AN ESTIMATE OF POPULATION SIZE AND TREND FOR THE LAC JOSEPH CARIBOU HERD AND THE GREATER REGION OF SOUTH CENTRAL LABRADOR:

RESULTS OF A LARGE-SCALE AERIAL CENSUS CONDUCTED DURING MARCH 2009

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Introduction

In Labrador, forest-dwelling caribou (*Rangifer tarandus caribou*) occur in a continuum across southern Labrador and Northeastern Quebec. These caribou are non-migratory and belong to the 'sedentary' ecotype (Bergerud 1988). Ecotypes are classes of populations that have adapted to different landscapes and environments. The 'sedentary' ecotype of caribou is distinguished from its taxonomically identical migratory counterpart on the basis by several behavioural, and morphological and features: sedentary caribou do not migrate above the treeline to calve and exhibit limited movement in general, are largely solitary and highly dispersed during calving, rut in discrete ranges (from migratory caribou), and exhibit a different antler and body morphology (Couturier et al 2010; Bergerud et al 2007). In addition, several studies have confirmed genetic differences between migratory and sedentary ecotypes using DNA microsatellites (Courtois et al 2003; Boulet et al 2007). In Labrador, 3 sedentary populations are currently recognized: the Lac Joseph, the Red Wine Mountain and the Mealy Mountain herds. Caribou also occur at low densities outside of these recognized ranges including a region surrounding Dominion Lake which is occasionally used by caribou from the RWM population (IFWD unpublished data), and in the vicinity of Lac Fourmont.

All sedentary caribou in Labrador were designated as Threatened under the Endangered Species Act of Newfoundland and Labrador on July 31 2002 (ESA E-10.1 2001). The Committee on the Status of Endangered Wildlife in Canada has also designated sedentary Woodland caribou, including those in Labrador as Threatened, and they are listed in Schedule 1 of the federal Species at Risk Act (SARA). A Recovery Strategy was prepared and released in July 2004 (Schmelzer et al 2004) which also contains detailed information on range use, population inventories, and threats to persistence.

During winter, migratory forest-tundra caribou from the George River population enter northern portions of the range of the three sedentary populations, resulting in intermingling of animals. These winter incursions occur primarily within the RWM range north of the Churchill River, and the north eastern parts of the range of the Lac Joseph population. Since caribou surveys take place during the winter months while George River caribou are present, the opportunity to conduct studies describing the distribution and range use of sedentary caribou within these regions has been constrained. However, incursions usually do not occur south of this area and surveys are still possible for sedentary caribou in areas such as the southern portion of the RWM range below the Churchill River and the majority of the Lac Joseph caribou range. Given that it had been 9 years since the last survey for the LJ population was conducted (March 2000-IEMR unpublished report) and because at least a third of this herd's range occurs within a military training area, it was felt that a survey of this population was a high priority. In addition, biologists have documented increased use of regions south of the Churchill River by RWM caribou (IFWD unpublished data), an area free of migratory caribou during winter 2009, and so this region was also included. The project was a collaboration between the Wildlife Division, Province of NL, and the Institute of Environmental Monitoring and Research (IEMR), an organization established to monitor and evaluate the environmental impacts of the Department of National Defence (DND)'s low level flight training program.

Objectives

My goal was twofold: to document the late winter occurrence and distribution of sedentary Woodland caribou in south-central Labrador and to derive a population estimate using a stratified aerial survey design with strip transects. Specific objectives included i) an estimate of population size for the Lac Joseph population within Labrador; ii) an estimate of density for 3 regions within the survey extent; iii) an estimate of calf recruitment throughout the survey extent and iv) an evaluation of trends in density and population size for the Lac Joseph population in relation to a similar survey conducted during the winter of 2000. As caribou densities are relatively low throughout Labrador, and to maximize sampling effort for available flying time, secondary objectives included; recording moose and wolf distribution and abundance and to deploy additional radio collars in a stratified manner throughout the survey area.

Methods

Study Area

Tree cover varies from a closed-crown boreal forest to lichen- or heath-dominated barrens at higher elevations in the Red Wine and Romaine Mountains, the two dominant topographical features within the survey area. Large areas are of lichen woodland occur at well-drained sites throughout the region. The dominant tree species in these open woodlands is Black spruce (*Picea mariana*). The western portion of the study area lies within the Smallwood Reservoir/Michikamau Ecoregions (http://www.heritage.nf.ca/environment/ecoregions_lab.html) which is characterized by a mid-subarctic forest with flat to gently rolling topography and many lakes with some tundra and alpine tundra vegetation at higher elevations. The southern portions are characterized by a more typical closed-canopy boreal forest. The south-central region along the Quebec-Labrador border occurs within the Mecatina River ecoregion, an area characterized by rugged topography glacial features and extensive black spruce forests. This region also contains stands of Trembling Aspen (*Populus tremuloidis*) , which occurs at its northern limit here. The Lake Melville ecoregion is an irregular lowland bisected by river valleys including the Churchill River and contains the survey areas' most productive forest.

The survey extent was delineated in relation to known caribou winter ranges in western and central Labrador. Caribou ranges were defined on the basis of mapped winter distributions from radio-collared caribou (1998 to 2009), and using group sightings from prior winter surveys (2000 and 2001 for LJ and RWM respectively; WD unpublished data) and from knowledge of caribou distribution garnered through fieldwork, traditional knowledge, collar deployments, and observations from hunters and conservation officers. As a result, it was not felt necessary to conduct a reconnaissance flight prior to the survey. The survey did not extend north of the Churchill River due to the presence of wintering migratory George River caribou and the intermingling of caribou ecotypes which would have precluded an independent estimate of sedentary caribou. As a result, the northern portion of the RWM range was not surveyed. I also plotted transects for adjacent western and Northwestern strata in order to evaluate and sample the distribution of caribou in this area. My rationale was based on a recommendation from the Labrador Woodland Caribou Recovery Team that this area should be included based on previous reports of caribou observations, and the areas' inclusion within a zone open to caribou hunting irrespective of the presence of caribou from the George River herd. The survey area did not extend below the Labrador border at the 52 parallel except for a region in which the Quebec-Labrador border occurs below this latitude, and in another area which juts above this latitude in the high density stratum. Caribou associated with the Mealy Mountain population, including the Joir River subpopulation, were not surveyed given logistic and financial constraints related to the size of this additional survey area.

The survey area spanned 59 646 km^2, and included approximately half the range of sedentary caribou in Labrador. The survey area was bounded by the Quebec border in the West (67^o 30') and the Minipi River in the East (61^o 20' W). The northern extend was bounded by latitude 53^o 30'N to the west of Churchill Falls, and the Churchill River east of there (Figure 1). The study area was divided into 3 strata in order to minimize variability in density between units*:* two 'low density' areas, and one 'high density' area. The 'high density' (HD) stratum corresponded with range of Lac Joseph Caribou population. It included 25 transects totaling 4282 km over an area of 38 980 km^2, or 65% of the study area. The first low density stratum included the southern portion of the Red Wine Mountain caribou range, spanning 13 643 km^2 (23% of the total area) which were sampled over 14 transects for a total distance of 1688 km. The final stratum, in the west was the smallest, at 7022 km^2, sampled over 8 transects for a total survey distance of 912 km. All transects were spaced 8 minutes apart, oriented N-S and ranged in length from 144 to 169 km. While typically greater sampling effort is used within high density stratum, the presence of military flight training activity (MTA) within the eastern-most (low density) stratum was used as a premise to intensify sampling effort within that region in order to facilitate appropriate monitoring and mitigation. Figure 1 shows the survey extent in relation to herd ranges. To compare relative distributions of caribou among stratum, estimated densities based on the proportions of land area within the different regions were calculated and compared using Chi-square tests. I expected that the number of observed animals within the high density stratum should be statistically greater than expected than if they occurred in proportion to the available stratum area. Animals observed within and outside the strip transects during the survey were used in these comparisons.

Approach

The survey was flown using a Bell 206L 'Long Ranger' helicopter to permit classification of caribou and allow more accurate identification of tracks. All transect endpoints were programmed into a Global Positioning System (GPS) and uploaded to the pilot's GPS to assist in navigating transects. A front seat navigator recorded all wildlife sightings called out by left and right observers and recorded observations on the datasheets and via waypoints on a handheld GPS. The pilot maintained survey altitude at 100 metres above ground level and a constant airspeed of *ca.* 100 km / hour. Strip width was 500 metres per side. All observations of caribou were recorded and georeferenced. Caribou were classified by age class (adult or calf), and where possible in smaller groups, gender was determined by a dark vulval patch on females. All caribou observed were examined for the presence of a radio collar. When only tracks were observed, the survey crew attempted to visually locate the group in the vicinity of the transect in order to classify them, returning to the transect to continue the survey. The location of groups on

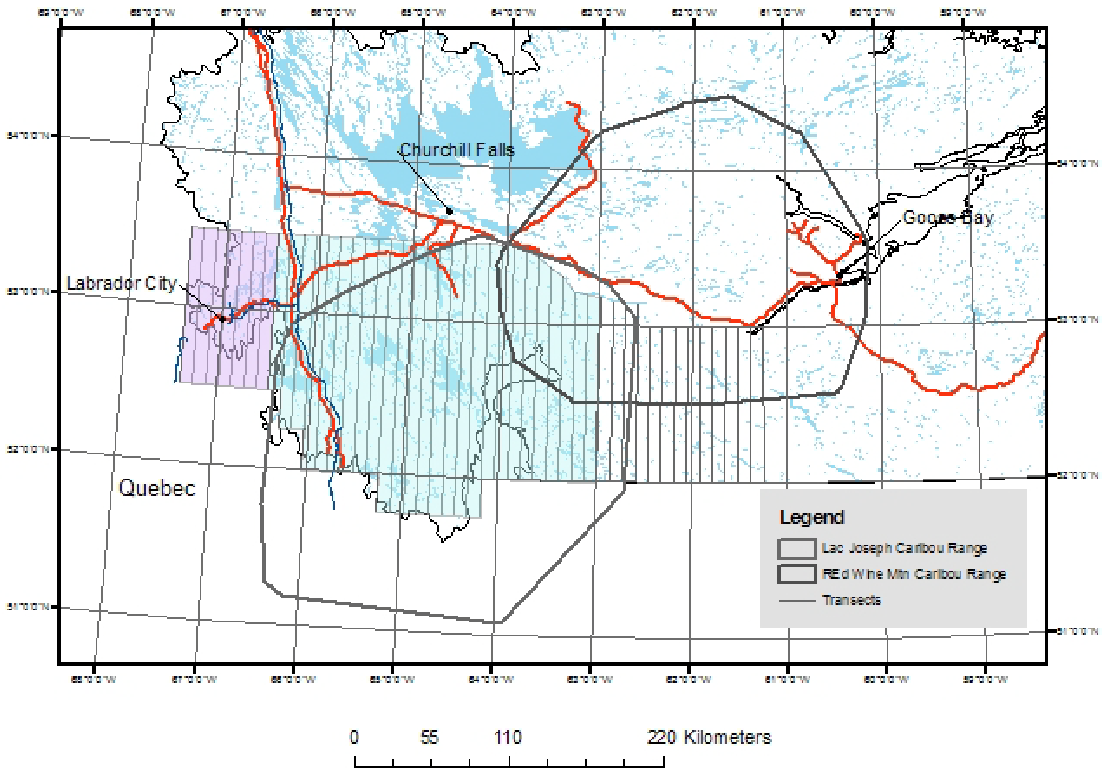

Figure 1: Flight lines and survey strata and extent in relation to LJ and RWM herd ranges for a systematic aerial survey of forest-dwelling sedentary caribou in south central Labrador, Canada.

transects that had already been flown was conveyed to a capture team which deployed a total of 12 new satellite collars. Observations of moose were recorded and georeferenced, and all moose were classified by age as adult or calf. Incidental observations of single or multiple wolves or their kills were also recorded.

Population Estimates

I used Jolly's (1969) Method 2 to calculate a population estimate of caribou in the surveyed area based on observations from unequal sized transects. It is a ratio estimator which calculates the density of caribou for each transect and then extrapolates it across the stratum using the equations:

1) $\check{R} = \sum y_i / \sum z_i$

where $\check{R}$ equals the estimated density, y_i the total animals counted and z_i the total area searched and

2) $\hat{Y} = \check{R} * Z$

where Ŷ equals the estimated population size and Z the stratum area. The software Aerial Survey Methods (Krebs 2003, version 6.1.1) was used for all calculations of population estimates, variance, and confidence intervals for each stratum.

Determining Trends in Abundance for Lac Joseph Caribou

Different survey extents and the use of a mark-recapture population estimator for the 2000 survey (IEMR 2002 unpublished report) initially precluded a direct comparison of population sizes. Assuming a population size in the order of 1000 individuals, and a desired coefficient of variation of no greater than 0.25 (corresponding to ± 50% of the population estimate) a sample size of at least 33 marked animals would have been necessary (Krebs p. 190) in order to use the Joint hypergeometric maximum likelihood estimator (JHMLE) as for the 2000 survey. Since only 12 animals were fitted with radio collars during March 2009, and because the survey involved use of more than 30 transects, the Jolly (1969) ratio estimator was deemed to be a more suitable estimator. As the 2000 census included a reconnaissance flight using the same strip widths (500m each side) and sampling intensity within the LJC range, and because the majority of caribou observations from the 2000 census occurred in the overlapping survey extent (IEMR 2002 unpublished report WD unpublished data), it is possible to calculate population size for the overlapping survey extents using the ratio estimator for the years 2000 and 2009 respectively, and to use these as a basis for an evaluation of population trends.

My approach was to determine the area of overlap between the 2000 and 2009 surveys, clip all transects for both surveys to the overlapping survey extent, restrict all observations to those within the new survey extent and finally to calculate density and population size for each of the two survey years. In addition, I postulated that if the LJC population was stable or increasing during the interval between surveys, the total number of caribou observed (as expressed in the minimum count) during the survey should be higher for 2009; that estimated densities and population size should be the same or higher for 2009.

Results

Density and Distribution

A total of 104 hours were flown to complete the systematic strip transect survey during 9 days between March 2 and March 26, 2009 (Appendix A, B). Most surveys occurred between March 2 and March 10. A total of 349 caribou were observed on and off transect over a total 6882 survey kilometers (Appendix C). Caribou were not evenly distributed throughout the survey area; fewer caribou than expected (as a function of proportion of the survey area) occurred in both the low density stratum, and the high density stratum contained almost 92% of all observations ($P < 0.0005$, $\alpha = 0.99$) (Table 1).

The highest densities of caribou occurred within the range of the Lac Joseph population at 0.03 caribou km^2 while densities in the other stratums were 0.004 (western) and 0.008 (Eastern/Southern RWM) caribou km^2 (Table 2). Most observations occurred within a region

Table 1: Observed distribution of caribou observations among stratum relative to the number expected assuming abundance was a function of land area within each stratum. Animals observed within and outside the strip transects during the survey were used in these comparisons. Expected values are calculated based on a total of 349 observations and a survey area of 60 000 km^2.

Stratum	**Proportion of Study Area**	**Expected Number of Observations**	**Total Number of Animals Observed**	**Percent Observations in Stratum**
Eastern (MD)	22.8	80	12	3.4
Central (HD)	65.4	228	321	91.9
Western (LD)	11.8	41	16	4.5
TOTAL	**100**	**349**	**349**	

Table 2: Observations of caribou summarized by survey stratum.

Stratum	**Cumulative Distance**	**Number of Transects**	**On Transect Observations**	**Off Transect Observations**	**Density (Caribou/km^2)**
Eastern (Southern RWM)	1688	14	12	0	0.008
Central (LJC Range, High Density)	4282	25	130	191	0.030
Western	912	8	3	13	0.004
TOTAL	**6882**	**47**	**145**	**204**	

centered around the Ashuanipi Lake, and south of Lac Joseph and Atikonak Lake. Densities declined with latitude in the Central stratum; only one group was observed north of the 53^o parallel, (Figure 2). As a result, it is likely that densities for this central stratum are underestimated. Only two groups were observed in the western stratum and both were in close proximity to the central, high density stratum suggesting that caribou densities in this portion of the range are quite low, and since this region corresponds to the western limit of the LJ caribou range, that this range boundary is reasonably accurate. In contrast, more than 21 observations of single or multiple moose occurred within this region. Caribou distribution in the Eastern Stratum was limited to a region just west of Dominion Lake. Interestingly, no caribou were observed off-transect within this region suggesting that the distribution and density of caribou outside the Dominion Lake area within the survey extent is limited. This (low density) stratum also contained the smallest number of caribou overall. However, this stratum does not include the Lac Fourmont area which includes the Joir River subpopulation associated with the Mealy Mountain herd. Moose were distributed throughout this stratum with the exception of a region in the southwest in the Romaine Mountains, with 30 separate observations of single or multiple animals (Figure 2). A total of 186 separate observations of single or multiple moose were made while flying transects. The majority of these occurred south of the latitutude 52^0 N 30', and in the western stratum near Labrador City.

Caribou were distributed over 30 groups, and distribution of caribou among groups was non-normal (Figure 3). Group sizes ranged from 1 to 47, with a mean size of 11.6 and a standard error of 2.02. The median value was 9, and the 75th percentile of all observations was 16. While the majority of all groups contained 10 or fewer animals, two large groups in excess of 40 animals were observed. No group sizes over 13 were observed in either low density stratum.

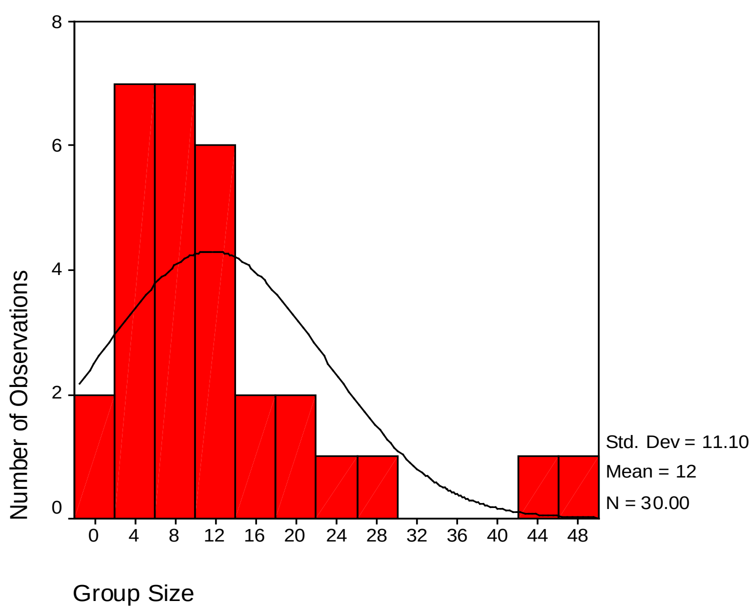

Figure 3: Frequency distribution of caribou group size during aerial surveys of central and southern Labrador during March 2009. Caribou observed within and outside the strip transects during the survey are shown.

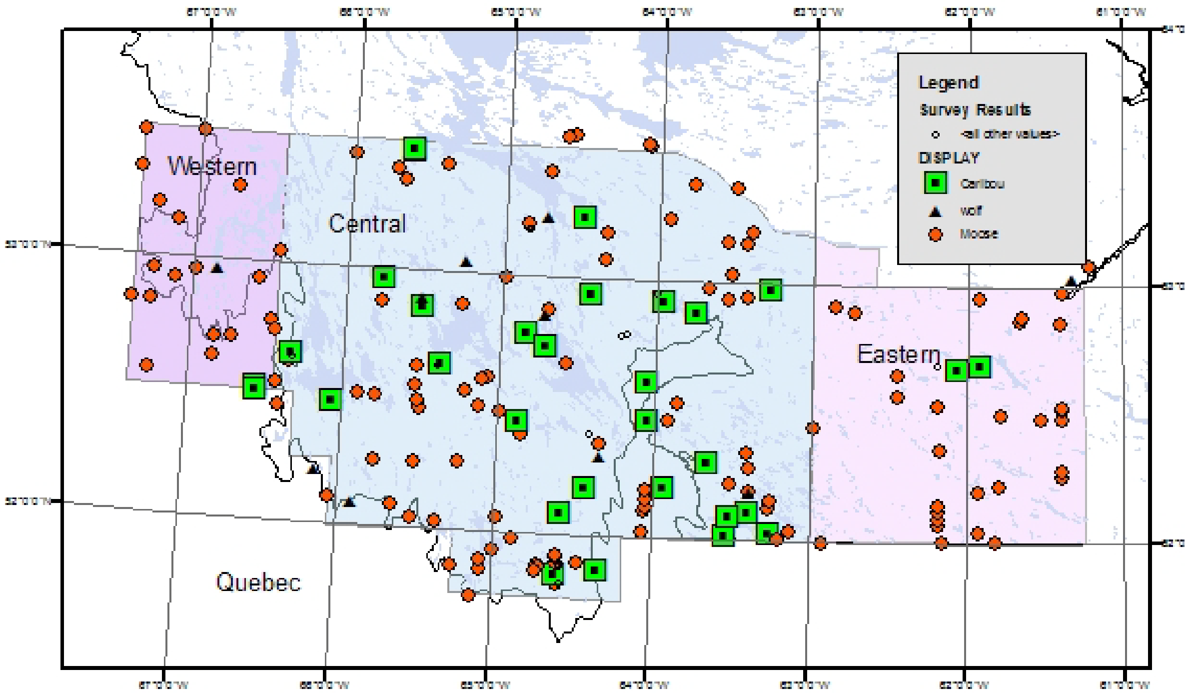

Figure 2: Distribution of caribou, moose and wolf observation summarized by stratum during an aerial stratified strip transect survey. Each observation may correspond to one or more animals.

Table 3: Group size summarized by survey stratum shown in relation to stratum densities.

Stratum	Density (caribou km^2)	Mean Size (± SE)	N
Eastern (LD)	0.008	6 (4)	2
Central (HD)	0.030	12.4 (2.4)	25
Western (LD)	0.004	8 (5)	2

Group sizes were larger in the central, (high density) stratum and larger group sizes were associated with higher caribou densities, though this difference is not statistically significant given the large range in group sizes in each stratum (Table 3).

A total of 79 calves were observed during the census. Calves were concentrated in the central stratum associated with the Lac Joseph caribou herd range (Table 4). Of 22 groups greater than 2 caribou, only 4 did not contain calves within this stratum, and all of these groups were exclusively composed of stags. As adult caribou in mixed groups were not always classified by gender, it is not possible to calculate calf:cow ratios. However, the proportion of calves, which can be used as an index of calf recruitment, was calculated for each stratum and is given in Table 4. The proportion of calves within each stratum ranged from 9% (Eastern) to 18% (Western) in the low densities stratums, to 31% in the Central high density stratum. These results indicate a positive relationship between density, group size and calf recruitment within this stratum.

Table 4: Calf recruitment summarized by survey stratum and density for a survey conducted during March 2009. Caribou observed within and outside the strip transects during the survey are shown (n = 349).

Stratum	Cumulative Distance	Adults	Calves	Density (caribou km^2)	% Calves
Eastern	1688	12	1	0.008	9.1
Central (HD)	4282	321	74	0.030	31.4
Western	912	16	3	0.004	18.7
TOTAL	**6882**	**145**	**204**		**30.1**

Population Estimates

Based on the Jolly (1969) ratio estimator for unequal length transects, Method 2 (sampling without replacement), 1414 (± 616) caribou occur throughout the survey extent (Table 5). The majority of animals occurred in the central, high density stratum, in which I estimated 1282 caribou (± 620). The coefficient of variation (CV = 0.25) for the survey area as a whole is acceptable given the sampling intensity, and is within the range typically reported for estimates of abundance based on line transect surveys. The eastern stratum contained 107 (± 141) caribou, and only 25 (± 41) caribou were estimated for the western stratum. Given the small number of caribou in both low density stratums and the fact that observations were clustered, population estimates for these regions are highly variable (CV > 0.8), and likely represent overestimates. All estimates include calves.

While the use of a helicopter, relatively slow survey speed and narrow transect width likely resulted in a low number of missed animals, I applied a correction factor of 10%, the lower level of Bergerud's (1963) recommendation for Labrador, to all estimates. While the median distance for all observations was 485m, caribou were routinely observed at distances of 500m to 800m (64th percentile), suggesting that visibility was good and that tracks and animals were readily seen, and that a correction factor of 10% is adequate.

Table 5: Analysis of data from an aerial survey of caribou in central and southern Labrador in March 2009. Population estimates and associated variance and confidence intervals were calculated after Jolly (1969). A correction factor of 1.1 has been applied to all estimates.

Stratum	Area (km^2)	Population Estimate	90% Confidence Interval	Variance	Coefficient of Variation	Sampling Intensity (%)
Eastern	13643	107	±141	6361	0.81	11.8
Central (HD)	38 980	1282	±620	131 548	0.30	11.0
Western	7022	25	±41	470	0.95	12.6
TOTAL		1414	±616	129 999	0.25	

Trends in Abundance for the Lac Joseph Population

Survey extents from 2000, and 2009 were compared and an overlapping survey extent calculated using ArcGIS. The resulting region was an area of 35 242 km^2 (Figure 4). During the 2000 census, transects within the high density stratum (which, as in the 2009 census, corresponded with the likely range of the LJ caribou population) were flown with a spacing of 10 km, an analogous sampling intensity as the one used in 2009. While the 2000 survey extended further south into Quebec, 93 % (179 of 192) of on-transect observations used in the 2000 population estimate occurred within the overlapping survey extent (IEMR 2002 unpublished report). Similarly, 85% (110 of 130 see Table 2) of all on-transect caribou observations used in the 2009 population estimate occurred within the overlapping area.

Table 6: A comparison of changes in density and abundance for the Lac Joseph caribou herd range within Labrador between 2000 and 2009. Estimates are calculated after Jolly (1969) Method Two and include a correction factor of 10%. The minimum count includes all (on and off transect) caribou observations except those observed during ferries.

Survey Year	Area (km^2)	Density	Minimum count	Population Estimate	90% Confidence Interval	Variance	Sampling Intensity (%)
2000	35 242	0.052	371	2028	±953	310 485	9.6
2009	35 242	0.027	210	1047	±506	88 151	11.6
% change				-51.6			

A total of 25 transects from the 2000 census occurred within the overlapping survey extent. This region included 3671 km of survey transects, and a total of 192 on-transect observations, with a total of 371 caribou observed. During 2009, 28 transects were flown over 4072 km within the overlapping extent. A total of 110 on-transect observations were made and the minimum count for the survey area was 210 caribou (Table 6). The population estimate for 2000, including a correction factor of 1.1 and 90% confidence intervals, was 2028 (± 953) and 1047 (± 506) during 2009 (Table 6). Results suggest abundance of caribou throughout the Labrador portion of the Lac Joseph caribou range has declined substantially between 2000 and 2009.

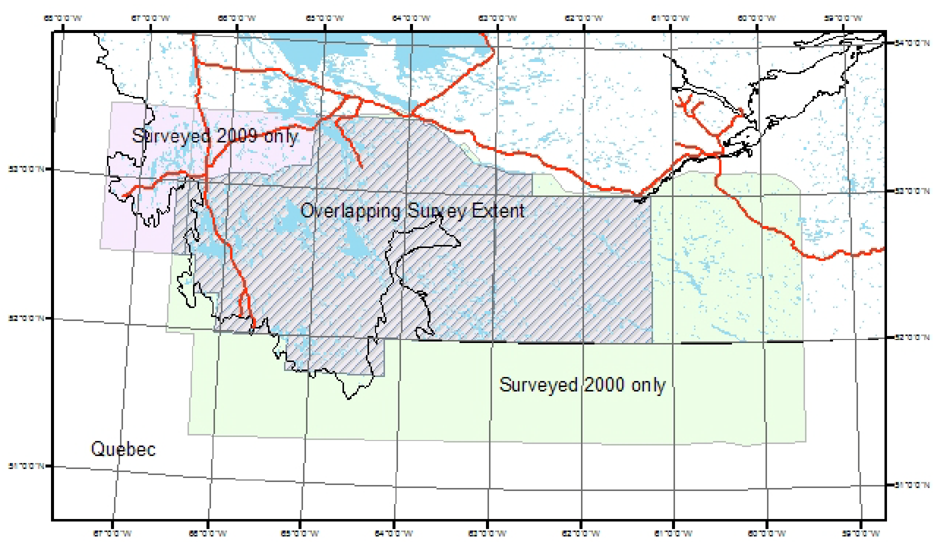

Figure 4: A comparison of survey extents during the 2000 and 2009 caribou censuses, showing the overlapping extents within which population estimates were calculated and compared. Note that 93% of on-transect observations during 2000, and 86% during 2009, occurred within this region.

Discussion

Survey results indicate that while caribou occur throughout central and southern Labrador, they are concentrated between 63° and 66° 30' West and between 51° 30'N and 53° N. This region corresponds fully to the area currently described as the Lac Joseph caribou range. The (high density) stratum corresponding to the herd range comprised 65% of the total survey area yet contained 92% of all caribou observations. Only 25 of the 349 total caribou observed occurred outside of the high density stratum associated with the range of the LJC herd. The first was a group of 10 animals and a cow calf pair, in the vicinity of Dominion Lake, group of caribou whose movements and range use have been studied for several years and are thought to be a subpopulation of the Red Wine Mountain population. Radio-telemetry data suggest that there is little exchange between caribou residing in this region and those north of the Churchill River, but that east-west movements of caribou between the Lac Joseph range and Dominion Lake, and between Dominion Lake and the Lac Fourmont area, are not infrequent (WD unpublished data). The second was a group of 13 animals seen west of Ashuanipi Lake on a transect immediately adjacent to the western-most boundary of the high density stratum. Collectively the distribution of caribou suggests that presence is concentrated within known ranges (e.g. the Lac Joseph, Dominion Lake). For example, caribou densities within the stratum corresponding to the LJ range were 4 and 7, respectively, times higher than those in adjacent areas outside the known range of this population. The reported density of 0.03 caribou per km^2 is comparable to that observed in prior surveys (summarized in Table 2 Schmelzer et al 2004), but half of that estimated for the same region (overlapping survey extent) during 2000. Distribution of groups was comparable to that documented for the 2000 census; groups were concentrated between 51^0 30' N and 53^0 N and between 63° and 66° 30' West. To the East, the only location in which groups were seen in 2000 was in the Dominion Lake area, the same as for the 2009 survey. Our results also suggest that caribou abundance south of the Churchill River within the survey extent, particularly in the Dominion Lake area, has not increased over the past 10 years. Increased numbers of locations by radio-collared animals within this region either reflects a change in the range use of individual caribou or a collaring bias toward caribou within the southern portion of the RWM range or (e.g. it is not a function of higher densities of caribou within that region).

During the 2000 survey, a cluster of caribou groups was observed in the extreme Southwestern portion of the study area, near the Caopascho and Moise Rivers (IEMR/WD unpublished data). These observations, which included 3 groups of caribou ranging from 6 to 27 animals within 5 kilometers of one another, and another group of 27 animals within 15 kilometers, were the only observations of caribou made outside the overlapping survey extent in the Lac Joseph region. Because each of these groups were seen off-transect, they did not influence the 2000 population estimate, nor the evaluation of trends between years. However limited radio-collar information (< 2 animals) suggests these caribou are associated with the Labrador portion of the Lac Joseph range and are worthy of further inquiry in the future, in particular in light of the proposed Romaine River hydro-electric development which includes this region. It also suggests that the population estimate for Lac Joseph caribou across their total range (which includes Québec) would be larger, though only modestly so given that the bulk of this population appears to occur within Labrador.

Relationship between Group Size, Density, and Calf Recruitment

Calf recruitment and group size were positively associated with population density. For example, group size within the high density stratum was almost double (12.4) that in either low density stratum. Similarly, calf recruitment was highest within the high density stratum and at 31% suggests that the population here is productive relative to the Dominion Lake area and the western stratum. Typical group size was 9 caribou, the same value as for the 2000 census (full extent (WD/IEMR unpublished data), though a small number of large groups (> 40) were seen during both 2000 and 2009. These results support the depiction that while caribou distribution across south-central Labrador is continuous, local population boundaries can be defined by higher densities, larger group sizes and greater calf recruitment. As caribou distribution is dynamic over time and space, it is possible that aerial surveys which summarize the latter metrics can be used as a starting point for delineation of local populations prior to the initiation of a telemetry program in landscape which allow for continuous distribution of caribou. The positive association between density, group size, and recruitment also shed insight into the mechanistic factors which regulate population growth in caribou populations under natural conditions.

An Overview of the Distribution and Occurrence of Moose

Caribou and moose observations generally overlapped throughout the survey extent; however there were several regions in which moose were the dominant ungulate, and/or no caribou were observed. For example, only moose were seen within the southern extent of the eastern low density stratum south of Dominion lake (south of approximately 51^{o} 30'N; Figure 2). Similarly, predominantly moose were seen the western (low density) stratum, a region that historically contained Woodland caribou (Schmelzer et al 2004). There were two regions in particular in which caribou groups and moose were seen in close proximity to one another, and both were near the Labrador-Quebec border, the southern limit of the survey area: the first near Domogaya Lake, and the second near Mercier Lake. It is possible that moose densities have increased since 2000. For example, Jung et al (2009) reported observing 143 moose throughout the 2000 survey extent, while 186 separate observations of one or more animals were made over a smaller survey extent in 2009. Moose densities based on the 2000 survey ranged from 1.6 to 3.0 moose per 100 km2 (Jung et al 2009), and moose were reported to be widely distributed below 54^{0} N. In their review of changing moose densities in two moose management areas, Chubbs and Schaefer reported moose densities of 8.5 to 16.8 moose km^{2}, and suggested the population was growing by 10%. Calf cow ratios reported in both prior studies also suggest the population may be growing as values were relatively high at 0.3 to 0.6 in 1994 (Chubbs and Schaefer 1997) and 0.8 during 2000 (Jung et al 2009). Further evaluation of moose densities throughout the survey area is warranted given that the southern limit of continuous caribou distribution is thought to correspond to the northern limit of high moose densities (Bergerud et al 2008). For example, densities of moose along 10 km segments of transect lines could be calculated. If these values exceed 0.10 km^{2}, it is likely that wolf densities are in the range of $7/1000km^{2}$, the 'stabilizing' threshold at which wolf predation is thought to lead to a mortality rate which exceeds recruitment (Bergerud et al 2008; Bergerud and Elliot 1986). It is unlikely that this threshold would be reached throughout the survey area as a whole, although possible that regions within the southern extent below 52^{0} 30 N may meet this criteria.

Trends in Abundance for the Lac Joseph Population

In order to explicitly compare (e.g. use the same population estimator and the same survey technique) population trends of the LJ herd between 2000 and 2009, this study reinterpreted raw data from the 2000 census. This re-analysis indicates that the estimate previously provided for 2000 (1100) was conservative, a possibility also raised by the report author (IEMR 2002 unpublished report). The authors of this report indicated that 'we observed more than twice the number of caribou than any prior survey" and also indicated that 'several large groups of caribou that were not encountered during the survey [were observed] during routine radio-collaring efforts after the survey had been completed'. In addition, the number of marked (radio-collared) animals during 2000 (16) was below the minimum sample size required for an estimated population size of 1000 individuals (which would have required 33 marked individuals) for the mark-recapture estimator used (Krebs, 1999). My reanalysis based on the transect data collected and using the Jolly (1969) ratio estimator for unequal length transects, Method 2 (sampling without replacement) indicates that 2410 (90% confidence interval 1367 to 3453) occurred within the 2000 survey extent. Note that this result, while it indicates the population was higher than initially reported in 2000, does not change the principle findings that caribou abundance and densities had, at the very least, doubled since the last prior survey conducted (St. Martin and Théberge 1986).

The author (unknown) of the 2000 report should be commended for retaining the raw data which permitted the re-analysis and the explicit assessment of population trends within the Labrador region between 2000 and 2009. A comparison of density and abundance of caribou within the overlapping survey extent (which coincides with the Labrador portion of the LJ caribou range) indicate these have declined significantly since 2000. Caribou densities are almost half of what they were in 2000, and this is corroborated by a 57% decline in the total number of caribou observed, in spite of slightly higher survey intensity during 2009. The population estimate within the overlapping survey extent in 2009, at 1047 caribou, is half of that estimated using the same methodology and estimator for 2000. Given that this estimate does not refer to the LJ range in its entirety (e.g. the portion within Quebec is excluded), the possibility that caribou occur outside the survey extent needs to be examined. The large majority (93% in 2000; 85% in 2009) of all on-transect caribou observations used in the population estimate for both 2000 and 2009 occurred within the overlapping survey extent, which indicates that the region used for comparison of trends between years contained the bulk of caribou associated with the LJ population during both years. During 2000, 4 groups of caribou ranging in size between 17 and 27 animals were seen off-transect in the extreme SW portion of the survey extent. Finally, analysis of radio-collared individuals does not suggest that a movement or migration of individuals outside the study region (IFWD/IEMR unpublished data) between 2000 and 2009 has occurred. Finally, none of the criteria associated with a stable or increasing population set at the outset of this study were met: density , at 0.027 caribou, was half that observed over the same region in 2000, and the total number of caribou seen during 2009 was only 57% of that observed during the 2000 census.

Historical Overview of Population Surveys

Uncertainty in census results and differing methodologies between censuses make it difficult to describe historical population trends in this herd with any accuracy. Range use and survey results for the Lac Joseph population have been summarized and reported in Schmelzer et al (2004, Table 2) and by Bergerud et al 2008. Briefly, historical accounts suggest that the Lac Joseph population began to decline during the 1860s (Folinsbee 1979), and continued to do so until at least the late 1890s (Banfield and Tener 1958). Counts between 1954 and 1972 suggest a stable population in the range of 4500 to 6000 individuals and a density of approximately 0.06 caribou /km^2 (Pilgrim 1981 summarized in Bergerud et al 2008). By 1977 a strip transect aerial survey of the winter range resulted in an estimate of 1317 caribou (1900 if using Bergerud's interpretation) with an overall density of 0.03 caribou/ km^2 (Folinsbee 1978 reinterpreted by Bergerud 1994). The population continued to decline throughout the 1980s and a 1986 survey estimated only 445 (± 398) animals, based on coverage of the entire herd range (Saint-Martin and Théberge 1986). No formal surveys were conducted between 1986 and 2000, but both the original reported estimate and my reanalysis suggest the population recovered to levels observed during the early 1970s during that time. A study by St. Martin (1987) indicated that the harmonic mean of survival rates of LJ caribou between 1984 and 1987 was 0.95, a level consistent with a growing population. In comparison, mean survival rate of 60 adult females radio-collared between 1998 and 2009 was 0.84, a significant decline from survival in the previous decade ($Z = 1.61$ $p < 0.04$; Schmelzer et al 2010). Consequently, in the absence of continuously high calf recruitment and in the face of illegal hunting, the decline observed between 2000 and 2009 is not completely unexpected. Deaths from hunting accounted for 30% of all known mortalities in the Lac Joseph population between 1998 and 2009, and mean adult survival increased from 0.84 to 0.89 in the absence of hunting-related mortality (Schmelzer et al 2010). In fact, demographic schedules for this herd (mean adult survival > 0.85 and calf recruitment > 20%) suggest that it has the capability to increase in the absence of hunting and increases in other sources of mortality.

Recommendations

1. Survey area:
   - i) Future surveys do not need to include areas west of 66^0 30' N, as no caribou (but many moose) were observed in this region.
   - ii) Further refinements can be made to survey stratum on the basis of caribou distributions during 2000 and 2009: a moderate density stratum could be constructed by removing the region north of 53^0 N from the former high density stratum. This region contained more caribou than both the low density stratum, but fewer than the remaining extent of the new high density stratum.
   - iii) The remaining extent (see above) of the high density stratum should extend south to 51^0 40' N, using the same eastern and western bounds.
   - iv) A targeted survey of the Riveriere Caopacho and Moise area could be undertaken in collaboration with Quebec, perhaps with a small telemetry program to further assess the relationship between caribou located here, and the bulk of the Lac Joseph population. The same is true for caribou being studied on the Romaine River area to the south of the 2009 survey extent.

2. An explicit correction fact for the Lac Joseph region should be developed.
3. Caribou were routinely observed outside of the 500 m strip width; in fact this distance represented only the 53rd percentile of the distribution of all observations. I recommend extending the strip width to 800m (64th percentile), as used for surveys in other subarctic areas with similar terrain.
4. I recommend exploring the use of a distance sampling method. The sophistication of devices that can accurately measure the distance between the observer and the caribou has increased, and provided this method proves reliable in test areas, could help to address the problems that clumped distribution and the number of off-transect observations pose to precision of estimates derived using traditional strip transect surveys.
5. Explicitly calculate moose densities along 10 km segments of the survey transects to evaluate changes in density that may have occurred over time, and to provide a baseline for future assessments.

Summary

These study indicates that caribou are distributed throughout south central Labrador, and that higher densities and larger groups occur within the Lac Joseph population range. Distribution of caribou throughout Labrador was similar to that reported for the 2000 census. A reinterpretation of the raw data from the 2000 census, which was collected using the same methodology as the 2009 census, indicates that 2410 caribou (1367-3453) occurred within the 2000 survey extent, 2028 (±953) within the region surveyed during both 2000 and 2009. In comparison, only 1047 (± 506) were estimated for the same area in 2009, indicating a significant population decline over the past 9 years. Mean densities of 0.03 caribou per km^2 are comparable to those observed in prior surveys but half of that estimated for the overlapping survey extent in 2000. A companion study indicates that adult survival rates have declined by 11% (0.95 to 0.84) between the mid 1980s and the present, and that 6% of this decline is associated with hunting-related mortality. However, demographic schedules for the Lac Joseph population suggest that it has the capability to increase in the absence of hunting and increases in other sources of mortality, including wolf predation.

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Literature Cited

Banfield, A.W.F. and J.S. Tener. 1958. A preliminary study of the Ungava caribou. *J Mammal*, **39: 560-573**.

Bergerud, A.T. 1988. Caribou, wolves, and man. *Trends Ecol Evol* **3:68-72**

Bergerud, A.T. 1994. The abundance and distribution of sedentary caribou in the Ungava. Newfoundland-Labrador Wildlife Division, Internal Report.

Bergerud, A.T. and J.P. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. *Can J Zool*, **64: 1515-1529**

Bergerud, A.T., S. N. Luttich, and L. Camps. 2008. **The Return of Caribou to Ungava**. McGill-Queen's University Press, Montreal, QU

Boulet M., S. Couturier , S.D. Coˆte´, R.D. Otto, L. Bernatchez L. 2007. Integrative use of spatial, genetic and demographic analyses for investigating genetic connectivity between migratory, montane,and resident caribou herds. *Mol Ecol* **16:4223–4240**

Caughley, G. 1977. Sampling in aerial surveys. *J Wildlife Manage* **41: 605-616**.

Chubbs, T.E and Schaefer J. A. 1997. Population growth of moose, *Alces alces*, in Labrador. *Can Field Nat* **111(2): 238-242**.

Courtois, R, L. Bernatchez, J. P. Ouellet, and L. Breton. 2003. Significance of caribou (Rangifer tarandus) ecotypes from a molecular genetics viewpoint. *Conserv Genet* **4:393-404**.

Couturier, S., R.D. Otto**,** S.D. Côté, G. Luther and S.P. Mahoney. 2010. Body size variations in caribou ecotypes and relationships with demography. *J Wildlife Manage* **74: 395-404**.

Folinsbee, J. 1979. Past and present distribution and abundance of caribou, *Rangifer tarandus,* in Southwestern Labrador and the adjacent area of Québec. Newfoundland- Labrador Wildlife Division, Internal Field Report.

Institute for Environmental Monitoring and Research (IEMR). 2002. An ecological study of Woodland caribou of the Lac Joseph herd and their spatial distribution in relation to the military training area of Quebec-Labrador (Draft). Unpublished report.

Jolly, G.M**.** 1969. Sampling methods for aerial census of wildlife populations. *E Afr For J* **34: 46-49**.

Jung, T.S., T.E. Chubbs, C.G. Jones, F.R. Phillips and R.D. Otto. 2009. Winter habitat associations of a low-density moose (*Alces americanus*) population in central Labrador. *Northeastern Naturalist*: **16(3): 471-480**.

Krebs, C.J. 1999. Ecological Methodology-2nd ed., A. Wesley Longman, NY, USA.

Schmelzer, I. & J. Brazil, T. Chubbs, S. French, B. Hearn, R. Jeffery, L, LeDrew, H. Martin, A.,McNeill, R., Nuna, R. Otto, F. Phillips, G. Mitchell, G. Pittman, N. Simon, G.Yetman. 2004. Recovery strategy for three Woodland caribou herds *(Rangifer tarandus caribou; Boreal population)* in Labrador. Department of Environment and Conservation, Government of Newfoundland and Labrador, Corner Brook.

Schmelzer, I. Jones, C and Rasuilis, A. 2010. Ecology of Woodland Caribou in Labrador: long-term monitoring in an undisturbed landscape. Abstract for Oral Presentation: 24th International Congress for Conservation Biology, Edmonton, Canada

Saint-Martin, G. 1987. The ecology of eastern-central Quebec and western Labrador caribou populations as it relates to proposed road development. MSc. Thesis, University of Waterloo, Waterloo, Ontario.

Saint-Martin, G. and J.B. Théberge. 1986. Caribou and other wildlife, Ross Bay Junction-Churchill Falls tote Road. Environmental Impact Assessment. Government of Newfoundland and Labrador, Department of Transport. Unpublished Report.

Appendix A: Estimated requirements for flight time for Labrador Caribou Survey: based on a flying speed of 100 km/hr during the survey and approximately 150 km/hr while ferrying to transect end points. Survey transects are spaced 8' apart (approximately 10 km). Available flight time and sponsoring agency are itemized in the second table.

Available Air Time	*IEMR*	*WD*	Sum
RWM	64		64
RWM		30	30
LJCH	40		40
GRAND TOTAL			**134**

Available flight time and funding agency:

	Distance (km)	Survey: hours required	Collaring hours required	TOTAL Hours Required
Eastern/central portion[1]	5000	50		
Western Portion[2]	3000	30		
Ferry Time (30%)		16		
Joir River collar Deployments (5)	NA		8	
Other collars (15-20)	NA		30	
TOTAL		96	36	**132**

Appendix B: An itemized overview of Wildlife Division (Department of Environment and Conservation—project lead) financial and logistical contributions to the survey.

ITEM	DESCRIPTION	AMOUNT		EXPENDITURE
30 Hours of Helicopter time	30 hours of airtime using the contract Long Ranger helicopter at Universal $1700/hr plus fuel	$55 000		**$55 000**
Place Remote Fuel Cache	Use Twin Otter to place 12 drums of fuel at remote Fuel Cache (fuel $500/drum; flight $7000)	$13000		**$13 000**
Fuel	20 Drums, $500 each	$10 000		**$10 000**
			TOTAL CASH	**$78 000**
	In Kind			
SALARY		Hours Spent	Includes, planning, logistics, survey	
Project Coordinator (IS)	5 days November, 10 days December,8 days January, 15 days February, 4 days March	336		**$8400**
Other Wildlife Staff	I technician, 25 days	200		**$5000**
Conservation Officer Support	2 officers 15 days for survey, 2 officers 8 days for fuel cache drops	368		**$9200**
GIS support	Mapping flight tracks	8		**$200**
Project Coordinator	20 days	160	Data compilation, analysis, presentation	**$4000**
			$25/hr wage used	
Meals and accommodation for field crew	Conservation officer 46 days total, Technician 25 days total Several overnight stays in Churchill Falls and Labrador City			**$2000**
Use of Trucks and fuel for placement of fuel caches	10 days/200 day			**$2000**
			TOTAL IN KIND	**$106,400**
		TOTAL FUNDS		**$184,400**

Appendix C: Caribou observed on and off transect during a systematic stratified aerial survey in south central Labrador during March 2 -26, 2009.

Transect	Distance	Caribou on transect*	Caribou off transect**	Group Size	Strata
1	117.0	0			1
2	117.0	0			1
3	117.0	0			1
4	117.0	0			1
5	117.0	0			1
6	117.0	2		2	1
7	117.0	10		10	1
8	117.0	0			1
9	117.0	0			1
10	117.0	0			1
11	128.0	0			1
12	129.0	0			1
13	129.0	0			1
14	132.0	0			1
15	134.0	0			2
16	134.0	22		18	2
16				4	2
17	147.0	18		18	2
18	152.0	3		3	2
18			8	8	2
19	160.0	16		16	2
20	165.0	0	3	2	2
21	169.0	1		1	2
			9	9	2
22	169.0	10		10	2
23	196.0	0			2
24	196.0	0	16	16	2
25	196.0	2		2	2
25			10	10	2
25			26	26	2
26	196.0	7		7	2
26		22		22	2
27	196.0	2		2	2
28	196.0	7		7	2
28		0	43	43	2
29	196.0	0			2
30	196.0	0			2
31	196.0	0			2
32	168.0	9		9	2

33	168.0	1		1	2
34	168.0	0	9	9	2
34		0	12	12	2
35	168.0	0	8	8	2
36	168.0	0			2
37	168.0	10		10	2
38	140.0	0			2
39	140.0	0	47	47	2
40	114.0	0			3
41	114.0	3		3	3
41			13	13	3
42	114.0	0			3
43	114.0	0			3
44	114.0	0			3
45	114.0	0			3
46	114.0	0			3
47	114.0	0			3

* Observed < = 500m on either side of the aircraft
** > 500m away from aircraft (but not during a ferry)