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Application of distance sampling to determine calving ground abundance and aggregation of parturient females in the Middle Ridge herd, June 2012

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Newfoundland Caribou Strategy

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Application of distance sampling to determine calving ground abundance and aggregation of parturient females in the Middle Ridge herd, June 2012

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EXECUTIVE SUMMARY

Female caribou typically aggregate on calving areas and the designation of herds is usually based on this aggregating behavior. However, it has recently been suggested that most caribou in Newfoundland have shifted from aggregated to dispersed calving areas. This would represent a remarkable shift in caribou ecology on the island. A census of Middle Ridge was conducted to assess the extent of caribou calving aggregation and to produce a population estimate.

An aerial survey covering 3844 km of survey lines was conducted 10-16 June 2012 using line transect distance sampling. Distance sampling is an effective, low-disturbance aerial method which corrects for imperfect detection of animals, and this survey represents its first use for caribou in Newfoundland. In addition, the locations of collared adult female caribou were used to assess the aggregation of productive females on the calving ground.

There was no indication of a shift to dispersed calving in the study area. Most caribou were highly aggregated in Middle Ridge North with a smaller aggregation in the extreme southern end of Middle Ridge South. In Middle Ridge North, caribou occupied the traditional calving grounds identified during the 1980s, in addition to an area extending up to 20 km further southwest along the Middle Ridge. Productive collared females were strongly aggregated within these areas while some non-productive females ranged more widely.

There were an estimated 2905 (95% CI: 1893 - 4459) caribou in the study area with 2766 (95% CI: 1770 - 4823) in Middle Ridge North and 139 (95% CI: 93 - 207) in Middle Ridge South. These numbers were broadly similar to those from surveys during 1979 - 1981. Our estimate is less than winter estimates for Middle Ridge which likely includes animals that calve outside the area we surveyed, as well as a greater proportion of males, yearlings, two-year olds and non-productive females.

Distance sampling is a cost effective means of estimating populations on calving grounds and should be extended to other calving areas to assess the degree of aggregation.

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INTRODUCTION

Female caribou typically aggregate on calving areas (Schaefer et al. 2000; Gunn and Miller 1986) and the designation of herds is usually based on this aggregating behavior. However, based on telemetry data, it has recently been suggested that most caribou in Newfoundland have shifted from aggregated to dispersed calving areas (COSEWIC 2011). This would represent a remarkable shift in caribou ecology on the island. However, field observations of caribou during calving (or immediately post-calving) suggest that traditional aggregated calving grounds still exist and are extensively used in the three areas studied as part of the five year Newfoundland Caribou Strategy. The Caribou Strategy is a partnership between the lead agency, the Sustainable Development and Strategic Science Branch and the Newfoundland and Labrador Wildlife Division. It is a comprehensive program to improve Newfoundland caribou management by improving ecosystem-level knowledge of caribou and their predators.

To address these conflicting caribou calving aggregation observations, a census of Middle Ridge was conducted. In addition to addressing the extent of aggregation, this survey also assessed population size, which in conjunction with information from the herd composition surveys, allowed for informed comparisons between the numbers of adult females using the calving grounds in Middle Ridge North and South. Combining knowledge of aggregative behavior and population size provides important information for resource management and environmental assessment.

Despite extensive investment in caribou telemetry collars from 1979 to the present, telemetry data cannot adequately address questions of aggregative behavior and population size without extremely high sample sizes, which can be prohibitively costly. This study estimates aggregative tendency and employs distance sampling techniques to estimate population size in the Middle Ridge caribou herd. Distance sampling is a commonly used approach to assess wildlife population abundance (see next section).

METHODS

Study area

The study was conducted in an area defined by spatially buffering the Middle Ridge calving grounds by 15 km on all sides (**Figure 1**). The calving grounds are based on the 95% kernel utilization distribution from collared calves (Mahoney 2000; Rayl 2012).

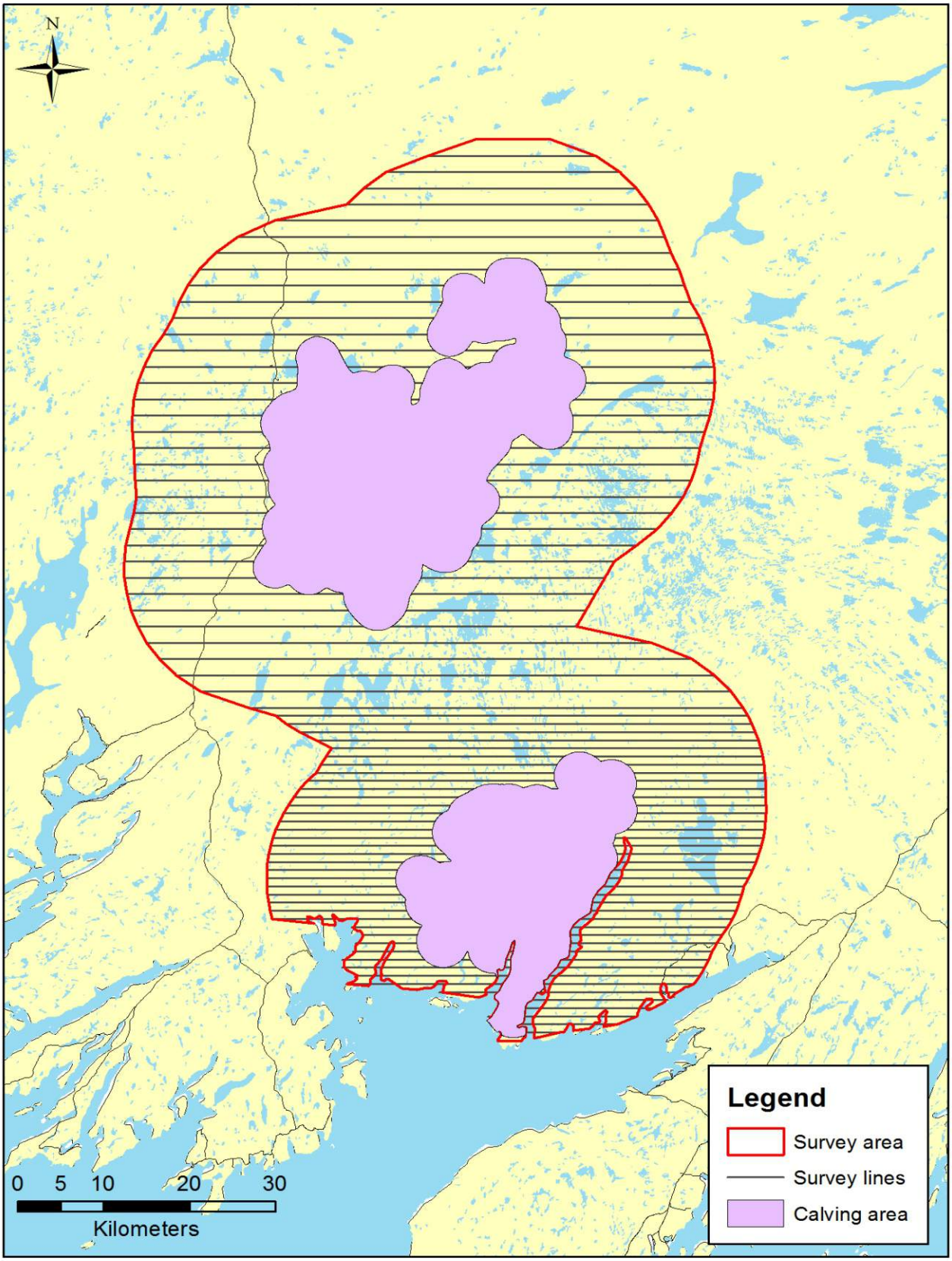


Figure 1. Map of the study area (red outline) showing calving grounds (purple polygons) and survey transects (black lines).

Distance sampling – A Brief Overview

Line transect distance sampling (Buckland et al. 2001) was utilized to estimate abundance and distribution of caribou. Distance sampling is a combination of field methodology and analytical technique that incorporates and corrects for imperfect detection of animals during surveys. In practice, it is similar to traditional strip count methods, except the horizontal distance from the survey line to each group of detected animals is recorded. During analysis, the distribution of these horizontal distances is used to fit a detection function, from which is computed the detection probability for the objects of interest. The detection probability is then used to "scale up" raw counts, to account for missed animals. Distance sampling analysis produces an estimate of density as its primary result, which is converted to an estimate of abundance based on the survey area covered:

$$\hat{N} = \frac{A * n * \hat{E}(s)}{2wL\hat{P}} \qquad \text{(Equation 1)}$$

where:

$\hat{N}$ = estimated abundance
A = size of the study area
n = number of groups detected
$\hat{E}(s)$ = mean group size
w = effective strip width
L = total length of survey lines
$\hat{P}$ = detection probability

Since mean group size can be biased by a few anomalously large groups or small groups that are less likely to be detected at greater distance, $\hat{E}(s)$ is estimated via size-biased regression (Buckland et al. 2001:73).

Each survey line can be envisaged as sampling the density of animals in the covered area (not the actual count). The net result is an absolute density (or abundance) estimate with a confidence interval that incorporates inherent variability in detection probability, the number of animal groups detected per line, and the size of these groups. In contrast, traditional strip transect methods inherently assume perfect detection and can only produce a single relative abundance estimate (the count) with no confidence interval.

Although detection function fitting is an inherently model-based enterprise, conventional distance sampling still relies on standard design-based statistical sampling theory in order to draw inference from the sampled area (i.e. the sample lines) to the entire study area (i.e. including the un-sampled area between or beyond the sample lines). As such, in order for abundance estimates to be unbiased, sample lines must be placed such that they are representative of the study area in question, via random or systematic sampling. In addition, at least 30-40 sample lines and at least 70-100 detections (groups of caribou in this study) are required in order to adequately estimate sampling variances.

In summary, distance sampling has the following advantages over traditional strip transect (total count) and/or mark-recapture methods:

1. In a "total count" survey, some animals are unavoidably missed, but usually we cannot tell how many. Distance sampling addresses this question by estimating the abundance of animals in the study area while taking imperfect detectability into account.

2. Distance sampling creates little disturbance and is cost-effective whereas initiating a mark-recapture approach would likely cause too much disturbance and calf abandonment on the calving grounds, and additionally, requires two passes over the survey area (once for marking and once for re-sighting).

3. Distance sampling provides an absolute abundance estimate with a confidence interval (whereas a total count simply gives a number).

4. "Double counting" is allowed and survey "strips" can abut (or even overlap) one another, thus eliminating analytic problems associated with these common occurrences when a strip census method is used.

5. Differences in observer ability, multiple aircraft and other covariates can be statistically controlled for which can be problematic when a strip census method is used.

Distance sampling is based on a small number of assumptions in order to provide unbiased estimates. The following list outlines the most important assumptions and the steps taken to meet them in this study:

1. Animals are distributed independently of line placement.
Violation (e.g. roadside counts) can produce substantial bias. Transect lines were placed systematically across the study area from a random start point in order to meet this assumption.

2. Animals on the survey line (i.e. at distance 0) are detected with certainty.
Violation will produce a negative bias in the estimate of abundance. This can be an issue for species that are difficult to detect, even at close distances. Within the study area, caribou were distributed in open habitats and surveys were flown at low elevation such that animals on the line were detected with a high level of certainty. This assumption can be tested using a more complex survey design involving independent double observer methods.

3. Animals do not move in response to the observer before they can be detected.
Few animals were observed to react to survey aircraft with most remaining stationary even in the presence of a hovering helicopter. Thus detection distances were estimated with certainty.

4. Distances are measured accurately.
Sighting angles were measured with precision instruments and horizontal distances were calculated using accurate aircraft and land altitudes from GPS and digital elevation model data sets, respectively (see next section and **Figure 2**). Random variation in the ability to sight caribou accurately using rangefinders from a moving aircraft could affect the precision of detection function fitting but would not induce bias.

Survey implementation

East-west running transects (n = 77, 3844km total length) were placed in the study area from a random start location. Lines were spaced 2 km apart in the northern portion of the study area and 1 km apart in the south. It was known *a priori* that few caribou were present in the southern portion of the study area, thus the closer line spacing in the south was designed to provide sufficient detections in this region to produce suitably precise individual abundance estimates for the northern and southern regions.

Transects were flown on 10-16 June using either a Cessna 185 Skywagon fixed-wing aircraft or a Bell 406 Long Ranger helicopter at speeds of 85-110 kts and 0-110 kts respectively, and at a height of approximately 300 m above ground level (AGL). In the Cessna, the two-person survey team consisted of a primary observer/data recorder (D. Fifield) and the pilot (B. Efford), who also acted as an observer. The helicopter team consisted of two primary observers (D. Fifield located on the port side in the front and either N. Rayl or M. Mumma on the starboard side in the rear), the pilot/secondary observer (B. Slade) and a data recorder/secondary observer (P. Tremblett).

On 10-14 June 2012, the Cessna was used to survey low density lines, starting in the south and proceeding north until caribou density precluded the ability to accurately count and record groups from the fixed-wing platform. Whereupon, the Cessna re-commenced surveying in the north and proceeded south until increasing caribou density again precluded the ability to count and record caribou groups. A total of 67 lines were surveyed in this manner. The remaining 10 lines in the central portion of the northern calving ground were covered by helicopter on 15-16 June 2012. In addition, to ensure that large numbers of caribou had not moved from this high density central region north or south into the adjoining area previously covered by Cessna (where they would be missed), the helicopter re-surveyed adjacent lines to the north and south of the central region until densities decreased to the level observed during Cessna surveys. A total of 6 lines were thus surveyed by both helicopter and fixed-wing aircraft and the increased survey effort was accounted for accordingly in the analysis.

Distance measurement

The core principle of distance sampling is that the horizontal distance is measured from the survey line perpendicularly to each group of detected animals (hereafter detection). A recommended approach to accomplish this during aerial surveys is to measure the sighting angle from the aircraft to the center of each group of animals (Buckland et al. 2001:286), subsequently calculating the horizontal distance using trigonometry. The sighting angle was measured for each detection using a Laser Technology TruPulse 360 handheld rangefinder[1]. The subsequent trigonometric calculation of horizontal distance required an accurate measurement of the height of the aircraft AGL (**Figure 2**). Aircraft equipped with radar altimeters can measure height AGL with sufficient accuracy; however the aircraft available for this study lacked such instrumentation. To overcome this obstacle, the following approach was used.

For each group detected, only the number of adult caribou was recorded while sex and reproductive status of individual animals was not determined. In addition, a waypoint was recorded on a handheld GPS (Garmin 76 CSx) which provided an accurate position and altitude of the aircraft (i.e. height above mean sea level). To obtain the aircraft height AGL, the elevation of the land at that location was subtracted from the aircraft altitude. Land elevation was acquired from the 1:50,000 Canadian Digital Elevation Dataset (CDED, http://www.geobase.ca/geobase/en/data/cded/index.html). The CDED provides land elevation on a grid with a resolution of 0.75 arc seconds and an accuracy of ca. 10 m in the study area. This resolution corresponds to a height measurement approximately every 23m north/south and every 11m east/west. Thus, horizontal distance was calculated for each detection (**Figure 2**) as:

$$\text{horiz\_dist} = \tan(90 - \theta) * \text{height\_AGL} \qquad \text{(Equation 2)}$$

where:

θ = sighting angle measured downward from the horizon
height_AGL = aircraft_altitude – land_elevation

Note that this approach does not take into account that the land elevation at the waypoint location (i.e. directly below the aircraft) may differ from the land elevation where the caribou were actually located. However, the variation in land elevation at such spatial scales is generally quite small (i.e. the land is quite flat) within most of the study area (particularly in the area where most caribou were detected; see Figure 3) and thus any error in horizontal detection distances caused by this variation would be quite small as well.

As is common in aerial surveys, visibility directly under the aircraft (within 100m on each side of the line) was limited, particularly for the Cessna and rear-seat observer in the helicopter. This zone of limited visibility is specified in the software, effectively offsetting the survey line 100 m to either side of the transects center, and does not affect detection function fitting or abundance estimation (Buckland et al. 2001:108).

[1] This device is also capable of calculating the horizontal detection distance directly internally based on the sighting angle and sighting distance from the observer to the caribou. However, this requires the use of the device's laser distance measurement feature, which did not function properly through aircraft windows or while moving (through an open window).

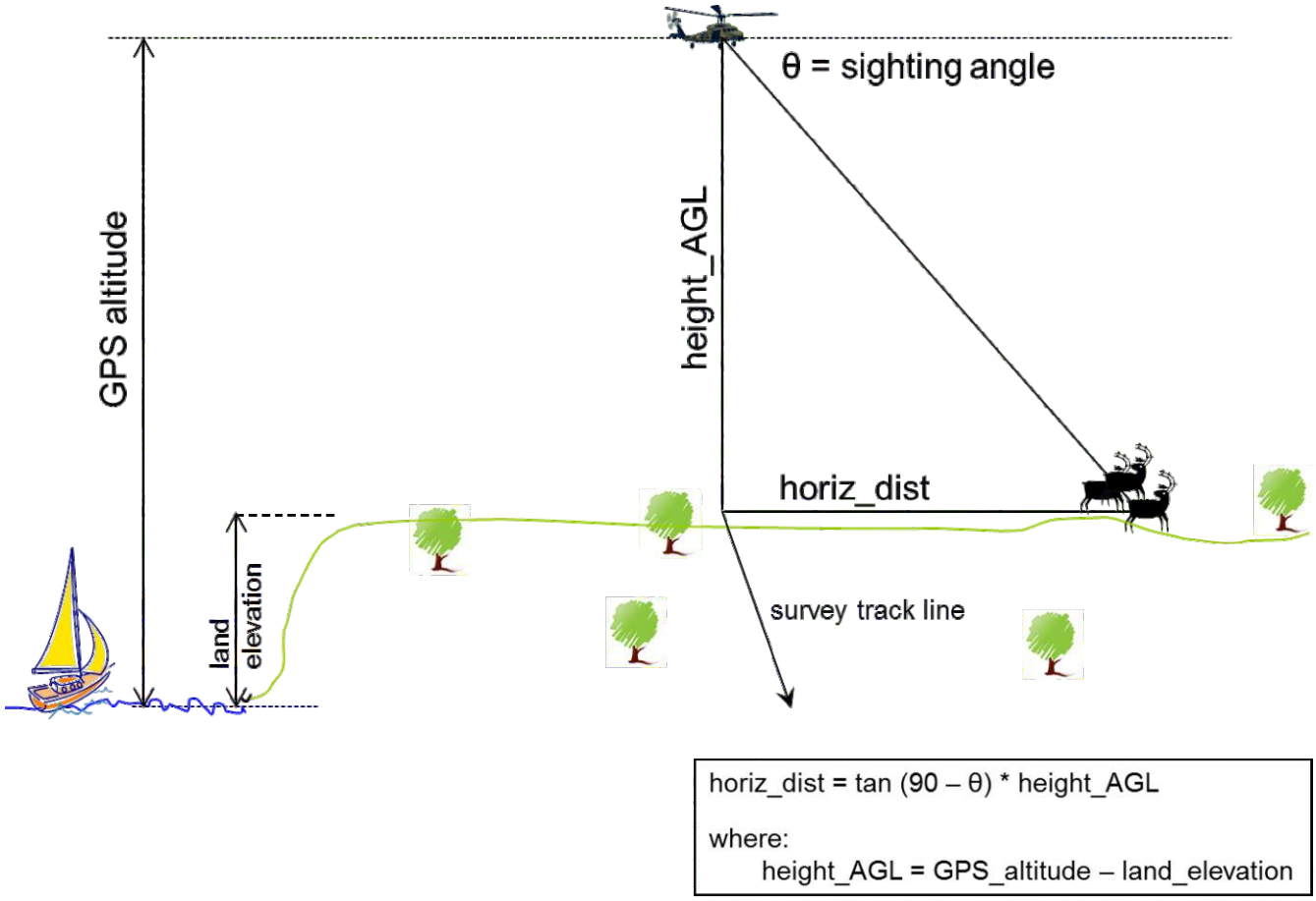


Figure 2. Schematic detailing the calculation of horizontal distance from the track line to caribou groups.

Data analysis

Program Distance version 6 release 2 (Thomas et al. 2010) was used to analyze the survey data. The analysis proceeded via a three step process (Buckland et al. 2001) for each of (1) the entire study area and (2) the calving areas only:

1) Detection probability was estimated by fitting the basic model forms available for covariate distance sampling: either a single parameter half-normal or a two parameter hazard rate model to the distribution of detection distances. Additional covariates for observer, aircraft, height above ground level and caribou group size were included. The "best" model was selected via Akaike Information Criteria (AIC; Burnham and Anderson 2002) and model fit was assessed using Q-Q plots and Komolgorov-Smirnov and Cramer-von Mises goodness of fit tests.

2) From the detection probability computed in step one, animal abundance was computed according to **Equation 1**.

3) Confidence intervals for estimates in step 2 were computed using a parametric bootstrap that re-sampled survey lines with replacement (n = 999, Buckland et al. 2001).

Telemetry data

As part of the Newfoundland Caribou Strategy, SDSS collared adult female caribou in Middle Ridge and assessed their breeding status through classification surveys. The locations of collared females with known reproductive status (n = 16) in the Middle Ridge area were plotted to assess whether reproductive status affected attendance on the calving grounds. This allowed us to assess the extent to which knowledge of reproductive status can bias and/or inform conclusions about calving aggregation.

RESULTS

Distance sampling

Caribou were detected, either singly or in loosely associated groups, ranging in size from 1 to 135 animals (median = 2, mean = 6.6). A total of 394 groups were detected totaling 2592 animals, the vast majority of which were in Middle Ridge North (**Figure 3**).

Detection function fitting

Initial detection function fitting indicated that very few observations were made beyond 1000 m. It is recommended practice to truncate detections in the tail of the detection histogram at distances beyond which detection probability is < 0.15, since these detections have little effect on the calculation of important detection parameters and can be difficult to model (**Figure 4**, Buckland et al., 2001:103). Therefore, the boundary of the area effectively surveyed was set at 1000 m. Initial fitting of half-normal and hazard rate models (with only distance as a covariate) showed that these data are best explained by the hazard rate model (**Table 1, Table 2**). Subsequently, additional covariates were added to the basic hazard rate model.

Entire study area

The detection function model with the lowest AIC was the one that included covariates for distance, height above ground level, aircraft, and caribou group size (**Table 1**). But, the current version of program Distance cannot estimate abundance in separate sub-areas of interest (i.e. Middle Ridge North and Middle Ridge South) when group size is included in the detection function model. The second model was almost identical (differing by only 0.21 AIC units) and this model was chosen as the "best" model. This chosen model indicated that detection probability (out to a distance of 1000 m) was 50% (CI 46% - 54%; **Table 1**).

Calving area only

The best detection function model was the one that included covariates for distance and height above ground level. This best model indicated that detection probability (out to a distance of 1000 m) was 53% (CI 48% - 58%; **Table 2**).

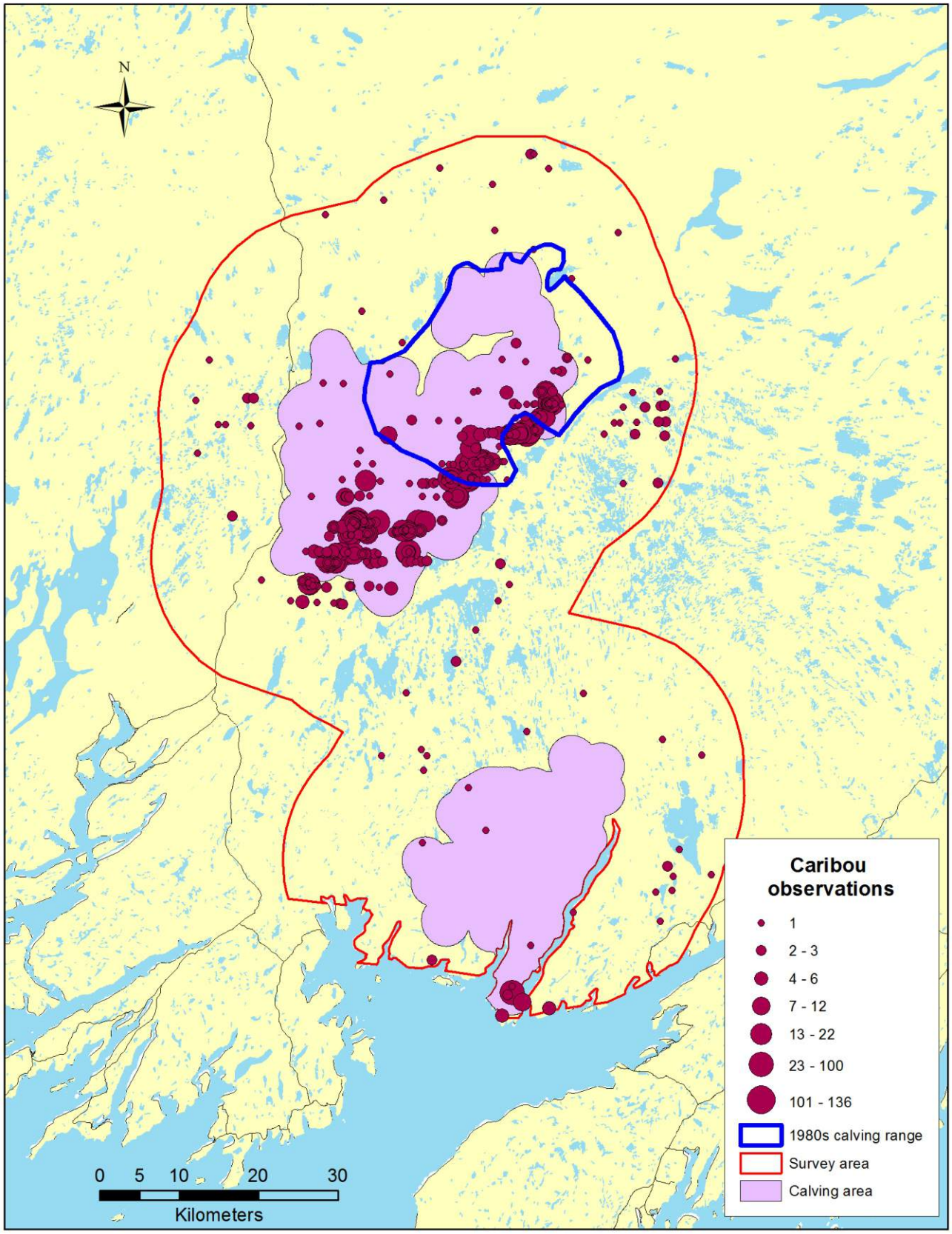
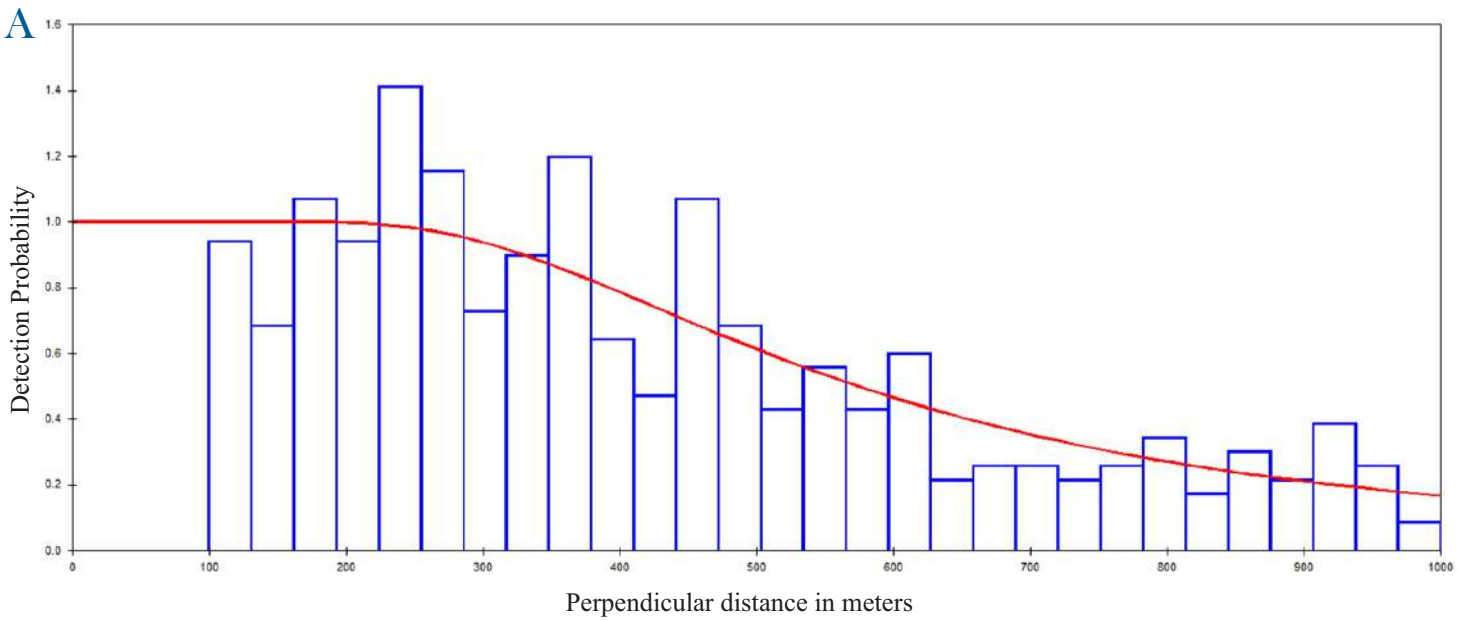


Figure 3. Unadjusted counts of caribou within the study area 10-16 June 2012. The 1980s calving range is reproduced from Mahoney (2000, v. 14).



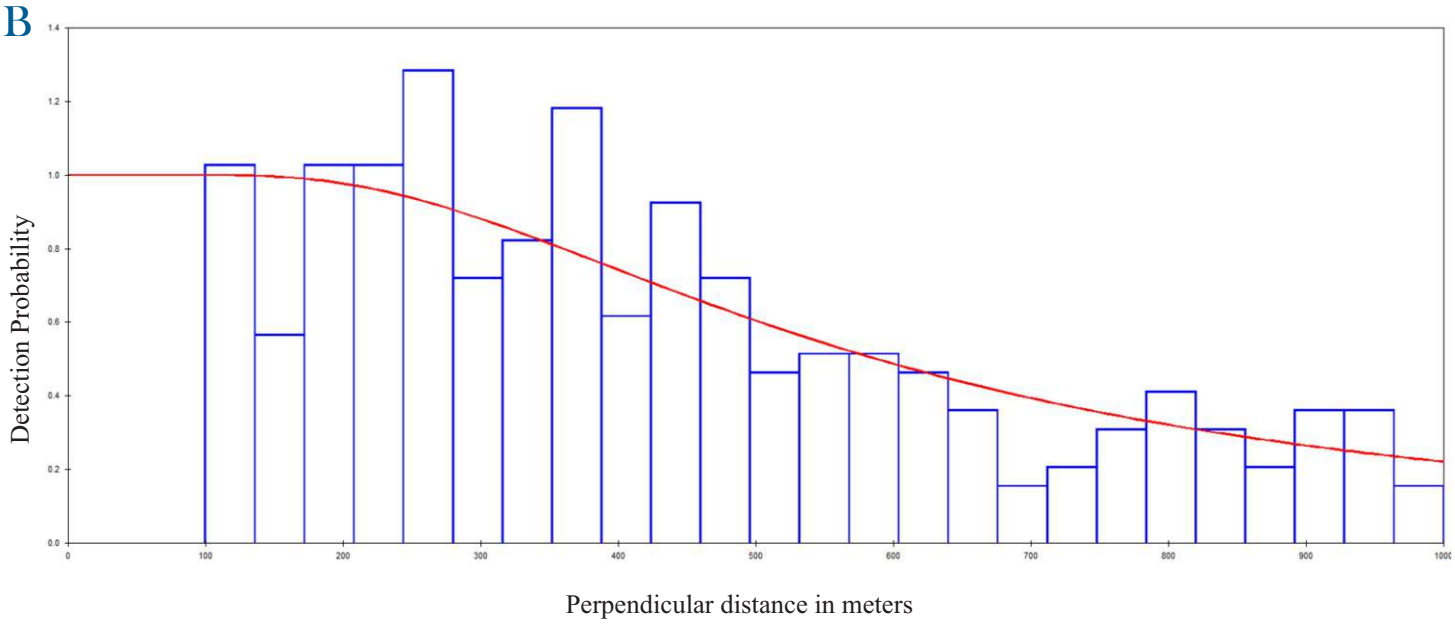


Figure 4. Detection functions (red lines) fitted to histogram of detection distances for (A) entire study area and (B) calving areas only.

Table 1. Relative ranking of detection function models for all observations in the Middle Ridge study area.

Base Model	Covariates	AIC	ΔAIC	Detection Probability (95% CI)
Hazard rate	distance + height_above_ground_level + aircraft + group size	5233.74	0.00	0.50 (0.46, 0.54)
Hazard rate	distance + height_above_ground_level + aircraft	5233.96	0.21	0.52 (0.49, 0.56)
Hazard rate	distance + height_above_ground_level	5234.44	0.70	0.51 (0.48, 0.55)
Hazard rate	distance + height_above_ground_level + group size	5235.67	1.92	0.52 (0.48, 0.55)
Hazard rate	distance + height_above_ground_level + observer	5236.40	2.66	0.50 (0.47, 0.54)
Hazard rate	distance + height_above_ground_level + aircraft + observer	5238.06	4.31	0.50 (0.46, 0.54)
Hazard rate	distance + height_above_ground_level + aircraft + observer + group size	5238.23	4.48	0.50 (0.46, 0.54)
Hazard rate	distance	5247.03	13.29	0.51 (0.45, 0.59)
Hazard rate	distance + group size	5247.73	13.99	0.52 (0.49, 0.56)
Hazard rate	distance + aircraft	5248.82	15.08	0.52 (0.48, 0.56)
Half normal	distance	5250.85	17.11	0.48 (0.44, 0.53
Hazard rate	distance + observer	5252.43	18.68	0.53 (0.49, 0.57)
Uniform	none (i.e. no distance sampling)	5360.29	126.54	assumed 1.0

Table 2. Relative ranking of detection function models for observations in the Middle Ridge calving area only.

Base Model	Covariates	AIC	ΔAIC	Detection Probability (95% CI)
Hazard rate	distance + height_above_ground_level	3815.04	0.00	0.53 (0.48, 0.58)
Hazard rate	distance + height_above_ground_level + aircraft + group size	3815.99	0.94	0.51 (0.47, 0.56)
Hazard rate	distance + height_above_ground_level + aircraft	3816.80	1.76	0.50 (0.46, 0.55)
Hazard rate	distance + height_above_ground_level + group size	3816.81	1.77	0.53 (0.49, 0.58)
Hazard rate	distance + height_above_ground_level + observer	3819.55	4.51	0.52 (0.48, 0.57)
Hazard rate	distance + height_above_ground_level + aircraft + group size + observer	3821.11	6.06	0.51 (0.47, 0.56)
Hazard rate	distance + height_above_ground_level + aircraft + observer	3821.80	6.76	0.49 (0.44, 0.54)
Hazard rate	distance	3827.76	12.71	0.54 (0.45, 0.64)
Hazard rate	distance + group size	3829.44	14.40	0.57 (0.53, 0.62)
Half normal	distance	3829.68	14.64	0.52 (0.46, 0.58)
Hazard rate	distance + aircraft	3830.73	15.69	0.57 (0.53, 0.62)
Hazard rate	distance + observer	3834.20	19.16	0.57 (0.53, 0.62)
Uniform	none (i.e. no distance sampling)	3890.97	75.93	assumed 1.0

Aggregation

Caribou were highly aggregated in the southeast portion of the Middle Ridge North calving area (**Figure 3**). A smaller area of less dense aggregation was also evident in the extreme south of Middle Ridge South. Outside of these areas, caribou were only rarely encountered and only in groups of one or (occasionally) two animals. The locations of adult female caribou collared by SDSS indicate that only one animal was in Middle Ridge South, while the rest (n = 15) were in Middle Ridge North (**Figure 5**). Productive females were strongly aggregated on the Middle Ridge North calving area as defined by the locations of calves collared in previous years (Mahoney 2000; Rayl 2012). All locations of known productive females (n = 10) from 29 May – 16 June 2012 occurred on (or within 1.5 km) of the calving grounds. The three known non-productive females spent all (n = 1) or part (n = 2) of this period outside the calving area boundary, whereas the three females with unknown productivity status spent all (n = 1) or part (n = 2) of this period inside the calving area boundary (**Figure 5**). Likewise, in 2009, 10 (of 13) known reproductive and three (of 6) non-productive radio-collared females occupied the calving area during 20 May – June 10. Two of the remaining three productive females spent at least part of this period in the calving area. Six non-productive females in 2009 also spent all (n = 3) or some (n = 2) of this period in the calving area. In 2010, 19 (of 20) productive females occupied the calving area for all (n = 14) or most (n = 5) of this period, while single non-productive and unknown-status females did, and did not do so, respectively. Comparable data for 2011 was unavailable.

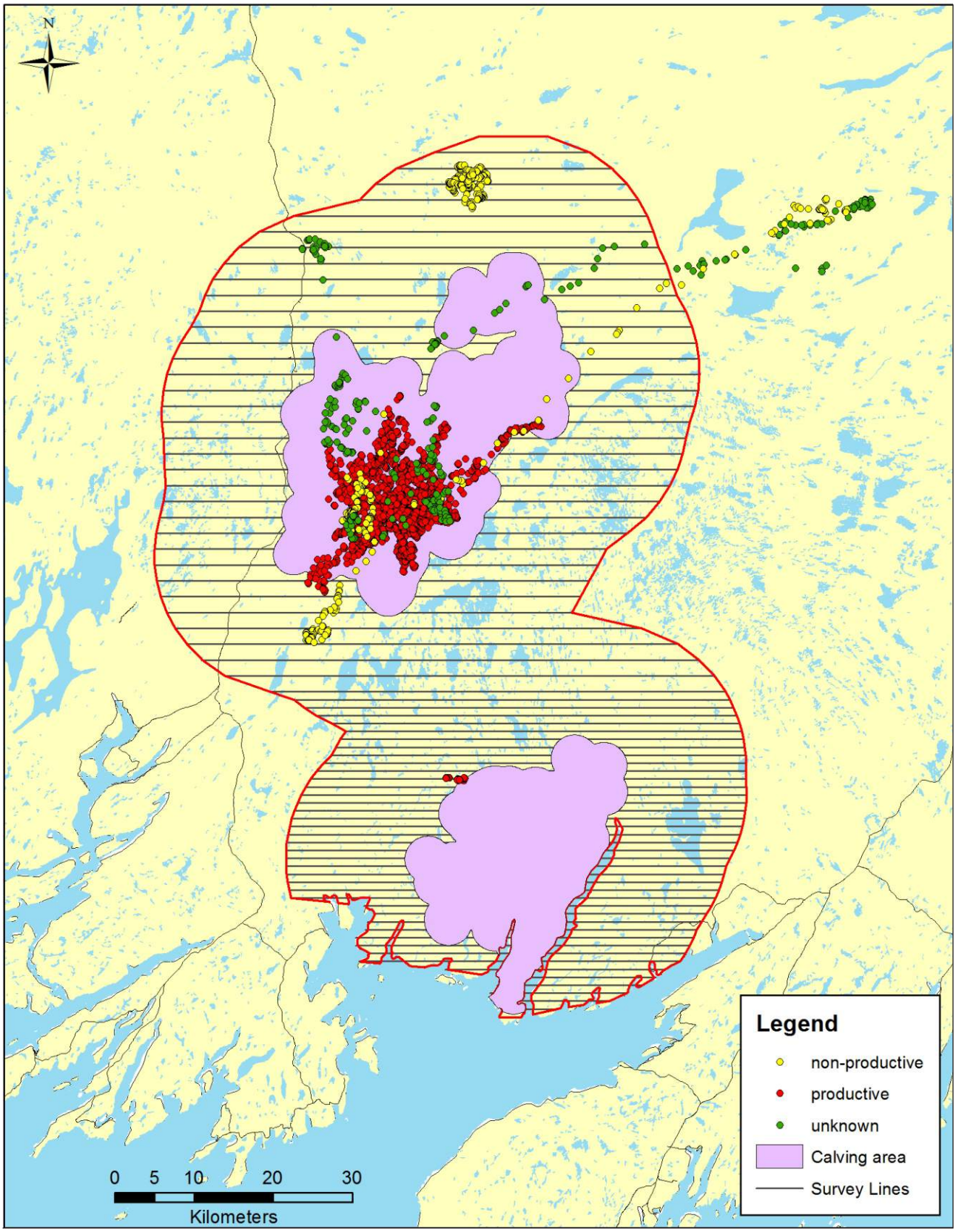


Figure 5. Locations and reproductive status of collared adult female caribou (n = 16 animals, 4852 locations) 29 May - 16 June 2012.

Abundance

Abundance estimates for the entire study area, the Middle Ridge North and Middle Ridge South sub-regions, and the calving areas are presented in **Table 3**. The results in **Table 3** do not account for males that did not attend the calving area. A classification survey of the Middle Ridge calving area in June 2012 produced only 16.4 % males. Adjusting for this difference, we estimate that 345 males in this population did not attend the calving area, bringing the population estimate for the Middle Ridge herd to 3250 (95% CI: 2237 – 4804).

Table 3. Estimated abundance (95% bootstrap CI) of caribou in Middle Ridge, June 2012. "Unadjusted counts" are raw counts before being corrected for missed individuals by distance sampling to produce the final "Abundance estimates".

	Full study area		Calving area only	
	Unadjusted count	Abundance estimate	Unadjusted count	Abundance estimate
Middle Ridge North	2512	2766 (1770 – 4823)	2132	2563 (1481 – 3924)
Middle Ridge South	80	139 (93 – 207)	37	39 (11 – 83)
Total	2592	2905 (1893 – 4459)	2169	2602 (1520 – 3985)

DISCUSSION

This is the first survey of caribou in Newfoundland to employ distance sampling. There are numerous advantages to this approach including integration of detectability, simple field protocol, and lack of disturbance which make it suitable for surveying caribou populations across Newfoundland throughout the year.

Aggregation

The vast majority of animals were contained in the northern half of the study area particularly in the southeastern portion of the Middle Ridge North calving area[2]. Thus, it is clear that caribou were highly aggregated at this time, with no indication that a shift from aggregated to dispersed calving has occurred. In comparison with historical aggregation data, the pattern of distribution in 2012 was similar to that identified for the early 1980s (**Figure 3**; Mahoney 2000, vol. 14, p. 16), except that the 2012 census showed that the area to the west of Kaegudeck Lake (southern portion of the dense aggregation in Figure 3) is now used in addition to the area outlined in Mahoney (2000).

[2] Note that the calving area was based on the telemetry locations of captured calves (Rayl 2012) rather than locations of a sample of pregnant/birthing does and as such, the calving area polygon itself may be biased.

We therefore reject the hypothesis that:

> "Significantly, most caribou in Newfoundland have shifted from aggregated calving to dispersed calving while undergoing a population decline (since 2000; P. Saunders, in litt)." (COSEWIC 2011:37)

This hypothesis was based on telemetry data from females with unknown reproductive status. Unless reproductive status is known for collared animals, it is impossible to know which telemetry locations represent calving individuals (and calving grounds) and which do not. Thus using collaring data without known reproductive status to assess calving aggregation is conjectural at best. Indeed, all known-status reproductive females (collared by SDSS) in the Middle Ridge area were strongly associated with the calving area whereas all known non-reproductive females spent some (or all) of the survey period outside the calving area (**Figure 5**). Additionally, this pattern was consistent with that for 2009 and 2010. While we could not determine the reproductive status of all non-collared females recorded on our lines, our data clearly indicate aggregation.

We attempted to conduct the survey a week earlier at the peak of calving, but were prevented due to inclement weather. Observations by field staff conducting daily reconnaissance of the area confirmed that the vast majority of animals were present in the same high density region of Middle Ridge North during the previous two weeks. Although, at small special scales (< 500m), they were aggregated into somewhat smaller groups at this time.

The question of whether caribou were aggregated or not implicitly involves the question of scale. It could be argued that at small spatial scales (e.g. hundreds of meters), the degree of aggregation is different than at larger spatial scales. The key question is whether aggregation is occurring at a spatial scale that is biologically meaningful to calving caribou. The traditional aggregated calving grounds in Middle Ridge (Mahoney 2000, vol. 14, p. 16) existed on the scale of a few tens of kilometers. It is obvious from the data presented herein that strong aggregation at this (and larger) spatial scale continues to be a defining characteristic of calving caribou in this area.

For distance sampling results to be unbiased the assumptions of the methodology must be met, and detecting all animals on the survey line in forested areas was a cause of concern. However, forested sections of the study area were not so dense as to prevent observation through the canopy to ground level, at least in a narrow strip below the aircraft. Despite this, only a single caribou was observed in dense forest. Examination of collared female locations during the survey period indicated that more than 90% of animal fixes occurred in unforested habitats indicating that caribou had not dispersed into the forest at the time of the survey, and that the survey was not biased by lack of detectability in forested areas. Even if large numbers of caribou were present in forested areas, the distance sampling methodology would still be applicable as long as the probability of detection was high on the line and decreased with increasing distance from the line (albeit more quickly than in open areas). In such a scenario, detectability would surely differ between forested and open areas and habitat type (for each observation) should be included as a covariate when modeling detectability (Marques et al. 2007).

Abundance

The distance sampling approach was successful in producing an absolute abundance estimate of animals for the entire study area and for sub-areas of interest. The overall abundance estimate for the entire study area is broadly similar to 1979 - 1981 spring abundance estimates (Mahoney 2000, vol. 14, p. 44-45, **Table 4**), particularly given that the actual area covered likely differed considerably between survey periods.

Table 4. Spring Middle Ridge caribou abundance estimates by year and method.

Year	Method	Estimate	Source
1960	strip	167	Mahoney 2000
1962	TAC[1]	505	Mahoney 2000
1964	strip	450	Mahoney 2000
1979	strip	3000	Mahoney 2000
1980	strip	1925	Mahoney 2000
1981	strip	2371	Mahoney 2000
1981	block	4057	Mahoney 2000
2012	line transect	2905 (1893 – 4459)	this study

[1]Total area census.

Recent winter surveys of the Middle Ridge area in February 2010 estimated 8814 ± 761 (mean ± SE) animals while winter 2006 (8748 ± 393) was similar (Dyke 2010). In comparison, smaller numbers are expected in this survey since winter groups likely included individuals from outside the area we surveyed. Likewise, a smaller proportion of males are present during calving (16.4 % males during our survey) versus wintering (23.4 % during winter 2011), and it is likely that not all yearlings, two-year olds or non-productive females were within the survey area at the time of census.

SUMMARY

The distance sampling line transect methodology was successfully applied for the first time to caribou in Newfoundland and produced an absolute abundance estimate of the caribou calving distribution in Middle Ridge.

Animals were highly aggregated in the southeastern portion of the Middle Ridge North calving area providing no evidence of dispersed calving.

An estimated 2905 (95% CI: 1893 – 4459) caribou were present in the study area, the vast majority of which were in Middle Ridge North.

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