DISTRIBUTION AND ABUNDANCE OF PEARY CARIBOU (*Rangifer tarandus pearyi*) ON LOUGHEED ISLAND, JULY 2016

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Summary

We flew a survey of Lougheed Island on July 28, 2016, as reconnaissance to find caribou groups for collection of fecal pellets. We encountered enough caribou groups to allow us to calculate a population estimate for the island, which had been last surveyed in 2007. We observed 61 caribou, 26 of which were on transect, during the flight. The estimate of 140±SE33 Peary caribou indicates a decline from the 2007 survey, which estimated 205-672 caribou on the island (95% CI, Jenkins et al. 2011). We did not see any muskoxen on Lougheed Island, but we did see 2 wolves last summer and wolf tracks this summer. Lougheed Island too remote to be regularly accessed for harvesting.

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Introduction

Peary caribou (*Rangifer tarandus pearyi*) are a small, light-coloured subspecies of caribou/reindeer inhabiting the Canadian Arctic Archipelago in the Northwest Territories and Nunavut from the Boothia Peninsula in the south to Ellesmere Island in the north. They are sympatric with muskoxen (*Ovibos moschatus*) over much of their range although diet, habitat preferences, and potentially interspecific interactions separate the two species at a finer scale (Resolute Bay Hunters and Trappers Association [HTA] and Iviq HTA, pers. comm.). Arctic wolves (*Canis lupus arctos*) occur at low densities throughout Peary caribou range, but the most significant cause of population-wide mortality appears to be irregular die-offs precipitated by severe winter weather and ground-fast ice that restricts access to forage (Miller et al 1975, Miller and Gunn 2003, Miller and Barry 2009).

Peary caribou have been surveyed infrequently and irregularly on the Canadian Arctic Archipelago since Tener's 1961 survey, which counted 232 caribou and calculated 4.2 caribou per square mile on Lougheed Island. This density was surprising for such a small, isolated island, but similar to western Mackenzie King Island, which was surveyed the same year (Tener 1963). Subsequent surveys indicated far lower densities of caribou, however - the most recent survey estimated 205-672 caribou on the island (95% CI, Jenkins et al. 2011).

Although there is no harvest currently reported of Peary caribou on Lougheed Island, there is some connectivity between the Findlay Group and the Bathurst Island Group, which is largely relied up on by Resolute for caribou harvesting, since the caribou population on Somerset and Prince of Wales islands has not yet recovered. Changes in distribution and abundance between Lougheed and Bathurst islands could indicate movements among the islands or a change in population across all islands.

Study Area

The survey area is predominantly polar desert and semi desert, with rolling topography, highest on the north of the island at 150 m, and a flat coastal plain in the south. Cushion forb barrens dominate the island, with some areas of graminoid-forb tundra, usually at <5% cover and <100 g/m^2 biomass, with isolated patches of 5-50% vegetation cover and biomass increases to 100-500 g/m^2 (Gould et al. 2003, Walker et al. 2005). Mean July temperatures are <3°C (Gould et al. 2003 and references therein).

Methods

Aerial Survey

To define the transect width, we marked survey aircraft wing struts following Norton-Griffiths (1978):

$$w = W\left(\frac{h}{H}\right)$$

where W is the strip width, H is the flight height, h is the observer height when the plane is on the ground and w is calculated, measured and marked on the ground to position wing strut marks. For this survey we only used one mark representing 500 m marked on the wing strut.

Four transects parallel to the long axis of the island were flown at 90 kts with a DeHavilland Twin Otter (Table 1). Weather was clear and sunny although fog banks were present offshore. Flight height was set at 152 m (500 ft) using a radar altimeter. We had one dedicated observer on each side, as well as a navigator/recorder. All observations were marked on a handheld Garmin Montana 650 global positioning system (GPS) unit, which also recorded the flight path every 15 seconds. Sex and age classification was limited, since the aircraft did not make multiple passes (to minimize disturbance), but adult/calf determination was straightforward for groups on transect. GPS tracks and waypoints were downloaded through DNR-GPS and saved in Garmin GPS eXchange Format and as ESRI shapefiles. Data was entered and manipulated in Microsoft Excel and ArcMAP (ESRI, Redlands, CA).

Table 1. Transects on Lougheed Island for a fixed-wing survey, July 28, 2016.

Transect	Length (km)	Lon (North)	Lat (North)	Lon (South)	Lat (South)
1	58.22	-105.5344	77.7193	-104.3511	77.1957
2	76.80	-105.8722	77.7620	-104.4662	77.1456
3	76.59	-106.0556	77.7399	-104.6470	77.1261
4	40.52	-105.6982	77.4915	-104.9597	77.1668

Analysis

Flights linking consecutive transects were removed for population analysis, although survey speed and height were maintained and all observations recorded as if on survey. Similarly, sections of transect crossing water were removed.

Although Jolly's (1969) Method II is widely used for population estimates from surveys, it is designed for a simple random design, rather than for a systematic survey of a patchy population. For comparison, population calculations following Jolly's Method II are provided in Appendix 4, along with calculations following a systematic stratified survey design (Cochran 1977). The muskoxen and caribou detected in this survey were patchily distributed and serially correlated, not randomly distributed. For systematic samples from serially correlated populations, estimates of uncertainty based on deviations from the sample mean are expected to be upwardly biased and influenced by the degree of serial correlation; high serial correlation implies that there is less random variation in the unsurveyed sections between systematically spaced transects than if serial correlation were low (Cochran 1977). Calculating uncertainty based on nearest-neighbor differences incorporates serial correlation, and the upward bias in the uncertainty is expected to be less than if it were calculated based on deviations from the sample mean. Nearest-neighbor methods have been used previously to calculate variance around survey estimates on the unweighted ratio estimate (Kingsley et al. 1981, Stirling et al. 1982, Kingsley et al. 1985, Anderson and Kingsley 2015).

The model for observations on a transect survey following Cochran (1977) is:

$$y_i = Rz_i + \varepsilon_i\sqrt{z_i}$$

Where y_i is the number of observations on transect ***i*** of area z_i, R is the mean density and error terms ε_i are independently and identically distributed. In this model, the variance of the error term is proportional to the area surveyed. The best estimate of the mean density $\hat{R}$ is:

$$\hat{R} = \frac{\sum_i y_i}{\sum_i z_i}$$

The error sum of squares, based on deviations from the sample mean, is given by:

$$\left(\sum_i \frac{{y_i}^2}{z_i}\right) - \frac{(\sum_i y_i)^2}{\sum_i z_i}$$

The finite-population corrected error variance of $\hat{R}$ is:

$$Var(\hat{R}) = \frac{(1-f)}{(n-1)\sum_i z_i}\left(\left(\sum_i \frac{{y_i}^2}{z_i}\right) - \frac{(\sum_i y_i)^2}{\sum_i z_i}\right)$$

Where f is the sampling fraction and n is the number of transects. The sampling fraction also provides the scaling factor for moving from a ratio (population density) to a population estimate. It is calculated as $(\sum z_i)/Z$, where Z is the study area and $\sum z_i$ is the area surveyed. The irregular study area boundaries mean that f varies from the 20% sampling fraction expected from a 1-km survey strip and 5-km transect spacing.

If we were to apply a model $y_i = Rz_i + \varepsilon_i$ instead, then the variance of the error term would be independent of z, so the variance would depend on the number of items in the sample, but not their total size. This would lead to a least squares estimate of R of $\sum zy \,/ \sum z^2$, rather than the more intuitive density definition and model for R presented above.

To incorporate serial correlation in the variance, we used a nearest-neighbor calculation, with the error sum of squares given by:

$$\sum_{i=1}^{n-1}\left(\frac{y_i^2}{z_i} + \frac{y_{i+1}^2}{z_{i+1}} - \frac{(y_i + y_{i+1})^2}{z_i + z_{i+1}}\right)$$

i.e. the sum of squared deviations from pairwise weighted mean densities. The nearest-neighbor error variance of $\hat{R}$ is:

$$Var(\hat{R}) = \frac{(1-f)}{(n-1)\sum_i z_i}\sum_{i=1}^{n-1}\left(\frac{y_i^2}{z_i} + \frac{y_{i+1}^2}{z_{i+1}} - \frac{(y_i + y_{i+1})^2}{z_i + z_{i+1}}\right)$$

Both variance calculations were applied to the Devon Island survey data. In addition, calculations for these strata based on Jolly's (1969) Method II and Cochran's (1977) systematic survey models are provided in the appendices for comparison. For the final estimate, we used the nearest neighbor variance. All distance measurements used North Pole Azimuthal Equidistant projection and area-dependent work used North Pole Lambert Azimuthal Equal Area, with central meridian at 88°W and latitude of origin at 76°N (centered over the study area for high precision).

Population growth rates were calculated following the exponential growth function, which approximates growth when populations are not limited by resources or competition (Johnson 1996):

$$N_t = N_0 e^{rt} \qquad \text{and} \qquad \lambda = e^r$$

Where N_t is the population size at time *t* and N_0 is the initial population size (taken here as the previous survey in 2008). The instantaneous rate of change is r, which is also represented as a constant ratio of population sizes, λ. When r >0 or λ >1, the population is increasing; when r <0 or λ <1 the population is decreasing. Values of r ~0 or λ ~1 suggest a stable population.

Results

We flew the survey on July 28, 2016 with 252 km on transect, equating to 18.5% coverage of Lougheed Island. The primary intent of the survey was to locate caribou groups for ground sampling efforts July 28-31, so Edmund Walker, Grosvenor, and Patterson islands were not covered. We saw 61 caribou (26 on transect) and no muskoxen. Although we saw no wolves during the survey, fresh tracks at the airstrip confirmed that they are still present on the island (2 wolves were seen on the south end of the island in July 2015). Spatial data presented in Figure 4 represents waypoints taken during the survey along transects and includes on- and off-transect sightings. Except for groups observed on the transect line, waypoints have error associated with the group's distance from the plane.

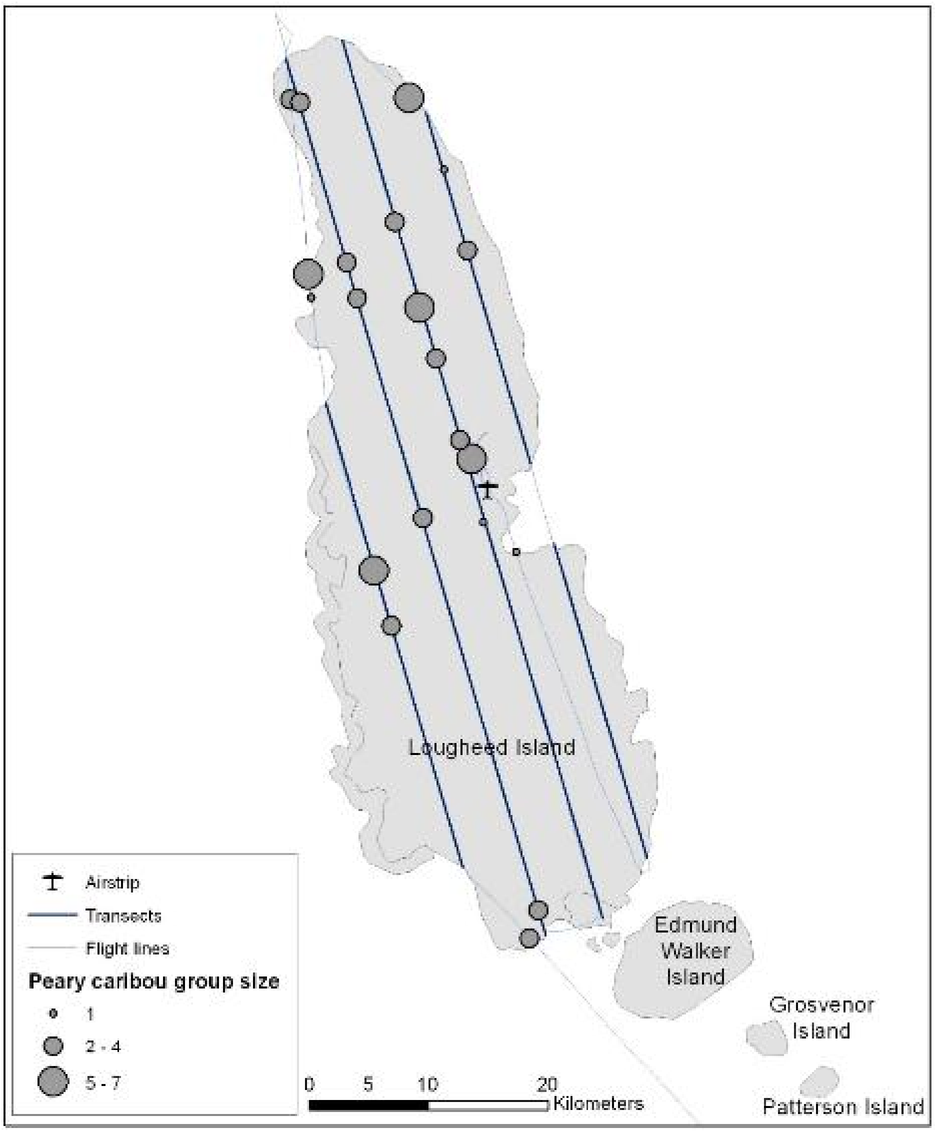

Figure 1. Observations of Peary caribou on Lougheed Island, July 2016, including observations on and off transect, and on ferry flights.

A population estimate was calculated for Peary caribou, but the few observations, limit the precision of the estimate. Population estimates and variances are presented in Table 2.

Table 2. Peary caribou population calculations Lougheed Island with variance calculated by nearest neighbor methods and by deviations from the sample mean.

	Stratum area Z (km^2)	Surveyed area z (km^2)	Count, y	Estimate, $\hat{Y}$	Density, $\hat{R}$ (per km^2)	Error Sum of Squares	Var ($\hat{Y}$)	SE	CV
Nearest-Neighbor Difference	1359.6	252.1	26	**140**	0.103	0.713	1064.78	32.63	0.232
Sample Mean Difference	1359.6	252.1	26	**140**	0.103	0.449	670.57	25.90	0.185

Caribou have declined since the last survey in 2007. Based on a population estimate of 140±SE33 in 2016 and 372 in 2007 (205-672, 95%CI; Jenkins et al. 2011), the instantaneous growth rate r is -0.11, and lambda λ is 0.90. More sophisticated analyses incorporating uncertainty in the estimates have not been undertaken.

Discussion

Previous surveys of Lougheed Island have used different survey platforms (Piper Super Cub and deHavilland Beaver, Tener 1963; Helio-courier, Gunn and Dragon 2002; Bell 206 helicopter, Jenkins et al. 2011; Twin Otter, this survey) with different coverage and at different times of the year (spring, Miller et al. 1977, Jenkins et al. 2011; summer, Tener 1961, Miller et al. 1977, Miller 1987, Gunn and Dragon 2002, this survey). In 1974 and 1985, only a few caribou were seen on the island. In 1997, the presence of 28±29 caribou carcasses suggested that a die-off had occurred on the island – weather-related die-offs had occurred in 1997 and for 3 years prior on the Bathurst Island Complex as well (Gunn and Dragon 2002).

Widespread weather-related die-offs recorded elsewhere in the Arctic Archipelago in the 1970s may have been responsible for the lack of caribou observed on the island in 1973 and 1974, either due to die-offs or movement off the island. Population densities equivalent to the 1961 survey have not been observed on Lougheed Island in the last 50 years of sporadic survey work. Lougheed Island caribou were impacted by the mid-1990s die-offs related to severe winter weather at least in 1996-97, an estimated 28±SE19 caribou carcasses on the island (Gunn and Dragon 2002). The 2007 survey recorded an increase in caribou numbers on Lougheed Island following die-offs in the 1990s, but the population appears to be lower now than 9 years ago. Higher caribou populations on both Melville Island and Bathurst Island could account for some of the 'missing' caribou. In October 1995, one satellite-collared female caribou crossed to Lougheed Island, at least 110 km across the sea ice from Bathurst Island (Poole et al. 2015). She then continued 110 km across the ice to Borden Island, where she died in December 1995 (Poole et al. 2015).

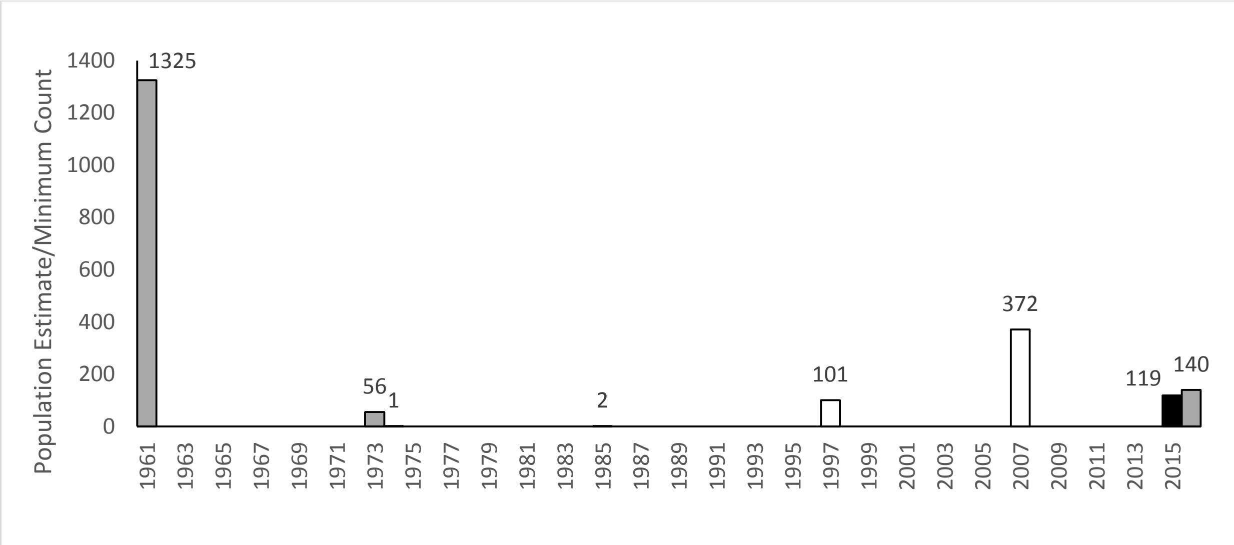

Figure 2. Population estimates for Peary caribou on Lougheed Island. Grey bars indicate estimates including calves (Tener 1963, Miller et al. 1977, this report), black bars are minimum counts (Miller et al. 1977, Miller 1987, this report for 2015), and white bars are population estimates of 1+-year-old caribou (Gunn and Dragon 2002, Jenkins et al. 2011).

Although not conducted as a survey, we did fly over Lougheed Island in 2015 to determine whether we could collect pellet samples using a Twin Otter drop-off and pick-up, or whether a helicopter would be required. We counted at least 119 Peary caribou during the flight, including some groups of 15-20 individuals (in which case the lower value was added for the minimum count of 119; Figure 4). Flight height was 90-150 m above ground and conditions were clear and sunny, with one observer each side of the plane and a navigator/recorder. No marks were made on the wing struts to define a survey strip.

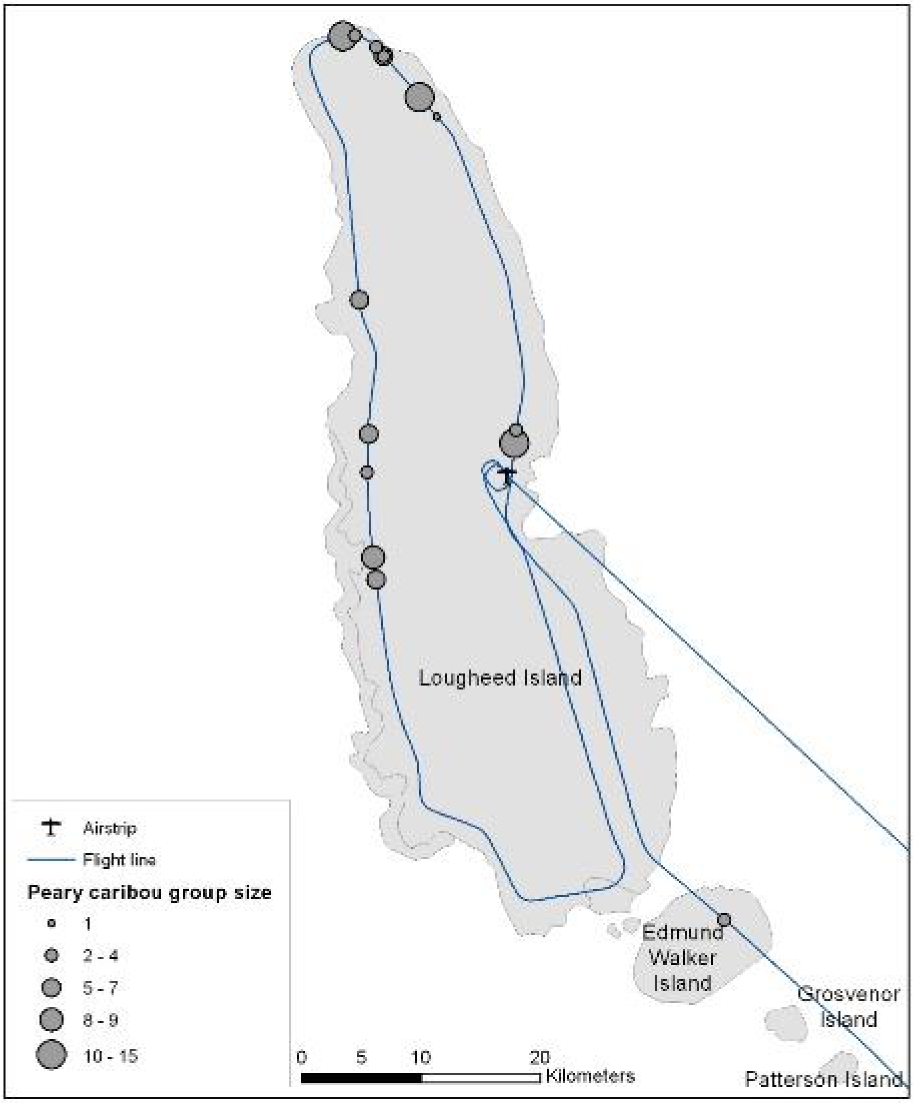

Figure 3. Locations of Peary caribou groups seen on a July 23, 2015 Twin Otter flight over Lougheed Island.

Management Recommendations

Harvest is low and accessibility of Lougheed Island is difficult. There is currently no TAH on Peary caribou, and no changes to harvest management are recommended based on this survey. Monitoring changes in both the Bathurst Island Group and Lougheed Island caribou populations as if they are one population unit may provide better information in future to determine whether caribou are moving among the islands or primarily increasing and decreasing based on survival and recruitment on the Bathurst Island group and Findlay Group separately. The continued lack of muskoxen on the island also makes Lougheed an ideal area to examine caribou behavior and population dynamics independent of the influence of muskoxen.

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Appendix 1. Alternate population calculations.

Jolly Method II Calculations

In this report, we used a systematic sampling approach to analysis, since we were estimating abundance of a patchy population rather than estimating density in a habitat (which varied across the study area). Other systematic aerial surveys have frequently used Jolly's Method II, and estimates derived from both analyses were similar. Population estimates for fixed-width strip sampling using Jolly's Method 2 for uneven sample sizes (Jolly 1969; summarized in Caughley 1977) are derived as follows:

$$\hat{Y} = RZ = Z\frac{\sum_i y_i}{\sum_i z_i}$$

Where $\hat{Y}$ is the estimated number of animals in the population, R is the observed density of animals (sum of animals seen on all transects $\sum_i y_i$ divided by the total area surveyed $\sum_i z_i$), and Z is the total study area. The variance is given by:

$$Var(\hat{Y}) = \frac{N(N-n)}{n}\left(s_y^2 - 2Rs_{zy} + R^2 s_z^2\right)$$

Where N is the total number of transects required to completely cover study area Z, and n is the number of transects sampled in the survey. s_y^2 is the variance in counts, s_z^2 is the variance in areas surveyed on transects, and s_{zy} is the covariance. The estimate $\hat{Y}$ and variance $Var(\hat{Y})$ are calculated for each stratum and summed. The Coefficient of Variation (CV = σ/$\hat{Y}$) was calculated as a measure of precision.

Table 3. Abundance estimates (Jolly 1969 Method II) for caribou on Lougheed Island, July 2016. *N* is the total number of transects required to completely cover study area *Z*, *n* is the number of transects sampled in the survey covering area *z*, *y* is the observed muskoxen, *Y* is the estimated muskoxen with variance Var(*Y*). The coefficient of variation (CV) is also included.

Y	**Var(Y)**	**n**	**Z (km^2)**	**z (km^2)**	**N**	**y**	**Density (per km^2)**	**CV**
140	1511.91	4	1359.58	252.13	24	26	0.1031	0.28