

Estimates of the number of barren-ground  
caribou in the Cape Bathurst and Bluenose-West  
herds; a reanalysis of post calving photography,  
July 1986 and 1987

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## INTRODUCTION

The first photo-census surveys of barren-ground caribou in the Inuvialuit Settlement Region were completed in 1986 and 1987 (McLean and Russell 1992). Since publication of that survey, evidence has been compiled that supports the hypothesis that there are two herds occupying the area surveyed in 1986 and 1987 (Nagy et al. 1999b). Capture locations and movement data have therefore been reviewed and mapped to retrospectively assign the groups photographed in 1986 and 1987 to Cape Bathurst or Bluenose-West herds. This reanalysis was then used to derive the parameters required to generate population estimate using a modified Lincoln-Petersen estimator (Russell et al. 1996). For purposes of completeness many sections of McLean and Russell (1992) have been repeated in this report.

Funding under the Northern Oil and Gas Action Program (NOGAP) of Indian and Northern Affairs Canada made it possible to capture and collar caribou in 1985 and test the feasibility of a post-calving photo survey of the Bluenose herd in July 1986. Funding for the July 1987 survey was made available through the Inuvialuit Implementation Wildlife Studies program, administered and conducted by the Government of the NWT on behalf of the Inuvialuit.

## METHODS

### ***Radio-collaring***

In preparation for the 1986 and 1987 post-calving photocensus, caribou were equipped with (VHF) radio collars in November 1985 ( $n = 30$  adult cows), in March 1986 ( $n = 5$  young bulls and 5 yearling females), and in March 1987 ( $n = 11$  female calves and 3 bulls) (Figure 1). Herd assignment for collared animals was done following relocation on calving grounds.

### ***Reconnaissance/telemetry surveys***

Caribou groups were monitored each day (except during bad weather) from 29 June – 14 July 1986, and 3 – 15 July 1987 by locating radio-collared caribou with a Cessna 185 aircraft and radio-tracking equipment. The starting dates for the surveys were chosen based on information from the Porcupine herd (D. Russell pers. comm.) and previous studies in the area (Heard and Williams pers. comm., (Carruthers and Jakimchuk 1981). While groups containing radio-collared caribou were being located, we scanned the terrain for other groups, using binoculars when needed. When groups were found that were gathered into a tight enough formation, they were photographed. Groups appropriate for photographing were no more than 2 kilometers wide to ensure animals in the background would be visible on the photos, but there was no length limit.

## ***Photography***

Cameras used were three 35 mm single-lens reflex equipped with normal 50 mm lenses, motor drives and through-the-lens automatic light metering. Color transparency film with ASA ratings of 64, 100 and 400 was used. Photographs were taken at an oblique angle from the side windows of the aircraft. Flight altitude was between 150 and 300 meters above ground level, and the plane was positioned slightly back from the near edge of the group and between the sun and the caribou to ensure good contrast. Two cameras were necessary, while a third was kept on hand as a spare. Two cameras provided for continuous exposure since one observer could reload while the other photographed. The camera in use was tilted up and down and fired often enough to ensure complete coverage of the entire group, with 10 – 25% overlap. The shutter speed used was 1/250 second or faster. The time between frames averaged about one second; therefore, minimal movement of animals occurred. Only one pass was required to photograph an entire group. The speed of this method ensured that there was minimal error caused by caribou crossing overlap lines.

Each group photographed was given a number, marked on a 1:250,000 scale map and noted as to roll number, frame number, radio-collars present and any comments deemed necessary for further reference, either on tape, a field notebook or both.

The monitoring of radio-collared caribou allowed the observers to assess the degree of aggregation, and note the amount of movement of groups from day to day. A photo survey is most likely to succeed where group size is large and the probability of groups without radio-collars is small. If we found small, scattered groups when monitoring we checked only a few collars and waited for better conditions.

## ***Counting caribou images and photographs***

The slides were projected onto a 21.5 by 28 cm sheet of white paper placed about 45 centimeters from the projector lens. Overlap lines were drawn between landmarks common to adjacent slides. This prevented double counting of caribou. Caribou were counted by marking each image with a penciled dot and pressing a tally machine. A magnifying glass was usually necessary to count animals clearly. Calves were the only distinguishable age class on the slides, so whenever a calf image was marked a second tally counter was activated. The counting of each slide resulted therefore in two numbers, one for caribou aged one year and older and one for calves approximately one month old.

The marking of each image with a pencil produced a hard copy of the interpretation and count that could be filed with the slides and/or verified by another observer.

### ***Population size***

The number of caribou available for the 1986 and 1987 photocensus was determined by reviewing the VHF telemetry tracking records for the period 1985 to 1988. The photo count data provided an estimate of the minimum number of non-calf caribou in the Cape Bathurst and Bluenose-West barren-ground caribou herds. However, because not all collared caribou are associated with aggregations and not all aggregations will always contain a collared caribou, total herd size will always be larger than the minimum count obtained during a photo-census (Russell et al. 1996). We estimated the total population size using a modification of the method presented by (Russell et al. 1996) that is based on the Lincoln-Petersen Index as applied to radio-telemetry data by (White and Garrott 1990). Not all aggregations photographed contained a radio-collared caribou but they were typically found in close proximity to aggregations that contained radio-collared caribou. We assumed that these groups formed a general aggregation of caribou that under more favorable conditions would have formed one group. By this method

$$N = (((M+1)(C+1))/(R+1)) - 1$$

Where: N = estimate of population size during the census

M = number of radio-collared caribou present in the herd (including all collars known to be active during the survey)

C = number of caribou in all aggregations observed during the survey

R = number of radio-collared caribou observed in these aggregations during the survey.

The 95% CI for the estimate can then be calculated as  $N_i = 1.96 \text{ Var}(N)^{0.5}$ , where:

$$\text{Var}(N) = ((M+1)(C+1)(M-R)(C-R))/(R+1)^2(R+2)$$

### ***Comparison of population estimates***

We used Lincoln-Petersen estimators to determine if the relative abundance of caribou (K) in each herd during 1986 and 1987 was significantly different (Williams et al. 2002). We assumed that capture probabilities were different between 1986 and 1987. We estimated K and constructed the appropriate 95% confidence intervals as follows (Williams et al. 2002):

$$K = [((n_{b1}+1)(n_{b2}+1)/(m_{b2}+1)) - 1] / (n_{a1}n_{a2}) / m_{a2}$$

with

$$\text{var}(K) = (m_{a2}n_{b1}n_{b2}/m_{b2}n_{a1}n_{a2}^3) [((n_{b2}-m_{b2})(n_{b1}-m_{b2})(m_{a2}n_{a1}n_{a2})) + ((n_{a2}-m_{a2})(n_{a1}-m_{a2})(m_{b2}n_{b1}n_{b2}))]$$

where  $n_1$  = number of collared animals available for the photo-census,  $n_2$  = number of caribou associated with radio collared caribou located,  $m_2$  = number of

collared caribou located during the photo-census, and the subscripts a and b refer to time period 1 and 2 of the comparisons, respectively.

We calculated the 95% CI of K as  $1.96 \text{ Var}(K)^{0.5}$  (Williams et al. 2002). If K was  $< 1$  and the 95% CI did not include 1, the population estimate for time period 2 was significantly lower than that for time period 1. If K was  $> 1$  and the 95% CI did not include 1, the population estimate for time period 2 was significantly higher than that for time period 1. If the 95% CI around K included 1, the population estimates for time periods 1 and 2 were not significantly different.

### ***Group size and number of collars***

To determine whether or not there was a relationship between groups size and the number of collars (regardless of sex), we compared the observed versus expected number of radio-collared caribou among the groups located during the census using a Chi-square test (Gibbons 1985). The expected number was based on the mean number of caribou observed per radio collar during the census.

## **RESULTS**

### ***1986 survey***

The first survey flights in the area were made on 29 June 1986. At that time approximately 80% of the radio-collared caribou were located within 10 km of the coast and from 25 km west of Paulatuk to 50 km east (Figure 2). However, they were too scattered to photograph. They soon began moving inland and by 4 July were sufficiently aggregated for photography. At this point some groups were up to 40 km inland, near the south of Rummy Lake. They then largely stayed in distinct areas until 10 July. The caribou in the Mackenzie Lake area remained scattered until after 14 July when they finally aggregated enough to allow photographing. Figure 2 shows the distribution of radio-collared Cape Bathurst and Bluenose-West barren-ground caribou relative to where they were captured during 1985 and 1986. The distribution of groups photographed is shown in Figure 3. The distribution of the largest groups photographed in the Bluenose-West herd relative to the sites where the radio-collared caribou in those groups were captured is shown in Figure 4.

Whenever groups were encountered in tight enough formation they were photographed. This resulted in groups in some areas being photographed several times. At project end on 15 July, 87 groups had been photographed on eight different days (Appendix A). However, it was only necessary to count 33 of these groups recorded on 4 of those days to obtain a complete count of the photographed portions of the herd (Table 1 and 2).

The first observer on the photos counted a total of 96, 936 non-calf caribou. Of these 13, 476 were in the post-calving/early summer range of the Cape Bathurst (Table 1) and 83,460 were in the post-calving/early summer range of the Bluenose-West herd (Table 2). A break down of the number of caribou on each slide is on file with the Department of Environment and Natural Resources, Inuvik, NT.

John Russell (J.R.) and Bruce McLean (B.M.) both counted the slides of several groups and a comparison of the counts was made (Table 3). There was a difference of approximately 3-10% (non-calves) on individual groups compared and an overall difference for all groups counted of 4% higher (non-calves) for J.R. than B.M. There was a much greater difference in the number of calves counted and one observer (B.M.) was less confident in distinguishing calves. In oblique photographs the animals in the background are much smaller and more difficult to see.

Two radio-collared caribou from photographed groups were observed to move near other areas. Caribou 33B moved from Langton Bay area to within 30 km of the nearest Rummy Lake groups on July 9 before looping back northwest and further away from them. Caribou 21B was observed to move from the Rummy Lake area to Hornaday Falls on July 7 and therefore was only 15 – 20 km from groups 25 and 27. We know of no interchange of animals from one area (group) to another between the days on which they were counted.

### **1987 survey**

In 1987 the survey started on 3 July with tracking flights to locate the radio-collared caribou and assess the degree of aggregation. The weather deteriorated on 4 July but had improved by 7 July. Suitable aggregations started to form on 8 July (Appendix D). The distribution of radio-collared Cape Bathurst and Bluenose-West barren-ground caribou relative to where they were captured during 1985, 1986, and 1987 is shown in Figure 5. As in 1986, the caribou were distributed over a large area (Figure 6). The largest aggregations (most suitable for photos) were observed on 9, 10, and 11 July. A large bull group (group 16) was photographed on 9 July and again on 11 July. The count on 11 July for this group was approximately 9,000 animals higher than on 9 July. All other groups were photographed once only on either 9 or 10 July. Twenty-four groups were located and photographed. Animals on the Cape Bathurst Peninsula area (north of Harrowby Bay) did not aggregate suitably for photography, although the number of caribou was visually estimated to be around 2500 non-calf caribou.

A total of 115,240 non-calf caribou was counted on the slides. Of these 10,728 were in the post-calving/early summer range of the Cape Bathurst (Table 4) and 104,512 were in the post-calving/early summer range of the Bluenose-West herd (Table 5). The frame numbers and the respective number of caribou counted are on file with the Department of Environment and Natural Resources,

Inuvik, NT. John Russell (J.R.) and Bruce McLean (B.M.) both counted a sample of the slides to verify the counts (Table 6). There was an overall difference of less than 2% (1.3%) in the non-calf counts. As in 1986 there was a larger difference in calf numbers counted.

### ***Population estimate 1986***

All three of the available radio-collared caribou in the Cape Bathurst herd were photographed (Table 7). We counted 13,476 non-calf and 2,774 calf caribou on the photos taken (Table 1). Approximately 17% of the total number of caribou counted was calves (Table 1). Three of the 8 groups photographed contained radio-collared caribou (Table 1). The largest group photographed contained 2,716 non-calf and 727 calf caribou (Table 1). The population estimate for this herd was 13,476 non-calf caribou (Table 7).

Thirty-three of the 35 available radio-collared caribou in the Bluenose-West herd were photographed (Table 7). We counted 83,460 non-calf and 20,463 calves on the photos taken (Table 2). Approximately 20% of the total number of caribou counted was calves (Table 2). Sixteen of the 25 groups photographed contained radio-collared caribou (Table 2). The largest group photographed contained 19,786 non-calf and 545 calf caribou (Table 2). The population estimate for this herd was 88,369  $\pm$ 6,899 non-calf caribou (CV = 4%) (Table 7).

### ***Population estimate 1987***

Five of the six available radio-collared caribou in the Cape Bathurst herd were photographed (Table 7). We counted 10,728 non-calf and 1,221 calf caribou on the photos taken (Table 4). Approximately 13% of the total number of caribou counted was calves (Table 4). Three of the four groups photographed contained radio-collared caribou (Table 4). The largest group photographed was 5,720 non-calf and 615 calf caribou (Table 4). The population estimate for this herd was 12,516  $\pm$ 3,504 non-calf caribou (CV = 14%) (Table 7). The population estimates based on the groups and radio-collared caribou photographed in 1986 and 1987 were not significantly different ( $K = 0.93$ ; upper and lower 95% CI are 0.59 and 1.27, respectively).

Forty-three of the 45 available radio-collared caribou in the Bluenose-West herd were photographed (Table 7). We counted 104,512 non-calf and 16,791 calves on the photos taken (Table 5). Approximately 14% of the total number of caribou counted was calves (Table 5). Nineteen of the 21 groups photographed contained radio-collared caribou (Table 5). The largest group photographed contained 22,843 non-calf and 712 calf caribou (Table 2). The population estimate for this herd was 109,263  $\pm$ 6,655 non-calf caribou (CV = 3%)(Table 7). The population estimates based on the groups and radio-collared caribou

photographed in 1987 was significantly higher than that for 1986 ( $K = 1.23$ ; upper and lower 95% CI are 1.11 and 1.36, respectively).

### ***Group size and number of collars***

The results of our analyses indicate that the number of radio-collars per group was random in 1986 (Appendix A) and in 1987 (Appendix B). In 1986 the number of caribou per radio collar was 2,617 while in 1987 it was 2,400. The average size of groups photographed was larger in 1987 (4,600 vs. 2,900), and there were fewer groups (27 vs. 33).

## **DISCUSSION**

The photo surveys in 1986 and 1987 gave a much higher, and hopefully more accurate, estimate of the population size than previous surveys. Although the photo method gives a direct count, several biases affect the accuracy of the estimate. Table 8 summarizes the factors that would increase or decrease the population estimates. Factors that result in under-estimating the numbers present would mean our estimates are conservative.

(Valkenburg et al. 1985) recommended three conditions for a successful radio search photo survey (where all animals are surveyed):

- 1) radio-collars must be randomly distributed;
- 2) caribou must be grouped during surveying and the numbers of groups is not large compared with the number of radio-collared individuals; and
- 3) all radio-collars must be heard and precisely located.

To assess the success of the photo surveys, these conditions as well as two additional factors were examined; namely the possibility of double counting and photo-interpretive error. The 1986 and 1987 surveys satisfy these conditions with some qualifications about the degree of randomness.

The radio-collars deployed in the Cape Bathurst and Bluenose-West herds are unlikely to be completely representative as the majority were placed on adult females with only 4 bulls having functional collars in 1986 and 5 in 1987. This could mean that part of the bull component of the herd was not found and, therefore, was underestimated. As we do not have the composition of the groups or know the adult sex ratio, we cannot determine the applicability of this possible bias.

The results of our analyses indicate that the number of radio-collars per group was random in 1986 and in 1987. In both years the aggregations were suitable for photographing with some large groups containing up to 20,000

caribou. However, all caribou did not aggregate in the same area or on the same date. In 1986 some large groups were located which did not have radio-collared individuals (e.g. group 70), while other collared groups had only a few hundred animals (group 36). This suggests that groups without radio-collared caribou in them could have been missed. Using the 1987 data and calculations based on (Valkenburg et al. 1985) there is theoretically an 86% probability of a group of 4600 caribou (1987 mean group size) having at least one radio-collar. It is unlikely that there were many groups that large that were not surveyed. Smaller groups of hundreds or 1-2,000 could easily be missed. We did not attempt a systematic survey of the rest of the summer range during our survey and cannot quantify the bias of missed animals. To do so would have increased survey costs. During surveys of four Alaskan herds, 87 to 90 percent of the caribou found by extensive visual search involving several aircraft would have been located using radio-search techniques alone (Valkenburg et al. 1985). They also found in Alaska that the number of animals per radio collar and groups size is quite variable among herds.

Our radio-tracking information indicates that there was no crossover among groups photographed and that all collars were accounted for (3 of the 41 collared caribou had died) in 1986. This greatly reduces the potential for double counting of groups photographed on different days.

The photos in 1987 were taken on two successive days in different areas except for the large bull group (group 16 on 9 July, group 25 on 11 July). Based on the collar locations there was no possible overlap among groups photographed on 9 and 10 July. The difference in the counts of the large bull group (13,900 on 9 July and 22,800 on 11 July) is more difficult to explain. The photographs are better on 11 July and the group was more aggregated. Possibly animals were missed in the immediate area on 9 July. As well, those photos were slightly overexposed. The other photographed groups were still more than 50 km away and did not add to this group (based on collared individuals). A recount of group 25 by a third observer gave a count of 23,000. If the 9 July count is used, the combined Cape Bathurst and Bluenose-West herd estimate would be reduced to 106,300 non-calf caribou. Forty-eight radio collars were accounted for in 1987, 1 bull was located far to the west and was likely solitary or in a very small group and 1 additional cow was not located.

The 1987 estimate for the Cape Bathurst herd was not significantly different from that in 1986, while that for the Bluenose-West herd was significantly higher. The greater number of collars operating in 1987 likely assisted in finding groups of caribou which might otherwise have been missed. This would increase the estimate. Growth of the Bluenose-West herd may also have accounted for the higher count in 1987. Allowing for potential photo-interpretive error and missed animals, the Cape Bathurst herd was likely in excess of 13,000 non-calf caribou and the Bluenose-West herd was likely more than 110,000 non-calf caribou in 1987.

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## **PERSONAL COMMUNICATIONS**

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Russell, Don. Porcupine Caribou Biologist, Canadian Wildlife Service, Whitehorse, Yukon.

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Table 1. Radio-collared caribou and number of caribou counted in each group photographed on 14 July 1986 in the Cape Bathurst herd near Paulatuk, NT.

Group	Date	Latitude	Longitude	No. Collars	Adults	Calves	Calves (%)	Area
65	14-Jul-86	70.067	-127.417	1	1435	109	7.1	Mackenzie Lake
66	14-Jul-86	70.009	-127.646	0	1415	206	12.7	Mackenzie Lake
67	14-Jul-86	70.012	-127.461	0	440	101	18.7	Mackenzie Lake
68	14-Jul-86	70.017	-127.367	1	1971	530	21.2	Mackenzie Lake
69	14-Jul-86	69.990	-127.419	0	1493	116	7.2	Mackenzie Lake
70b	14-Jul-86	69.965	-127.418	0	2716	727	21.1	Mackenzie Lake
71	14-Jul-86	70.000	-127.167	1	2108	617	22.6	Mackenzie Lake
72	14-Jul-86	69.944	-127.531	0	1898	368	16.2	Mackenzie Lake
Total				3	13476	2774	17.1	

Group 70b: 55 caribou in this group were not photographed but noted and added to the adult column.

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Table 2. Radio-collared caribou and number of caribou counted in each group photographed between 4-9 July 1986 in the Bluenose-West herds near Paulatuk, NT.

Group	Date	Latitude	Longitude	No. Collars	Adults	Calves	Calves (%)	Area
1	04-Jul-86	69.200	-125.650	2	2251	691	23.5	Langton Bay
2	04-Jul-86	69.217	-125.652	0	1622	474	22.6	Langton Bay
3	04-Jul-86	69.183	-125.650	1	1888	542	22.3	Langton Bay
4	04-Jul-86	69.233	-125.833	2	5166	1954	27.4	Langton Bay
5	04-Jul-86	69.367	-126.500	2	19786	545	2.7	Langton Bay
33	07-Jul-86	68.933	-122.633	4	4658	1856	28.5	E. Hornaday River
34	07-Jul-86	68.950	-122.417	2	2729	1086	28.5	E. Hornaday River
35	07-Jul-86	68.800	-121.033	1	2250	440	16.4	E. Hornaday River
36	07-Jul-86	68.817	-121.200	1	278	115	29.3	E. Hornaday River
37	07-Jul-86	69.400	-122.583	1	1437	536	27.2	E. Hornaday River
38	07-Jul-86	69.383	-122.533	1	888	267	23.1	E. Hornaday River
39	07-Jul-86	69.319	-122.547	0	814	258	24.1	E. Hornaday River
40	07-Jul-86	69.267	-122.533	1	2718	910	25.1	E. Hornaday River
41a	07-Jul-86	69.215	-122.558	0	1041	231	18.2	E. Hornaday River
42	07-Jul-86	69.271	-122.636	0	574	207	26.5	E. Hornaday River
43	07-Jul-86	69.083	-122.767	1	1136	402	26.1	Hornaday Falls
44	07-Jul-86	69.055	-122.693	0	831	414	33.3	Hornaday Falls
45	07-Jul-86	69.143	-122.944	0	1276	509	28.5	Hornaday Falls
54	09-Jul-86	68.950	-123.500	2	4622	983	17.5	Rummy Lake
55	09-Jul-86	68.897	-123.633	0	1763	308	14.9	Rummy Lake
56	09-Jul-86	68.884	-123.639	0	1341	394	22.7	Rummy Lake
57	09-Jul-86	68.767	-123.667	2	3646	741	16.9	Rummy Lake
58	09-Jul-86	68.830	-123.747	0	490	64	11.6	Rummy Lake
59	09-Jul-86	68.850	-123.833	9	16703	5783	25.7	Rummy Lake
60	09-Jul-86	68.700	-123.583	1	3552	753	17.5	Rummy Lake
Total				33	83460	20463	19.7	

Group 41a: 60 unphotographed caribou were added to the adult column.

Table 3. A comparison of counts between observers of post-calving photos, July 1986.

Group #	Adults	Calves	Total	Observer
1	2103	31	2134	B.M.
5	17821	34	17855	B.M.
34	3061	339	3400	B.M.
36	269	57	326	B.M.
41 (6)	53	11	64	B.M.
1	2251	691	2942	J.R.
5	18892	545	19437	J.R.
34	2729	1086	3815	J.R.
36	278	115	393	J.R.
41 (6)	55	13	68	J.R.
Total	24205	2450	26655	J.R.
	23307	472	23779	B.M.
difference (J.R. minus B.M.)	898	1978	2876	

Table 4. Radio-collared caribou and number of caribou counted in each group photographed on 10 July 1987 in the Cape Bathurst herd near Paulatuk, NT.

<b>Group</b>	<b>Date</b>	<b>Latitude</b>	<b>Longitude</b>	<b>No. Collars</b>	<b>Adults</b>	<b>Calves</b>	<b>Calves (%)</b>
<b>21</b>	10-Jul-87	69.667	-126.567	<b>1</b>	1047	97	8.5
<b>22</b>	10-Jul-87	70.250	-127.233	<b>2</b>	5720	615	9.7
<b>23</b>	10-Jul-87	70.288	-127.287	<b>0</b>	1461	509	25.8
<b>26</b>	10-Jul-87	70.350	-127.600	<b>2</b>	2500		no photos
<b>Total</b>				<b>5</b>	<b>10728</b>	<b>1221</b>	<b>12.9</b>

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Table 5. Radio-collared caribou and number of caribou counted in each group photographed between 4-9 July 1987 in the Bluenose-West herds near Paulatuk, NT.

<b>Group</b>	<b>Date</b>	<b>Latitude</b>	<b>Longitude</b>	<b>No. Collars</b>	<b>Adults</b>	<b>Calves</b>	<b>Calves (%)</b>
1	09-Jul-87	69.467	-122.617	1	616	32	4.9
2	09-Jul-87	69.767	-122.700	1	2273	261	10.3
3	09-Jul-87	69.617	-122.083	1	555	102	15.5
4	09-Jul-87	69.333	-121.900	2	1479	39	2.6
5	09-Jul-87	69.167	-122.650	1	160	34	17.5
6	09-Jul-87	69.267	-123.000	1	4054	1052	20.6
7	09-Jul-87	69.183	-124.350	4	2763	552	16.7
8	09-Jul-87	69.200	-125.133	6	6923	708	9.3
9	09-Jul-87	69.276	-125.459	0	2226	403	15.3
10	09-Jul-87	69.217	-125.717	5	16592	4453	21.2
11	09-Jul-87	69.217	-125.900	7	15178	3566	19.0
12	09-Jul-87	69.050	-124.067	1	1110	275	19.9
13	09-Jul-87	69.333	-125.583	1	2795	349	11.1
14	09-Jul-87	69.299	-125.450	0	2215	272	10.9
15	09-Jul-87	69.417	-125.167	1	2815	227	7.5
17	09-Jul-87	69.350	-125.883	1	7732	2500	24.4
18	09-Jul-87	68.950	-124.750	1	942	219	18.9
19	10-Jul-87	69.483	-126.267	1	3445	180	5.0
20	10-Jul-87	69.517	-126.333	3	7014	682	8.9
24	10-Jul-87	69.300	-124.000	1	782	173	18.1
25	11-Jul-87	69.250	-127.183	4	22843	712	3.0
<b>Total</b>				<b>43</b>	<b>104512</b>	<b>16791</b>	<b>13.8</b>

Table 6. A comparison of caribou counts between observers of the post-calving aggregation photos, July 1987.

Roll No.	Frame No.	Adults	Calves	Observer
4	9	212	27	B.M.
4	13	371	89	B.M.
4	22	2089	25	B.M.
5	1	117	0	B.M.
5	1	248	20	B.M.
5	3	251	12	B.M.
5	5	477	15	B.M.
5	10	39	9	B.M.
5	15	32	5	B.M.
5	20	79	9	B.M.
5	25	263	26	B.M.
5	35	86	31	B.M.
5	37	94	27	B.M.
6	2	71	9	B.M.
6	13	232	2	B.M.
6	17	160	34	B.M.
4	9	193	53	J.R.
4	13	371	133	J.R.
4	22	2077	551	J.R.
5	1	111	9	J.R.
5	2	231	47	J.R.
5	3	247	111	J.R.
5	5	460	130	J.R.
5	10	41	13	J.R.
5	15	32	6	J.R.
5	20	87	23	J.R.
5	25	268	65	J.R.
5	35	82	47	J.R.
5	37	102	31	J.R.
6	2	65	17	J.R.
6	13	240	58	J.R.
6	17	153	50	J.R.
Total		4821	340	B.M.
		4760	1344	J.R.
B.M. minus J.R.		61		

Table 7. Non-calf population estimates for Cape Bathurst and Bluenose-West barren-ground caribou herds in 1986 and 1987.

Herd	Year	M	C	R	N	95% CI	Number Counted on Photos	Coefficient of Variation (%)
Cape Bathurst	1986	3	13476	3	13476			
	1987	6	10728	5	12516	$\pm 3504$	10728	0.14
Bluenose-West	1986	35	83460	33	88369	$\pm 6899$	83460	0.04
	1987	45	104512	43	109263	$\pm 6655$	104512	0.03

The estimate of population size for each census was calculated as

$$N = (((M+1)(C+1))/(R+1))-1; \text{ where:}$$

N = estimate of population size during the census

M = number of radio-collared caribou present in the herd (including all collars known to be active during the survey)

C = number of caribou observed in aggregations containing at least one radio-collared caribou during the survey

R = number of radio-collared caribou observed in these aggregations during the survey.

The 95% CI for the estimate was calculated as  $N_i \pm 1.96 \text{ Var}(N)^{0.5}$ , where:

$$\text{Var}(N) = ((M-1)(C-1)(M-R)(C-R))/(R+1)^2(R+2)$$

Table 8. Factors that influence the accuracy of the population estimates obtained for the Cape Bathurst and Bluenose-West barren-ground caribou herds in 1986 and 1987.

Year	Effect on Population Size		
	Photo interpretive error	Groups missed	Double counting
1986	<ul style="list-style-type: none"> <li>- JR counts 4% higher than BM</li> <li>- over-estimate population size</li> </ul>	<ul style="list-style-type: none"> <li>- high chance groups were missed</li> <li>- under-estimate population size</li> </ul>	<ul style="list-style-type: none"> <li>- moderate chance</li> <li>- over-estimate population size</li> </ul>
1987	<ul style="list-style-type: none"> <li>- JR counts 2% higher than BM</li> <li>- over-estimate population size</li> </ul>	<ul style="list-style-type: none"> <li>- moderate</li> <li>- under-estimate population size</li> </ul>	<ul style="list-style-type: none"> <li>- low chance</li> <li>- over-estimate population size</li> </ul>

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Figure 1. Distribution of capture sites for Cape Bathurst and Bluenose-West barren-ground caribou radio collared during November 1985, March 1986, and March 1987.

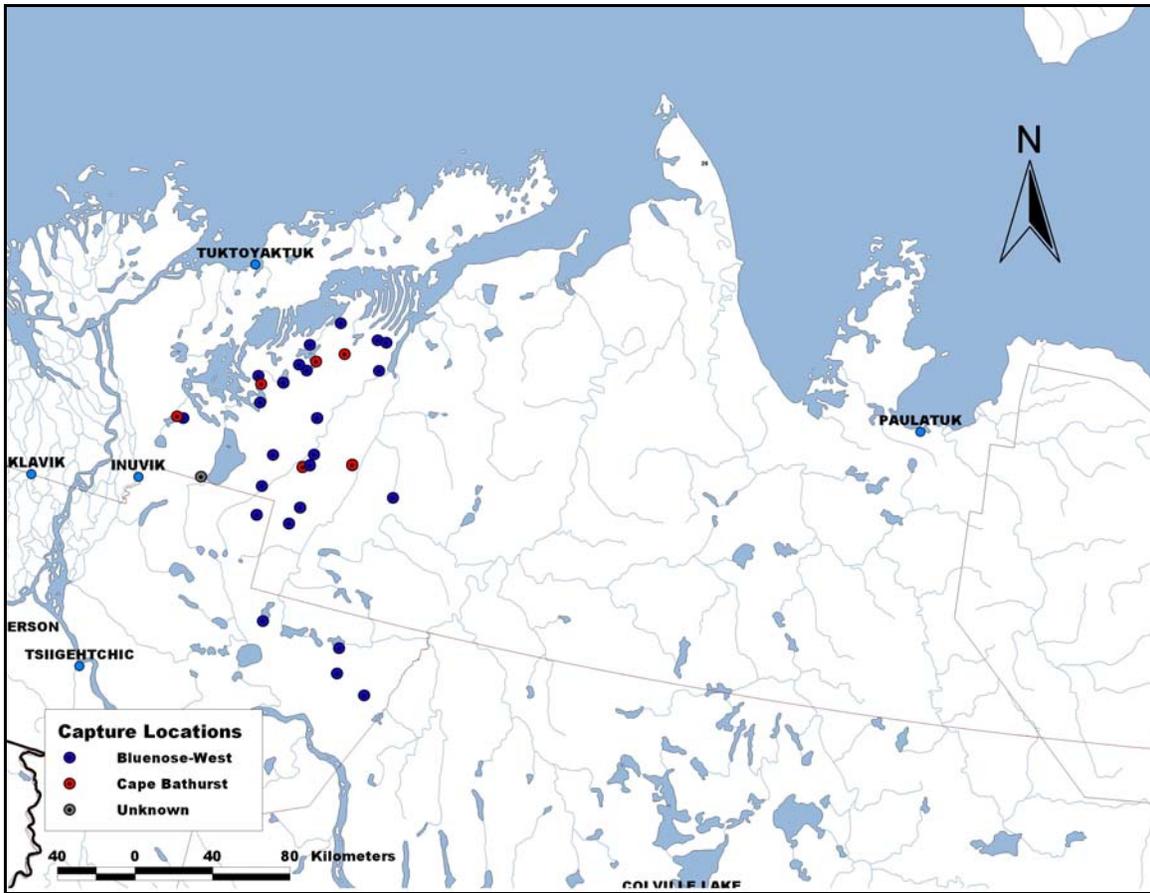


Figure 2. Distribution of radio-collared Cape Bathurst and Bluenose-West barren-ground caribou relative to where they were captured during 1985 and 1986.

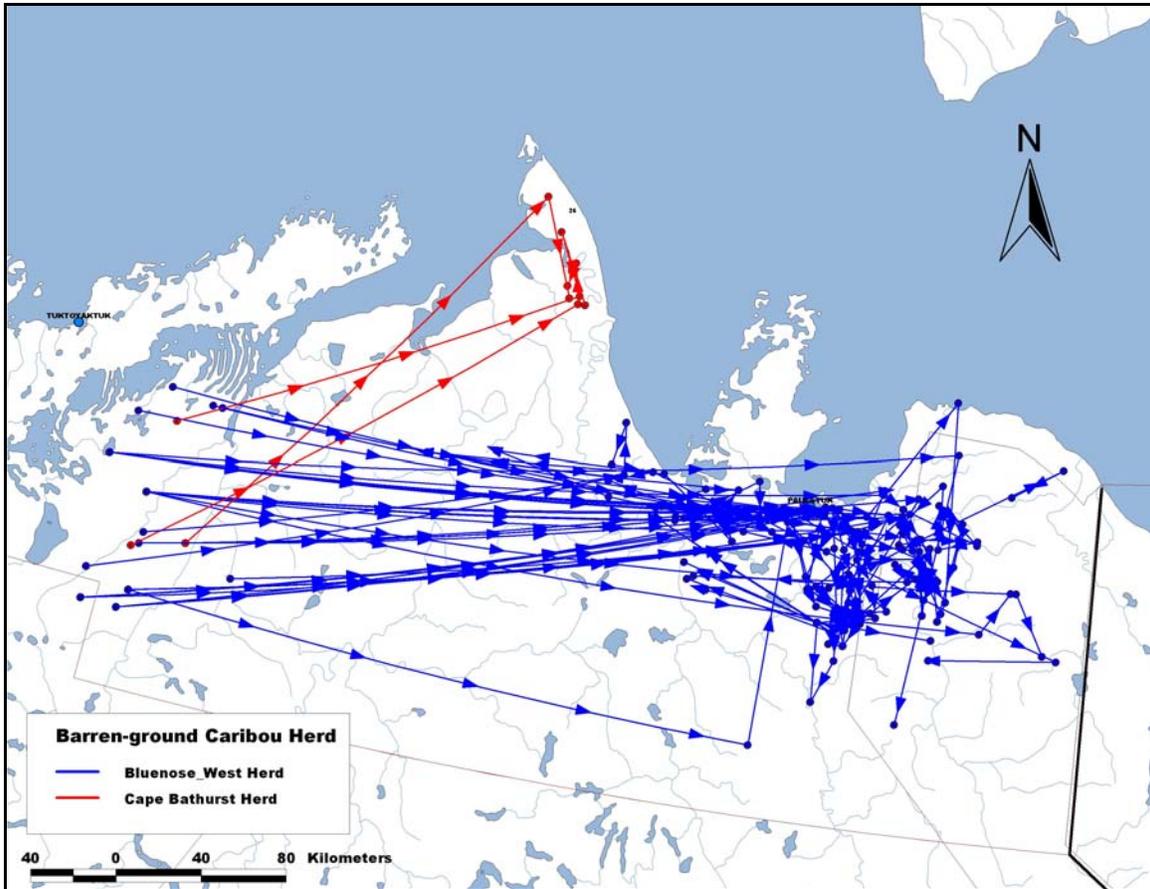


Figure 3. Distribution of groups of Cape Bathurst and Bluenose-West barren-ground caribou photographed during 4 – 15 July 1986.

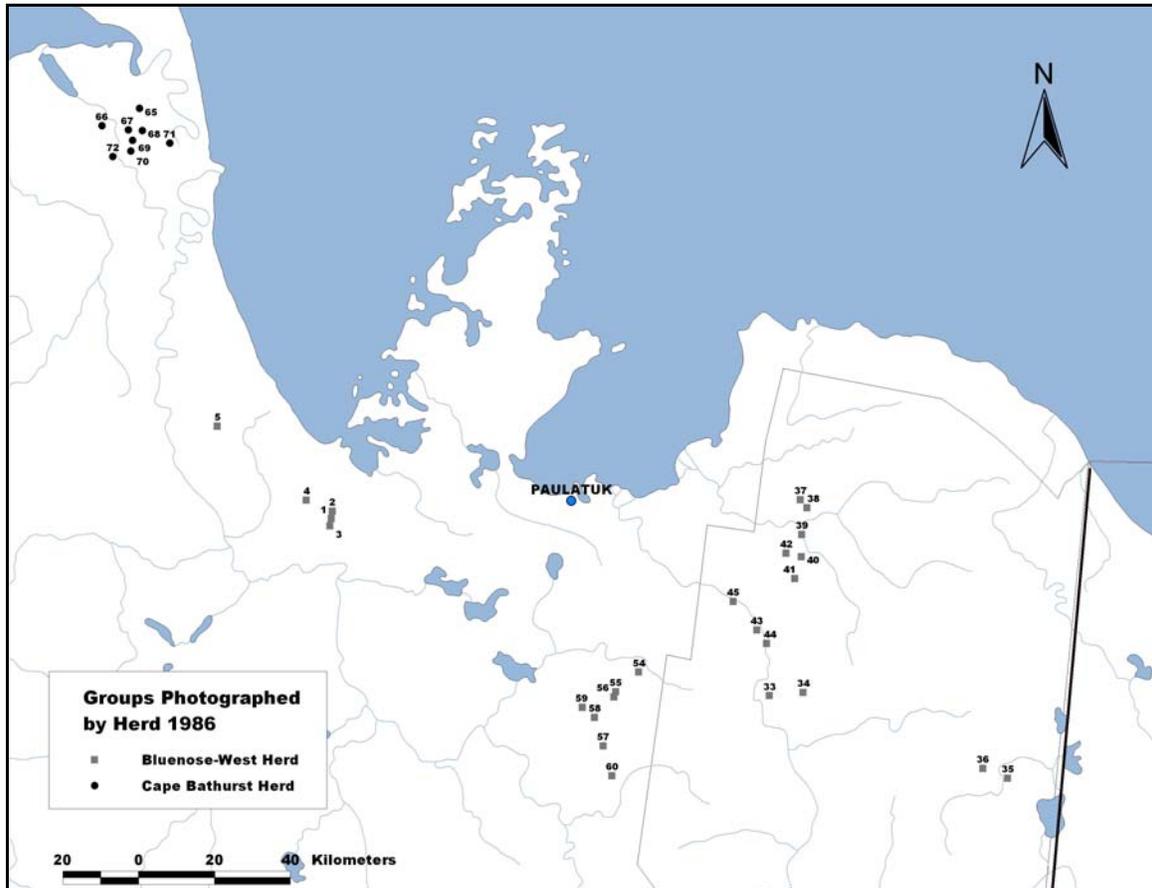


Figure 4. Distribution of the largest groups photographed in the Bluenose-West herd relative to the sites where the radio-collared caribou in those groups were captured.

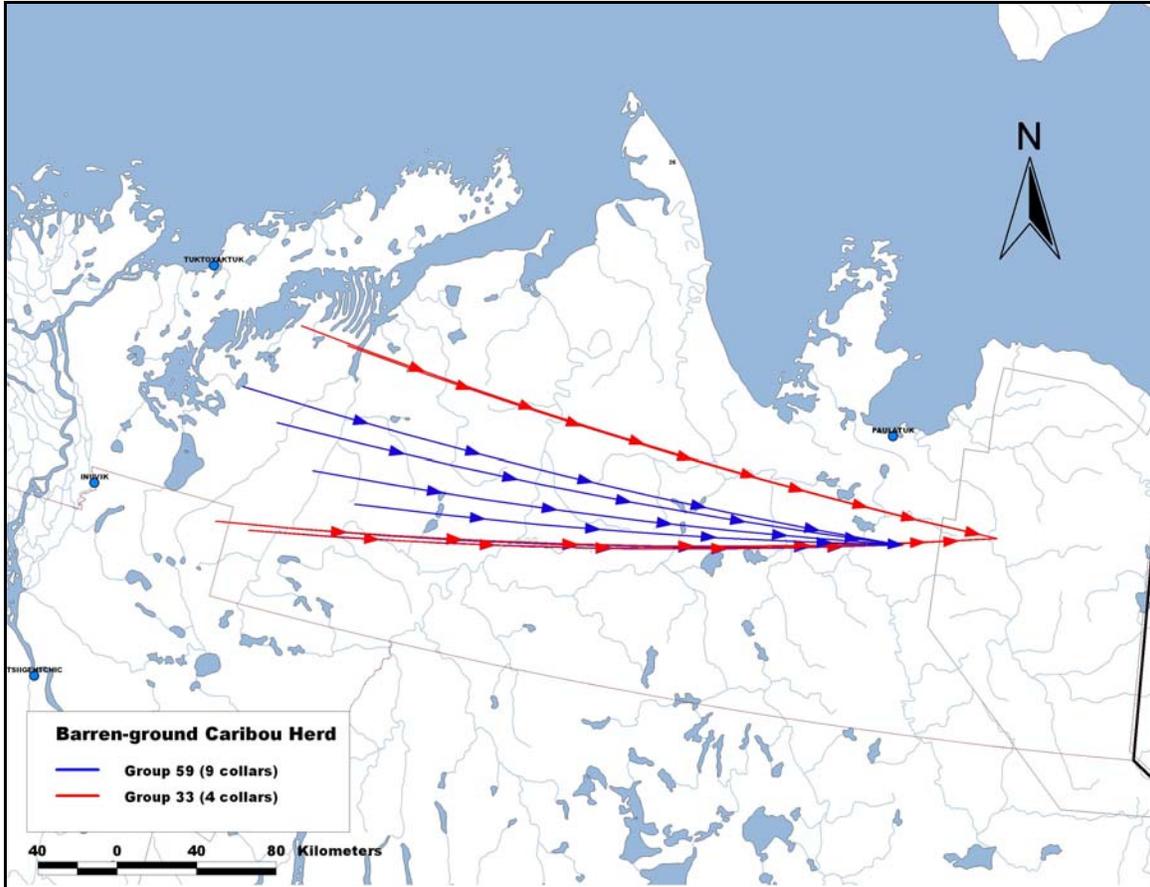


Figure 5. Distribution of radio-collared Cape Bathurst and Bluenose-West barren-ground caribou relative to where they were captured during 1985, 1986, and 1987.

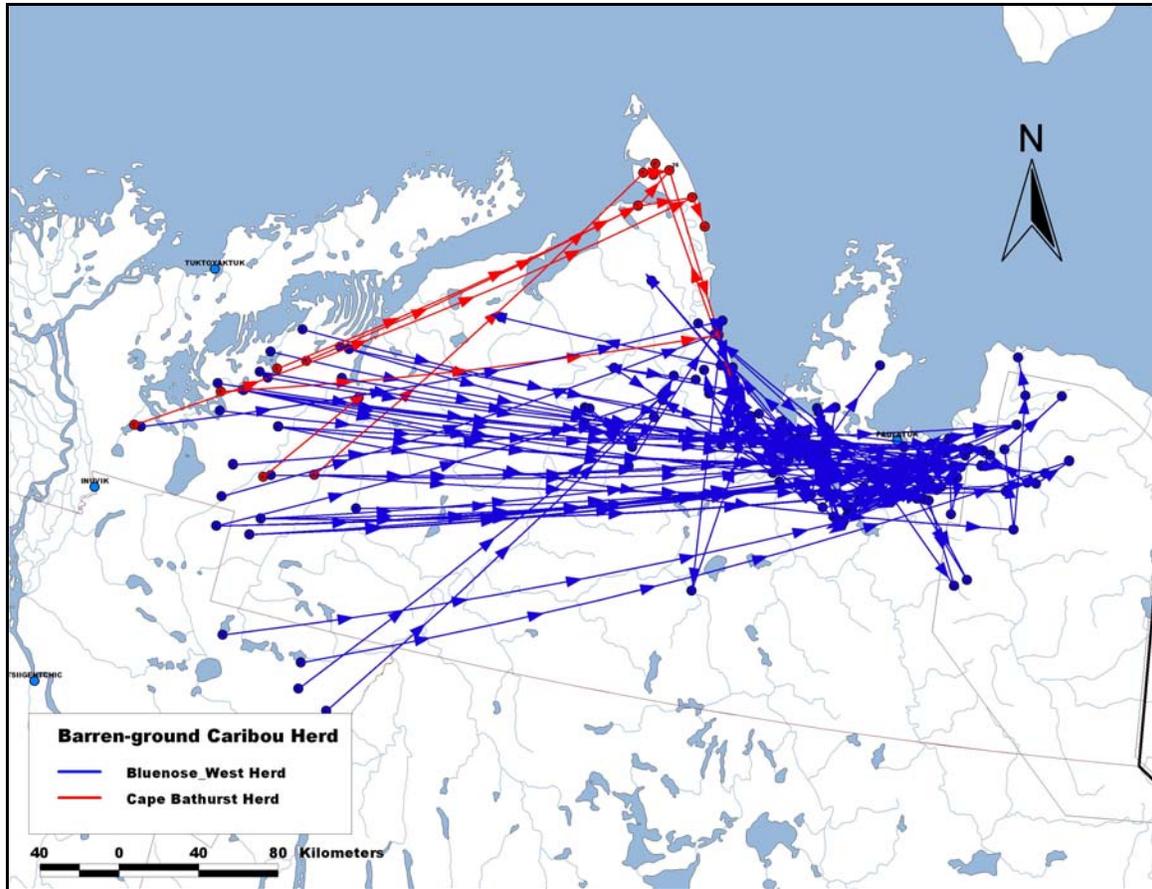


Figure 6. Distribution of groups of Cape Bathurst and Bluenose-West barren-ground caribou photographed during 9 - 11 July 1987.

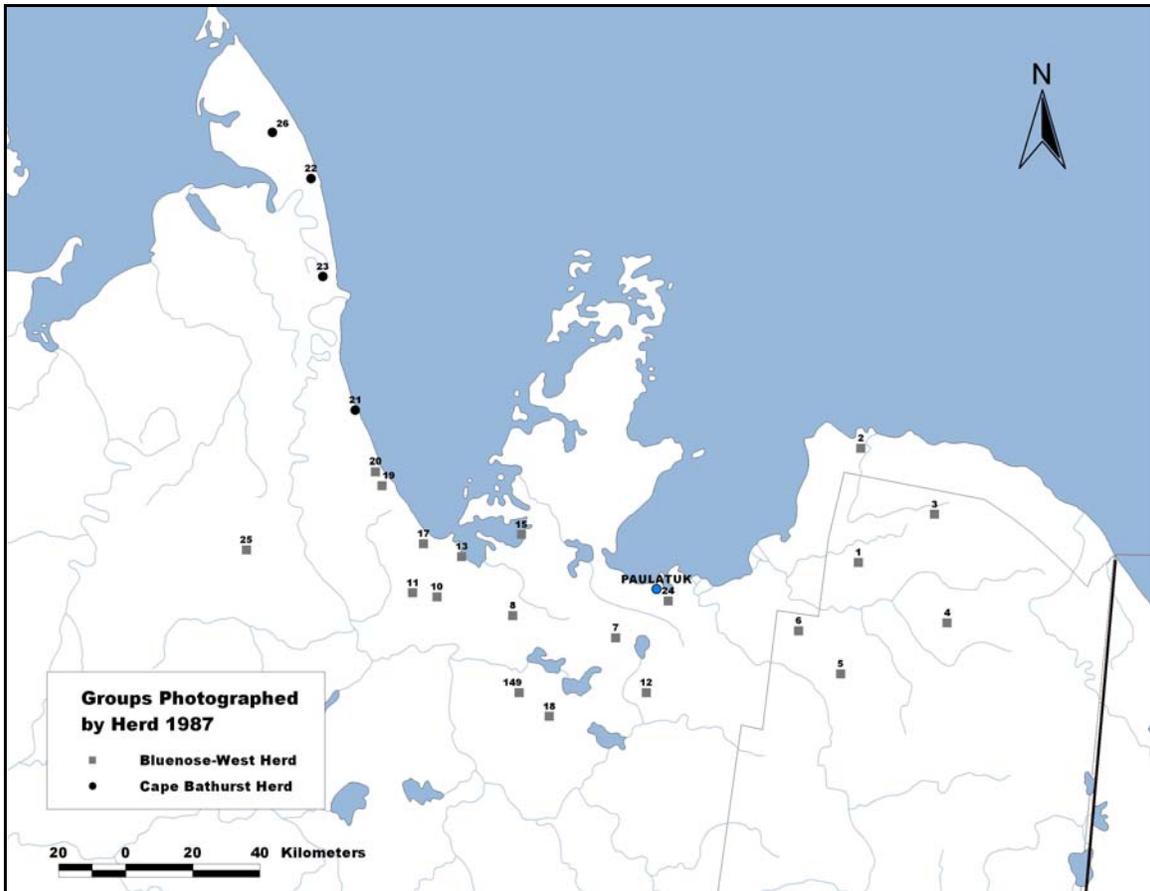
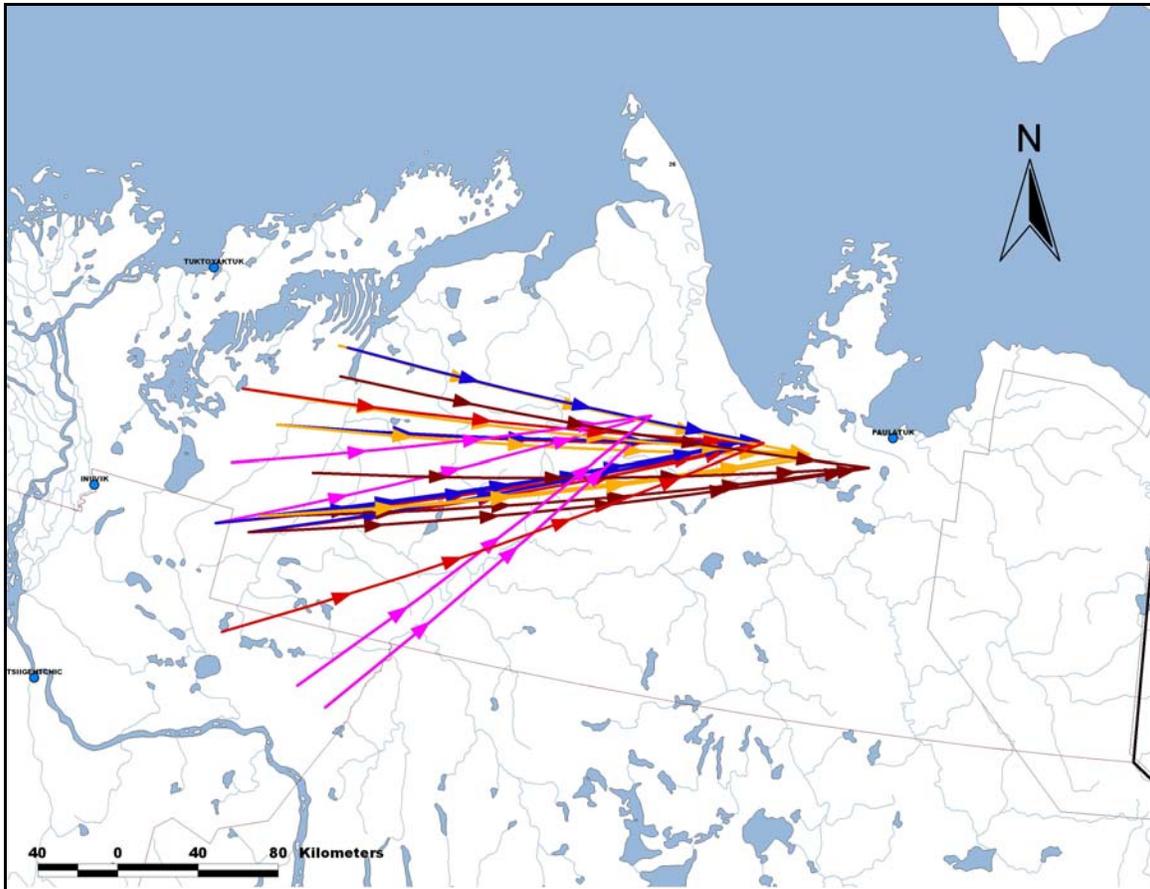


Figure 7. Distribution of the largest groups photographed in the Bluenose-West herd relative to the sites where the radio-collared caribou in those groups were captured.



Groups: group 7 = brown (4 collars), group 8 = orange (5 collars), group 10 = red (5 collars), group 11 = blue (7 collars), and group 25 = light purple (4 collars).

Appendix A. Distribution of 38 radio-collared caribou among post-calving aggregations of the Cape Bathurst and Bluenose-West herds during a photo census 4 to 14 July 1986 (excluding calves).

Group No.	Group Size		Number of radio-collared caribou in group	Expected number of radio-collared caribou in group
1	2251	a	2	0.9
2	1622	a	0	0.6
3	1888	a	1	0.7
4	5166		2	2
5a	19786		2	7.6
33	4658	a	4	1.8
34	2729	a	2	1.0
35	2250	a	1	0.9
36	278	a	1	0.8
37	1437	a	1	0.5
38	888	a	1	0.3
39	814	a	0	0.3
40	2718	a	1	1.0
41	1041	a	0	0.4
42	574	a	1	0.2
43	1136	a	0	0.4
44	831	a	0	0.3
45	1276	a	0	0.5
54	4622	a	2	1.8
55	1763	a	0	0.7
56	1341	a	0	0.5
57	3646	a	2	1.4
58	490	a	0	0.2
59	16703		9	6.4
60	3552	a	1	1.4
65	1435	a	1	0.5
66	1415	a	0	0.5
67	440	a	0	0.2
68	1971	a	1	0.8
69	1493	a	0	0.6
70	2716	a	0	1.0
71	2108	a	1	0.8
72	1898	a	0	0.7
b	500	a	1	0.2
b	2000	a	1	0.8
Total	99436		38	38.7

Number of caribou per radio collar = 2617.

a. For all groups smaller than 10,000 were combined chi-square = 7.69 (P < 0.05, df = 4)

b. Group not photographed.

Appendix B. Distribution of 48 radio-collared caribou among post-calving aggregations of the Cape Bathurst and Bluenose-West herds during a photo census 9 to 11 July 1987.

Group No.	Group Size	Number of radio-collared caribou in group	Expected number of radio-collared caribou in group
1	616b	1	0.3
2	2273	1	1.1
3	555b	1	0.2
4	1479b	2	0.6
5	160b	1	0.1
6	4054	1	1.7
7	2763	4	1.1
8	6923	5	2.9
9	2226b	0	0.9
10	16592	6	6.8
11	15178	7	6.3
12	1110b	1	0.8
13	2795	1	1.0
14	2215b	0	0.9
15	2815	1	1.2
17	7732	1	3.2
18	942b	1	0.4
19	3445	1	1.4
20	7014	3	2.9
21	1047b	1	0.4
22	5710	2	2.4
23	1461b	0	0.6
24	782b	1	0.3
25	22843	4	9.4
26	2500a	2	1.0
Total	115230	48	47.9

a. Visually estimated, not counted from photos.

b. For chi-square analysis groups less than 2400 were combined. Chi-square = 9.488 ( $P < 0.05$ ,  $df = 4$ ).

Appendix C. Post-calving photo survey field schedule and weather conditions, 29 June – 15 July 1986.

Date	Weather	Activity
29-Jun-86	Warm, 20°C, wind light, cumulus	Initial reon, loose groups
30-Jun-86	Cooler, rain squalls	Caribou scattered
01-Jul-86	Fog, weather poor	Caribou scattered
02-Jul-86	Fog in morning, improving later	Loose aggregations
03-Jul-86	Fog persisting, weather cool	Loose aggregations
04-Jul-86	Sunny, warm, 10°C, wind light	First aggregations forming
05-Jul-86	Sunny, warm, 10°C, wind light	Aggregations in some areas
06-Jul-86	Sunny, 20°C inland, windy in PM	Aggregations
07-Jul-86	Sunny, 20°C, warm, buggy	Large aggregations
08-Jul-86	Sunny, 20°C, warm, smoke in air	Aggregations
09-Jul-86	Cooler, 15°C	All photos, except C. Bathurst Pen
10-Jul-86	Early fog, smoke haze, 10°C	No new aggregations
11-13-Jul-86	Back in Inuvik	Review results, wait for C. Bathurst grouping
14-Jul-86	High cloud, 15°C, windy	Photos on Cape Bathurst Peninsula
15-Jul-86	Sunny, 15°C, light wind	Aggregations breaking up; return to Inuvik

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Appendix D. Post-calving photo survey field schedule, 3 – 15 July 1987.

Date	Weather	Activity
03-Jul-87	Scattered, 15°C, light wind	Loose groups, tracking
04-Jul-87	Weathered out, fog, drizzle	Small groups, 33BM only
05-Jul-87	Weather still poor, overcast	Small groups
06-Jul-87	Low cloud, 2°C, light wind	Groups 1-2,000 scattered
07-Jul-87	CAVU, 10°C, light wind	Aggregations S. Paulatuk
08-Jul-87	CAVU, 10-15°C, light wind	Aggregations
09-Jul-87	CAVU, 10-15°C, light wind	Photo aggregations

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