of population size, for management purposes an estimate of total population size is desirable.

The Qamanirjuaq caribou fall composition survey was flown out of Churchill Manitoba and Arviat Nunavut between October 17th and 21st 2008 (Figure 7). The survey itself used the locations of 30 Telonics GPS III and IV collars to locate flight lines and establish search patterns. The fall composition searched the most southerly collars first and proceeded north ending at the most northerly collar locations. Caribou groups in the immediate vicinity of the collars were classified and tracks followed to locate other groups. All collar locations were searched a minimum of twenty kilometers to the north, east, south and west (exceptions were made when adjacent areas included boulder fields, large lakes, the Hudson Bay coast). Fresh tracks were used in all areas to locate new groups. The search of a collar area would terminate once no fresh new track were observed or when a possibility of double sampling occurred. In instances where several hours passed between classification runs, previous GPS tracks were followed to relocated the group previously classified to insure the same groups were not re-sampled which at times required the skipping of groups where mixing could have occurred. Once a collar or cluster of collars was thoroughly searched, the survey would then proceed to the nearest collar north of the completed area. In total 277 groups and 23,709 individuals of Qamanirjuaq caribou were classified.

To estimate the total population size, the number of breeding females estimated in June 2008 was divided by the product of the proportion of females in the population and the proportion of females that were pregnant. The proportion of females in the population assumed a 50:50 sex ratio for yearlings. As the proportion of females pregnant was not immediately known we used the same proportions used in past Bathurst caribou surveys (Gunn *et al*. 2005). Variances for the total population estimate were estimated using the delta method (Seber, 1982).

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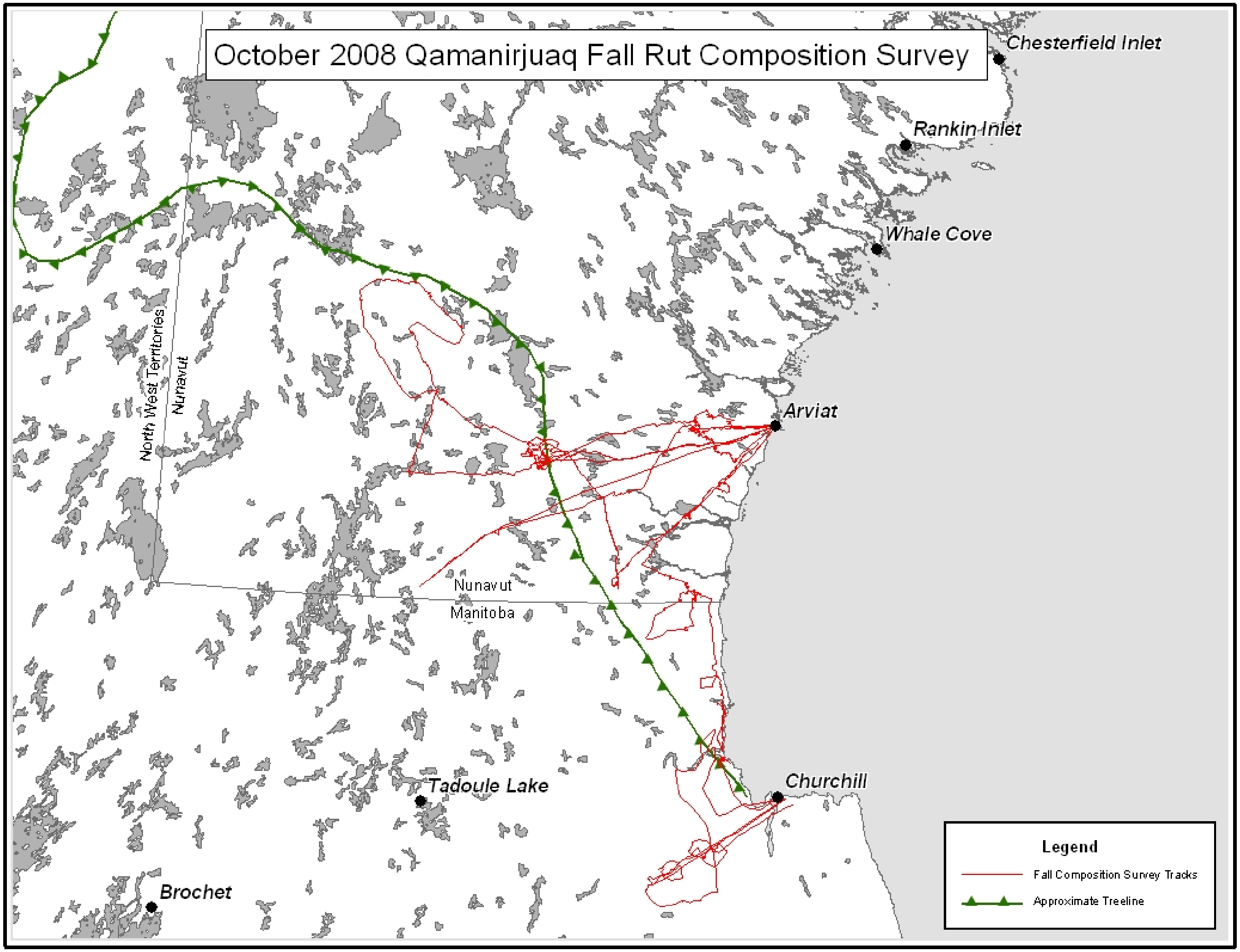

Figure 7 Track logs of the Late October, 2008 Qamanirjuaq Fall Rut composition survey.

4.0 RESULTS

*4.1 Pre-Survey***Error! Bookmark not defined.**

Periodic spring ratios of calves per 100 cows of the Qamanirjuaq herd are available from April 1979 to present (Heard and Calef, 1986; Gates, 1985). Prior to the initiation of 2008 the Qamanirjuaq calving-ground photographic survey semi-annual spring composition studies were carried out between March/April/May 1994 and May 2008 (Figure 8). The purpose of these studies was to monitor herd productivity by estimating over winter survival of calves. It is generally accepted that for mainland migratory barren-ground caribou populations a calf per hundred cow ratio of 25 likely indicates a stable population (Graf and Heard, 1990) assuming that adult female survival is within normal levels observed in other herds though caution should be used when using such indicators across herds for analysis purposes. Calf cow ratios below this value for consecutive years would suggest a declining trend and as a result would trigger the need for a population estimate to confirm the trend. Between 2003 and 2006 ratios dropped from 26 calves/hundred cows to 16 indicating a declining trend (Figure 8). The 2007 results further confirmed the trend when 19 calves/hundred cows was observed. Preparations of the 2008 photo survey were made following the 2007 result. The 2008 observations further confirmed the declining trend when 17 calves / hundred cows was observed.

We used ESRI Spatial Analyst Extension to examine fifteen years of satellite and GPS collar point data to determine the annual concentrated calving extents for the purposes of survey planning and logistics. The kernel analysis utilized a search radius of 30 kilometers and an output cell size of one kilometer. Annual concentrated calving extents for the purposes of this report were defined by all locations of collared caribou cows between 1993 and 2008 during the calving period, which for the Qamanirjuaq herd is considered to be from June 1st to June 25th (BQCMB annual report, Campbell, 2008). Collars from known years of late or no arrival onto the traditional calving ground were treated as outliers and removed. It is important to note that the area described here is meant to represent the geographic area most intensively used by caribou in 12 out of 15 years and does not represent all areas where Qamanirjuaq caribou calve (Figure 9). We use the calving extents as a reference throughout this report when describing breeding female distributions.

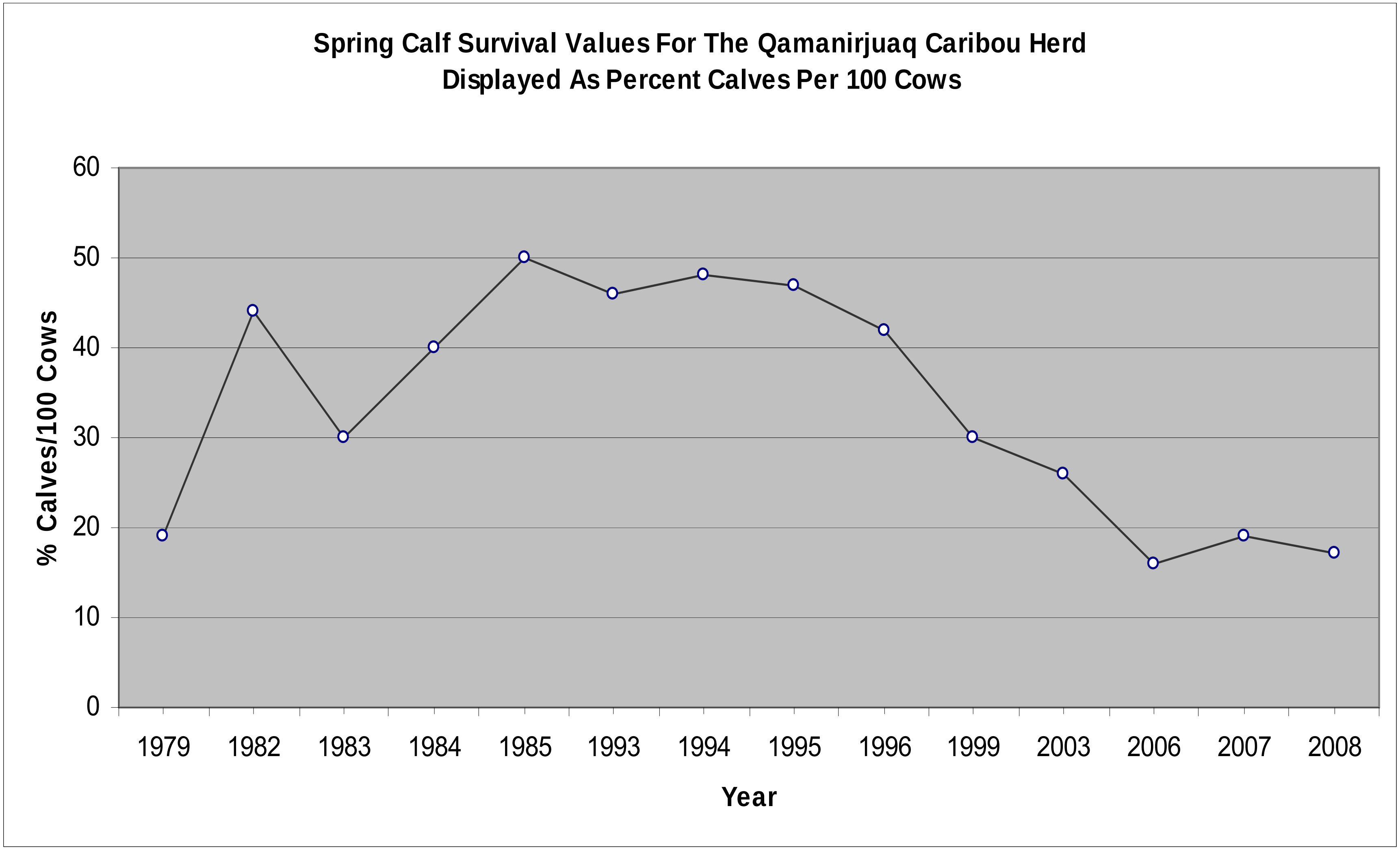

Figure 8 Productivity of the Qamanirjuaq herd as indicated by calf-cow ratios on their late winter and spring migratory corridors. Calf-cow ratios are affected by the proportion of females that give birth each year and the overwinter calf survival. . Twenty five calves / hundred cows is used as an “index” only of a stable population and as a result should be interpreted with caution (Croft pers comm., Boulangier pers. Comm.). Data prior to 1993 from (Heard and Calef, 1986).

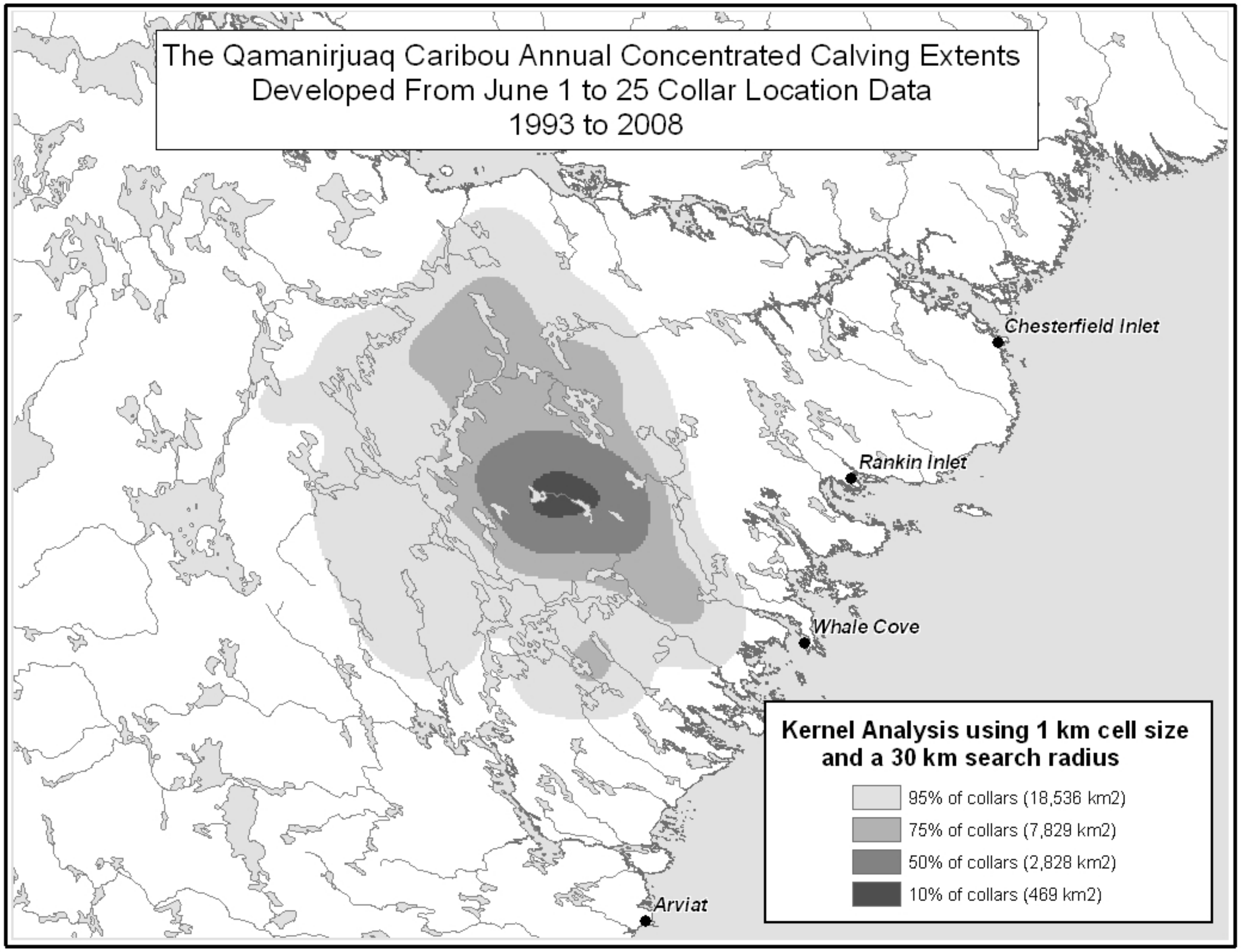

Figure 9 A Kernel Analysis of Qamanirjuaq cow collar locations from June 1st to 25th 1993 through 2008. The analysis removed collar locations from 3 out of 15 years when caribou were known to have calved outside the traditional calving grounds

4.2 Reconnaissance Surveys

The collar reconnaissance was initiated and completed June 6th 2008. By June 6th, twentyfive of the thirty three collars still active on Qamanirjuaq caribou cows were within large aggregations of breeding females well within historically delineated extents of the Qamanirjuaq Herds core calving ground (Figure 10). Of the eight remaining collars two were in the vicinity of Quartzite Lake south-south west of the main aggregation of collars (Figure 11). The collar reconnaissance for these two collars observed 427 caribou of which 0.9 percent (4 individuals) were calves and 19.7 percent (84 individuals) were breeding females. An additional four collars were south of the main aggregation, and the remaining two collars over to the west-south west of the main collar aggregations. All six collars were associated with predominantly non-breeding females, yearlings, young bulls and mature bulls (Figure 11, 12). The collar reconnaissance of these more distant six collars observed 2,354 caribou of which 0.3 percent (7 individuals) were calves and 4.8 percent (113 individuals) were breeding females. By June 12 all but three collars had moved within the annual concentrated calving area. All three collared cows outside the calving area were non-breeding females.

The systematic reconnaissance was initiated June 7th and completed June 12th, 2008 surveying an area 31,044 km2 (Figure 13). Both the collar and systematic reconnaissance surveys delineated a distinct area within the known calving grounds composed mainly of breeding females. With the exception of a small area 70km south of the main breeding female aggregation, no groups of breeding females were observed southwest along the spring migratory corridor (Figure 14). The Systematic reconnaissance covered all aggregations of breeding females in excess of 5 caribou per kilometer squared, indicated during the collar reconnaissance, by June 7th (Table 2). In an effort to ensure aggregations of breeding females were not missed the survey continued with the last transects being flown June 12th, 2008. A total of 20,591 adult and yearling caribou and 3,001 calves were observed on transect between June 7th and 12th.

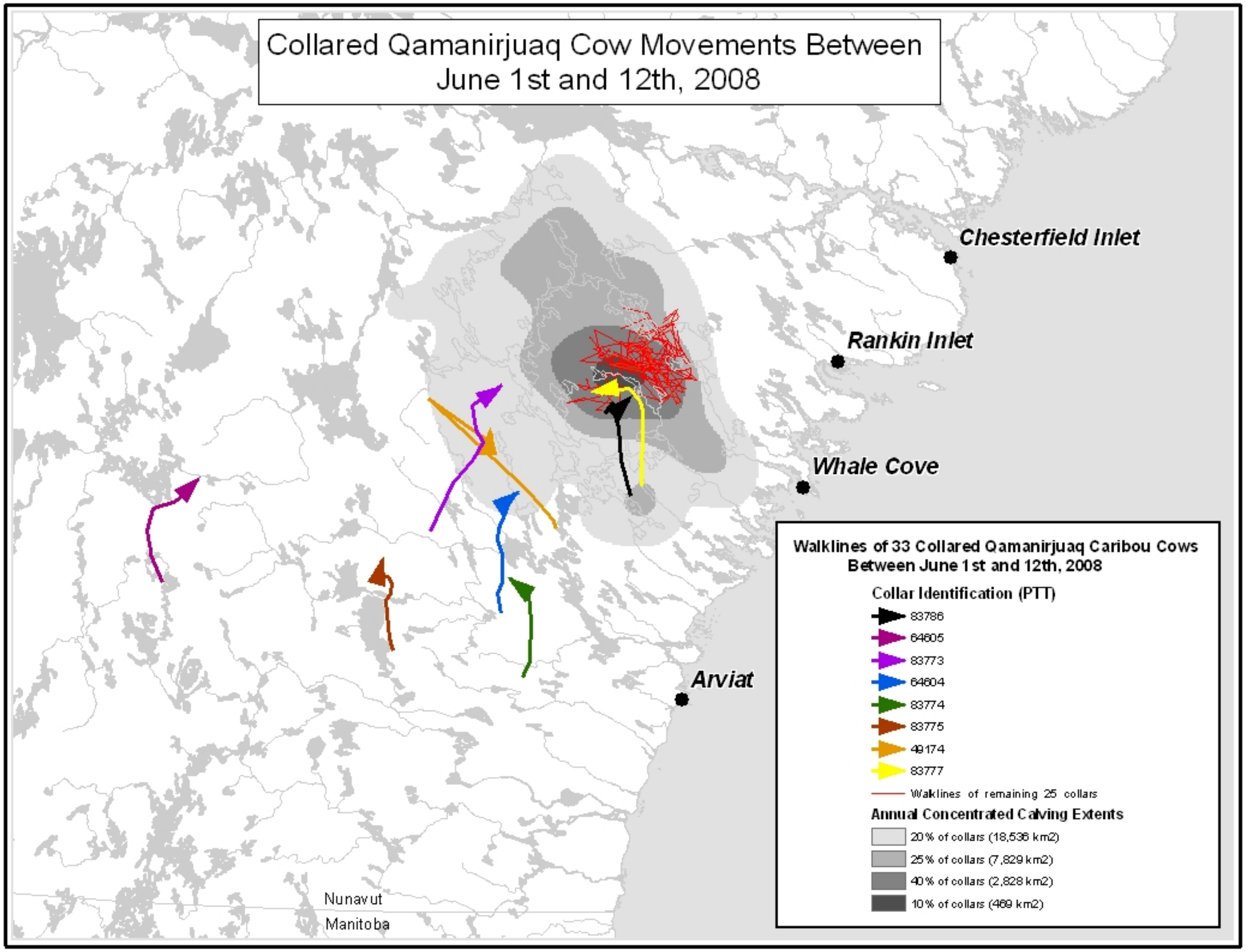

Figure 10 June 1st to 12th 2008 Qamanirjuaq caribou walk lines. Eight Individual PTT's have been separated out to show movements into and outside of the annual concentrated calving area.

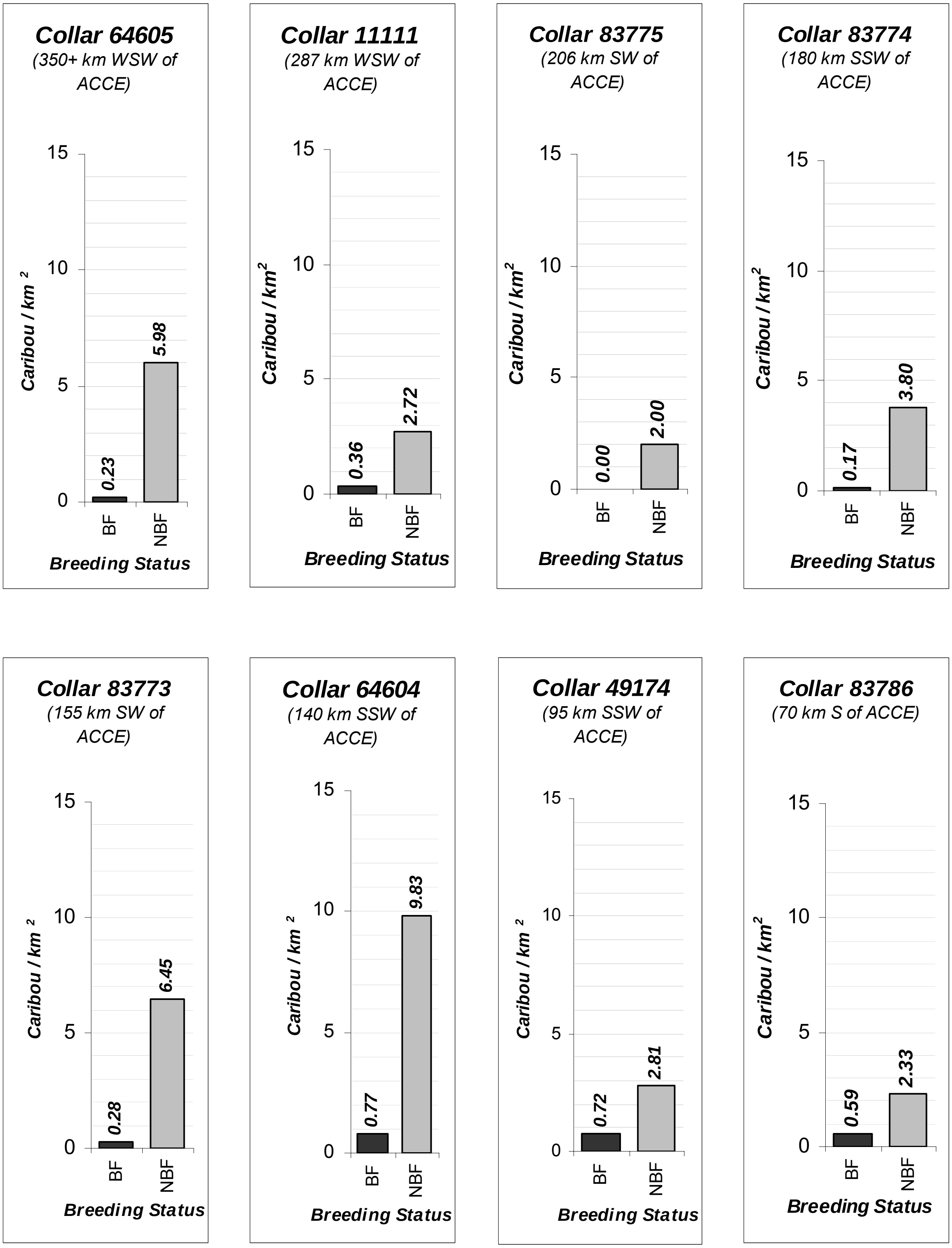

Figure 11 Results of the collar recon. survey. Densities for each collar are calculated based on a surveyed area of 64 km^2. (BF = Breeding Females; NBF = Non-Breeding Females; ACCE = Annual Concentrated Calving Extents based on Figure 9).

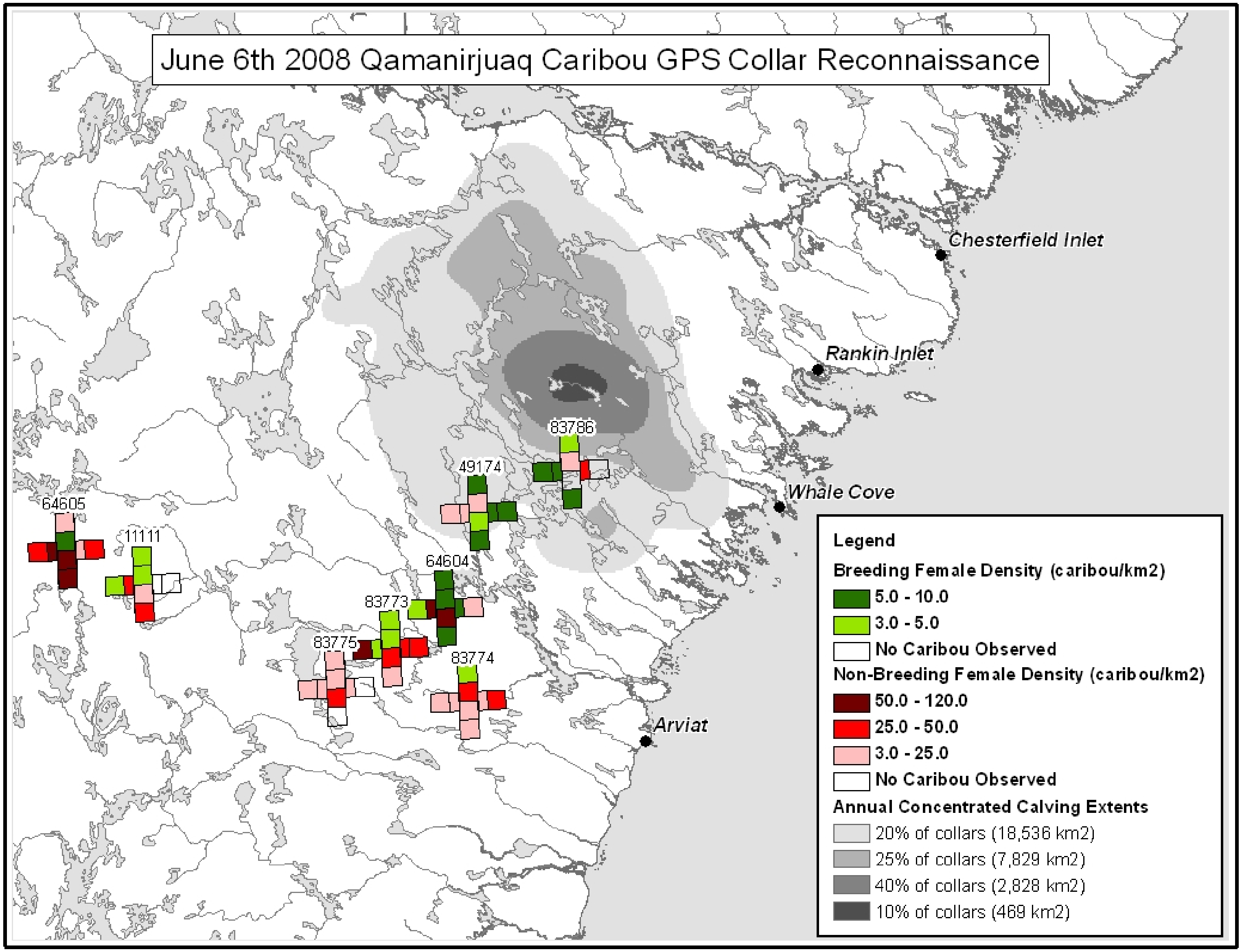

Figure 12 The June 2008 collar reconnaissance with breeding female densities displayed on top of adult densities.

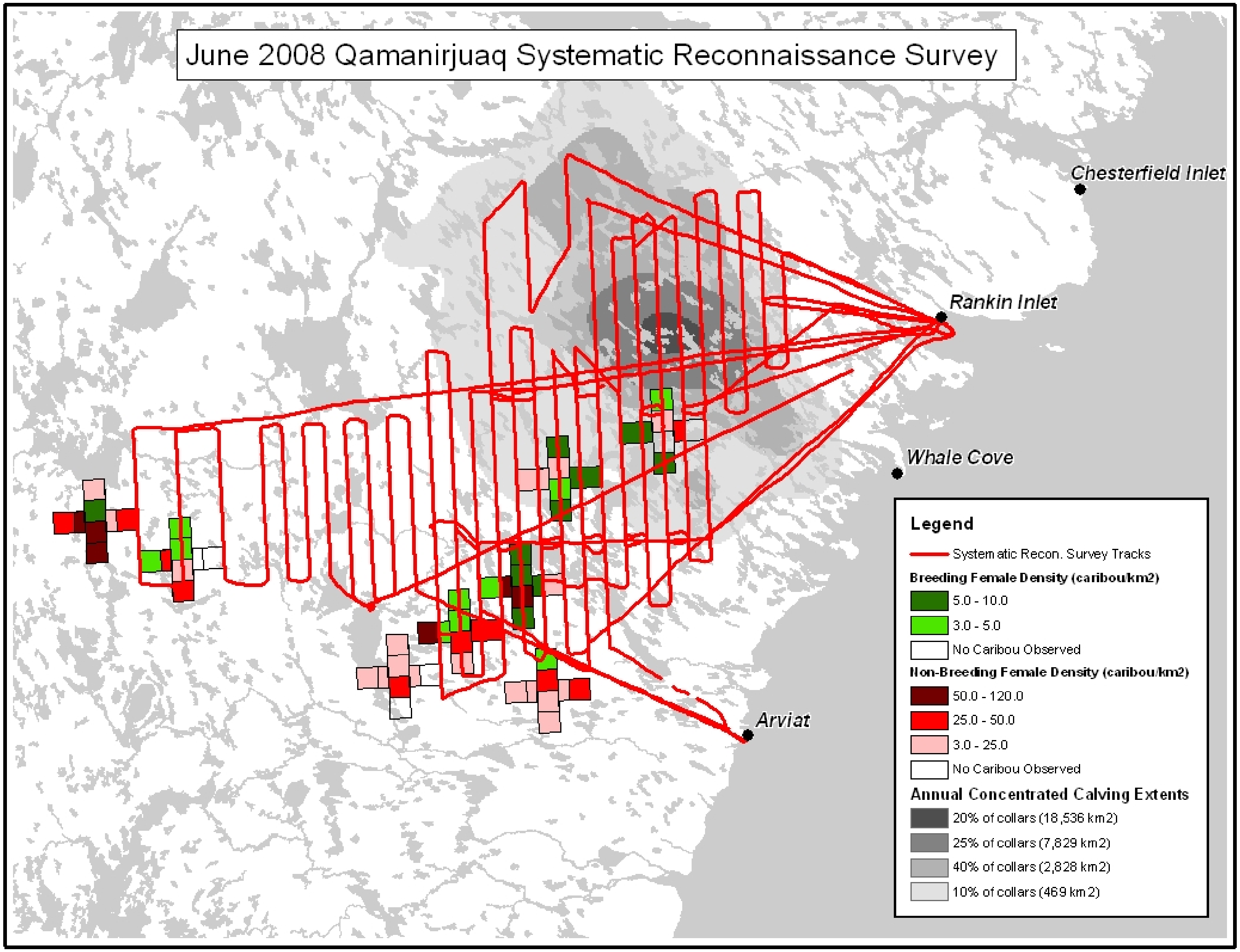

Figure 13 Tracks of the June 2008 systematic reconnaissance survey of Qamanirjuaq caribou.

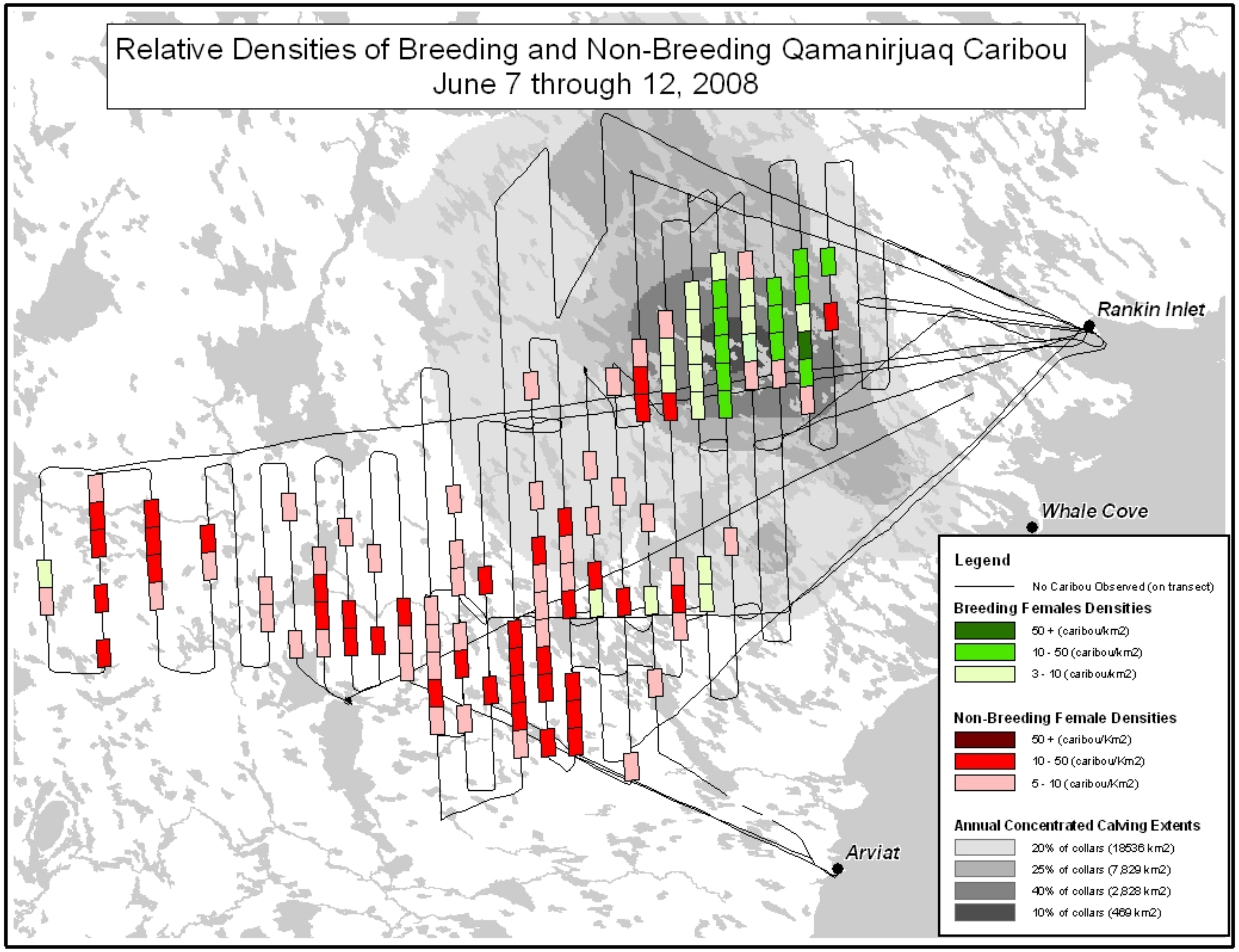

Figure 14 Relative densities of breeding and non-breeding (Cows, young bulls, mature bulls and yearlings) Qamanirjuaq caribou. Density data collected between June 7th and 12th, 2008. Breeding female density layer is placed on top of the non-breeding caribou layer to show all observations of breeding females.

Table 2 Survey Initiation and completion dates for the 2008 June Qamanirjuaq Calving Ground Photographic Survey.

Survey Type	Date Flown						
	June 6th	June 7th	June 8th	June 9th	June 10th	June 11th	June 12th
Collar Reconnaissance	X						
Systematic Reconnaissance		X	X	X	X	X	X
High Density Photographic				X			
High Density Composition					X		
Medium Density Photographic					X		
Medium Density Composition						X	
Medium/Low Density Photographic						X	
Medium/Low Composition							X
Low Density Visual (Strata 1, 2, 3 & 4)					X		
Low Density # 2 Composition					X		
Low Density # 3 Composition					X		
Low Density # 1 Composition						X	
Low Density # 2 Composition						X	
Low Density # 4 Composition							X

4.3 Visual and Photographic Surveys

Strata for the visual and photographic surveys were delineated according to the observed relative densities of breeding females from the systematic reconnaissance survey (Figure 15). Aerial photography over the calving ground of the high, medium and medium-low density strata was completed June 9th and 10th while the visual survey of the four low density strata began and was completed June 10th. (Figure 16). A total of 77,179 adult caribou were counted from transect photos within the high, medium and medium-low photographic strata while a total of 3,419 adults and yearlings were counted on transect within the four low density visual strata (Table 3).

Table 3 Stratum transect counts/observations during the photographic and visual surveys of the Qamanirjuaq calving grounds, June/2008.

Animals Observed	Low Density Visual Strata				Photographic Strata		
	# 1	# 2	# 3	# 4	High	Medium	Medium/Low
Adults & Yearlings	741	295	2165	218	40,021	34,056	3,102
Calves	0	0	6	0	N/A	N/A	N/A

As adult (1+ year old) caribou densities were the most consistent of recon observation data, we used these data in the selection of composition sampling points within delineated strata (Figure 17). High, medium and medium-low density stratum composition surveys were all completed the day following the photography of the respective stratum (Figure 18). Low density visual strata were completed within two days of the survey. High, Medium, Medium/Low and low density strata sampling sites, groups and individual caribou classified are listed (Table 4). In total 14,600 caribou were classified within photographic and visual strata. Breeding female proportions were highest in the high and medium photographic strata and lowest in the low-D stratum (Figure 19). Although strata low-B and low-C had relatively high proportions of breeding females, *ca*. 50%, the overall abundance of caribou in the stratum were very low (Figure 19).

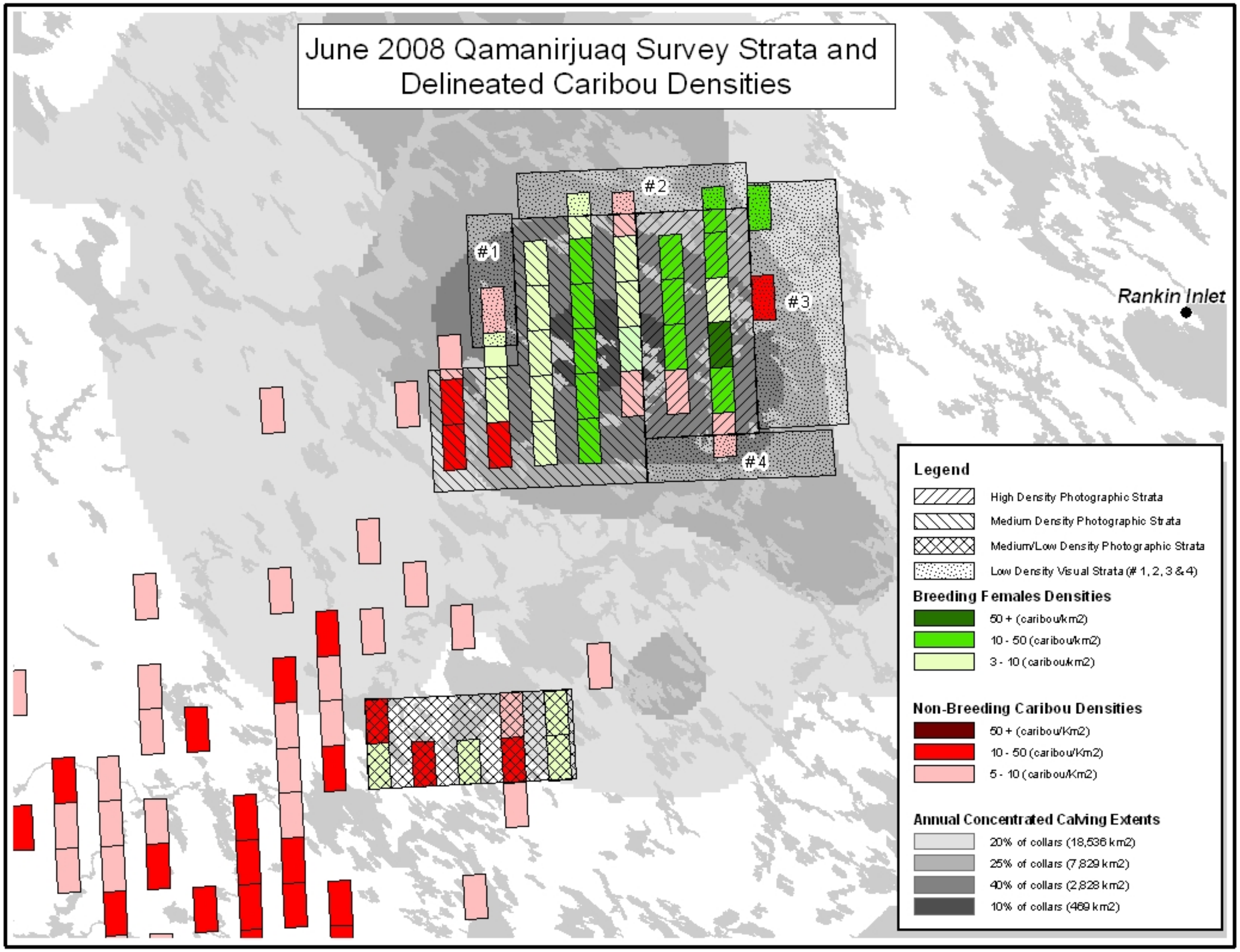

Figure 15 The delineation of density strata using graphically displayed relative density blocks derived from systematic reconnaissance observations on the Qamanirjuaq calving-ground, June 2008. Breeding female density layer is placed on top of the non-breeding caribou layer to show all observations of breeding females.

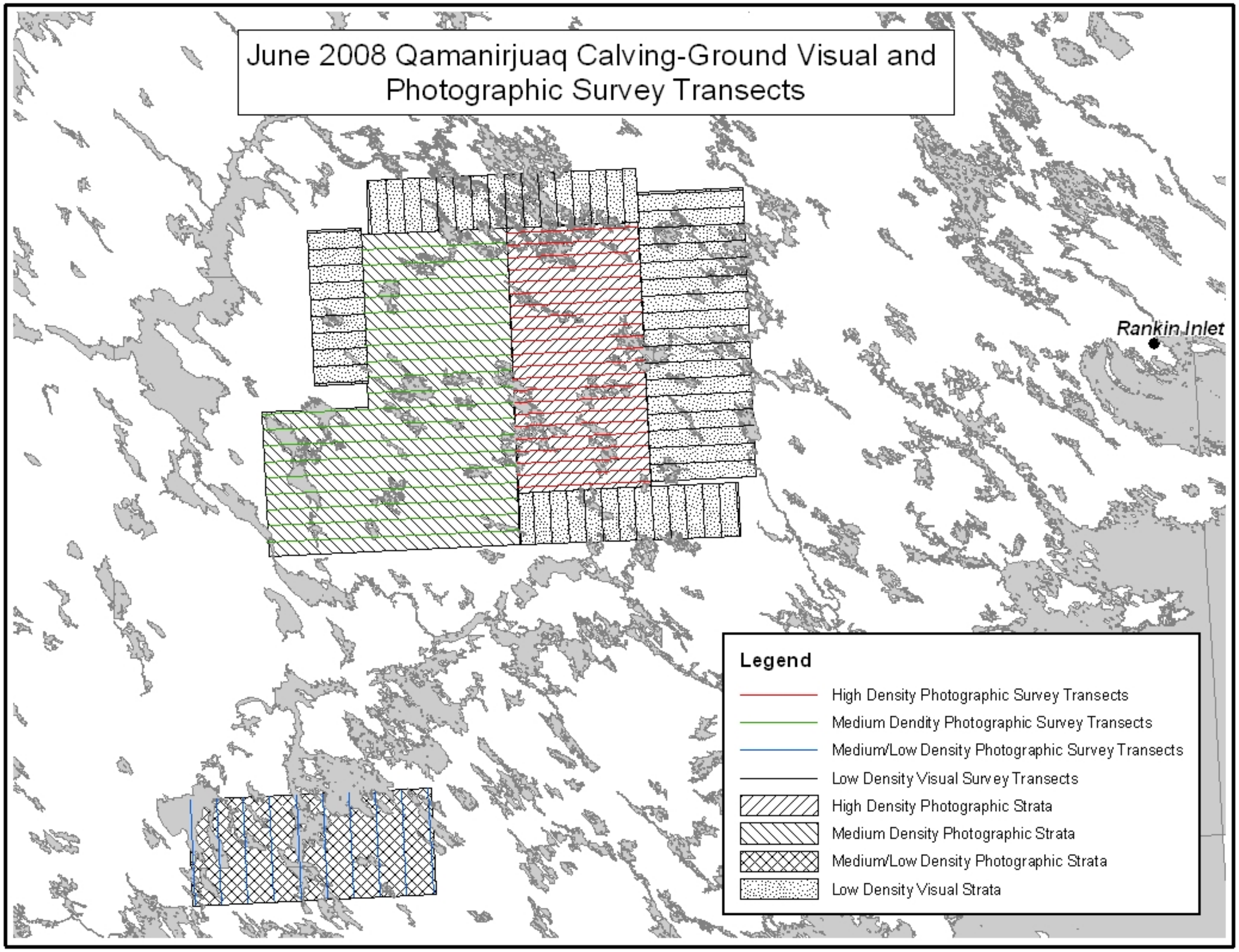

Figure 16 The June 2008 Qamanirjuaq Visual and Photographic survey Transects and strata.

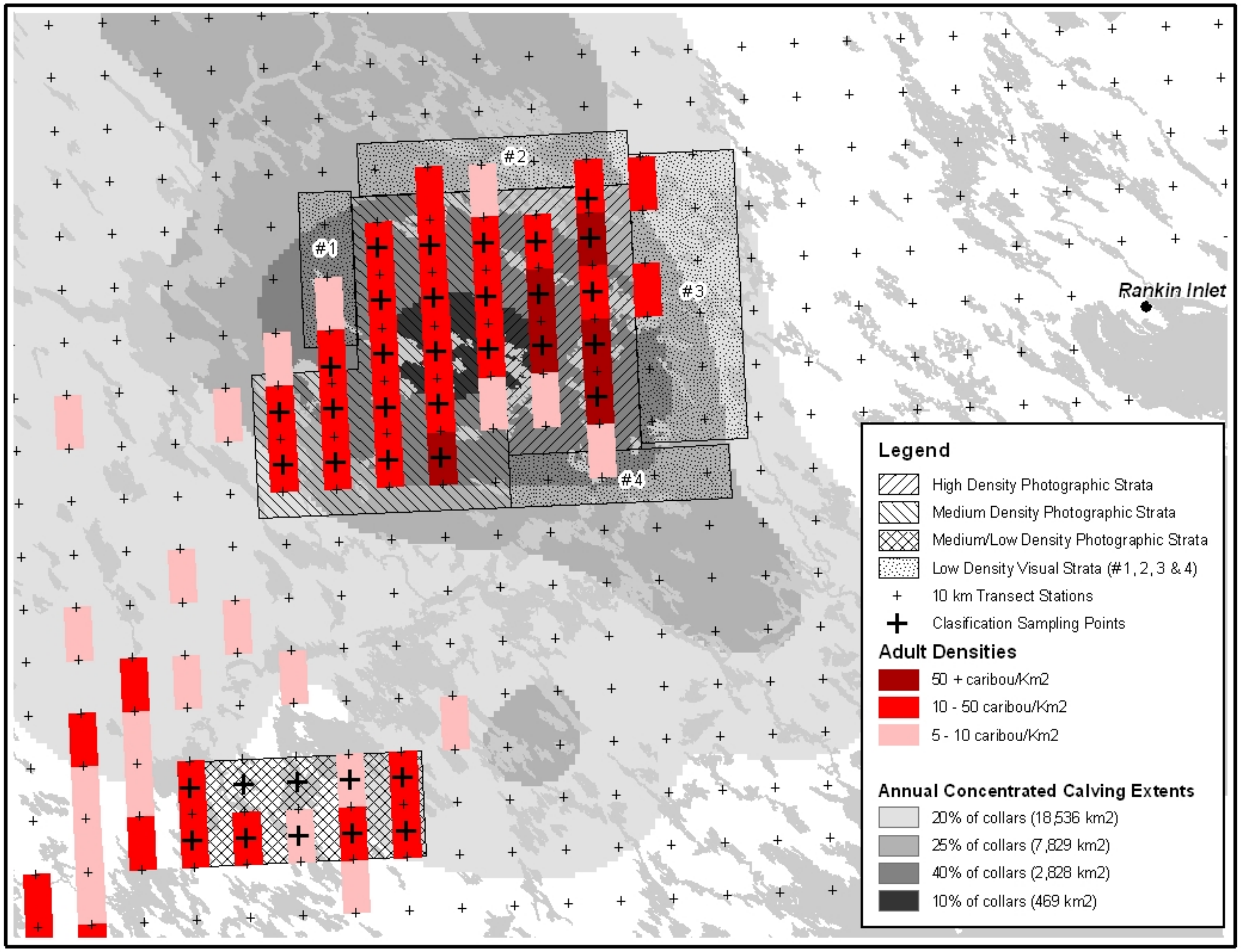

Figure 17 The selection of photographic strata sampling points for the composition survey using adult densities derived from the June 2008 Qamanirjuaq systematic reconnaissance survey.

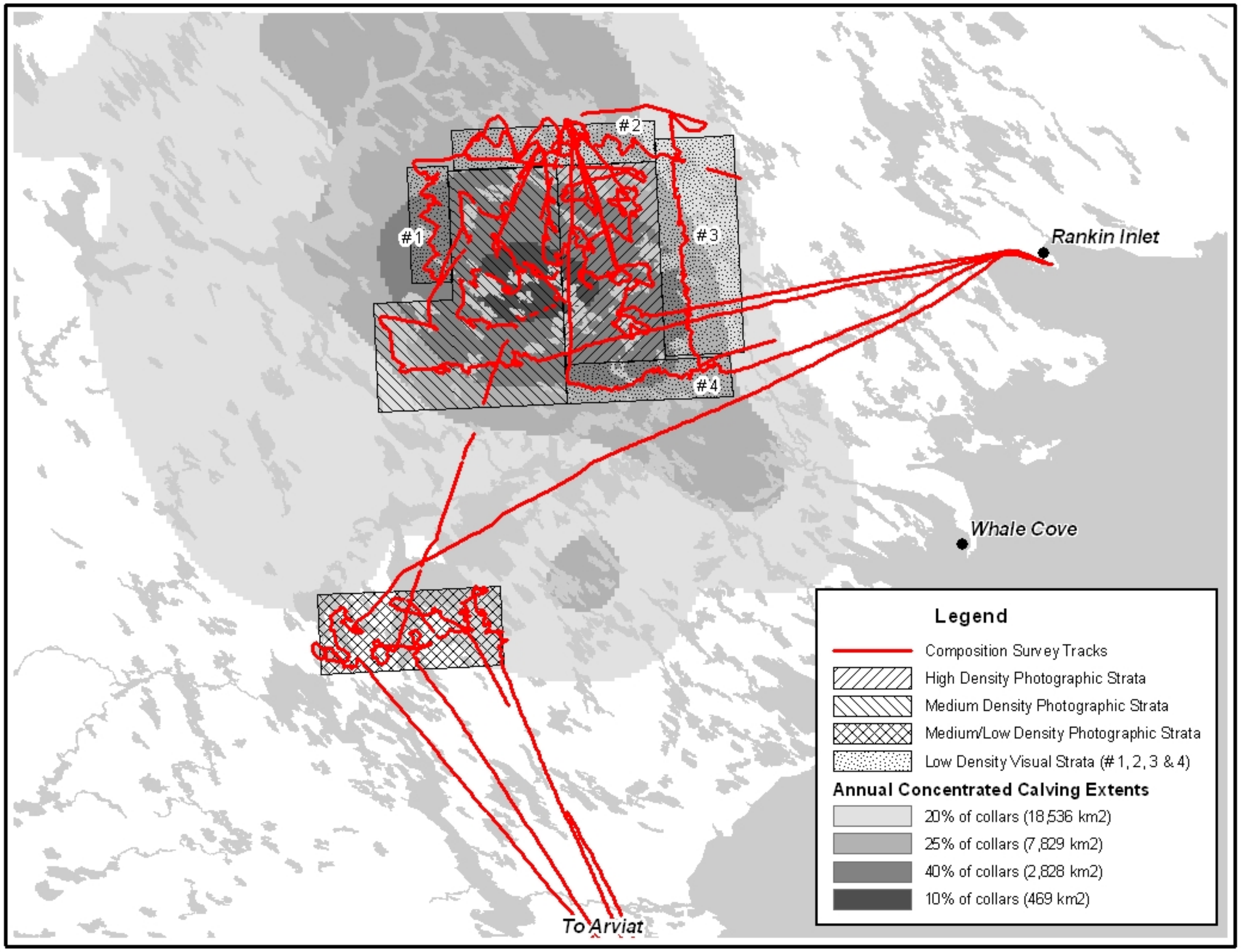

Figure 18 Tracks flown for the Qamanirjuaq caribou June 2008 calving-ground composition survey. Tracks within both photographic and visual strata are shown.

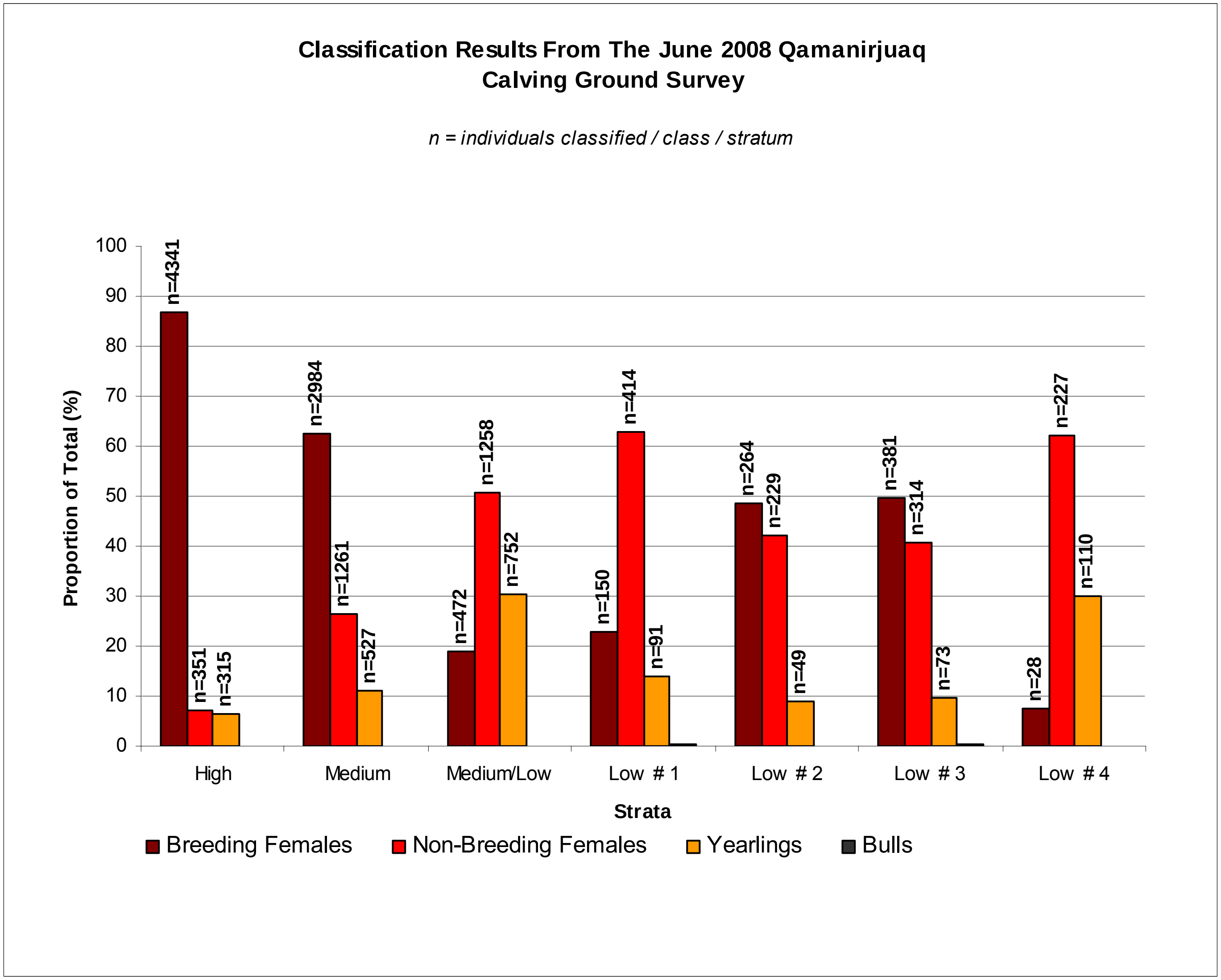

Figure 19 Results of the composition survey. Proportions are based on totals for individual strata.

Table 4 Composition survey sampling effort for both visual and photographic strata the 2008 Qamanirjuaq June Calving Ground photographic survey.

Sampling Details	Stratum Sampled						
	High	**Medium**	**Medium / Low**	**Low # 1**	**Low-# 2**	**Low # 3**	**Low # 4**
Number of Sites Sampled	8	18	10	N/A	N/A	N/A	N/A
Total Number of Groups Classified	36	37	34	15	17	17	18
Total Number of Caribou Classified	**5,007**	**4,773**	**2,486**	**657**	**542**	**770**	**365**

We used Jolly's Method 1 and 2 (Jolly 1969 *in* Norton-Griffiths, Krebs 1989) to estimate the number of breeding females on the Qamanirjuaq calving ground between June 9th and 11th 2008. A total of 238,651 caribou were estimated across all survey strata (Table 5). Composition surveys conducted on the calving ground were used to estimate the proportion of breeding females in each strata. A bootstrap method (Manly 1997) was used to estimate variance and unbiased proportion of breeding females within survey strata (Table 6). The population estimate (Yh) was multiplied by the breeding proportion to obtain estimates of breeding females for each strata (Table 7). Variances for the estimate were derived using the delta method (assuming 0 covariance between the population estimate and breeding proportions) (Seber 1982).

The estimate of breeding females is the best indicator of population size since all of the necessary parameters are estimated directly during the calving ground surveys. However, for management purposes a total population estimate is also desired. The fall composition survey flown October 17th to 21st estimated the total number of adult cows, calves, yearlings and bulls at a time of year when all ages and sexes are well mixed (Figure 20).

To estimate the total population size the number of breeding females were divided by the proportion of females in the population and the proportion of females that were pregnant. The proportion females in the population (including yearlings (assuming a 50:50 sex ratio of yearlings) was estimated from the 2008 fall composition survey. The proportion females pregnant is not immediately known and the same proportion was used as in past Bathurst caribou surveys (Gunn et al. 2005). Variances for the total population estimate were also estimated using the delta method (Table 8). Using this information an estimate of 348,661 (SE = 44,861) was calculated.

Table 5 Estimate of 1+ year-old caribou on annual concentrated calving area (Yh)

Stratum	Y_h	N =	Var(Y_h)	SE	CV
Low # 1	2,742	10	460,637.79	678.70	0.248
Low # 2	1,180	16	139,493.60	373.49	0.317
Low # 3	8,660	17	4,668,105.00	2160.58	0.249
Low # 4	872	13	24,314.00	155.93	0.179
High (Photo)	98,233	22	102,497,219.87	10124.09	0.103
Medium (Photo)	112,884	19	248,683,107.21	15769.69	0.140
Medium/Low (Photo)	15,510	10	15,456,791.11	3,941.13	0.254
Total	**240,081**		**371,929,668.58**	**19,285.48**	**0.080**

Table 6 Proportions of breeding females from calving ground composition surveys.

Stratum	Proportion breeding	SE (Proportion breeding)
Low #1	0.22464	0.025338
Low # 2	0.32777	0.065488
Low # 3	0.25819	0.062947
Low # 4	0.08763	0.020712
High (Photo)	0.83451	0.020009
Medium (photo)	0.6102	0.035956
Medium/Low (photo)	0.16834	0.019317

Table 7 Estimates of breeding females derived from population estimates of caribou on calving ground and estimates of proportion females breeding.

Stratum	Y_h Breeding Females	Variance	SE	CV
Low # 1	616	28,072.25	167.55	0.272
Low # 2	387	20,957.80	144.77	0.374
Low # 3	2,236	608,342.51	779.96	0.349
Low # 4	76	512.90	22.65	0.296
High (Photo)	81,976	75,243,138.07	8,674.28	0.106
Medium (Photo)	68,882	109,069,994.62	10,443.66	0.152
Medium/Low (Photo)	2,611	529,929.71	727.96	0.279
TOTALS	**156,784**	**185,500,947.86**	**13,619.87**	**0.087**

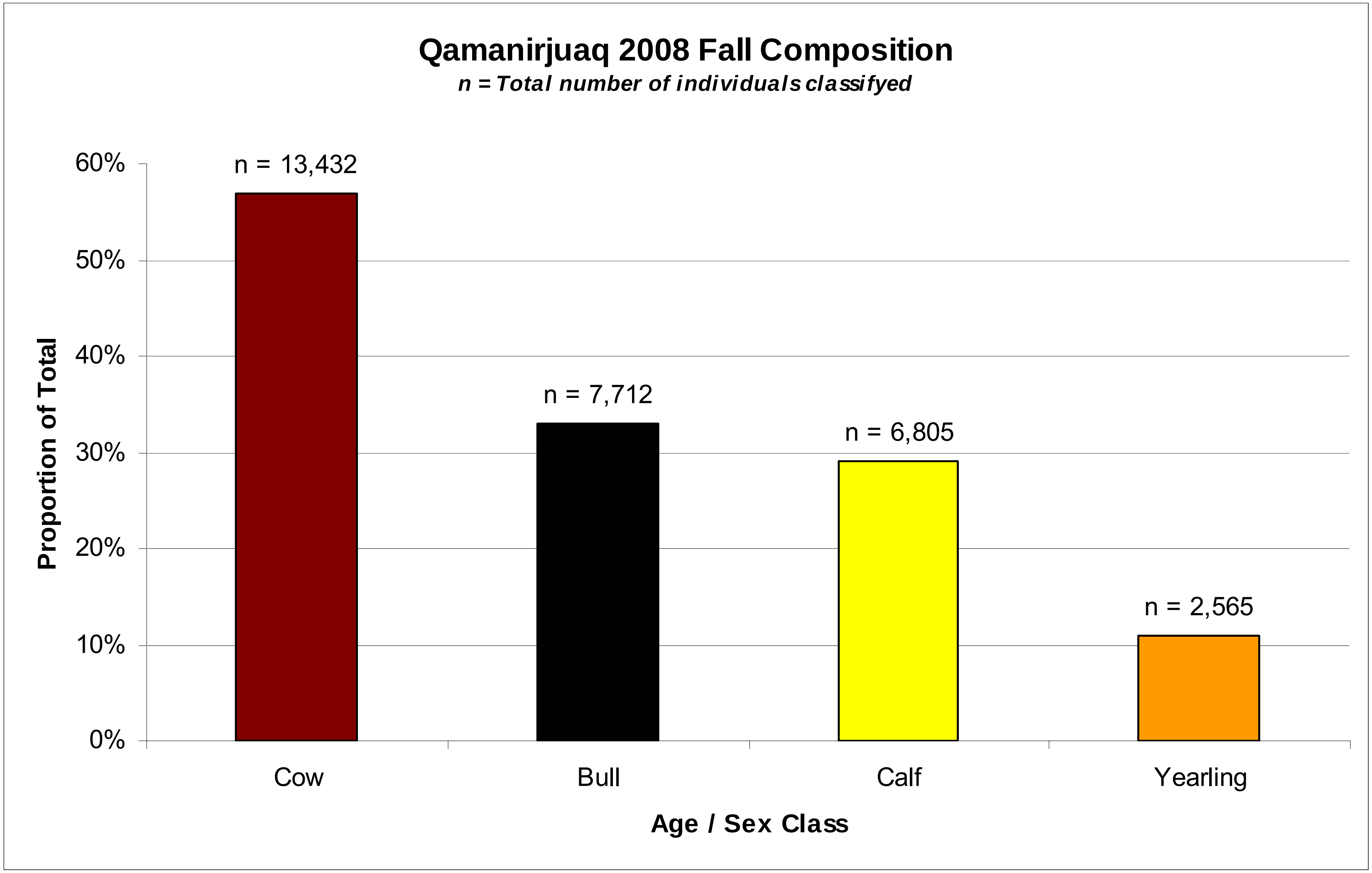

Figure 20 Results of the fall composition survey. Proportions are based on totals for all animals observed including calves.

Table 8 Extrapolated estimates of the total population size (calves not included in estimate)

Survey Data	Estimate	SE	CV
Number of 1+ year-old Caribou on Calving Ground	240,081	19,285.48	0.080
Number of Breeding Females	156,784	13,619.87	0.087
Proportion of Females in the Entire Population	0.625	0.006	0.010
Proportion of 1.5+ yr Females Pregnant	0.720		0.100
Total Population Estimate	**348,661**	**44,860.52**	**0.129**

Statistical analysis was conducted on the time series of breeding cow photo survey estimates to assess if changes in the breeding cows could be detected. The estimate of breeding cows has the least number of assumptions regarding pregnancy rates and sex ratios and therefore is the best indicator of overall herd trend. For the first analysis, a weighted least squares regression was used to estimate trend from the time series of data (Brown and Rothery, 1993). Each population estimate was weighted by the inverse of its variance to account for unequal variances of surveys, and to give more weight in the estimation to the more precise surveys. It was possible that non-linear trends could be evident in the population and therefore information theoretic methods (Burnham and Anderson, 1998) and significance tests were used to determine if significant non-linear trends existed as indicated by significant polynomial terms in the regression analysis. The model with the lowest AICc score was considered the most parsimonious, thus optimizing the tradeoff between bias and precision (Burnham and Anderson, 1998). The difference between any given model and the most supported (ΔAICc) was used to evaluate the relative fit of models when their AICc scores were similar. In general, any model with a ΔAICc score of <2 is considered to be supported by the data.

The population size estimate was log transformed to partially account for the exponential nature of population change and allow direct estimation of the per-capita rate growth rate (r) (Thompson, 1998). More exactly, the estimated slope from the regression was an estimate of *r,* the per capita growth rate. The per capita growth rate can be related to the population rate of change (λ) using the equation $\lambda=e^r=N_{t+1}/N_t$. If $\lambda=1$ then a population is stable. If λ is less than 1 then the population is decreasing, and if λ is greater than 1 then the population is increasing.

For the first analysis, potential trends in the time series of photo surveys from 1983 to 2008 were considered with linear, quadratic, and cubic trend models as candidate models (Figure 21). Of these, a linear trend model was most supported with AICc weight for this model being close to 1. The estimate of λ from this model was 1.02 suggesting an increasing population, however, confidence limits overlapped 1 (CI=0.99-1.06) and the trend term in the regression was not significant ($t=2.76, df=1, p=0.07217$).

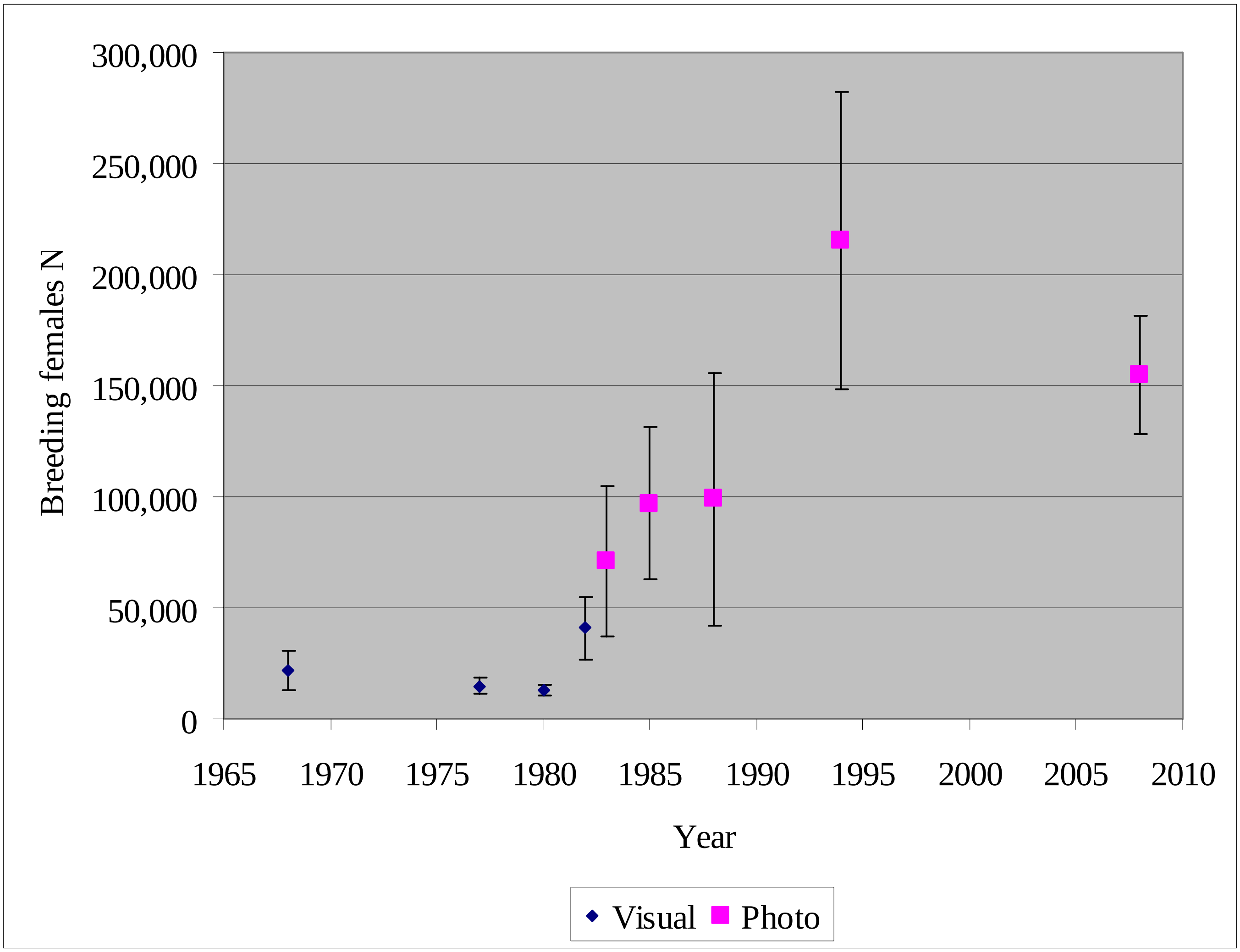

Figure 21 Population estimates of breeding females of the Qamanirjuaq caribou population June 1968 to 2008.

Comparision of herd estimates suggests that the Qamanirjuaq population has declined 30.4 % from the 496,000 (SE = 105,000) estimated in June 1994 to 348,661 (SE = 44,861) in June 2008. The lower standard error of the breeding female estimates makes these estimates a more accurate measure of change. The decline in breeding females agreed well with the total population estimates indicating a decline of 27.9 % from 215,198 (SE = 34,188) in June 1994 to 155,154 (SE = 13,558) in June 2008 (Table 9). This would suggest an annual rate of decline during this 14 year period of approximately two percent. Further inspection of the confidence limits of the 1994 and 2008 estimates shows that they overlap and therefore a statistical difference between these 2 estimates cannot be detected. Overall, the weighted least squares regression analysis, and confidence interval estimates suggest that it is not possible to decisively determine the trend in population size of breeding females for the Qamanirjuaq Herd. The actual trend in the Qamanirjuaq Herd will be influenced by both productivity (proportions of adult females that give birth on the calving ground and the survival of the calves) and adult survival. As discussed later, a demographic model-based approach (Boulanger et al 2010) that integrates information from survival rates, calf-cow ratios, and calving ground estimates will be used to further explore caribou demography and population trends.

Table 9 The history of calving-ground visual and photographic surveys on the Qamanirjuaq calving ground. Where both visual and photographic surveys were conducted in the same year the photo survey results were used.

Year	Breeding Females			Total Herd Size			Source
	Y_h	SE	CV	Y_h	SE	CV	
1968	22,000	4,428	0.205	63,000			Parker, 1972 *(Visual Calving-ground Survey)*
1974	21,403	6,403					*Hawkins & Howard, 1974 (Visual Calving-ground Survey)*
1976	15,380			43,800			*Calef & Hawkins, 1981 (Visual Calving-ground Survey)*
1977	14,787	1,936	0.131	44,095	n/a	n/a	Heard, 1981 *(Visual Calving-ground Survey)*
1980	13,000	1,260	0.097	39,000	n/a	n/a	Heard & Calef, 1986 *(Visual Calving-ground Survey)*
1982	41,000	7,200	0.176	180,000	n/a	n/a	Heard & Calef, 1986; Gates, 1985 *(Visual Calving-ground Survey)*
1983	71,000	17,200	0.242	230,000	59,000	0.258	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1985	97,000	17,400	0.179	272,000	142,000	0.523	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1988	99,000	29,000	0.293	221,000	72,000	0.328	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1994	215,198	34,188	0.159	495,665	105,426	0.213	Unpublished data; Thomas, 1996 (Calving-ground Photo-Survey)
2008	156,784	13,620	0.087	348,661	48,861	0.129	This report *(Calving-ground Photo-Survey)*

5.0 DISCUSSION

5.1 The Calving Ground Survey

Since the first calving ground delineation survey conducted by Malfair (1963), the Qamanirjuaq calving grounds were surveyed 19 times up to and including the current study. The survey data has shown the Qamanirjuaq caribou herd to have had a high level of fidelity towards the Qamanirjuaq and Banks Lake areas. It should be noted however, that qualitative observations by experienced biologists and local hunters have indicated that the Qamanirjuaq herd likely wintered north and northeast of Baker Lake in 1975 and 1976, migrating south onto the calving grounds during those years (Calef and Hawkins, 1976; Fleck and Gunn, 1982). Ideal conditions for a calving ground survey on the Qamanirjuaq range are lacking in some years and according to collar location data the number of collared cows making it to the annual concentrated calving extents (ACCE) has varried from 16 to 100 percent between 1993 and present. These inconsistencies must be monitored carefully during a survey year to help ensure that all monitored indices suggest a year of high fidelity to annual concentrated calving extents. At the same time we must also consider that environmental conditions during the spring migration to the calving ground may have a strong effect on the proportion of breeding females that actually congregate on the annual calving ground. Through (15 years) the initiation of the satellite collaring program in 1993 to the present GPS program in 2008, two collared caribou cows moved and remained north of Chesterfield Inlet between 1998 and 2008. Over the same collaring program there has been two years, 2000 and 2005, when Qamanirjuaq caribou spring migration was delayed resulting in extensive calving south of the annual concentrated calving extents (Table 10; Figure 22). Though it is difficult to compare years due to the inconsistent numbers of collars deployed, proportionlly the 2008 calving season had 87% of the collared caribou cows on the annual concentrated calving area by June 5th 2008. In addition the 2008 calving season had the highest number (33) of satellite and GPS collars deployed. The 2008 calving season showed high fidelity to the annual concentrated calving extents with only six out of 33 collars (4 of which moved within the ACCE by mid-June) maintaining positions south of annual concentrated calving extents throughout the 2008 survey period.

Table 10 An Index of Individual collared Qamanirjuaq caribou fidelity to Annual Concentrated Calving Extents (ACCE) during the first week of calving (June 1st to 5th) throughout the history of the Qamanirjuaq satellite /GPS collaring program (1993 to present).

Year	***Collars Deployed At Calving (#)***	***Collars within ACCE (#)***	***Collars Within ACCE (%)***
1993	5	5	100
1994	4	3	75
1995	0	n/a	n/a
1996	3	3	100
1997	0	n/a	n/a
1998	10	7	70
1999	8	7	87
2000	6	1	16
2001	2	2	100
2002	1		
2003	1		
2004	10	9	90
2005	7	2	28
2006	18	18	100
2007	17	11	64
2008	33	27	81

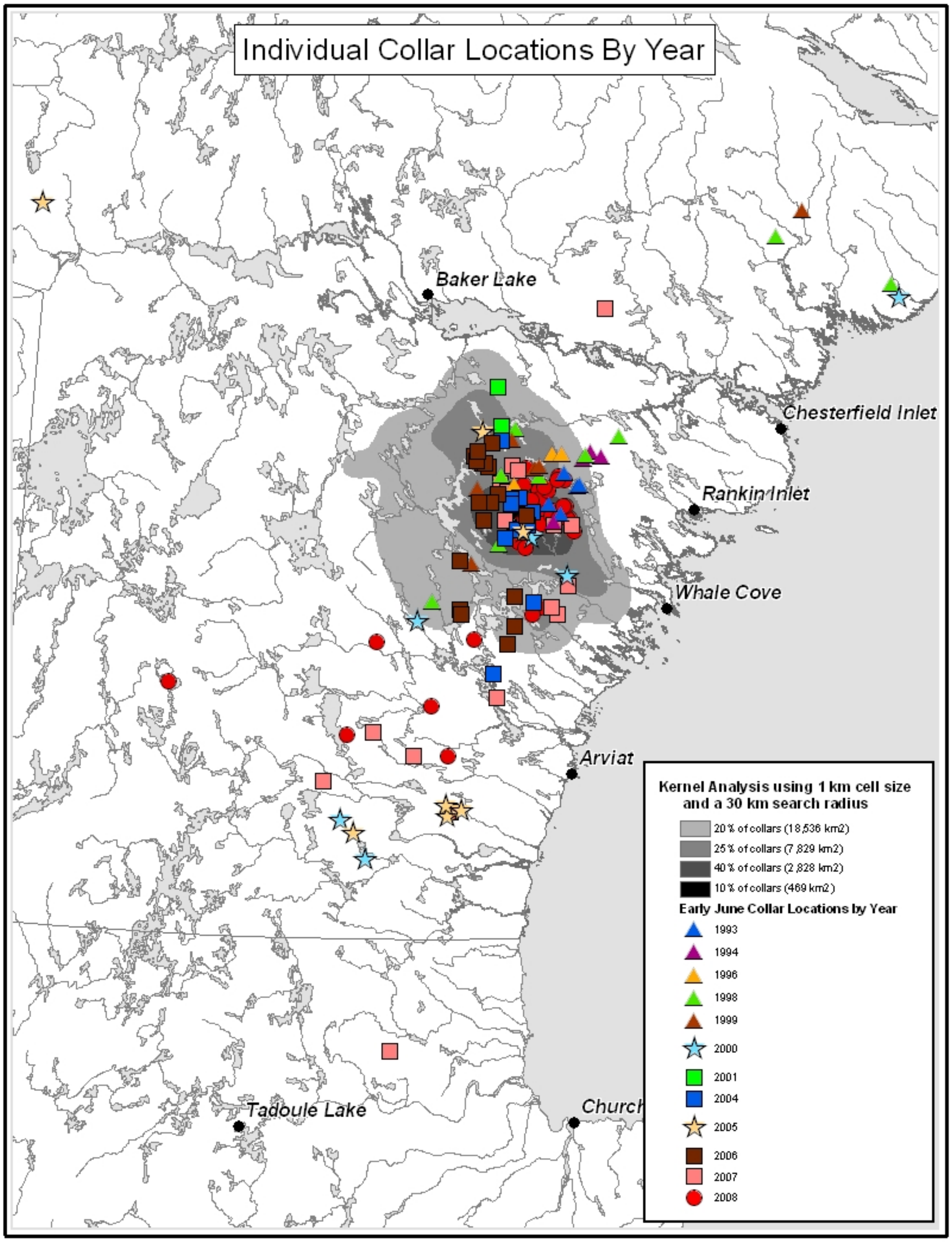

Figure 22 Individual collar locations by year. The years 2000 and 2005 stand out as years when the herd was either late arriving on the calving grounds or that there was a higher proportion of non-breeders during those years. Comparisons must be made cautiously due to inconsistent annual numbers of collars.

In total, the 2008 reconnaissance survey covered 31,045 square kilometers, 3,110 linear kilometers on transect, representing just over 8% coverage. A review of the available literature suggests that the 2008 reconnassance survey exceeded all previous reconnaissance of the Qamanirjuaq caribou herd during calving, though much of the reconnaissance data, despite an extensive search, could not be located. In addition, the methods used for reconnaissance surveys have varied over the years and as a result are difficult to compare.

Survey effort was substantially greater in 2008 when compared with previous calving-ground photographic surveys of the Qamanirjuaq herd (Table 11). There were 36 collars deployed 2 years prior to the 2008 survey with 33 active (2 on 5-day duty cycles and 31 on 1-day duty cycles) at the time of the survey while in 1994 four collars with a four-day duty cycle were active at the time of the survey. The only other survey years with the benefit of collars were June 1985 and 1988 where a number of VHF collars were deployed prior to the survey date. The total survey area (also considered the calving area for that survey year), calculated using delineated photographic and visual stratum, for the 2008 June calving ground photographic survey, was 6,476 km^2. To cover this area 2,179 kilometers were flown on transect within both visual and photogtaphic stratum, representing a mean survey coverage of 29% (21% to 42%). In comparison, during the 1994 calving ground photographic survey, an analysis of original maps and data sheets used during the survey reveal a survey/calving area of 8,916 km^2. To cover this area 1,059 linaer kilometers were flown on transect within only photographic stratum, representing a mean survey coverage of 11.2% (8% to 18%). During the 1994 survey 1,327 photos were shot as compared to a total of 4,017 photos shot in June 2008. In addition, the 2008 survey included 4 low density visual strata, while the 1994 survey and all previous photographic surveys of the Qamanirjuaq herd dileneated no visual strata. During the present study the combined total of 1+ year old caribou estimated on the 4 low density strata represented <5% of the estimate. Similarly, the contribution of low density strata to the estimate of breeding females was around 2%.

Table 11 Qamanirjuaq calving-ground survey details June 1966 through 2008.

Year	Survey Type	Breeding Female Estimate	SE	Survey / Calving Extents (km^2)	# Photos Taken	Coverage (%)	# Collars	Reference
1966	Visual	n/a	n/a	6,400	0	n/a	0	*Parker, 1972*
1967	Visual	n/a		6,400	0	n/a	0	*Parke, 1972r*
1968	Visual	22,000	4,428	6,066	0	n/a	0	*Parker, 1972*
1970	Visual	n/a	n/a	5,200	0	n/a	0	*Miller & Broughton, 1974*
1971	Visual	n/a	n/a	4,784	0	n/a	0	*Land & Bowden, 1971*
1972	Visual	n/a	n/a	5,021	0	n/a	0	*Bowden & Timmerman, 1972*
1973	Visual	n/a	n/a	2,995	0	n/a	0	*Land & Hawkins, 1973*
1974	Visual	21,403	6,403	11,045	0	n/a	0	*Hawkins & Howard, 1974*
1976	Visual	15,380		9,763	0	20	0	*Calef & Hawkins, 1981*
1977	Visual	16,503	1,936	18,500	0	2 - 38	0	*Heard, 1981*
1978	Visual	n/a	n/a	8,200	0	n/a	0	*Darby, 1978*
1979	Visual	n/a	n/a	6,500	0	n/a	0	*Darby, 1979*
1980	Visual	13,000	1,260	1,525	0	n/a	0	*Heard, 1980*
1982	Visual	41,000	7,200	n/a	0	n/a	0	*Heard & Calef, 1986*
1983	Photo Only	71,000	17,200	n/a	n/a	n/a	0	*Heard and Jackson, 1990*
1985	Photo Only	97,000	17,400	n/a	n/a	n/a	37 (vhs)	*Heard and Jackson, 1990*
1988	Photo Only	99,000	29,000	7,843	2,233	6- 14	26 (vhs)	*Heard & Jackson, 1989*
1990	Visual/Delineation	n/a	n/a	3,390	0	n/a	0	*Gauthier & Mulders, 1990*
1994	Photo Only	215,198	34,188	8,916	1,327	8 - 18	4 (sat.)	*Unpublished data; Thomas, 1996*
2008	Photo & Visual	156,784	13,620	6,476	4,017	21 - 42	33 (GPS)	*This Report*

In 1981 Heard grappled with the inaccuracy and imprecision of previous visual calving ground surveys of the Qamanirjuaq herd noting, amongst other issues, the following five survey design flaws pertinent to the present study;

1. Animals were found in groups too large to count accurately.
2. Lack of consistent and robust statistical analysis of results.
3. Error resulting from fixed wing inconsistent flying characteristics and blind spots.
4. The need to collect data on 2 of the 3 parameters (sex ratio, pregnancy rate, stratum composition).
5. Observer bias and caribou sightability.

In response to similar concerns over the more modern technique of photography a barren-ground caribou calving ground photography workshop was held November 2000 in Yellowknife NWT. Discussions during this meeting mainly centered on how to reduce errors within survey estimates by Increasing survey coverage and numbers of collared caribou.

In response to these and other concerns the 2008 survey made the following changes to the overall survey design strategy;

1 The overall proposed budget increased to allow for an increase in survey effort.

2 Improved collar technologies and increased number of deployed collars added assurances to the timing of calving and helped steer reconnaissance survey effort used to define and stratify calving extents.

3 Reconnaissance survey coverage followed a standardized systematic transect technique and was the most extensive on record. Reconnaissance survey transects aligned with concurrent Beverly caribou reconnaissance survey transects (NWT unpublished Government research, June 2008) along the western extents of the Qamanirjuaq range.

4 A visual survey component was added to the periphery of the annual calving extents where caribou densities were very low to allow for tighter stratification of higher density areas. Visual survey estimate accounted for 2.1% of the total calving ground estimate.

5 Visual survey observers were trained prior to the actual survey.

6 Additional trained observers were available within the survey aircraft to alleviate error due to primary observer fatigue.

7 All visual survey aircraft were equipped with a radar altimeter for a more consistently maintained altitude above ground level.

8 Photographic coverage was increased two to three fold over previous Qamanirjuaq photographic surveys.

9 There were no weather delays during either the visual or photographic surveys largely reducing the possibility of extensive movements between strata.

10 Strata composition encountered no weather delays and as a result was conducted immediately following abundance surveys allowing minimal time for caribou movement between strata.

11 Fall composition studies to determine the sex ratio of the herd were completed within the same year as the survey.

Despite attempts to reduce overall type one and type two errors, there is still much room for improvement to consider for future surveys. The use of the visual survey technique in very low density areas allowed us to focus more resources within higher density areas which we believe increased the accuracy of the survey result. Observer error will always be a problem when conducting visual estimates, however, adding distance sampling (Buckland *et al*, 1993) or a double observer platform (Koneff *et al,* 2008) may vastly improve this methods reliability and should be considered for future surveys.

Increased collar deployment can become a political issue amongst northern communities because they are concerned about the long term effects of handling and collaring caribou; however, it is considered an effective technical means of improving the reliability of survey estimates and population trends (Fisher *et al*, 2008). Collars help both to determine timing of arrival onto the calving ground as well as calving extents and with an appropriate number of collars deployed can also be used to analyse cow survival rates. Though the 33 collars available during the June 2008 survey defined the calving extents very well, Rettie (2008) determined that 80 or more collared females per herd would be required to detect moderate (6 to 7% / year) changes in female survival an important connection between survey results, herd productivity and trend.

Observer training could be improved by using experienced observers to cross train new observers. Maintaining a consistency of trained observers both within and between surveys would improve the quality of observations. In addition, it is possible to use double observer methods to account for differences in the ability of observers to sight caribou (Koneff *et al,* 2008). Considering the extensive daylight during early June, we also recommend the use of more than one survey aircraft and crew to reduce time on transect for any one crew and thus observer fatigue, as well as to reduce delays between reconnaissance phase and abundance phases of future surveys.

More effective means of extrapolating relative density information from reconnaissance surveys into survey stratum are needed to further reduce times between recon completion and survey commencement. Developing custom tools within the ESRI suite of GIS software is strongly recommended as it remains the most common analytical GIS software used across the north and has many atvantages concerning accuracy and precision that are often lacking within less robust GIS software packages.

Finally, the ability of this study to ensure if the survey is adequately estimating all breeding females in the population is always going to be hampered by by the unknown caribou distributions outside of the survey areas regardless of how strict the criteria for continuing to fly down a particular transect is. This study strongly recommends concurrent reconnaisance surveys of caribou ranges known to surround the area within which a caribou population is being estimated. Without this, critics will always have an argument over whether survey crews have covered an appropriate area (i.e., where the caribou might have been if we had only looked there). This major change will require considerably greater resources then are currently available to jurisdictions, as well as an improvement in inter-jurisdictional cooperation.

5.2 Demographics

When considering the survey history of the Qamanirjuaq population, results suggest that herd numbers had reached their lowest recorded valves between 1968 and 1980 then began climbing over a period of 14 years to their highest recorded levels in 1994 (Figure 21). Between 1968 and 1980 the population remained relatively stable with breeding female estimates between 22,000 (SE = 4,500) and 13,000 (SE = 1,260). Following 1980, the herd began increasing with a period of relative stability between 1983 and 1988. After 1982, photo-survey methodologies were used which could have affected estimates by reducing negative bias due to sightabilility with visual surveys. Therefore, some of the observed increased in population size between the 1982 survey and later surveys could have been due to changes in survey methodology. The six year period following the 1988 survey year up to the 1994 survey year showed an increase in estimates from 99,000 (SE = 29,000) breeding females in 1988 to 215,198 (SE = 34,188) breeding females in 1994. This followed by a potential decline of 27.9 % between 1994 and 2008 over 14 years seems small however spring calf/ cow ratios suggest that the annual rate of decrease of the herd may be greater then indicated. However, large confidence limits on the 1994 survey make it difficult to determine the reliability of the overall population estimate and subsequent trend estimate as indicated by confidence interval overlap between the 1988, 1994, and 2008 breeding female estimates

Spreadsheet models developed for the Qamanirjuaq population by Graf and Heard (1990) suggest that given a natural mortality rate of 8.4% and a total subsistence harvest of 6,600 animals (6% calves and equal sex) the population should stabilize at 24 calves per 100 cows assuming a total population size of 221,000. These results however should be treated cautiously since the level of sustainable harvest is only qualitatively estimated and any rate of decline based on overall mortality would be strongly influenced by total population size. This would be most significant in a situation where mortality rates remain constant on a declining population. In this situation, the proportional rate of decline would increase with a decrease in the population. Stochastic models should be used to address many of these issues, particularly in situations where inconsistancys exist in the available demographic parameters of the population being modeled. Such would be the case for the Qamanirjuaq population.

Although spring composition data are incomplete over the survey history of the Qamanirjuaq Herd, the available information tracks well with both the breeding female estimates and total population estimates (Figure 23). Both Heard and Calef (1986) and Bergerud (1983) suggest that predation may affect over-winter survival rates of Qamanirjuaq calves. The hypothesis is that disturbance from predators and other sources including anthropogenic and natural (eg., insect harassment), may affect behavior and forage intake by caribou. Therefore reduced disturbance results in improved forage and energetic intake which can result in increased over-winter calf survival (expressed as calves/100 cows) and respective increases in population (Bergerud, 1983; Herd and Calef, 1986; Stankowich, 2008; Astrup, 2000; Altmann, 1958; Beale and Monaghan, 2004; Bender *et al*, 1999; Bergerud, 1974; Calef, *et al*, 1976; Colman *et al*, 2001; Horejsi, 1981; Klein, 1974; Mahoney *et al*, 2001; McCourt *et al*, 1974; Miller and Gunn, 1979; Nellemann *et al*, 2000; Nellemann *et al*, 2001; Nellemann *et al*, 2003; Reimers and Colmon, 2006; Reimers *et al*, 2003; Reimers *et al*, 2006; Reimers *et al*, 2007; Karin *et al*, 2001; Tyler, 1991; Vistnes *et al*, 2004). Conversely, it is hypothesized that increased disturbance on the range would cause over-winter survival of calves to decline below a point at which overall recruitment does not exceed mortality and the population declines.

The proportion of cows in the Qamanirjuaq caribou population appears to have remained relatively constant throughout its recorded history (Parker, 1972; Kelsall, 1968; Heard and Calef, 1986; Heard and Jackson, 1989; Figure 24). A decline in the proportion of bulls during the declining phase is not apparent when examining the available historic data. Proportions provided by Kelsall (1968) Parker (1972) and Heard and Calef (1986) point out that values from 1958, 1968, 1977 and 1980 came from very small sample sizes and should be interpreted with caution.

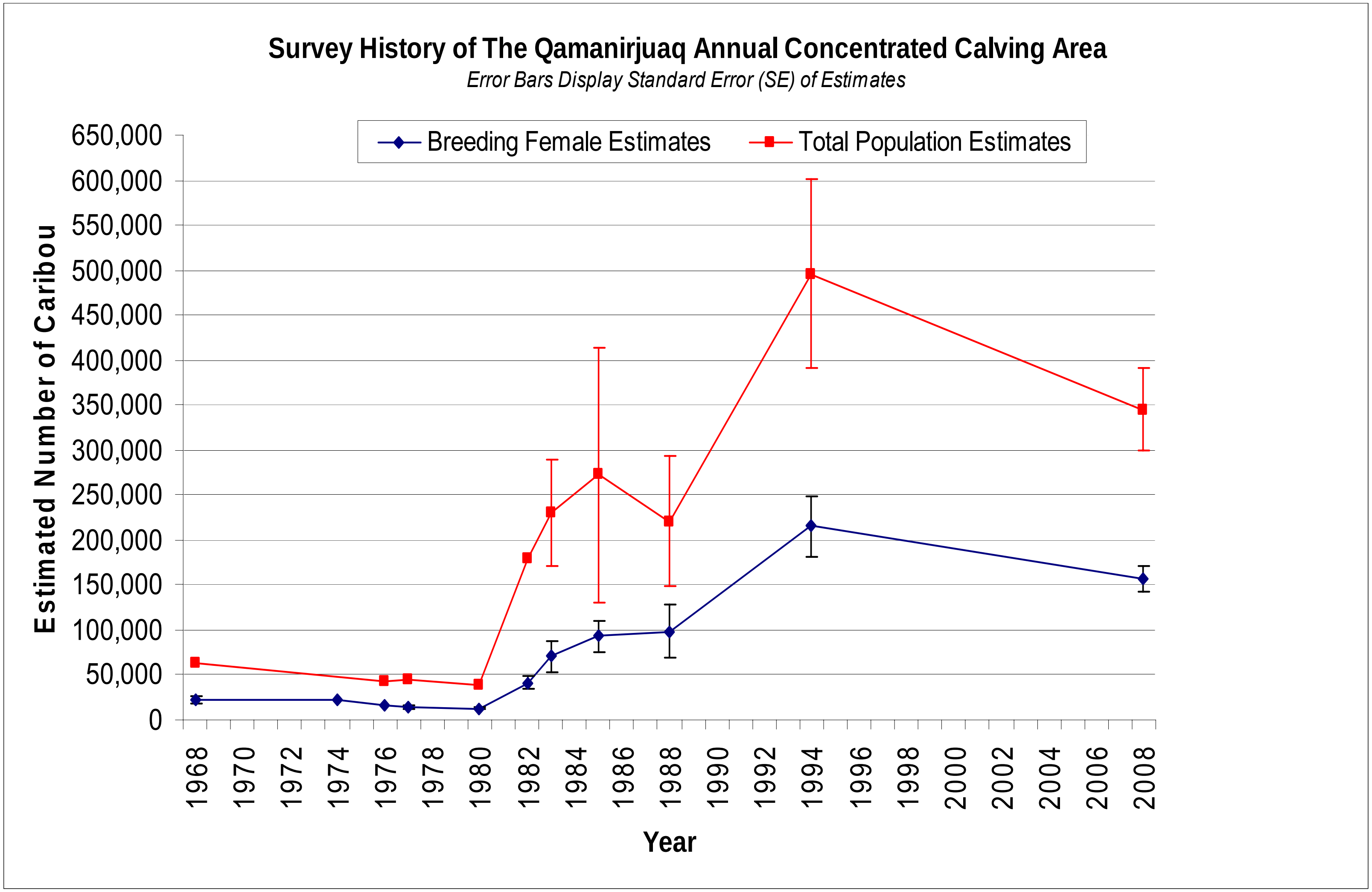

Figure 23 The survey history of the Qamanirjuaq caribou Herd on its calving grounds. Estimates of variation were not available for the 1968, 1977, 1980 or 1982 total population estimates. Historic data taken from (Parker, 1972; Kelsall, 1968; Heard and Calef, 1986; Heard and Jackson, 1989).

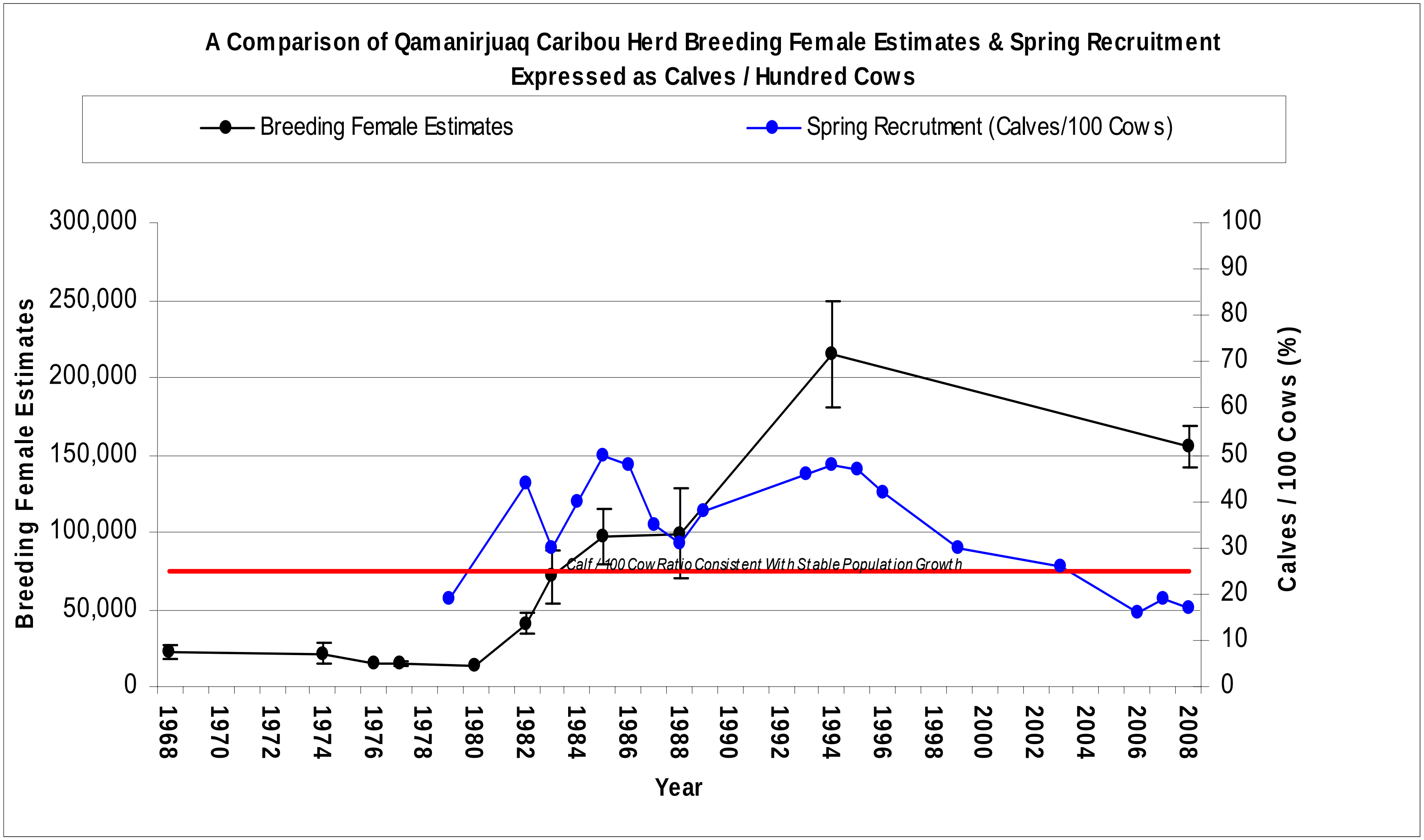

Figure 24 A comparison of Qamanirjuaq caribou herd spring calf recruitment results expressed as calves / hundred cows, with breeding female estimates, June 1979 through 2008. Data for pre 1993 calf/Cow ratios from Williams et. Al. (1989) and Heard and Calef (1986). Error bars indicate standard error of estimates. Historic data taken from Parker, 1972; Kelsall, 1968; Heard and Calef, 1986; Heard and Jackson, 1989). Displayed data assumes average adult survival.

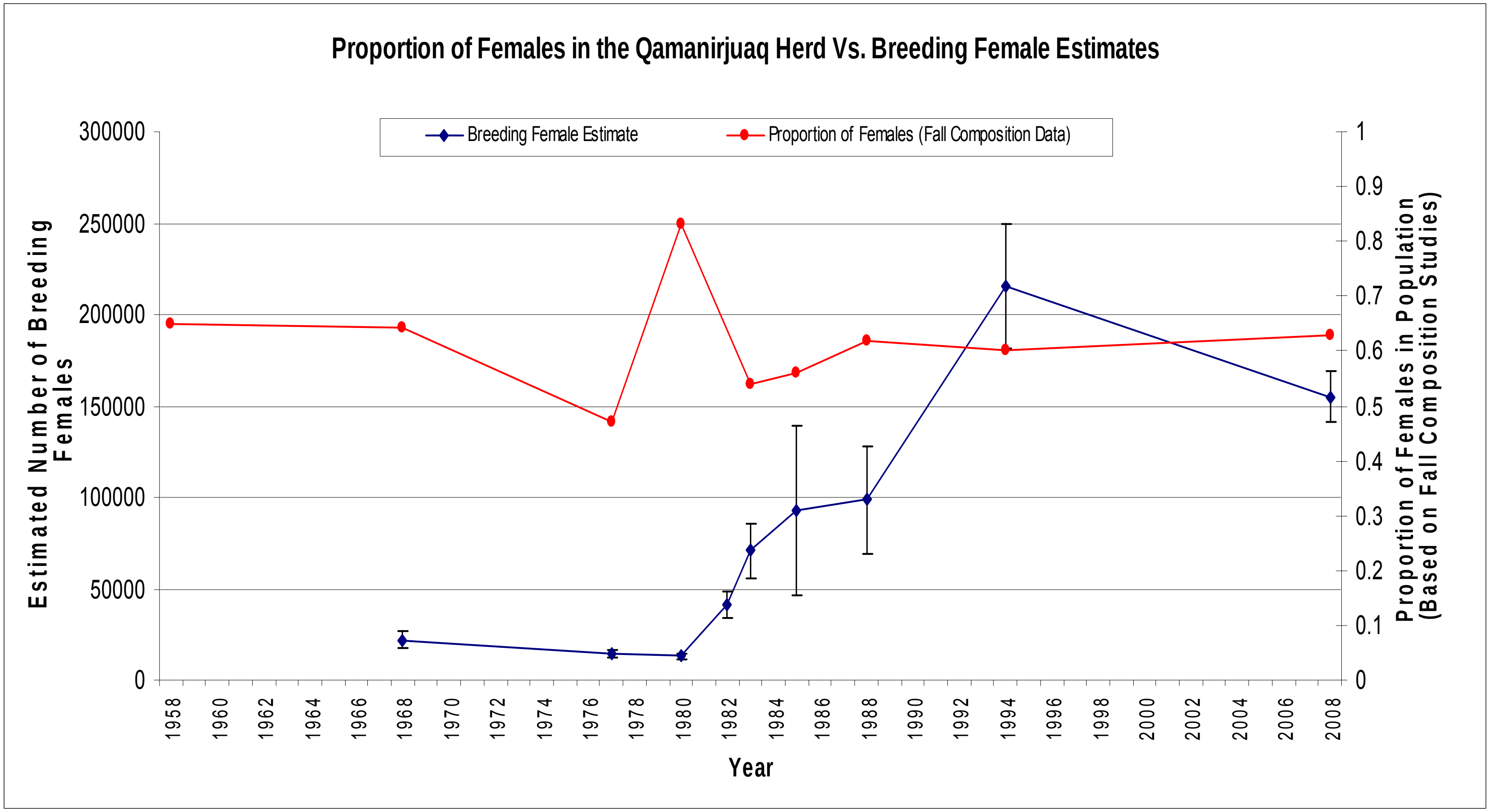

Figure 25 Proportions of breeding females compared with breeding female estimates for the Qamanirjuaq population of barren-ground caribou. Historic data taken from Parker, 1972; Kelsall, 1968; Heard and Calef, 1986; Heard and Jackson, 1989). Error bars indicate standard error of estimates.

5.3 Decline Mechanisims

5.3.1 Hunter Harvest

Within the Kivalliq region of Nunavut, harvest rates are reported to have been stable between 1990 and 1998 and in decline between 1998 and 2001 (NWMB harvest study, 1996, 2006; Figure 26).

Unfortunately, harvest statistics are not available for communities outside of Nunavut. Although the Beverly and Qamanirjuaq Caribou Management Boards (BQCMB) 2006, in cooperation with Intergroup consultants have estimated the annual Manitoba harvest of Qamanirjuaq caribou at 2,070 and the Saskatchewan harvest at 500 to 1,000. When combined with the 2006 Nunavut estimates a total annual harvest of 10,308 Qamanirjuaq caribou is derived (Figure 27).

Since the severe declines and/or range shift documented for the Beverly Heard in 2006, 2007, and 2008 (Johnson, 2008) much of the northeastern Saskatchewan caribou harvest, centralized out of Wollaston Lake, has shifted from Beverly caribou to Qamanirjuaq caribou (Trottier pers. comm, 2008). Though no formal studies quantifying this increased harvest have been initiated, distribution data provided by the Kivalliq caribou monitoring program supports these observations.

We note that if the Qamanirjuaq Herd is declining than a constant rate of harvest may potentially affect the herd to a greater degree each year as herd numbers get lower. Therefore, monitoring of harvest along with other demographic indicators is essential to ensure sustainability of harvest on the Qamanirjuaq herd. A case study of the likely role of harvest on a declining herd is evident in the recent decline of the Bathurst herd (Boulanger et al 2010).

Though the cultural value of caribou to Kivalliq Inuit is beyond this reports ability to describe, we can examine the economic value that would be lost if for some reason the Qamanirjuaq caribou herd was no longer available to range wide harvesters. In 2008 InterGroup consultants estimated the dollar value of the Beverly and Qamanirjuaq caribou herds to the peoples living and harvesting on the annual range. Examining the Qamanirjuaq herd only with available harvest estimates, the study conservatively estimated the value of the Herd at $15.07 million dollars annually. Of the total amount, $10.62 million annually is used for subsistence, $0.42 million annually for non-aboriginal residents living on the range, $0.54 million annually for commercial meat sales, and $3.49 million annually is uses within the commercial sport hunting industry (Figure 28). Kivalliq Inuit are the largest consumers of Qamanirjuaq caribou utilizing 78% of the range wide harvest annually. There is a risk that if f the population is slowly declining, a relatively constant rate of harvest could accelerate the overall rate of decline over time. Therefore, it will be important to increase monitoring efforts of population trend and hunter harvest (i.e., annual offtake and relative hunting effort) to ensure that harvest rates are sustainable and can be managed in a timely fashion.

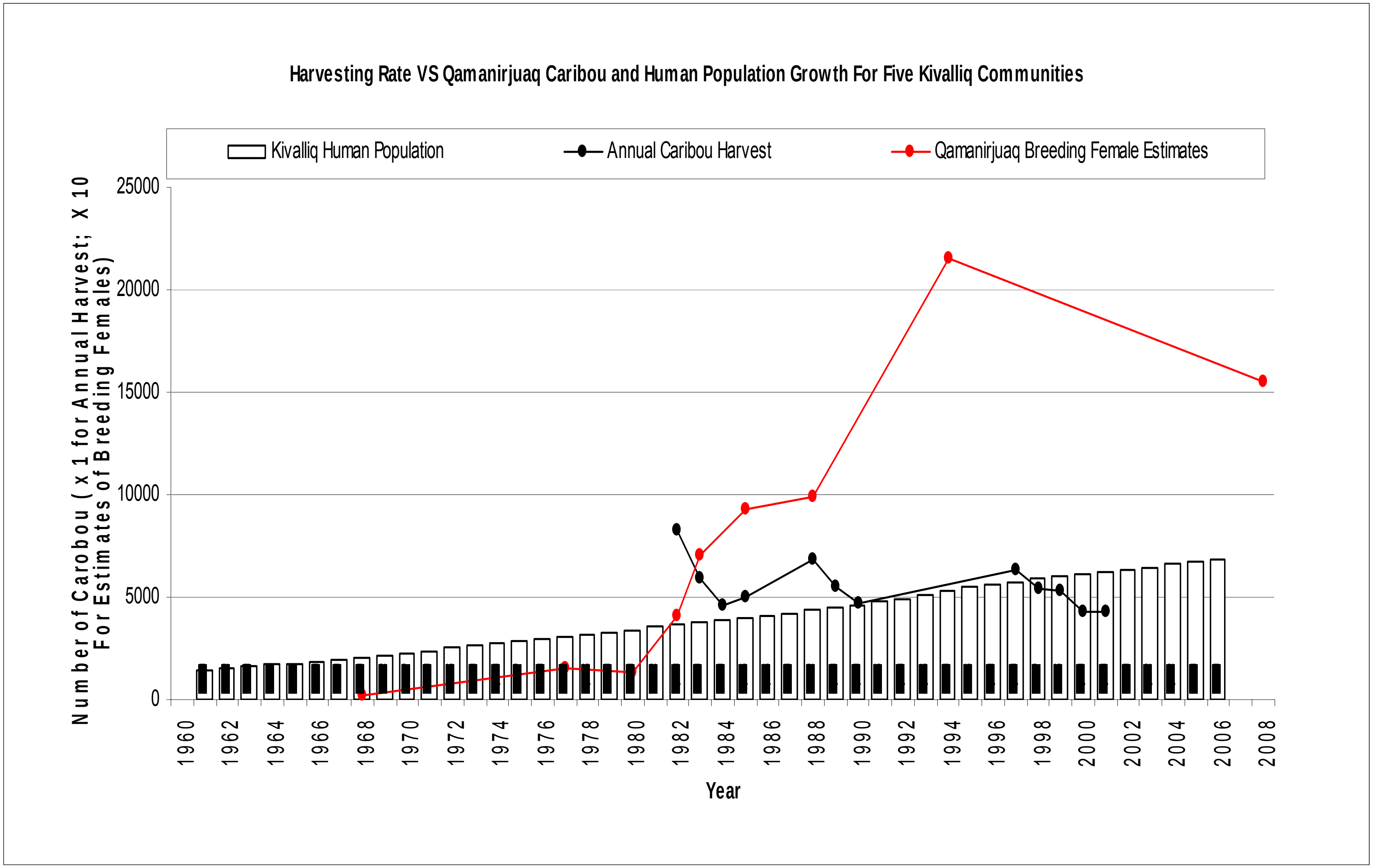

Figure 26 The history of harvesting Qamanirjuaq caribou compared with human population growth and caribou population growth and decline. Only the Kivalliq communities of Arviat, Baker Lake, Chesterfield Inlet, Rankin Inlet and Whale Cove are shown (Harvest data based on the NWMB 2004 harvest study).

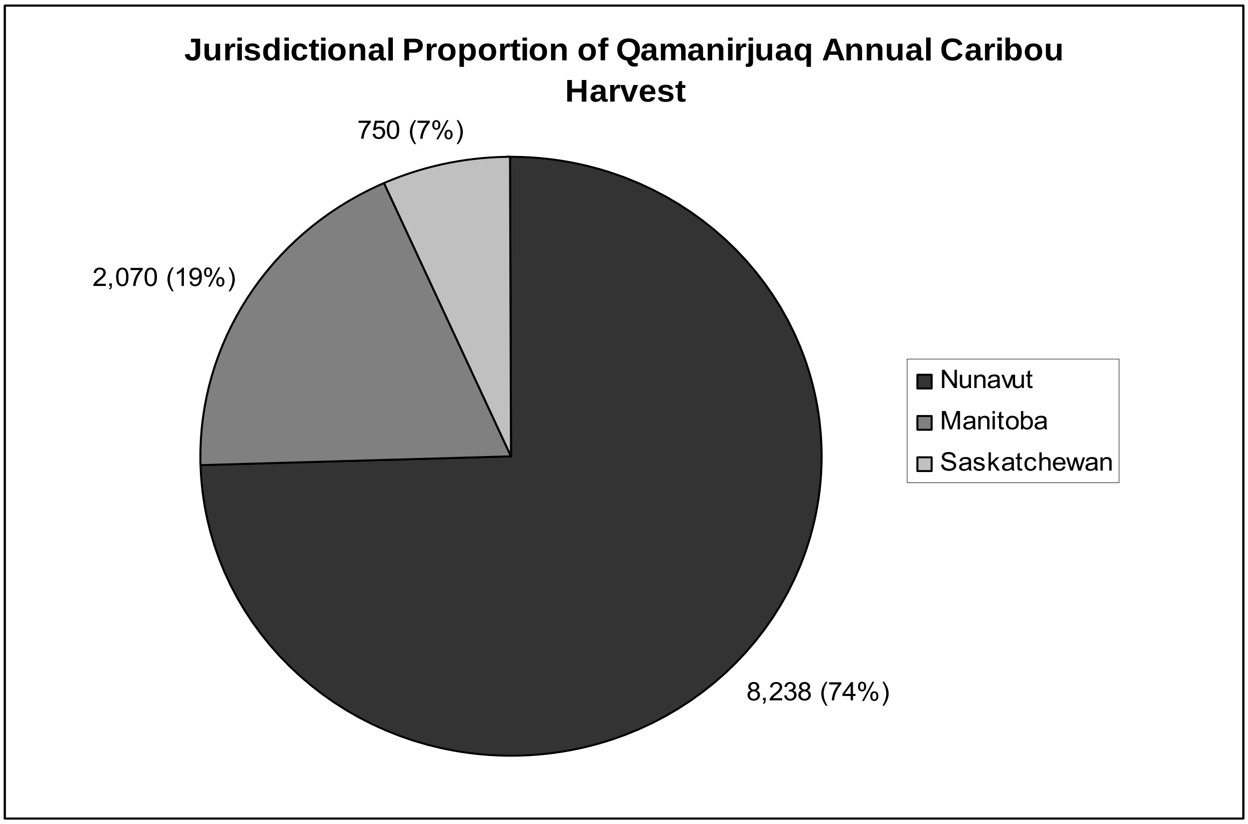

Figure 27 Estimated proportion of Qamanirjuaq caribou annually harvested range wide (Based on 2006 estimates)(After Intergroup Consultants, 2008).

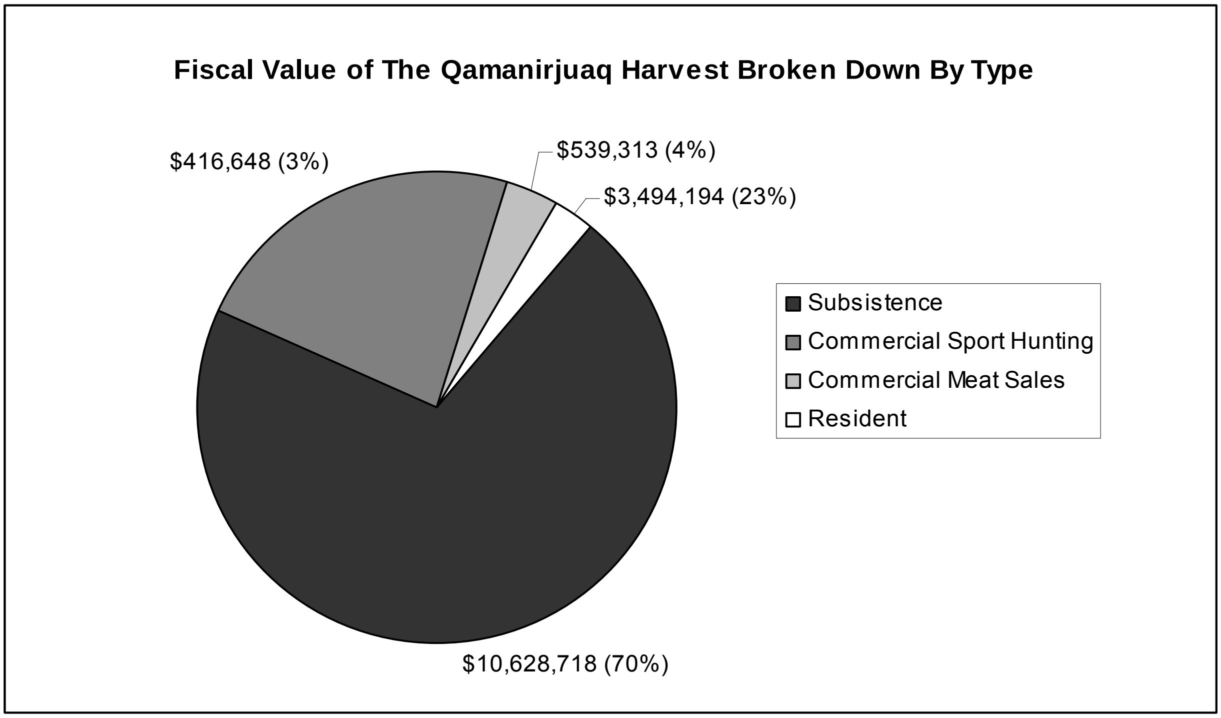

Figure 28 Proportion of the Qamanirjuaq harvest by type. (After Intergroup consultants, 2008).

5.3.2 Predators:

A review of the literature discussing past surveys of the Qamanirjuaq Herd on its calving grounds has provided little comparative information on the number of predators observed. Due to this lack of comparative survey information there is presently no way of quantifying whether predation on the 2008 calving ground has increased through the years of study. During the reconnaissance survey (with an estimated 8% coverage of the 2008 early June caribou distribution) a total of thirteen wolves and five barren-ground grizzly bears were observed (Figure 29). Within the annual concentrated calving extents three wolves and two barren-ground grizzly bears were observed. Wolves were also sighted within the low density visual strata flown directly following the reconnaissance survey. One wolf was sighted within each of the Low # 2, Low #3 and Low #4 strata. Though the effects of predation on adult and calf survival cannot currently be quantified, it is clear from this study that predation is active within the northern reaches of the Qamanirjuaq spring migratory corridor as well as their annual concentrated calving grounds.

A growing body of evidence from traditional and scientific sources indicates that large migratory caribou herds periodically increase and decrease in response to factors such as predation and hunting (Banfield 1954; Kelsall 1968; Bergerud 1974, 1980), climate (Klein 1991; Caughleyand and Gunn 1993), and food limitation due to overgrazing (Messier et al. 1988; Crête and Huot 1993). Two main factors influencing reproductive output and survival in ungulates are nutrition (Skogland 1986; Gunn 1992) and predation (Miller and Broughton 1970; Parker 1972; Miller et al. 1985; Miller et al. 1988; Adams et al. 1995; Young and McCabe 1997; McLoughlin 2001). The relative role of these two factors is spatially and temporally affected by stochastic environmental conditions (Gunn 1992; Post and Stenseth 1999) and local abundance of predators.

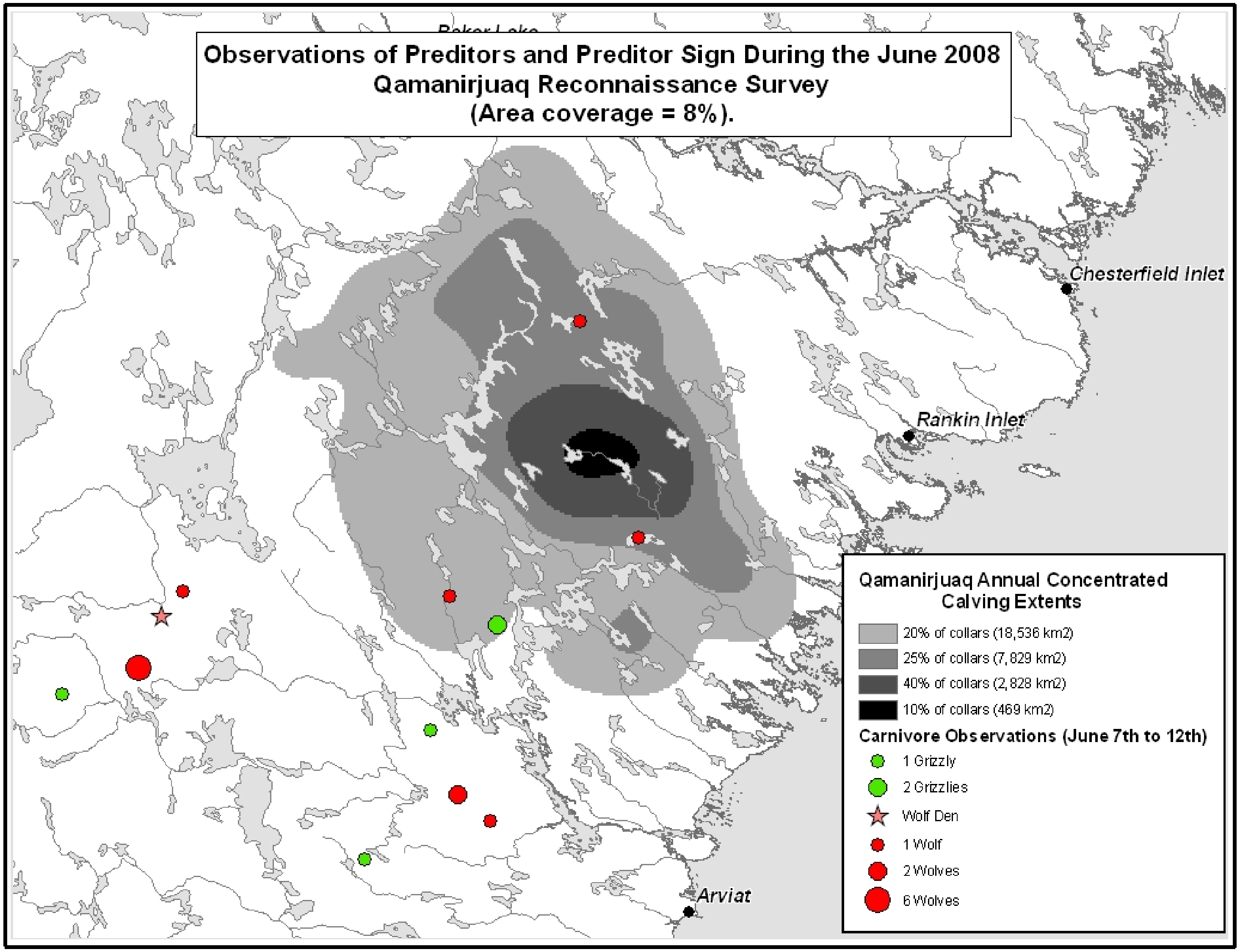

Figure 29 Predator observations during the June 2008 calving-ground recognissance survey. All observations were made between the 7th and eighth of June. Recognissance survey coverage = 8%.

In the Kivalliq region of Nunavut, barren-ground caribou are preyed upon by a suite of predators, including barren ground grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*). Some studies have addressed the major role of wolves on the neonate mortality of caribou on barren lands (Miller and Broughton 1970; Miller et al. 1988; Williams 1995). Adams et al. (1995) described different patterns of grizzly bear and wolf predation that are related to differences in abundance, distribution and predatory characteristic of these carnivores. Grizzly bears are solitary and are ambush predators that contrast sharply with the socially cooperative methods of wolves. Gauthier and Theberge (1987) described that where wolves and bears are co-predators of an ungulate species, bears can be more important in reducing ungulate numbers than wolves, primarily through their effect on younger age classes. Additional predators such as Black bears, golden eagles, and wolverines must also be considered in this multi-predator system in addition to human harvest. Combined predation and human harvest, particularly when a caribou herd is in decline phase, could accelerated the rate of decline. Impact of predation including human harvest on the Qamanirjuaq Caribou Herd is largely unknown and ecological resilience to limiting factors in this predator -prey system (multiple sympatric predators and a single-prey) has not been studied. We must also consider that the negative feedback from excessive predation ultimately controlling the number of these predators, is not necessarily similar to feedbacks to human harvest as accessibility to caribou increases with increases in development and mobility.

Previously Parker (1972) identified that the high losses of calf crops during the first month of life lead to a low annual increment limiting growth of the Qamanirjuaq herd. The most recent declines in recruitment are of great concern to wildlife managers because recruitment replaces the loss of adults from predators, harvest and other factors and an imbalance between recruitment and mortality ultimately leads to decreases in population size. Efforts to evaluate the status of the range and the condition of the herd were undertaken in recent years (Campbell 2008). Predation, on the other hand, has received limited attention (Miller and Broughton 1974) so far in Nunavut. In other jurisdictions such as

Alaska (Golden and Rinaldi 2008), and Northwest Territories (Miller et al. 1988; Williams 1995) research studies has been conducted to identify the mechanisms of decline in their herds. There are some recent ecological changes on the Qamanirjuaq herd's annual ranges, such as increases in muskoxen (alternate prey) populations (Fournier and Gunn 1998); and increases in grizzly bears – so change in predation rates are likely on the Qamanirjuaqs annual range. Mortality of calves can be estimated from tracking changes in calf:cow ratios and the causes of calf death can be estimated from carcass examination.

Recent studies have revealed that barren-ground grizzly bears are effective predators on caribou. McLoughlin (2001) identified grizzly bears as important predators of barren-ground caribou. Gau et al. (2002) between 1994 and 1997 observed radio-collared grizzlies on 136 caribou kill sites, and further from fecal analysis concluded that barren-ground grizzly bears lead a predominantly carnivorous lifestyle and are effective predators of caribou. Young and McCabe (1997) in northeastern Alaska described estimated kill rate of 4.8 kills/bear/day of caribou calves obtained by conventional radio-tracking point surveys. During 1984-87, Adams et al. (1995), while studying the extent, timing, and causes of calf mortality in the Denali Caribou Herd, observed that overall, 39% (n= 226 calves; ≤3 days old) of radio-collared calves died as neonates (≤15 days old), and 98% of those deaths were attributed to predation. Grizzly bears, wolves, and unknown large predators (i.e., grizzly bears or wolves) accounted for 49, 29, and 16% of the neonatal deaths, respectively. The rate of bear-caused mortalities declined with calf age, and wolf predation was not related to calf age and peaked 10 days after onset of calving which would be consistent with the increased mobility of pups born in May.

Miller et al. (1988) and Williams (1995) described that wolf predation was the important detected cause of death for newborn caribou calves during their first week of life on the Beverley calving grounds. Overall rates of neonatal mortality/calf crop in their first week of life for Beverley calving ground was estimated 5-7% in 1981-83 (Miller et al. 1988) and 9% in 1993-94 (Williams

1995). Miller and Broughton (1974) conducted a study of calf mortality in the Qamanirjuaq herd in June 1970. In this study wolf kills amounted to 19% (n=31) for calves 7 day old or less and 26% (n=43) for calves 14 day old or less. Miller et al. (1983) compared caribou calf mortality on calving grounds of the Qamanirjuaq herd (1970; Miller and Broughton 1974) with Beverley herd (1981), concluded that among the observed mortality to calves wolf predation accounted for 35% (n=52) in Qamanirjuaq and to 54% (n=69) in Beverley. Later Williams (1995) reported 70% (n=33) in 1993 and 61% (n=28) in 1994 of calf carcasses examined on the Beverley herd showed evidence of wolf predation as the cause of death. Miller et al. (1985) documented multiple kills of barren-ground caribou calves by wolves on Beverley calving grounds. In one day Miller et al. (1985) found 34 calves killed by wolves clumped in a 3-km^2 area. Boertje and Gardner (2000) investigated mortality (from June to September) among 217 radio-collared caribou calves (1994-97) in Fortymile Caribou Herd in Alaska and described that wolf and grizzly bears were consistently the major predators. Of the 99 calves (<4 months old) for which cause of death was determined, wolves and grizzly bears each killed 36 calves. Miller et al. (1988) described that lower fraction of calf mortality was attributed to bears (0.4%) on the Beverley herd calving ground between 1981 and 1983, while Williams (1995) estimated grizzly bear mortality as 3% in June 1993.

If the Qamanirjuaq Herd is experiencing nutritional bottlenecks, calf body mass at birth may be reduced. Smaller calves are more vulnerable to various causes of death including predation. Examining the body mass of newborn calves may contribute to understanding underlying causes for the reduced recruitment (Griffith et al. 2002).

Fleck and Gunn (1982) suggested that the location of the calving areas is related to predator avoidance, as there are low numbers of wolves and bears in the calving areas. Cluff et al. (2002) reported few breeding wolves actually den on the caribou calving ground. Parker (1973) described that most wolves do not den near caribou calving grounds, instead wolves select sites near the tree line

(Frame et al. 2008), likely as a strategy to optimize access to caribou for rearing pups (Cluff et al. 2002). Heard et al. (1990) observed 137 wolves and 17 bears per 1,000 hours flown on Beverley calving ground in 1987. Williams (1995) described that sighting rate of both wolves and bears have increased (393 wolves and 97 bears/1,000 hours flown) since 1987 on the Beverley calving ground in 1993 and 1994. Miller and Broughton (1974) made more wolf sightings (n=19) in June 1970 on the Qamanirjuaq calving grounds than were made by Miller et al. (1988) on Beverley calving grounds (n=12 in 1981; n=10 in 1982; and n=3 in 1983). Miller et al. (1988) suggested that a key to maximizing early calf survival may be to have few or no wolves present on the calving ground. Further Miller et al. (1988) recommended that the exact number of predators and their distribution (coordinates) be routinely required during future surveys of the calving grounds. Better records should be an essential part of any intensive management program, to allow evaluations of kinds and numbers of predators occupying the calving grounds during the calving and post calving period.

Case et al. (1996) estimated that 55,500 caribou in the Bathurst herd are taken annually by wolves, or 16% of the 1990 population estimate of Bathurst caribou of 351,683 caribou. Those Case's estimates are difficult to substantiate it is known that studies of food habits of wolves at high latitudes indicate that ungulates are their primary prey (Petersen 1998). Clarkson and Liepins (1992) collected and analyzed 177 wolf scat samples from 9 dens in 1989 in Inuvik region, western Arctic. Caribou was the main prey in 55% of the scats. Since wolf predation could be decreasing caribou recruitment, performing a wolf diet analysis is an important step in understanding their role in caribou survival. Stable isotope analysis of 13C and 15N is commonly used in ecological studies and has been applied to various diet studies (Hobson and Wassenaar 1999). McFadden et al. (2006) described that isotopic diet studies offer advantages over other methods in that isotopic ratios reflect nutrients assimilated over extended periods of time and not simply those recently ingested.

5.3.3 Disturbance:

Disturbance effects to caribou caused by man have long been a major concern of conservationists, wildlife managers and local peoples across the circumpolar north. Within Nunavut's wildlife management regime this issue is greatly confused largely due to disagreements and in fighting between several interests groups the majority of which include the Nunavut Department of Environment (DoE), Nunavut Wildlife Management Board (NWMB), Nunavut Tunngavik Incorporated (NTI), Nunavut Planning Commission (NPC), Kivalliq Inuit Association (KIA), Indian and Northern Affairs Canada (INAC), The Nunavut Impact Review Board (NIRB), the Kivalliq Wildlife Board (KWB), and the Hunters and Trappers Organizations (HTO) on the Qamanirjuaq range including, Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake. Of all the organizations only two, INAC and NIRB, have provided any interim protection from development and disturbance to the Qamanirjuaq caribou population on their calving and post-calving grounds, NIRB through stringent review processes, and INAC through the caribou protection measures. Unfortunately the NIRB process does not necessarily insure final protection to caribou on their critical range, and the INAC protection measures is not legally bound, is dated and sparsely enforced. What is urgently needed if we are to conserve Nunavut's caribou populations for subsistence and commercial harvesters of all Jurisdictions is a protected areas strategy for Nunavut spearheaded by the Nunavut Department of Environment.

Using satellite collar and aerial survey data (Boulanger et al 2004, Boulanger et al 2009) analyzed the movements of Bathurst caribou on post-calving range. Using a multi strata analysis Boulanger et al (2004) detected a trend of increasing rates of movement of caribou from the vicinity of the Ekati and Diavik mine sites. Using RSF (Resource Selection Function Analysis) and AICc model selection methods Boulanger et al (2009) found that caribou selection of habitat increased with increased distance from mine site development for up to 16 Kilometers. Caribou were about four times more likely to select habitat at greater distances from the mine complex than within the zone of influence. The implications are that caribou are responding to industrial developments at greater distances than shown in other areas, possibly related to dust deposition from mines.

Boulanger et al (2009) results are the most pertinent to the Qamanirjuaq population due to their close proximity and behavioral similarities but do not come as a surprise. The results of Boulanger (2009) identify dust deposition from roads as a potential cause for larger areas of avoidance around mine areas. The analysis of Boulanger et al (2009) does not consider behavioural avoidance and instead focuses on larger-scale factors.

Stankowich (2006) in his comprehensive review of ungulate flight responses found evidence across studies that ungulates as a group pay attention to approacher behavior, have greater perceptions of risk when disturbed in open habitats, and females or groups with young offspring show greater flight responses then wholly adult groups. In addition Stankowich's conclusions that hunted populations of ungulates showed significantly greater flight responses than non-hunted populations is of particular concern to the Nunavut caribou populations.

Subsistence harvesting of caribou in Nunavut is a fundamental right of Inuit and an integral part of Inuit culture. Of particular concern is the combination of effects within Nunavut that make Kivalliq caribou more susceptible to developmental and airborne disturbance. In the Kivalliq the landscape is open, the calving and post-calving grounds are centered within these open tundra habitats, and the population is hunted year round. This would make them highly susceptible to other forms of disturbance and development. Proposals to construct road corridors into exploration and mining sites would certainly increase hunting pressure and ground based disturbance which, as discussed by Stankowich will likely cause a distributional shift away from these critical core areas into far less desirable habitat. Less desirable habitat means reduced productivity, higher mortality and a number of other negative impacts that have yet to be fully understood.

With the information available we can state with some certainty that roads into calving and post-calving grounds will increase the frequency and amount of hunting pressure and disturbance which in turn will make caribou much more suceptable to other forms of developmental disturbance. The type of environment within wich all this will be occouring, that being open tundra, reduces cover possibly intensifying these effects.

5.3.4 Disease, Parasites and Biting Insects:

In 1992 the Canadian Polar Commission released a status report on Brucellosis in the Circumpolar Arctic (O'Reilly, 1992). In the report O'Reilly summarized the incidence of Brucellosis across the Circumpolar arctic (Table 12).

Table 12 Circumpolar Incidence of Brucellosis in Barren-ground Caribou and Reindeer. (After O'Reilly, 1992).

Herd	Incidence (%)	Date	Remarks	Source
Southampton	Not Present	1990	75 samples	(NWT Wildlife notes)
Qamanirjuaq	4%	1966-68		(NWT Wildlife notes, 1983)
Beverly	< 2%	1983	118 samples	(Goldfarb, 1990)
Bathurst	Present	1981-1983	3 samples	(NWT Wildlife notes, 1983)
Baffin Island	14-35%	Mid-1980's	N Baffin highest	(O'Reilly, 1992)
Melville/Boothia	20-35%	1980's	17 samples	(O'Reilly, 1992; Gunn et al. 1991)
Ahiak	?			
Porcupine	15-20%	1980's	?	(O'Reilly, 1992)
Central Arctic	15-20%	1980's	?	(O'Reilly, 1992)
Western Arctic	</= 30%	1960-1980	?	(O'Reilly, 1992; Neiland et al. 1968)
Nechina	1-6.5%	1962-65	?	(Neiland et al. 1968)
George River	Not Present	1987-88	?	(Forbes 1991; Greenberg et al. 1958)
QEI Peary	Present	1980's	1 sample (P. of W. Island)	(Forbes, 1991)

Brucellosis prevalence within the Qamanirjuaq Herd is currently unknown though a screening study for the disease within Qamanirjuaq caribou is ongoing. Recent studies on Southampton Island caribou clearly demonstrate the efficiency of the disease to initiate a decline in a caribou population by heavily affecting productivity (Campbell, in Prep). Though it is unclear whether Brucella or any other reproductive disease is responsible for the decline currently observed during the 2008 Qamanirjuaq survey, it is certainly possible that it is a contribution factor.

Insect harassment on both domestic and wild ungulates is well known to interfere with habitat utilization and feeding intensity and duration (Darling, 1937; Pruitt, 1960; Espmark and Langvatn, 1979; Helle, 1981; Hugues *et al,* 1981; Woollard and Bullock, 1987; Renecker and Hudson, 1990; Ralley *et al,* 1993; Duncan and Cowtan, 1980; Harvey and Launchbaugh, 1982; Keiper and Berger, 1982; Sleeman and Grey, 1982; Downes *et al*, 1986; Toupin, 1996). There is a growing body of literature that clearly demonstrates the ability of insect harassment to force ungulates into energetically demanding avoidance responses and concentrate animals into lower quality poorly vegetated environments such as ridge tops, coastal regions, snow patches, lee sides of large inland lakes (Kelsall, 1968; Downes, 1984; Helle and Aspi, 1984; Dau, 1986; Camps and Linders, 1989; Helle et al., 1992; Walsh et al., 1992; Toupin, 1996). The result of severe insect harassment can result in a negative energy balance and the resultant decline in health and condition and ultimately productivity (Roby, 1978; Russell *et al*, 1993; Helle and Kojola, 1994; Toupin, 1996).

Within the literature the primary insects observed to be responsible for harassing caribou include mosquitoes (Family Culicidae), black flies (Family Simuliidae), horse flies (Family Tabanidae), and warble and nose bot flies (Family Oestridae) also referred to as oestrid flies (Hagemoen and Reimers, 2002). Interestingly, mosquitoes, blackflies and tabanid flies are not considered the primary harassers of reindeer and caribou but rather the oestrid fly's (Bergman, 1917; Downes *et al*, 1986; Morschel and Klein, 1997; Andersen *et al*., 2001; and Rolf *et al*, 2002).

Rolf *et al,* (2002) suggested oestrid flies caused considerable losses in reindeer husbandry despite a widespread yet poorly documented belief that mosquitoes are the primary harassers. According to Rolf et al (2002) in Norway osterid fly harassment was apparent from the 3rd of July to the 17th of August as early as 07:10 h (August 4th) and as late as 23:20 h (July 17th) with severe harassment being observed between 09:20 h and 20:13 h. Rold et al further reported that osterid activity was strongly positively correlated with ambient temperatures with the lowest measured temperature for osterid activity being 6.9^{0}C. Above 14.0^{0}C oestrid fly activity was always recorded and increased in intensity when reindeer were exposed to direct sunlight.

Toupin (1996) in their study of insect harassment on the George River Herd found that biting insect activity was at its greatest on or about mid July. The observed harassment reduce time spent feeding from 50% to 30%, and time spent standing from 1% to 39%. In addition, habitat use was modified towards snow patches. Overall however the study concluded that though insect harassment had a significant impact on caribou behavior, it simply was not intense enough over a long enough period to have significantly contributed to a negative energy balance. Though no studies have yet examined the extent of insect harassment on the Qamanirjuaq population there is evidence that it could be occurring at longer durations then observed in northern Quebec. The Qamanirjuaq caribou-collaring program has been on going since fall of 1993. When all the location data is analyzed as mean daily movement rates some clear patterns emerge (Figure 30) that would suggest a high energy output during the times of year ideal for biting insects.

5.3.5 Cumulative impacts

The observed decline in the Qamanirjuaq herd could be the result of any one or a combination of the above disturbance, health effects but more likely it results from a combination of all of the above plus some additional effects not discussed in this report. One might say that an accumulation of these productivity impacts or “cumulative impacts” would be the most likely explanation.

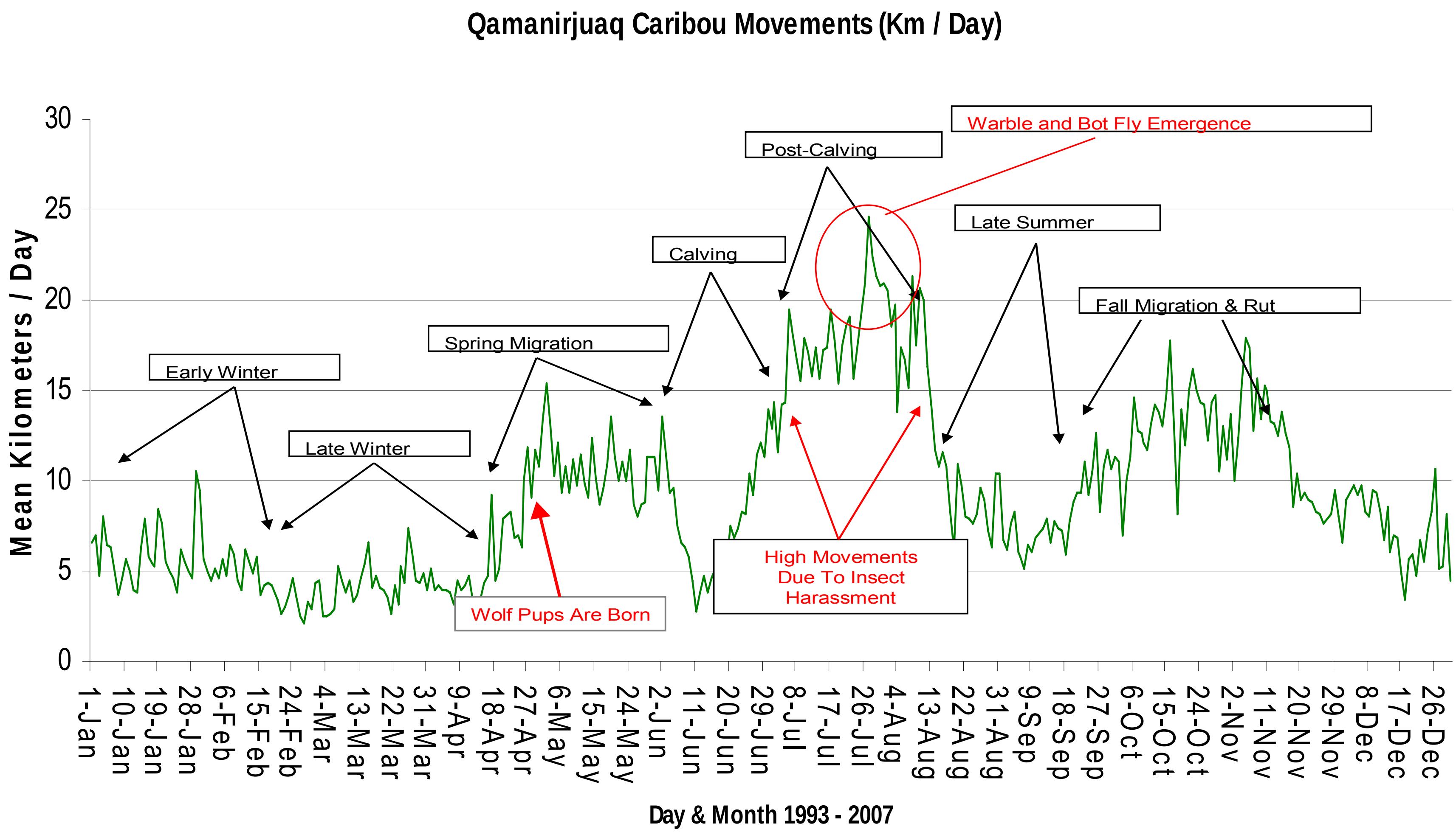

Figure 30 Mean daily movement patterns of the Qamanirjuaq caribou herd. Movement data compiled from collar location data collected between November 1993 and November 2007.

6.0 CONCLUSIONS & RECOMMENDATIONS

Section 6.0 through 6.4 was developed by M. W. Campbell in accordance with GNU DoE Wildlife Management roles and responsibilities. The subject matter discussed within this section may not nesecerrarly reflect the Co-Authors views and/or opinions.

6.1 Management

The BQCMB management plan allocates a sustainable harvest of Qamanirjuaq caribou by taking 5% of what they define as the "standing stock". The standing stock in turn is defined by the BQCMB as 75% of the herd estimate, which in 1994 was 495,665 animals thus yielding 18,600 caribou available to harvest sustainably (given a ratio of harvest of 50% male and female). The actual harvest was estimated by the BQCMB per community on the range and then adjusted by a factor of 1.25 for estimated wounding loss. Using this system the total harvest was estimated at 12,852, which is 5,748 animals below the calculated maximum sustainable harvest.

Applying this method to the 2008 Qamanirjuaq population estimate of 348,661 an estimated sustainable harvest of 12,939 caribou is calculated. In the absence of more recent data the estimated 2006 range wide harvest of 10,308 caribou multiplying through a factor of 1.25 for wounding loss and would yield a total sustainable harvest of 12,885 caribou. Given the change in productivity in recent years it is unclear as to whether this harvest is sustainable. If the current productivity estimates (based on spring recruitment surveys) do not improve it is likely that the current estimated harvest may not be sustainable over the long term.

Although in this report there has been no statistically validated decline identified between the 2008 and 1994 estimates of the Qamanirjuaq population, there seems to be a signal that a slight decline may have occurred, which combined with data on calf:cow ratios, we believe, necessitates a conservative approach. As a result additional and improved monitoring of trend and harvest levels (offtake and effort) are recommended.

Many steps can be taken to reduce human harvesting impacts on a declining population. Reductions in commercial harvesting should be considered prior to any discussions concerning subsistence harvesting. The rights and needs of subsistence harvesters across the range must be ultimately respected. Working directly with subsistence harvesters to come up with innovative ways to reduce overall impacts will be critical. Harvesting males when possible, harvesting only what is needed for subsistence, and reducing wounding loss and associated wastage would be amongst a series of positive step towards mitigating future hardship. Additional steps that could help should be discussed with each community on the range and any management decision made in partnership. Respecting and seeking subsistence harvesters experience and knowledge of caribou on their range will be a critical first step to any successful management decisions concerning the future health of any caribou population.

Caribou declines are complex involving many environmental agents and conditions combined with disturbance from natural resource development, tourism, as well as human harvest so many considerations must be made prior to making any management decisions.

6.2 Monitoring Plan

The delineation of caribou calving and post-calving aggregations, winter, spring and fall seasonal habitats requires a minimum of 50 radio-collared individuals per priority herd. A recent independent peer review of barren-ground caribou management in the NWT by the Alberta Research Council (2008) concluded that the number of collars on caribou should be substantially increased above the 30 to 40 collars per heard currently deployed (Bathurst, Ahiak and Qamanirjuaq). This level of sampling will be addressed by deploying 20 satellite GPS collars every year with the expectation that the collars will last 3 years with some mortality and failure loss. Capacity for real time GIS (kernel) analysis is necessary so daily identification of winter, spring, calving, post-calving, and fall/rut aggregations are possible. Regulations that identify an appropriate protocol for area closures must include a daily review process through the calving and post-calving interval. These regulations must include a sound (ecologically effective) working definition for “area closure” developed by a more comprehensive caribou-monitoring program. Space use analysis (resource selection functions, burns, development impacts, etc) will be conducted on an ongoing basis as data accumulate, new methods emerge, and habitat data become available. These analyses will provide guidance to land use regulators and community residents regarding anticipated impacts and forecasts of caribou abundance and availability.

Future monitoring will need to index all harvested caribou populations using systematic reconnaissance survey methods at least once every 5 years and for indicated declining populations every 2 years for identified priority herds. Priority herds will be idendified according to their trend and estimated rate of harvest. Because of the potential indicated decline of the Qamanirjuaq Herd we will now need to monitor spring and fall herd composition and herd specific birth and death rates to monitor the declines depth and duration for proactive harvest management decision making. Spring composition surveys occur prior to calving and provide an estimate of recruitment. Spring composition surveys identify the proportion mature cows with calves, the proportion of the herd that is sub-adults (yearlings), and the proportion of adults that are male and female.

A demographic model (Boulanger and Gunn, 2007; Boulanger *et al* 2010) that considers population size estimates, calf-cow ratios, adult survival rates, fall sex ratios, and other indicators of herd health should be developed to gain a better understanding of the overall demography of the Qamanirjuaq herd. This type of model has been successfully used with the Bathurst herd to assess the effects of hunter harvests, varying levels of productivity, and other factors affecting Bathurst herd demography. In general, this approach provided greater power to detect changes in adult survival, recruitment rates, and population size compared to assessment of collar-based survival rates alone since it considered all the data sources in one analysis (Boulanger *et al,* 2010).

Community hunts will be organized to take 20+ individuals of all sex and age categories to assess disease and parasites and general health/condition. The meat will be brought to community elders, single-parent families, and shared with the sponsoring community. Blood and tissue analysis will be conducted. Condition analysis will be conducted on all samples submitted by local hunters, conservation officers, and biologists. Contaminant assays will be done in cooperation with the Northern Contaminants Program. Condition analysis will be conducted by the DoE and analyzed along with documented weather and disturbance events to develop indices for future management.

ELC (Ecological Land Classification) and RSF (Resource Selection Function) and dietary analysis will be used to identify critical seasonal habitats and preferred forage spp. and determine forage quantity, quality and availability based on focused studies. The methods will determine critical seasonal habitats and forage quantity, quality and availability of forage. In addition we will also need to study the effects of short term and long-term (climate) weather effects on caribou health and productivity as it pertains (largely) to forage quantity, quality and availability.

Studies examining the effects of changing predator numbers, distribution and behaviors on the Qamanirjuaq Range will also have to be initiated if were to understand population trends. Cumulative impact studies can then be used to tie all these studies together to better understand and quantify natural and anthropogenic disturbance effects and to determine the caribou productivity impacts of combined anthropogenic and environmental factors.

Of course all these studies and their findings mean little when the animals in question cross multiple political boundaries. Because of this any management initiatives based on caribou monitoring and research programs will have to compliment and support similar efforts in neighboring jurisdictions that share many of Nunavut’s caribou herds, and be responsive to caribou management plans that are currently in place.

6.3 Minimum Monitoring Requirements:

In order to set priorities a minimum state of knowledge is necessary. Knowledge of harvest and additional anthropogenic disturbances must be understood before further studies can occur. Comprehensive literature reviews and IQ studies are a first step. Low coverage delineation/reconnaissance surveys flown during the calving season are an excellent monitoring tool. Frequency of these surveys should be inversely proportional to herd trend. The value of these surveys would be dramatically increased if coordinated with similar surveys of neighboring populations as this would provide confidence in the case that low relative densities are not just the result of a distributional shift into another heard's annual range. Once these reconnaissance surveys are established they can be re-flown under the identified survey schedule to estimate trend.

The monitoring objectives described in this document are not all always required on all populations at all times. Like many caribou management programs currently in place, various observed demographic trends require various levels of monitoring intensity in order to substantiate the state of the population as well as identify possible cause and effect relationships impacting caribou health and behavior. Complicating this are the current knowledge gaps that have to be filled in order to meet the objectives of this monitoring plan. Table 13 has been developed to assign monitoring program intensity to Nunavut's caribou populations. The table attempts to allocate effort based on a priority matrix. It does not attempt to show what is already available or what other jurisdictions may already be doing. The overall purpose of the table is to list what would be considered the minimum requirements necessary to properly manage Nunavut's caribou populations into the future in a sustainable manner.

Table 13 Minimum monitoring actions required for long-term sustainable caribou management of Nunavut's harvested caribou populations. Monitoring intensity based on priority (Table 1). The management actions listed in this table are based on the current state of knowledge and will require regular updating as technologies change.

Population Identification	Population Type	Management Needs Score	Priority	Below Crisis Level	Monitoring Actions: Literature Review	Seasonal Distribution: 20 collar Deployment	Seasonal Distribution: 50 Collar Deployment	Demographic Studies: Index Surveys: 10 Year Rotation	Demographic Studies: Index Surveys: 5 Year Rotation	Demographic Studies: Index Surveys: 2 Year Rotation	Demographic Studies: Population Estimate: 10 Year Rotation	Demographic Studies: Population Estimate: 5 Year Rotation	Demographic Studies: Population Estimate: 2 Year Rotation	Demographic Studies: Fall Composition: 10 Year Rotation	Demographic Studies: Fall Composition: 5 Year Rotation	Demographic Studies: Fall Composition: 2 Year Rotation	Demographic Studies: Spring Composition: 2 Year Rotation	Demographic Studies: Spring Composition: Annually	Demographic Studies: Productivity: 2 Year Rotation	Disease & Parisites: 5 Year Rotation	Disease & Parisites: Annually	Condition/Health Monitoring: 2 Year Rotation	Condition/Health Monitoring: Annually	Ecological Land Classification	Forage/Range Studies: Quantity	Forage/Range Studies: Quantity/Quality	Forage/Range Studies: Quan/Qual/Availability	IQ Studies	Weather & Climate Studies	Predator Studies: Relative Abundance	Predator Studies: Abundance/Distribution	Predator Studies: Abundan/Dist/Ecology	Athroprogenic Disturbance Studies	Cumul;ative Effects Studies
Ahiak	MMBG	7	3		X		X			X			X			X		X	X		X		X	X			X	X	X			X	X	X
Bathurst	MMBG	9	2		X		X			X			X			X		X	X		X		X	X			X	X	X			X	X	X
Beverly	MMBG	11	1	X	X		X			X			X			X		X	X		X		X	X			X	X	X			X	X	X
Qam.	MMBG	7	3		X		X			X			X			X		X	X		X		X	X			X	X	X			X	X	X
Lorrilard	MBG	5	5		X	X			X			X			X		X			X		X		X		X		X	X		X		X	X
Wager	MBG	5	5		X	X			X			X			X		X			X		X		X		X		X	X		X		X	X
SHI	IBG	6	4		X	X			X			X			X		X			X		X		X		X		X	X		X		X	X
Coats	IBG	0	0																															
N Baffin	IBG																																	
S.Baffin	IBG																																	
D&U	DU																																	
BNEast	MMBG																																	
BNWest	MMBG																																	
Cape B	MBG																																	

Manage. Needs Score 2+ (green) | Manage. Needs Score 5+ (yellow) | Manage. Needs Score 7+ (red)

6.4 Budget and Staffing

The budget was developed by summing the incremental costs of the objectives listed in this report while taking into account research that is already being conducted on Nunavut's caribou populations by other Jurisdictions and/or stakeholders. These estimates were based on the historical costs for these types of research activities as of January 2007 and do not project the changing costs into the future. When there was a commitment for inter-jurisdictional or inter-agency partnerships, the cost of the initiative was reduced accordingly. In that sense, the Nunavut Caribou Monitoring Plan (NCMP) is best viewed as a component of Canada's caribou monitoring program.

The Department of Environment Wildlife Research Division (DoE WRD) will require a minimum of 3 additional PYs to implement the NCMSP. As caribou research is exclusively conducted out of each of the Baffin, Kitikmeot and Kivalliq regions it is strongly recommended that the 3 requested PY's be divided amongst the three regions. Some of the activities identified in the NCMSP would occur as part of Nunavut's annual research agenda that is identified as a priority setting exercise. The Nunavut Wildlife Research Section is identified for 500K of their Vote 1 budget which is a rough average of historical Territorial annual expenditures on caribou research. The intent of the caribou monitoring plan is to build on existing programs, not to replace or duplicate them.

The Wildlife Research Section has currently 16 positions including 7 biologists, 7 technicians and 2 administrative. The Regional staff for wildlife research consists of 2 PYs (1 Biologist and 1 Technician per Region), and they address the research responsibilities for the Section at the regional level and territorial level when needed. By leveraging partnership contributions, the Regional Biologists manage to identify about 1.0-1.5 million dollars annually for ungulate research. This works out to about 167-250K total project cost per person year dedicated to ungulate research. If we use this range and project the staff requirements for the caribou monitoring plan, the estimated number of staff required would be an additional 3 PYs. Our caribou monitoring plan identifies 3 additional Regional

PYs for more than double the current work load. Any work on other terrestrial species (Muskox, Bears, Wolves, Wolverine, Furbearers, Raptors, etc) would be in addition to the NCMSP tasks, and this work is included as part of the Regional Biologist's job descriptions. Based on the cost of the NCMSP alone, the work load per PY for the Regional staff would increase by 2.0 with an additional 3 PYs. This increase is possible (feasible) because of efficiencies realized by implementing the program as line item monitoring rather than on-again, off-again independent annual research initiatives. We also count on a synergy by building up regional teams.

Identification of fewer PYs or organizing these PYs as HQ staff rather than Regional staff would not allow these staff to work at the efficiency level required to implement the monitoring program. Igloolik is one of the communities that are geographically distant from any of the caribou herds that are identified for monitoring except the North Baffin caribou.

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