Population Estimates for Peary Caribou and Muskox on Banks Island, NWT, July 1998

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ABSTRACT

A stratified strip transect aerial survey was conducted on Banks Island, NWT during early July 1998 to document the numbers and distribution of Peary caribou (*Rangifer tarandus pearyi*) and muskox (*Ovibos moschatus*).

We observed 142 non-calf and 39 calf caribou on transect giving estimates of 451 ± 123 (95% CI) non-calf and 115 ± 53 (95% CI) calf caribou on the island. Approximately 18.9% of the caribou observed were calves. Overall there were 0.006 non-calf caribou per km^2 on the island. The number of non-calf caribou in the population declined significantly during the period 1994 to 1998. This decline may have been the residual effect of an icing event that occurred on Banks Island during winter 1993-1994.

We observed 10,293 non-calf and 2,375 calf muskoxen on transect giving estimates of 45,922 ± 4,097 (95% CI) non-calf and 10,651 ± 1,035 (95% CI) calf muskoxen on the island. Approximately 18.7% of the muskoxen observed on transect were calves. Overall there were 0.651 non-calf muskoxen per km^2 on the island, with densities reaching 1.296, 1.828, and 1.382 muskoxen per km^2 in the Egg, Massik, and Thomsen river drainages, respectively. The number of non-calf muskoxen in the population declined significantly during the period 1994 to 1998. This is the first decline documented for non-calf muskoxen in the Banks Island population since monitoring began in 1972. This decline may be in part a residual effect of an icing event that occurred on Banks Island during winter 1993-1994 and/or density-dependent regulatory effects on calving rates and/or adult and calf survival.

The number of sightings of wolves has increased during the surveys done between 1992 and 1998. It is not known if this reflects an increase in the number of wolves on Banks Island.

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INTRODUCTION

The history of the Peary caribou and muskox population on Banks Island has been well documented (Nagy et al. 1996; Nagy et al. 1998). Between 1972 and 1989, five whole-island surveys had been conducted to document the number of caribou and muskoxen on the island (Urquhart 1983; Latour 1985; McLean et al. 1986; McLean 1992; McLean and Fraser 1992; Nagy et al. 2007e). Between 1972 and 1992, the Peary caribou population declined from about 12,000 to 2,600 non-calf animals, while the muskox population increased from about 3,800 to about 34,300 non-calf animals (Urquhart 1983; Latour 1985; McLean et al. 1986; McLean 1992; McLean and Fraser 1992; Nagy et al. 2007e).

Because of the national "endangered" designation status of Peary caribou and the importance of Peary caribou and muskox to the community of Sachs Harbour (subsistence and commercial harvest), the Department of Environment and Natural Resources established a plan in the early 1990s to continue to survey these populations every two to four years to monitor their status (McLean 1992; McLean and Fraser 1992; Nagy et al. 2007a, b, c, d). Surveys conducted between 1989 and 1994 indicated the Peary caribou population continued to decline between 1989 and 1992 (Nagy et al. 2007a) but appeared to stabilize between 1992 and 1994 (Nagy et al. 2013). The muskox population continued to increase during this period (Nagy et al. 2007a, b).

A stratified strip transect aerial survey designed to obtain population estimates for Peary caribou and muskox on Banks Island was conducted in early July 1998 with the following objectives:

- to obtain estimates of the number of non-calf and calf caribou and muskoxen;
- to determine the status of the Peary caribou and muskox population;
- to document observations of wolves and den sites;

- to document the distribution of caribou and muskoxen;
- to recommend whether the current quotas for caribou and muskoxen are sustainable; and
- if necessary, recommend management options to facilitate recovery of the Peary caribou population.

This report summarizes the results of the survey completed on Banks Island during July 1998.

METHODS

In order to conduct a strip transect survey, we partitioned Banks Island into survey blocks (Figure 1). Transects were oriented to intersect major river systems and drainages at approximately a 90° angle (Figure 2). Survey blocks A, B, C, D, P, and T were flown at 20% coverage (transects spaced at 5 km intervals). Survey blocks E and M were flown at 40% coverage (transects spaced at 2.5 km intervals).

Figure 1: Location of survey blocks for the July 1998 Banks Island Peary caribou and muskox survey.

The survey crews included a pilot, an observer in the left back seat, and an observer/recorder in the front right seat of the aircraft. Transect lines were marked on 1:250,000 scale NTS maps for each survey block. These maps were used by the pilots to navigate along transects. The aircraft flew at an altitude of 100 m above ground level and airspeed of 160 km/h.

Caribou were counted inside and outside of the boundaries of a 500 m wide strip on each side of the aircraft. Muskoxen were counted within the boundaries of the strip. Strip width was marked using wooden dowels taped to the wing struts (Cessna 185) or a tape marker on a wire stretched between the tie-down rings and the fuselage (Helio Courier) using the formula:

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

where *w* is the calculated strip width on the ground, *W* is the chosen survey strip width, *h* is the height of the observer on the ground, and *H* is the chosen survey altitude (Norton-Griffiths 1987). All sightings of wolves were recorded.

Caribou were classified as adults (cows and yearlings), bulls, calves, or unknown. Muskoxen were classified as adults (age ≥1 year) and calves (age <1 year). Observers were equipped with binoculars to help ensure that caribou and muskoxen were counted and classified accurately. If an observer had difficulty, the pilot flew the aircraft off transect and flew in a tight circle around the caribou or muskoxen, so that an accurate count and classification could be done. The pilot then flew the aircraft back to on transect and the survey resumed. The pilot recorded the sighting numbers on the 1:250,000 NTS maps.

The field crew working on northern Banks Island surveyed block B first. This area has contained the most caribou during past surveys (Latour 1985; McLean et al. 1986; McLean 1992;

McLean and Fraser 1992; Nagy et al. 2007a, b;). Areas of high and low densities of caribou were stratified in block B and the area of high density caribou was re-flown at 40% coverage.

We downloaded rasterized versions of the 1:250,000 NTS map sheets covering Banks Island from Toporama (http://toporama.cits.rncan.gc.ca/toporama_en.html). These were appended using PCI Geomatica software (Geomatica software Geomatica) to create a single raster covering the entire study area. The resulting digital map was imported into OziExplorer GPS software (OziExplorer GPS Mapping Software). We used OziExplorer to create waypoints at the start and end of each transect and to digitize the location of each observation made during the survey. The resulting OziExplorer waypoint files were parsed using Microsoft Excel and the data for each observation was then entered from the field data sheets. At the end of this process the survey data were geo-referenced. This allowed us to map the distribution of Peary caribou and muskoxen observed during the survey.

Shape files were created for each survey block so that the total area of each could be measured using ArcView 3.2 GIS software (Environmental Systems Research Institute). The specifications of the projection used are as follows: Lambert Conformal Conic, NAD83, Central Meridian: 123.0 W, Latitude of Origin: 73.0 N, SP1: 72.0 N, SP2: 74.0 N.

The numbers of non-calf and calf caribou and muskoxen observed on and off transect for each transect was summarized using Microsoft Excel. The length of each transect was derived using the start and end point coordinates of each transect and the route function in OziExplorer.

The population estimates and associated statistics were calculated using the Aerial2 version 3.0 method 2 (Krebs 1999). Estimates for non-calf, calf, and all caribou and muskoxen, respectively, were derived for each survey block. Population and variance estimates from each

stratum were combined to derive an overall population and population variance estimate for non-calf, calf, and all caribou and muskoxen, respectively, in all survey blocks.

The estimation of population number and variance from stratified surveys is given in Compton et al. (1995) cited in Johnson et al. (2004). The total population number is the summation of individual strata estimates or (equation 1):

$$\hat{N}_{total} = \sum_{h=1}^{L} \hat{N}_h$$

Where there are L strata units. Assuming that the selection of sample units within each stratum is independent of the other strata units, the variance is estimated as the sum of individual variance estimates for each stratum, or (equation 2):

$$\mathrm{var}_{total} = \sum_{h=1}^{L} \mathrm{var}_h$$

Confidence intervals for population estimate can be approximated by (equation 3):

$$\hat{N}_{total} \pm t\sqrt{\mathrm{var}_{total}}$$

The degrees of freedom (*d*) for the t-statistic can be approximated by the following formula (equation 4):

$$d = \frac{\left(\sum_{h=1}^{L} a_h s_h^2\right)^2}{\left[\sum_{h=1}^{L}\left((a_h s_h^2)^2 / (n_h - 1)\right)\right]}$$

Where $a_h = N_h(N_h - n_h)/n_h$ where N_h is the possible number of transects in an individual block and n_h is the actual number of transects flown. The sample variance from each block is denoted as s^2 in the above formula, and L is the total number of strata (Compton et al. 1995). This assumes that the population estimates and variance estimates from each stratum are unbiased and independent.

We used a two-tailed t-test to determine whether the estimates of the non-calf and calf caribou and muskoxen in 1998 were significantly different from those in 1994. We calculated the t-statistic (t^2) using the following formula (equation 5) (Gasaway et al. 1986:62):

$$t^2 = T_{1998} - T4/[V(T_{1998)} + V(T_{1994})]^{0.5}$$

Where:

- T_{1998} and T_{1994} = population estimates of non-calf and calf caribou and muskox from surveys in 1998 and 1994, respectively; and
- $V(T_{1998})$ and $V(T_{1994})$ = variances of population estimates of non-calf and calf caribou and muskoxen from surveys in 1998 and 1994, respectively.

We used the following formula to estimate the total degrees of freedom (v_t) associated with the t-statistic (equation 6) (from Section 4.2.1.2, page 62, Gasaway et al. 1986):

$$[V(T_{1998}) + V(T_{1994})]^2 / \{[V(T_{1998})^2 / v_{o1998}] + [V(T_{1994})^2 / v_{o1994}]\}$$

Where:

- $V(T_{1998})$ and $V(T_{1994})$ = variances of population estimates of non-calf and calf caribou and muskox from surveys in 1998 and 1994, respectively; and
- v_{o1998} and v_{o1994} = degrees of freedom from surveys in 1998 and 1994, respectively (derived from equation 4).

Maps showing the distribution of caribou observed on and off transect, muskoxen observed on transect, and wolves on Banks Islands were created using ArcView (Environmental Systems Research Institute).

RESULTS

The survey was completed during early July 1998. Weather conditions were generally good throughout the survey period. All transect lines were flown as planned (Figure 2).

Peary caribou

The distribution of non-calf and calf Peary caribou observed during the initial survey of all blocks is shown in Figure 3 and Figure 4, respectively. During this component of the survey, we observed a total of 76 non-calf and 23 calf caribou on transect giving estimates of 381 ± 179 (95% CI) non-calf and 115 ± 80 (95% CI) calf caribou on the island (Table 1). We then stratified survey block B into areas of high and low densities of caribou (Figure 5 and Figure 6) and re-surveyed the high-density area at 40%.

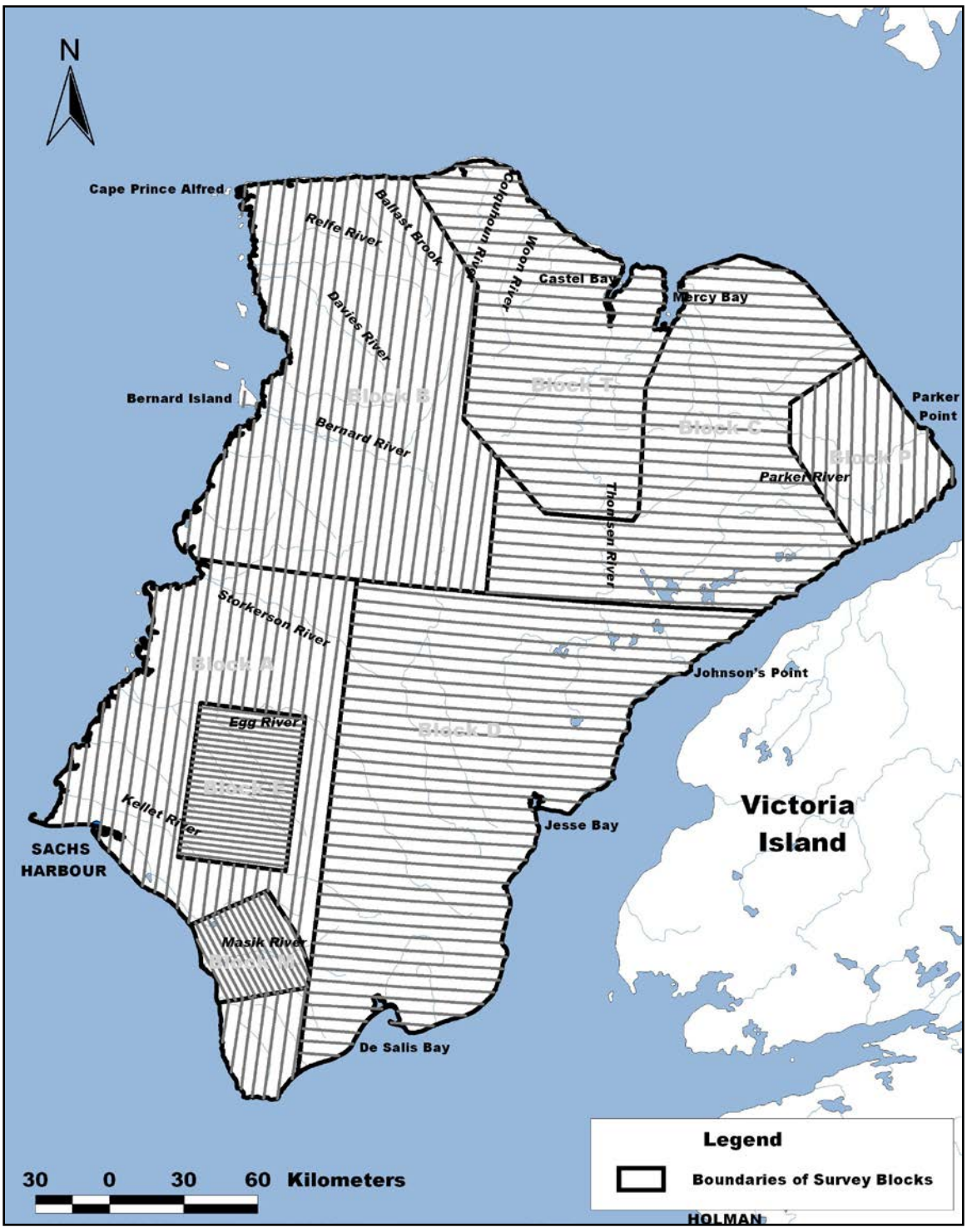

Figure 2: Distribution of survey blocks and transect lines for the July 1998 Banks Island Peary caribou and muskox survey as planned and flown.

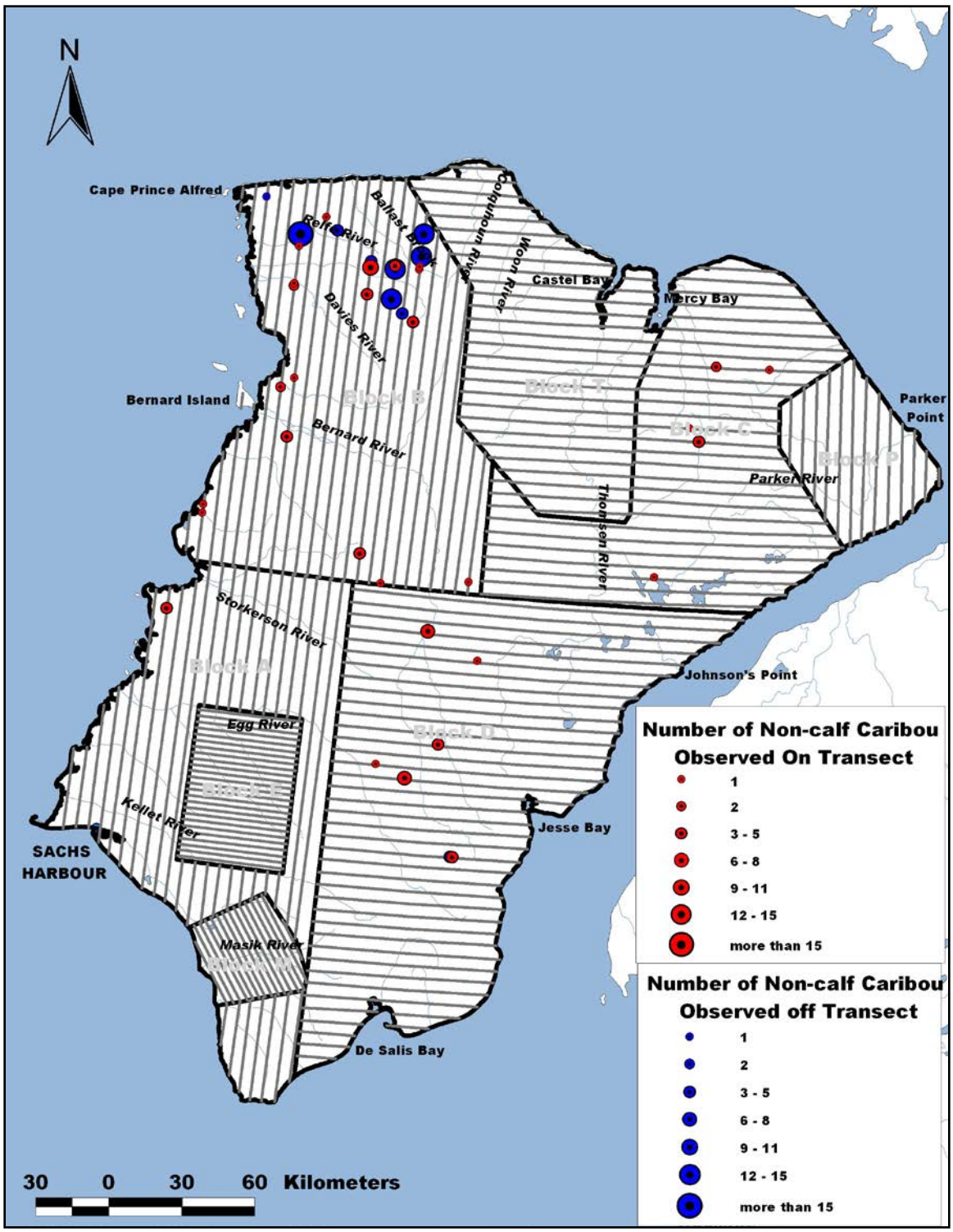

Figure 3: Distribution of non-calf caribou on Banks Island during the July 1998 Banks Island Peary caribou and muskox survey.

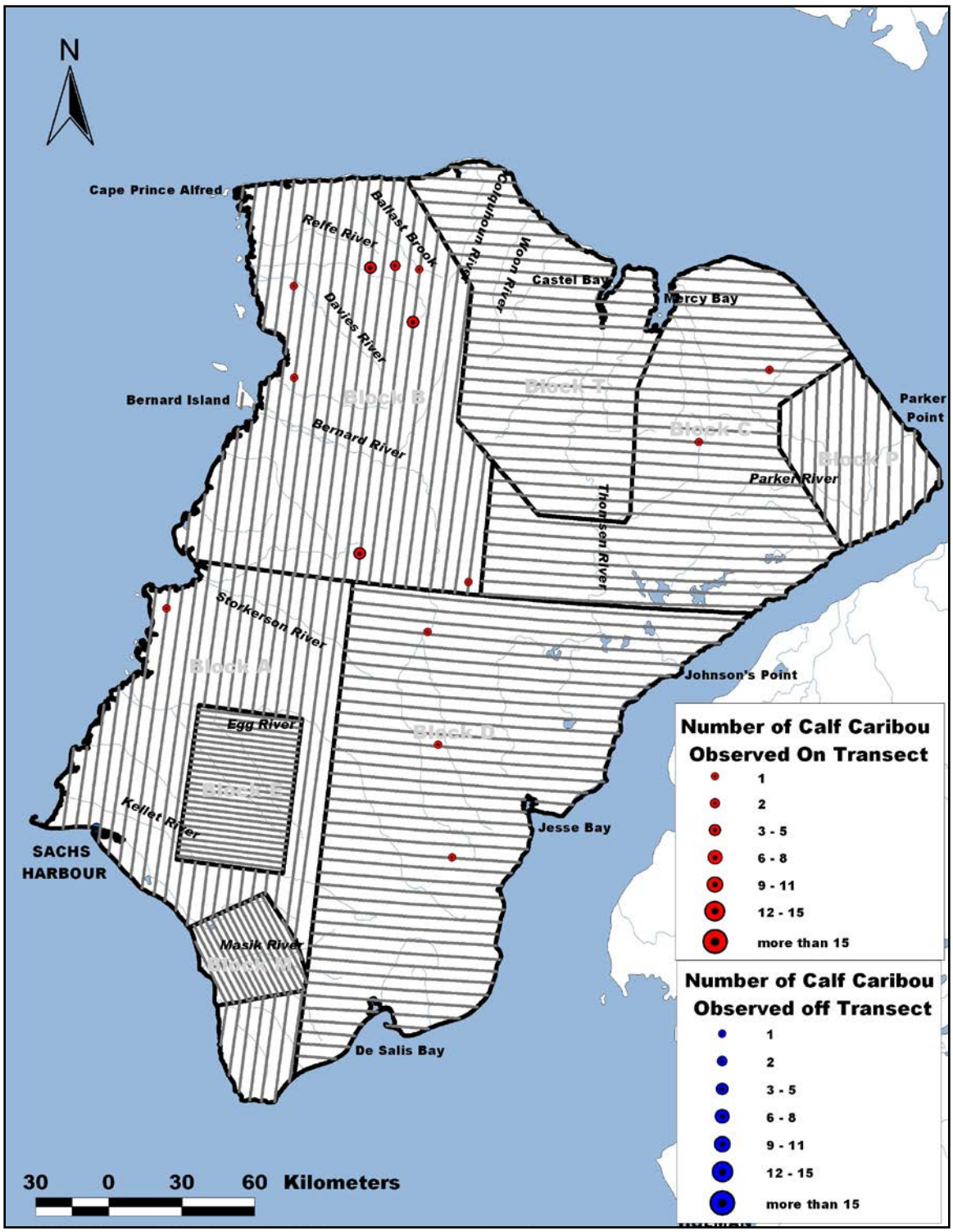

Figure 4: Distribution of calf caribou on Banks Island during the July 1998 Banks Island Peary caribou and muskox survey.

Table 1: Population estimates for Peary caribou on Banks Island pre-stratification, July 1998.

Stratum	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	% of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient Of Variation	df
Caribou: Non-calf													
A	10851	22	112.3	0.001	16	185.9	13.6	28	19.3	3	0	0.88	
B	14828	23	126.1	0.015	221	6625.8	81.4	169	19.9	44	101	0.37	
C	11477	28	142.8	0.004	40	403.3	20.1	41	20.0	8	0	0.50	
D	17832	39	202.4	0.006	104	202.9	44.8	91	20.1	21	3	0.43	
E	2698	25	63.3	0.000	0				39.6	0	0		
M	1427	15	45.7	0.000	0				38.9	0	0		
P	2983	13	66	0.000	0				19.9	0	0		
T	8487	28	140.7	0.000	0				19.9	0	0		
Sum of blocks	70583	193	899.3	0.005	381	7418.0	86.1	179	21.0	76	104	0.23	22
Caribou: Calf													
A	10851	22	112.3	0.001	5	20.7	4.5	9	19.3	1	0	0.88	
B	14828	23	126.1	0.006	85	1354.4	36.8	76	19.9	17	0	0.43	
C	11477	28	142.8	0.001	10	42.0	6.5	13	20.0	2	0	0.65	
D	17832	39	202.4	0.001	15	60.3	7.8	16	20.1	3	0	0.52	
E	2698	25	63.3	0.000	0				39.6	0	0		
M	1427	15	45.7	0.000	0				38.9	0	0		
P	2983	13	66	0.000	0				19.9	0	0		
T	8487	28	140.7	0.000	0				19.9	0	0		
Sum of blocks	70583	193	899.3	0.002	115	1477.4	38.4	80	21.0	23	0	0.33	22
Caribou: Total													
A	10851	22	112.3	0.002	21	330.5	18.2	38	19.3	4	0	0.88	
B	14828	23	126.1	0.021	306	13500.4	116.2	241	19.9	61	101	0.38	
C	11477	28	142.8	0.004	50	692.4	26.3	54	20.0	10	0	0.53	
D	17832	39	202.4	0.007	119	2504.0	50.0	101	20.1	24	3	0.42	
E	2698	25	63.3	0.000	0				39.6	0	0		
M	1427	15	45.7	0.000	0				38.9	0	0		
P	2983	13	66	0.000	0				19.9	0	0		
T	8487	28	140.7	0.000	0				19.9	0	0		
Sum of blocks	70583	193	899.3	0.007	496	17027.3	130.5	271	21.0	99	104	0.26	23

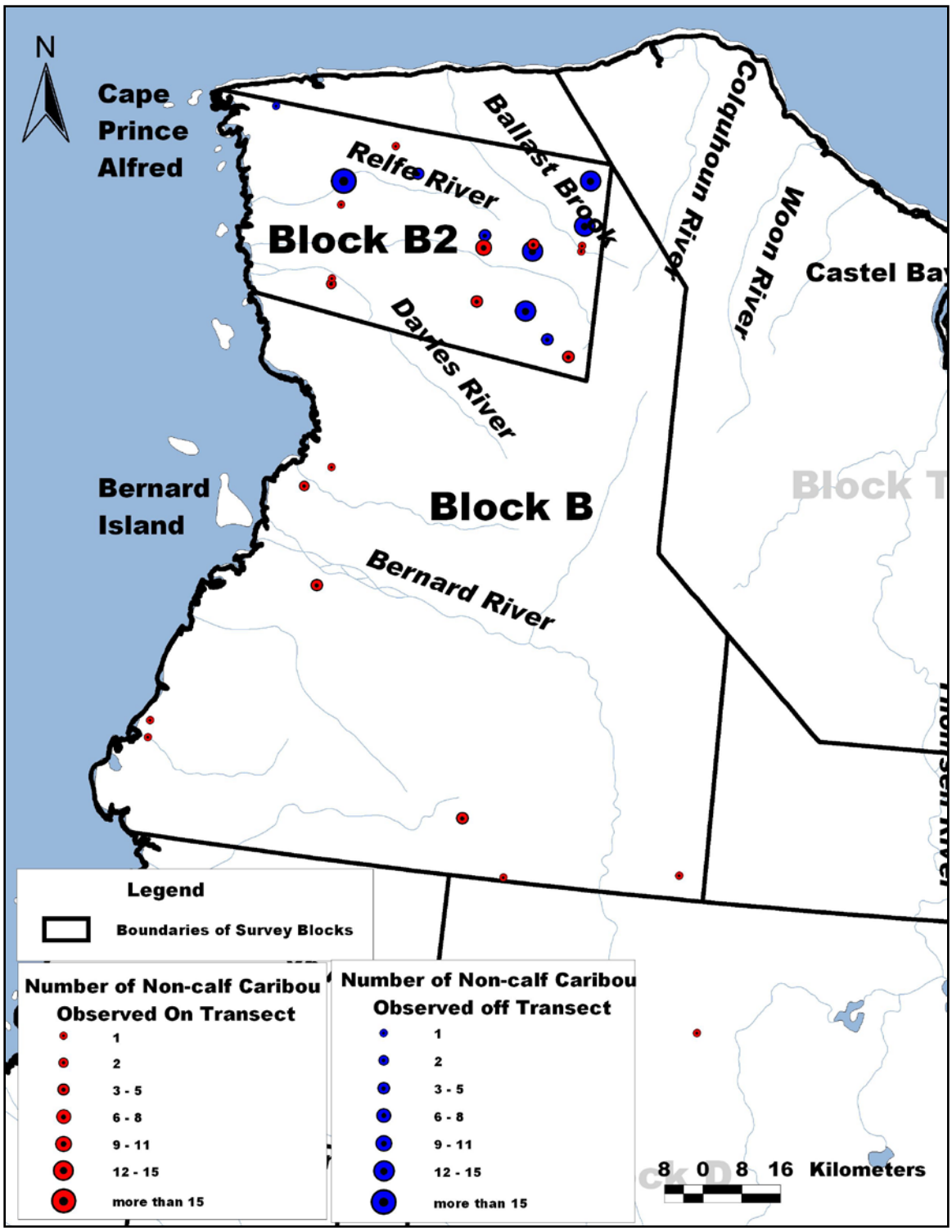

Figure 5: Stratification of survey.

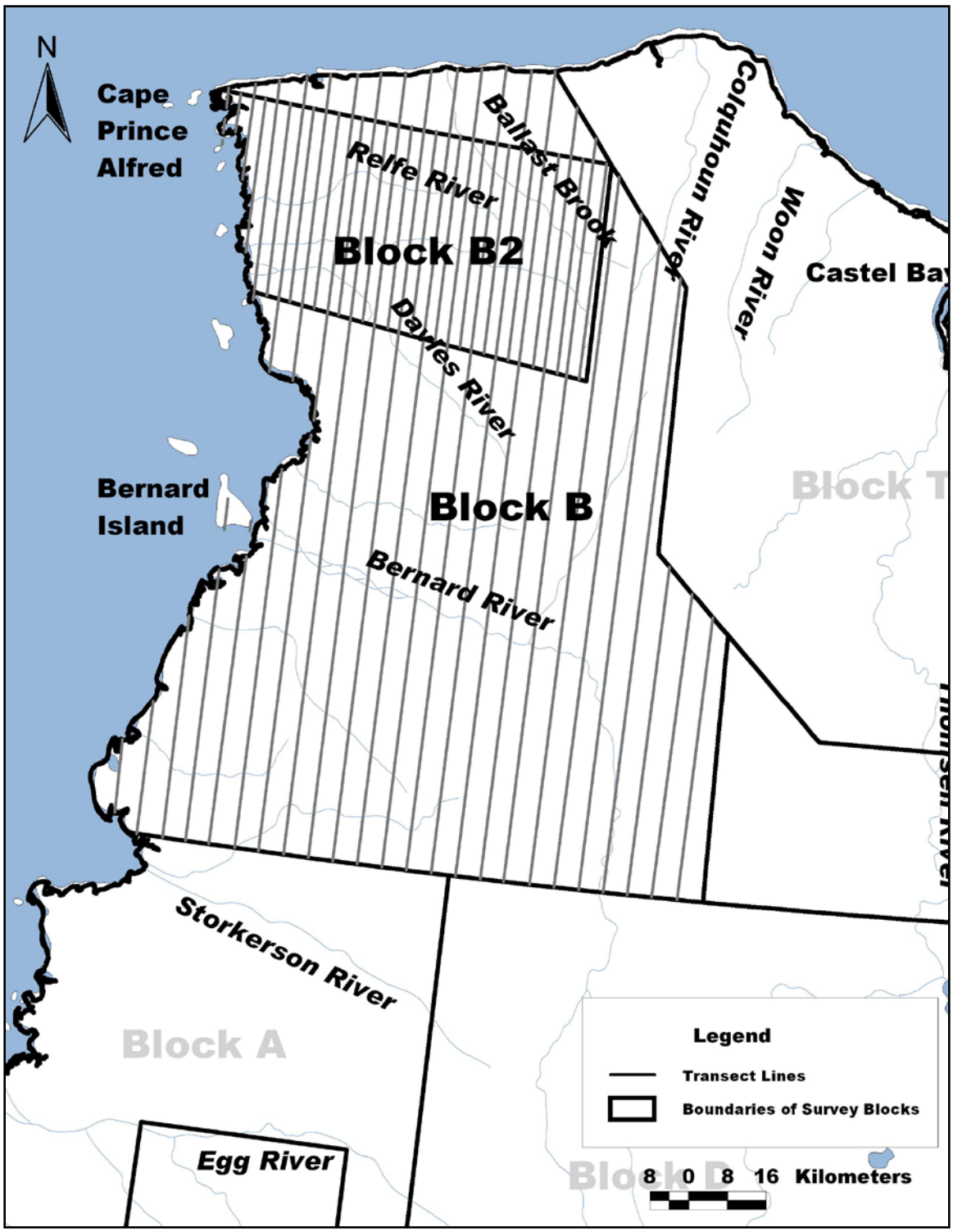

Figure 6: Distribution of survey blocks and transects flown in survey blocks B/B2 during the 1998 Banks Island Peary caribou and muskox survey.

The distribution of non-calf and calf Peary caribou in survey blocks B2 and B minus B2 is given in Figure 7 and Figure 8. During this component of the survey we observed 89 non-calf and 24 calf caribou in survey block B2 (Table 2). There were a total of 142 non-calf and 39 calf caribou on transect in blocks B2, blocks B minus B2, and the remainder of the island giving estimates of 451 ± 123 (95% CI) non-calf and 115 ± 53 (95% CI) calf caribou on the island (Table 2). This estimate and the original estimate were not significantly different for the non-calf (t^2 = 0.671, 40 df, $p>0.05$) or calf (t^2 = 0.016, 39 df, $P>0.05$) caribou.

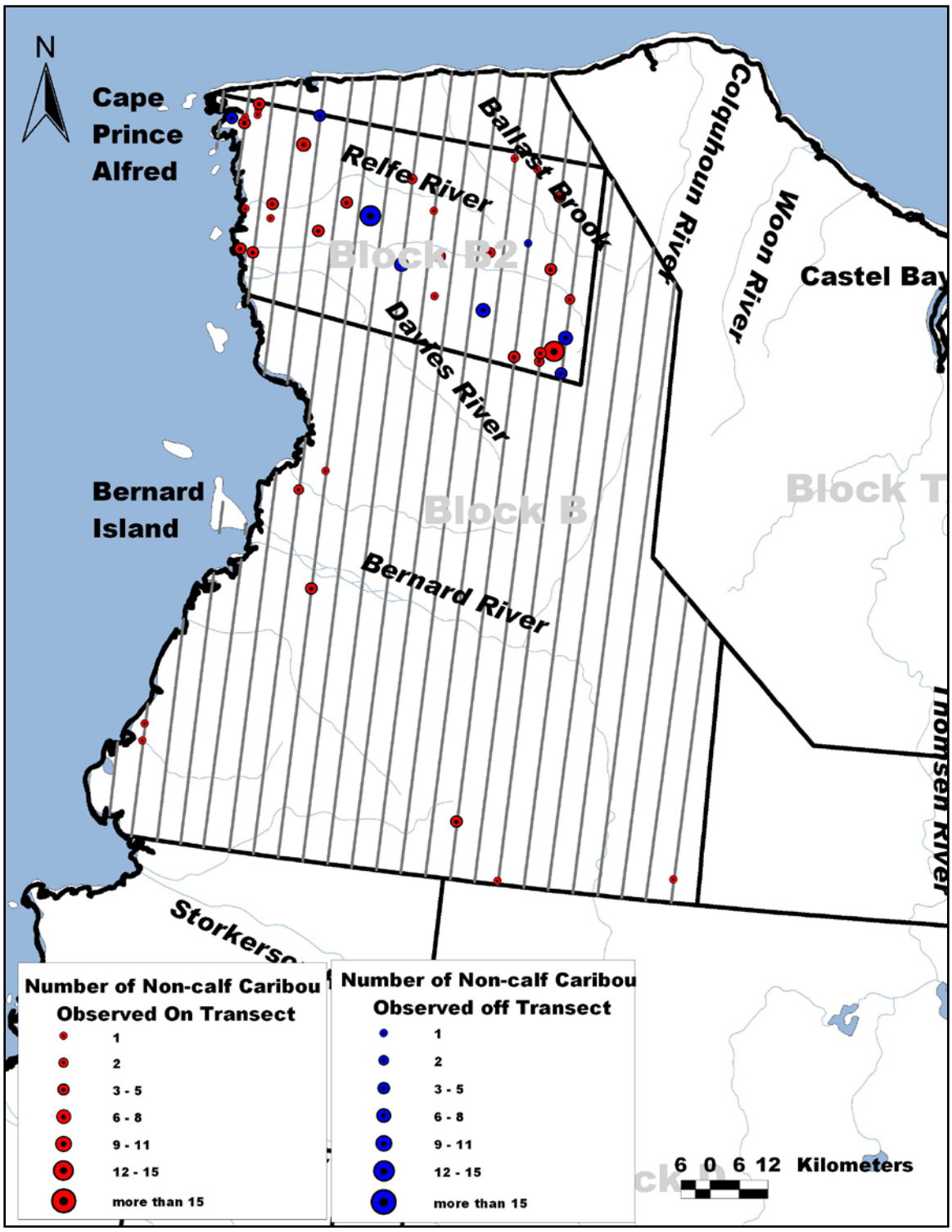

Figure 7: Distribution of non-calf caribou in survey blocks B/B2 during the 1998 Banks Island Peary caribou and muskox survey.

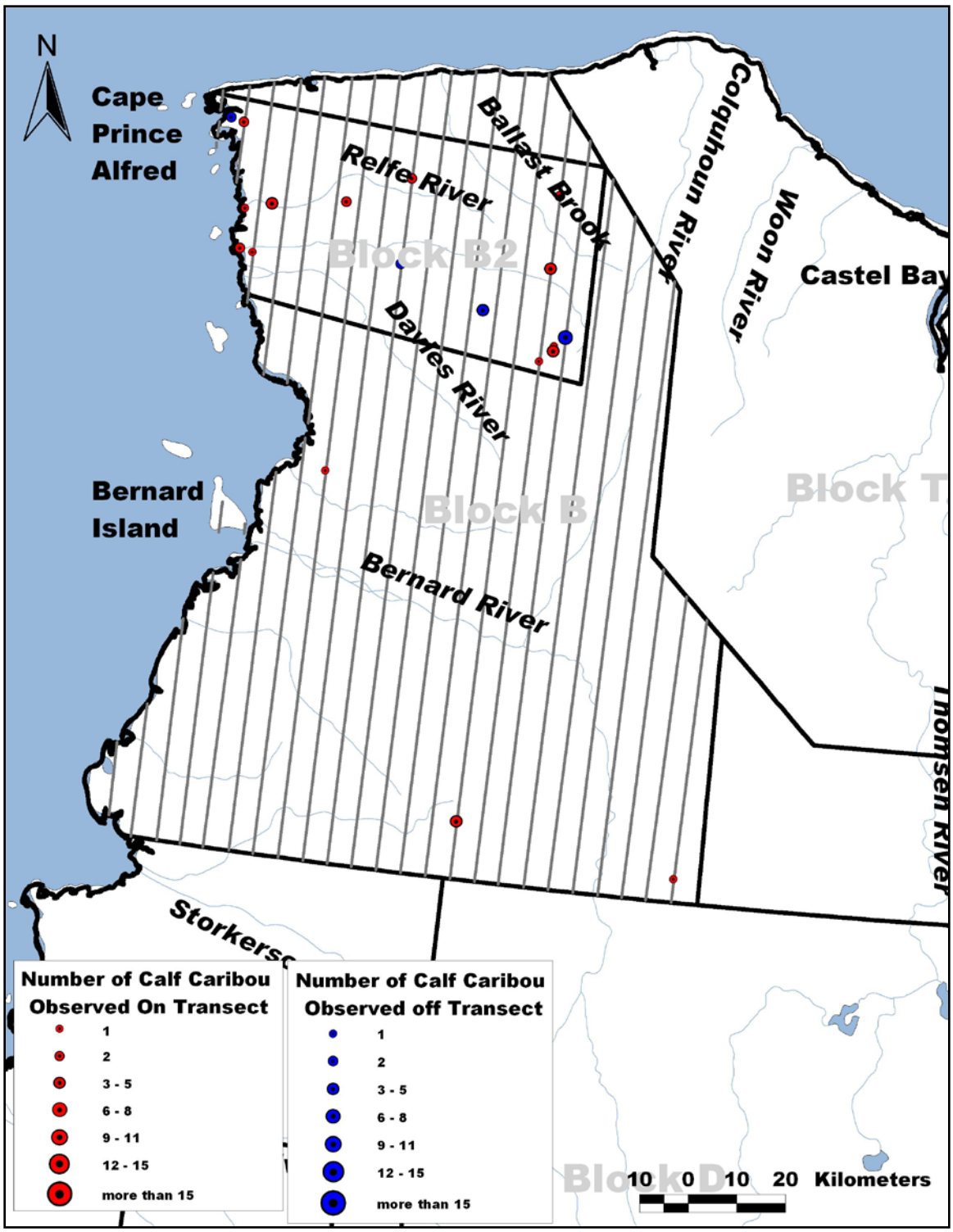

Figure 8: Distribution of calf caribou in survey blocks B/B2 during the 1998 Banks Island Peary caribou and muskox survey.

The 1998 estimate of non-calf caribou was significantly lower than that reported for 1994 (Nagy et al. 2007b) ($t2 = 2.010$, 40 df, $P<0.05$). In comparison, the estimate of calf caribou was not significantly different from that reported for 1994 (Nagy et al. 2013) ($t2 = 1.351$, 44 df, $P>0.05$). A comparison of the mean population estimates for 1994 and 1998 indicate that the caribou population declined at an annual finite rate of 15% per year during this period (Caughley 1977). The Peary caribou population trend for 1982 to 1998 is shown in Figure 9.

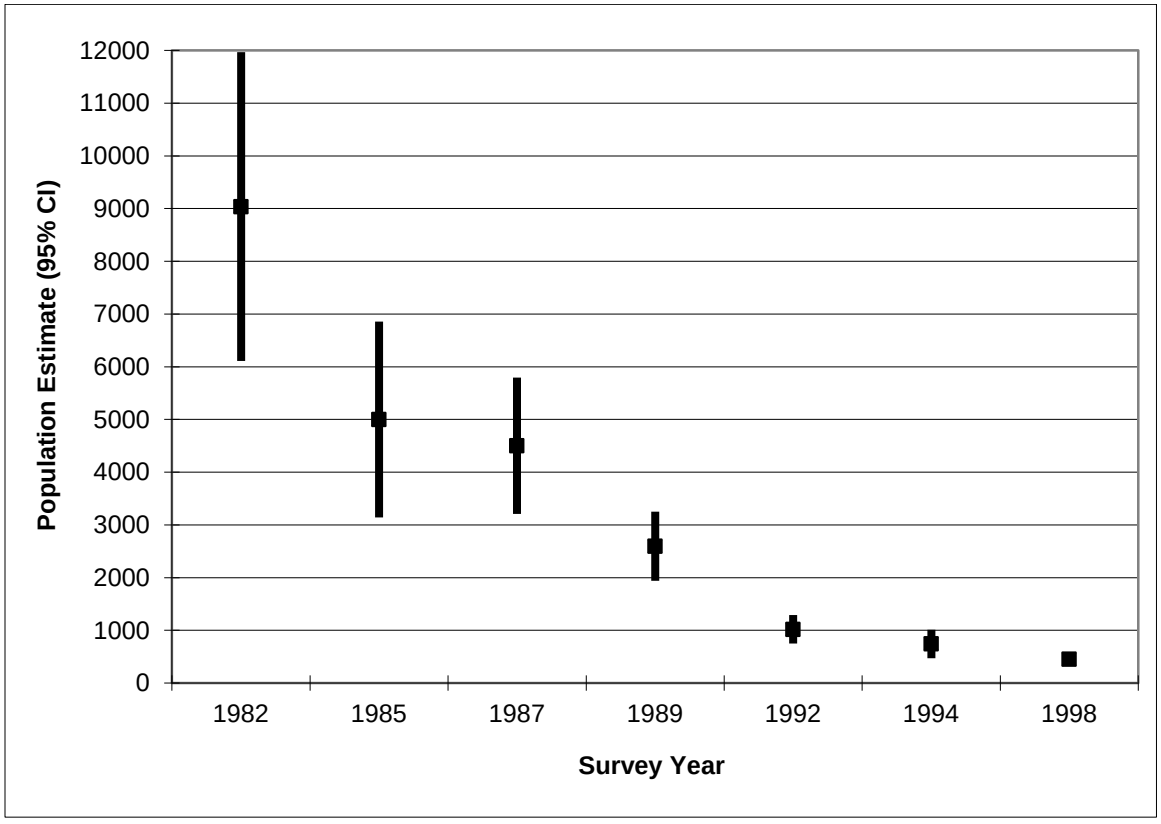

Figure 9: Population estimates with 95% CI for non-calf Peary caribou on Banks Island, NWT, 1982 to 1998.[1]

[1] Population estimates obtained from:
1982 (Nagy et al. 2007e); 1985 (McLean et al. 1986); 1987 (McLean 1992) Information required to calculate 95% CI was not provided. We estimated the 95% CI as SE*1.96; 1989 (McLean and Fraser 1992) Information required to calculate 95% CI was not provided. We estimated the 95% CI as SE*1.96; 1992 (Nagy et al. 2007a); 1994 (Nagy et al. 2013); 1998 (this report).

Following stratification of survey block B, we observed a total of 227 non-calf and 53 calf caribou on and off transect. There were 23.3 calves per 100 cows. Approximately 18.9% of the caribou observed were calves. The majority of these caribou (192 non-calf and 47 calves) were found on the northwestern portion of the island in survey block B (Table 2 and Figures 3, 4, 7, and 8).

We did not find any caribou mortality sites during the survey.

Table 2: Population estimates for Peary caribou on Banks Island post-stratification, July 1998.

Stratum	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	% of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient Of Variation	df
Caribou: Non-calf													
A	10,851	22	112.3	0.001	16	185.9	13.6	28	19.3	3	0	0.88	
B2	3,037	32	81.3	0.073	221	1,909.6	43.7	89	40.2	89	55	0.20	
B-B2	11,790	23	126.1	0.006	70	850.2	29.2	60	20.1	21	27	0.42	
C	11,477	28	142.8	0.004	40	403.3	20.1	41	20.0	8	0	0.50	
D	17,832	39	202.4	0.006	104	202.9	44.8	91	20.1	21	3	0.43	
E	2,698	25	63.3	0.000	0				39.6	0	0		
M	1,427	15	45.7	0.000	0				38.9	0	0		
P	2,983	13	66	0.000	0				19.9	0	0		
T	8,487	28	140.7	0.000	0				19.9	0	0		
Sum of blocks	70,582	225	980.6	0.006	451	3,552.0	59.6	123	21.9	142	85	0.13	25
Caribou: Calf													
A	10,851	22	112.3	0.001	5	20.7	4.5	9	19.3	1	0	0.88	
B2	2,374	32	81.3	0.020	60	302.0	17.4	35	40.2	24	14	0.29	
B-B2	12,454	23	126.1	0.002	25	230.8	15.2	31	20.1	9	0	0.61	
C	11,477	28	142.8	0.001	10	42.0	6.5	13	20.0	2	0		
D	17,832	39	202.4	0.001	15	60.3	7.8	16	20.1	3	0	0.52	
E	2,698	25	63.3	0.000	0				39.6	0	0		
M	1,427	15	45.7	0.000	0				38.9	0	0		
P	2,983	13	66	0.000	0				19.9	0	0		
T	8,487	28	140.7	0.000	0				19.9	0	0		

Stratum	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	% of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient Of Variation	df
Sum of blocks	70,583	225	980.6	0.002	115	655.7	25.6	53	21.9	39	14	0.22	24
Caribou: Total													
A	10,851	22	112.3	0.002	21	330.5	18.2	38	19.3	4	0	0.88	
B2	2,374	32	81.3	0.093	281	3,450.2	58.7	120	40.2	113	69	0.21	
B-B2	12,454	23	126.1	0.008	95	1,645.6	40.6	84	20.1	30	27	0.43	
C	11,477	28	142.8	0.004	50	692.4	26.3	54	107.8	10	0	0.53	
D	17,832	39	202.4	0.007	119	2,504.0	50.0	101	84.8	24	3	0.42	
E	2,698	25	63.3	0.000	0				39.6	0	0		
M	1,427	15	45.7	0.000	0				38.9	0	0		
P	2,983	13	66	0.000	0				19.9	0	0		
T	8,487	28	140.7	0.000	0				19.9	0	0		
Sum of blocks	70,583	225	980.6	0.008	566	8,622.7	92.9	189	21.9	181	99	0.16	34

Muskox

The distribution of non-calf and calf muskoxen observed during the survey is shown in Figure 10 and Figure 11, respectively. We observed a total of 10,293 non-calf and 2,375 calf muskoxen on transect giving estimates of 45,922 ± 4,097 (95% CI) non-calf and 10,651 ± 1,035 (95% CI) calf muskoxen on the island (Table 3). There were 23.1 calves per 100 non-calf muskoxen. Approximately 18.7% of the muskoxen observed on transect were calves.

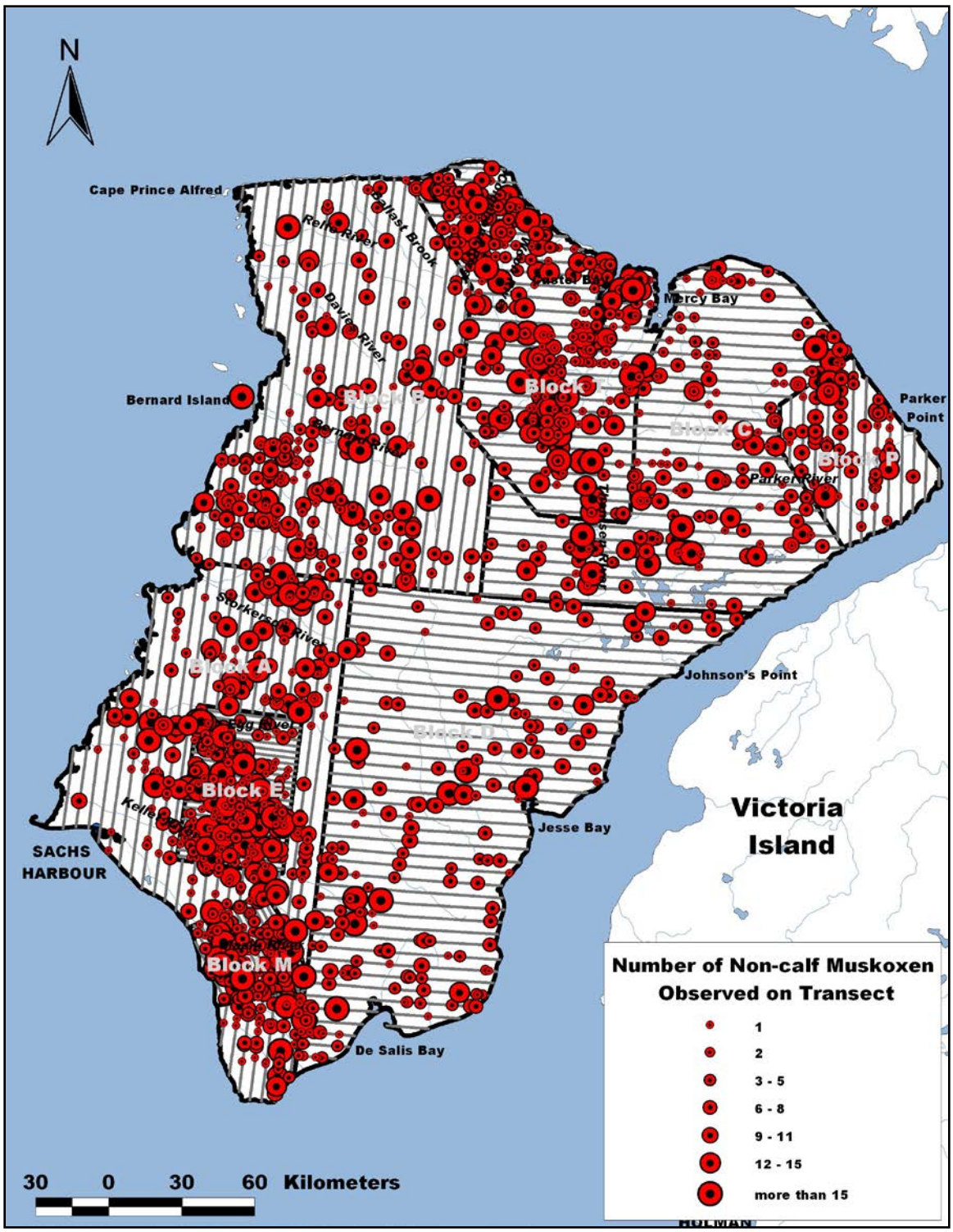

Figure 10: Distribution of non-calf muskox on Banks Island during the July 1998 Banks Island Peary caribou and muskox survey.

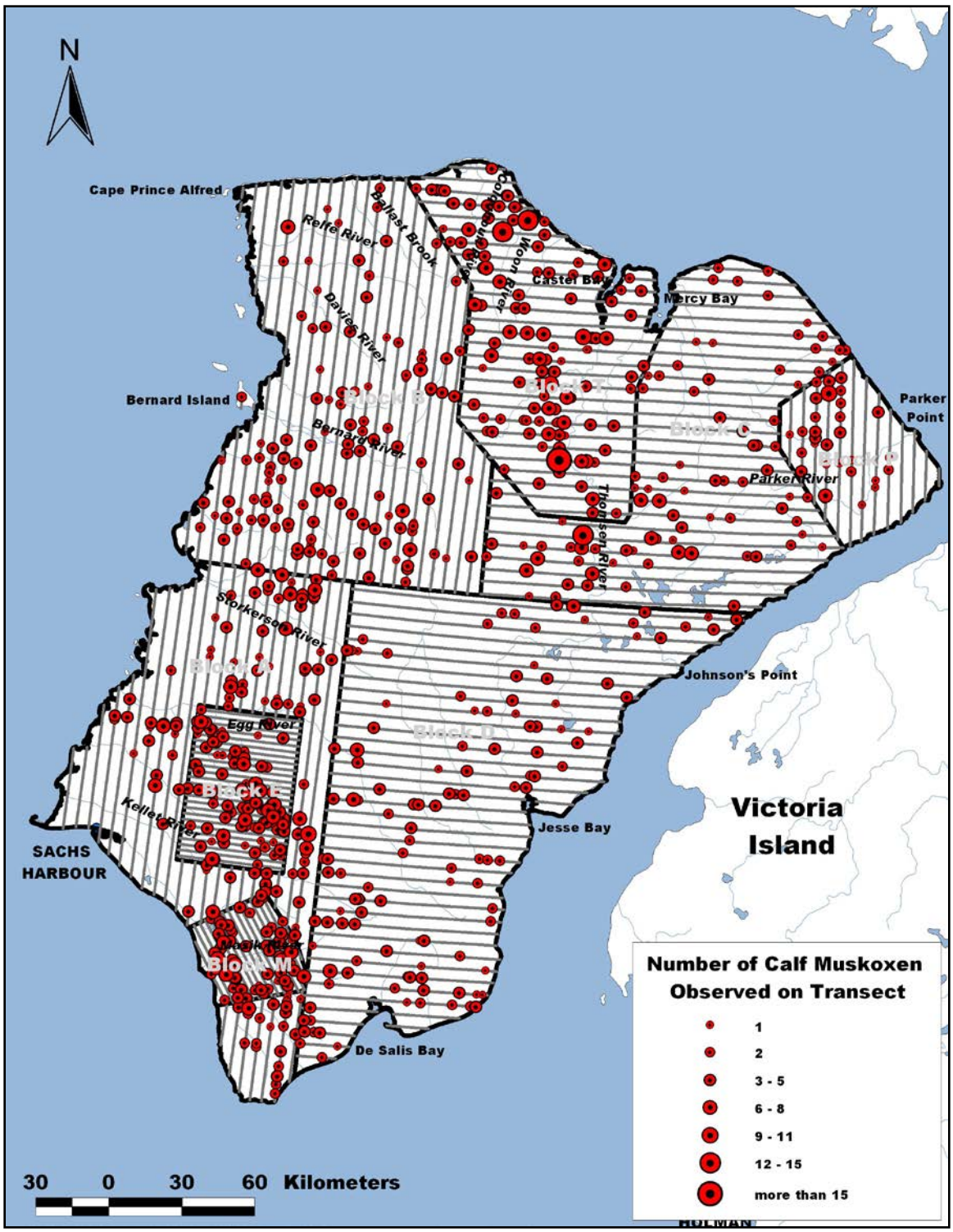

Figure 11: Distribution of calf muskox on Banks Island during the July 1998 Banks Island Peary caribou and muskox survey.

Table 3: Population estimate for muskox on Banks Island, July 1998.

Stratum	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	Percent of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient of Variation	df
Muskoxen: Non-calf													
A	10,851	22	112.3	0.747	8,104	1,154,602.0	1,074.5	2,235	19.3	1,563	not recorded	0.13	
B	14,828	23	126.1	0.488	7,235	356,168.4	596.8	1,238	19.9	1,442	not recorded	0.08	
C	11,477	28	142.8	0.438	5,028	451,106.5	671.6	1,378	20.0	1,004	not recorded	0.13	
D	17,832	39	202.4	0.328	5,846	276,662.0	526.0	1,065	20.1	1,175	not recorded	0.09	
E	2,698	25	63.3	1.296	3,496	85,115.3	291.7	602	39.6	1,384	not recorded	0.08	
M	1,427	15	45.7	1.828	2,608	184,134.7	429.1	920	38.9	1,014	not recorded	0.16	
P	2,983	13	66	0.628	1,874	166,403.6	407.9	889	19.9	373	not recorded	0.22	
T	8,487	28	140.7	1.382	11,731	1,282,912.1	1,132.7	2,324	19.9	2,338	not recorded	0.10	
Sum of blocks	70,583	193	899.3	0.651	45,922	3,957,104.6	1,989.2	4,097	21.0	10,293		0.04	25
Muskoxen: Calf													
A	10,851	22	112.3	0.171	1,851	76,170.5	276.0	574	19.3	357	not recorded	0.15	
B	14,828	23	126.1	0.114	1,691	18,057.6	134.4	279	19.9	337	not recorded	0.08	
C	11,477	28	142.8	0.101	1,157	33,159.2	182.1	374	20.0	231	not recorded	0.16	
D	17,832	39	202.4	0.089	1,587	27,239.3	165.0	334	20.1	319	not recorded	0.10	
E	2,698	25	63.3	0.278	750	5,117.9	71.5	148	39.6	297	not recorded	0.10	
M	1,427	15	45.7	0.420	599	12,153.4	110.2	236	38.9	233	not recorded	0.18	
P	2,983	13	66	0.131	392	14,399.2	120.0	261	19.9	78	not recorded	0.31	
T	8,487	28	140.7	0.309	2,624	66,453.8	257.8	529	19.9	523	not recorded	0.10	
Sum of blocks	70,583	193	899.3	0.151	10,651	252,751.0	502.7	1,035	21.0	2,375		0.05	25
Muskoxen: Total													
A	10,851	22	112.3	0.917	9,955	1,802,011.4	1,342.4	2,792	19.3	1,920	not recorded	0.13	
B	14,828	23	126.1	0.602	8,926	497,144.9	705.1	1,462	19.9	1,779	not recorded	0.08	
C	11,477	28	142.8	0.539	6,185	698,919.9	836.0	1,716	20.0	1,235	not recorded	0.14	
D	17,832	39	202.4	0.417	7,433	447,746.6	669.1	1,354	20.1	1,494	not recorded	0.09	
E	2,698	25	63.3	1.574	4,246	128,002.7	357.8	738	39.6	1,681	not recorded	0.08	
M	1,427	15	45.7	2.248	3,208	286,811.2	535.5	1,149	38.9	1,247	not recorded	0.17	
P	2,983	13	66	0.760	2,266	272,762.8	522.3	1,138	19.9	451	not recorded	0.23	
T	8,487	28	140.7	1.691	14,355	1,830,047.9	1,352.8	2,776	19.9	2,861	not recorded	0.09	
Sum of blocks	70,583	193	899.3	0.802	56,573	5,963,447.4	2,442.0	5,040	21.0	12,668		0.04	25

The 1998 estimate of non-calf muskoxen was significantly lower than that reported for 1994 (Nagy et al. 2013) (t^2 = 40.040, 48 df, P<0.001). In comparison, the estimate of calf muskoxen was significantly higher than that reported for 1994 (Nagy et al. 2013) (t^2 = 7.085, 52 df, P<0.001). A comparison of the mean population estimates for 1994 and 1998 indicates that the non-calf muskox population decreased at an annual finite rate of 17.3% per year during this period (Caughley 1977).

Figure 12 shows the population trend for muskox for the period from 1982 to 1998.

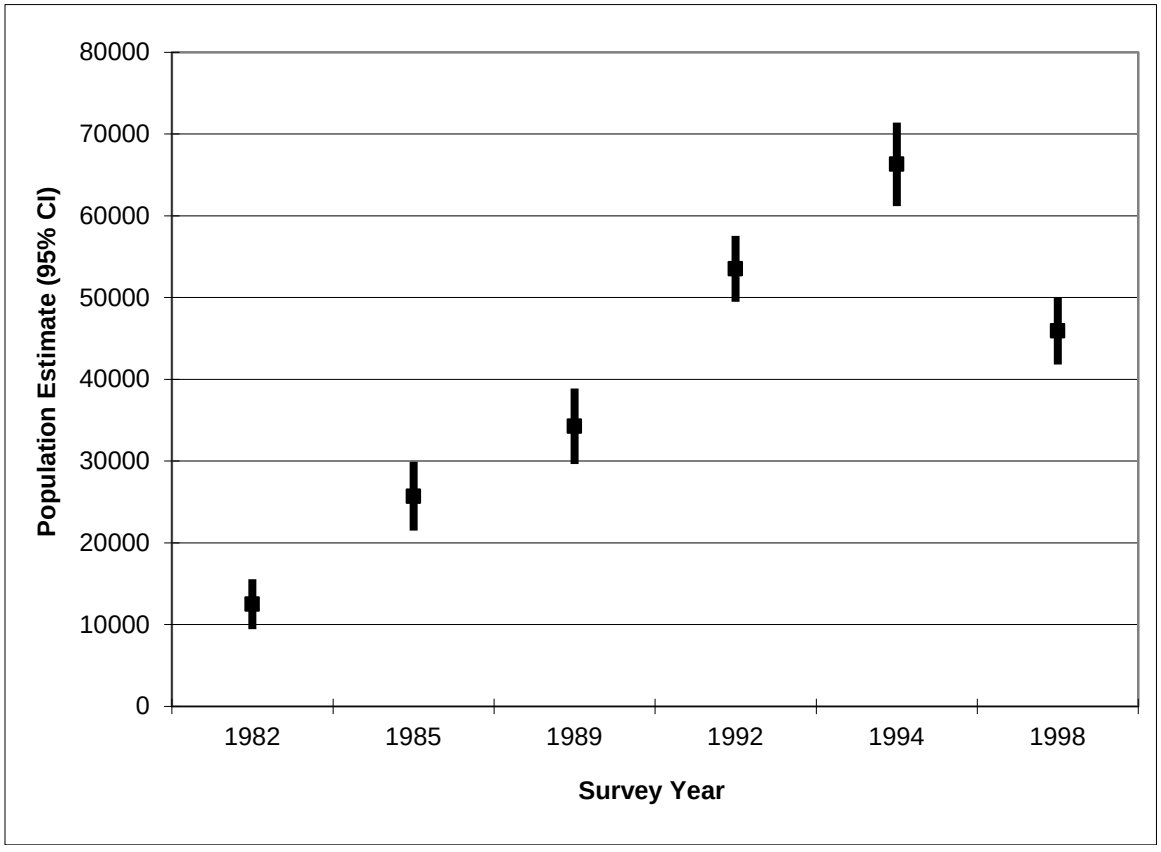

Figure 12: Population estimates with 95% CI for non-calf muskox on Banks Island, NWT, 1982 to 1998.[2]

[2] Population estimates obtained from: 1982 (Nagy et al. 2007e); 1985 (McLean et al. 1986); 1987 (McLean 1992) Information required to calculate 95% CI was not provided. We estimated the 95% CI as

We observed 31 dead muskoxen during the survey. The majority of these were found within the high-density muskox areas on the southwestern portion of the island (survey blocks A, E, M) and in the northwestern northern portion of the island (survey block B) (Figure 13).

SE*1.96; 1989 (McLean and Fraser 1992) Information required to calculate 95% CI was not provided. We estimated the 95% CI as SE*1.96; 1992 (Nagy et al. 2007a); 1994 (Nagy et al. 2013); 1998 (this report).

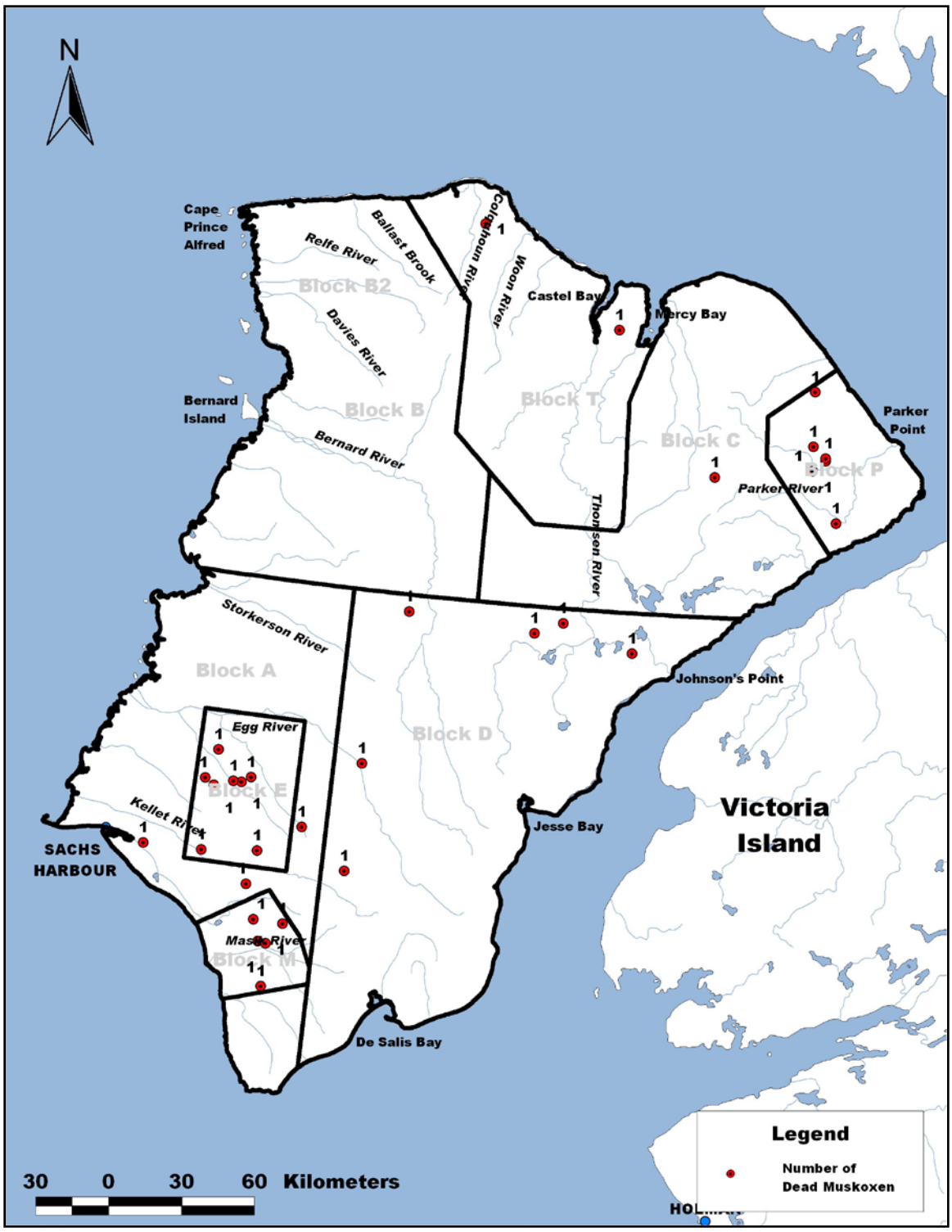

Figure 13: Distribution of dead muskox observed during the 1998 Banks Island Peary caribou and muskox survey.

Wolves

We observed a total of 26 wolves. The majority of these were found on the northern portion of the island (Figure 14). A pack of four wolves was found within the post-calving range of the caribou herd.

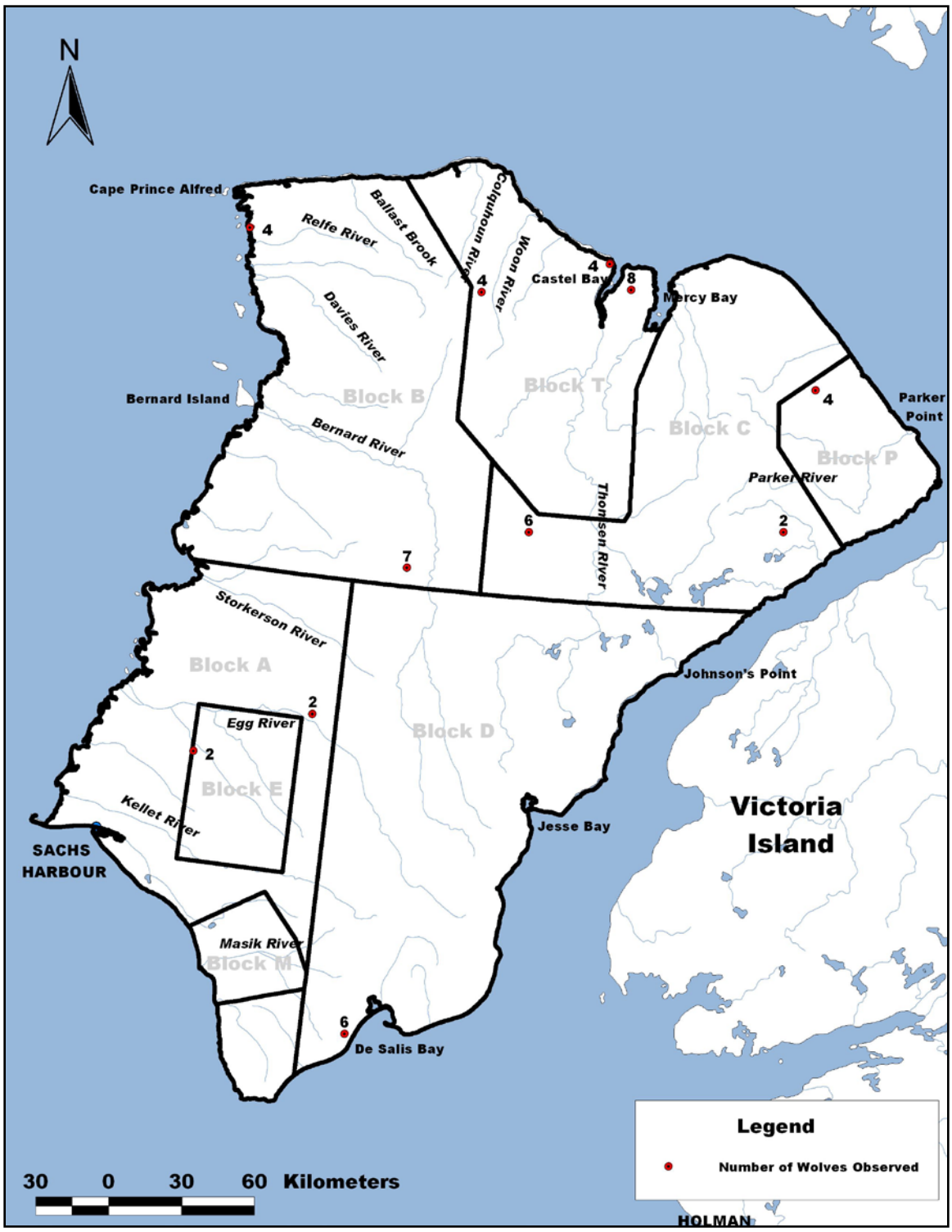

Figure 14: Distribution of wolves observed during the 1998 Banks Island Peary caribou and muskox survey.

DISCUSSION

The results of our survey indicate that there were approximately 451 ± 123 (95% CI) non-calf and 115 ± 53 (95% CI) calf caribou on Banks Island (70,583 km^2) in July 1998. The 1998 estimate for non-calf caribou was significantly lower than that for 1994 indicating that the population has continued to decline. The 1998 and 1994 estimates for calf caribou were not significantly different. Few calves were observed in July 1994.

Freezing rains occurred on Banks Island during October and November 1993. Approximately 50% of the caribou winter range on southern Banks Island was ice-covered (Larter and Nagy 1994). These conditions may have had a negative impact on adult cow body condition resulting in lower pregnancy rates or higher pre- or post-natal mortality. The low number of calves observed in July 1994 may have been a result of these severe winter conditions. The reason for the low number of calves observed in 1998 is unknown.

The majority of the Peary caribou in early July are typically found on the post-calving ranges on the extreme northwestern portion of Banks Island. The majority of caribou observed during the July 1998 survey were found in this area.

There were approximately 45,922 ± 4,097 (95% CI) non-calf and 10,651 ± 1,035 (95% CI) calf muskoxen on Banks Island in July 1998. Overall there were 0.651 non-calf muskoxen per km^2 on the island, with densities exceeding one muskox per km^2 in the Egg, Massik, and Thomsen river drainages (Table 3). This was consistent with previous observations.

The 1998 estimate of non-calf muskoxen was significantly lower than that reported for 1994. In comparison, there were significantly more calves. This is the first decline documented for non-calf muskoxen in the Banks Island population since monitoring began in 1972. This decline may in part be a residual effect of an icing event that occurred on Banks Island during winter 1993-1994 (i.e. reduced recruitment in years immediately following the winter 1993-

1994 icing event, and/or density dependent regulatory effects on calving rates and or adult and calf survival).

We observed two and 23 wolves during the surveys conducted in 1992 and 1994, respectively. In 1998 we observed 26 wolves. Whether this increase in number of sightings reflects an increase in the number of wolves on the island is not known. Significantly, we observed eight wolves within the post-calving range of the caribou herd.

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APPENDIX A: Transect data for the 1998 Banks Island caribou and muskox survey.

Survey Block	Transect Number	Transect Area (km^2)	Caribou: Non-calf	Caribou: Calf	Caribou: Total	Muskox: Non-calf	Muskox: Calf	Muskox: Total
A	1	32.914	0	0	0	0	0	0
	2	32.723	0	0	0	10	0	10
	3	50.044	0	0	0	1	0	1
	4	63.618	0	0	0	19	6	25
	5	73.0247	0	0	0	30	6	36
	6	113.048	0	0	0	6	1	7
	7	118.288	3	1	4	58	9	67
	8	123.243	0	0	0	74	23	97
	9	128.522	0	0	0	64	12	76
	10	138.433	0	0	0	58	4	62
	11	78.391	0	0	0	25	3	28
	12	83.726	0	0	0	37	11	48
	13	81.542	0	0	0	82	21	103
	14	78.617	0	0	0	92	23	115
	15	75.364	0	0	0	95	22	117
	16	89.381	0	0	0	62	13	75
	17	99.836	0	0	0	105	28	133
	18	104.383	0	0	0	199	45	244
	19	113.874	0	0	0	183	38	221
	20	185.394	0	0	0	112	28	140
	21	191.174	0	0	0	231	60	291
	22	37.372	0	0	0	20	4	24
	Total	2,092.9117	3	1	4	1,563	357	1,920
B	1	57.543	1	1	2	11	3	14
	2	61.941	0	0	0	8	1	9
	3	66.955	0	0	0	15	4	19
	4	125.082	0	0	0	28	9	37
	5	131.543	0	0	0	53	14	67
	6	137.219	0	0	0	113	26	139
	7	144.208	0	0	0	79	24	103
	8	151.351	8	4	12	63	14	77
	9	157.032	0	0	0	74	18	92
	10	163.865	8	5	13	31	11	42
	11	163.387	0	0	0	81	16	97
	12	163.596	13	5	18	100	31	131
	13	162.633	0	0	0	77	23	100
	14	161.79	0	0	0	63	20	83
	15	160.904	0	0	0	113	24	137
	16	159.6	1	0	1	65	12	77
	17	159.015	5	1	6	104	19	123
	18	155.016	6	1	7	105	20	125
	19	139.348	0	0	0	73	19	92
	20	120.663	0	0	0	48	6	54
	21	106.171	0	0	0	104	16	120

	22	68.583	0	0	0	14	2	16
	23	37.795	2	0	2	20	5	25
	Total	2,955.24	44	17	61	1,442	337	1,779
C	1	31.385	0	0	0	14	4	18
	2	47.607	0	0	0	29	4	33
	3	54.812	0	0	0	7	2	9
	4	56.607	0	0	0	0	0	0
	5	63.631	0	0	0	8	1	9
	6	71.001	0	0	0	18	4	22
	7	76.759	0	0	0	41	8	49
	8	76.601	0	0	0	25	1	26
	9	72.165	3	1	4	25	6	31
	10	66.627	0	0	0	41	8	49
	11	62.077	0	0	0	26	4	30
	12	57.569	0	0	0	6	0	6
	13	57.883	0	0	0	20	5	25
	14	58.188	1	0	1	14	5	19
	15	58.288	3	1	4	42	10	52
	16	61.037	0	0	0	1	0	1
	17	64.775	0	0	0	28	4	32
	18	68.719	0	0	0	53	11	64
	19	79.806	0	0	0	60	6	66
	20	88.461	0	0	0	62	25	87
	21	96.981	0	0	0	35	8	43
	22	140.872	0	0	0	46	5	51
	23	144.452	0	0	0	83	27	110
	24	138.579	0	0	0	177	41	218
	25	133.147	0	0	0	50	13	63
	26	126.95	1	0	1	39	14	53
	27	123.166	0	0	0	30	8	38
	28	113.58	0	0	0	24	7	31
	Total	2,291.725	8	2	10	1,004	231	1,235
D	1	158.884	0	0	0	48	17	65
	2	155.075	0	0	0	57	13	70
	3	150.448	0	0	0	24	8	32
	4	141.714	6	1	7	1	0	1
	5	136.652	0	0	0	6	2	8
	6	132.067	1	0	1	42	10	52
	7	124.288	0	0	0	19	10	29
	8	120.305	0	0	0	23	3	26
	9	115.019	0	0	0	52	6	58
	10	114.365	0	0	0	35	5	40
	11	114.362	0	0	0	27	9	36
	12	112.927	0	0	0	19	9	28
	13	111.745	3	1	4	27	8	35
	14	110.93	0	0	0	40	12	52
	15	110.729	1	0	1	48	14	62
	16	104.406	7	0	7	34	6	40

	17	94.721	0	0	0	53	12	65
	18	80.654	0	0	0	64	25	89
	19	82.98	0	0	0	12	2	14
	20	83.753	0	0	0	18	5	23
	21	83.163	0	0	0	9	2	11
	22	80.744	3	1	4	30	8	38
	23	77.901	0	0	0	23	8	31
	24	74.668	0	0	0	36	9	45
	25	75.361	0	0	0	2	2	4
	26	76.571	0	0	0	51	14	65
	27	75.832	0	0	0	17	6	23
	28	75.265	0	0	0	45	14	59
	29	75.207	0	0	0	29	5	34
	30	77.543	0	0	0	30	6	36
	31	76.579	0	0	0	18	4	22
	32	75.819	0	0	0	38	18	56
	33	74.221	0	0	0	39	12	51
	34	70.639	0	0	0	25	10	35
	35	57.525	0	0	0	37	4	41
	36	42.121	0	0	0	35	7	42
	37	22.437	0	0	0	35	9	44
	38	20.753	0	0	0	15	3	18
	39	15.834	0	0	0	12	2	14
	Total	3,584.207	21	3	24	1,175	319	1,494
E	1	42.099	0	0	0	5	2	7
	2	42.149	0	0	0	18	5	23
	3	42.202	0	0	0	64	13	77
	4	42.254	0	0	0	71	14	85
	5	42.306	0	0	0	57	9	66
	6	42.357	0	0	0	32	6	38
	7	42.411	0	0	0	43	9	52
	8	42.46	0	0	0	43	10	53
	9	42.514	0	0	0	78	18	96
	10	42.566	0	0	0	12	3	15
	11	42.617	0	0	0	40	7	47
	12	42.668	0	0	0	33	7	40
	13	42.722	0	0	0	46	12	58
	14	42.774	0	0	0	95	19	114
	15	42.826	0	0	0	67	17	84
	16	42.877	0	0	0	121	27	148
	17	42.929	0	0	0	91	21	112
	18	42.982	0	0	0	93	28	121
	19	43.032	0	0	0	74	21	95
	20	43.085	0	0	0	22	7	29
	21	43.138	0	0	0	47	10	57
	22	43.194	0	0	0	81	11	92
	23	43.243	0	0	0	81	11	92
	24	43.291	0	0	0	18	0	18
	25	43.341	0	0	0	52	10	62

	Total	1,068.037	0	0	0	1,384	297	1,681
M	1	28.31	0	0	0	18	4	22
	2	35.481	0	0	0	33	8	41
	3	36.221	0	0	0	153	35	188
	4	36.858	0	0	0	95	22	117
	5	37.488	0	0	0	168	40	208
	6	38.136	0	0	0	77	13	90
	7	38.743	0	0	0	65	13	78
	8	39.442	0	0	0	33	6	39
	9	40.078	0	0	0	30	3	33
	10	40.692	0	0	0	42	4	46
	11	41.459	0	0	0	62	20	82
	12	42.171	0	0	0	56	13	69
	13	42.69	0	0	0	64	21	85
	14	39.097	0	0	0	108	28	136
	15	17.881	0	0	0	10	3	13
	Total	554.747	0	0	0	1,014	233	1,247
P	1	27.508	0	0	0	7	1	8
	2	38.578	0	0	0	25	7	32
	3	50.031	0	0	0	57	19	76
	4	60.351	0	0	0	104	25	129
	5	71.634	0	0	0	53	13	66
	6	74.93	0	0	0	29	3	32
	7	65.948	0	0	0	13	1	14
	8	56.694	0	0	0	45	6	51
	9	48.034	0	0	0	33	3	36
	10	40.036	0	0	0	0	0	0
	11	32.971	0	0	0	7	0	7
	12	20.021	0	0	0	0	0	0
	13	7.069	0	0	0	0	0	0
	Total	593.805	0	0	0	373	78	451
T	1	22.042	0	0	0	10	3	13
	2	37.379	0	0	0	21	0	21
	3	44.09	0	0	0	187	27	214
	4	45.481	0	0	0	157	23	180
	5	48.682	0	0	0	83	23	106
	6	52.999	0	0	0	111	28	139
	7	56.072	0	0	0	92	19	111
	8	65.768	0	0	0	103	20	123
	9	74.399	0	0	0	132	24	156
	10	70.971	0	0	0	93	13	106
	11	74.513	0	0	0	43	11	54
	12	72.672	0	0	0	80	22	102
	13	71.78	0	0	0	17	0	17
	14	76.255	0	0	0	180	54	234
	15	74.795	0	0	0	59	10	69
	16	73.352	0	0	0	110	27	137

17	71.885	0	0	0	102	27	129
18	70.603	0	0	0	86	31	117
19	70.862	0	0	0	66	15	81
20	71.136	0	0	0	77	22	99
21	71.357	0	0	0	162	29	191
22	67.922	0	0	0	93	24	117
23	63.214	0	0	0	25	9	34
24	58.125	0	0	0	103	32	135
25	53.636	0	0	0	24	6	30
26	48.905	0	0	0	50	9	59
27	44.025	0	0	0	37	9	46
28	38.536	0	0	0	35	6	41
Total	1,691.456	0	0	0		523	2,861

APPENDIX B: Transect Data for Survey Block B2, Banks Island Caribou and Muskox Survey July 1998.

Survey Block	Transect Number	Transect Area (km^2)	Caribou: Non-calf	Caribou: Calf	Caribou: Total
B2	1	43.849	0	0	0
	2	43.711	2	0	2
	3	43.53	14	5	19
	4	43.358	14	6	20
	5	43.163	0	0	0
	6	42.959	5	0	5
	7	42.77	0	0	0
	8	42.565	1	0	1
	9	42.403	2	0	2
	10	42.262	0	0	0
	11	42.044	0	0	0
	12	41.859	0	0	0
	13	41.653	6	0	6
	14	41.464	1	0	1
	15	41.283	0	0	0
	16	41.157	2	2	4
	17	40.949	0	0	0
	18	40.758	0	0	0
	19	40.54	0	0	0
	20	40.459	0	0	0
	21	40.182	4	2	6
	22	39.97	0	0	0
	23	39.793	5	0	5
	24	39.649	0	0	0
	25	39.433	6	0	6
	26	39.263	0	0	0
	27	39.091	6	3	9
	28	38.748	4	1	5
	29	31.309	5	3	8
	30	17.129	6	2	8
	31	7.846	6	0	6
	32	6.065	0	0	0
	Total	1,221.214	89	24	113

APPENDIX C: Transect Data for Survey Block B Minus B2, Banks Island Caribou and Muskox Survey July 1998.

Survey Block	Transect Number	Transect Area (km^2)	Caribou: Non-calf	Caribou: Calf	Caribou: Total
B-B2	1	57.543	1	1	2
	2	61.941	0	0	0
	3	66.955	0	0	0
	4	125.082	0	0	0
	5	131.543	0	0	0
	6	137.219	0	0	0
	7	144.208	0	0	0
	8	107.640	1	0	1
	9	113.674	0	0	0
	10	120.906	3	3	6
	11	120.822	0	0	0
	12	121.334	0	0	0
	13	120.774	0	0	0
	14	120.326	0	0	0
	15	119.747	0	0	0
	16	118.841	0	0	0
	17	118.556	5	1	6
	18	115.046	2	0	2
	19	99.699	0	0	0
	20	81.400	0	0	0
	21	67.423	0	0	0
	22	51.454	0	0	0
	23	31.730	2	0	2
	24	14.798	0	0	0
	Total	2,368.661	14	5	19