

CALF:COW RATIOS ESTIMATED AT OR
NEAR THE PEAK OF CALVING FOR THE
CAPE BATHURST HERD, 2002 TO 2006

John A. Nagy¹ and Deborah Johnson²

¹Department of Environment and Natural Resources
Government of the Northwest Territories
Yellowknife, NT X1ANT X1A 2L9
Canada

²Department of Environment and Natural Resources
Government of the Northwest Territories
Fort Smith, NT X0E NT X0E 0P0
Canada

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ABSTRACT

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INTRODUCTION

Hawley *et al.* (1979) reported that the “Bluenose” herd used three general calving areas; one of these was located on the Cape Bathurst Peninsula. Hawley *et al.* (1979) flew an extensive survey of the range of the “Bluenose” herd during 24 to 29 April 1974. Caribou were observed over a large area but four high-density concentrations were recorded. One concentration was on the Cape Bathurst Peninsula in the vicinity of the Old Horton River (mean estimate 4,746 caribou).

Surveys designed to obtain estimates of population size and productivity for the “Bluenose” herd were conducted in 1978 (Brackett *et al.*, 1979), 1979 (Brackett *et al.*, 1979), 1981 Latour and Heard (1985), and 1983 (Latour *et al.*, 1986). Brackett *et al.* (1979) surveyed the Cape Bathurst Peninsula but only detected one cow/calf pair in 1978 and three cow/calf pairs in 1979, respectively. Latour and Heard (1985) observed no concentrations of calving females on the Cape Bathurst Peninsula, although two newborn calves were observed there in 1981. These animals were likely Bluenose caribou, however, the possibility of them being reindeer could not be discounted (Latour and Heard, 1985). Latour *et al.* (1986) did not survey the northern portion of the Cape Bathurst Peninsula in 1983. Reconnaissance survey transects were spaced at 20-km intervals in 1978 and 1979 (Brackett *et al.*, 1979), and at 25-km intervals in 1981 (Latour *et al.*, 1986) and, as a result, concentrations of calving caribou may have been missed.

McLean and Fraser (1992) evaluated the calving ground fidelity of the Bluenose caribou herd between 1986 and 1988. We mapped the locations of

VHF radio collar cows obtained during the calving period by McLean and Fraser (1992) and found that there were 2 radio-collared cows on the area defined as the calving range of the Cape Bathurst herd (Nagy *et al.*, 2005) during the calving period in June 1986, 3 in 1987, and 2 in 1988. Cow 39B was on the Cape Bathurst calving range in all three years. Cow 45BC, captured in February 1987, was on the Cape Bathurst calving range in early June 1987 and 1988. Cow 43BC was on the Cape Bathurst calving range in early June 1987 but was found at the base of the Peary Peninsula in 1988. McLean and Fraser (1992) did not provide information on the number of caribou associated with these radio-collared cows. However, these data indicate that the calving area on the Cape Bathurst Peninsula was in use during the mid 1980s and at least some cows showed repeated use of the area during the calving period.

Latour and Heard (1985) and Latour *et al.*, (1986) classified caribou on the calving grounds of the Bluenose herd in 1981 and 1983. The area they surveyed included the calving ranges of the Bluenose-West and Bluenose-East herds as defined by Nagy *et al.* (2005). There were 83.9 and 71.7 calves per 100 females age greater than 1 year in the area surveyed in 1981 and 1983, respectively. Latour and Heard (1985) found few calving caribou on the Cape Bathurst Peninsula (calving range of the Cape Bathurst herd; Nagy *et al.*, 2005) in 1981 and Latour *et al.* (1986) did not survey the area in 1983.

Theberge and Nagy (2001) surveyed the Cape Bathurst calving grounds on 11 June 2000 and found approximately 64.4 calves per 100 cows age greater than 1 year. A similar survey was conducted on 15 June 2001; 19.2 calves per

100 cows age greater than 1 year were found (Theberge and Nagy, 2001). These calf:cow ratios are much lower than those reported for the “Bluenose” herd by Latour and Heard (1985) and Latour *et al.* (1986) during the early 1980s.

In this paper, we report the results of surveys that were conducted on the calving grounds of the Cape Bathurst herd each year from 2002 to 2006 (Nagy *et al.*, 1999). These surveys were done to document calf:cow ratios and the distribution of caribou on the calving grounds of the herd during or shortly after the peak of calving. We conducted aerial strip transect surveys over the calving grounds in June 2002, 2003, and 2004. In June 2005 and 2006, we located the majority of the cows radio-collared in preparation for a photo-census (Nagy and Johnson, 2007) and photographed the caribou associated with these cows. Our objectives were to obtain calf:cow ratios for the Cape Bathurst herd based on a representative sample of cows in the herd.

We also present the results of analyses completed to map the distribution of cows and calves on the calving grounds. We used the interpolation technique “kriging” to predict and map the distribution (number of calves or cows per km^2) on the calving grounds based on the distribution of survey observations. In addition, we present a standardized method of analysing transect survey data to mapping the extent of annual calving areas.

METHODS

Surveys to Estimate Calf Production

Transect surveys conducted in 2002, 2003, and 2004

In 2002, the boundaries of the survey area were delineated so that they encompassed the main distribution of locations obtained for satellite-collared cows tracked during 10 to 25 June 1996 to 2001 (Figure 1). Transect lines within this area were spaced at 5-km intervals and perpendicular to major river systems (Figure 1). The boundaries of the survey area were adjusted in 2003 and 2004 to reflect the distribution of calf:cow groups and calving caribou (Figures 2 and 3).

The areas were surveyed at or near the peak of calving. The survey crew had a laptop computer equipped with OziExplorer (OziExplorer GPS Mapping Software), a digital map of the survey area, and a digital data file of the waypoints for the ends of each transect. Each day, OziExplorer was used to download the waypoints for the ends of each transect from the laptop to the GPS of the aircraft. The pilot used these waypoints to navigate to the start and end points of each transect.

Markers positioned on the wing struts (Cessna 185) or on a wire stretched between the tie-down rings and the fuselage (Helio Courier) of the survey aircraft were calibrated using the formula:

$$w = W \times h / H$$

where w is the calculated strip width on the ground, W is the chosen survey strip width, h is the height of the observer on the ground, and H is the chosen survey altitude (Norton-Griffiths 1987). The markers were positioned to delineate a 0.5-km wide strip on either side of the aircraft flying at an altitude of 100 m above ground level. Caribou within the boundaries delineated by the markers were designated as “on transect”; those that were beyond the boundaries delineated by the markers were designated as “off transect”. The inter-transect interval was 5 km giving a survey coverage of 20 percent. The aircraft flew at an air speed of 160 km per hour.

Survey crews were comprised of the pilot and an observer and an observer/recorder seated in the back of the aircraft (Helio Courier or Cessna 185). Caribou were classified as calves, cows, yearlings, young bulls, or mature bulls, whenever possible, or as unknown. The observers were equipped with binoculars to help ensure that counts and classifications were done accurately. If an observer had difficulty counting or classifying a group of caribou, the pilot flew to the group and then flew in a tight circle around the group so that it could be accurately counted and classified. The pilot then flew the aircraft back to the point where we broke off the transect line and resumed surveying.

The observer/recorder created a GPS waypoint for each group of caribou observed and recorded the waypoint number, the number and classes of caribou in the group, and whether the group was on or off transect. At the end of each day the waypoint files were downloaded to the laptop computer. The files were

then imported into a Microsoft Excel spread sheet and the waypoint coordinate data (number, latitude and longitude coordinates, date and time) were appended to the observation data. We used the GPS to create a track file so that the location of each transect flown could be accurately recorded (location recorded every 30 seconds). The track files were down loaded to the laptop computer at the end of each flight.

Photographic survey of calf:cow groups in 2005 and 2006

In 2005 and 2006, we used a Helio Courier fixed-wing aircraft equipped with an ATS scanner/receiver (Advanced Telemetry Systems Inc., Isanti, MN) and 2 model RA-2AK dual antennae (Telonics Corp. Ltd., Mesa, AZ) to locate radio-collared cows on the calving grounds. We flew transect lines spaced approximately 20 to 40 km apart; flight altitude was between 440 and 1320 m agl. Once a radio signal was heard we located the collared caribou. The collared caribou and all other caribou associated with it were then photographed from the Helio Courier fixed-wing aircraft with a handheld Nikon D70 digital (6.6 megapixel) camera equipped Nikon AF 35 mm 1:2 D lens. The aircraft flew between 110 and 330 m above and parallel to each group when the photos were taken. The photographer sat in the rear seat of the aircraft behind the pilot and removed the rear window for each photo session. We photographed each group a number of times in rapid succession to provide different views of the group and reduce the possibility of missing calves. The group number, longitude and

latitude co-ordinates, radio frequencies of collars present, and frame numbers of photos taken were recorded for each group photographed.

In the lab we selected the best photo or series of photos taken of each group. We used OziExplorer GPS Mapping Software, Version 3.95.4m, D & L Software Pty Ltd. to create a photomap of each digital image. The photomaps were scanned visually on a computer screen and a waypoint was created on each caribou. The waypoint count gave the number of caribou present on each photomap. OziExplorer allowed us to easily change the magnification at which the images could be viewed thus ensuring that all caribou could be accurately counted and classified. We classified caribou as calves, cows, yearlings, young bulls, or mature bulls, whenever possible, or unknown. We assigned a unique symbol colour for each class of caribou. In the OziExplorer Mapping Software each colour has a unique number code. Once all caribou were counted, we imported the waypoint files into Microsoft Excel and determined the number of caribou counted in each class by doing a frequency count of each colour code. This was particularly useful for large mixed-class groups of caribou.

Calculation of calf:cow ratios

Calf:cow ratios were estimated using the Tukey-Jackknife technique (Cochran, 1977). We used a one-sided t-test to determine whether the calf:cow ratios were significantly different between years. We calculated the t-statistic (t^2) using the formulas in Section 2.3.2, page 39 to 2.3.5 page 44 of (Ramsay and Schafer, 2002).

Defining and Mapping the Extent of Annual Calving Areas

Preparation of data for analyses to define extent of calving area

Location data for caribou observations and transect end points were imported into ArcMap 9.1 (Environmental Systems Research Institute). We used Hawth's Analysis Tools (Beyer, 2007) to created a polyline for each transect using its endpoints. We then split each of these polylines into 5-km segments and created a centroid for each segment using XTools Pro (Data East, 2005). We measured the length of each polyline segment and created longitude and latitude (NAD 83) X and Y coordinates for each centroid using XTools Pro. We then spatially joined the centroid and polyline data files using ArcMap 9.1, and used Hawth's Analysis Tools to create a buffer around each centroid with a radius $\frac{1}{2}$ of the length of it's polyline segment. The resulting buffered centroid data file was spatially joined with the survey data using ArcMap 9.1 and the number of caribou cows and calves observed on transect that fell within the buffer around each centroid was summed. We used the resulting data file to estimate the total number (Equation 1) and density (Equation 2) of cows and calves within a 25-km² area around each centroid as follows:

- estimated number of cows or calves = number of cows or calves observed / percent coverage (Equation 1)
- estimated density of cows or calves (calves per km²) = estimated number of cows or calves / [segment length (km) \times inter-transect width (km)] (Equation 2)

The resulting data were imported into ArcGIS 9.1 for geospatial analyses. All point, line, and polygon features were transformed from a geographic coordinate system to a projected coordinate system of NAD 1983 projection datum of North America Lambert Conformal Conic (Central Meridian: -112, Standard Parallel 1: 62, Standard Parallel 2: 70, and Latitude of Origin: 0). This transformation ensured that the point, line, and polygon features represented uniform map scale and actual locations and distances over the land surface, which is required for geostatistical analysis (Sarangi *et al.*, 2006)

b. Modeling the distribution of caribou on the calving grounds

The ordinary kriging prediction map method in ArcGIS 9.1 was used to model the distribution of caribou on the calving grounds. We used a heuristic approach to select the best-fit semivariogram model (Circular, Spherical, Tetraspherical, Pentaspherical, Exponential, Gaussian, Rational Quadratic, Hole Effect, K-Bessel, J-Bessel, Stable). Kriging as a predictor does not require that your data have a normal distribution (Johnston *et al.*, 2003). When considering only predictors that are formed from weighted averages, kriging is the best unbiased predictor whether or not your data is normally distributed (Johnston *et al.*, 2003). One of the main issues with ordinary kriging is whether the assumptions of a constant mean is reasonable, however, sometimes there are good scientific reasons to reject this assumption (Johnston *et al.*, 2003). Ordinary kriging has remarkable flexibility as it can use either semivariograms or

covariances, it can use transformations and remove trend, and can allow for measurement error (Johnston *et al.*, 2003).

Kriging was carried out using the estimated cow or calf density values (number of cows or calves per km^2) at the transect centroids, respectively. We used a second order trend removal for all models. Lag size was set at one-third of the largest distance between the data points divided by the number of lags (lag number was set at 12). This consideration was based on a rule of thumb; which states that the lag size times the number of lags should be less than one half of the largest distance in the database (Sarangi *et al.*, 2006; Sarangi *et al.*, 2005; Johnston *et al.*, 2003). The corresponding sill, nugget, and range values were observed for different model types. The presence of isotropy and anisotropy in the data were observed in the variogram fitting (Sarangi *et al.*, 2006; Sarangi *et al.*, 2005). We used a search neighbourhood of five data points, with a minimum of two included, and an 8-sector circular neighbourhood.

Generally, the best model was the one that had the standardized mean nearest to zero, the smallest root-mean-square prediction error, the average standard error was nearest the root-mean-square prediction error, and the root-mean-square standardized prediction error was nearest to 1 (Johnston *et al.*, 2003). When comparing one model to another, the root-mean-square prediction error may be closer to the average estimated prediction standard error in one than in the other (Johnston *et al.*, 2003). The former is a more valid model because when you predict at a point without data, you only have the estimated standard errors to assess your uncertainty of that prediction (Johnston *et al.*,

2003). When the average estimated prediction standard errors are close to the root-mean-square prediction errors from cross validation, then one is confident that the prediction standard errors are appropriate (Johnston *et al.*, 2003).

We used a cell size of 1000 m to create the output raster as once the semivariogram is estimated (i.e. the best model), a smaller cell size can be used in creating the actual output raster (ESRI 2007). The output raster was then reclassified into the following density classes (calves or cows per km²) and mapped:

- > 0 to 1.0 per km²
- > 1.0 to 6.0 per km²
- > 6.0 to 11.0 per km²
- > 11.0 to 16.0 per km²
- > 16.0 to 21.0 per km²
- > 21.0 to 26.0 per km²

We applied a spatial mask to limit these analyses to the boundaries of the survey area.

Defining the extent of annual calving areas

The area which included 95 percent of the calves observed on transect was considered to be the annual calving area. An iterative approach was used to define the boundaries of this area for each year by reclassifying the output raster from the best semivariogram model using Spatial Analyst (Johnston *et al.*, 2003).

The output raster for each model was reclassified using its minimum density, a test density, and its maximum density as break values. Test density values ranged from 0.05 to 0.50 km², with an interval of 0.05 km². The areas that had calf densities greater than test density and less than or equal to maximum density were “potential annual calving areas”. We intersected the survey data with the raster layers for these “potential annual calving areas” to determine the total number of calves and cows observed on transect that fell within each of these areas using the intersect point tool in Hawth’s Tools (Beyer, 2007). The “potential annual calving area” that included 95 percent of the calves observed on transect was considered to be the annual calving area for the herd. The attribute table for each test density raster layer gave the number of 1-km² cells or the total area of each “potential annual calving area”. We created raster layers for the 2002, 2003, and 2004 calving areas once the appropriate test densities were identified. We applied a spatial mask to limit these analyses to the boundaries of the survey area.

Overlap in annual calving areas

The values for cells in the raster layer that fell within the 2002 calving area were reclassified as 1, with the values for the remaining cells set at 0. Similarly the values for cells that fell within the 2003 and 2004 calving areas were reclassified as 20 and 300, respectively, with the values for the remaining cells set at 0. We summed the values for these three raster layers using raster calculator in Spatial Analyst and created a new raster layer. The cell values in the

new layer indicated the years when each cell was included in the annual calving areas as follows:

- cell value 1 = in calving area in 2002,
- cell value 20 = in calving area in 2003,
- cell value 21 = in calving area in 2002 and 2003,
- cell value 300 = in calving area in 2004,
- cell value 301 = in calving area in 2002 and 2004,
- cell value 320 = in calving area in 2003 and 2004, and
- cell value 321 = in calving area in 2002, 2003, and 2004.

The resulting classification was mapped to show the years in which different portions of the combined calving area were used.

The values for cells in the raster layers that fell within the calving area during 2002, 2003, and 2004 were reclassified as 1, with the values for the remaining cells set at 0 for each layer. We summed the values for these three raster layers using the raster calculator in Spatial Analyst and created a new raster layer. The cell values in the new raster layer indicated the number of times a cell was included in the annual calving areas during the three-year period 2002 to 2004 as follows:

- cell value 1 = in calving area 1 of 3 years,
- cell value 2 = in calving area 2 of 3 years, and
- cell value 3 = in calving area 3 of 3 years.

The resulting classification was mapped to show the number of years in which different portions of the combined calving area were used.

RESULTS

Surveys to Estimate Calf Production

Transect surveys conducted in 2002

This survey was conducted between 22 to 23 June 2002. Weather conditions were favourable throughout the survey. There was approximately 50 to 75 percent snow covered throughout the survey area. We classified 1,451 caribou including: 966 cows (801 on transect, 165 off transect), 320 calves (260 on transect, 60 off transect), 4 yearlings (4 on transect), 88 bulls (75 on transect, 13 off transect), and 73 unknown (2 on transect, 71 off transect). We noted that there was a range of age classes of calves present including ones that were highly mobile and had changed colour, highly mobile reddish coloured calves, and calves that had just been born. We also saw evidence of a few cows in the southern portion of the survey area that still had not yet given birth.

The calf:cow ratio for caribou observed on transect was 32.35 calves per 100 cows (95% CI 27.37 to 37.32; Table 1; Figure 4). This calf:cow ratio was significantly higher than reported for 15 June 2001 by (Theberge and Nagy, 2001) (t -statistic = 2.398, df = 203, $0.01 > p$ -value > 0.005).

Transect surveys conducted in 2003

This survey was flown between 25 and 26 June 2003. Weather conditions were generally favourable. Snow cover was patchy (less than 25% cover) and largely restricted to the northern portion of the survey area. We classified 2475 caribou including: 1,197 cows (1,194 on transect, 3 off transect), 561 calves (561 on transect), 91 yearlings (83 on transect, 8 off transect), 624 bulls (508 on transect, 116 off transect), and 2 unknown (2 off transect). As in 2002 we noted that ranged in age. We also observed cows, particularly in the southern portion of the survey area that had not yet calved.

The calf:cow ratio for caribou observed on transect was 47 calves per 100 cows (95% CI 43.23 to 50.77; Table 1; Figure 4). This calf:cow ratio was significantly higher than that reported for June 2001 by (Theberge and Nagy, 2001) (t -statistic = 6.109, df = 225, p -value <0.0005) and for late June 2002 (this paper; t -statistic = 4.675, df = 346, p -value < 0.0005; Table 1).

Transect surveys conducted in 2004

This survey was conducted on 25 June 2004. Weather conditions were favourable during the survey and the survey area was essentially snow free. We classified 1,617 caribou including: 827 cows (823 on transect, 4 off transect), 372 calves (372 on transect), 8 yearlings (7 on transect, 1 off transect), 132 bulls (121 on transect, 11 off transect), and 278 unknown (278 off transect). Unlike 2002 and 2003, all calves were highly mobile and had changed colour. These caribou had started to form large post-calving aggregations.

The calf:cow ratio for caribou observed on transect was 46.46 calves per 100 cows (95% CI 28.88 to 64.03; Table 1; Figure 4). This calf:cow ratio was significantly higher than those reported for late June 2001 by (Theberge and Nagy, 2001) (t -statistic = 2.833, df = 78, $0.005 > p\text{-value} > 0.0025$) and June 2002 (this paper; t -statistic = 2.091, df = 199, $0.02 > p\text{-value} > 0.01$) but not significantly different from that reported for June 2003 (t -statistic = 0.094, df = 221, $0.20 < p\text{-value} < 0.15$; Table 1).

Photographic survey of calf:cow groups in 2005

This survey was conducted on 16 June 2005. Weather conditions were favourable throughout the survey. The survey area was snow-free. We located 19 radio-collared cows during the survey and, including these caribou we classified a total 427 cows and 223 calves. The distribution of calf:cow groups photographed is shown in Figure 5. As in 2002 and 2003 we noted that was a range of age classes of calves.

The calf:cow ratio for the groups of caribou photographed during this survey was 52.63 calves per 100 cows (95% CI 47.15 to 58.12; Table 1; Figure 4). This calf:cow ratio was significantly higher than those reported for late June 2001 by (Theberge and Nagy, 2001) (t -statistic = 4.766, df = 58, $p\text{-value} < 0.0005$) and June 2002 (t -statistic = 2.640, df = 179, $0.005 > p\text{-value} > 0.0025$), but not significantly different from those reported for June 2003 (t -statistic = 0.905, df = 201, $0.20 < p\text{-value} < 0.15$), or June 2004 (t -statistic = 0.473, df = 54, $p\text{-value} > 0.25$; Table 1).

Photographic survey of calf:cow groups in 2006

This survey was conducted on 18 June 2005. Weather conditions were favourable throughout the survey and the survey area was snow-free. We located and classified caribou associated with 7 radio-collared cows during the survey (7 groups). We also classified 17 additional groups of caribou. In total, we classified 799 caribou including: 577 cows, 189 calves, and 33 yearlings. The distribution of the calf:cow groups that were photographed is shown in Figure 6. As in 2002, 2003, and 2005 we noted that calves ranged in age.

The calf:cow ratio for the groups of caribou photographed during this survey was 32.92 calves per 100 cows (95% CI 25.94 to 39.90; Table 1; Figure 4). This calf:cow ratio was significantly higher than that reported for late June 2001 (t -statistic = 2.256, df = 69, $0.02 > p$ -value > 0.01), was significantly lower than those reported for June 2003 (t -statistic = 2.790, df = 212, $0.005 > p$ -value > 0.0025) and June 2005 (t -statistic = 3.989, df = 45, p -value < 0.0005), but not significantly different from those reported for June 2002 (t -statistic = 0.093, df = 190, $0.20 < p$ -value < 0.15) and June 2004 (t -statistic = 1.277, df = 65, $0.15 < p$ -value < 0.10 ; Table 1).

Defining and Mapping the Extent of Annual Calving Areas

Ordinary kriging prediction maps for cows and calves

We fitted models for cows and calves for each year transect surveys were completed. The locations of the centroids for transects flown in 2002, 2003, and 2004 are given Figures 7, 8, and 9, respectively.

Cows

The ordinary kriging prediction maps of the distribution of cows observed on transect during 2002, 2003, and 2004 are given in Figures 10, 11, and 12, respectively. The cross-validation results for these models are given in Table 2. In all models selected the standardized mean was near 0, they had the smallest root-mean-square prediction error, the difference between the average standard error and the root-mean-square prediction error was near 0, and the root-mean-square standardized prediction error was near 1 (Johnston *et al.*, 2003) (Table 2). The nugget effect was small for the models generated for 2002, but was comparatively larger for 2003 and 2004. Theoretically, the nugget effect should be zero but due to errors resulting from sampling design, measurement, or analyses the nugget effect is usually greater than zero (Siska and Hung, 2007). Additional modelling efforts may reduce the nugget effect for the 2003 model, although altering the lag size, lag number, or neighbourhood size did not reduce the nugget value for these models. The values for cow densities at the centroids for each model were overlain on the corresponding prediction maps for 2002, 2003, and 2004 (Figures 13, 14 and 15). A visual examination of these values

indicates that the models reasonably fit the data when generalized to a 1-km grid. Approximately 81, 97, and 99 percent of the cows observed on transect during 2002, 2003, and 2004, respectively, were made in areas where predicted calf densities were greater than 1 calf per km².

Calves

The ordinary kriging prediction maps of the distribution of calves observed on transect during 2002, 2003, and 2004 are given in Figures 16, 17, and 18, respectively. The cross-validation results for these models are given in Table 3. In all models selected the standardized mean was near 0, they had the smallest root-mean-square prediction error, the difference between the average standard error and the root-mean-square prediction error was near 0, and the root-mean-square standardized prediction error was near 1 (Johnston *et al.*, 2003) (Table 3). The nugget effect was near 0 or relatively small for all three models. The distribution of calves observed on and off transect were overlain on the prediction maps generated for the three years. A visual examination of these maps indicates that in all cases the models reasonably fit the actual distribution of sightings (Figures 16, 17, and 18). Approximately 75, 94, and 98 percent of the calves observed on transect during 2002, 2003, and 2004, respectively, were made in areas where predicted calf densities were greater than 1 calf per km². The values for calf densities at the centroids for each model were overlain on the corresponding prediction maps for 2002, 2003, and 2004 (Figures 19, 20 and

21). A visual examination of these values indicates that the models reasonably fit the data when generalized to a 5-km grid.

Distribution of cows without calves, satellite collared cows, yearlings and bulls

All sightings of cows without calves, yearlings and bulls made on and off transect and locations of satellite-collared cows were overlain on the prediction maps for calves generated for 2002, 2003, and 2004.

Cows without calves

Prediction maps of the distribution of calves with sites where cows without calves were observed on and off transect overlain are given for 2002, 2003, and 2004 in Figures 22, 23, and 24, respectively. A visual examination of the map for 2002 indicates that the cows without calves were more widely distributed and most were observed outside of areas where predicted calf densities were greater than 1 calf per km². This distribution of cows without calves may reflect our observations that some cows in the southern portion of the survey area had not yet given birth. In 2003 and 2004, most of the cow without calves were in or adjacent to areas with predicted calf densities were greater than 1 calf per km².

Satellite collared cows

Prediction maps of the distribution of calves with locations indicating where the satellite collared cows in the Cape Bathurst herd were located during the survey period overlain are given for 2002, 2003, and 2004 in Figures 25, 26,

and 27, respectively. In 2002, 4 of the 8 satellite-collared cows were within areas with calf densities greater than 1 calf per km^2 , while an additional 3 were in close proximity to these areas (Figure 25). Similarly in 2003, 4 of the 4 satellite collared cows were within areas with predicted calf densities greater than 1 calf per km^2 (Figure 26). In 2004, there was only 1 cow with an active satellite collar and this cow was in the area with predicted calf densities greater than 1 calf per km^2 (Figure 27). These data suggest that satellite collared cows are good indicators of where the majority of cows in a herd are located during the calving period.

Yearlings

Prediction maps of the distribution of calves with sites where yearlings were observed on and off transect overlain are given for 2002, 2003, and 2004 in Figures 28, 29, and 30, respectively. Few yearlings were observed during 2002. In 2003, the majority of the yearlings observed in the southern portion survey area, south of the area where predicted calf densities greater than 1 calf per km^2 (Figure 29). In 2004, few yearlings were observed (Figure 30).

Bulls

Prediction maps of the distribution of calves with sites where bulls were observed on and off transect overlain are given for 2002, 2003, and 2004 in Figures 31, 32, and 332, respectively. In 2002, most of the bulls observed were in the area between the Mason and Anderson rivers in the southern portion of the survey area. A large number of bulls were observed in 2003 few bulls (Figure

32). The majority of these were observed in the western part of the Cape Bathurst Peninsula between Harrowby Bay and the Anderson River and south of the area where predicted calf densities greater than 1 calf per km^2 . In 2004, the majority of the bulls were observed in or adjacent to areas where predicted calf densities were greater than 1 calf per km^2 .

Distribution of grizzly bears, wolves, golden eagles, and muskoxen

All sightings of grizzly bears, wolves, golden eagles, and muskoxen made during the survey were overlain on the prediction maps generated for calves in 2002, 2003, and 2004.

2002

We observed 1 adult grizzly bear and 2 golden eagles south of Harrowby Bay near an area where predicted calf densities greater than 1 calf per km^2 (Figure 34). In addition, we observed 2 groups of muskoxen (61 adults and 20 calves, 6 adults and 1 calf) near the Mason River well to the south of areas where predicted calf densities greater than 1 calf per km^2 .

2003

We observed a total of 23 grizzly bears including 11 lone adults, 1 adult pair, 2 sows with 2 cubs of the year each, and 1 sow with 3 yearlings (Figure 35). The majority of these bears were in or adjacent to areas where predicted calf densities greater than 1 calf per km^2 . None of our sightings of golden eagles fell within the area surveyed. In addition, we observed a total of 84 muskoxen (73

adults and 11 calves; Figure 35). The majority of these were found in the headwaters of the Mason River. We also observed 3 cow moose, 2 in the headwaters of the Mason River and 1 south of the Anderson River.

2004

We observed one adult grizzly bear along the coast near the mouth of the Horton River (Figure 36). In addition we observed 2 groups of muskoxen (9 adults and 1 adult) between Harrowby Bay and the Mason River (Figure 36).

2005 and 2006

No other wildlife sightings were recorded.

Defining the extent of annual calving areas

The results of the iterative analyses used to determine the minimum number of calves per km^2 , when used to define the boundaries of an annual calving area, included 95 percent of the calves observed on transect during the survey are given in Table 4. In 2002, this density was 0.25 calves per km^2 , and when used to define the boundaries of the calving area, the resulting area included 1,166 km^2 , 95 percent of the calves, and 84 percent of the cows (Table 4; Figure 37). In 2003, the density was 0.35 calves per km^2 , and when used to define the boundaries of this calving area, the resulting area included 1,469 km^2 , 95 percent of the calves, and 94 percent of the cows (Table 4; Figure 38).

Overlap in annual calving areas

The combined area used by the Cape Bathurst herd during calving in 2002 and 2003, and the years when different portions of this area were used is shown in Figure 39. The combined calving area was 1,904 km² (Table 5). Approximately 37.3 percent of this area was used in 2002 and 2003 (Table 5). This area was largely north and east of the Mason River and south and east of Harrowby Bay on the Cape Bathurst Peninsula. Approximately 23.2 percent of the combined area was used only in 2002 and 39.5 percent of the combined area was used only in 2003 (Figure 39). These data indicate that the distribution of caribou on the calving grounds varied during these years but there was a significant area of overlap (37.3 percent).

DISCUSSION

The average post-calving calf:cow ratio for the Cape Bathurst herd during the period 2000 to 2006 was 42.1 (range 19.23 to 64.4). This is lower than the values of 83.9 and 71.7 calves per 100 cows in 1981 and 1983 reported for the "Bluenose" herd in 1981 and 1983. These values are lower than the average value of 60 calves per 100 cows (range 44 to 74) reported for the Porcupine caribou herd during the 14 year period from 1987 to 2000 (Parks Canada, 2002). Mixed age classes of calves were observed during all years except 2004 indicating that calving occurred over a protracted time period, with some born as late as the 3rd week of June. Calves born late in June just prior to the onset of the insect relief period likely have lower survival rates than those born in early June.

The geospatial analytical tool “ordinary kriging” provided an objective method of analysing and generating prediction maps that showed how the density of (number per km^2) and distribution of calves and cows varied within the calving grounds of the Cape Bathurst herd each year and among years. We used an iterative procedure to identify the minimum density that when used to reclassify the output from kriging the resulting area included 95 percent of the calves observed on transect. This method standardized the map output to a population parameter rather than an arbitrary density value (i.e. areas of moderate or high density of calves). We arbitrarily selected 95 percent of the calves observed on transect as the critical value, however, this value can be higher or lower depending on management objectives. The underlying assumption of this method is that the survey coverage was sufficient to document the full distribution of calves on the calving range of the herd.

Using this approach, our analyses of indicate that the total area of annual calving area of the Cape Bathurst herd varied among years, ranging from around $1,166 \text{ km}^2$ in 2002 and $1,470 \text{ km}^2$ in 2003. Use of different portions of the calving range varied during these years but approximately 37 percent of the combined area used in 2002 and 2003. We did not included data from 2004 as the cows and calves had already formed large post-calving aggregations.

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Table 1. Calf:cow ratios documented at or near the peak of calving for the Cape Bathurst herd, 2000 to 2006.

Year	Dates of survey	No. of groups classified	No. of calves	No. of cows	Statistical parameters for calf:cow ratios estimated using the Tukey-Jackknife method							
					Calves per 100 cows	SD	VAR	SE	CV	CI 95%	Lower 95%CI	Upper 95%CI
2000	11 June		246	382	64.40							
2001a	15 June	42	29	148	19.23	28.6419	4.8050	3.3824	17.6	8.7671	10.46	28.00
2002	22 to 23 June	163	260	801	32.35	32.3083	10.4383	2.5306	7.8	4.9751	27.37	37.32
2003	25 to 26 June	185	561	1194	47.00	26.1144	6.8196	1.9200	4.1	3.7733	43.23	50.77
2004	25 June	38	372	823	46.46	54.5500	29.7571	8.8492	19.0	17.577	28.88	64.03
2005	16 June	18	223	427	52.63	11.5371	1.3311	2.7193	5.2	5.4843	47.15	58.12
2006	18 June	29	189	577	32.92	18.8467	3.5520	3.4997	10.6	6.9808	25.94	39.90

a Original data from (Theberge and Nagy, 2001).

Table 2. Cross-validation results for ordinary kriging prediction maps generated for density distribution data obtained for cows on the calving grounds of the Cape Bathurst barren-ground caribou herd during 2002, 2003, and 2004.

Year	2002	2003	2004
Class of caribou	cows	cows	cows
Number of points	168	334	119
Kriging method ^a	OKPM	OKPM	OKPM
Order of trend removal	second	second	second
Semivariogram model	J-Bessel	Stable	Tetraspherical
Major range	33976	50447	26480
Anisotropy	yes	no	yes
Partial sill	1.7393	7.4298	70.31
Nugget	3.4985	11.228	7.762
Lag size	2993	4444	2234
Number of lags	12	12	12
Neighbours to include	5	5	5
Minimum number of neighbours included	2	2	2
Search neighbourhood ^b	8SC	8SC	8SC
Prediction Errors:			
Root-mean-square (1)	2.019	3.809	5.403
Average standard error (2)	2.050	3.481	5.417
(1) minus (2)	0.031	0.328	0.014
Mean standardize	0.007	-0.003	-0.005
Root-Mean-Square Standardized	0.9927	1.085	1.005

^aOrdinary kriging prediction map.

^b8 sector circular.

Table 3. Cross-validation results for ordinary kriging prediction maps generated for density distribution data obtained for calves on the calving grounds of the Cape Bathurst barren-ground caribou herd during 2002, 2003, and 2004.

Year	2002	2003	2004
Class of caribou	calves	calves	calves
Number of points	168	334	119
Kriging method ^a	OKPM	OKPM	OKPM
Order of trend removal	second	second	second
Semivariogram model	Circular	K-Bessell	Stable
Major range	12377	50447	25360
Anisotropy	no	no	no
Partial sill	0.5464	1.023	21.204
Nugget	0.16514	2.264	2.3548
Lag size	2993	4444	2234
Number of lags	12	12	12
Neighbours to include	5	5	5
Minimum number of neighbours included	2	2	2
Search neighbourhood ^b	8SC	8SC	8SC
Prediction Errors:			
Root-mean-square (1)	0.6443	1.603	3.295
Average standard error (2)	0.6641	1.572	3.333
(1) minus (2)	0.0198	0.031	0.038
Mean standardize	-0.0018	-0.003	0.003
Root-Mean-Square Standardized	0.9915	1.018	0.9983

^aOrdinary kriging prediction map.

^b8 sector circular.

Table 4. Results of iterative analyses used to determine the minimum number of calves per km², when used to define the boundaries of the calving areas, included 95% of calves observed on transect during surveys of the calving grounds of the Cape Bathurst barren-ground caribou herd during 2002 and 2003.^a

Year of Survey	Minimum number of calves per km ² used to define boundary of calving area	Area (km ²)	Percent of area surveyed	Number within defined boundary		Percent of total observed on transect		Number per km ²	
				cows	calves	cows	calves	cows	calves
2002	0.05	1995	53	725	259	91	100	0.36	0.13
	0.10	1602	11	698	255	87	98	0.44	0.16
	0.15	1398	37	682	251	85	97	0.49	0.18
	0.20	1278	34	680	251	85	97	0.53	0.20
	0.25	1166	31	672	247	84	95	0.58	0.21
	0.30	1048	28	669	247	84	95	0.64	0.24
	0.35	948	25	662	242	83	93	0.70	0.26
	0.40	865	23	643	237	80	91	0.74	0.27
	0.45	808	22	643	237	80	91	0.80	0.29
	0.50	754	20	597	228	75	88	0.79	0.30
2003	0.05	2850	39	1147	546	96	97	0.40	0.19
	0.10	2131	29	1139	541	95	96	0.53	0.25
	0.15	1884	26	1133	537	95	96	0.60	0.29
	0.20	1710	23	1133	537	95	96	0.66	0.31
	0.25	1610	22	1133	537	95	96	0.70	0.33
	0.30	1538	21	1133	537	95	96	0.74	0.35
	0.35	1469	20	1127	535	94	95	0.77	0.36
	0.40	1414	19	1126	534	94	95	0.80	0.38
	0.45	1371	19	1126	534	94	95	0.82	0.39
	0.50	1334	18	1114	531	93	95	0.84	0.40
	0.55	1300	18	1108	529	93	94	0.85	0.41
	0.60	1273	17	1108	529	93	94	0.87	0.42

a We did not include data from the 2004 survey as cows had already formed large post-calving aggregations as a result were no longer distributed throughout the calving area. These aggregations included cows, calves, yearlings, and bulls.

Table 5. Years in which different portions of the combined calving area for the Cape Bathurst herd were used.

Years	Amount of combined calving area used	
	km²	percent
2002	441	23.2
2003	752	39.5
2002, 2003	711	37.3
Total area	1904	100.0

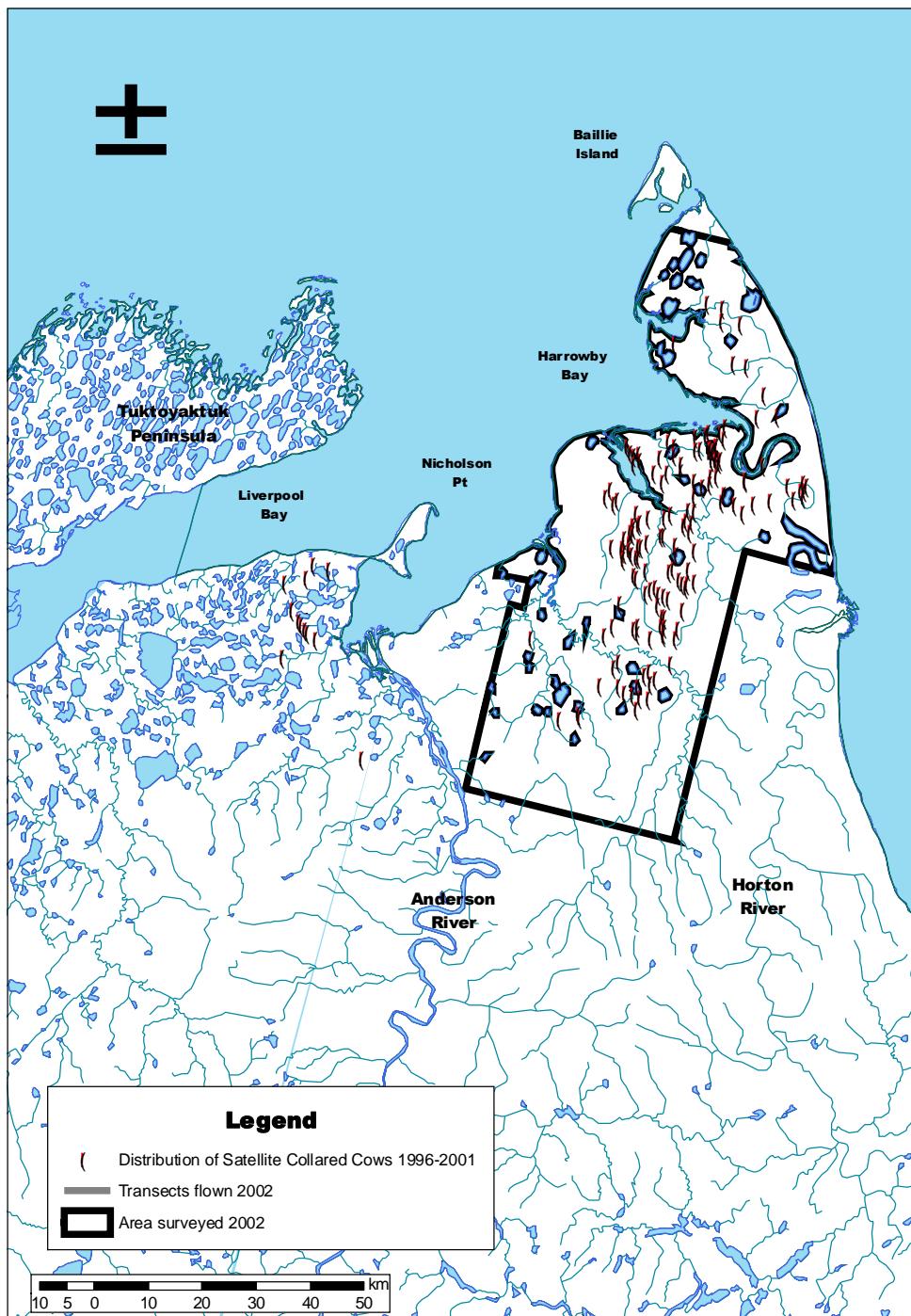


Figure 1. Distribution of Cape Bathurst barren-ground caribou cows tracked using satellite collars during 10 to 25 June 1996 to 2001, boundary of survey area, and transects flown during 2002.

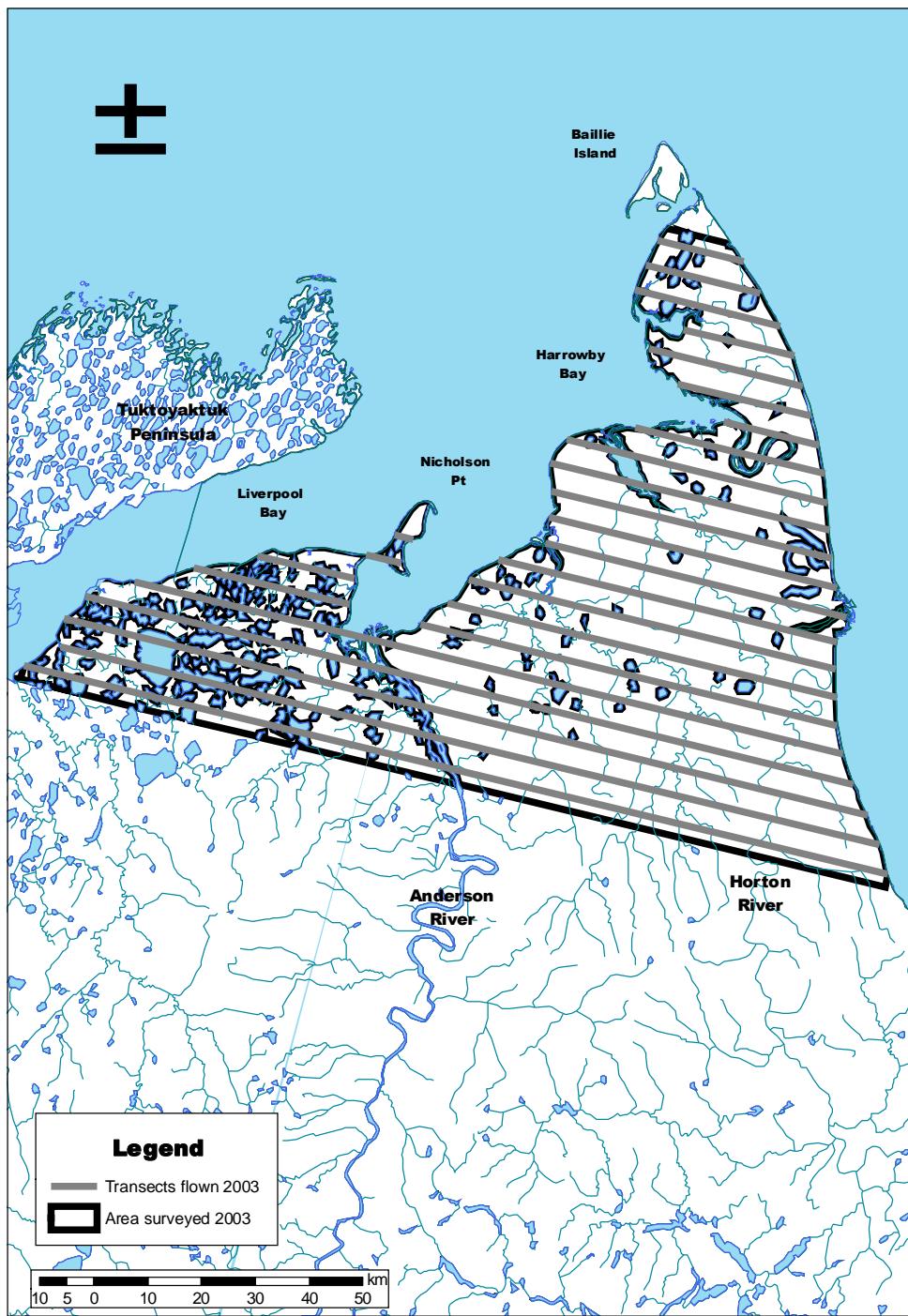


Figure 2. Boundaries of area surveyed and transects flown on the calving grounds of the Cape Bathurst herd, 2003.

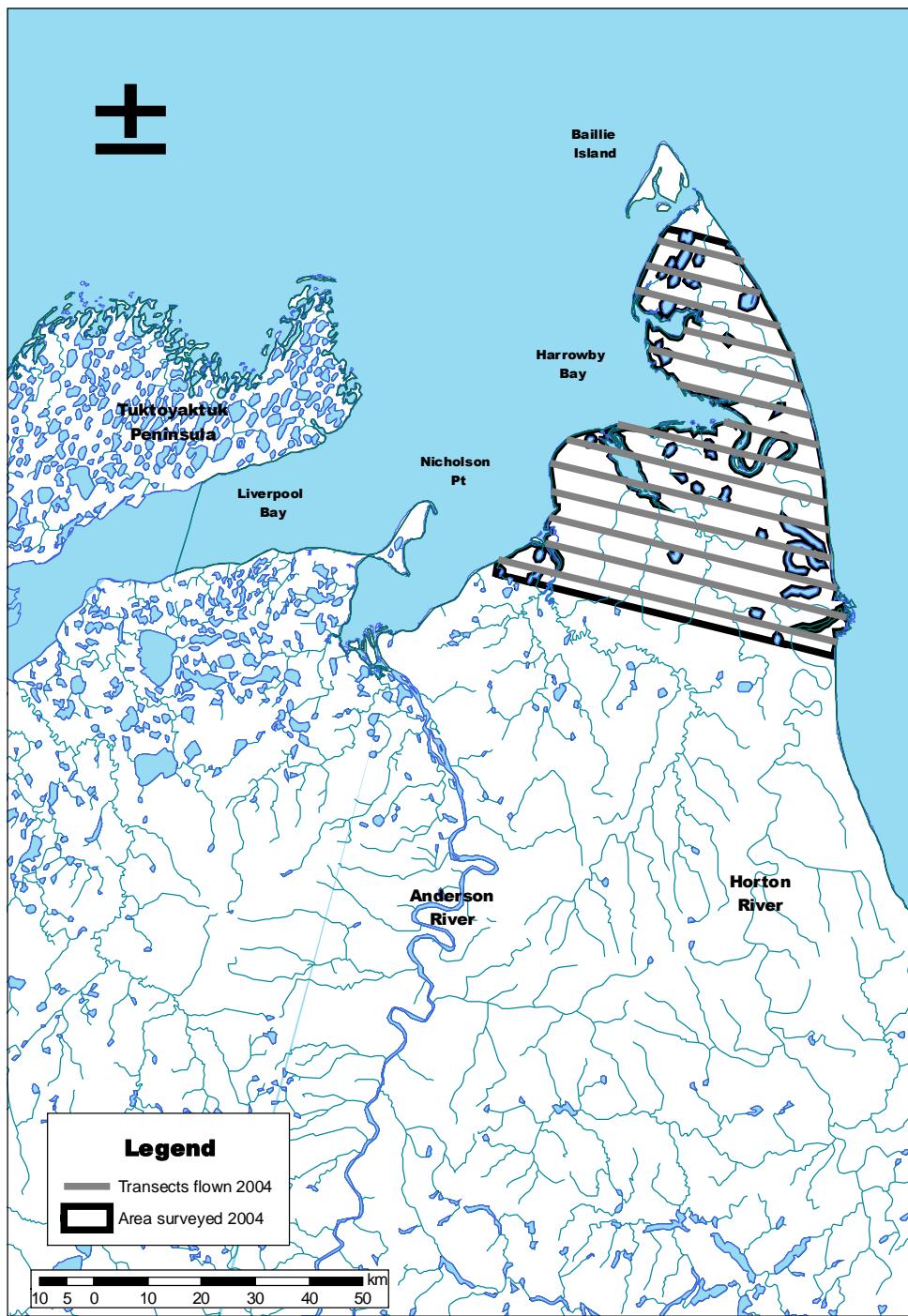


Figure 3. Boundaries of area surveyed and transects flown on the calving grounds of the Cape Bathurst herd, 2004.

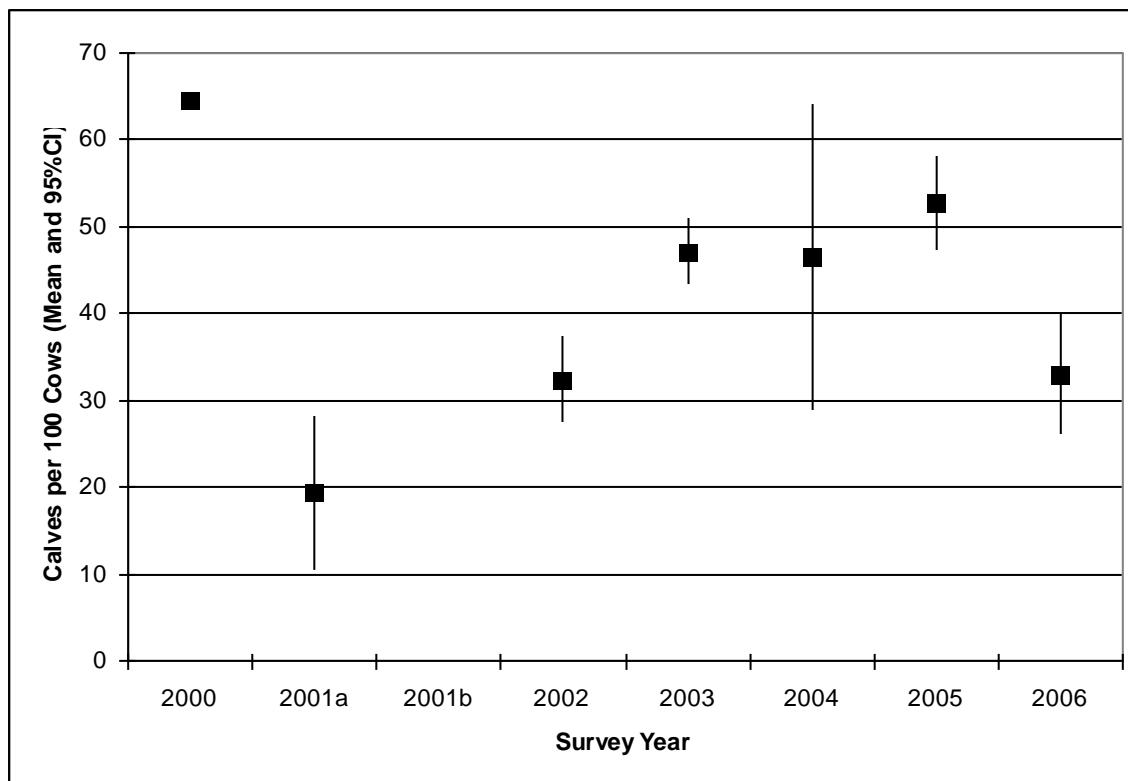


Figure 4. Comparison of the number of calves observed per 100 cows during surveys done on the calving grounds of the Cape Bathurst herd during 2000 to 2006^a.

^aSurveys completed on the following dates:

- 2000 11 June
- 2001a 15 June
- 2002 22 to 23 June
- 2003 25 to 26 June
- 2004 25 June
- 2005 16 June
- 2006 18 June

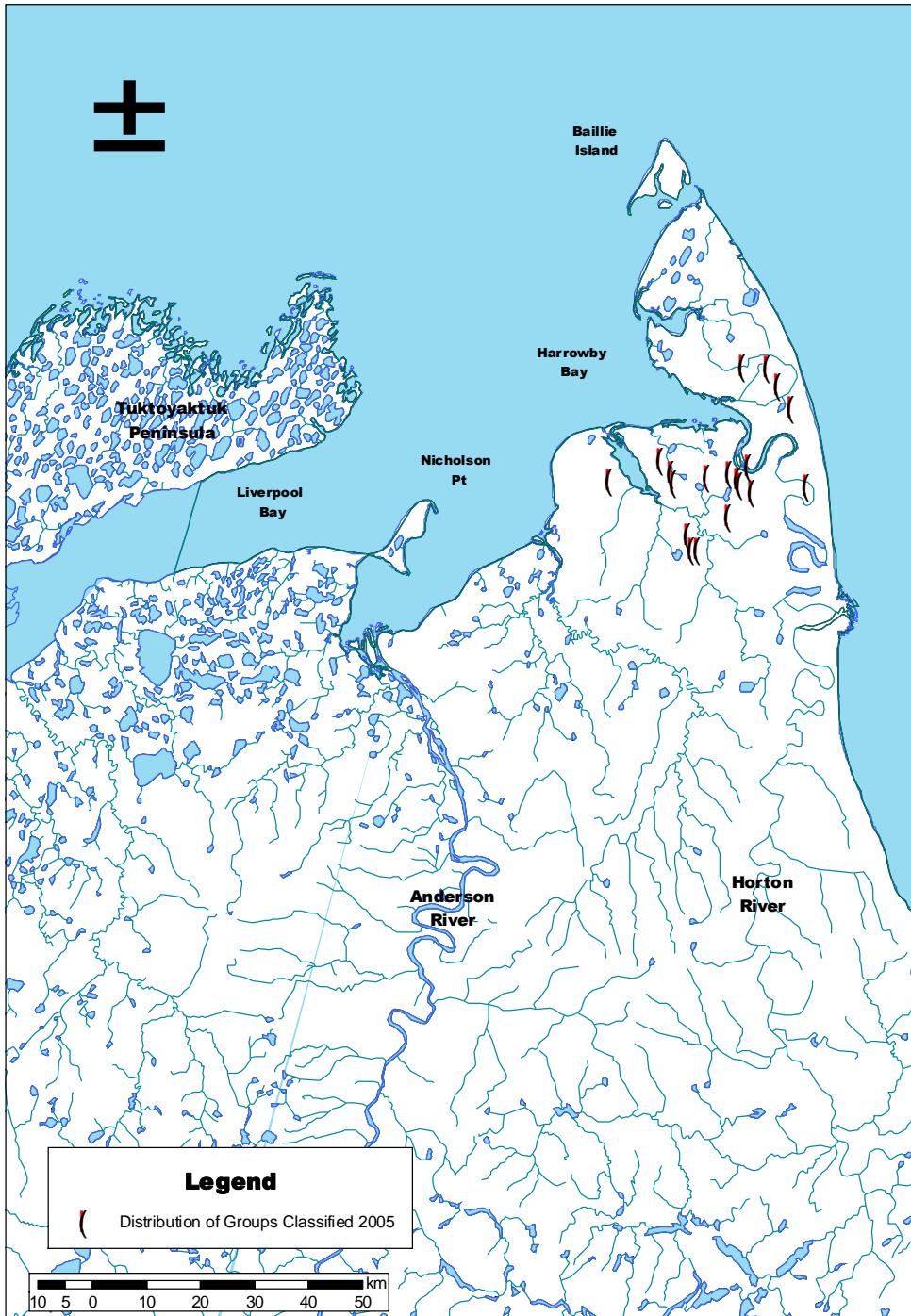


Figure 5. Distribution of calf:cow groups classified on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2005.

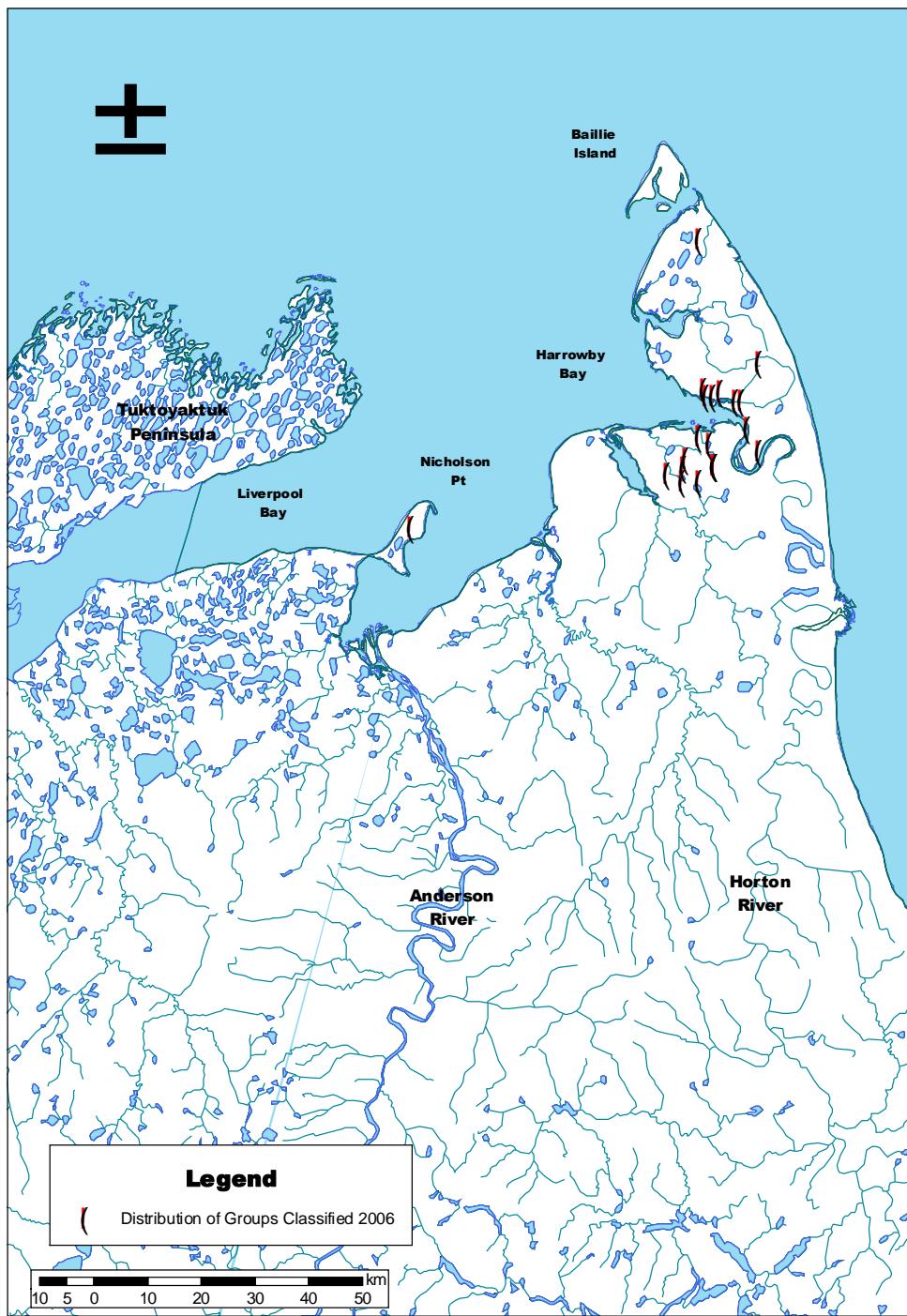


Figure 6. Distribution of calf:cow groups classified on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2005.

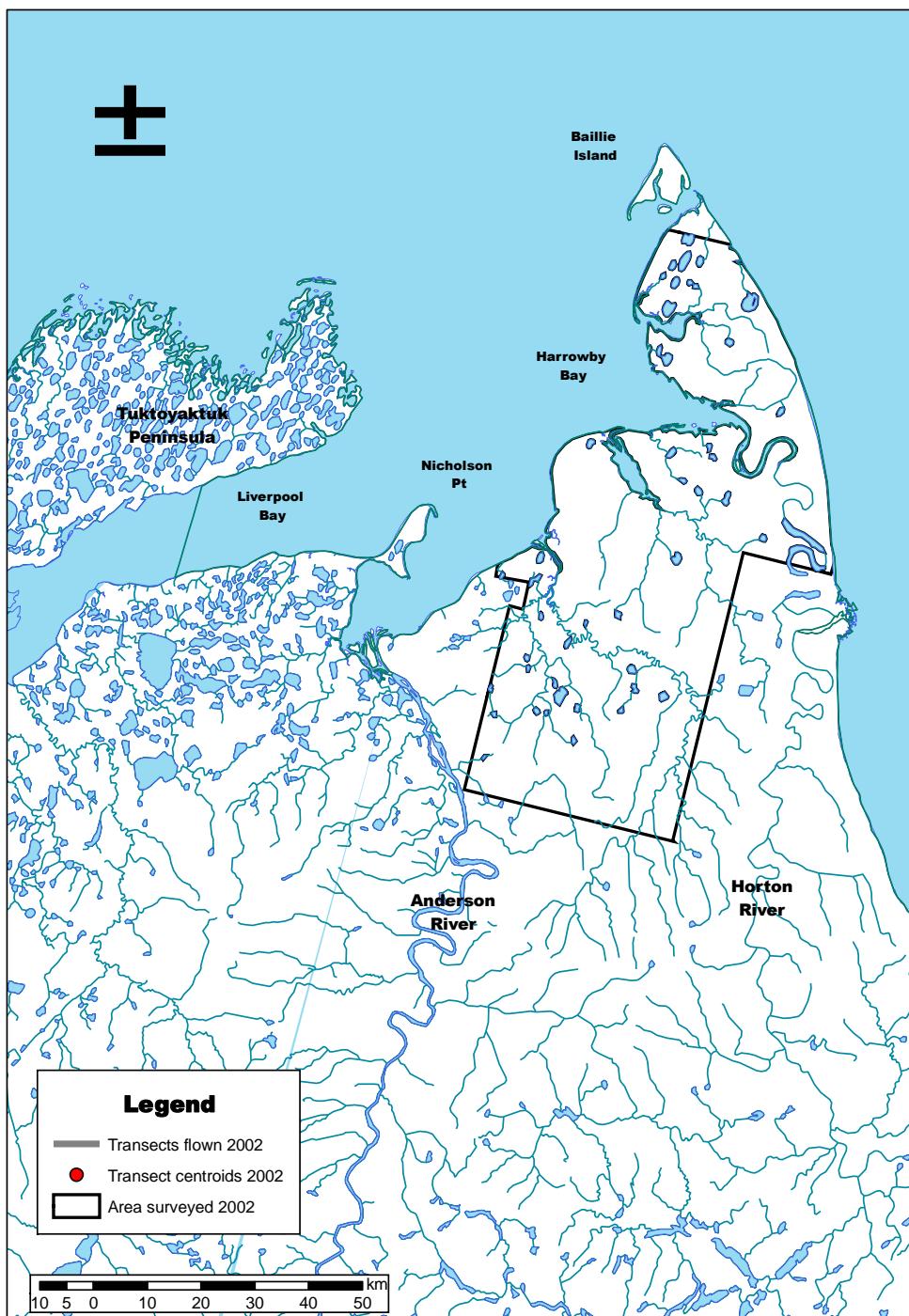


Figure 7. Centroids for transects flown on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2002.

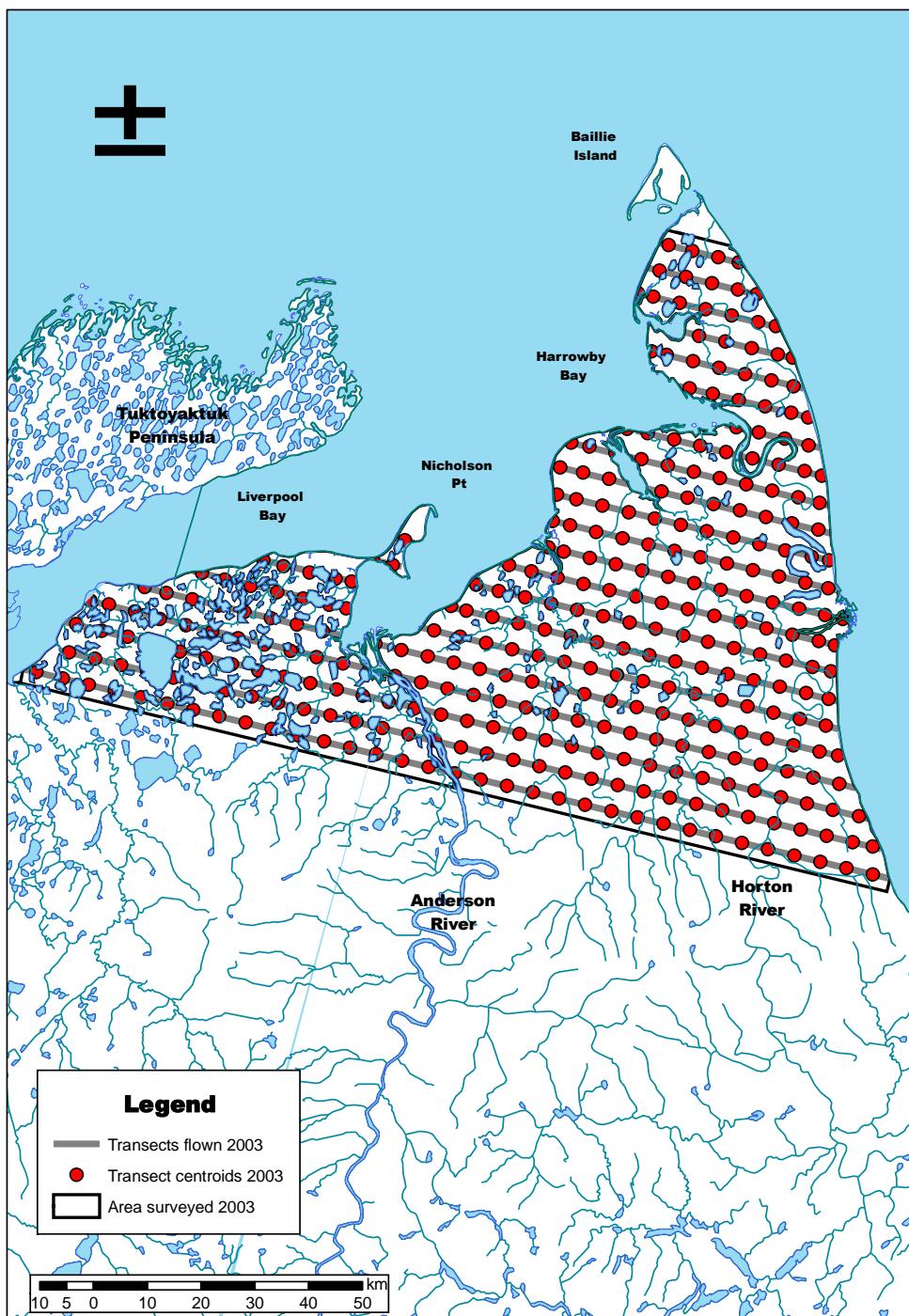


Figure 8. Centroids for transects flown on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2003.

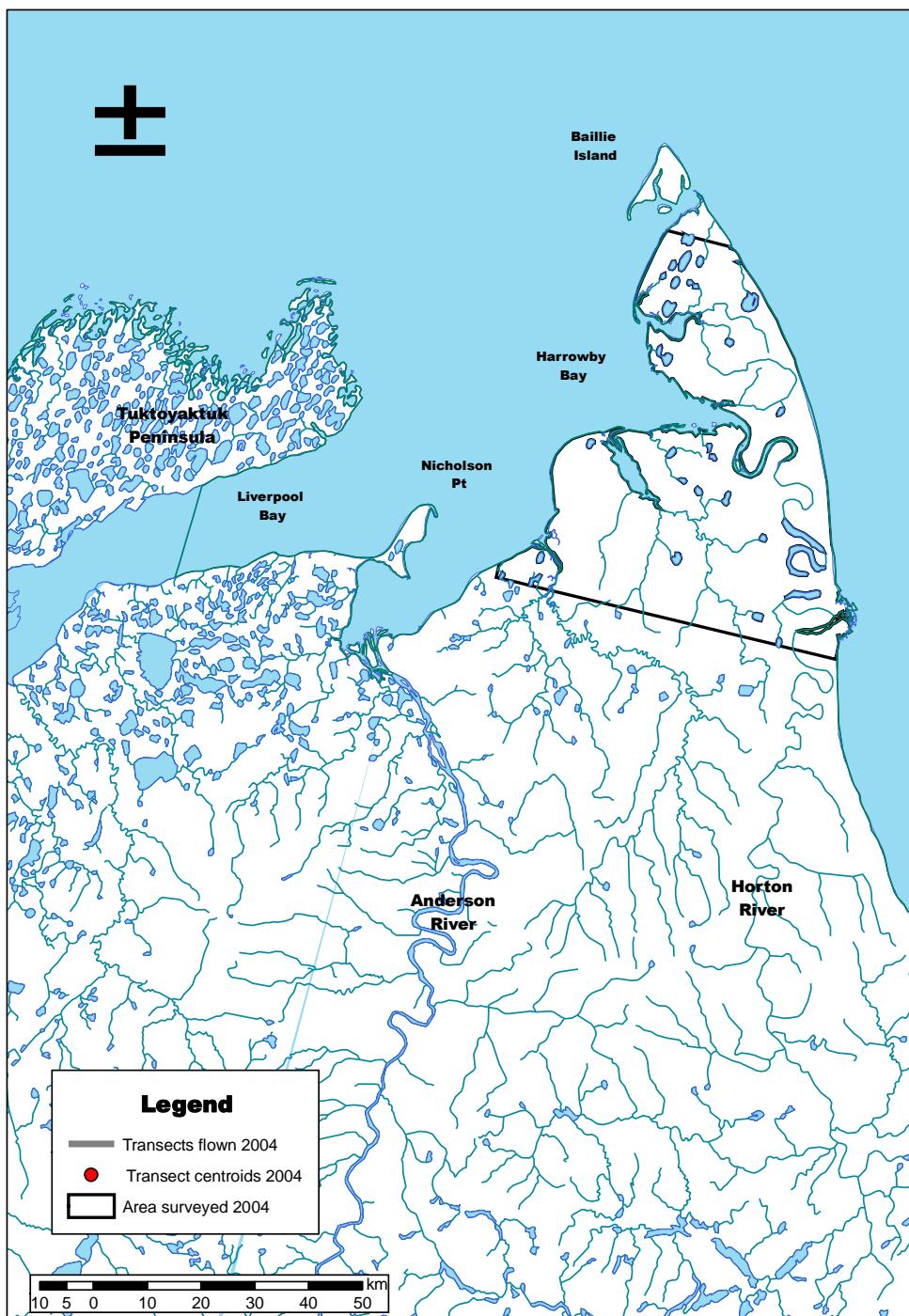


Figure 9. Centroids for transects flown on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2004.

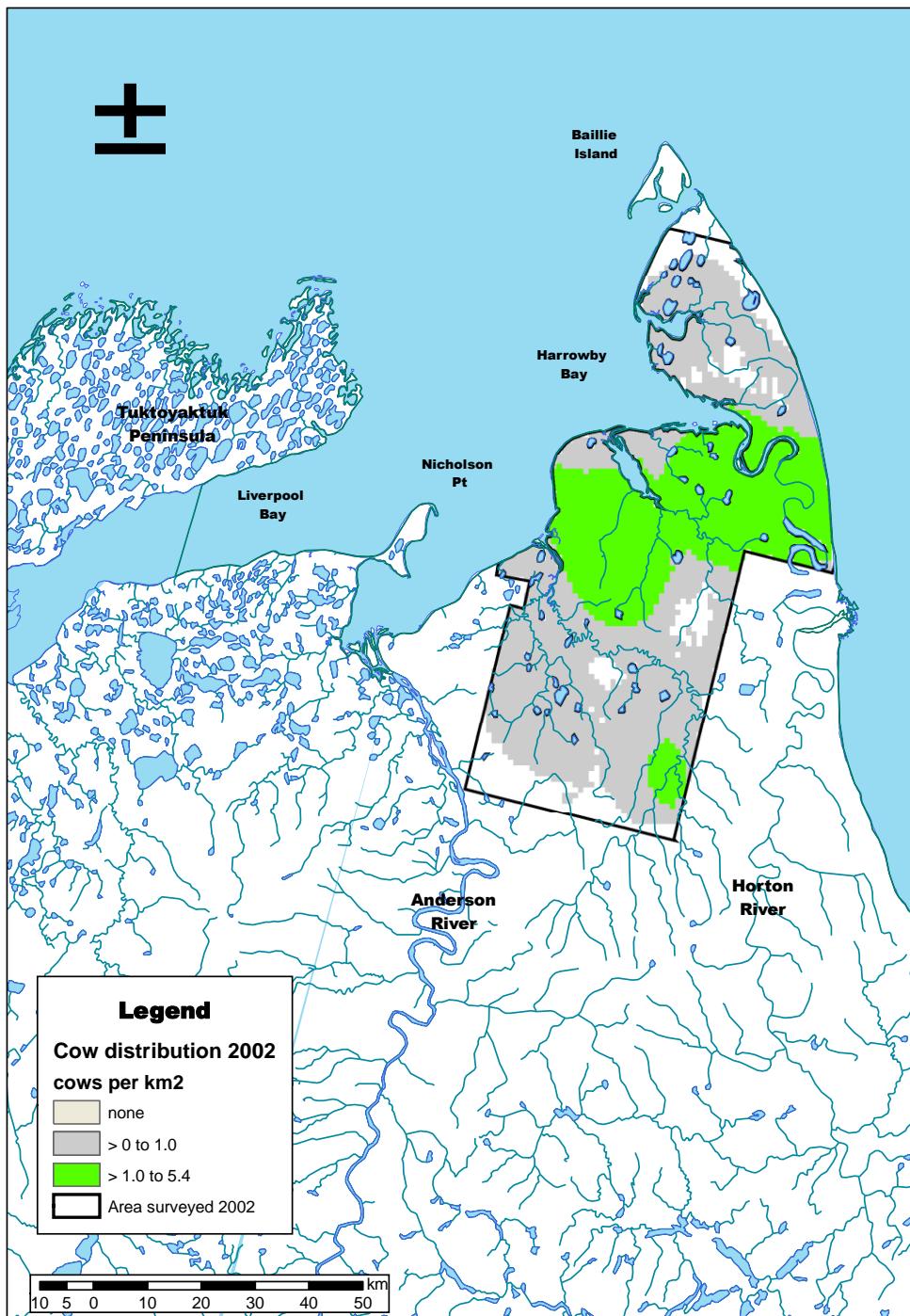


Figure 10. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2002.

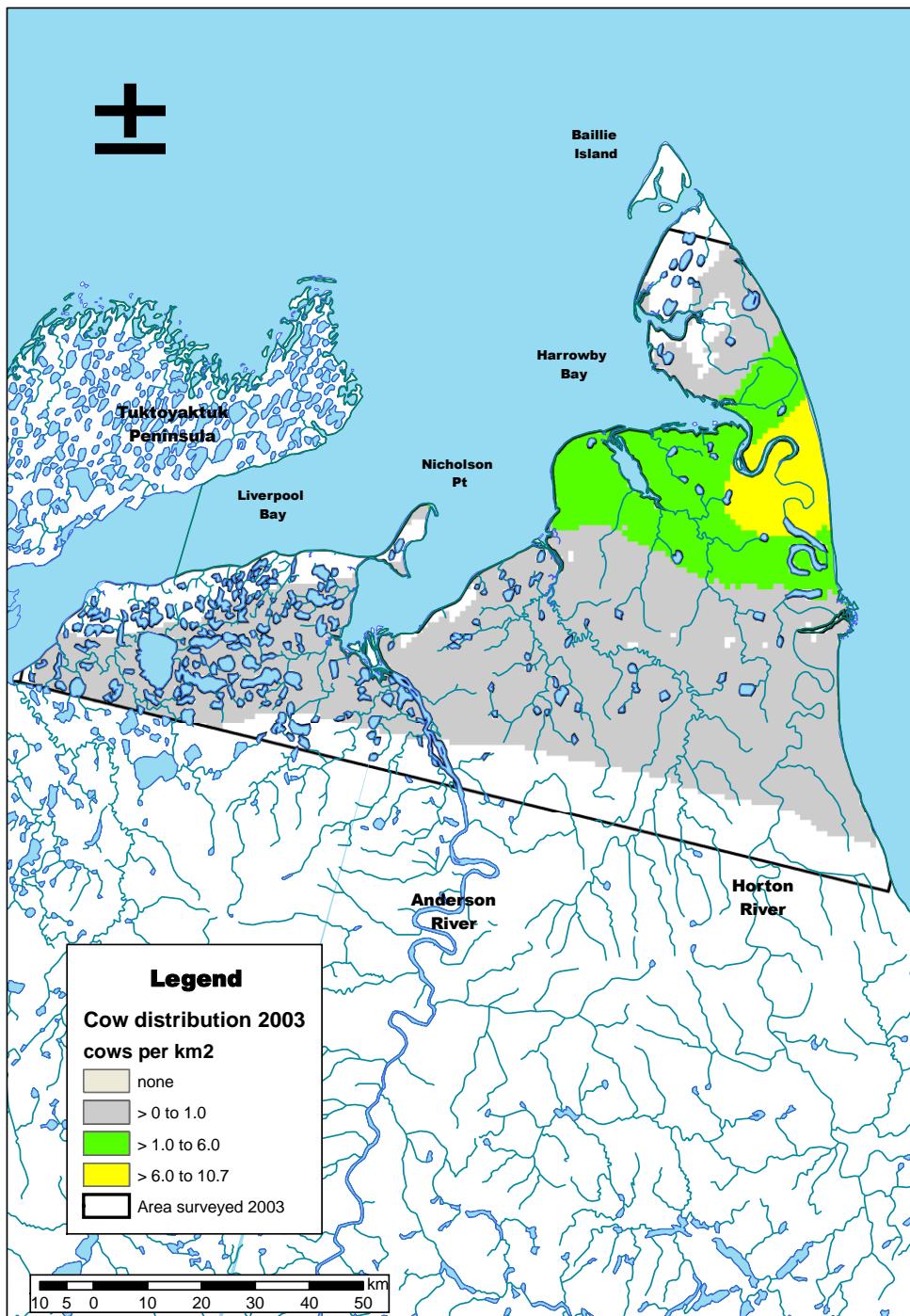


Figure 11. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2003.

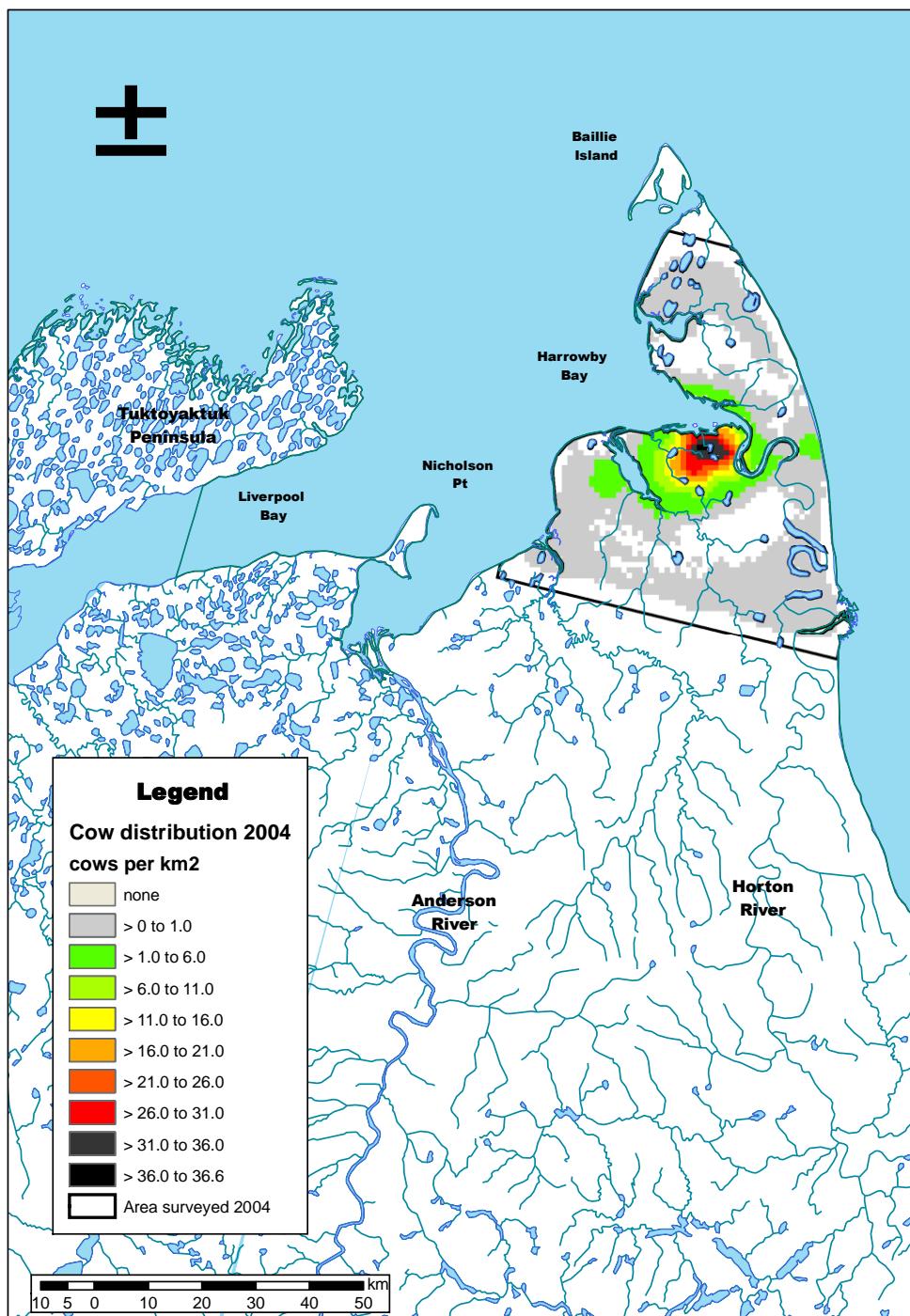


Figure 12. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2004.

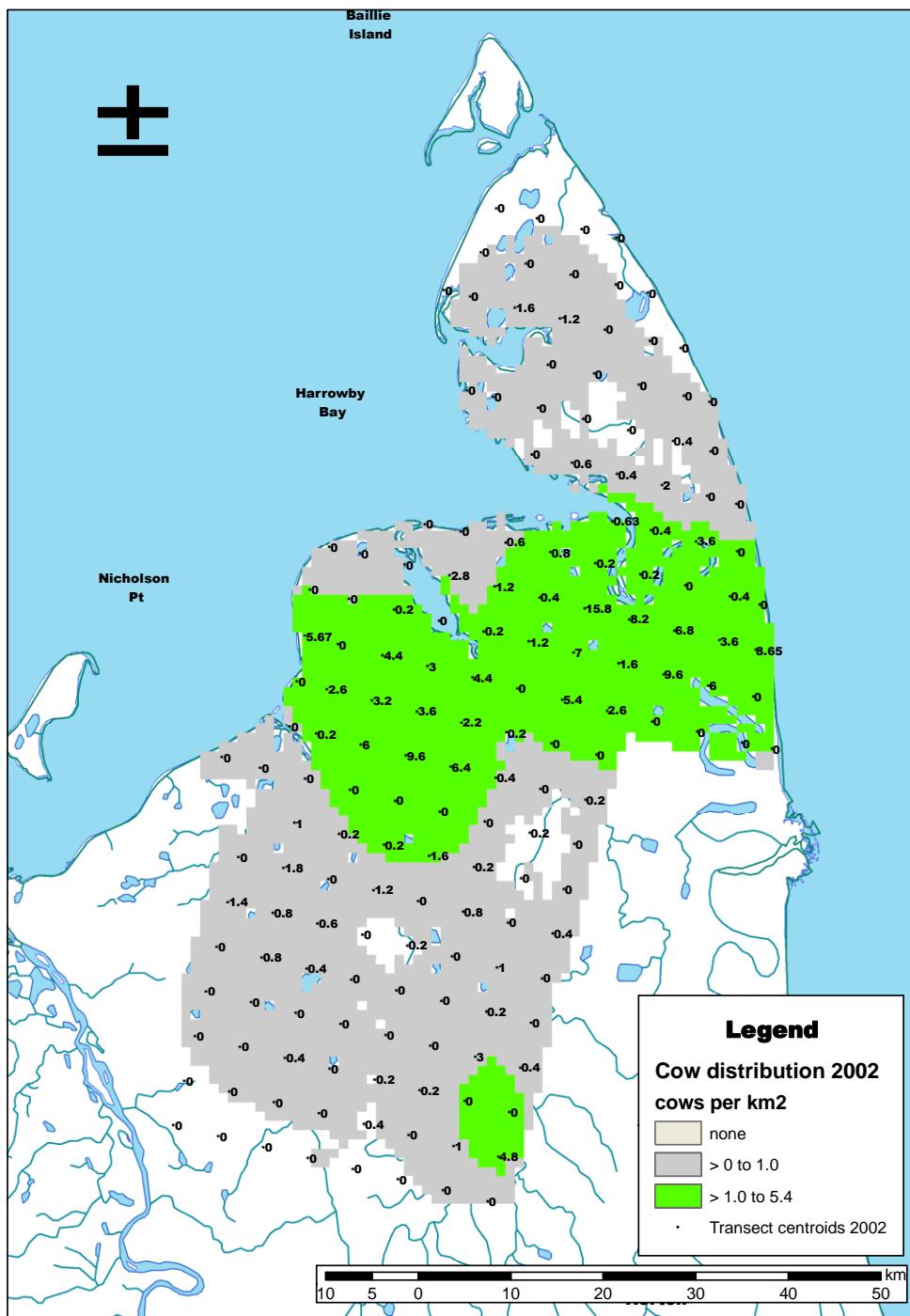


Figure 13. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2002.

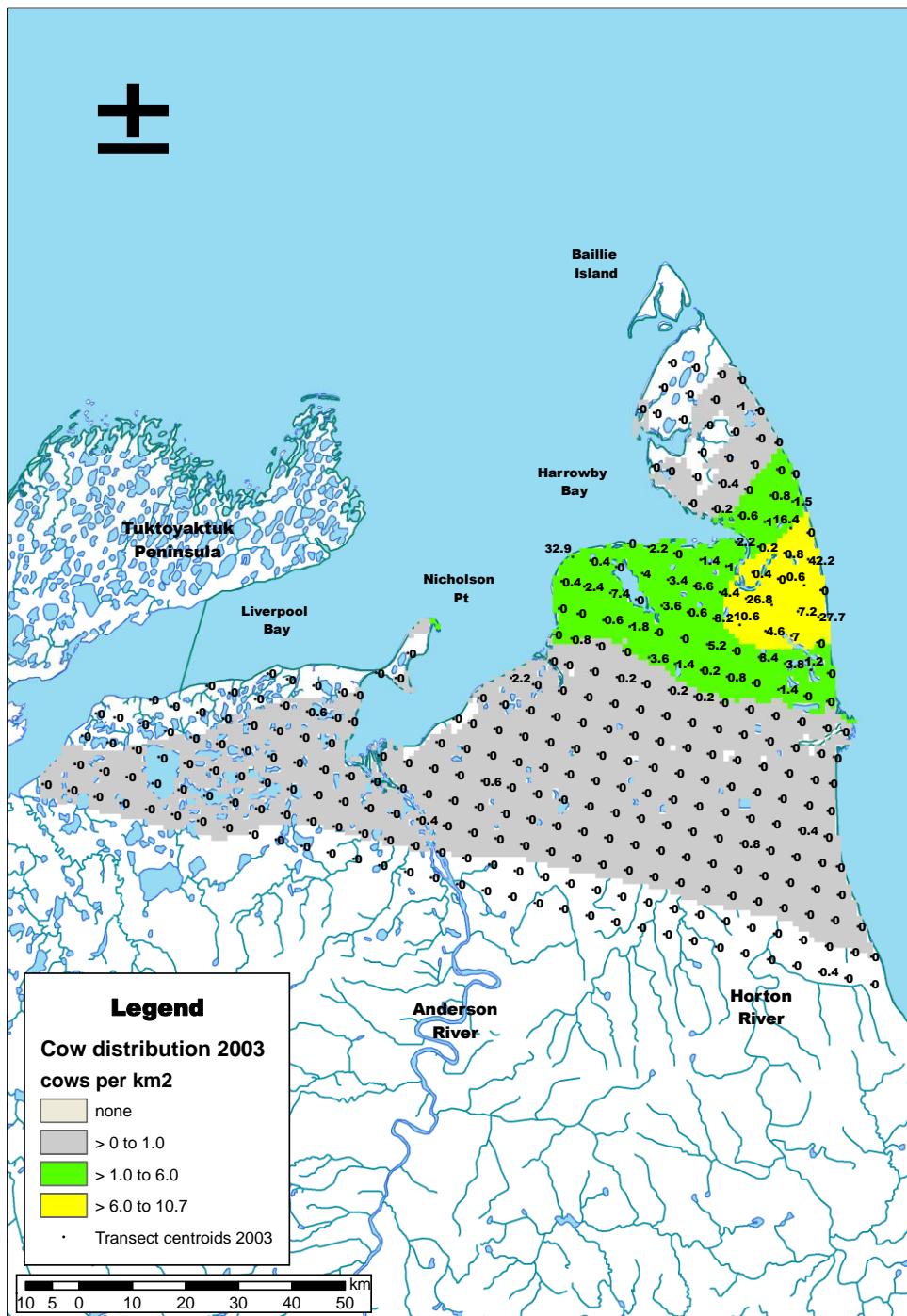


Figure 14. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2003.

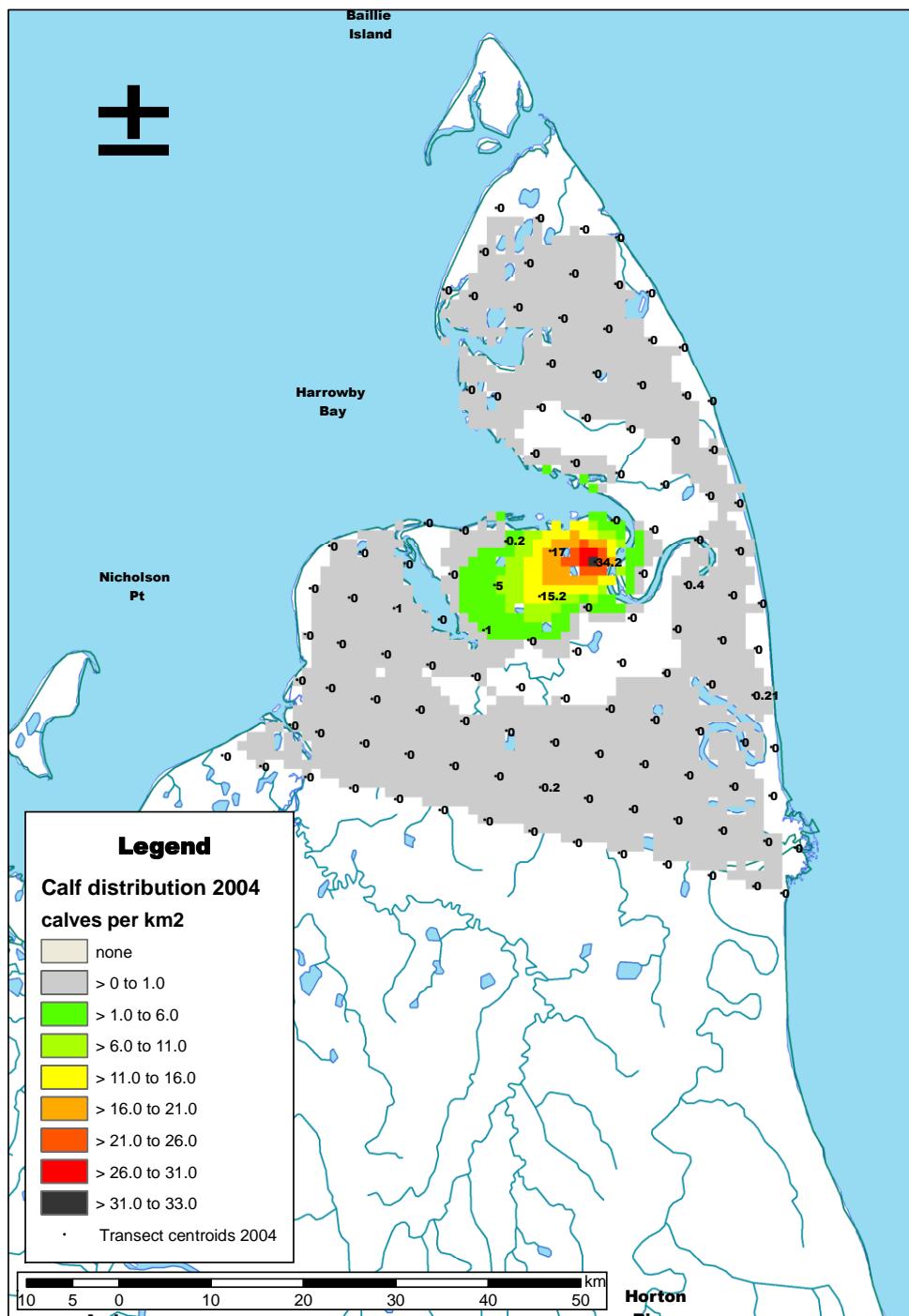


Figure 15. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Cape Bathurst barren-ground caribou herd, 2004.

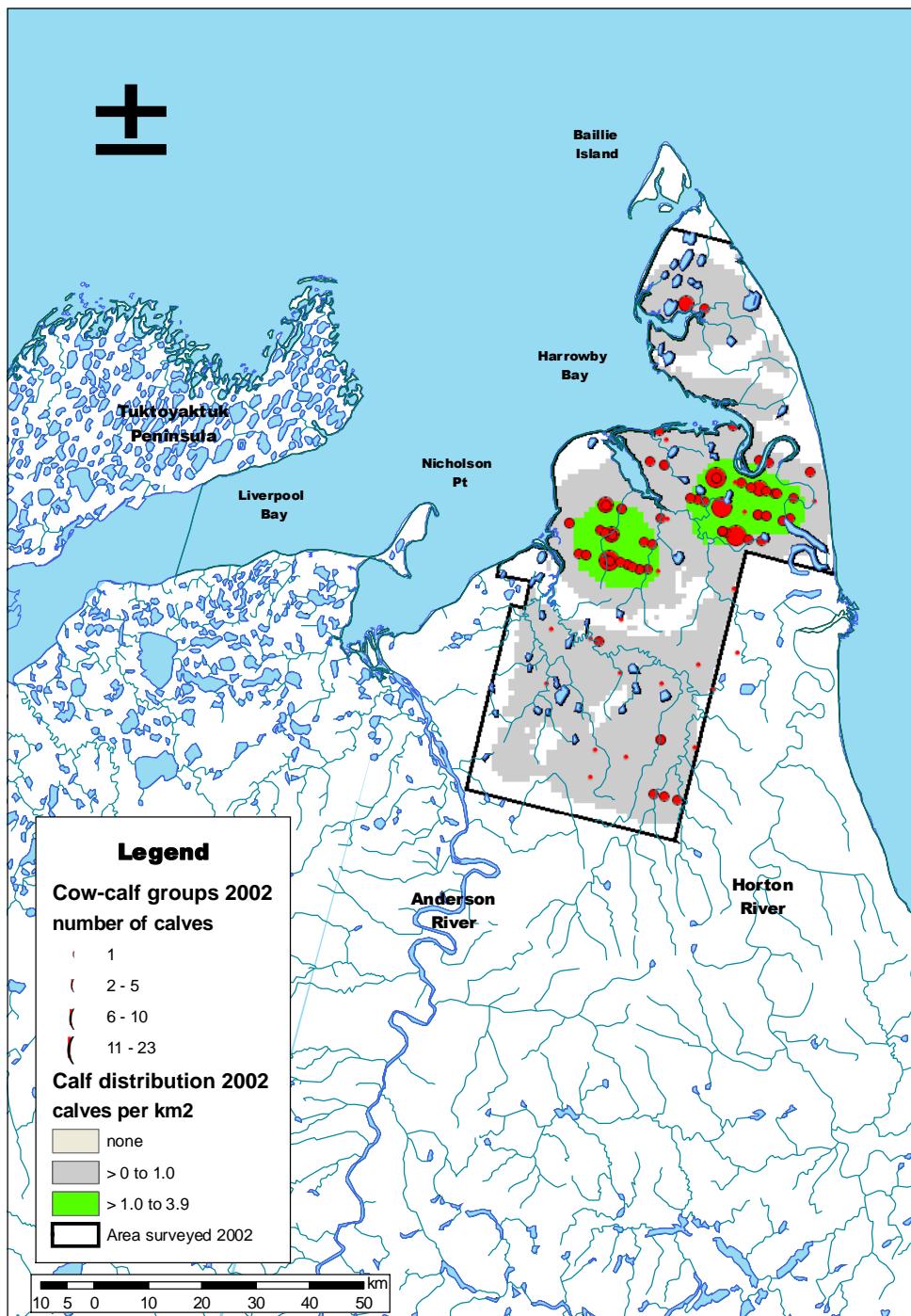


Figure 16. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2002 survey of the calving grounds of the Cape Bathurst barren-ground caribou herd.

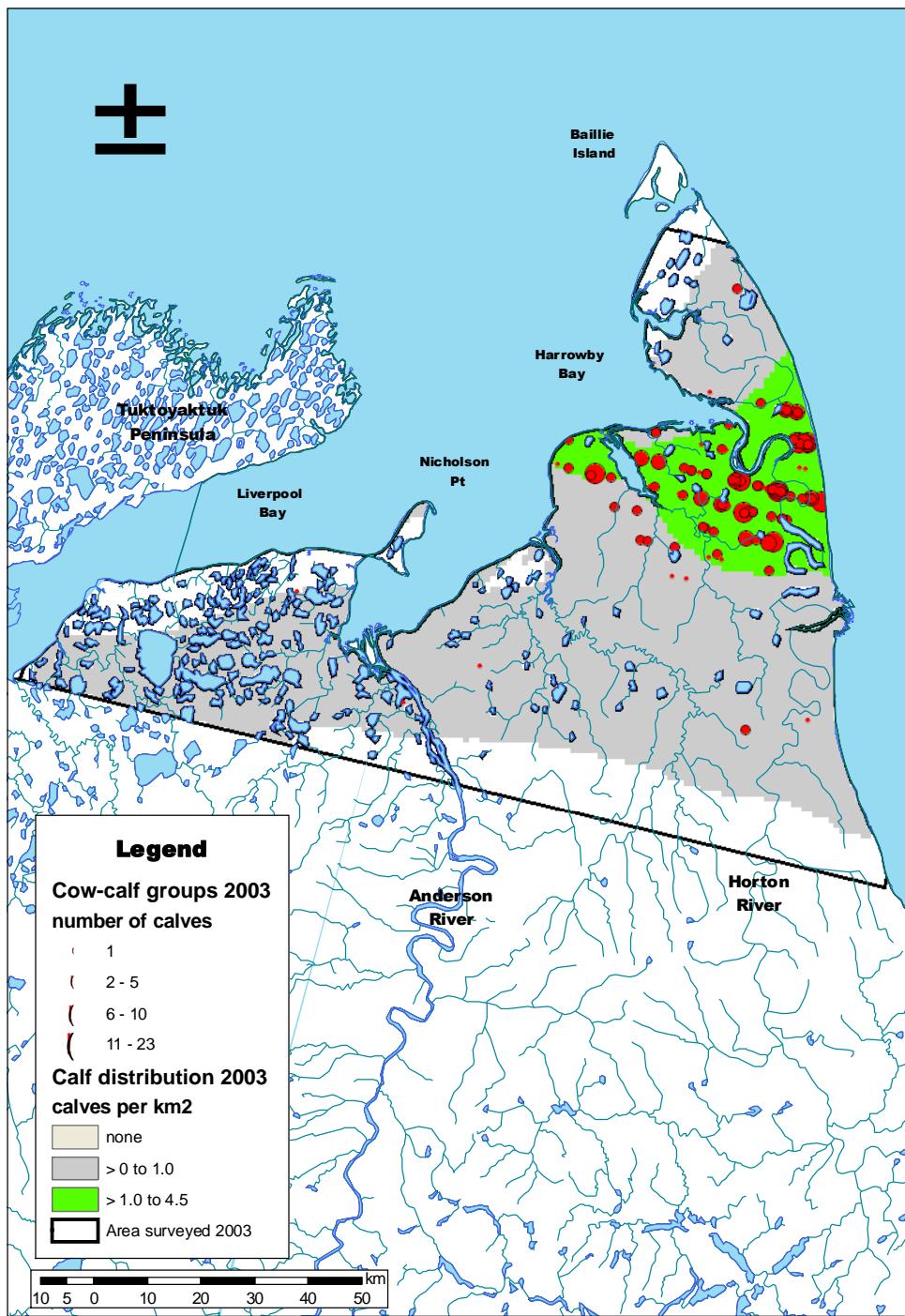


Figure 17. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2003 survey of the calving grounds of the Cape Bathurst barren-ground caribou herd.

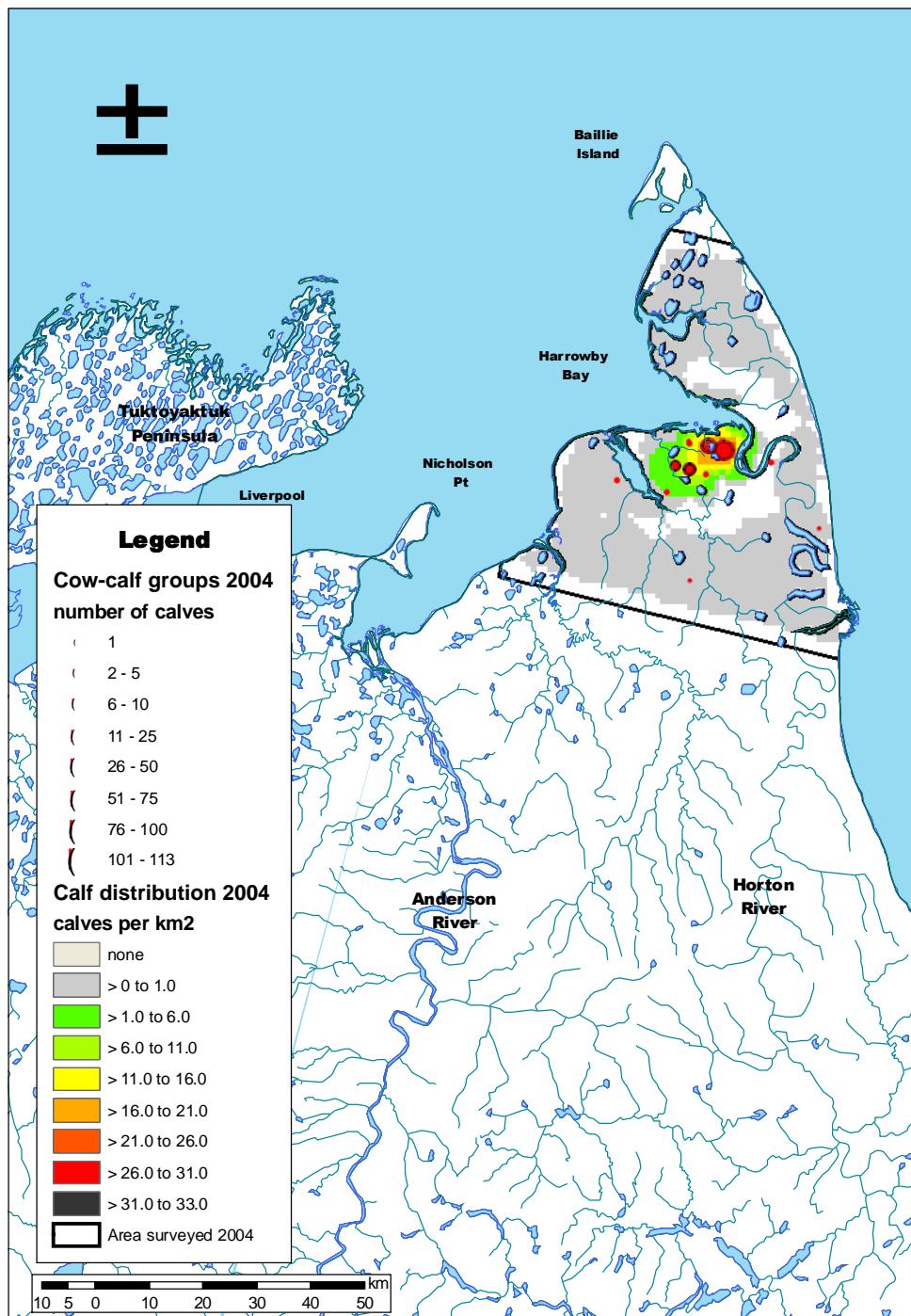


Figure 18. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2004 survey of the calving grounds of the Cape Bathurst barren-ground caribou herd.

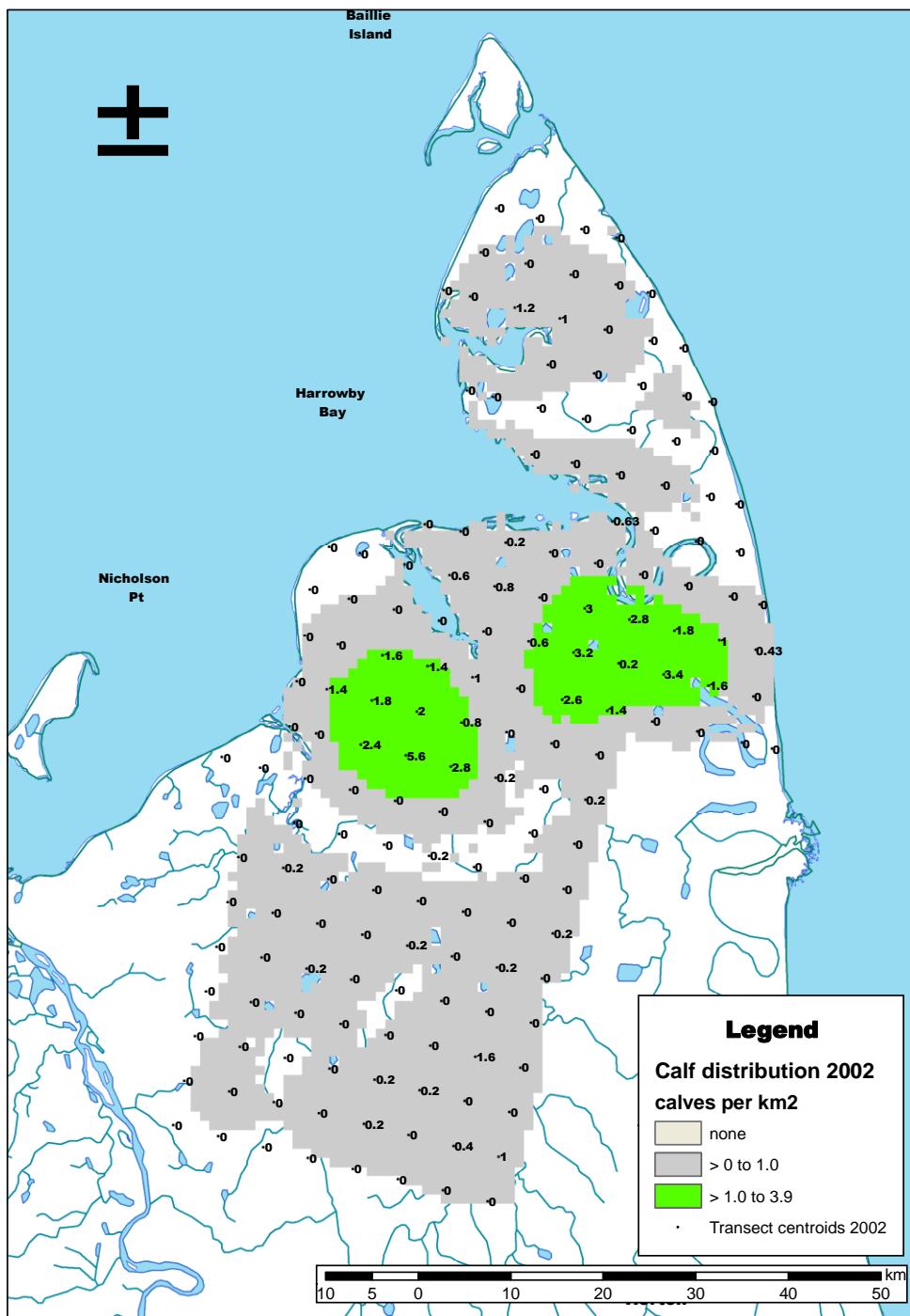


Figure 19. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2002 survey of the Cape Bathurst barren-ground caribou herd calving grounds.

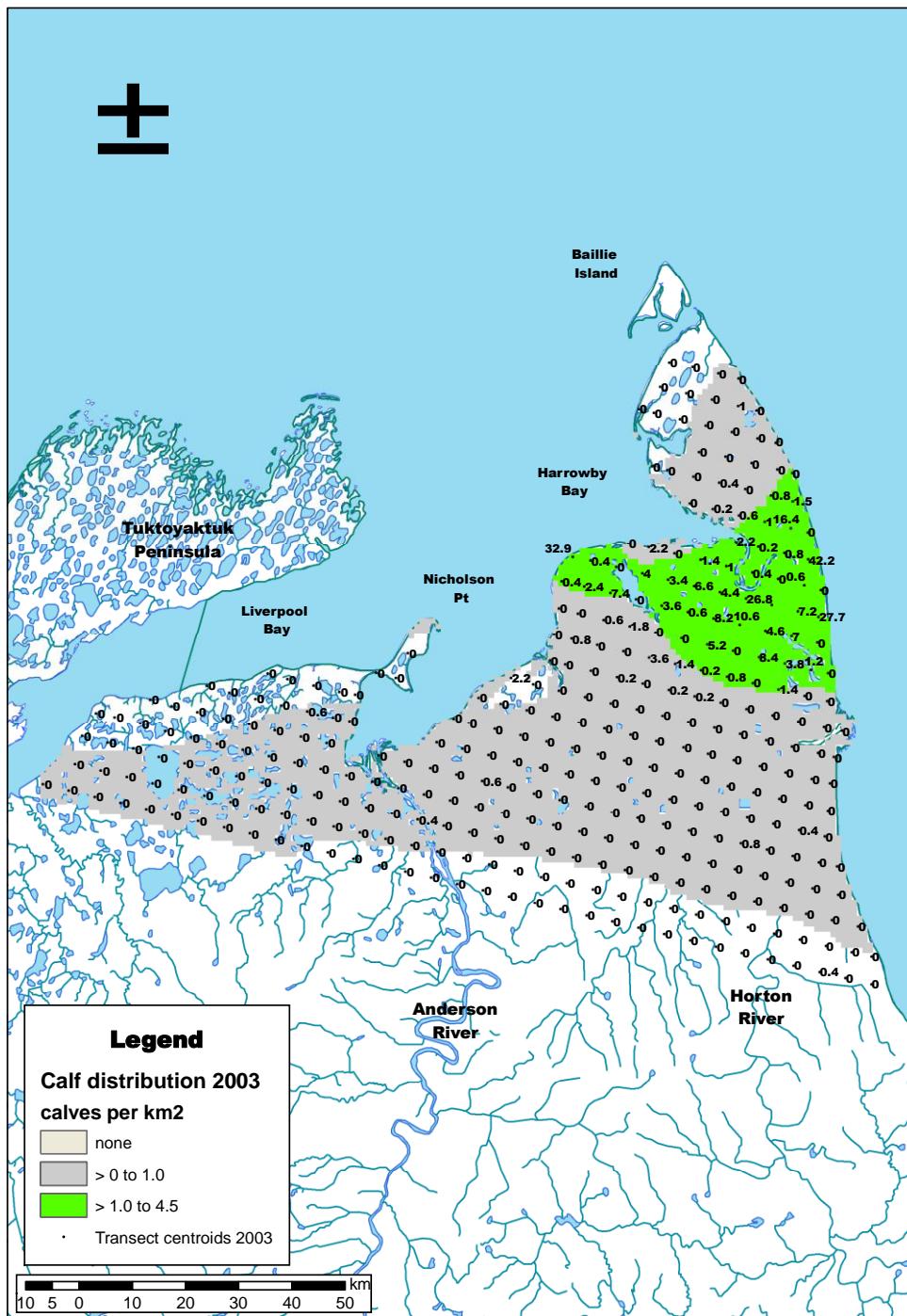


Figure 20. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2003 survey of the Cape Bathurst barren-ground caribou herd calving grounds.

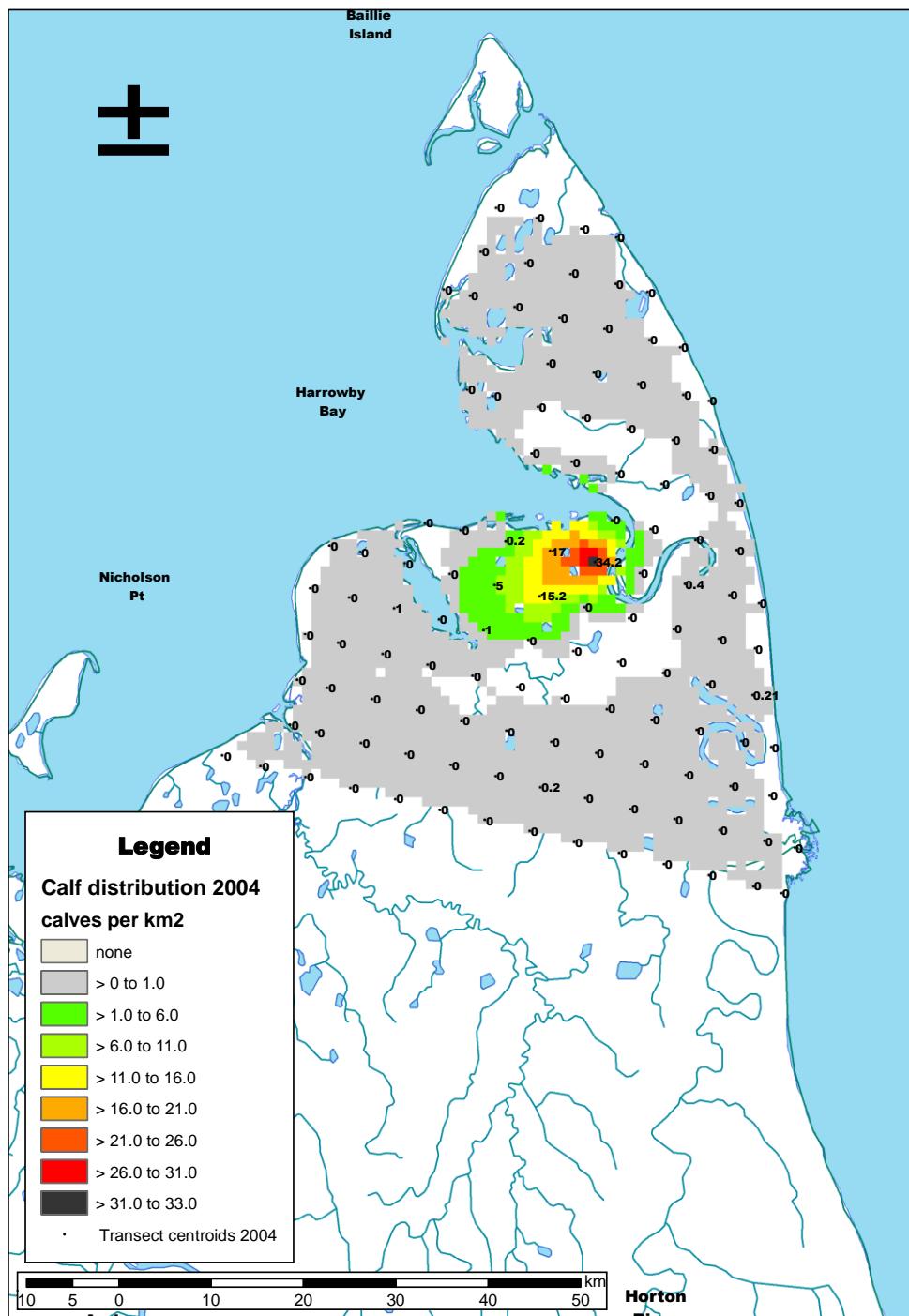


Figure 21. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2004 survey of the Cape Bathurst barren-ground caribou herd calving grounds.

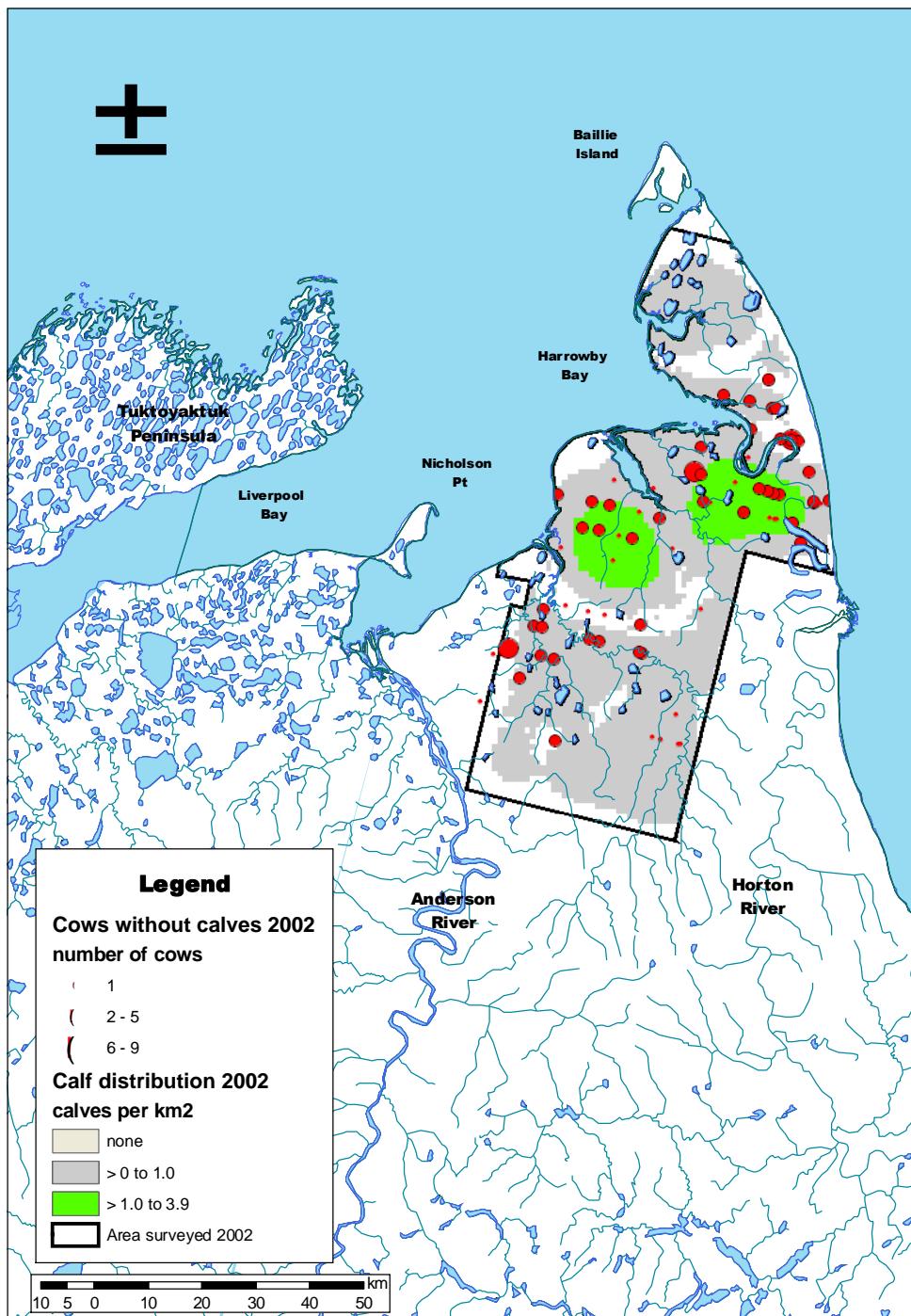


Figure 22. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2002.

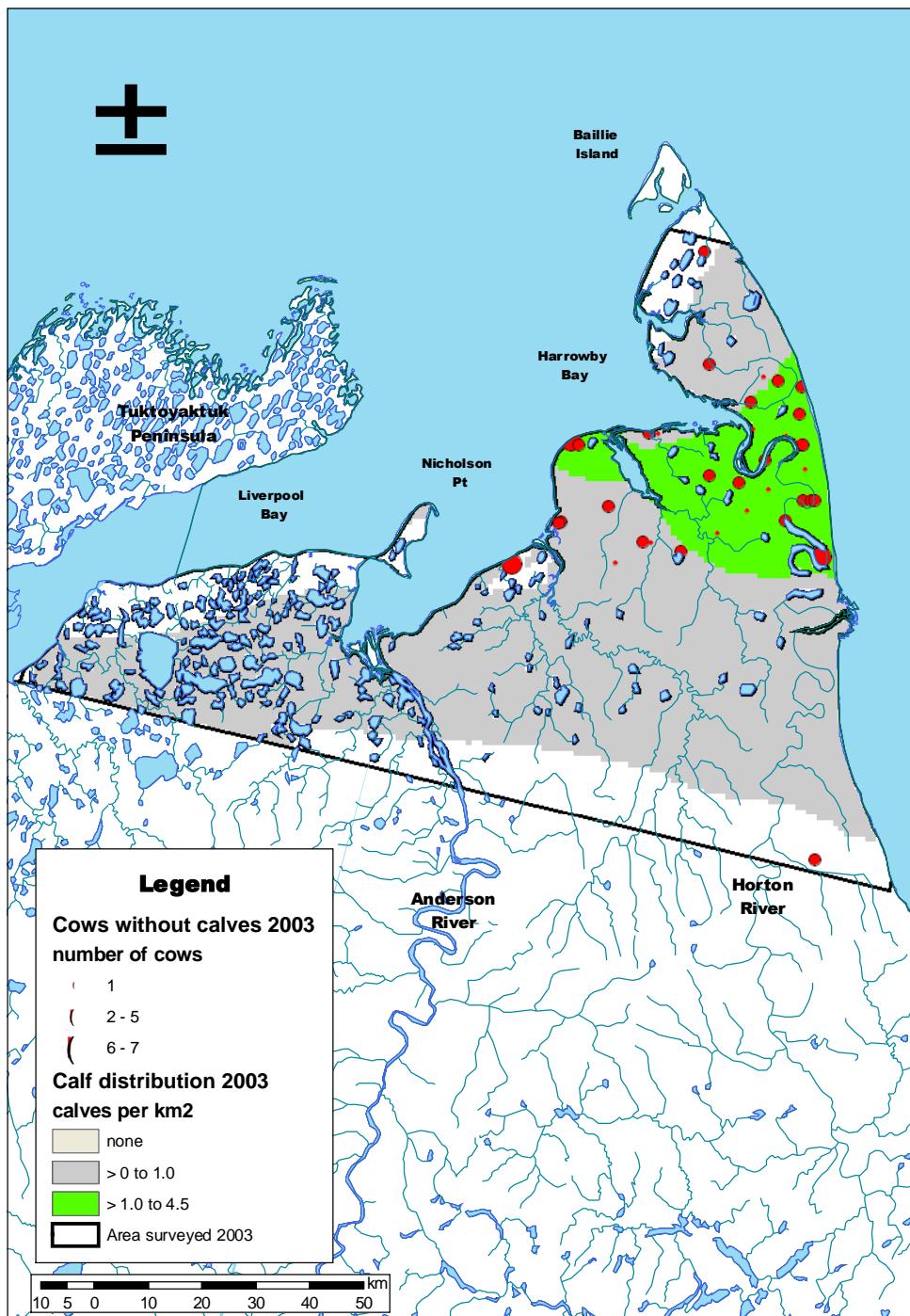


Figure 23. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2003.

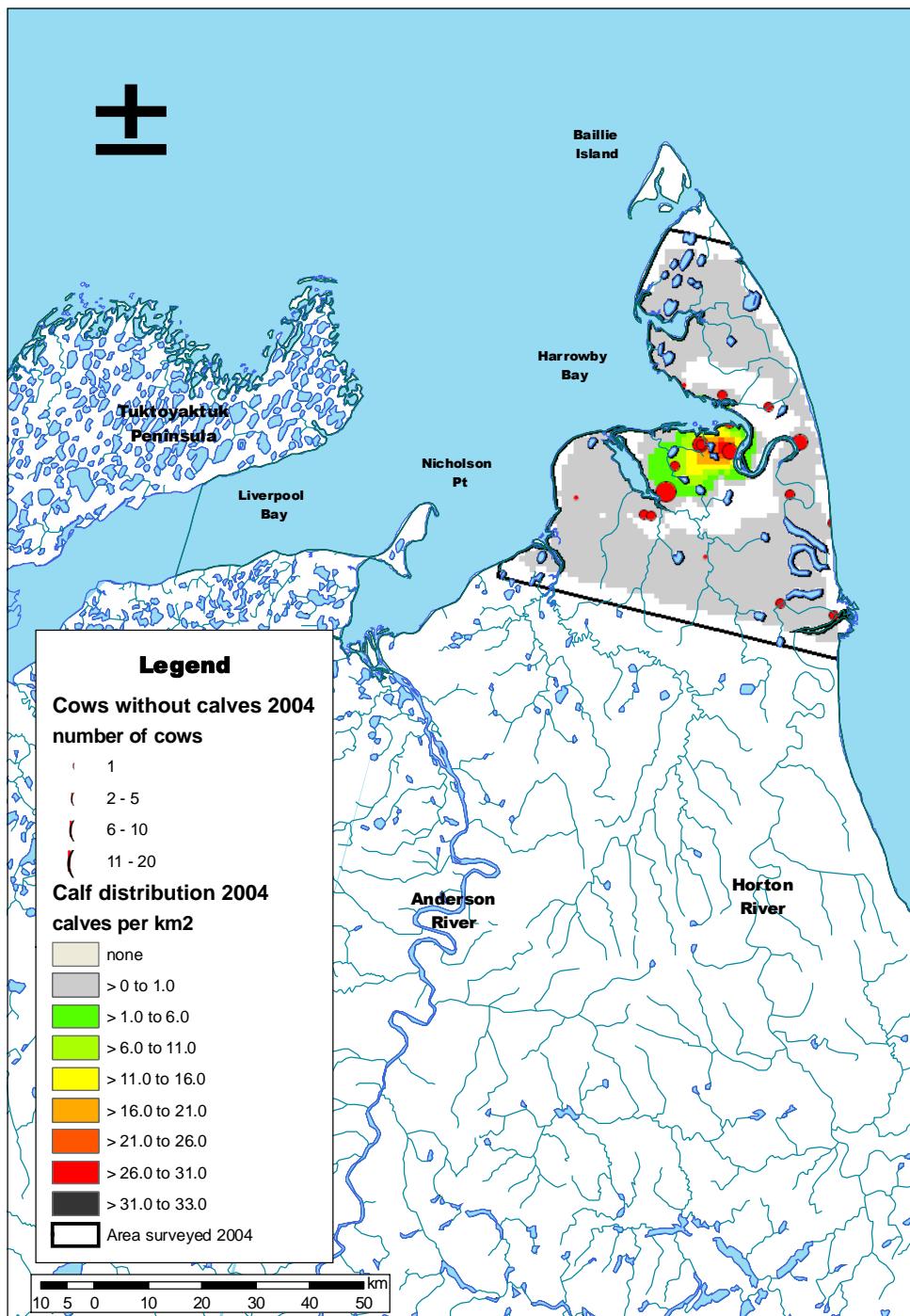


Figure 24. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2004.

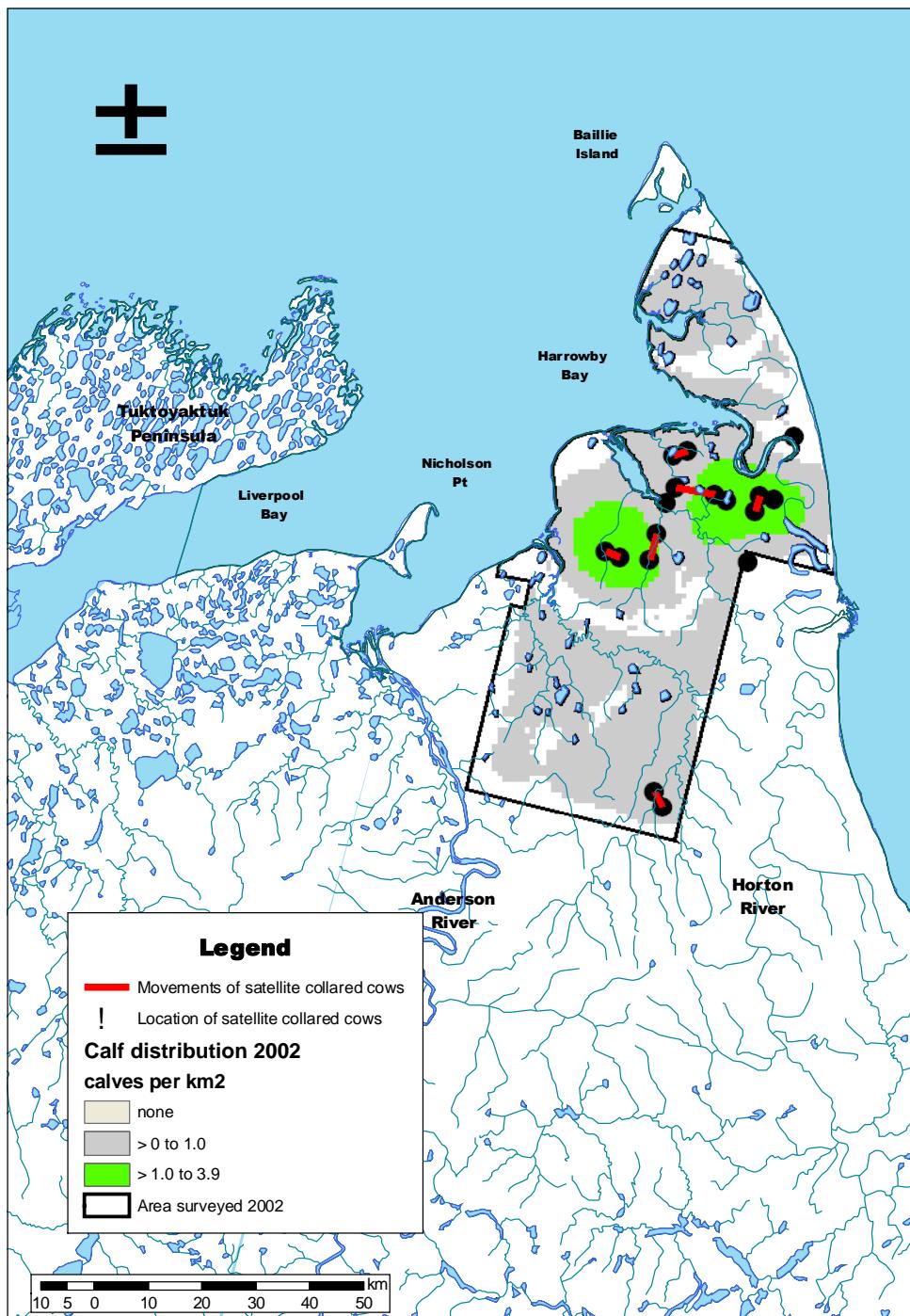


Figure 25. Distribution of satellite-collared cows in relationship to the distribution of calves on the Cape Bathurst calving ground 2002.

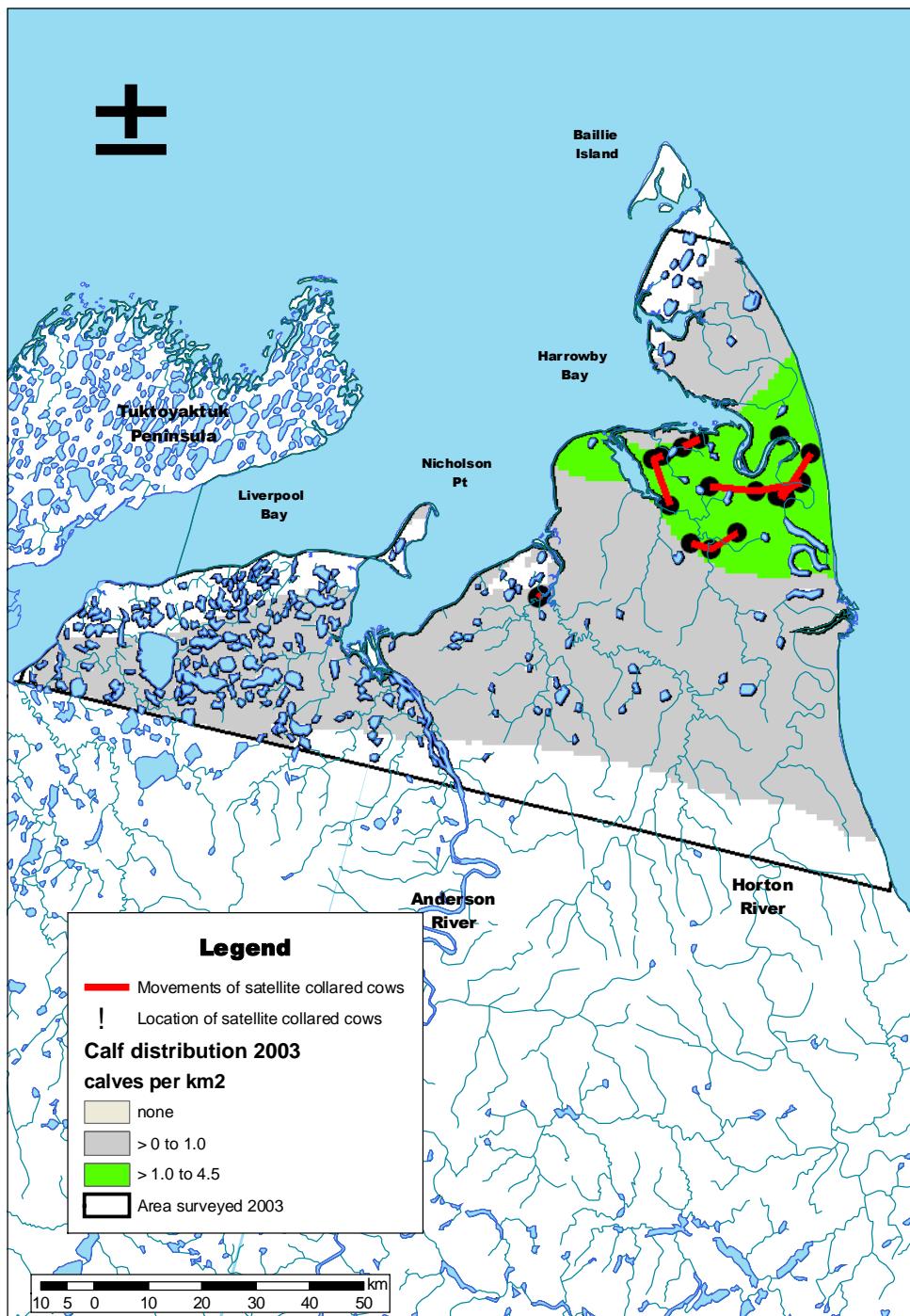


Figure 26. Distribution of satellite-collared cows in relationship to the distribution of calves on the Cape Bathurst calving grounds, 2003.

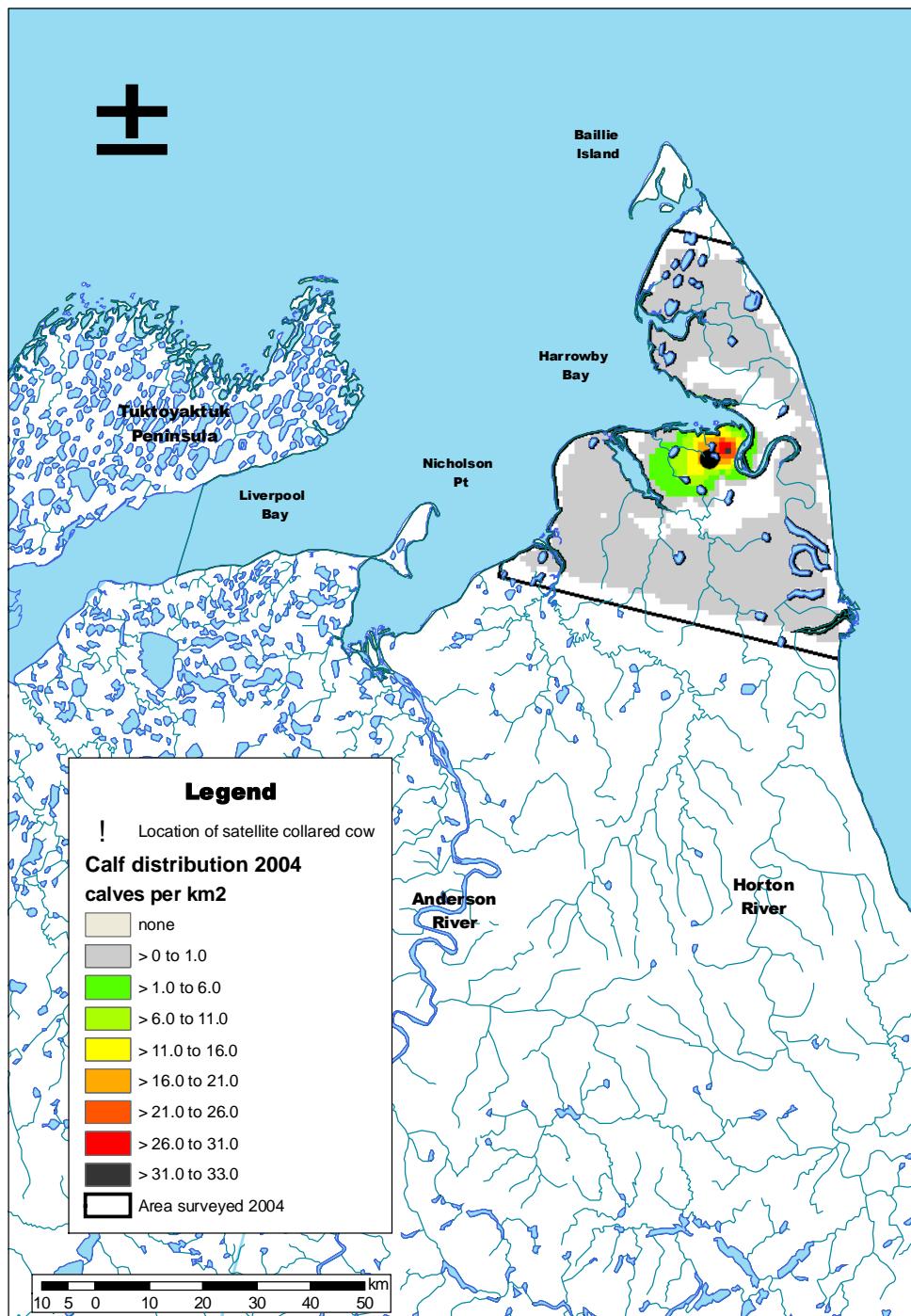


Figure 27. Distribution of satellite-collared cows in relationship to the distribution of calves on the Cape Bathurst calving grounds, 2004.

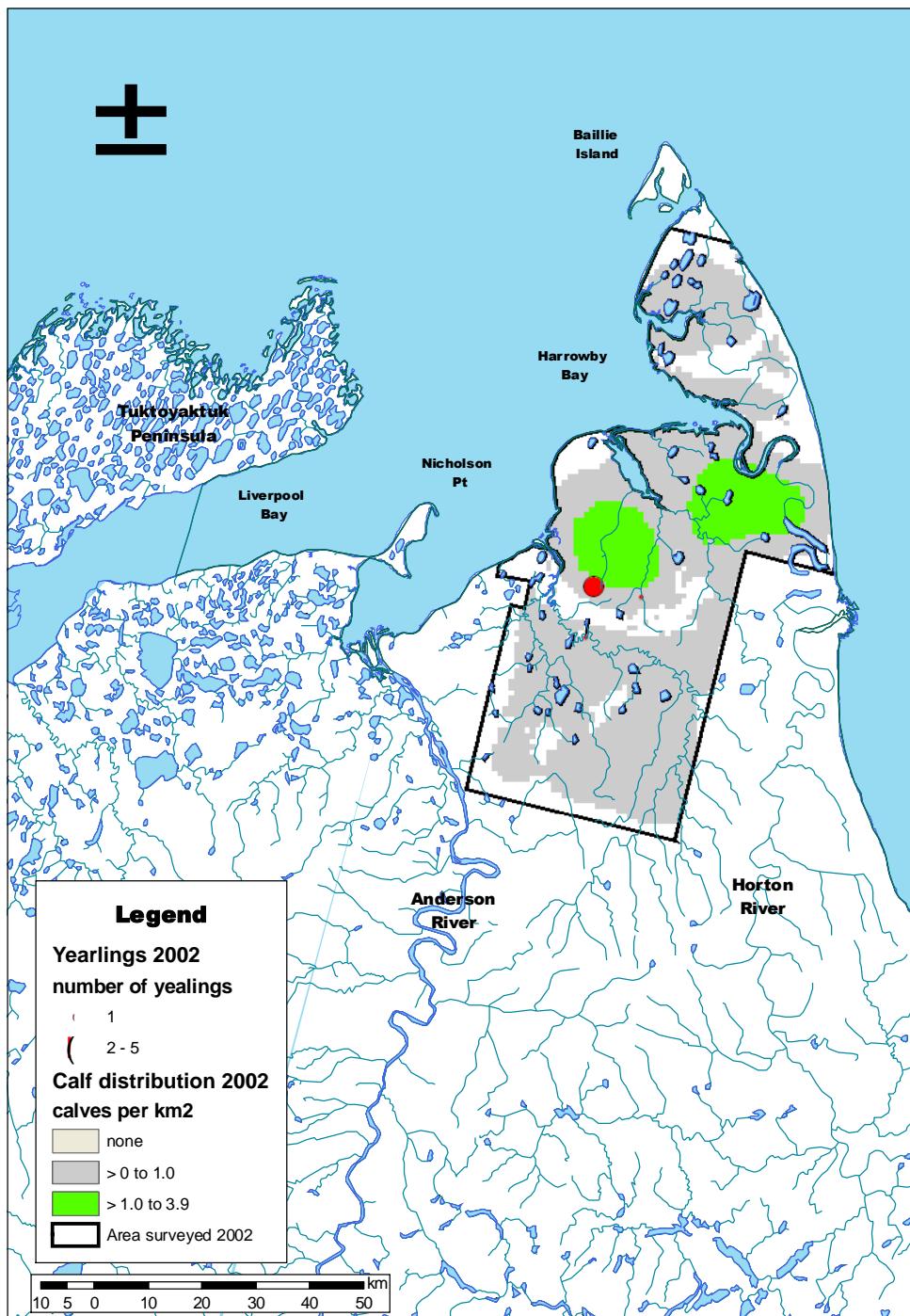


Figure 28. Distribution of yearlings observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2002.

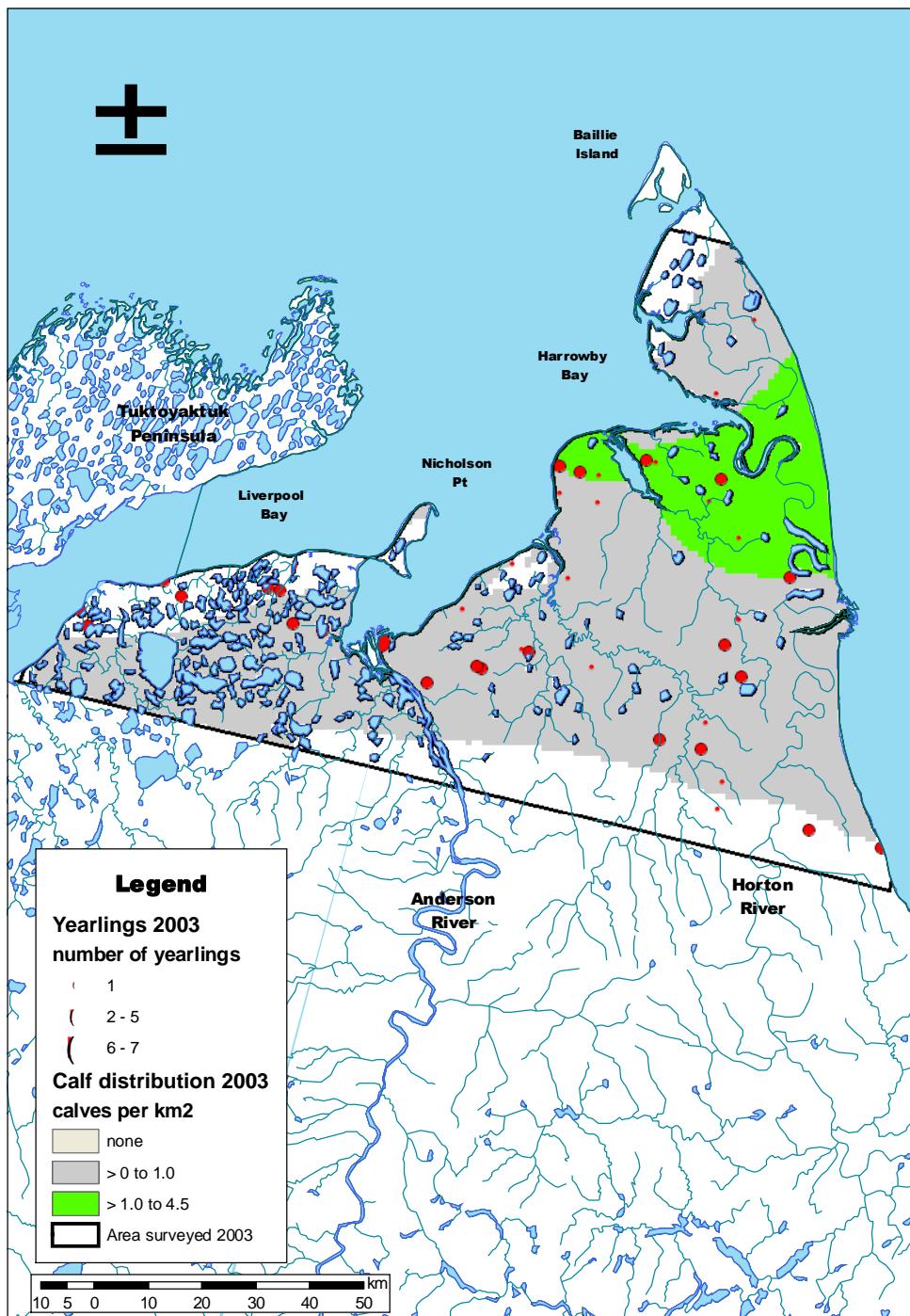


Figure 29. Distribution of yearlings observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2003.

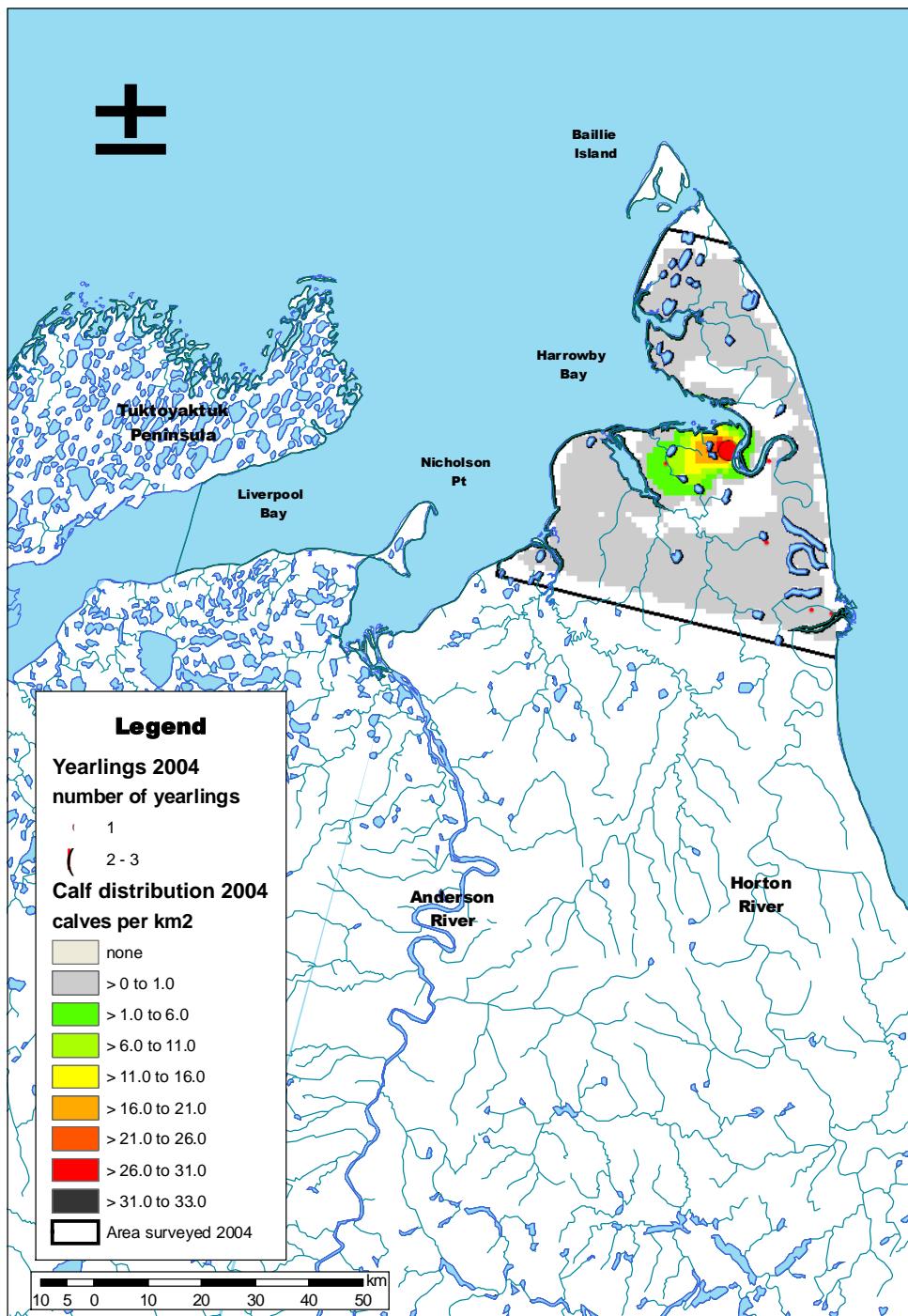


Figure 30. Distribution of yearlings observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2004.

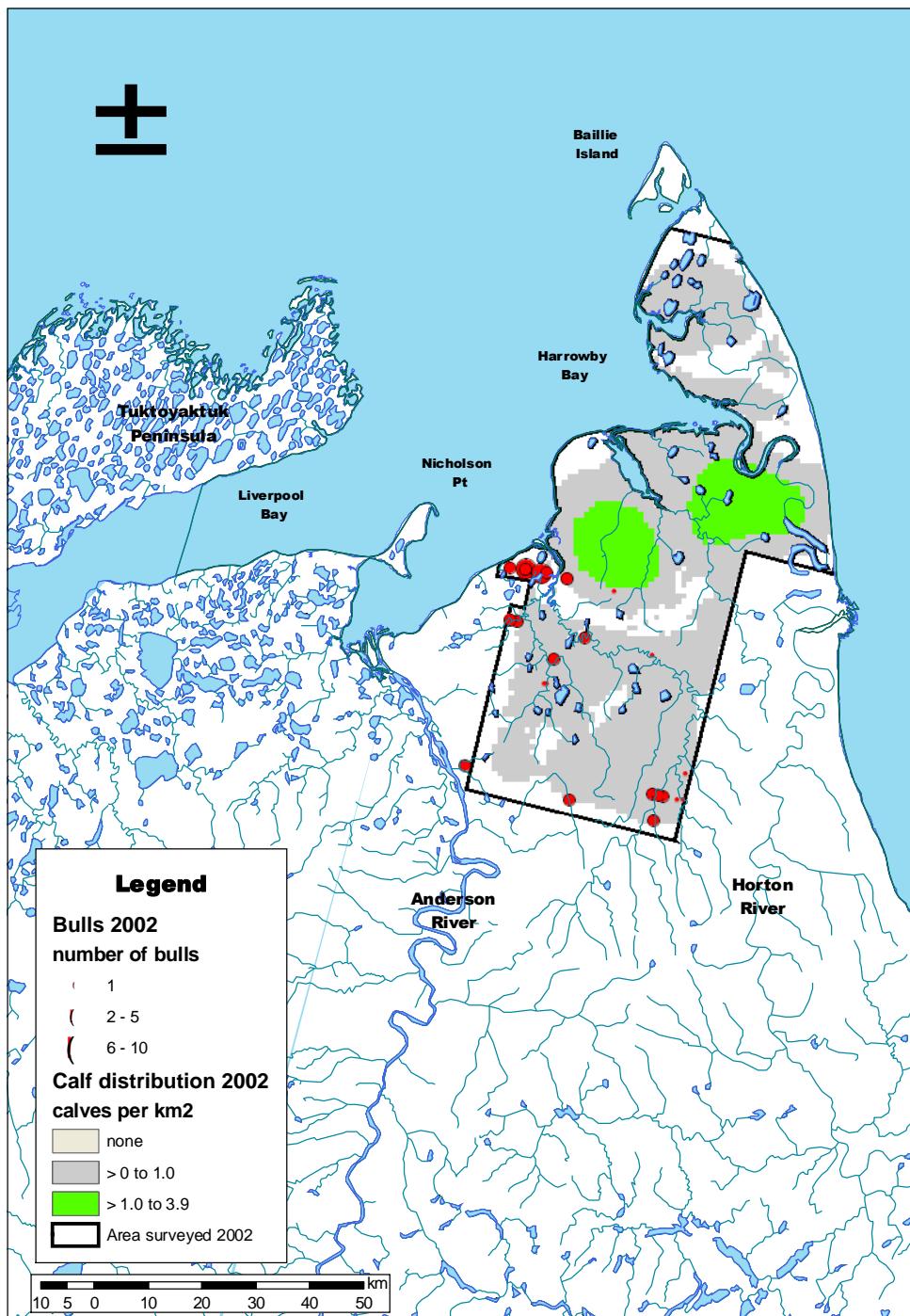


Figure 31. Distribution of bulls observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2002.

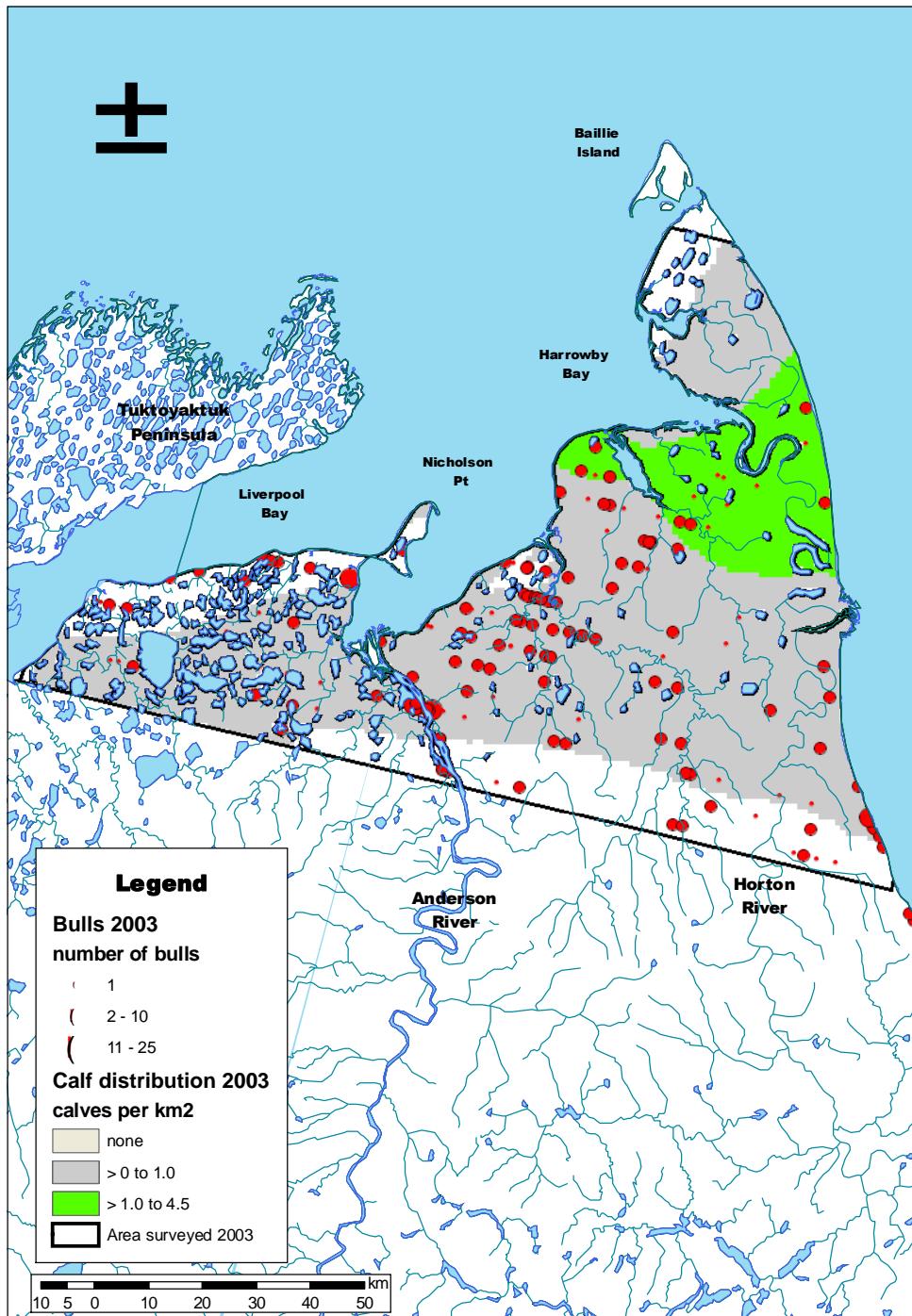


Figure 32. Distribution of bulls observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2003.

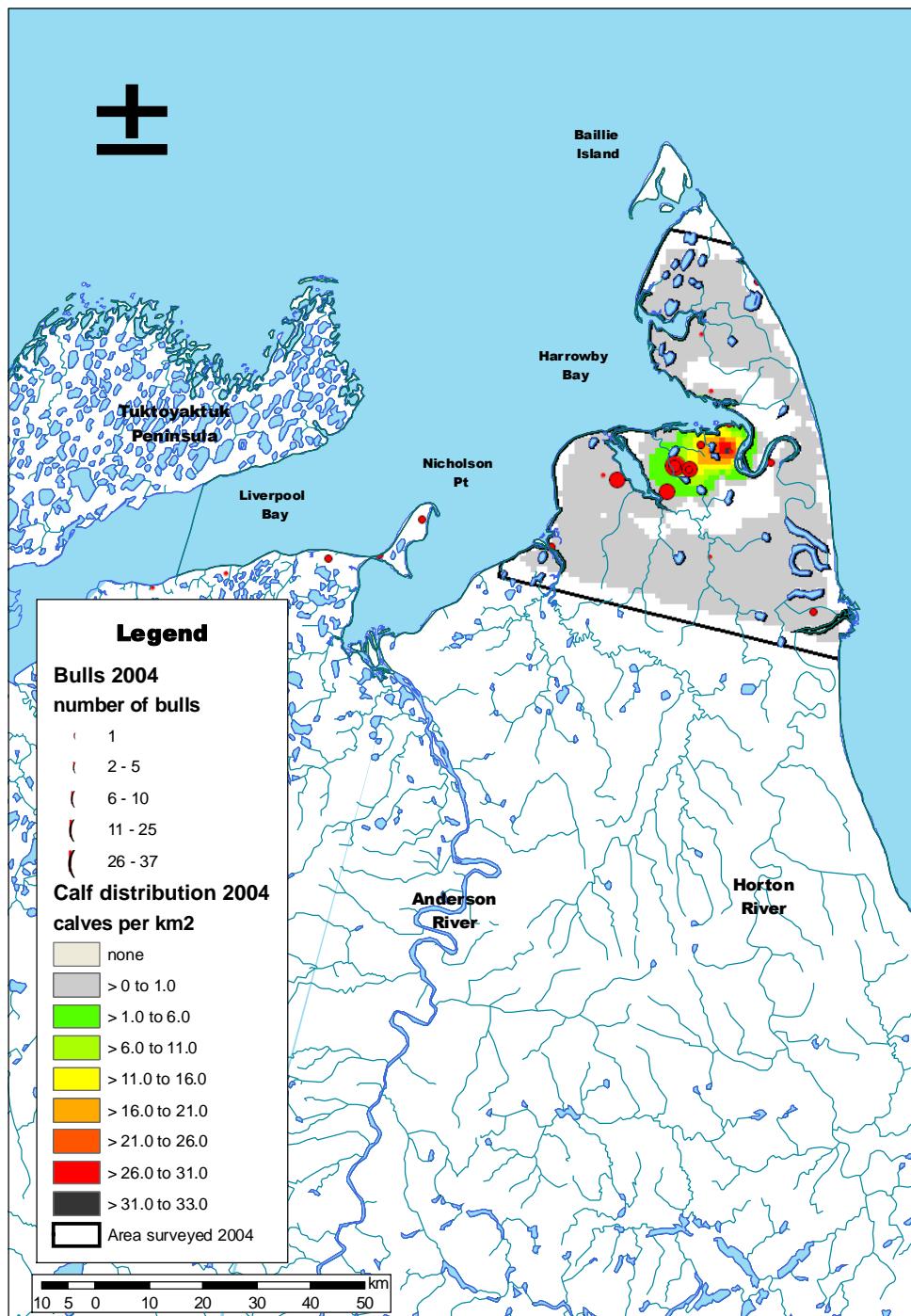


Figure 33. Distribution of bulls observed on and off transect in relationship to the distribution of calves on the calving grounds of the Cape Bathurst herd modelled using ordinary kriging prediction mapping techniques, 2004.

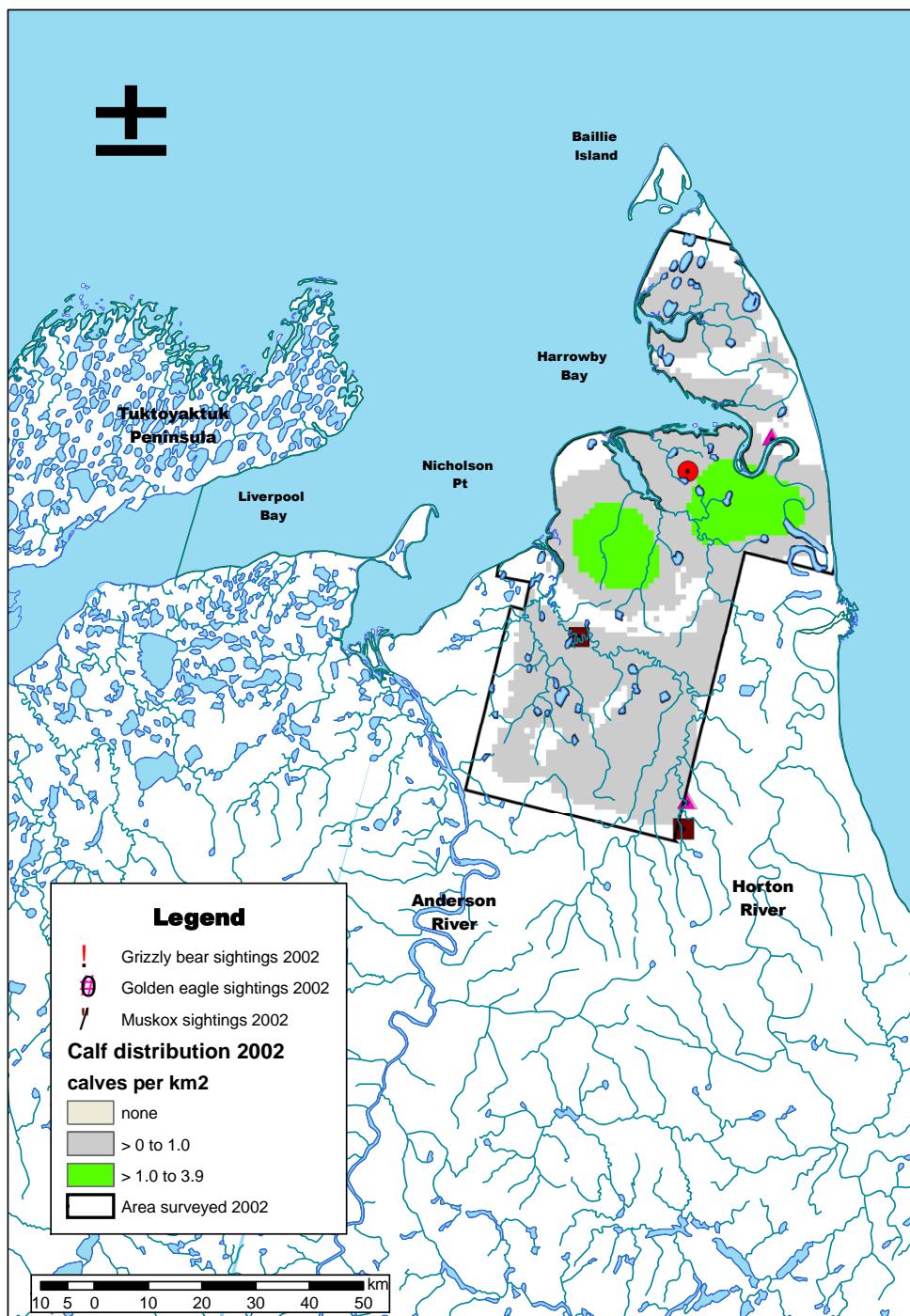


Figure 34. Distribution of grizzly bear, golden eagle, and wolf sightings in relationship to the distribution of calf caribou observed on transect during 2002.

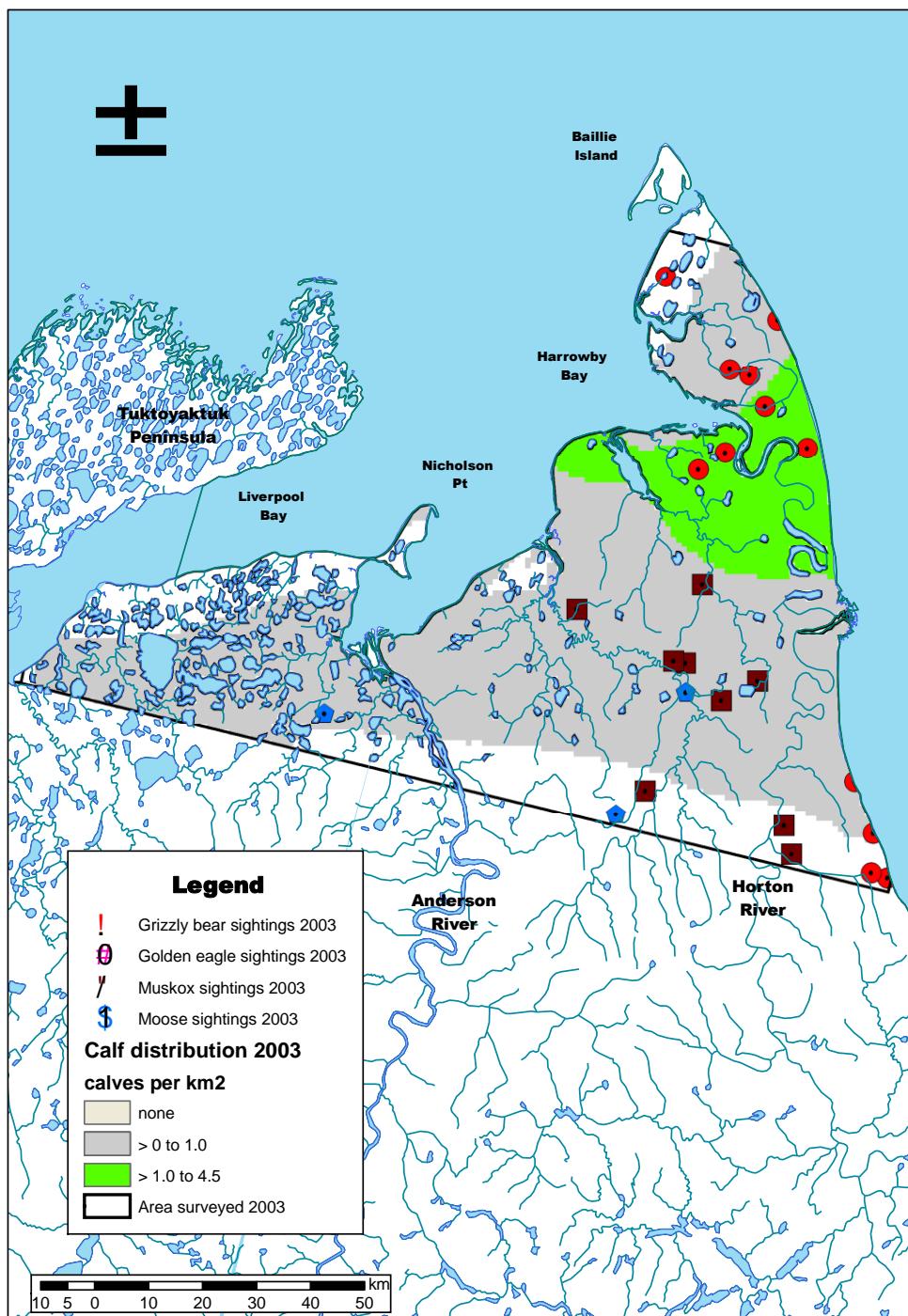


Figure 35. Distribution of grizzly bear, golden eagle, wolf and muskox sightings in relationship to the distribution of calf caribou observed on transect during 2003.

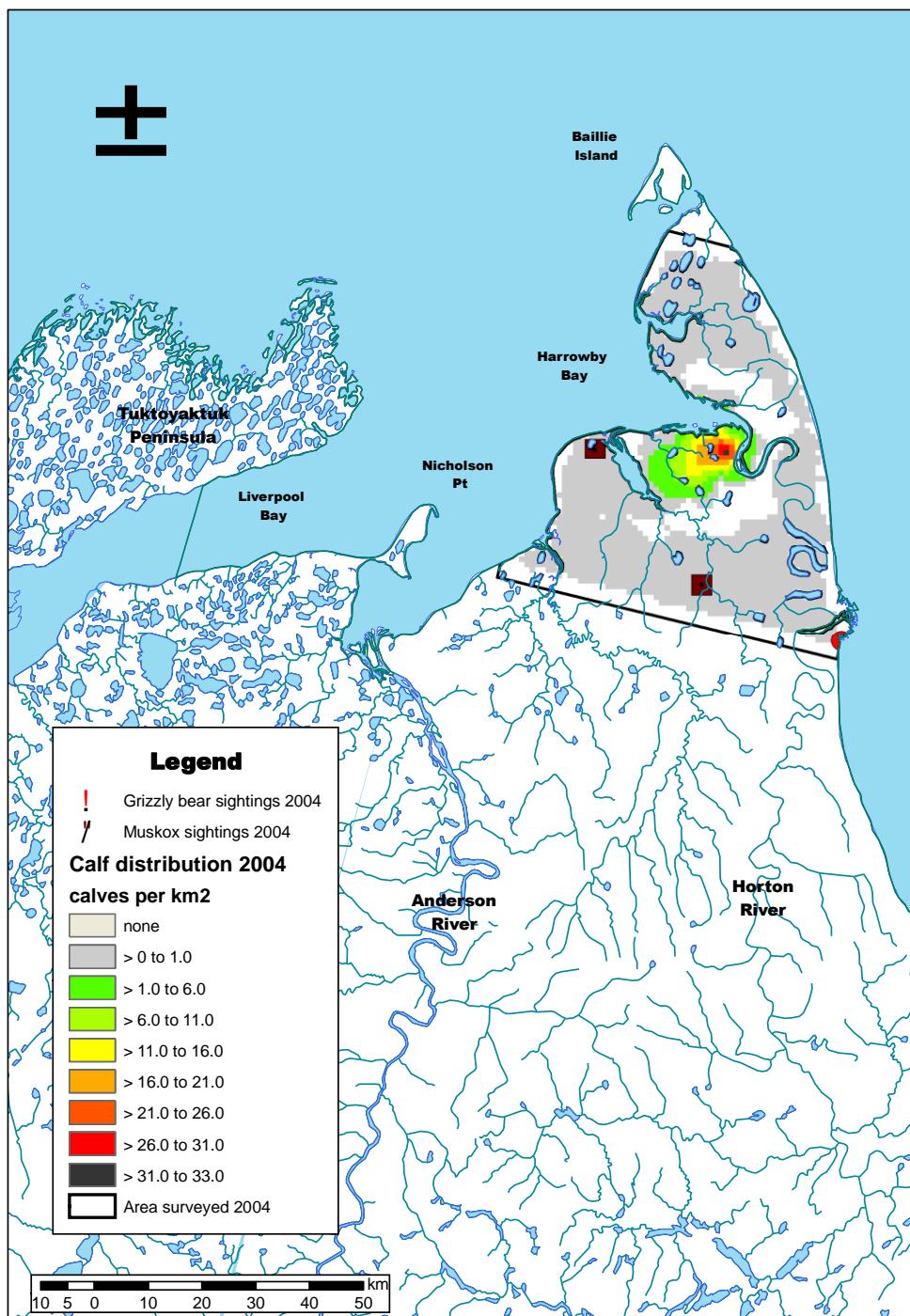


Figure 36. Distribution of grizzly bear, golden eagle, and muskox sightings in relationship to the distribution of calf caribou observed on transect during 2004.

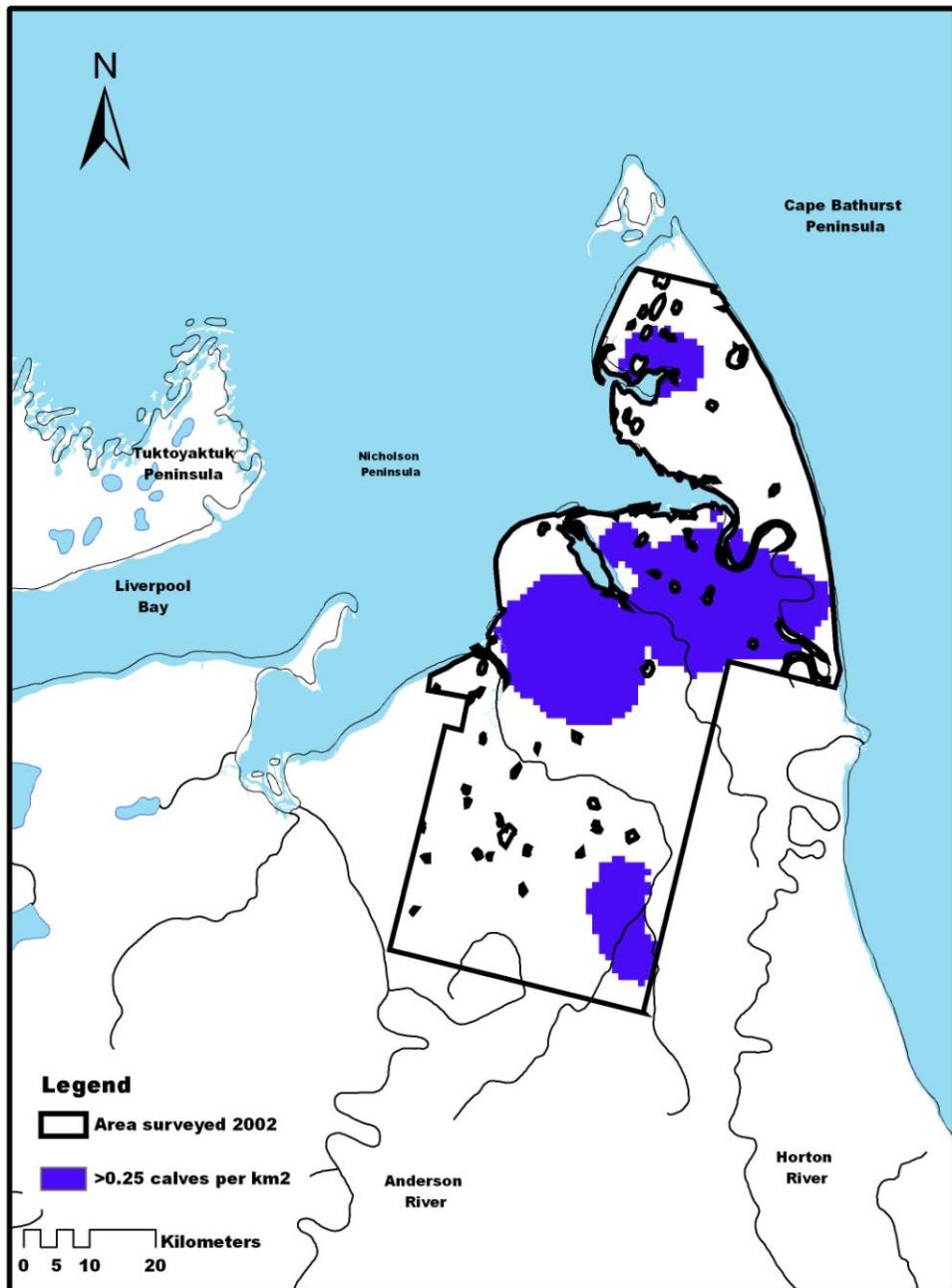


Figure 37. Extent of the Cape Bathurst calving area 2002.

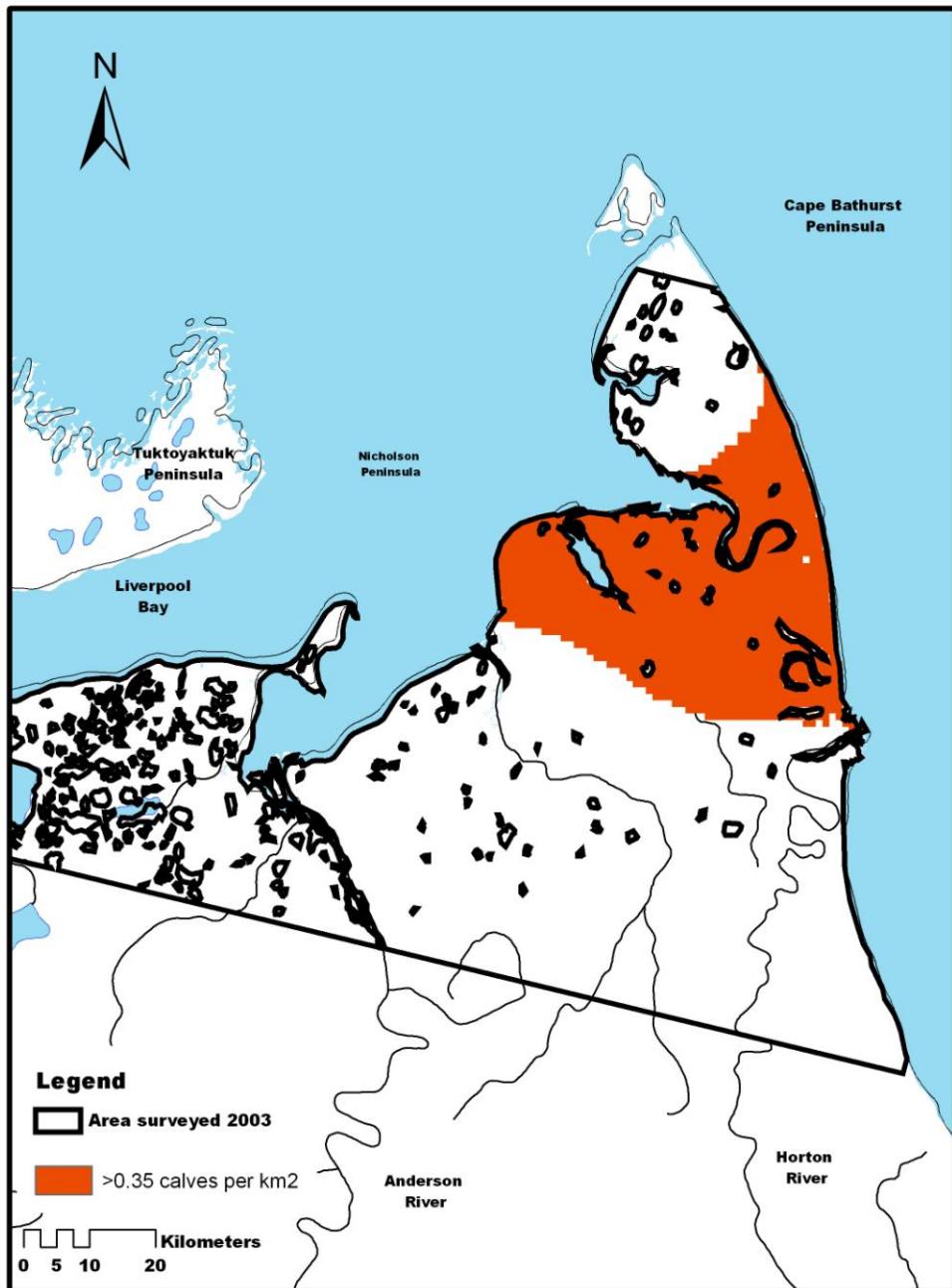


Figure 38. Extent of Cape Bathurst calving area 2003.

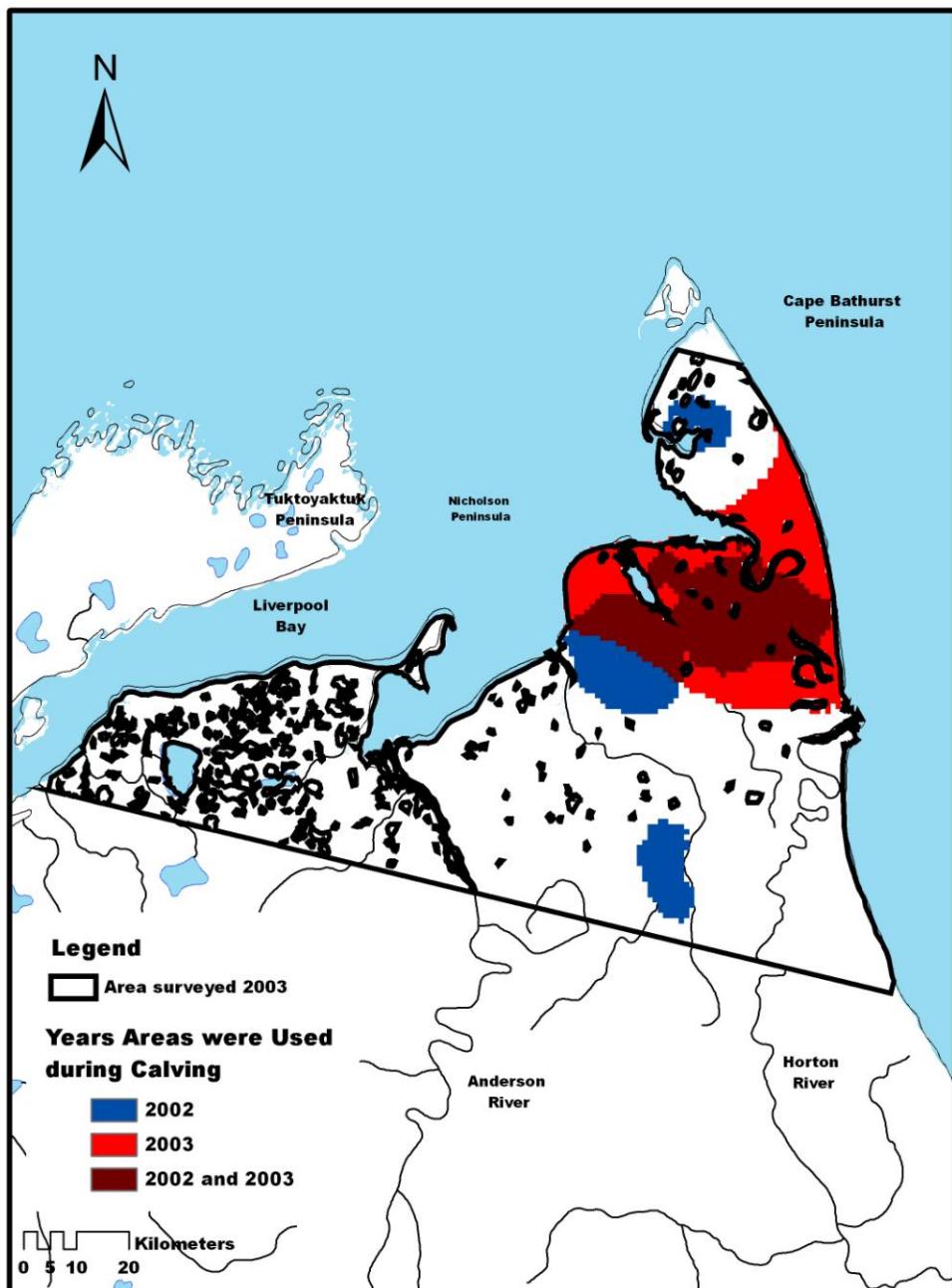


Figure 39. Extent of the calving grounds of the Cape Bathurst herd based on surveys completed in 2002 and 2003: years different areas within the calving grounds were used.