CALF:COW RATIOS ESTIMATED AT OR NEAR THE PEAK OF CALVING FOR THE BLUENOSE-WEST HERD, 2002 TO 2005

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INTRODUCTION

Surveys of the calving grounds of the Bluenose-West herd (Nagy et al. 1999; Nagy et al. 1999) were conducted annually during the period 2002 to 2005 to obtain current estimates of productivity. Earlier surveys designed to obtain estimates of productivity for this herd were conducted in 1979 (dates of survey not given but assumed to be early June) (Brackett et al. 1979) and 1983 (11 to 13 June) (Latour et al. 1986), and in 2000 and 2001 (Theberge and Nagy 2001). In 1979 and 1983 early June calf:cow ratios were around 81 calves per 100 cows (Brackett et al. 1979; Latour et al. 1986). In 2000 the calf:cow ratio of approximately 39 calves per 100 cows (survey completed between 9 to 11 June) (Theberge and Nagy 2001)was significantly lower than those reported by (Brackett et al. 1979) and (Latour et al. 1986). In 2001 (Theberge and Nagy 2001) found that although about 15 percent of the cows had calved by 15 June, most cows calved between the 15 and 23 of June. The calf:cow ratio between 23 to 26 June 2001 was approximately 54 calves per 100 cows (Theberge and Nagy 2001), again lower than the values reported by (Brackett et al. 1979) and (Latour et al. 1986).

In this paper, we report the results of 4 annual post-calving classification surveys completed for the Bluenose-West herd during 2002 to 2005. These surveys were done to monitor the annual productivity rates of the herd and to the document its distribution during or shortly after the peak of calving. We conducted transect surveys over the calving grounds in June 2002, 2003, and 2004. In June 2005 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. The objective of this survey was to obtain a calf:cow ratio 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

a. Transect surveys conducted in 2002, 2003, and 2004

In 2002 the boundaries of the survey area were delineated so that it encompassed the main distribution of locations obtained for satellite-collared cows tracked during 10-25 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 cow:calf groups and calving caribou (Figure 2 and 3).

The areas were surveyed at or near the peak of calving. Survey crew were equipped with laptop computers 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 installed. 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 either positioned on the wing struts (Cessna 185) or on a wire stretched between the tie-down rings and the fuselage (Helio Courrier) 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, and 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 observed at each site, and whether the observation 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 transects 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.

b. Photographic survey of cow:calf groups in 2005

In 2005 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 conduct a telemetry survey to locate radio-collared cows on the calving grounds. We flew transect lines spaced approximately 20-40 km apart, while flight altitude ranged 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 Courrier 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 for each group photographed were recorded.

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, and mature bulls, whenever possible, and unknown. We assigned a unique symbol color for each class of caribou. In the OziExplorer Mapping Software each color 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 color code. This was particularly useful for large mixed-class groups of caribou.

c. Calculation of calf:cow ratios

Calf:cow ratios were estimated using the Tukey-jacknife technique (Cochran 1977). We used a one-sided t-test to determine whether the cow:calf 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

a. 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 2004) 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 of ½ 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 km^2 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 km^2) = estimated number of cows or calves / [segment length (km) X 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 represent uniform map scale and actual locations and distances over land surface, which is required for geostatistical analysis (Sarangi et al. 2006)

b. Modelling 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 neighborhood of 5 data points, with a minimum of 2 included, and an 8 sector circular neighborhood.

Generally, the best model was selected as the one that had the standardized mean nearest to zero, the smallest root-mean-square prediction error, the average standard error was nearest the root-mean-square prediction error, and the root-mean-square standardized prediction error was nearest to one (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 km^2):

$>$ 0 to 1.0 per km^2
$>$ 1.0 to 6.0 per km^2
$>$ 6.0 to 11.0 per km^2
$>$ 11.0 to 16.0 per km^2
$>$ 16.0 to 21.0 per km^2
$>$ 21.0 to 26.0 per km^2

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

c. Defining the extent of annual calving areas

The area which included 95% 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 the minimum density, a test density, and the maximum density as break values. Test density values ranged from 0.05 to 0.50 km^2, with an interval of 0.05 km^2. The areas that had calf densities > test density and ≤ 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 2004). The "potential annual calving area" that included 95% 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 km^2 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.

d. 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 cells were 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 3 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

a. Transect surveys conducted in 2002

This survey was conducted between 19 and 22 June 2002. Weather conditions were favourable throughout the survey. Although snow covered most of the area when we began the survey on 19 June, most of the snow had melted by the time we completed the survey on 22 June. We classified 4301 cows (3192 on transect, 1109 off transect), 1996 calves (1769 on transect, 227 off transect), 17 yearlings (4 on transect, 13 off transect), 21 mature bulls (4 on transect, 17 off transect), 33 young bulls (31 on transect, 2 off transect), and 378 unknown (156 on transect, 222 off transect). We noted that there were 2 age classes of calves present. A small proportion of calves that were highly mobile and had change colour but the majority had just been born or a few days old. This was evidenced by some calves running to or under its mother rather than running independently when we flew over. We also observed cows, particularly in the southern and eastern portion of the survey area that had not yet calved.

The calf:cow ratio for caribou observed on transect was 53.72 (95% CI 50.66 to 56.79) (Table 1) (Figure 4). This calf:cow ratio was not significantly different from that reported for late June 2001 by (Theberge and Nagy 2001) (t-statistic = 0.314, df = 789, one-sided p-value >0.25).

b. Transect surveys conducted in 2003

This survey was flown between 21 and 24 June 2003. Weather conditions were generally favourable, although we encountered fog in the mornings at Paulatuk and low overcast conditions and periodic light snow flurries in the survey area on the 22 and 23 of June. Snow cover was restricted to areas of high elevation in the Melville Hills. We classified 4703 cows (3926 on transect, 777 off transect), 1094 calves (927 on transect, 167 off transect), 226 yearlings (198 on transect, 28 off transect), 65 bulls (37 on transect, 28 off transect), and 219 unknown (2 on transect, 217 off transect). As in 2002 we noted that there were 2 age classes of calves. We observed < 100 calves that were highly mobile and had change colour while the majority had just been born or a few days old. We also observed cows, particularly in the southern and eastern portion of the survey area that had not yet calved.

The calf:cow ratio for caribou observed on transect was 53.24 (95% CI 49.65 to 56.82) (Table 1) (Figure 4). This calf:cow ratio was not significantly different from that reported for late June 2001 by (Theberge and Nagy 2001) (*t*-statistic = 0.147, df = 904, one-sided *p*-value >0.25) or for late June 2002 (this paper) (*t*-statistic = 0.925, df = 1523, one-sided *p*-value 0.20 > *p*-value > 0.15) (Table 1).

c. Transect surveys conducted in 2004

This survey was conducted between 18 to 23 June 2004. Weather conditions were variable during the survey period but favourable when we were able to fly. Low cloud, rain, and snow flurries prevent us from flying on 19 and 20 June. Snow cover was nearly 100 percent on the eastern and northern half of the survey area. We classified 2725 cows (2457 on transect, 268 off transect), 1597 calves (1495 on transect, 102 off transect), 515 yearlings (441 on transect, 74 off transect), 118 bulls (95 on transect, 238 off transect), and 719 unknown (21 on transect, 698 off transect). Unlike 2002 and 2003, all calves observed had either just been born or a few days old. We also observed cows throughout the survey area that had not yet calved.

The calf:cow ratio for caribou observed on transect was 60.92 (95% CI 58.11 to 63.73) (Table 1) (Figure 4). This calf:cow ratio was significantly higher than that reported for late June 2001 by (Theberge and Nagy 2001) (*t*-statistic = 1.847, df = 635, one-sided *p*-value 0.05 > *p*-value >0.025), for late June 2002 (this paper) (*t*-statistic = 2.517, df = 1254, one-sided *p*-value 0.01 > *p*-value > 0.005), and for late June 2003 (*t*-statistic = 3.071, df = 1369, one-sided *p*-value 0.003 > *p*-value > 0.001) (Table 1).

d. Photographic survey of cow:calf groups in 2005

This survey was conducted on 19 to 21 June 2005. Weather conditions were favourable throughout the survey. The survey area was essentially snow free, a result of unusually warm temperatures in early June. We located 44 radio-collared cows during the survey and including these caribou, we classified at total 789 cows and 470 calves. The distribution of calf:cow groups photographed is shown in Figure 5. As in 2004, we observed only one age class of calves. The oldest calves observed were estimated to be around 1 week old, this based on mobility of the calves. No other sightings of wildlife were recorded during the survey.

The calf:cow ratio for groups of caribou photographed during this survey was 59.36 (95% CI 52.04 to 66.693) (Table 1) (Figure 4). This calf:cow ratio was not significantly different from that reported for late June 2001 by (Theberge and Nagy 2001) (*t*-statistic = 1.341, df = 128, one-sided *p*-value 0.05 < *p*-value >0.10) nor was it significantly different from those reported in this paper for late June 2002 (*t*-statistic = 0.656, df = 747, one-sided *p*-value > 0.25), late June 2003 (*t*-statistic = 0.808, df = 862, one-sided *p*-value 0.20 < *p*-value < 0.25), or late June 2004 (*t*-statistic = 0.255, df = 593, one-sided *p*-value > 0.25) (Table 1).

Defining and Mapping the Extent of Annual Calving Areas

a. 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 the transects flown in 2002, 2003, and 2004 are given Figures 6, 7, and 8, respectively.

i Cows

The ordinary kriging prediction maps of the distribution of cows observed on transect during 2002, 2003, and 2004 are given in Figures 9, 10, and 11, respectively. The cross-validation results for these models are given in Table 2. In all models selected the standardized mean was near zero, 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 zero, and the root-mean-square standardized prediction error was near one (Johnston et al. 2003) (Table 1). The nugget effect was small for the models generated for 2002 and 2004, but was comparatively large for 2003. 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. The values for cow densities at the centroids for each model were overlain on the corresponding prediction maps for 2002, 2003, and 2004 (Figure 12, 13 and 14). A visual examination of these values indicates that the models reasonably fit the data when generalized to a 5 km grid.

ii Calves

The ordinary kriging prediction maps of the distribution of calves observed on transect during 2002, 2003, and 2004 are given in Figures 15, 16, and 17, respectively. The cross-validation results for these models are given in Table 3. In all models selected the standardized mean was near zero, 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 zero, and the root-mean-square standardized prediction error was near one (Johnston et al. 2003) (Table 2). The nugget effect was relatively small for all three models. The distribution of calves observed on and off transect were overlain on the prediction maps generated for the 3 years. A visual examination of these maps indicates that in all cases the models reasonably fit the actual distribution of sightings (Figures 15, 16, and 17). The majority of sightings of calves were made in areas where predicted calf densities were > 1 calf per km^2. The values for calf densities at the centroids for each model were overlain on the corresponding prediction maps for 2002, 2003, and 2004 (Figure 18, 19 and 20). A visual examination of these values indicates that the models reasonably fit the data when generalized to a 5 km grid.

b. 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.

i 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 21, 22, 23, respectively. A visual examination of maps for all years indicates that the majority of cows without calves were observed within or adjacent to areas where predicted calf densities were > 1 calf per km^2.

ii satellite collared cows

Prediction maps of the distribution of calves with locations indicating where the satellite collared cows in the Bluenose-West herd were located during the survey period overlain are given for 2002, 2003, and 2004 in Figures 24, 25, and 26, respectively. In 2002, 4 of the 5 satellite-collared cows were within areas with calf densities > 1 calf per km^2. The remaining collared cow was at the northwestern edge of the survey area (Figure 24). Similarly in 2003, 3 of the 4 satellite collared cows were within areas with calf densities > 1 calf per km^2. The remaining collared cow was at the northwestern edge of the survey area (Figure 25). In 2004 both satellite collared cows were in areas with calf densities > 1 calf per km^2 (Figure 26). 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.

iii 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 27, 28, and 29, respectivley. Few yearlings were observed during 2002. Most of these were observed on the northwestern edge of the survey area. In 2003 the majority of the yearlings observed were along the western and southern edges of the survey area. In comparison in 2004 most of the yearlings were observed in areas where predicted calf densities were > 1 calf per km^2.

iv 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 30, 31, and 32, respectively. Typically few bulls are observed within the calving area during early to mid June. Most of the bulls are usually found in the coastal areas south and west of Paulatuk at this time. In 2002 few bulls were observed and these were located on the northwestern portion of the survey area. Again in 2003 few bulls were observed, with these located in the extreme northwestern and southern portions of the survey area. Similarly in 2004 few bulls were observed but these were scattered as individuals or in small groups throughout the survey area. The largest groups were observed in areas where predicted calf densities were > 1 calf per km^2 on the western portion of the survey area.

c. 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 2002, 2003, and 2004.

i 2002

We observed a total of 11 grizzly bears including 4 lone adults, one sow with cubs of the year, and 2 male:female pairs. In addition, we observed 2 wolves and 2 golden eagles. The majority of these sightings made either in or near areas with calf densities > 1 calf per km^2 (Figure 33).

ii 2003

We observed a total of 18 grizzly bears including 7 lone bears, 2 male:female pairs, 1 sow with 2 yearlings, and 2 sows with 1 yearling each. In addition we observed 3 golden eagles, 1 wolf, and 16 adult and 1 calf muskoxen. The majority of the grizzly bear sightings were made in the area near Billy Lake southeast and southeast to the northwestern edge of the survey area, with others scattered through the survey area (Figure 34). Similarly, the wolves, golden eagles, and muskoxen observed were scattered throughout the area (Figure 34).

iii 2004

We observed a total of 26 grizzly bears including 8 lone bears, 2 male:female pairs, 1 sow with 3 2-year olds, 2 sows with 2 cubs of the year each, and 1 sow with 1 cub of the year. In addition we observed 3 golden eagles, and 23 adult and 5 calf muskoxen. The majority of these sightings were made in the area between Billy and Fallaize lakes east to the western boundary of Tuktut Nogait National Park (Figure 35).

d. 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% of the calves observed on transect during the survey are given in Table 4. In 2002 this density was 0.275 calves per km^2, and when used to define the boundaries of the calving area, the resulting area included 8094 km^2, 96 percent of the calves, and 93 percent of the cows (Table 4)(Figure 36). In 2003 the density was 0.40 calves per km^2, and when used to define the boundaries of this calving area, the resulting area included 5981 km^2, 95 percent of the calves, and 94 percent of the cows (Table 4)(Figure 37). In 2004 the density was 0.325 calves per km^2, and when used to define the boundaries of this calving area, the resulting area included 5973 km^2, 95 percent of the calves, and 92 percent of the cows (Table 4)(Figure 38).

e. Overlap in annual calving areas

The combined area used by the Bluenose-West herd during calving in 2002, 2003, and 2004 and the years when different portions of this area were used is shown in Figure 39. The combined calving area was 11236 km^2 (Table 5). Approximately 24 percent of this area was used in all years (Table 5). This area was largely east of the Hornaday River and south of the Brock River and north of the Little Hornaday River. An additional 21 percent of the combined area near the Brock River and in the area of the Little Hornaday rivers was used only in 2002 and 2003. Approximately 20 percent of the combined area was used only in 2002. This area was largely east of the Hornaday River area used in all three years (Figure 39). Similarly, approximately 19 percent of the combined area was used only in 2004. This area was west of the Hornaday River area used in all three years. These data indicate that the distribution of caribou on the calving grounds varied during these three years but overlapped the Hornaday River area each year.

The combined area used by the Bluenose-West herd during calving in 2002, 2003, and 2004 and the number of years that different portions of this area was used is shown in Figure 40. Again the combined calving area was 11236 km^2 (Table 6). Approximately 24 percent of this area was used 3 of the 3 survey years, 30 percent during 2 of the 3 survey years, and 46 percent was in 1 of the 3 survey years.

DISCUSSION

The results of surveys conducted on the calving grounds of the Bluenose-West herd during the period 2000 to 2005 indicate that cows calved progressively later and that calf:cow ratios were significantly lower than those documented in the 1979 and 1983. Ratios declined from around 81 calves per 100 cows in 1979 and 1983 to an average of 57 calves per 100 cows (range 53 to 61) during the period 2001 to 2005. These values are similar to 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). However, the fact that by 2004 almost all of the cows in the Bluenose-West herd were calving during the 3rd week of June is of concern. 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” was used as 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 Bluenose-West 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 standardizes the map output to a population parameter rather than an arbitrary density value, ie 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 Bluenose-West herd varied among years, ranging from around 6000 km^2 in 2003 and 2004 to 8100 km^2 in 2002. Use of different portions of the calving range varied among years but approximately 25 percent of the combined area used in 2002, 2003, and 2004 was used in all three years. Approximately 54 percent of the combined area used in 2002, 2003, and 2004 was used during at least 2 of the three years.

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Figure 1. Distribution of Bluenose-West 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.

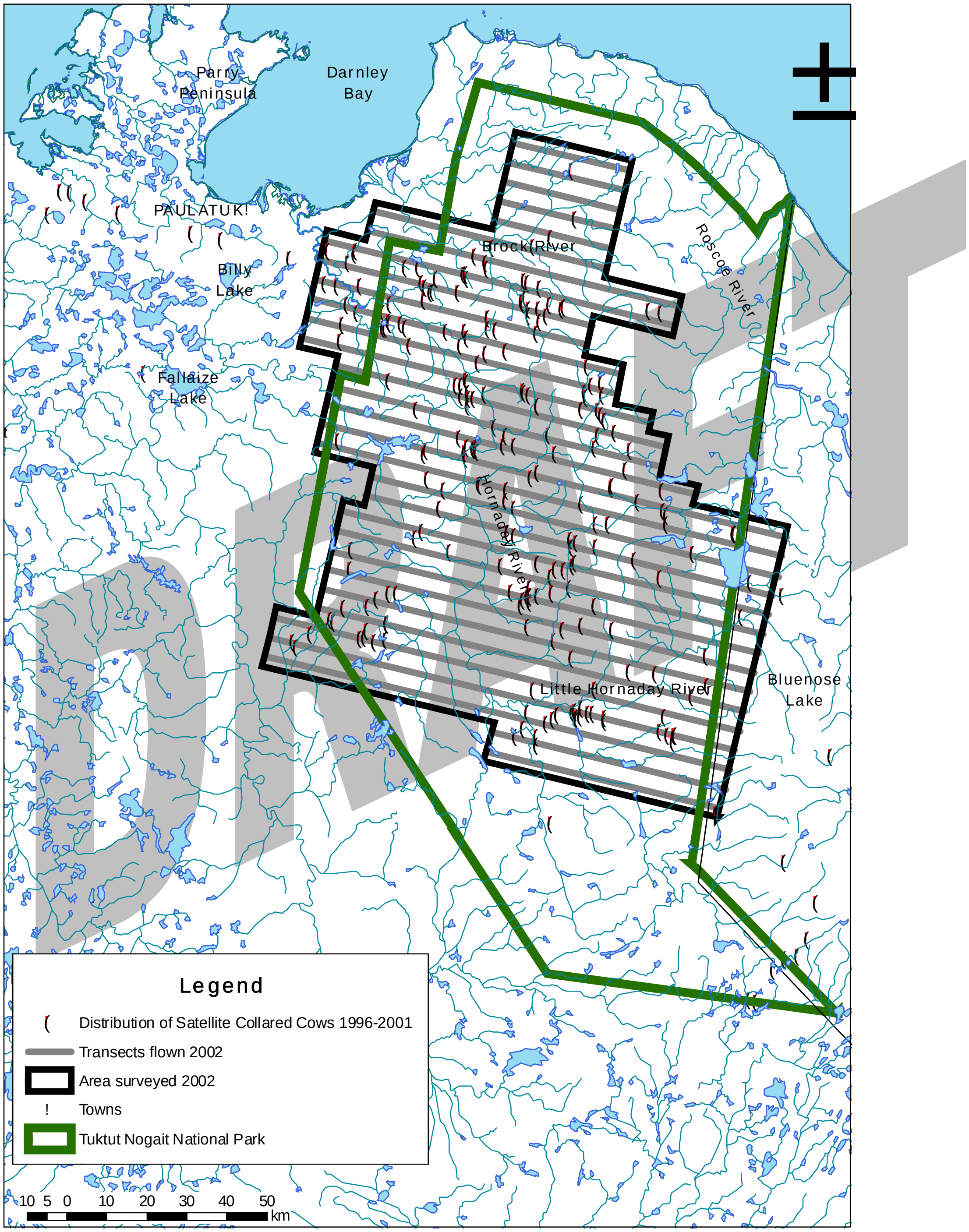


Figure 2. Boundaries of area surveyed and transects flown on the calving grounds of the Bluenose-West herd, 2003.

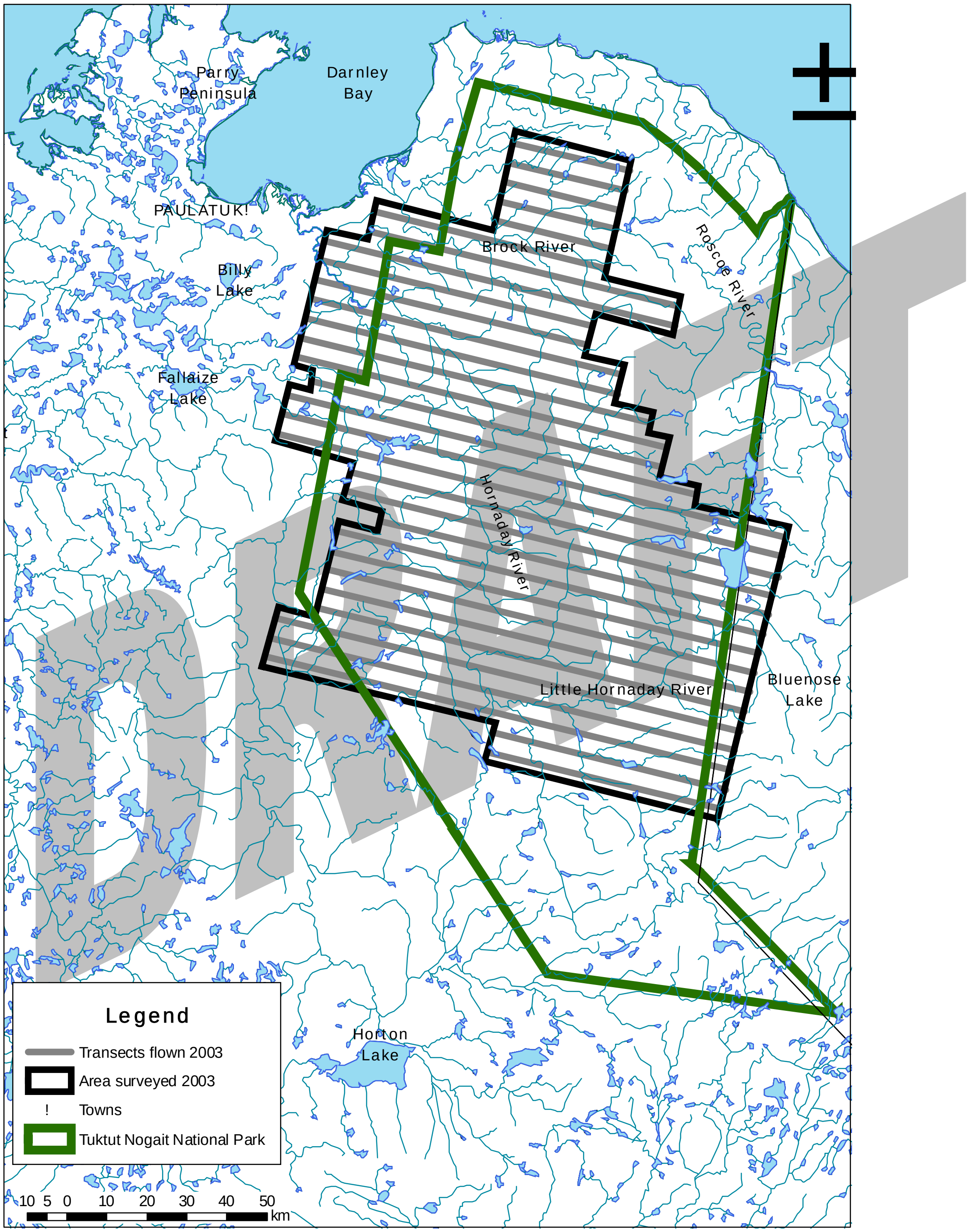


Figure 3. Boundaries of area surveyed and transects flown on the calving grounds of the Bluenose-West herd, 2004.

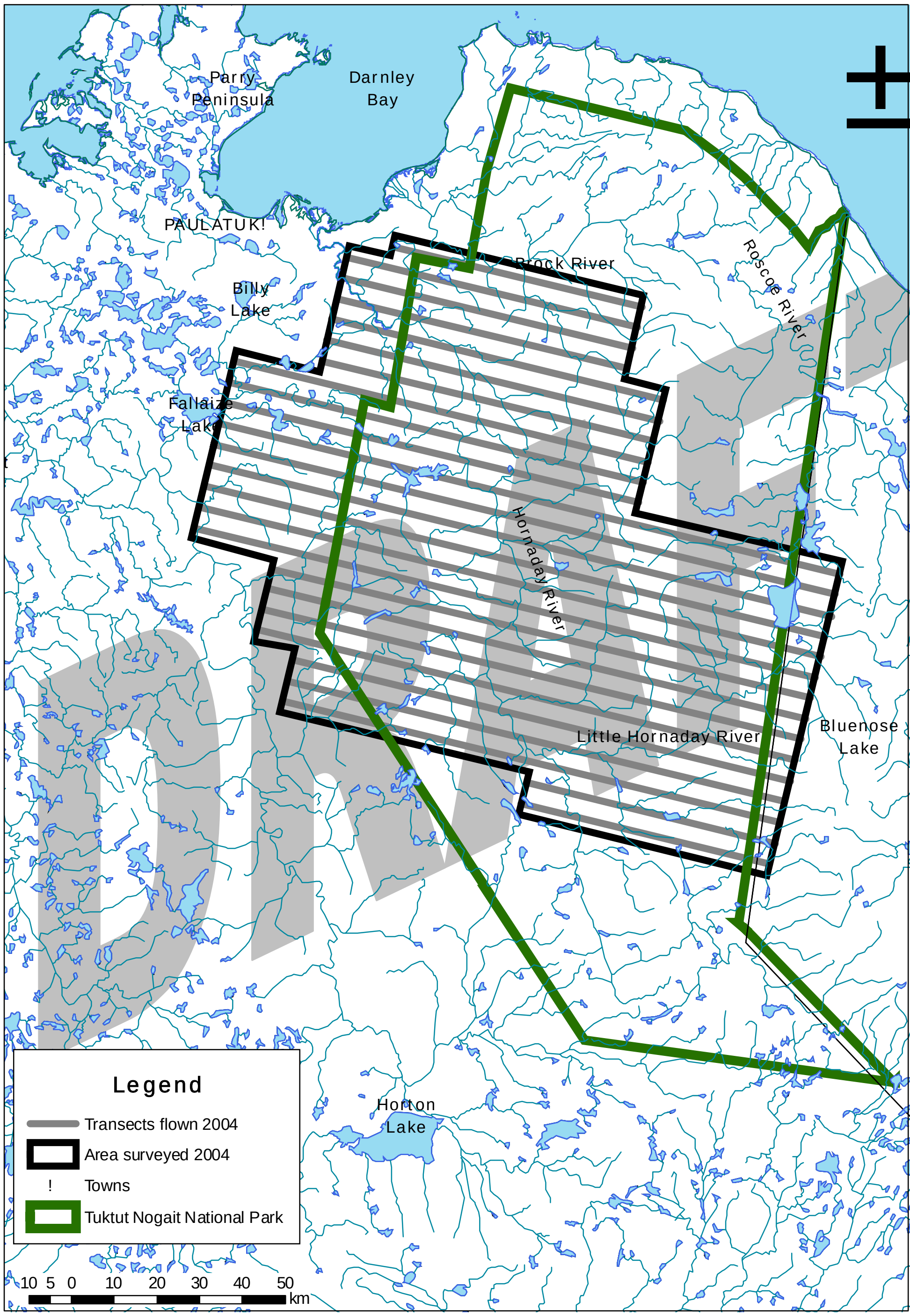
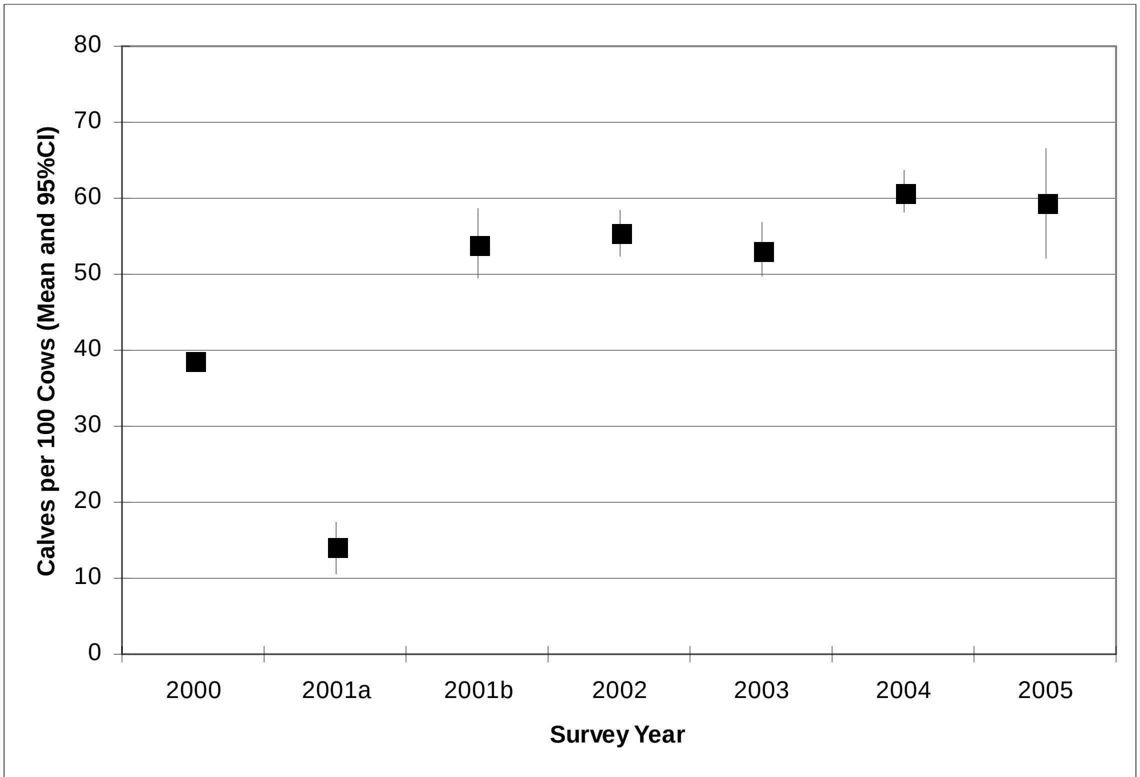


Figure 4. Comparison of the number of calves observed per 100 cows during surveys done on the calving grounds of the Bluenose-West herd during 2000 to 2005[a].



[a]Surveys completed on the following dates:

- 2000	9 to 11 June
- 2001a	12 to 15 June
- 2001b	23 to 26 June
- 2002	19 to 22 June
- 2003	21 to 25 June
- 2004	18 to 23 June
- 2005	19 to 21 June

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

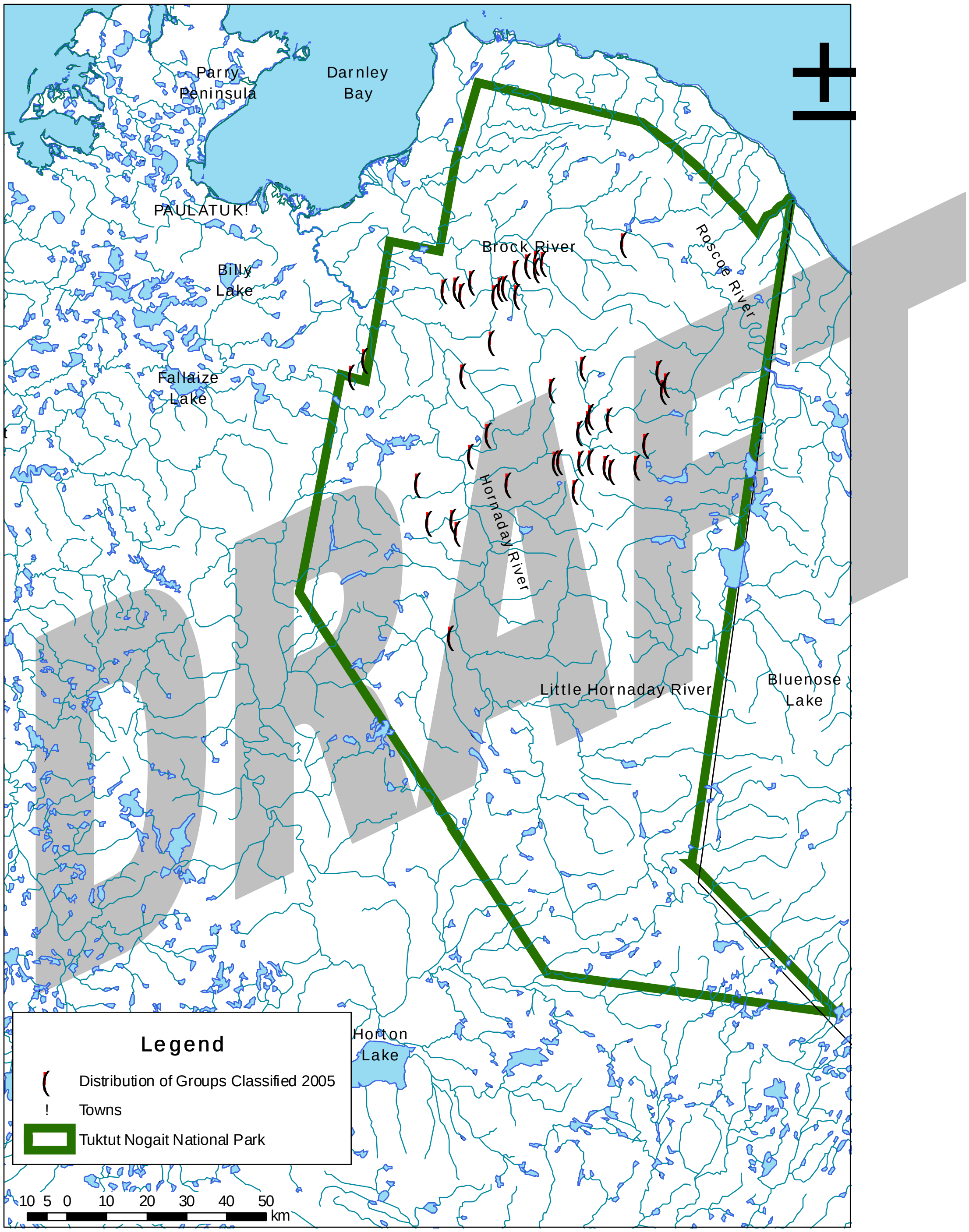


Figure 6. Centroids for transects flown on the calving grounds of the Bluenose-West barren-ground caribou herd, 2002.

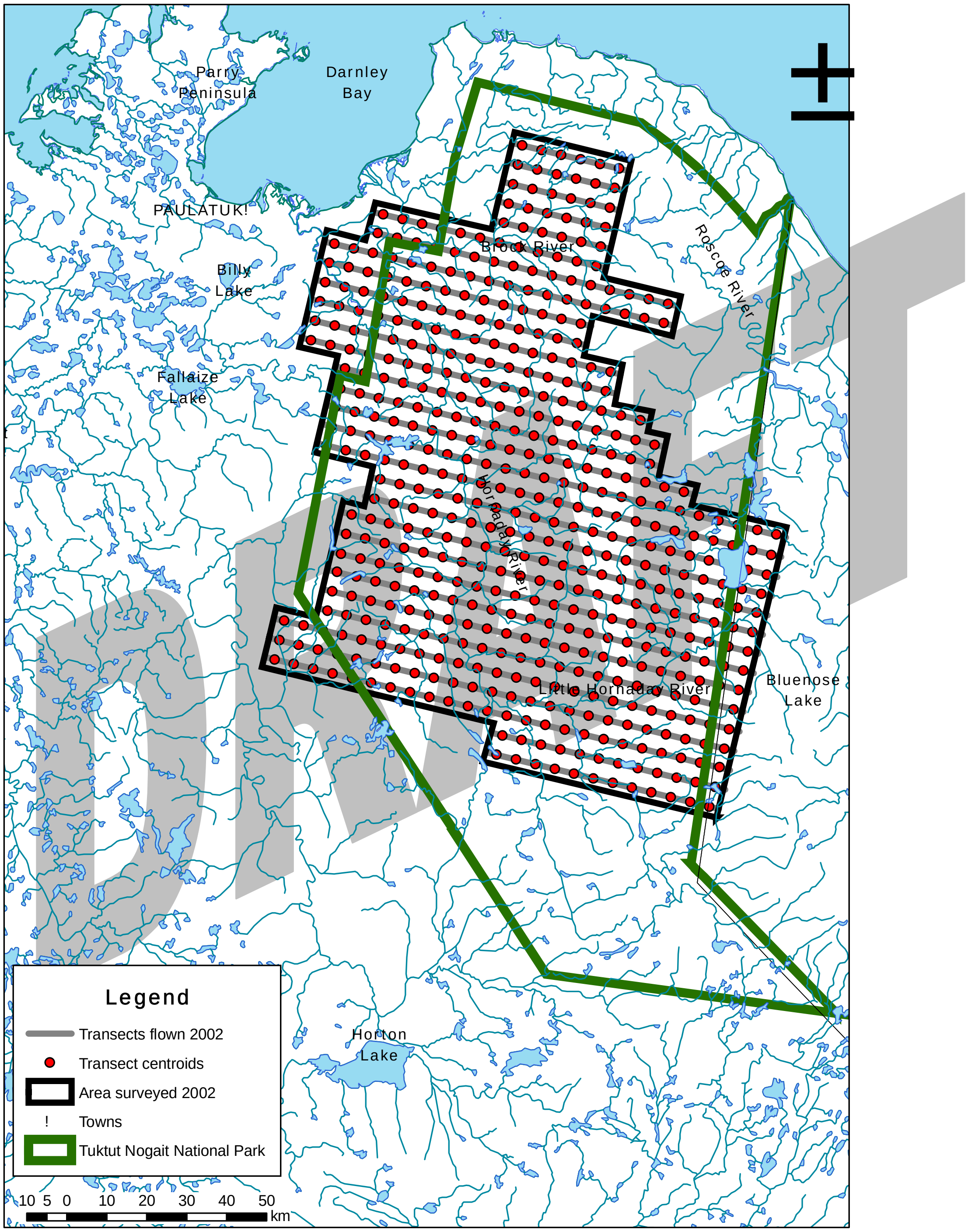


Figure7. Centroids for transects flown on the calving grounds of the Bluenose-West barren-ground caribou herd, 2003.

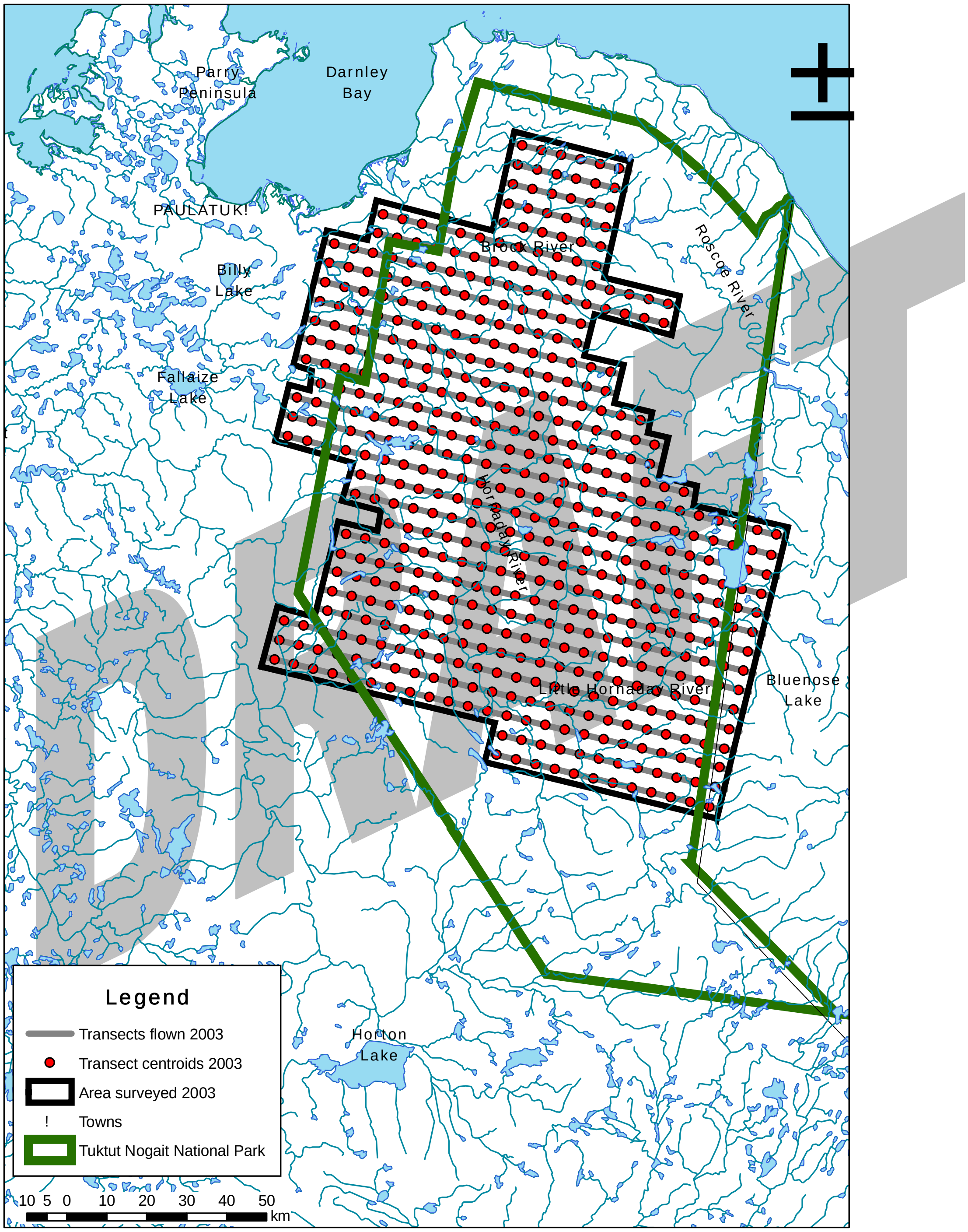


Figure 8. Centroids for transects flown on the calving grounds of the Bluenose-West barren-ground caribou herd, 2004

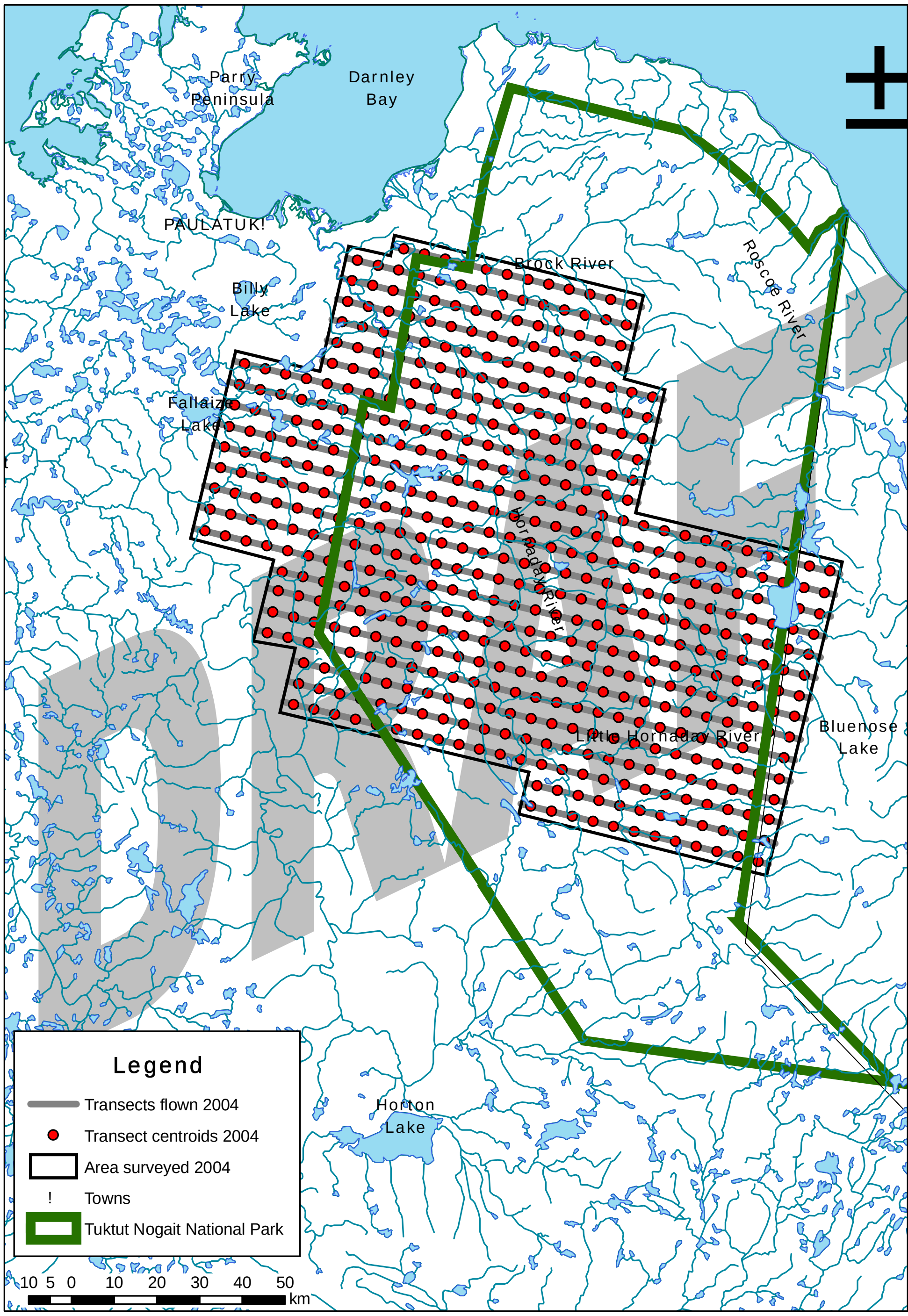


Figure 9. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2002.

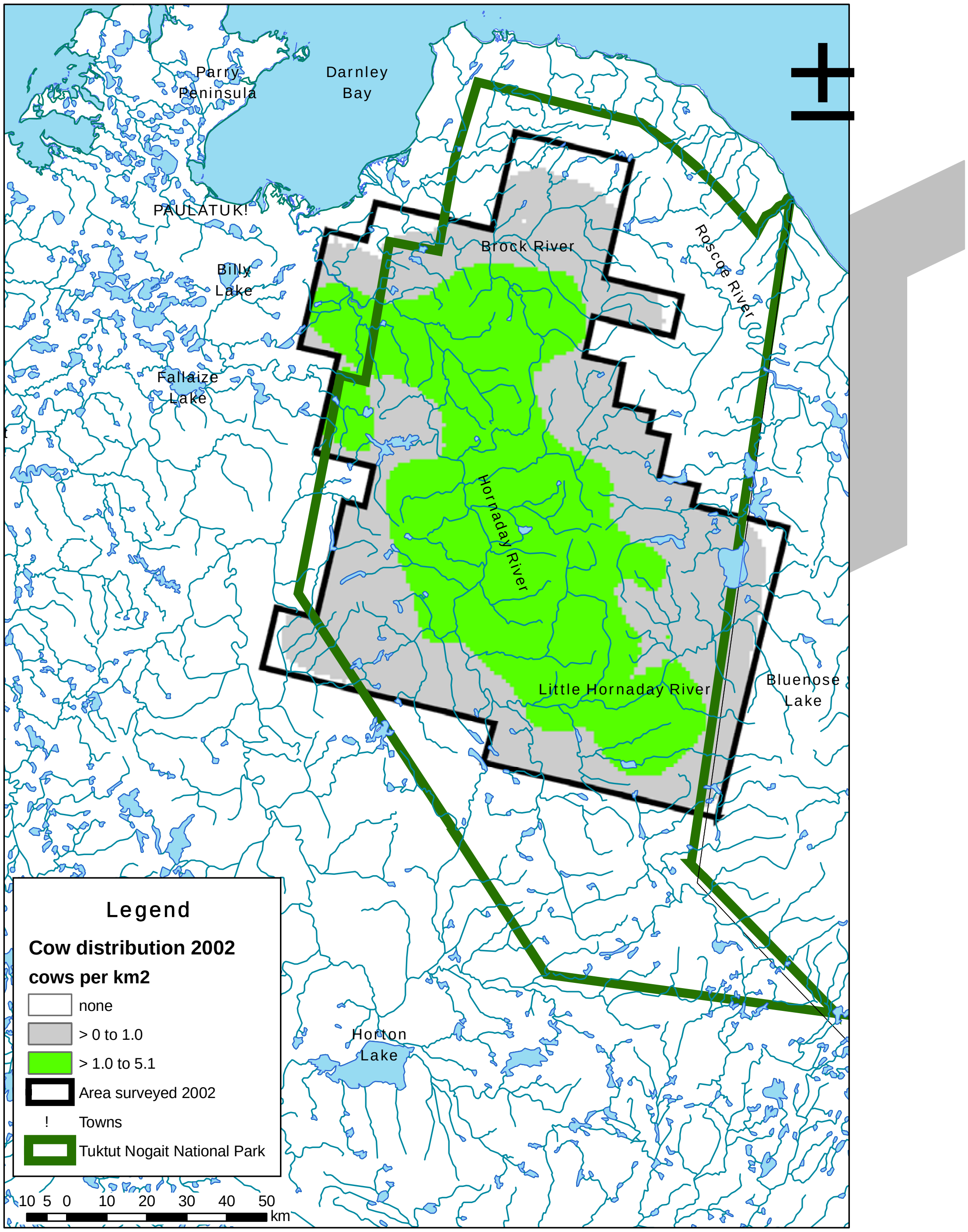


Figure 10. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2003.

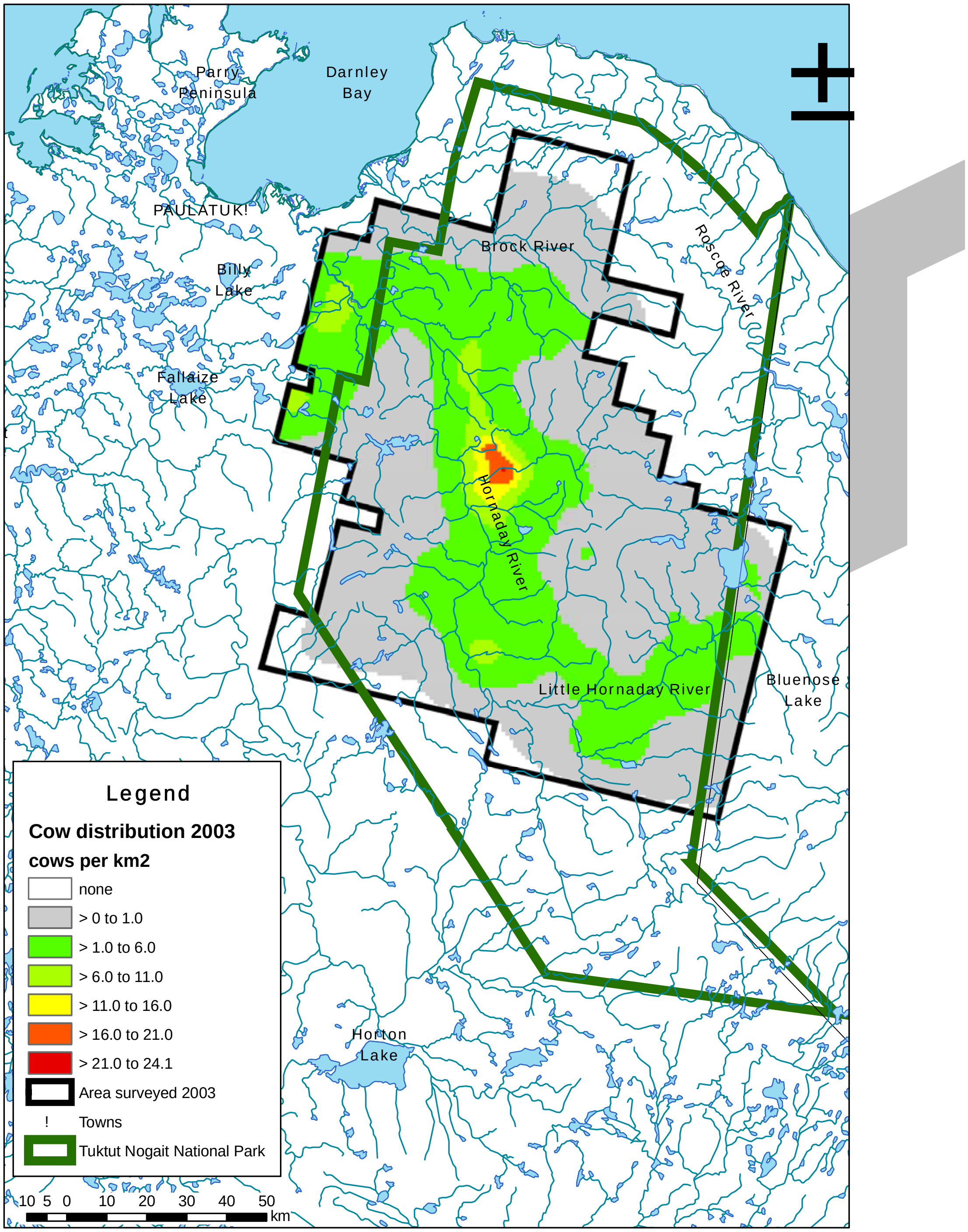


Figure 11. Ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2004.

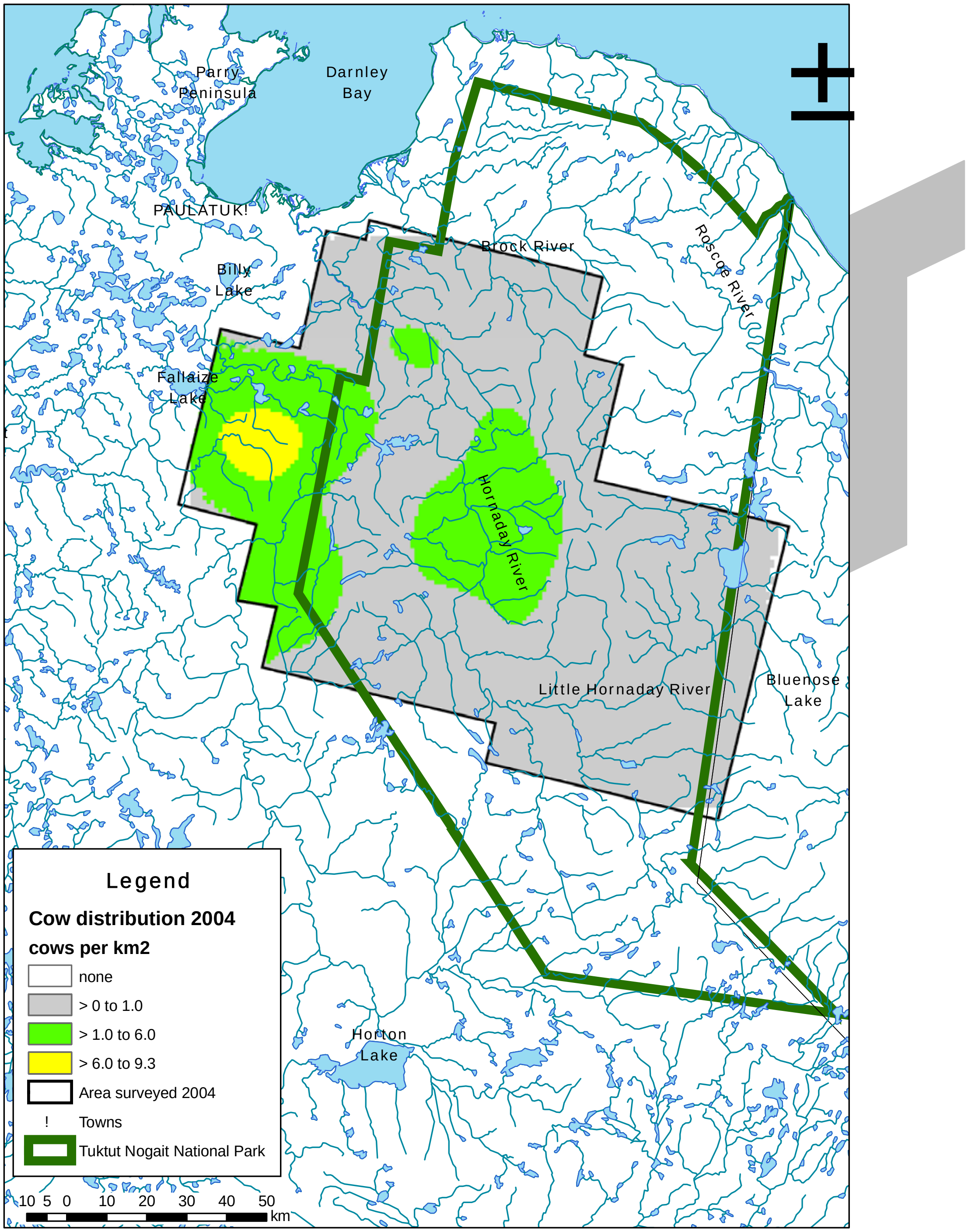


Figure 12. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2002.

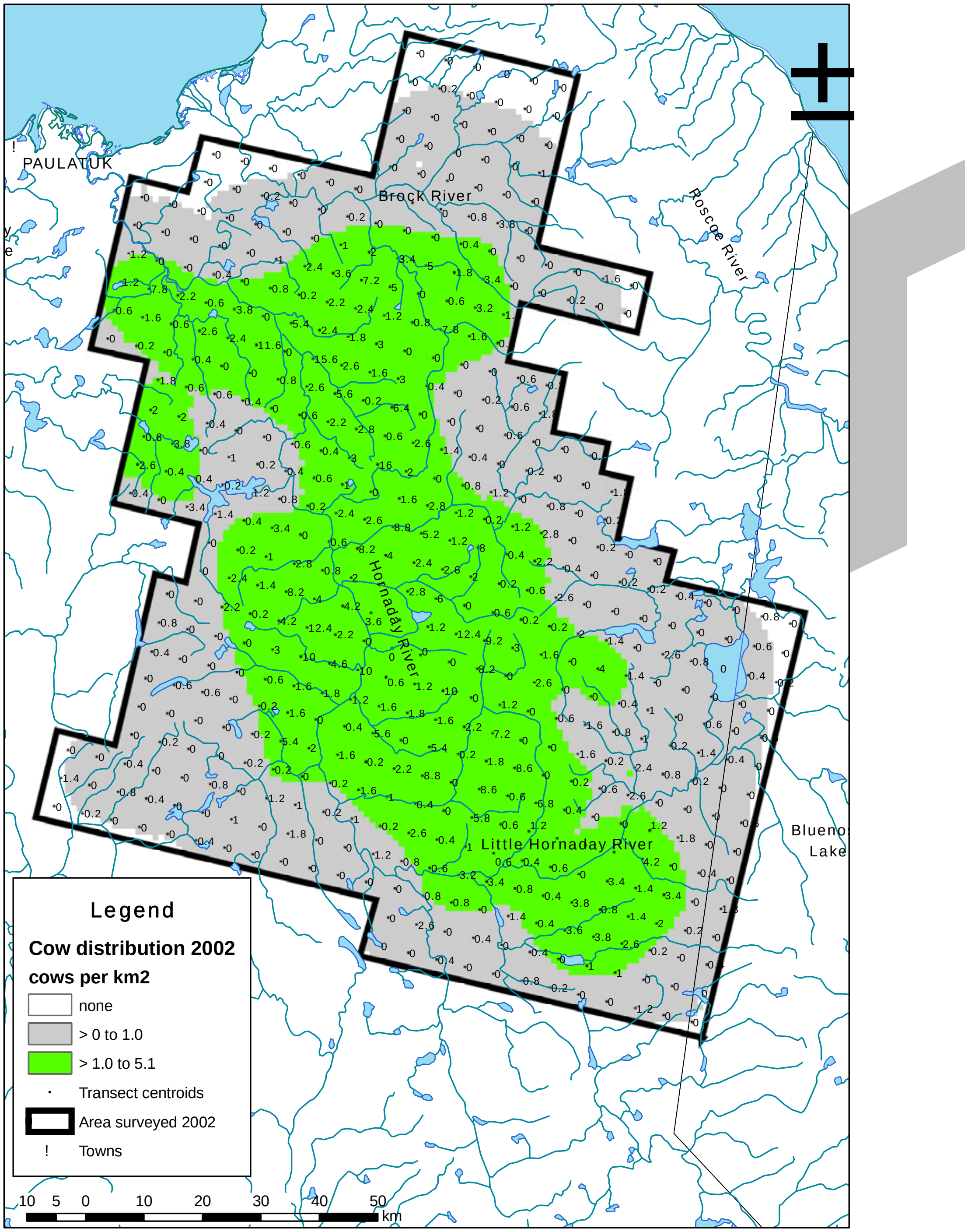


Figure 13. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2003.

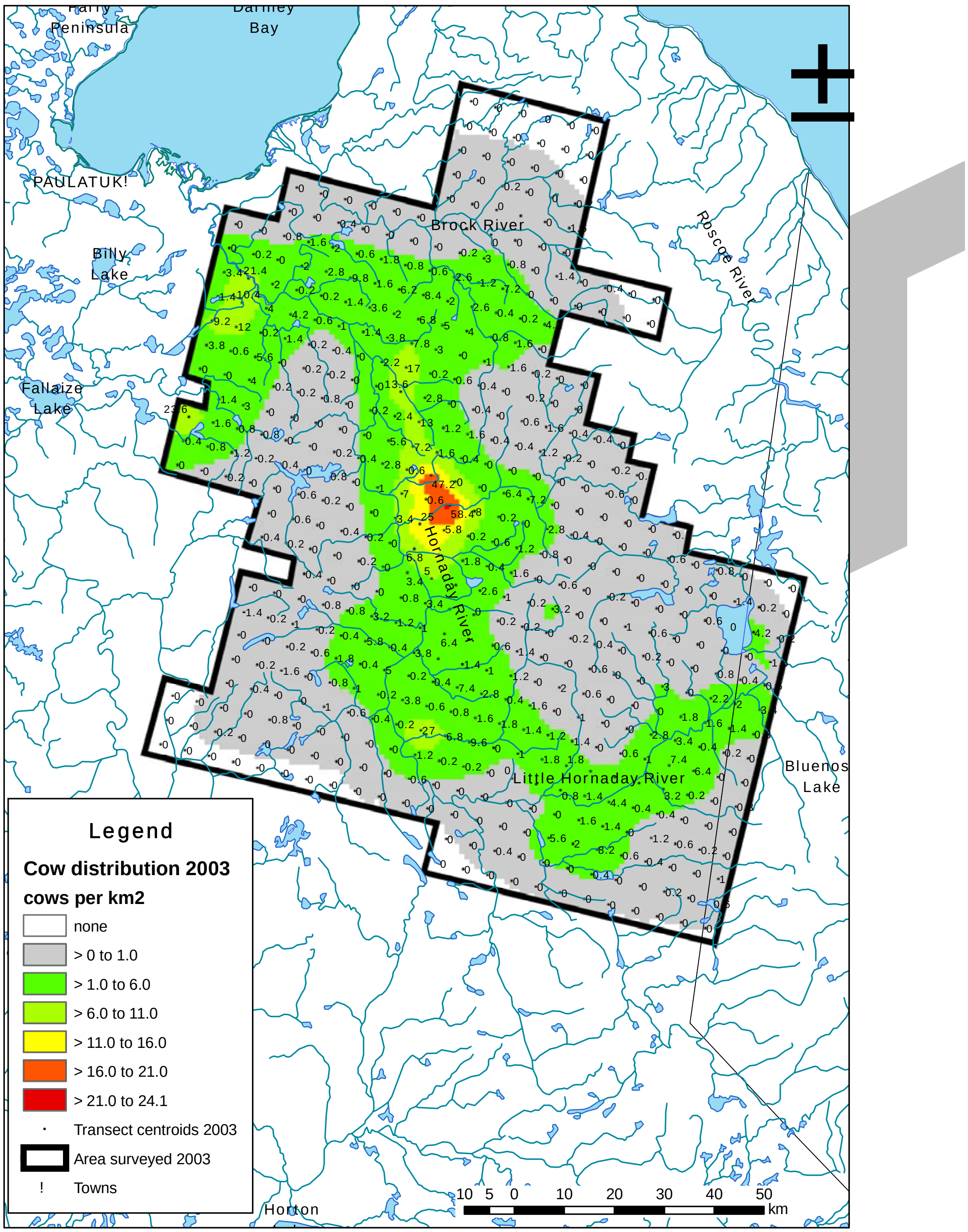


Figure 14. Cow density values at centroids used to generate an ordinary kriging prediction map of the distribution of cows observed on transect on the calving grounds of the Bluenose-West barren-ground caribou herd, 2004.

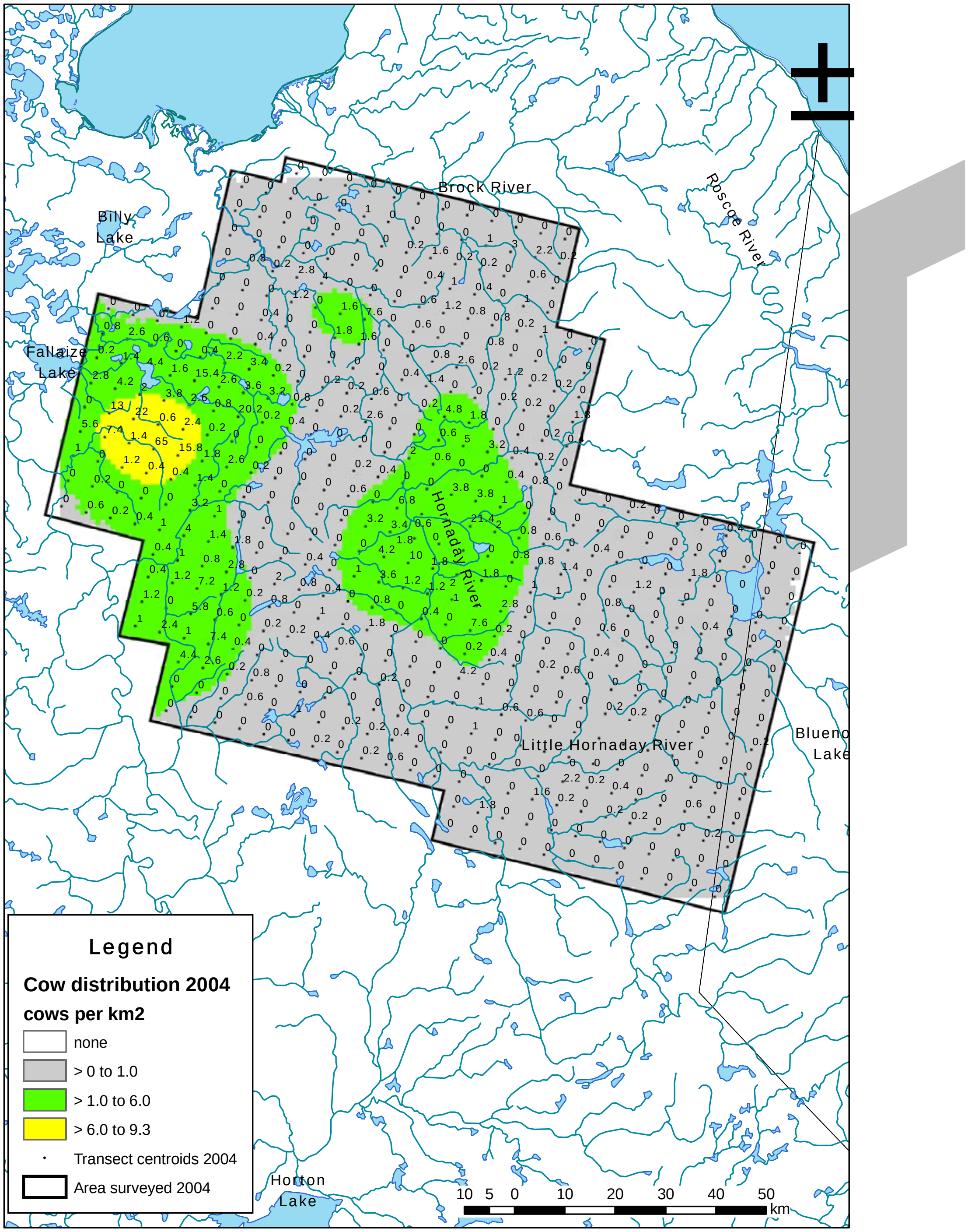


Figure 15. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2002 survey of the calving grounds of the Bluenose-West barren-ground caribou herd.

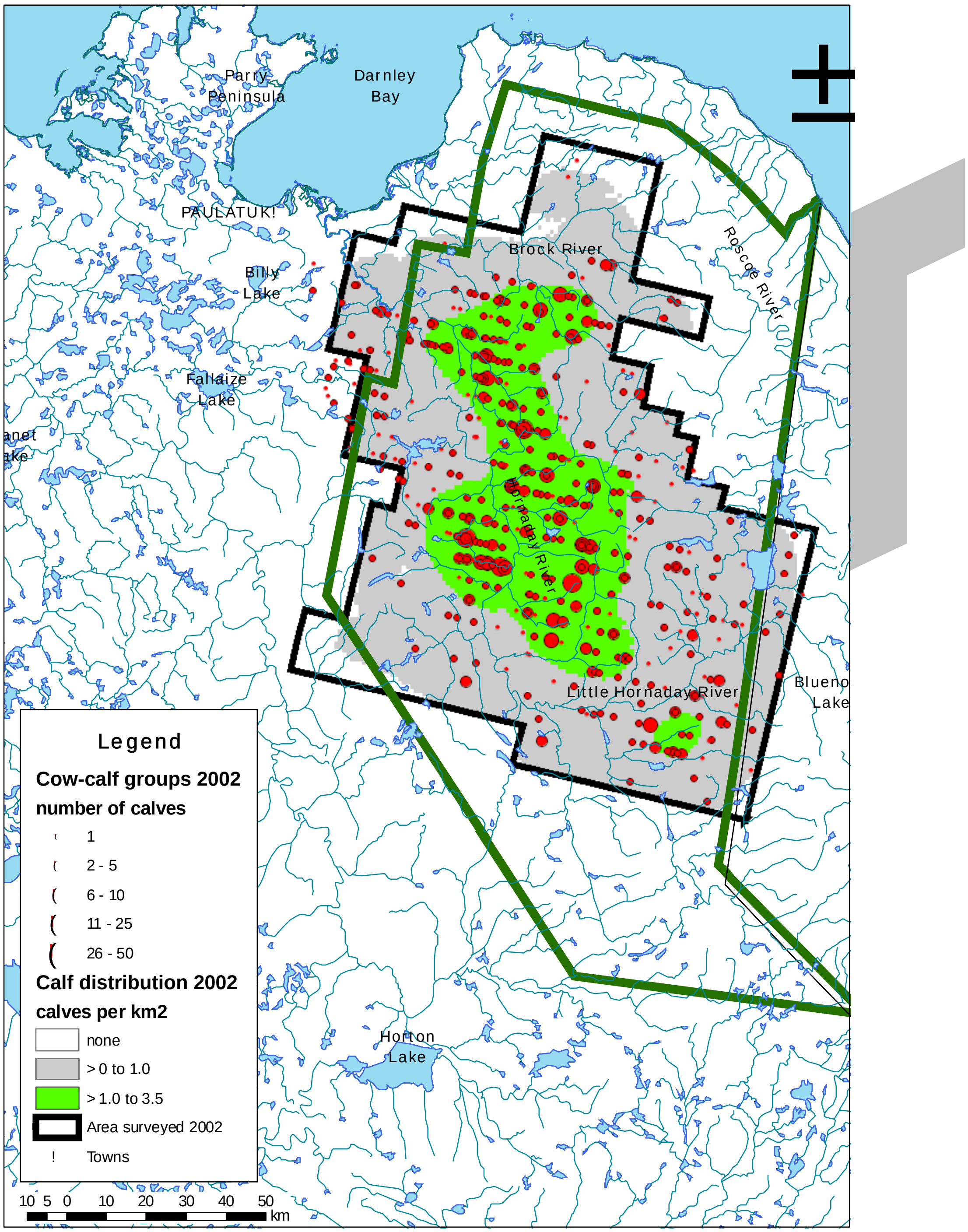


Figure 16. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2003 survey of the calving grounds of the Bluenose-West barren-ground caribou herd.

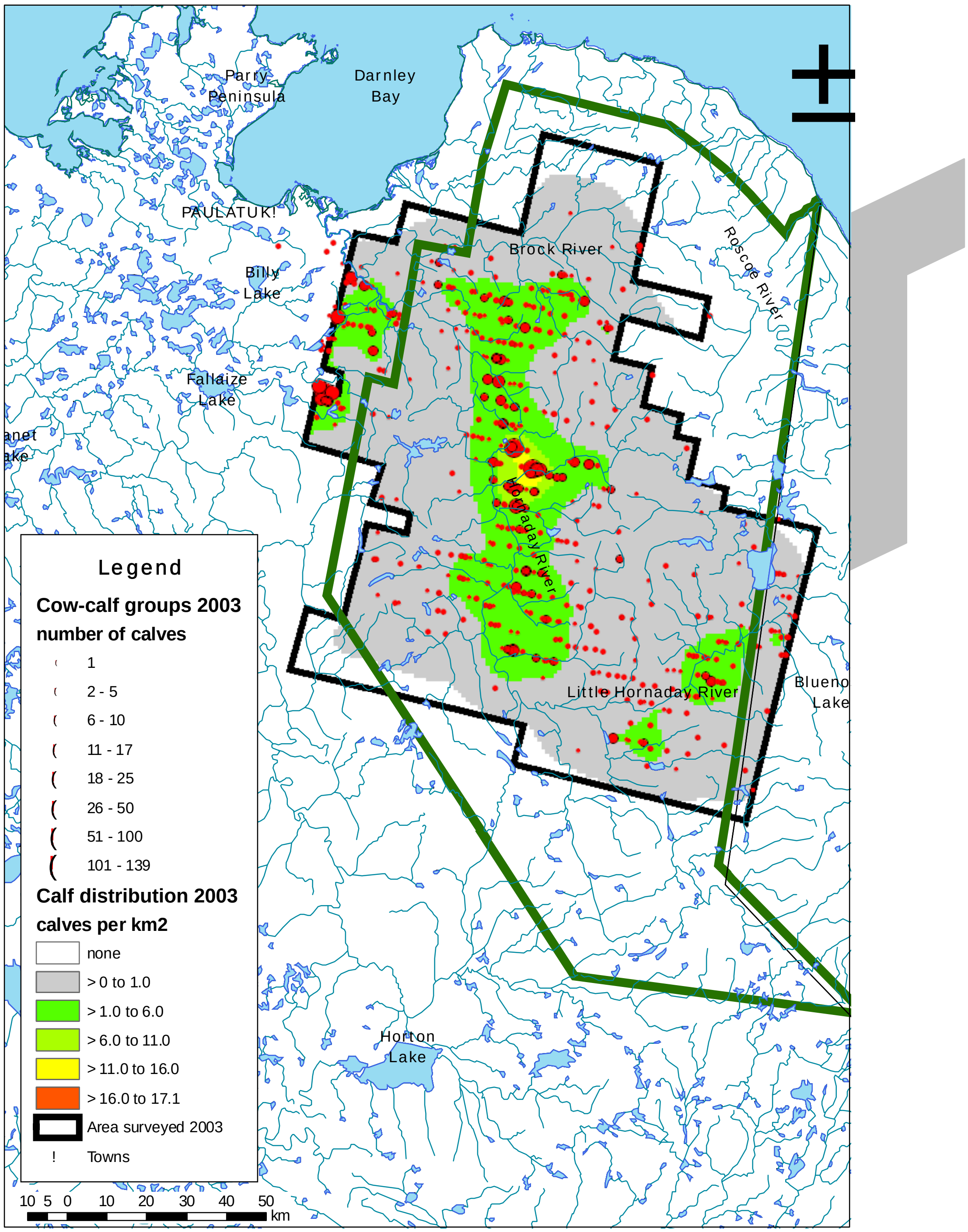


Figure 17. Ordinary kriging prediction map of the distribution of calves and the numbers of calves observed on and off transect during the 2004 survey of the calving grounds of the Bluenose-West barren-ground caribou herd.

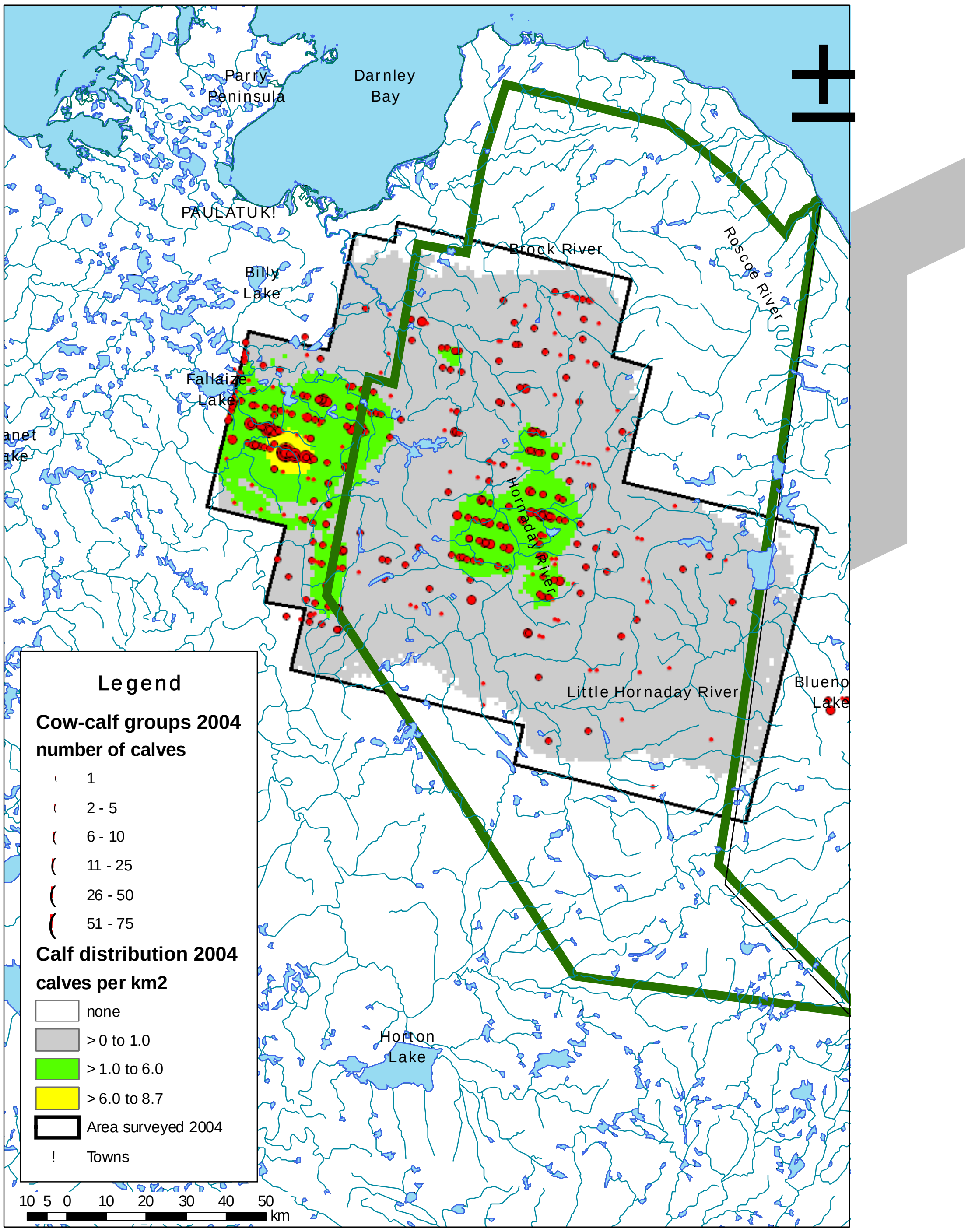


Figure 18. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2002 survey of the Bluenose-West barren-ground caribou herd calving grounds.

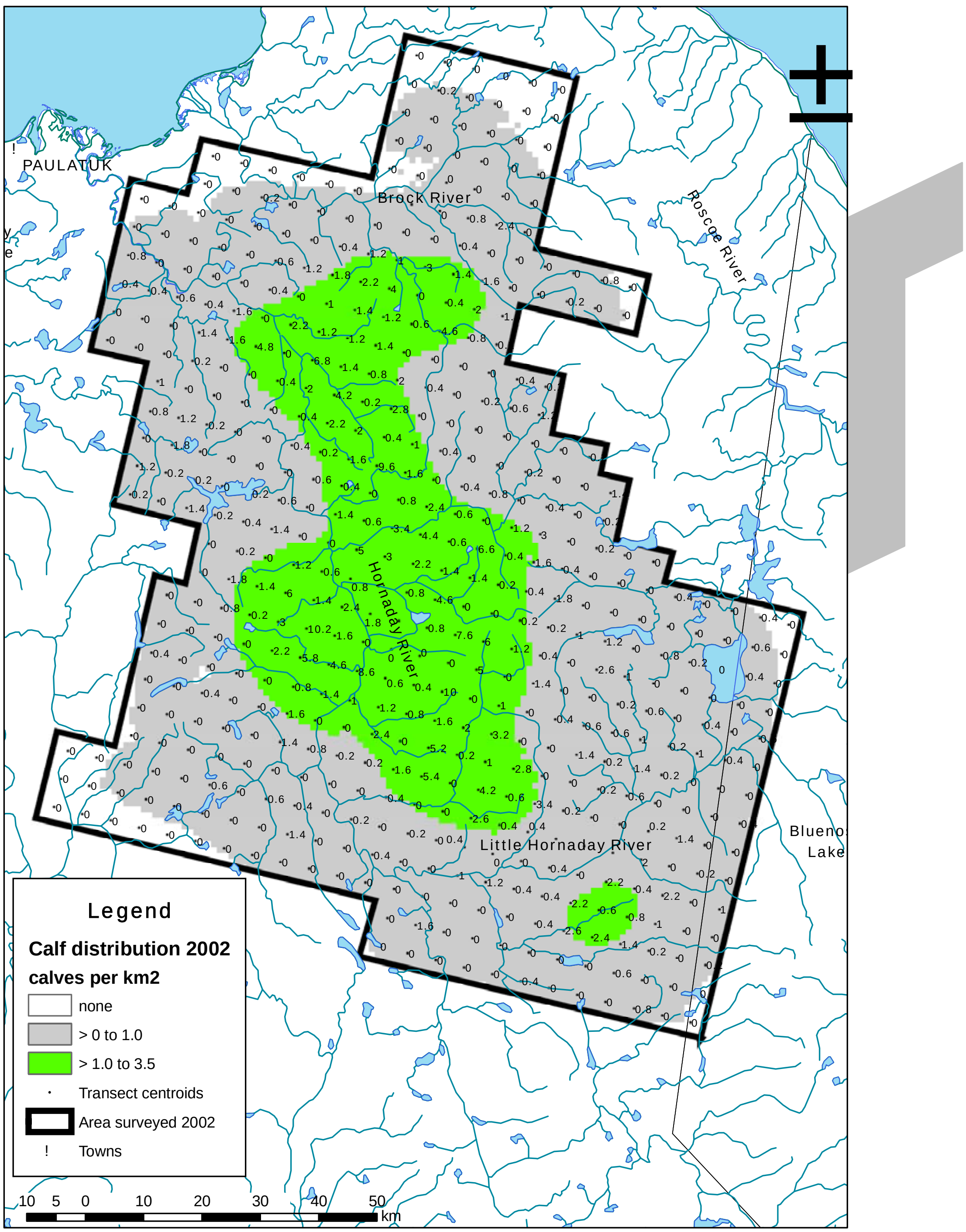


Figure 19. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2003 survey of the Bluenose-West barren-ground caribou herd calving grounds.

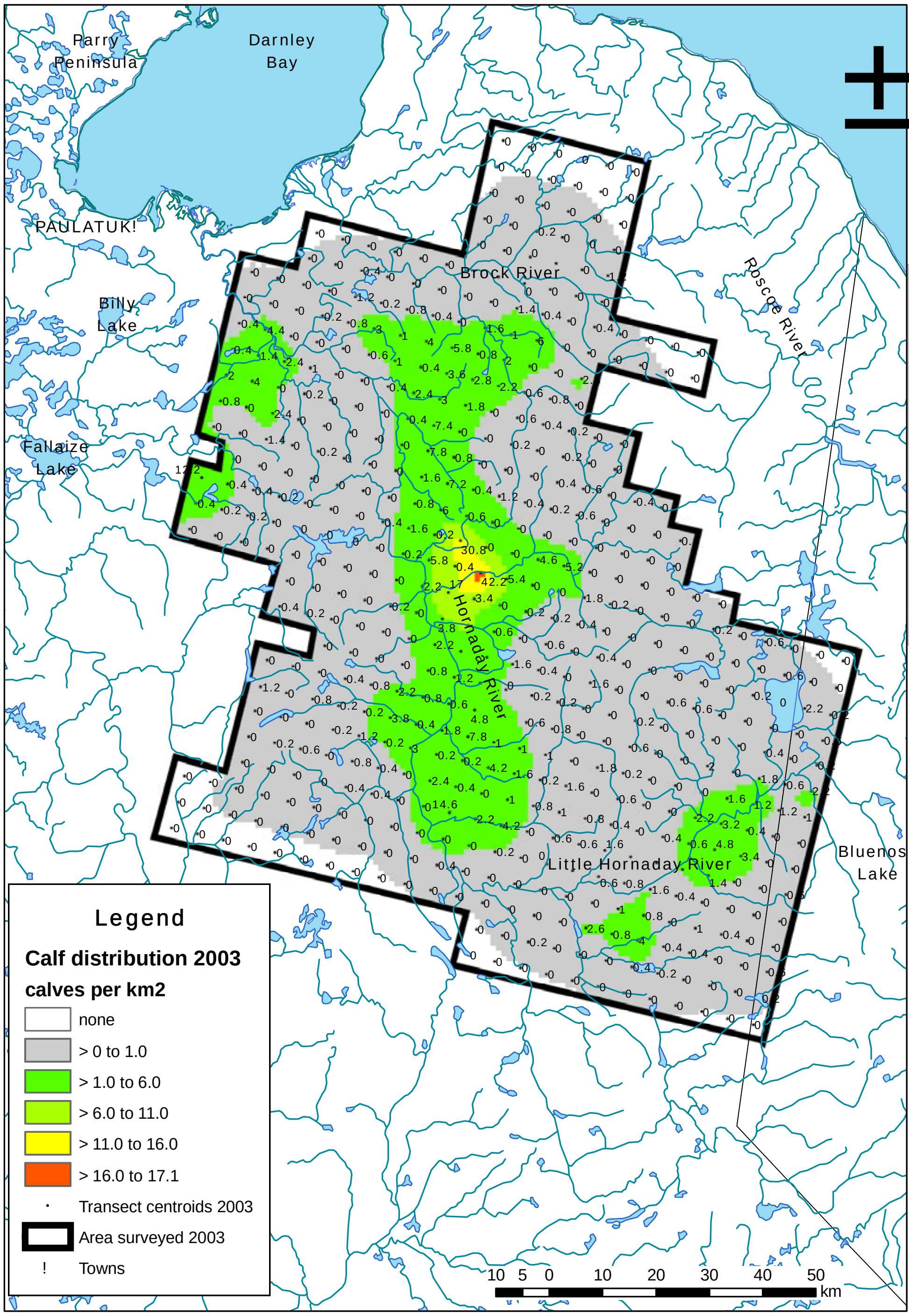


Figure 20. Calf density values at centroids used to generate an ordinary kriging prediction map of the distribution of calves observed on transect during the 2004 survey of the Bluenose-West barren-ground caribou herd calving grounds.

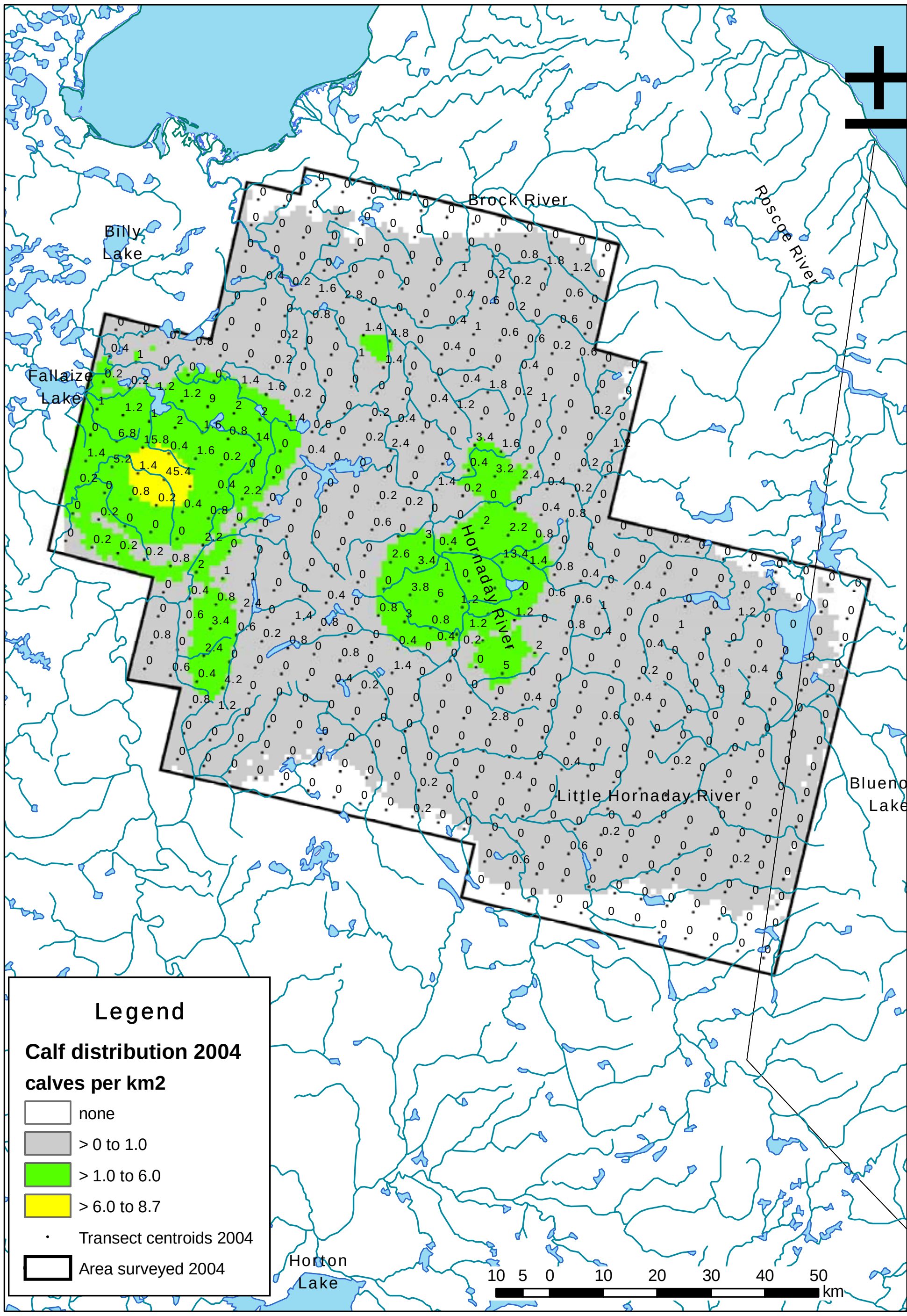


Figure 21. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2002.

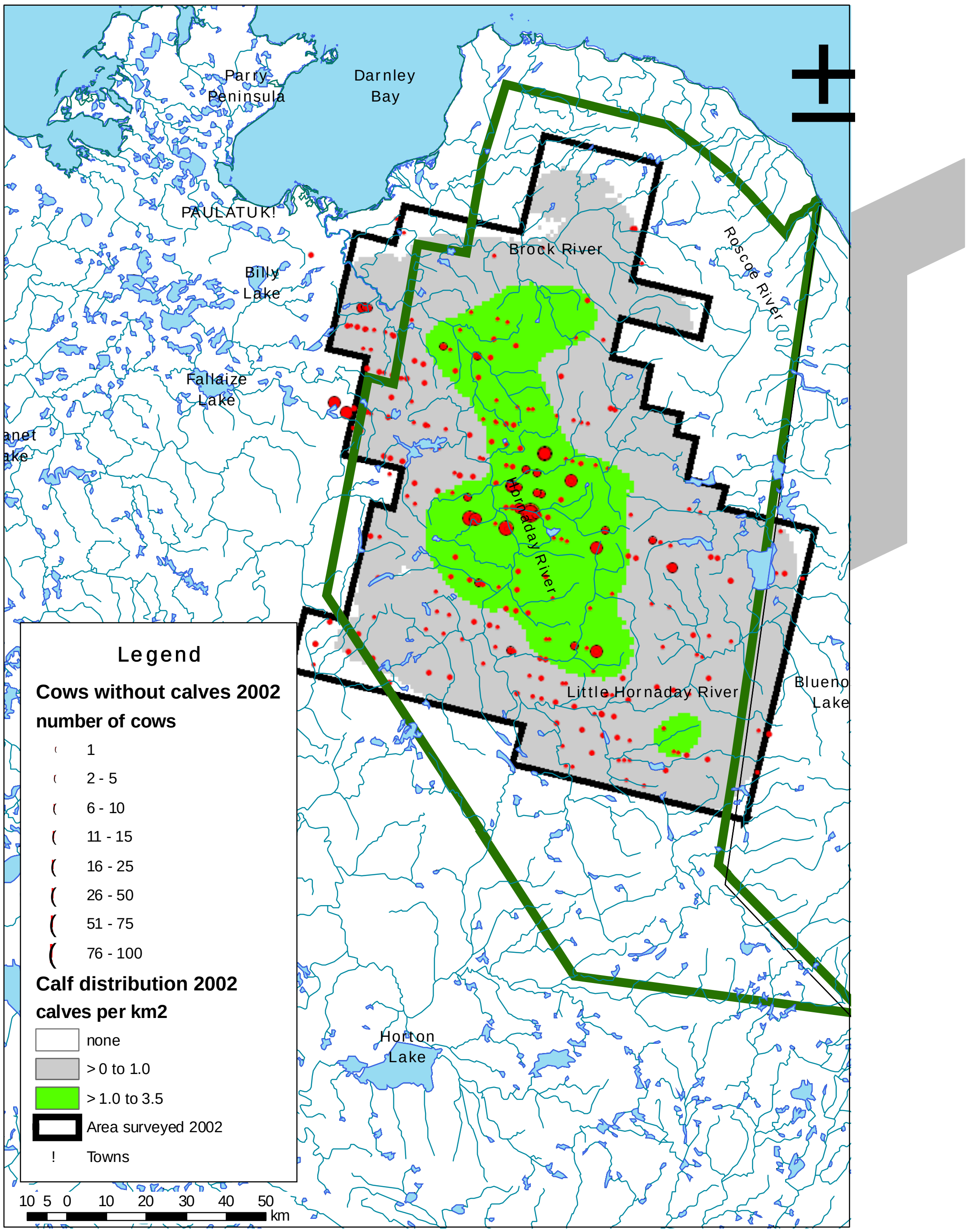


Figure 22. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2003.

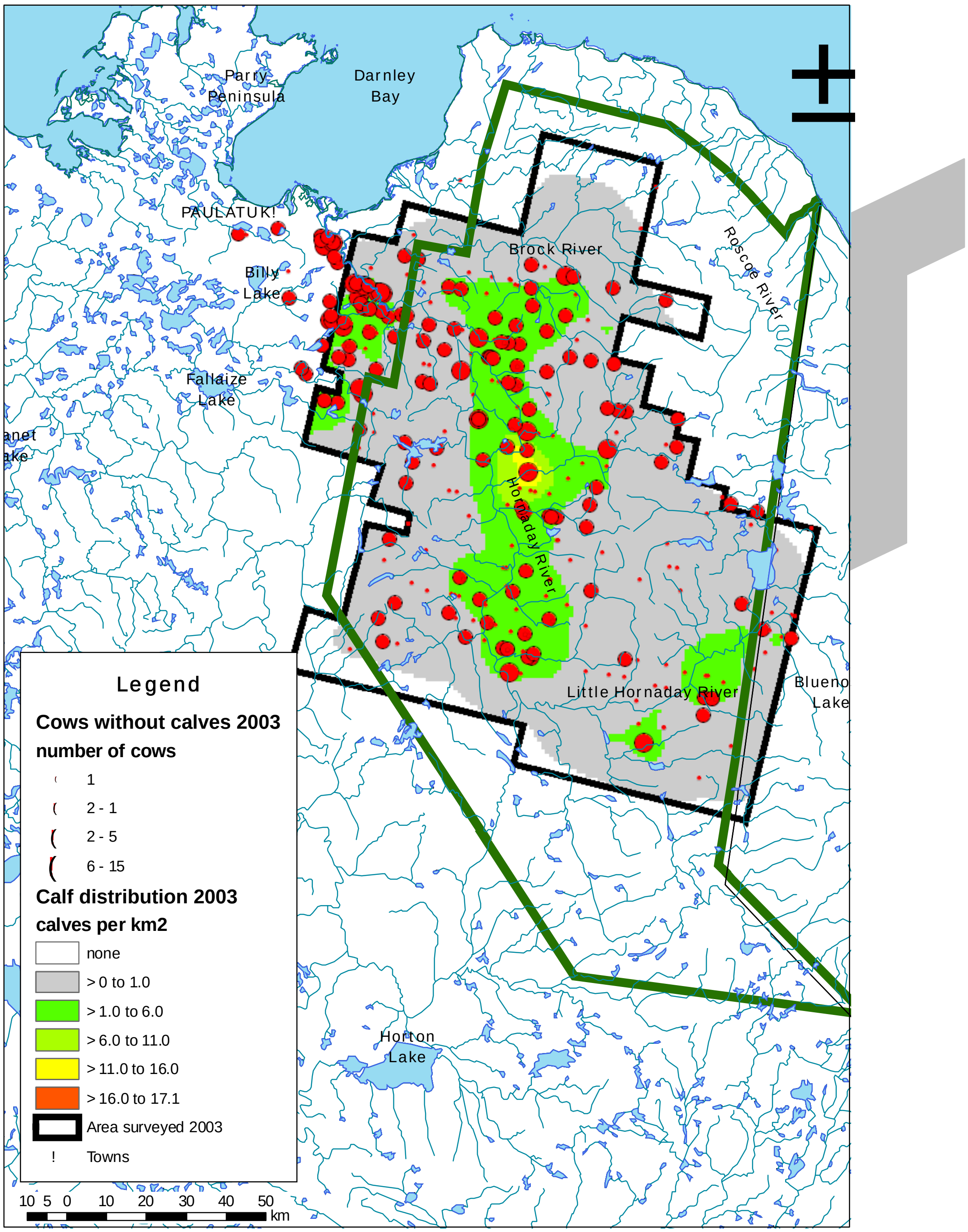


Figure 23. Distribution of cows without calves observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2004.

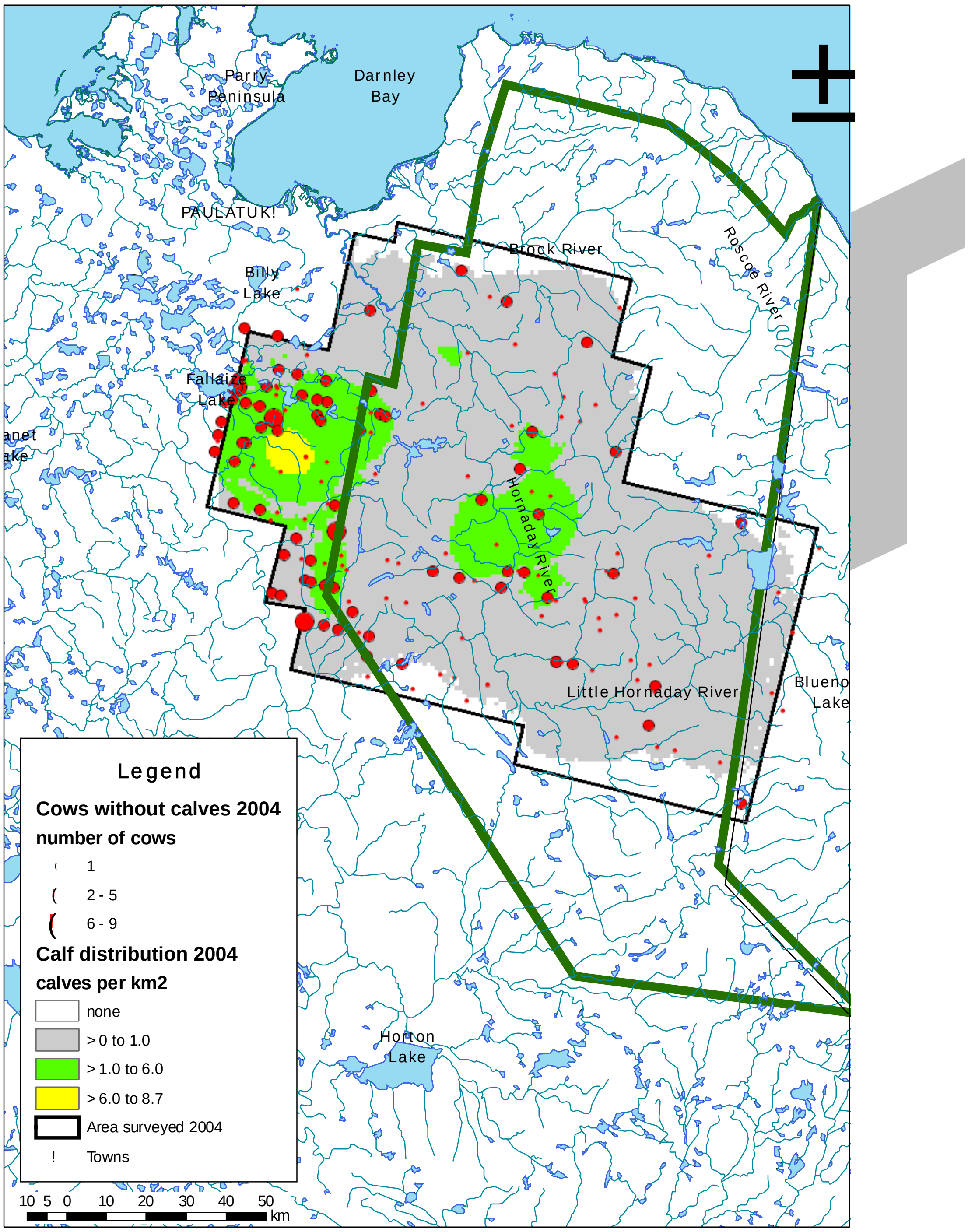


Figure 24. Distribution of satellite-collared cows relative to the distribution of calves on the Bluenose-West calving ground 2002.

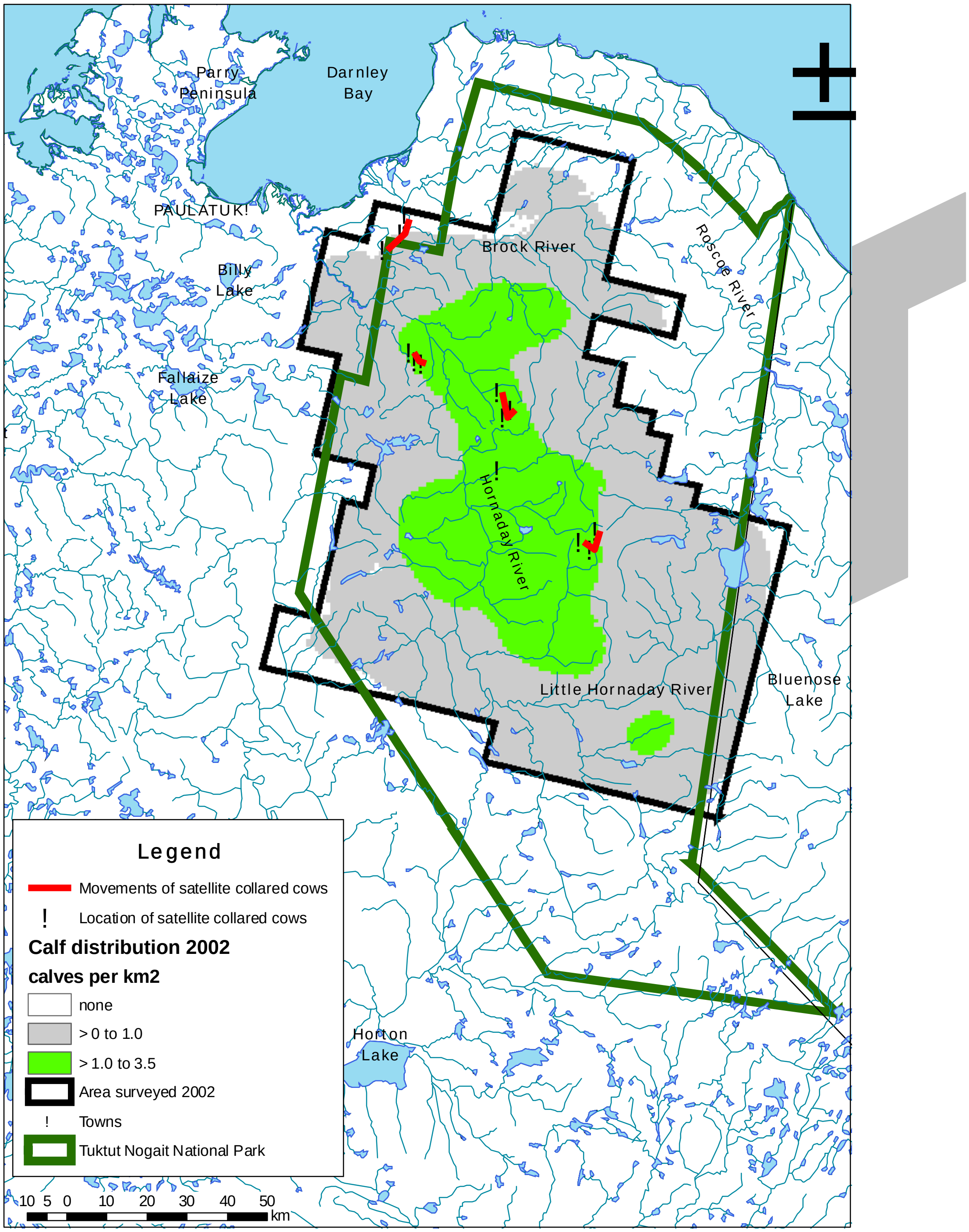


Figure 25. Distribution of satellite-collared cows relative to the distribution of calves on the Bluenose-West calving grounds, 2003.

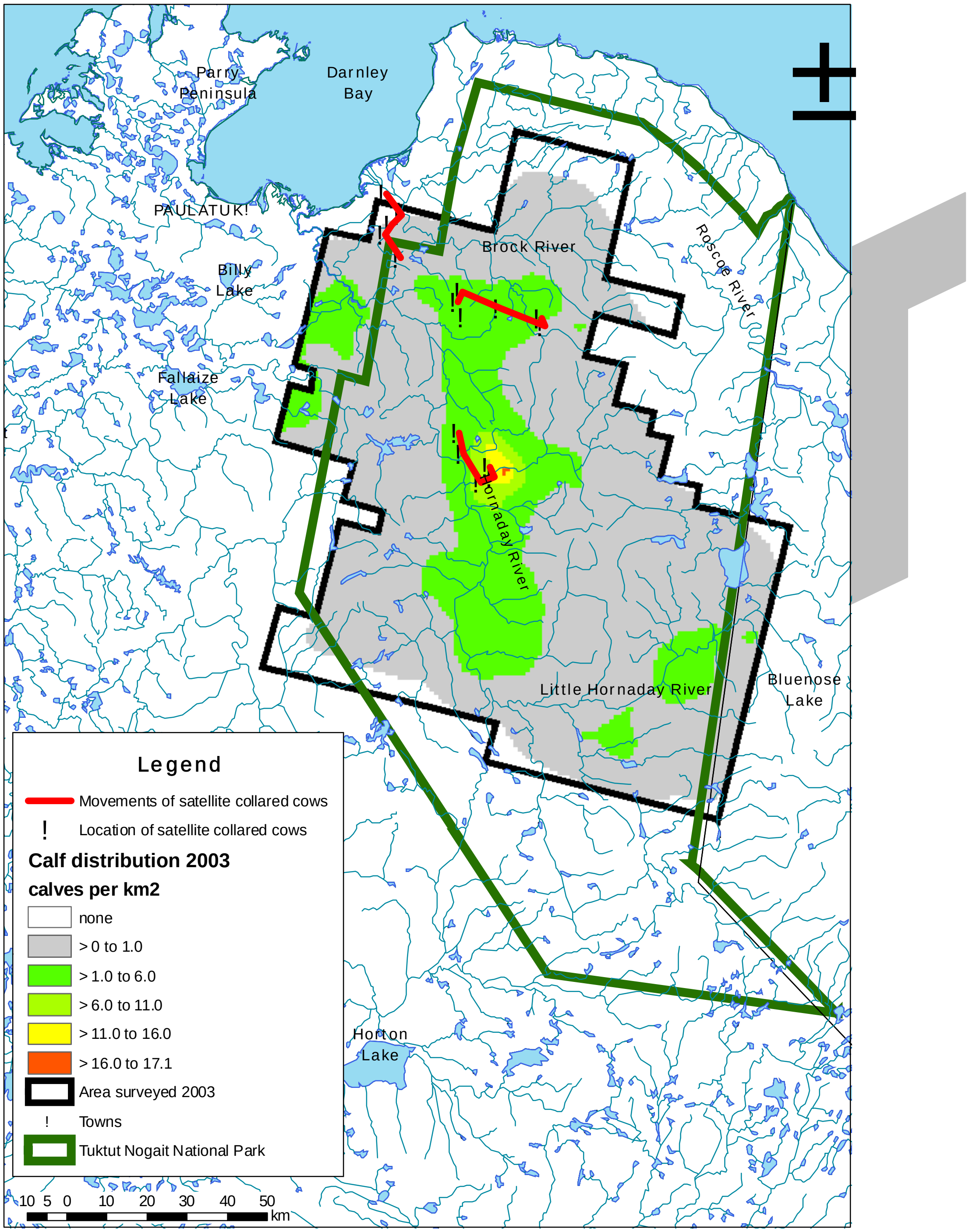


Figure 26. Distribution of satellite-collared cows relative to the distribution of calves on the Bluenose-West calving grounds, 2004.

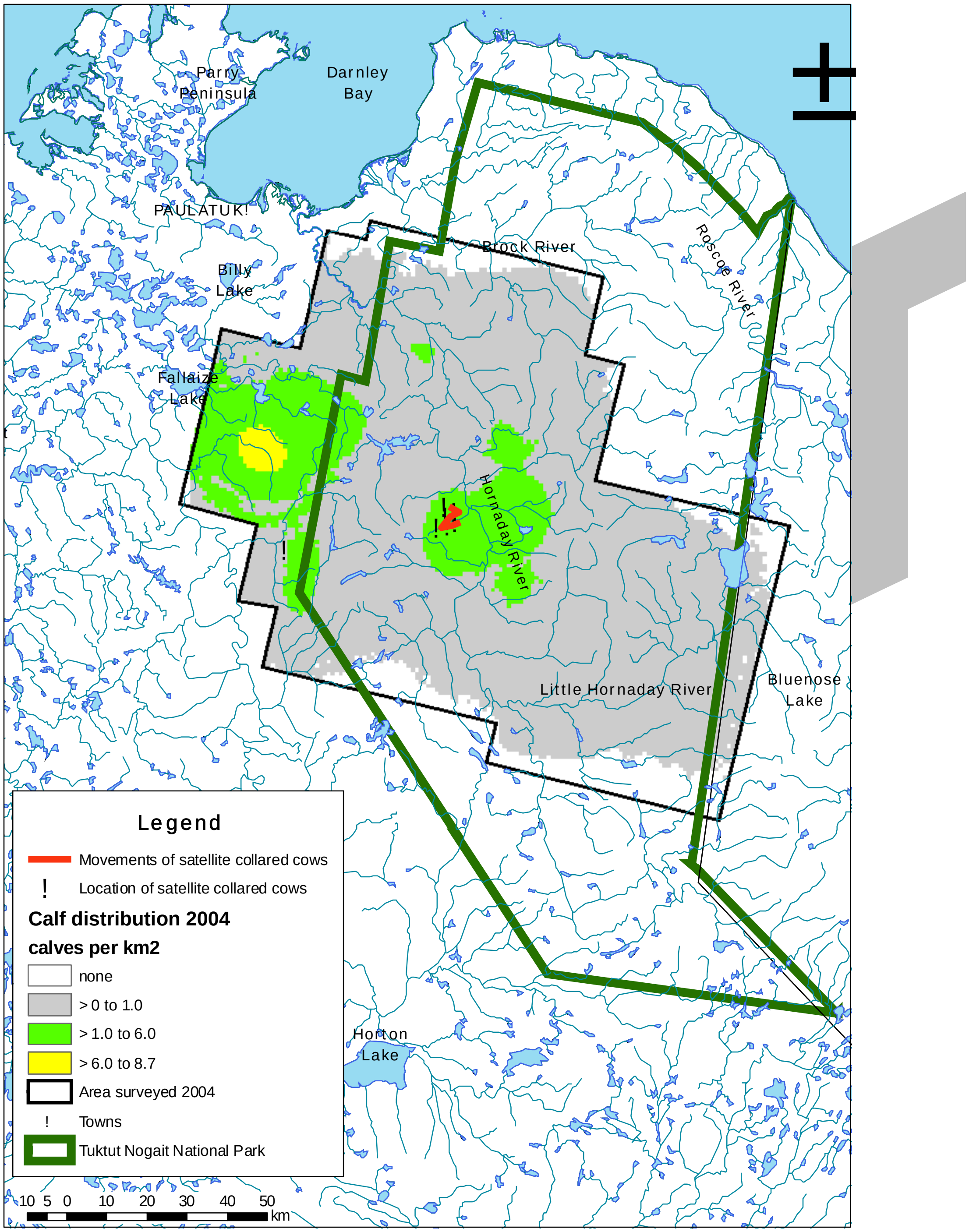


Figure 27. Distribution of yearlings observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2002.

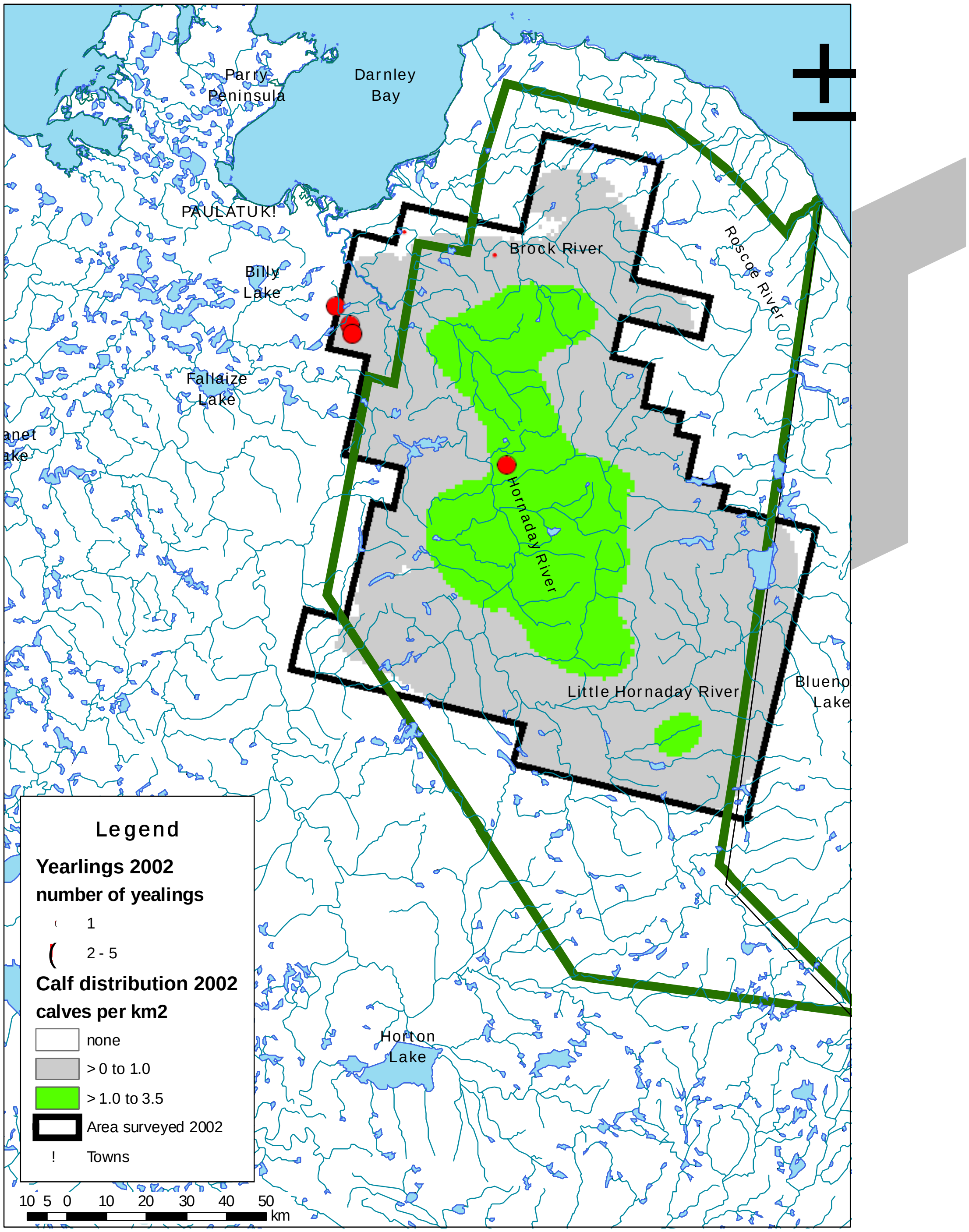


Figure 28. Distribution of yearlings observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2003.

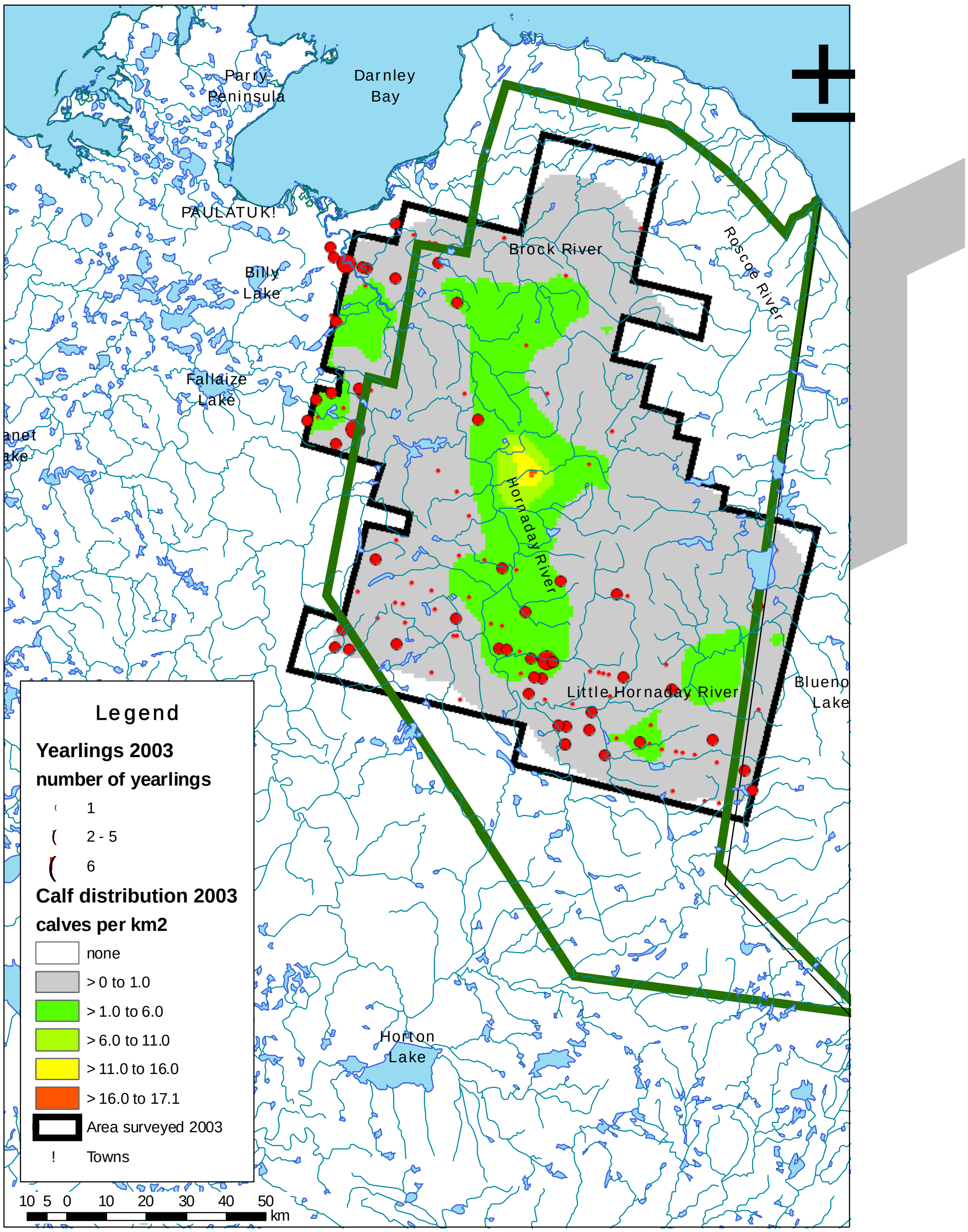


Figure 29. Distribution of yearlings observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2004.

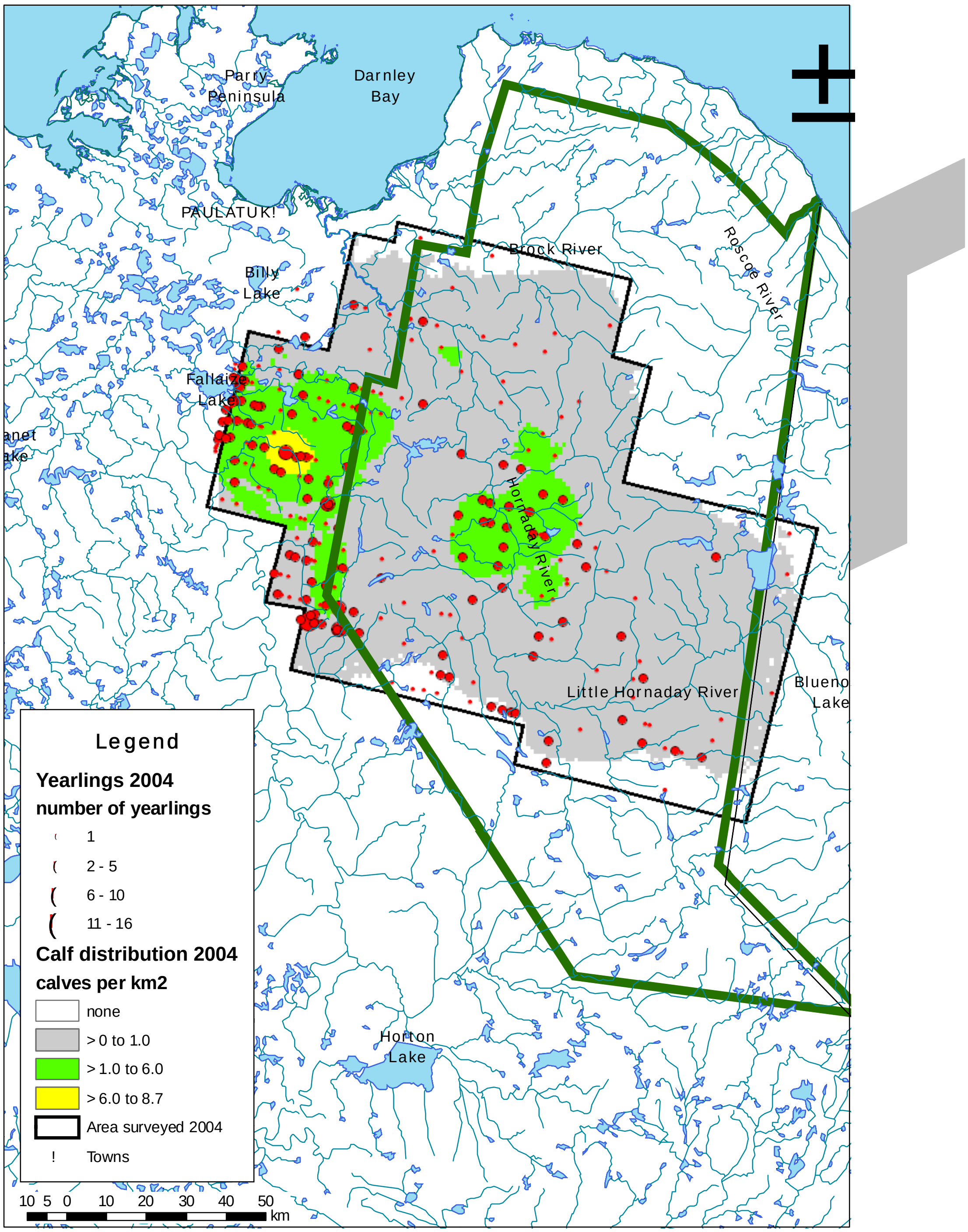


Figure 30. Distribution of bulls observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2002.

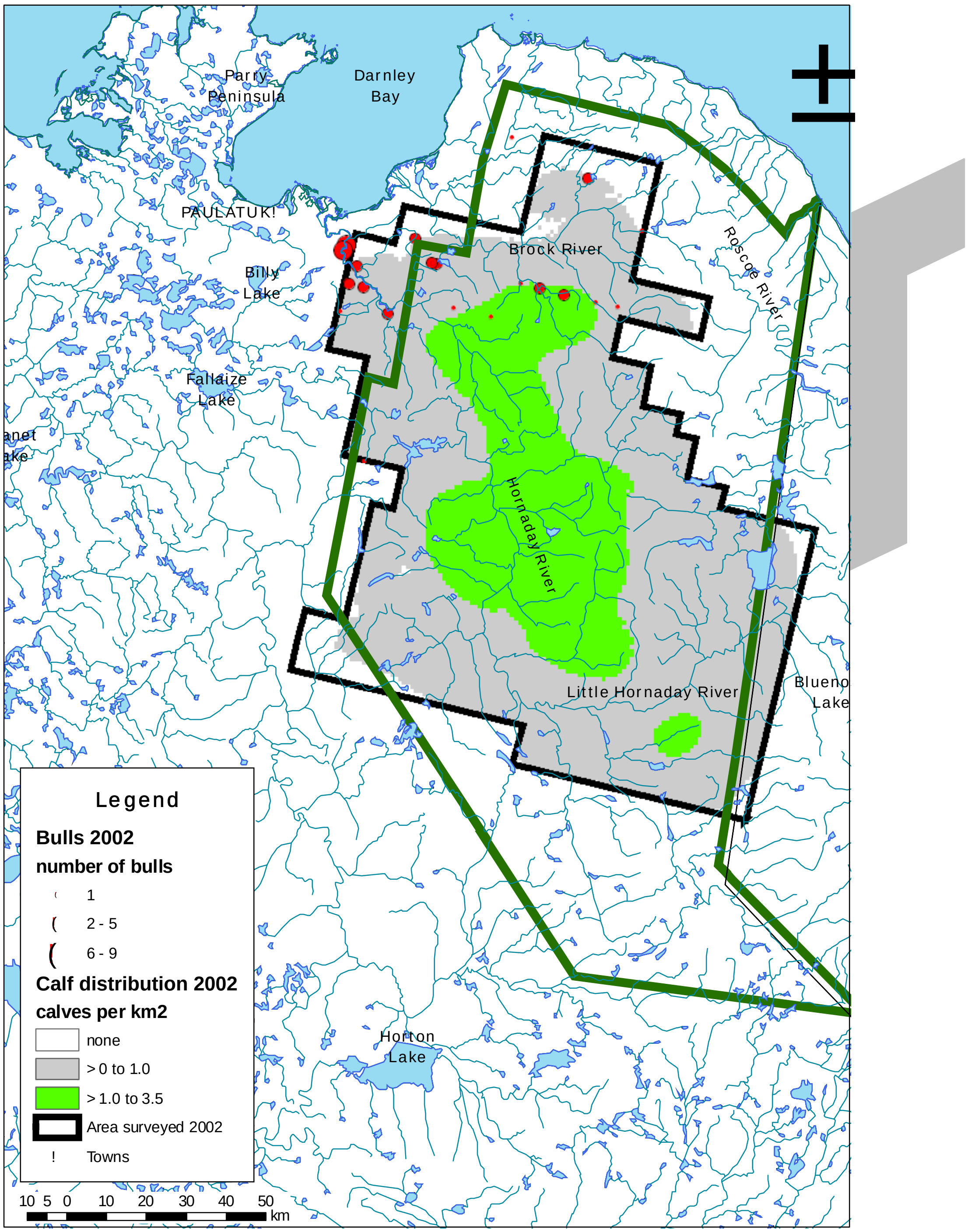


Figure 31. Distribution of bulls observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2003.

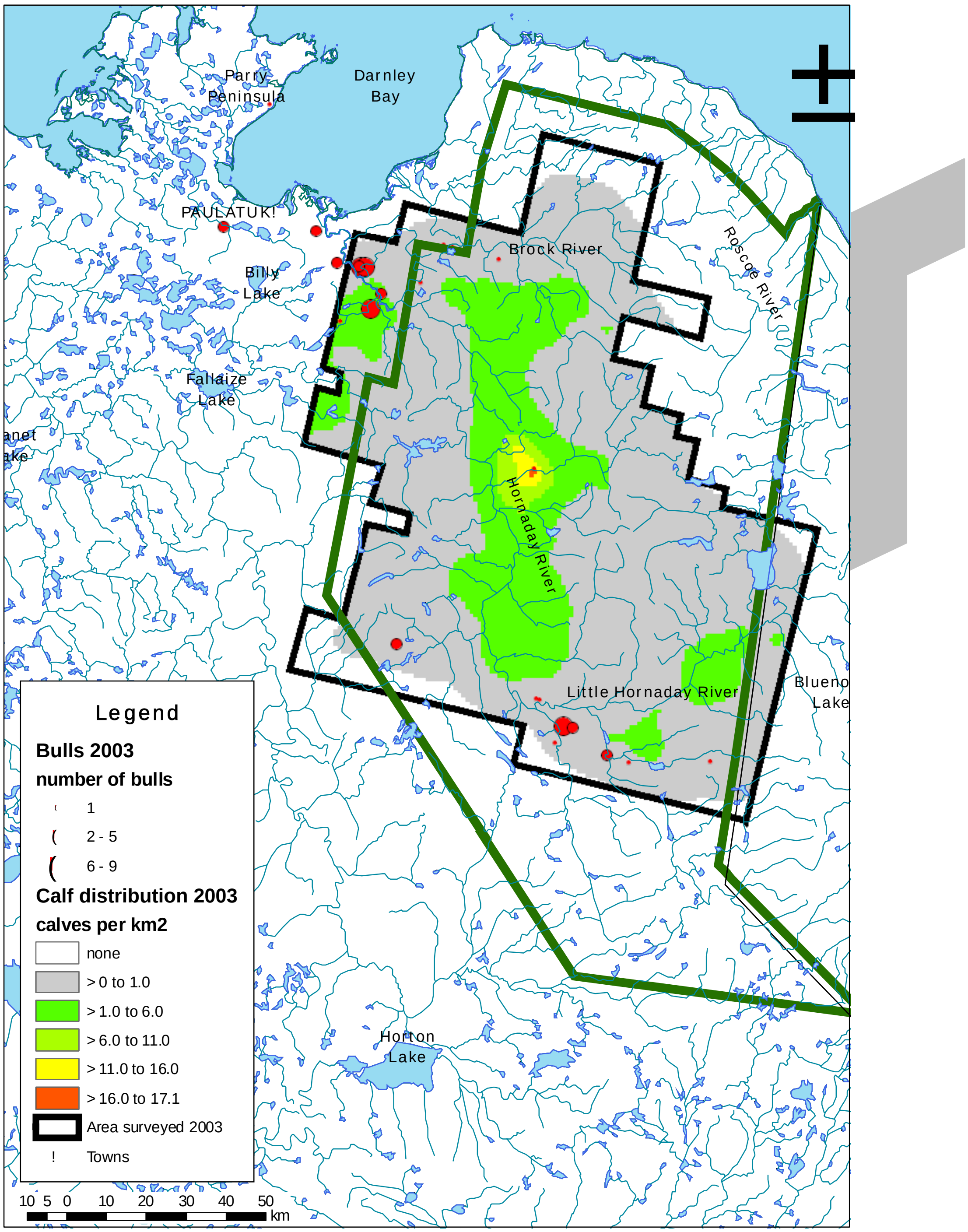


Figure 32. Distribution of bulls observed on and off transect relative to the distribution of calves on the calving grounds of the Bluenose-West herd modelled using ordinary kriging prediction mapping techniques, 2004.

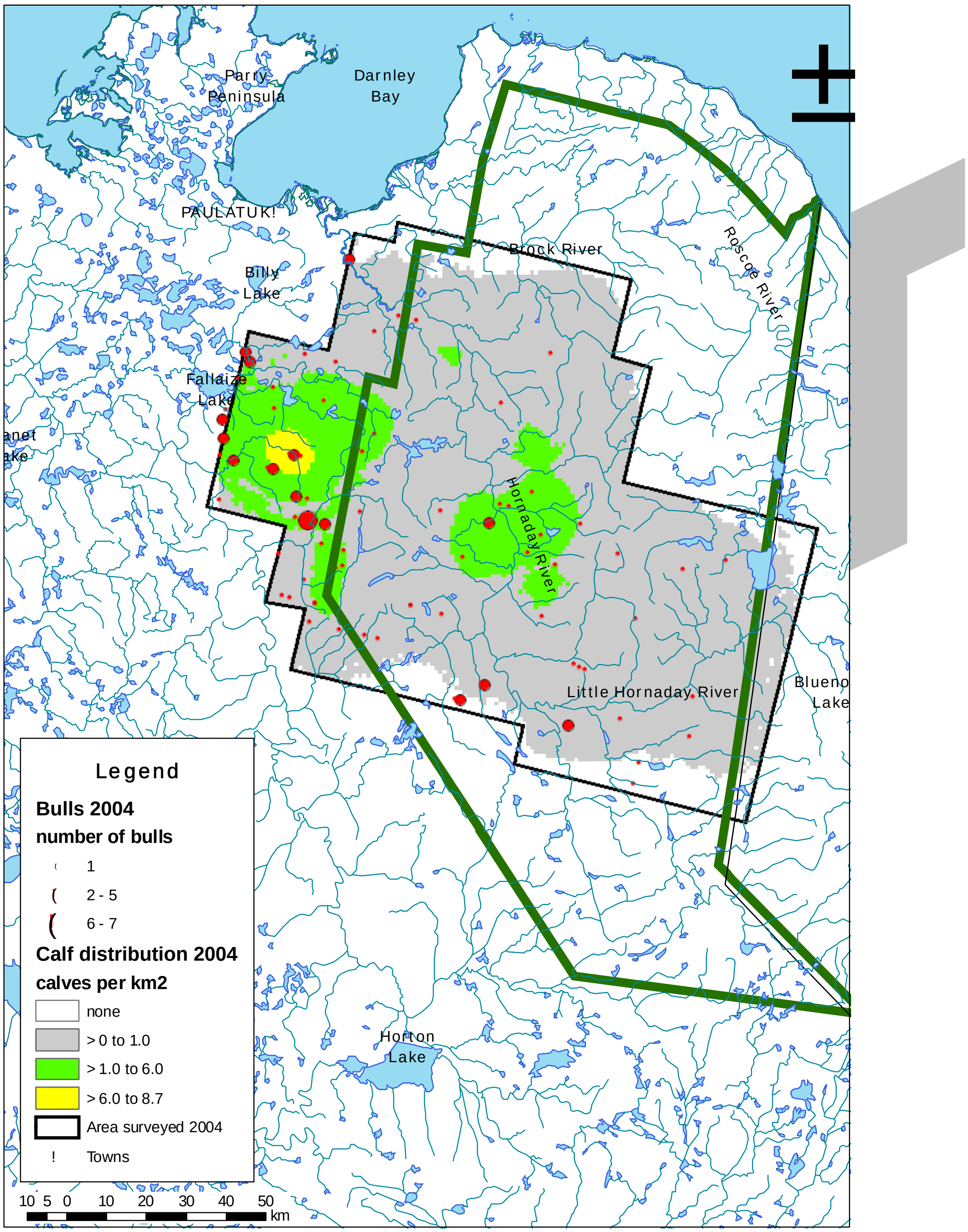


Figure 33. Distribution of grizzly bear, golden eagle, and wolf sightings in relationship to the distribution of calf caribou observed on transect during 2002.

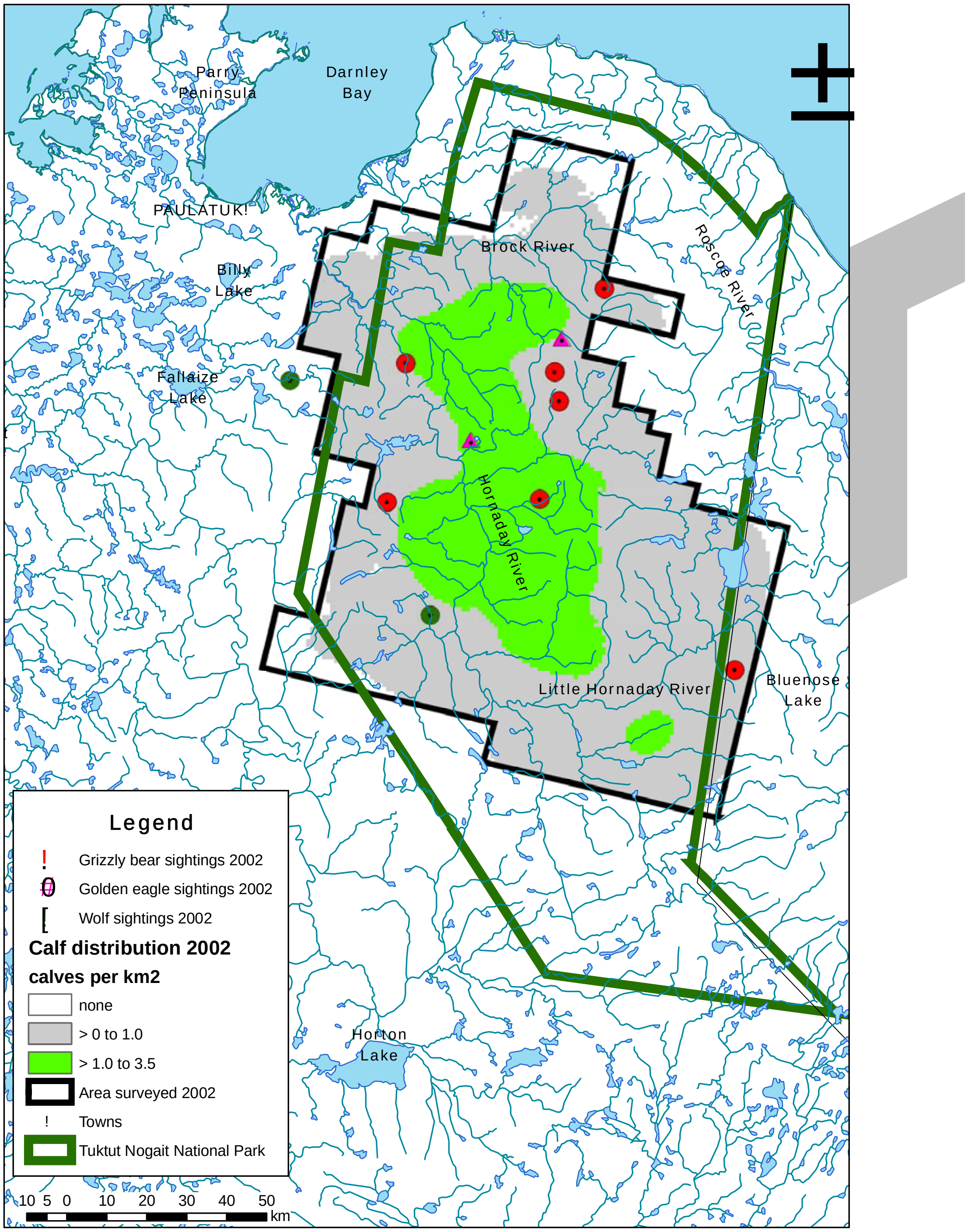


Figure 34. Distribution of grizzly bear, golden eagle, wolf and muskox sightings in relationship to the distribution of calf caribou observed on transect during 2003.

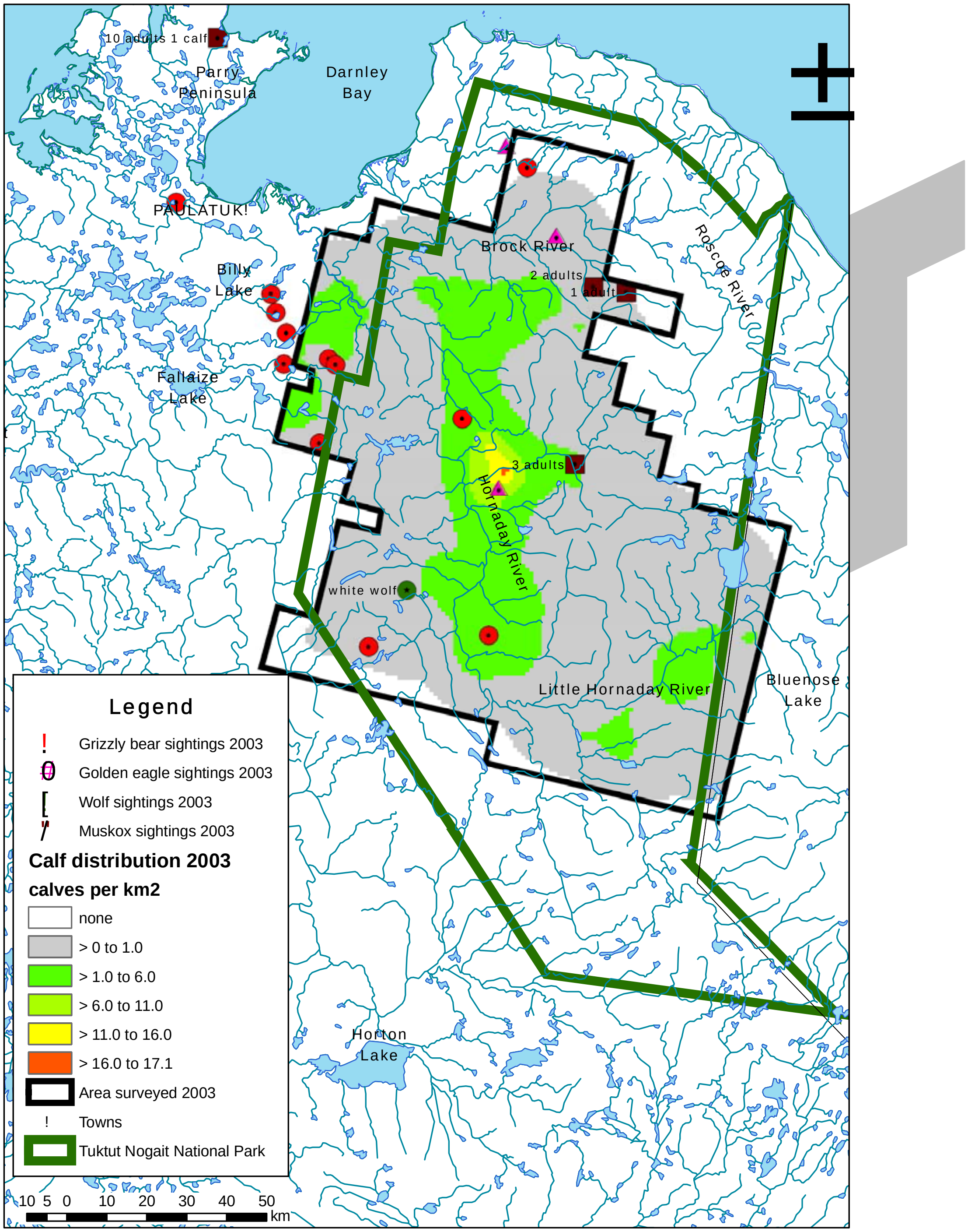


Figure 35. Distribution of grizzly bear, golden eagle, and muskox sightings in relationship to the distribution of calf caribou observed on transect during 2004.

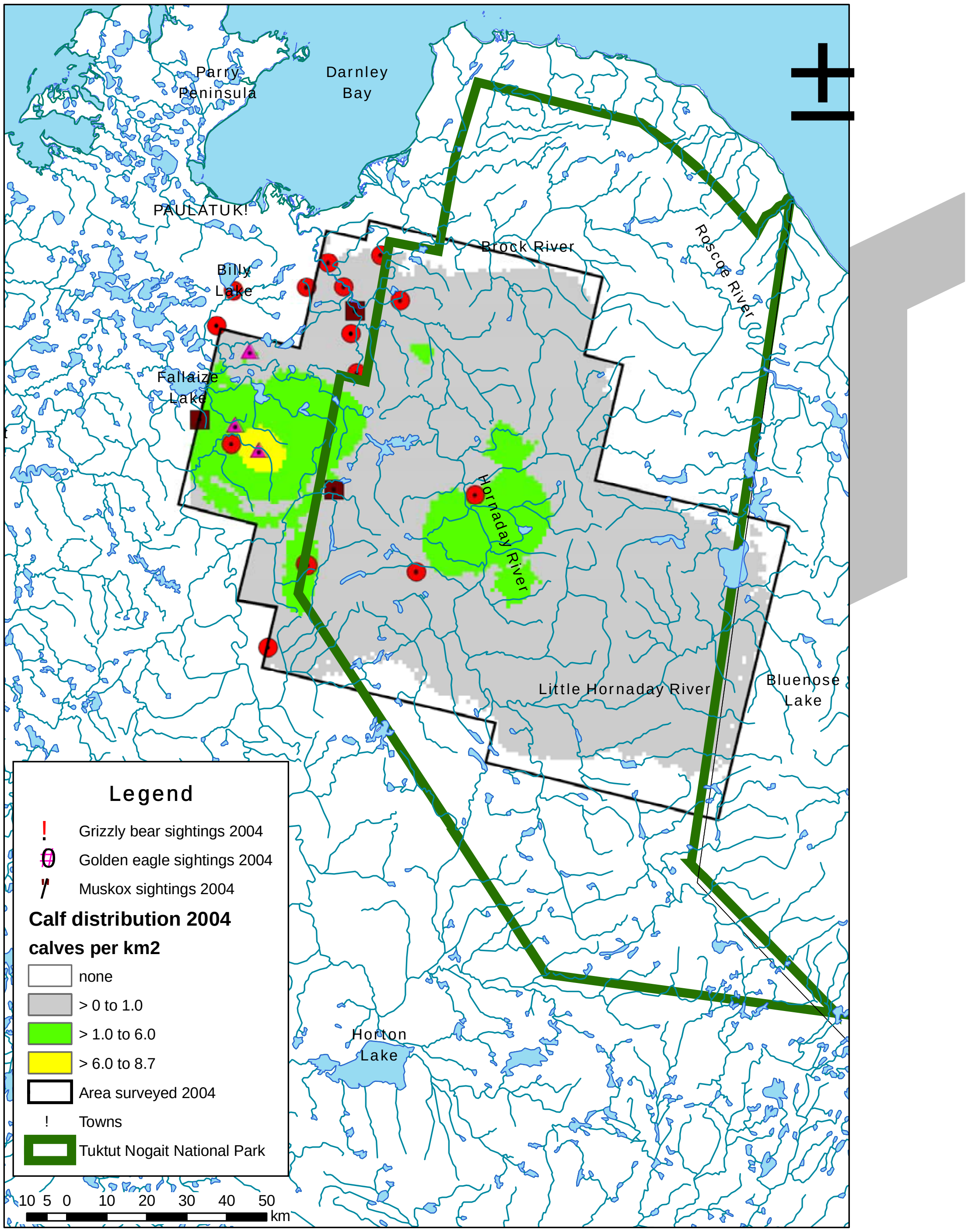


Figure 36. Extent of calving area 2002.

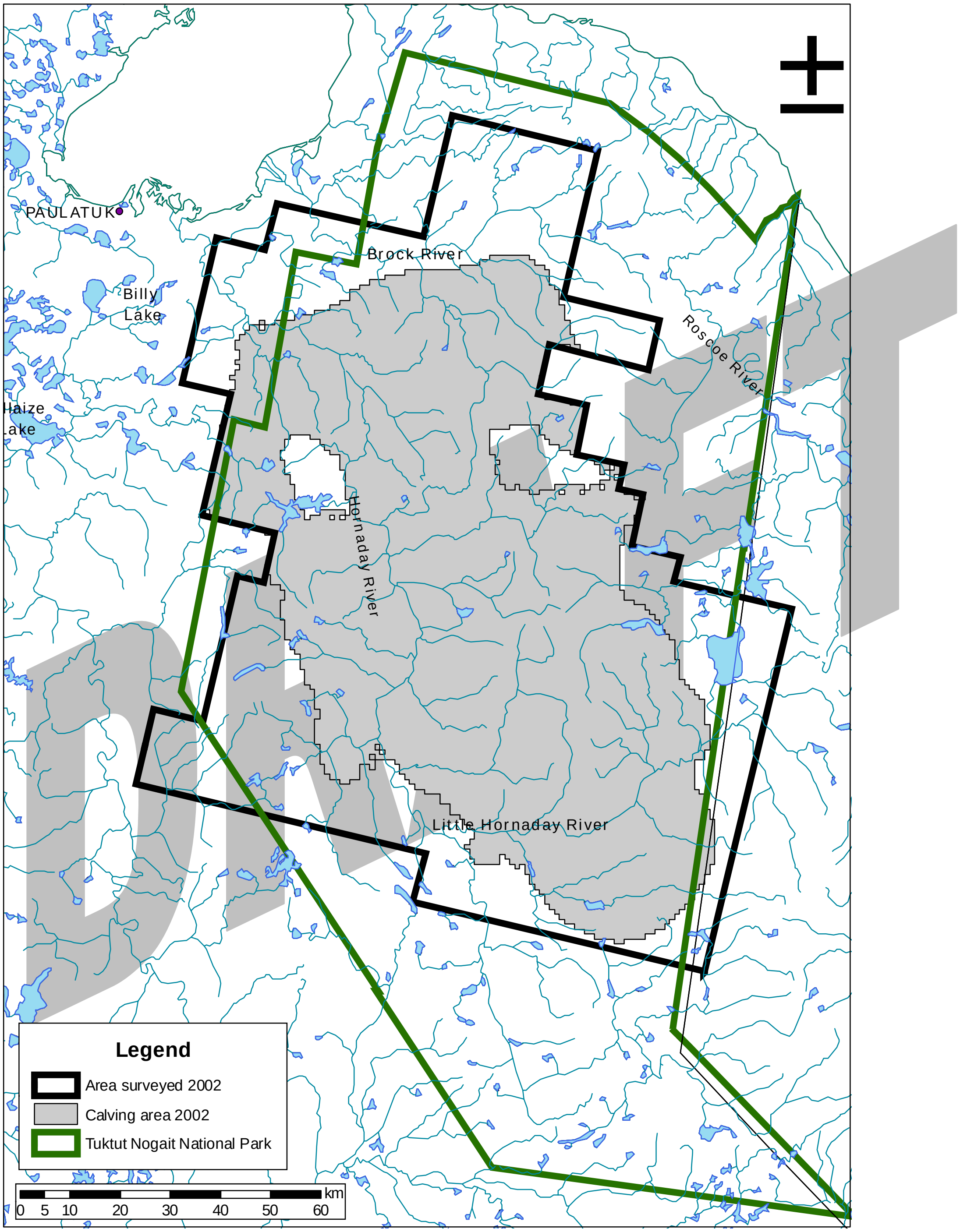


Figure 37. Extent of calving area 2003

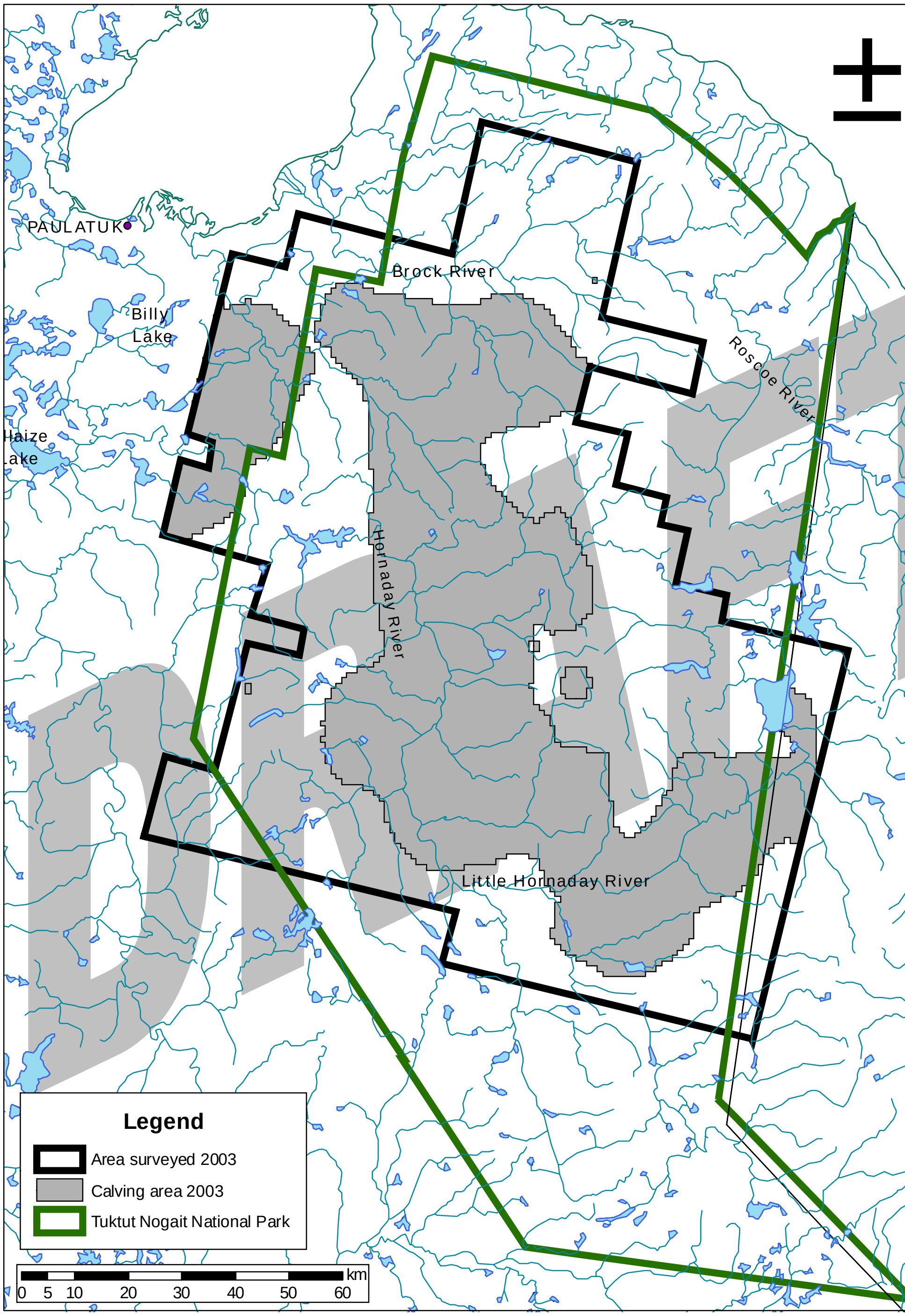


Figure 38. Extent of calving area 2004.

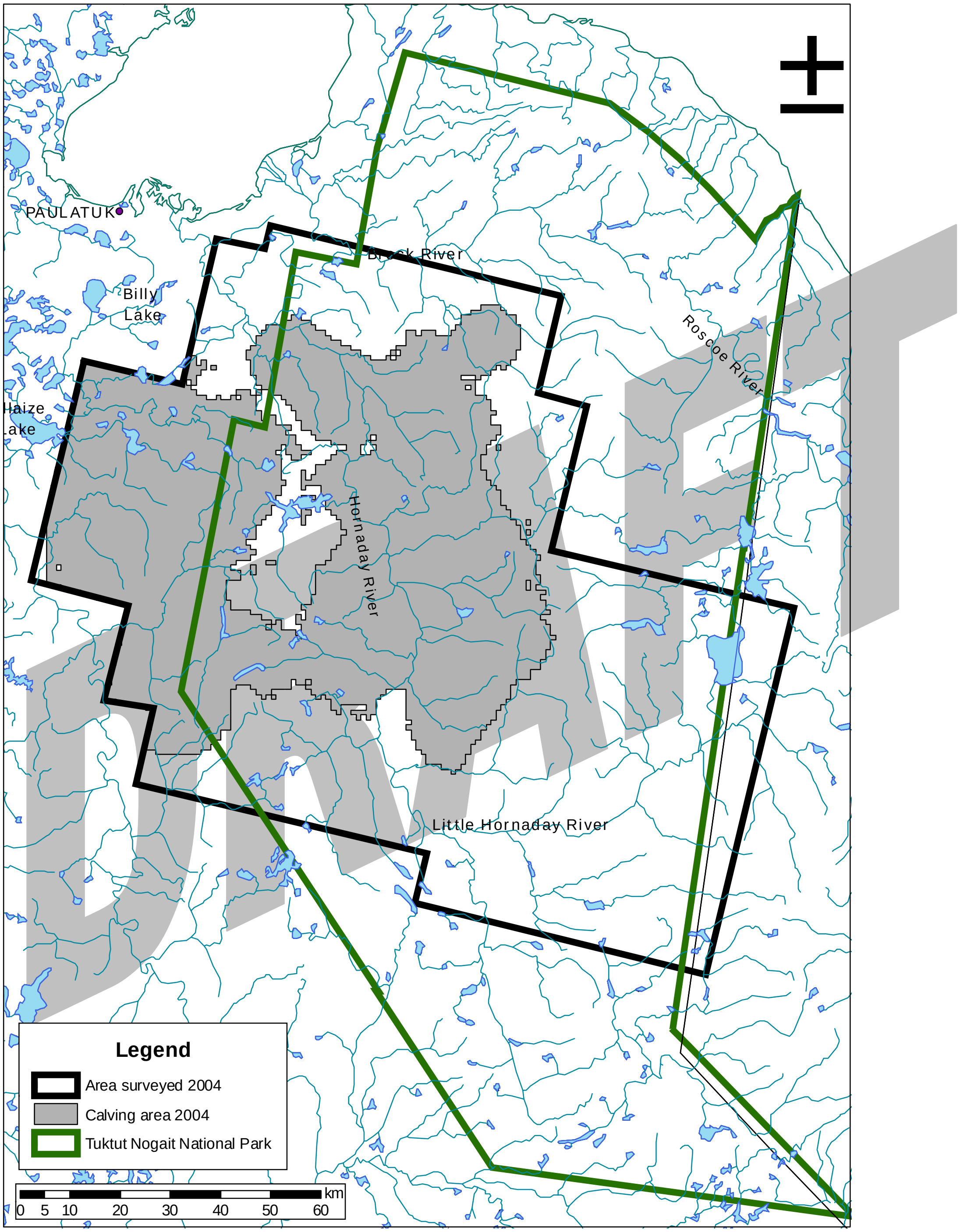


Figure 39. Extent of the calving grounds of the Bluenose-West herd based on surveys completed in 2002, 2003, and 2004: years different areas within the calving grounds were used.

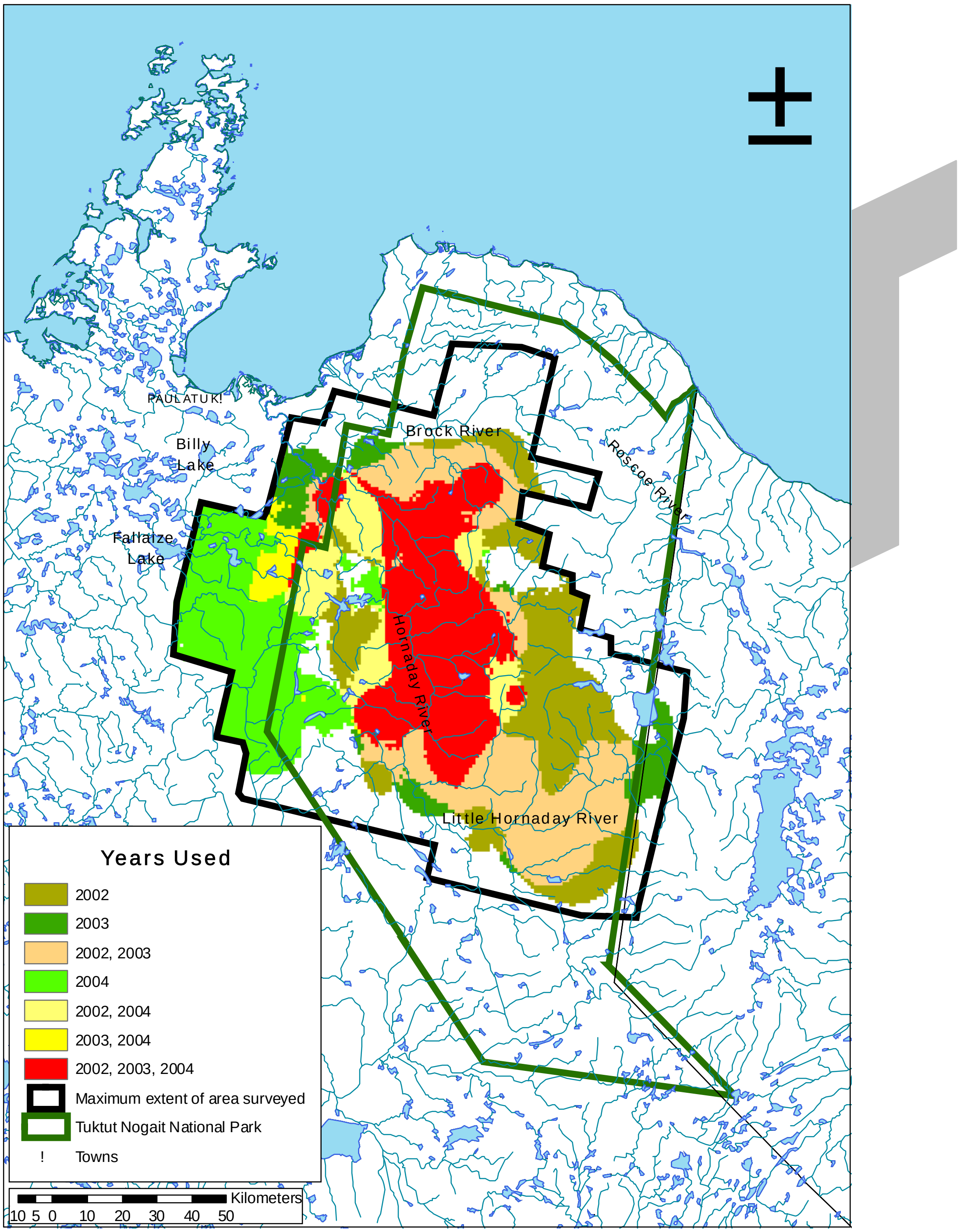


Figure 40. Extent of the calving grounds of the Bluenose-West herd based on surveys completed in 2002, 2003, and 2004: number of years different areas within the calving grounds were used.

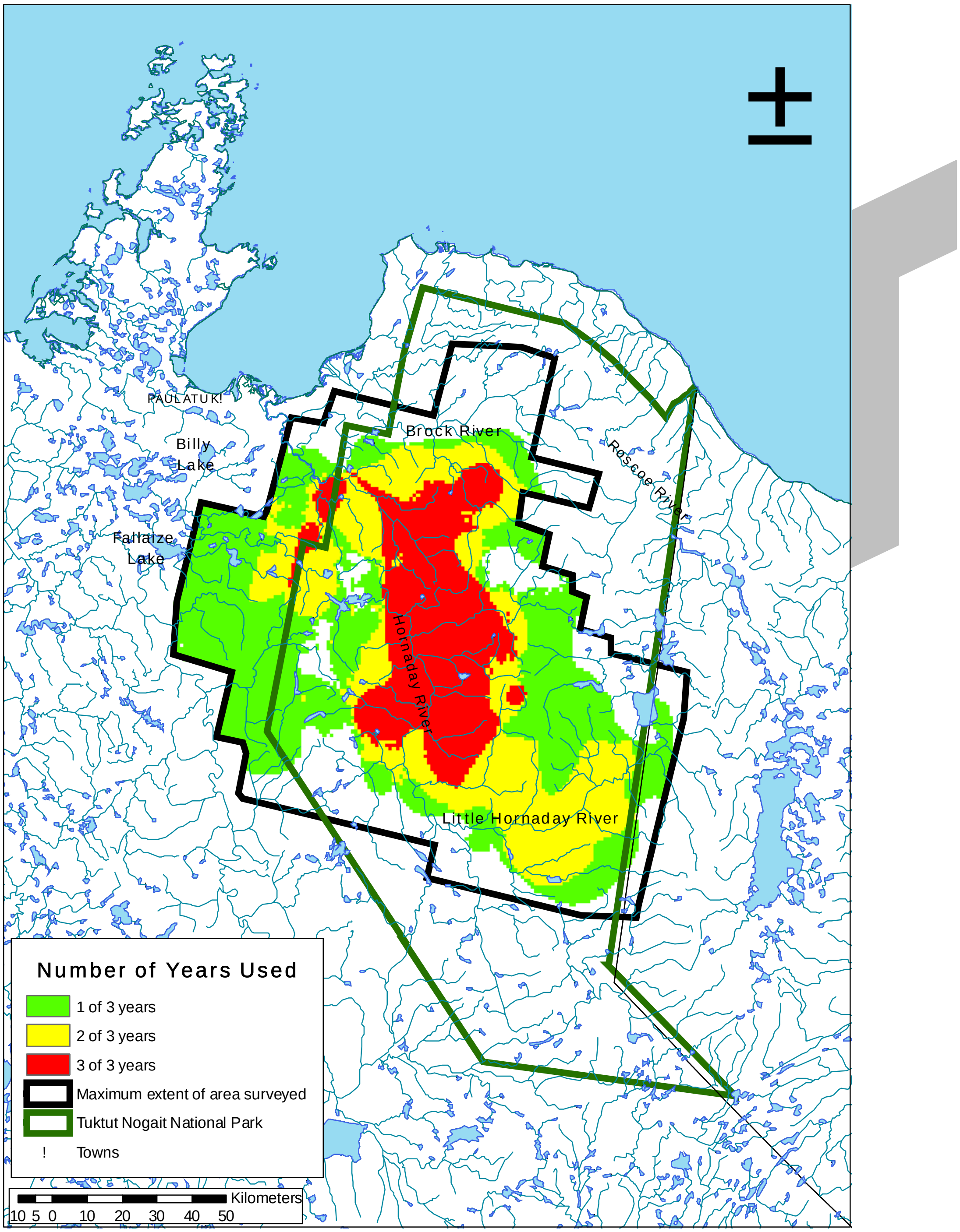


Table 1. Calf:cow ratios documented at or near the peak of calving for the Bluenose-West herd, 2000 to 2005.

					Statistical parameters for calf:cow ratios estimated using theTukey-Jacknife method							
Year	**Dates of survey**	**No. of groups classified**	**No. of calves**	**No. of cows**	**Calves per 100 cows**	**SD**	**VAR**	**SE**	**CV**	**CI 95%**	**Lower 95%CI**	**Upper 95%CI**
2000[a]	9 to 11 June		560	1446	38.73							
2001[a]	12 to 15 June	317	155	1094	14.01	31.2518	9.7668	1.7553	12.5	3.4457	10.57	17.46
2001[a]	23 to 26 June	86	1224	2267	54.08	21.3164	4.5439	2.2986	4.3	4.5316	49.55	58.62
2002	19 to 22 June	705	1769	3192	53.72	41.4863	17.2112	1.5625	2.9	3.0645	50.66	56.79
2003	21 to 25 June	820	2087	3926	53.24	52.2869	27.3392	1.8259	3.4	3.5810	49.65	56.82
2004	18 to 23 June	551	1493	2452	60.92	33.5779	11.2747	1.4305	2.3	2.8062	58.11	63.73
2005	19 to 21 June	44	470	789	59.36	24.5075	6.0062	3.6946	6.2	7.3251	52.04	66.69

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 Bluenose-West barren-ground caribou herd during 2002, 2003, and 2004.

Year	**2002**	**2003**	**2004**
Class of caribou	cows	cows	cows
Number of points	525	534	542
Kriging method[a]	OKPM	OKPM	OKPM
Order of trend removal	second	second	second
Semivariogram model	Gaussian	Exponential	Hole Effect
Major range	20979	33623	27556
Anisotropy	no	no	no
Partial sill	1.5216	13.796	0.99008
Nugget	3.7787	11.21	10.528
Lag size	4778	4778	4728
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)	1.999	4.106	3.357
Average standard error (2)	2.082	4.198	3.378
(1) minus (2)	0.083	0.092	0.021
Mean standardize	0.083	0.092	0.006
Root-Mean-Square Standardized	0.9656	0.9824	0.9965

[a]Ordinary kriging prediction map.
[b]8 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 Bluenose-West barren-ground caribou herd during 2002, 2003, and 2004.

Year	**2002**	**2003**	**2004**
Class of caribou	calves	calves	calves
Number of points	525	534	542
Kriging method[a]	OKPM	OKPM	OKPM
Order of trend removal	second	second	second
Semivariogram model	Gaussian	Exponential	Hole Effect
Major range	24837	37166	19735
Anisotropy	no	no	no
Partial sill	0.75693	6.1275	0.78091
Nugget	1.4522	4.5505	4.5392
Lag size	4778	4778	4728
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)	1.230	2.616	2.288
Average standard error (2)	1.284	2.676	2.295
(1) minus (2)	0.054	0.06	0.007
Mean standardize	-0.0023	-0.0018	0.0069
Root-Mean-Square Standardized	0.9644	0.9831	1.0000

[a]Ordinary kriging prediction map.
[b]8 sector circular.

Table 4. Results of Iterative analyses used to determine the minimum number of calves per km^2, 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 Bluenose-West barren-ground caribou herd during 2002, 2003, and 2004.

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	11098	85	3143	1757	98	99	0.28	0.16
	0.10	10364	80	3121	1746	98	99	0.30	0.17
	0.15	9689	75	3080	1728	96	98	0.32	0.18
	0.20	8985	69	3043	1722	95	97	0.34	0.19
	0.25	8373	65	2981	1705	93	96	0.36	0.20
	0.275	**8094**	**62**	**2958**	**1700**	**93**	**96**	**0.37**	**0.21**
	0.30	7782	60	2892	1670	91	94	0.37	0.21
	0.35	7243	56	2847	1649	89	93	0.39	0.23
	0.40	6725	52	2741	1613	86	91	0.41	0.24
	0.45	6259	48	2671	1588	84	90	0.43	0.25
	0.50	5846	45	2588	1544	81	87	0.44	0.26
2003	0.05	10675	81	3883	2082	99	100	0.36	0.20
	0.10	9581	72	3866	2080	98	100	0.40	0.22
	0.15	8760	66	3848	2074	98	99	0.44	0.24
	0.20	7996	60	3832	2065	98	99	0.48	0.26
	0.25	7349	56	3782	2040	96	98	0.51	0.28
	0.30	6857	52	3726	2012	95	96	0.54	0.29
	0.35	6406	48	3706	2000	94	96	0.58	0.31
	0.40	**5981**	**45**	**3678**	**1991**	**94**	**95**	**0.61**	**0.33**
	0.45	5649	43	3637	1971	93	94	0.64	0.35
	0.50	5355	40	3570	1951	91	93	0.67	0.36
2004	0.05	10021	75	2418	1492	98	100	0.24	0.15
	0.10	8846	66	2393	1484	97	99	0.27	0.17
	0.15	8052	60	2362	1469	96	98	0.29	0.18
	0.20	7289	54	2334	1454	95	97	0.32	0.20
	0.25	6716	50	2307	1441	94	96	0.34	0.21
	0.30	6206	46	2286	1429	93	96	0.37	0.23
	0.325	**5973**	**44**	**2271**	**1420**	**92**	**95**	**0.38**	**0.24**
	0.35	5727	43	2257	1408	92	94	0.39	0.25
	0.40	5209	39	2224	1387	91	93	0.43	0.27
	0.45	4684	35	2163	1342	88	90	0.46	0.29
	0.50	4195	31	2117	1313	86	88	0.50	0.31

Table 5. Years in which different portions of the combine calving area were used.

Years	Amount of combined calving area used	
	km^2	percent
2002	2217	19.7
2003	743	6.6
2002, 2003	2303	20.5
2004	2181	19.4
2002, 2004	863	7.7
2003, 2004	220	2.0
2002, 2003, 2004	2709	24.1
Total area	11236	100.0

Table 6. Number of years in which different portions of the combined calving area were used.

No. of years	Amount of combined calving area used	
	km^2	percent
1 of 3 years	5141	45.8
2 of 3 years	3386	30.1
3 of 3 years	2709	24.1
Total area	11236	100.0