BATHURST CALVING GROUND SURVEY

1996

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ABSTRACT

Our current management strategy is to track herd size at 6-year intervals. Thus, we undertook a survey in June 1996 with the objective of estimating the number of breeding cows on the calving ground to test our prediction that the herd had not changed significantly in size. We used the technique developed and standardised by Heard (1985) and used for the Bathurst herd since 1984 and our results are comparable to the previous surveys. We found high densities of calving caribou west of Bathurst Inlet between the Hood and Burnside rivers. The number of caribou on the calving ground was estimated to be 195 000 $\pm$ 41 900 SE (standard error) and the number of breeding females on the calving ground was estimated to be 151 000 $\pm$ 35 200 SE (coefficient of variation of 0.23). Total herd size was estimated at 349 000 $\pm$ 94 900 SE (coefficient of variation of 0.27). As predicted, there was no significant difference between the 1990 and 1996 estimates. The overall trend, then, since 1990 is stable.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Bathurst herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) was last surveyed in 1990 to estimate the number of breeding females on the calving ground. At that time, the number of breeding females on the calving ground was estimated to be 152 000 ± 25 800 SE (standard error) and from that estimate the total number of caribou in the population was extrapolated to be 352 000 ± 77 800 SE. Heard (1985) explains the rationale and technique for estimating herd size from calving ground surveys and his method is the standard one used for the Bathurst, Beverly and Qamanirjuaq herds.

We had no information to suggest either a large increase or decrease in the herd since 1990. Recruitment between 1990 and 1994 ranged from 33 to 46 calves:100 cows and caribou in the early 1990s were in good physical shape (Case 1996, Williams and Fournier 1996) which suggested favourable environmental conditions. The only known change in the caribou's environment was an increase in mineral exploration.

Our current management strategy is to track herd size at 6-year intervals. Thus we undertook a survey in June 1996 with the objective of estimating the number of breeding cows on the calving ground to test our prediction that the herd had not changed significantly in size. In this report, we describe the survey and also include previously unpublished reports for the 1990 and 1986 surveys.

D. Heard and M. Williams had written up the two surveys in 1991, but their typescripts remained unpublished. They are included in this report for the convenience of having all the information together in preparation for co-mar planning for the herd (Appendix C and D).

METHODS

Because information collected in 1986, 1990 and 1995 suggested calving was progressively shifting west (Sutherland and Gunn 1996), we selected a site 60 km east of Rideout Island (67° 15.27'N, 106° 19.17'W) for our field camp during the 1996 survey. This camp location was further west than the previously used camp at Waller Lake (67° 25.51'N 104° 43.11'W) (Appendix C and D) and provided a place where we could land a fixed-wing aircraft on an esker or a lake depending on ice conditions. Fuel was cached at camp, at Waller Lake and on an unnamed lake located at 67° 14.49'N 105° 52.08'W.

We followed similar methods used for the 1986 and 1990 calving ground surveys (Appendix C and D, respectively) except we did not fly the initial unsystematic reconnaissance survey. Instead we used the locations of 10 satellite-collared cows to locate the general distribution of calving cows. We flew a systematic reconnaissance survey to determine the relative densities of caribou on the calving ground and to delineate the boundaries of the calving ground.

Our survey aircraft was a Helio-Courier on tundra tires. The survey crew included a front seat navigator and observers in the right and left rear seats. We divided the transect lines on 1:250 000 scale map sheets into 10-km segments each with a letter reference. In areas where caribou densities were low (1-15 caribou/km^2), the pilot plotted locations on 1:250 000 maps while the navigator

recorded observations on data sheets. In areas of high caribou densities (15-several 100 caribou/km^2), the pilot called out each 10-km segment as it was entered and observers recorded the letter reference and their observations into tape recorders. Transect lines were 10 km apart and ran perpendicular to the north-south axis of Bathurst Inlet and major rivers to avoid sampling bias if animals were concentrated along valleys. Transect strip width was 0.8 km (0.4 km strip on each side of the aircraft) and we calculated transect boundaries (Norton-Griffiths 1978) and marked them on a rope stretched from an eyebolt on the fuselage of the plane to an eyebolt on each wing. Our survey altitude was 120 m above ground level and survey speed was approximately 160 km per hour.

We determined the boundaries for the calving ground by flying for approximately 10 km after the last caribou seen on the transect. We used the caribou densities determined from the systematic survey to divide the calving ground into 4 strata with high, medium and low densities. Effort for the photographic survey was allocated between strata using the following formula:

$$n_i=(Y_i(M))/(TL_i)(\int TL_i)\ (\sum(Y_i/TL_i))$$

where:

Y_i = stratum population estimate.
M = total number of line km available for photography.
TL_i =mean length of transect in stratum I.

Heard (1987a).

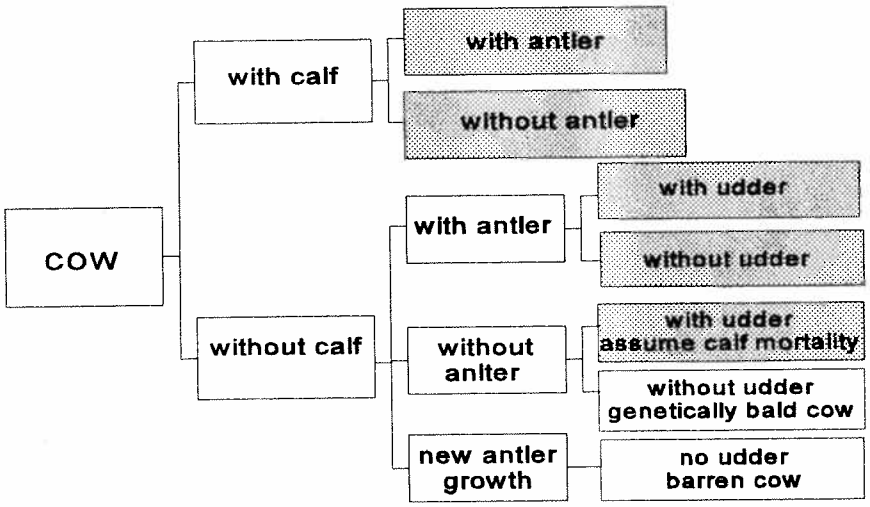
We contracted Geographic Air Survey Ltd. for the photographic survey

and their Aero-commander aircraft was equipped with a radar altimeter, and a Wilde RC30 camera with forward motion compensator. We used a mobile satellite phone at camp to contact the company headquarters in Edmonton, Alberta. The day we finished the systematic reconnaissance (8 June), we called the company with the coordinates for the flight lines to be photographed. The following day, the survey aircraft took a biologist (J. Nishi) and maps to Echo Bay's Lupin mine as the nearest base for the photo aircraft. The photographic survey started that day. The photo plane was flown at 600 m above ground level. The crew only photographed between 0800 hrs - 1830 hrs to ensure proper sun angle (25-30°). The biologist on board the photo plane monitored the caribou distribution and extended or shortened the photo lines as necessary.

Concomitant with the photographic survey, we started composition surveys to determine the proportion of breeding females on the calving ground within the four strata delineated for the photographic survey. In high and medium density strata, we first located groups of caribou from a Bell Jet Ranger 206B. The pilot was instructed to land 100-500 m away from the caribou and allow observers to make their final approach on foot using rises in the terrain and rocks as cover. One observer watched and classified the caribou through a spotting scope; the second observer recorded the data. To avoid selecting individual caribou, observers attempted to systematically observe all animals within visual range and classified the caribou as they walked away. In low density strata, where caribou were in groups of <20-30, the front seat observer

classified caribou from the helicopter. For larger groups, we landed and used the same procedure as in the high and medium density strata.

We classified caribou into three categories: breeding females, non-breeding females and yearlings and bulls (see below for female classification categories where shaded boxes represent breeding females and white boxes represent non-breeding females).



Breeding females (pregnant and post-partum) were identified by the presence of hard antler and/or a distended udder. Cows with distended udders and without hard antlers were probably breeding cows which had lost their calf. Non-breeding cows showed new antler growth and had no udder (barren) or had no udder but were genetically bald. Cows with hard antlers and without an udder or calf may have lost their calf or had not yet given birth. Yearlings were identified by their shorter face and smaller body size while bulls were easily

identified by their relatively large antlers in velvet.

We collected any calf carcasses seen during the classification flights and carried them in the rear of the helicopter for later necropsy. We used Miller *et al.* 's (1988) criteria for hoof wear, umbilical condition and pelage to assign an age to the carcasses. We diagnosed the cause of death after an autopsy following Miller *et al.* 's (1988) procedure.

Data analyses

We contracted Paul Roy of H.P. Roy and Associates (Ottawa, Ontario) to count the caribou on the photographs using a stereoscope. We checked to confirm that the scale was 1:4000 by comparing distances on the 1:250 000 scale map to distances on the photographs. By comparing the counts of caribou on each line to the 1:250 000 map showing the photographic survey lines, we were able to adjust the boundaries of the stratum to include only those areas which actually contained caribou. This ensured that the population estimate for each stratum was not inflated by extrapolation of the density to large areas that did not contain caribou. Population estimates for each stratum were calculated using the Jolly 2 Method for unequal sample units (Jolly 1969).

The proportion of breeding females in each stratum was multiplied by the population mean estimate for that stratum to obtain an estimate of the number of breeding females on the calving ground. Total herd size was estimated by dividing the number of breeding females by the sex ratio of the population (66

males: 100 females) and by the pregnancy rate of female caribou (72%). We analysed composition data using Cochran's (1977) Jackknife method to calculate the mean proportion of breeding females in each stratum. The variances of the number of breeding females and the total herd estimate were calculated as by Heard (1987b).

Muskox observations were recorded by observers during the systematic reconnaissance survey but were not counted on the photographs. A population estimate was not calculated.

RESULTS

Distribution

As the satellite-collared cows were all west of Bathurst Inlet, we flew the systematic reconnaissance survey in that area first (6 June) and found high densities of calving caribou between the Hood and Burnside Rivers. The northern and northwestern boundaries were all well defined as we saw only single scattered caribou. By the 7 June, the 10 satellite-collared cows were clumped together southwest of Bathurst Inlet in the vicinity of those high densities. On 7 June, we flew east of Bathurst Inlet and found only scattered caribou (including two cow-calf pairs) until we were northeast of Spyder Lake (BHP's Boston bulk sampling site) where we started to see more caribou (Fig. 1). We continued flying east into the central Queen Maud Gulf Migratory Bird Sanctuary and although we were still seeing high densities (10-50 caribou/10km^2) of cows with calves, we broke off the line and flew west along the next line south where we found lower densities (<10 caribou/10 km^2). The four satellite-collared cows from the Queen Maud Gulf herd were in the vicinity of this coastal calving area between the Ellice and Perry rivers. The two calving areas east and west of the Inlet were separated by a distinct zone with only scattered caribou and we interpreted the distribution as the Bathurst herd calved west of the Inlet and the Queen Maud Gulf herd calved east of the Inlet.

The western edge of the calving ground was sharply defined by a virtual

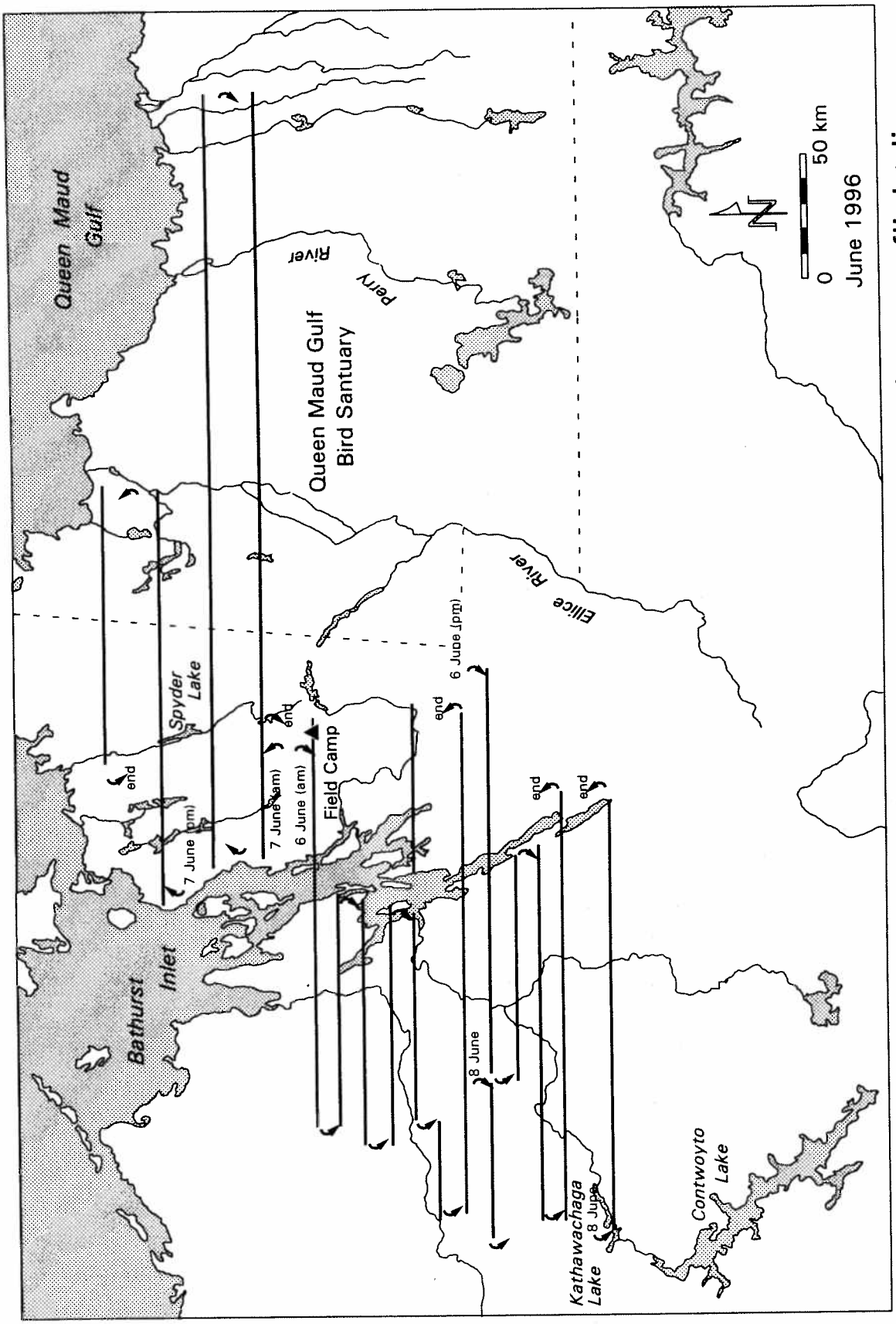


Figure 1. Bathurst calving ground systematic reconnaissance flight lines, 6-8 June 1996

absence of caribou. Along the southernmost transect in the southwest corner (Kathawachaga Lake), we saw mostly antlerless cows, and yearlings in a 20-km strip with a density of 5-10 caribou/10 km^2, but we did see a few newborn calves in what seemed to be the tail end of the migration. Further east toward Bathurst Inlet, densities dropped to <5 caribou/10km^2 and we saw no calves.

We defined four strata for the photographic survey and based on caribou densities, we allocated coverage as 25% for Stratum I, 22% for Stratum II, 15% for Stratum III and 14% for Stratum IV (Fig. 2). The photo plane flew on 9-11 June, 1996 and took 2669 photographs.

On 9 June, the photographic survey for Stratum I (high density) was completed as planned except lines 8 and 9 were extended 5 km north to include a high density clump of caribou whose northern boundary was conspicuous (Fig. 3). Eight of nine satellite-collared cows were within Stratum I on 9 June and the ninth cow was 3 km north of the stratum boundary but in an area where the on-board biologist commented on seeing only a few caribou (Fig 3.). Stratum III (moderate density) was started on 9 June, but low cloud prevented a resumption on 10 June and it was completed on 11 June. In Stratum III, no caribou were seen in the eastern part of Stratum III and so line 8 was dropped. Caribou were seen along the western boundary so the western edge was extended by the addition of lines 10 and 11. On the western edge (line 11), densities were still quite high (14 caribou/ km^2) but the on-board biologist was confident that it was the edge of the caribou distribution. The two northern strata, II and IV, were flown as planned from the systematic reconnaissance.

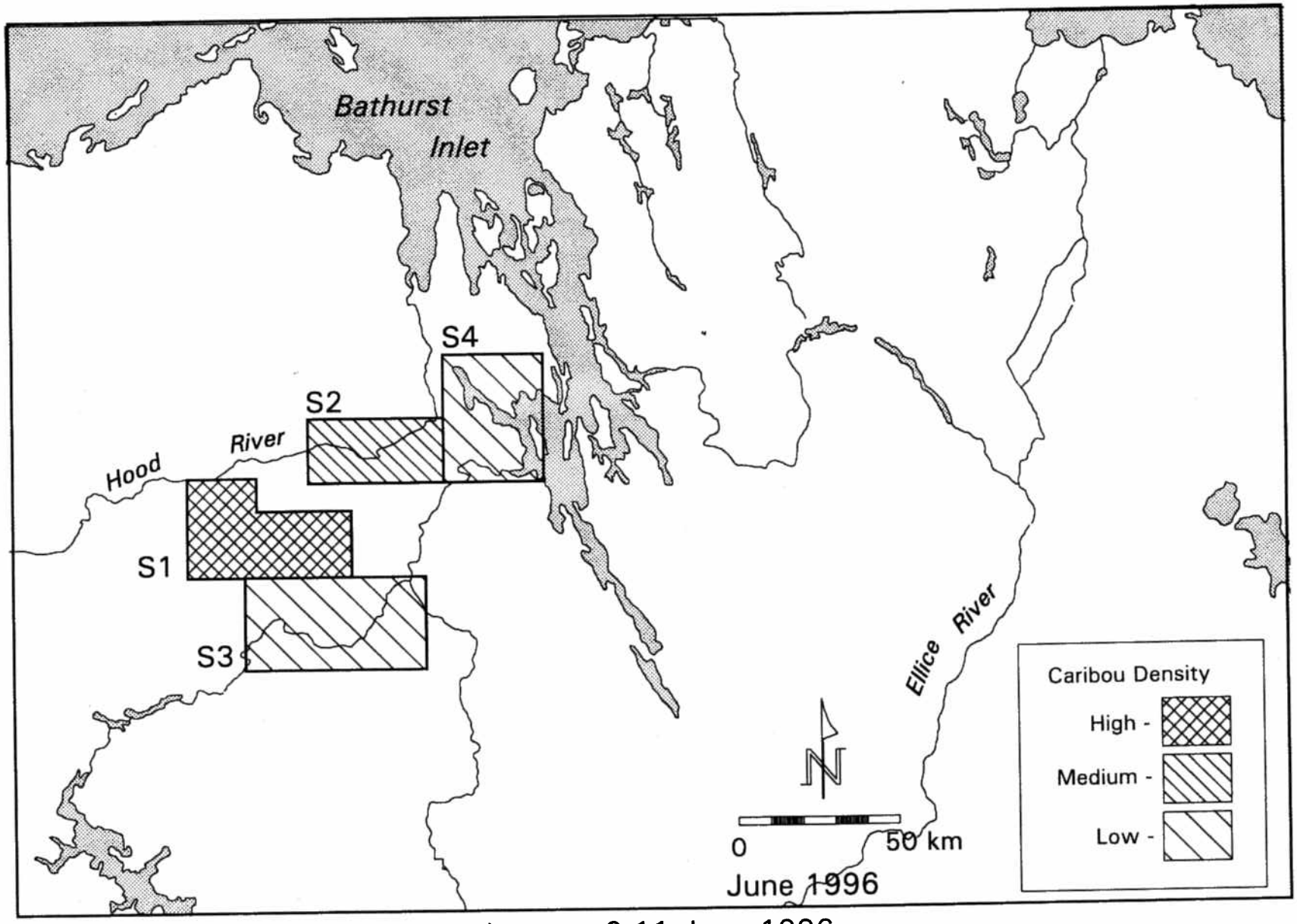


Figure 2. Bathurst calving ground strata, 6-11 June 1996.

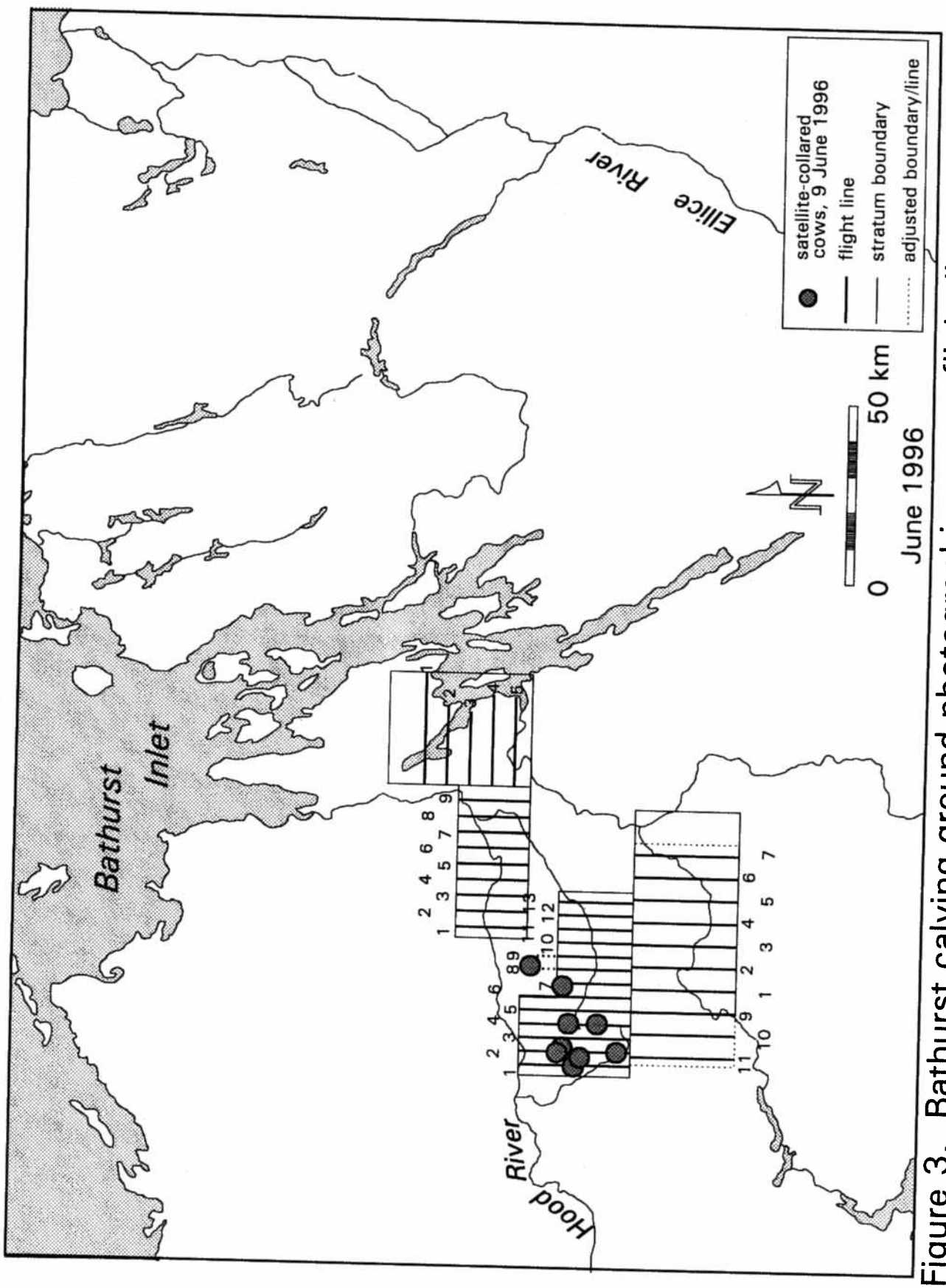


Figure 3. Bathurst calving ground photographic survey flight lines, 9-11 June 1996 and locations of 9 satellite-collared cows (9 June).

We estimated the number of caribou on the calving ground from the photographic counts to be 195 000 ± 41 900 SE (Table 1). All but 72 of the 40 572 1^+ -year-old caribou counted from the photographs were on strata I and III. Because so few caribou were counted on stratum II and IV, these strata were dropped from all further calculations.

The composition surveys were conducted on 9-11 June 1996 and the proportion of breeding females in the four strata ranged from 14% to 85% (Appendix B). Using the proportions and the number of caribou from strata I and III, we estimated the number of breeding females on the calving ground to be 151 000 ± 35 200 SE (Table 2). The Coefficient of Variation was relatively high (0.23). This estimate of breeding females was not significantly different from the estimate obtained in June 1990

($t_{(2)}$ = 0.012, 18 df, p > 0.50) (Appendix F).

The total herd size, which was estimated at 349 000 ± 94 900 SE (coefficient of variation of 0.27) was extrapolated from the estimate of the number of breeding females on the calving ground and using a sex ration of 100 females:66 males (based on Heard unpublished data, 1978) and a pregnancy rate of 0.72 (Heard 1985) (Table 3).

The peak of calving was established to be 5-9 June 1996 as on 6 June we observed half the cows to have newborn calves (calves with bent hocks and bowed backs). The mean distance travelled by the satellite-collared cows

Table 1. The number of caribou estimated in strata 1 through 4 based on a photographic strip transect survey of the Bathurst calving ground survey, June 1996.

Stratum	Stratum Area (km^2)	Survey coverage	Estimate	Density caribou/km^2	Variance X 10^8	Standard Error	CV
I	1441	25%	160 551	111.4	16.03	40 040	0.25
II[a]	884	22%		0.1			
III	1778	15%	34 169	19.2	1.26	11 215	0.33
IV[a]	1272	14%		0.3			
Total	3219		194 720		17.56	41 901	0.22

[a] Strata II and IV were dropped from all other calculations because too few caribou were counted.

Table 2. Estimated number of breeding females on the Bathurst calving ground, June 1996 based on composition counts and stratum population estimates.

Stratum	Estimate	Proportion of breeding females	Estimated number of breeding females	Variance X 10^6	Standard Error	CV
I	160 551	0.85	137 111	1199.4		
III	34 169	0.42	14 283	35.8		
Total	194 720		151 393	1235.1	35 145	0.23

showed a significant decline in the daily distance travelled during this period (Table 4).

We found only four dead calves. Wolves had killed two, one died from starvation/abandonment, and one had been trampled to death.

In addition to caribou, we saw 331 muskoxen in 32 groups (Fig. 4). Mean group size was 10.2 ± 2.0 (range 1-42).

After the photography and composition survey were finished, we returned to delineate the Queen Maud Gulf herd's calving area by flying east-west lines on 12 and 13 June. These results will be described in a separate report.

Table 3. Extrapolation of the 1996 Bathurst calving ground survey data to an estimate of total herd size.

Survey data	Estimate	Standard Error	CV
Number of caribou on the calving ground	194 720	41 901	0.22
Number of breeding females on the calving ground	151 393	35 187	0.23
Proportion of females in the entire herd	0.54		0.1[a]
Proportion of 1.5 year old and older females pregnant	0.72		0.1[a]
Total population estimate[b]	349 046	94 880	0.27

[a] no data; value only a guess.

[b] total population = number of breeding females/proportion of females in the population/proportion of females pregnant.

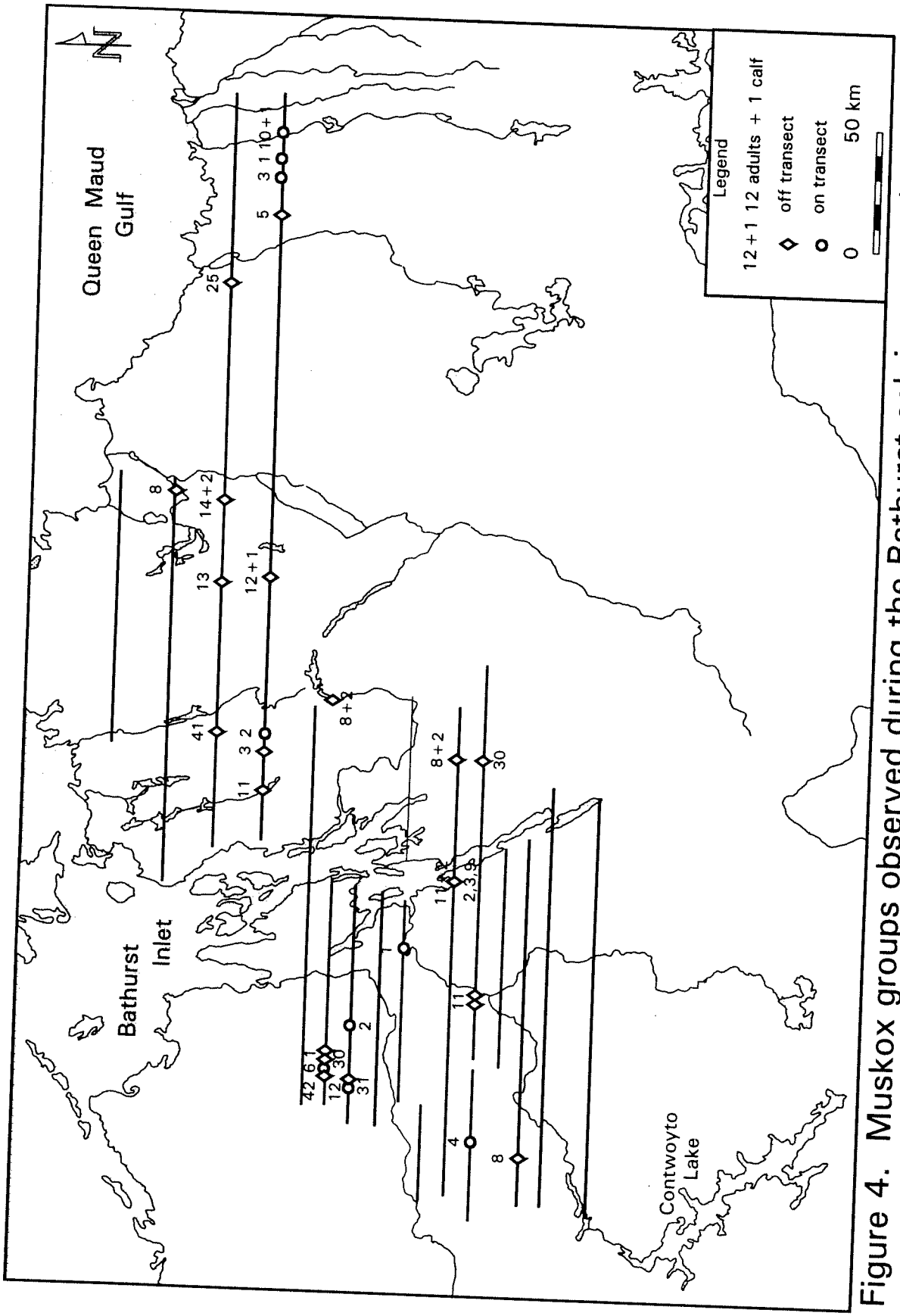


Figure 4. Muskox groups observed during the Bathurst calving ground systematic survey, 6-8 June 1996.

DISCUSSION

Trend In Herd Size

Our results suggest that the number of breeding females on the calving ground is almost identical to the number estimated in 1990. Between 1986 and 1990, Heard and Williams (Appendix C and D) concluded that the apparent decrease was not statistically significant. The overall trend, then, since 1990 is stable.

We used the technique developed and standardised by Heard (1985) and used for the Bathurst herd since 1984 and our results are comparable to the previous surveys. We experienced no technical problems carrying out the survey and timing and survey sequence was optimal both in relation to the peak of calving and because delays between the systematic reconnaissance and photographic surveys were minimal. Synchronizing the survey with the peak of calving is desirable because cow movements are at a minimum when the calves are newborn. We estimated the peak of calving to be 5-9 June 1996 as on 6 June during the reconnaissance flights half the cows had newborn calves. Most cows had calved by 9 June when we started the composition flights. A peak between 5 and 9 June is average timing for the Bathurst Herd (Sutherland and Gunn 1996). The systematic reconnaissance survey was conducted during the peak of calving and immediately preceded the photographic and composition surveys which were conducted during the same 3 days. Further support for our

designating 5-9 June as the peak comes from examining the mean distances travelled by the satellite-collared cows (Table 4) which declined 6-9 June. However, we did not visually check if those collared cows had calved, although it is a reasonable assumption given their clumped distribution and synchronous reduction in movements.

The tight sequence of the systematic (6-8 June) and photographic survey (9-11 June) meant less time for movements to confound the stratification. Nonetheless, movements were detected and corrected for during the photographic survey. Caribou travelling south from Stratum II were seen and included in Stratum I by extending lines 9 and 10. Caribou moving west from Stratum III were included by a western extension of the stratum. Stratum IV was low density (<5 caribou/10 km^2) on 6 June but almost no caribou were seen there during the photographic or the composition survey. The location where the only large group (about 100 caribou) seen in Stratum IV on 6 June was only 60 km northeast of Stratum I so the caribou may have travelled to Stratum I and been counted or may have been missed as they moved between Stratum IV and III.

We are confident that the entire Bathurst herd's calving distribution was included in this survey. The technical merits of the survey were a result of the extensive systematic reconnaissance, a close association between the visually located calving area with the locations of satellite-collared cows from the two areas of winter distribution, relatively few movements of caribou that confounded

stratification, and lack of weather days.

The estimates are, however, relatively imprecise which reflects the clumped distribution of the caribou within the strata. At the time of stratifying, we had four strata and proportioned our survey effort accordingly. In hindsight, our stratification could have been improved to more tightly reflect the clumped distribution in the high and medium density strata. Within strata I and III, the caribou were clumped into high density patches and the estimates were imprecise (CV's of .25 and .33 respectively) (Table 1). In stratum I, densities on individual lines varied from 2.8 to 359 caribou/km^2 and within Stratum III, densities varied from 1.3 to 70 caribou/km^2. Statisticians usually frown upon post-survey stratification (Norton-Griffiths 1978) although it may be applicable under certain conditions (see Anganussi and Buckland 1993). In our case, dividing Stratum III, as a test, into two strata based on density did not greatly improve precision because the number of sample units (transects) in each stratum was low (n=5).

Although we accepted the null hypothesis that there was no significant change in number of breeding female caribou since 1990, imprecision of the estimates means our ability to detect a numerical change is poor. Using Gasaway et al.'s (1986) formulae, and the levels of precision in the 1996 (CV=0.23) and 1990 estimates (CV=0.17), we determined that we could have only detected a 75% change in number of breeding females (assuming assigned probabilities of Type 1 and Type 2 errors at 10% (α=0.10) and 20% (β=0.20)

respectively). This effect of imprecision extends further when extrapolated to total herd size. Critics of calving ground photography (Thomas in prep.) have used this problem of low precision as the rationale to drop the technique. An alternate approach would be to improve precision through more efficient stratification and possibly post-stratification, and increase coverage within individual strata. Increased coverage also has to be balanced by increasing the number of sampling units. We will consult a biometrican to investigate whether we can develop a valid post-stratification technique and whether we can subsample the transects (either fixed length blocks or photographs).

The estimate's imprecision means our ability to detect a numerical change is poor. Using Gasaway *et al.*'s (1986) formulae, we calculate that with this 1996 estimate's precision (CV = 0.27) compared to the 1990 estimate (CV = 0.22) we could only detect an 80% change in population size with power of 80%. Critics of calving ground photography (Thomas in prep.) have used this problem of low precision as one of the reasons to drop the technique. An alternate approach would be to increase precision through improved stratification and greater coverage within individual strata. Greater coverage also has to be balanced by increasing the number of sampling units. We will consult a biometrican to investigate whether we can develop a valid poststratification technique and whether we can subsample the transects (either fixed length blocks or photographs).

The calving ground survey has two advantages in addition to estimating

total caribou numbers by means other than calving ground surveys such as post-calving photography. Firstly, the distribution information contributes to protecting caribou calving grounds. The mapped distribution is the basis for defining the traditional calving grounds and Sutherland and Gunn (1996) describe this. The second advantage for the calving ground survey is that fecundity is measured to determine the number of breeding females from the number of caribou. A cow's physical condition, pregnancy and calf survival are tightly related (Thomas 1982, Skogland 1985, Eloranta and Nieminen 1986, Cameron *et al.* 1993). The timing of the availability of high quality forage is then a key element in calf growth and the cow replenishing her body reserves. Changes in fecundity will be an early warning to predict eventual changes in population size - the magnitude of the changes also depends on adult survival (Crête *et al.* 1996).

CONCLUSIONS

1. Numbers of breeding females in the Bathurst caribou herd have not statistically changed since 1986.

2. Our ability to detect changes in numbers based on calving ground photography would be improved by increasing the estimate's precision by increased photographic coverage and improved stratification.

ACKNOWLEDGMENTS

The success of the survey rested in part on Mark Williams' help. When he left the Department in 1994, he wrote a detailed practical manual which guided us through this survey. He also gave freely of his time to check our calculations and we are grateful to him for sharing his experience. Perry Linton (Northwright Aviation Ltd) piloted the Helio-Courier with his usual skills. Marc Hutchinson flew the Bell 206B helicopter with his usual skills. Al Weiderich was the pilot and Marvin Hengen the photographer for Geographic Air Survey Ltd. Polar Continental Shelf Project supported the survey with helicopter time and Department of Northern Development and Indian Affairs assisted with gas caching. Mika Sutherland and Paul Nicklen assisted with the plant phenology and contributed uniquely to the smooth running of the project. Joe Mackenzie, Edward Camille, George Kuptana and George Panegyuk shared the experience of the calving ground and the spectacle of the massed cows and calves with us.

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APPENDIX A. Composition of 1^{+} -year-old caribou classified in strata 1 through 4 of the Bathurst herd's calving ground survey, 9-12 June 1996.

Classification	Number of caribou				
	Stratum 1 n=33	Stratum 2 n=1	Stratum 3 n=22	Stratum 4 n=7	Total n=63
Breeding females					
calf antlers	1743	0	114	117	1974
calf no antler	665	0	275	40	980
no calf antler udder	107	1	48	8	164
no calf antler no udder	12	0	8	0	20
no calf no antler udder	77	0	46	12	135
Non-breeding females					
Bald: no calf no antler no udder	166	4	266	20	456
Barren: no calf new antler no udder	11	0	0	0	11
Yearlings and bulls	269	2	417	27	715
Total	3050	7	1174	224	4455
Proportion of pregnant cows	0.854	0.143	0.418	0.790	0.735
SD*	3.99		11.27	19.76	
CV*	0.04		0.26	0.22	

*Jackknife method (Cochran 1977)

APPENDIX B. Number of 1^{+} -year-old caribou counted on each photographic transect of the Bathurst herd's calving ground survey 9-12 June 1996.

Transect Number	Transect Area (km^2)	1^{+} -year-old caribou counted	Transect Number	Transect Area (km^2)	1 -year-old caribou counted
Stratum 1			**Stratum 2**		
1	26.91	76	1	18.51	4
2	27.25	66	2	18.17	1
3	27.37	379	3	18.17	2
4	27.25	3696	4	18.17	2
5	27.30	8500	5	18.05	4
6	27.08	9734	6	18.80	3
7	18.86	4699	7	18.76	1
8	18.86	2990	8	18.57	1
9	27.14	3086	9	18.76	1
10	24.37	964			
11	18.92	832			
12	18.86	103			
13	18.86	66			
Total	309.03	35 191	Total	165.96	19
Stratum 3			**Stratum 4**		
1	27.37	1834	1	29.08	2
2	27.42	1108	2	21.58	9
3	28.00	208	3	20.96	7
4	27.25	70	4	23.39	13
5	27.37	55	5	22.74	3
6	27.30	60			
7	27.42	37			
8	Not photographed				
9	27.25	549			
10	27.25	931			
11	34.13	477			
Total	280.76	5329	Total	118.00	33

APPENDIX C. Bathurst calving ground survey, June 1986. Douglas C. Heard and T. Mark Williams. Department of Renewable Resources. Government of the Northwest Territories. 1991

ABSTRACT

In June 1986, the number of caribou on the Bathurst caribou herd's calving ground was estimated using a stratified transect strip survey where caribou were counted on aerial photographs and visually where photography was not possible. The survey resulted in an estimate of 285,400 ± 17,300 (SE) caribou one year old and older on the calving ground. Based on the reproductive condition of a sample of animals classified from a helicopter, the number of parturient (pregnant and post-partum) females on the calving ground was estimated to be 204,000 ± 12,700 (SE), which extrapolates to a total population estimate of 472,000 ± 72,900 (SE). The increase in herd size which began in 1980, appears to be continuing.

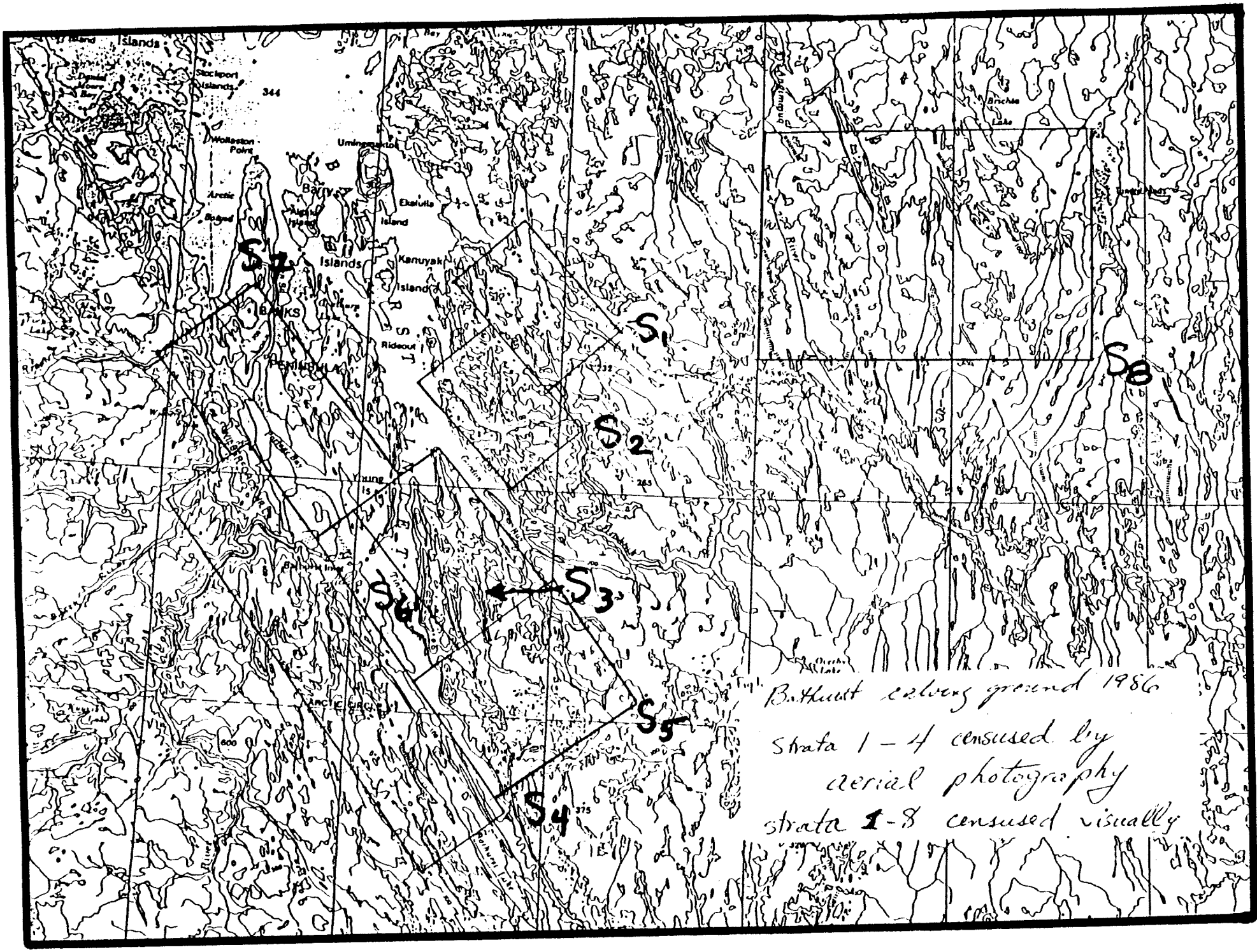
INTRODUCTION

Prior to the first use of aerial photography in 1980, the trend in the size of the Bathurst caribou herd was based on visual sample counts along strip transects on the calving ground (Heard 1985). Population estimates using aerial photography provide a more accurate indication of herd trend and the first three such estimates suggested that the herd had been increasing since 1982 (Williams and Heard 1986). This report describes the results of the 1986 census.

METHODS

Reconnaissance flights were flown on 8 and 9 June to locate the general distribution of calving cows. On 10, 15, and 16 June, transects spaced 10km apart were flown over the entire calving distribution as determined by reconnaissance, the 'systematic' survey. Two Cessna 185 aircraft were used concurrently. Observers counted all caribou except neonates within a 400m strip on each side of the aircraft. Transects were flown at 120m above ground level at approximately 170-180 kph.

Caribou densities determined from the systematic survey were then used to divide the calving ground into 8 strata, where densities within each stratum were similar (Fig 1). Those density estimates were also used to determine the optimal allocation of survey effort (flight lines) that would maximize

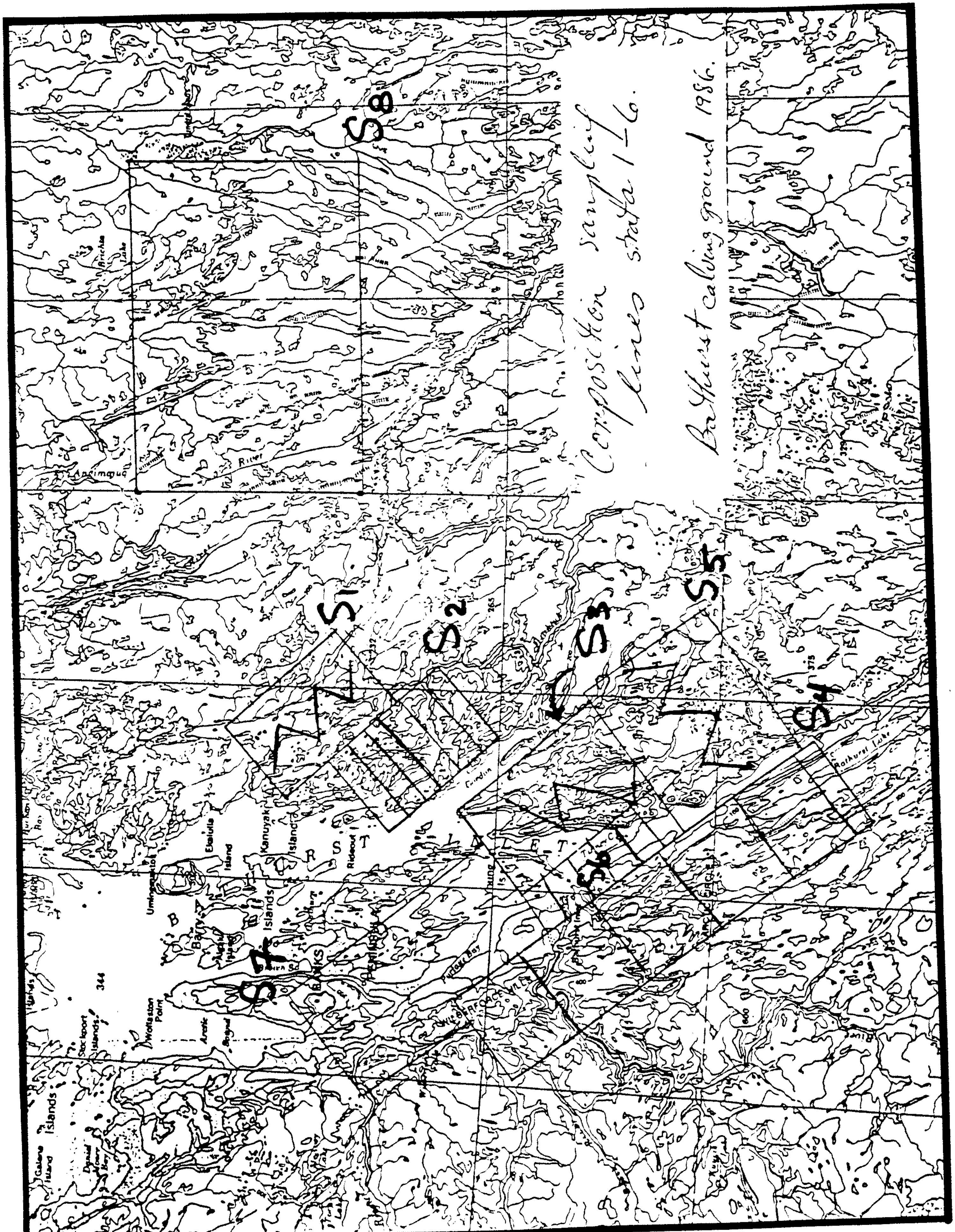

Islands
Stockport Islands
344
Wollaston Point
Arctic Bay
Umingmaktok
Barry
Islands
Kanuyak Island
BANKS
PENINSULA
Rideout
Young Is
ARCTIC CIRCLE
Bathurst caribou ground 1986
Strata 1 – 4 censused by aerial photography
strata 1-8 censused visually

the precision of the population estimate (Heard 1987a). On 17 and 18 June, strata 1 through 7 were resurveyed by observers in the 2 Cessna 185's, the 'visual' census.

On 16 and 17 June, strata 1, 2, 3, and 4 were resurveyed using aerial photography, the 'photographic' census. Density estimates from the transect survey were used to determine the optimal allocation of survey effort (flight lines) that would maximize the precision of the population estimate. Strata 5 through 8 were purposely not photographed because of their relatively low density. Two thousand six hundred and eighteen photographs (black and white, 230cm x 230cm, XX2405 film) were taken from 600m above ground level to provide an average image scale of 1:4000. Because ground elevation changes were too rapid for the aircraft to parallel, scale varied from 1:3000 to 1:5000. Photographs had 60% forward overlap. Caribou were counted on the photographic contact prints using a stereoscope. To calculate the density of caribou within each stratum based on photographic counts, photograph scale was assumed to be 1:4,000.

On 17, 18, and 19 June, the age, sex and reproductive condition of all caribou observed from a Bell Jet Ranger 206B helicopter were recorded while flying along lines zig zagging across or systematically spaced within strata 1 through 6 (Fig 2). The helicopter was flown at about 50m and 100 kph although speed and height were variable. Caribou were classed as neonates, yearlings, two year old and older males, and two year old and older cows. Parturient females, pregnant and post-partum cows, were identified by the presence of an udder. The proportion of parturient females in each stratum was the weighted mean and its variance was calculated using the binomial (Snedecor and Cochran 1967:514) with a finite population correction factor equal to the number of caribou classified divided by the stratum population estimate.

The proportion of parturient females was multiplied by the stratum population estimate to obtain an estimate of the number of parturient females within each stratum. Stratum population estimates were based on the number of adult caribou recorded on photographs taken during the photographic strip transects. In the photographed areas, densities based on photography were 3.0 times higher than densities based on visual transect strip counts. In the areas not covered by photography, the stratum population estimates were obtained by multiplying the visual transect strip counts by 3.0, the sightability correction factor. Total herd size was calculated by dividing the estimate of the


Composition sampling
lines strata 1-6.
Bathurst calving ground 1986.
S1
S2
S3
S4
S5
S6
S7
S8
Bathurst Lake
Banks Peninsula
Wilberforce
Stockport Islands
Wollaston Point
Kanuyak Island
Elsuidla Island
Rideout
344

number of parturient females by the sex ratio of the population (66 males: 100 females; the mean of 6 fall composition estimates available from different NWT caribou herds) and by the proportion of females in a caribou herd that are usually pregnant.

RESULTS AND DISCUSSION

Calving occurred adjacent to the south and east shores of Bathurst Inlet, the first time calving has been documented that far west since 1950 (Fleck and Gunn 1982). Calving usually occurs around Brichta Lake and the Ellice River over 100km further east. Caribou may have calved at the lower elevations around Bathurst Inlet where there were extensive snow-free areas. Snow melt in 1986 was extremely late and there was still 100% snow cover at Brichta Lake. When caribou have a choice they prefer to calve in partially snow-free areas (Bergerud et al. 1984).

About 108,000 caribou were estimated in the area covered by the systematic survey; 106,000 in strata 1 through 7 and 2000 in stratum 8. The more detailed visual census of strata 1 through 7 resulted in a similar estimate; 103,000 ± 9,700 (Table 1).

The number of caribou estimated from the aerial photographs in strata 1 through 4 and 6 was 223,000 ± 15,000 (Table 2) where the visual estimate was only 73,000. The photographic survey was considered to be the most accurate (Heard 1985) because animals were overlooked during the visual census, the 'sightability' bias. True densities were assumed to be 3.0 times higher than those estimate during the visual census (223,000/73,000). To estimate the total number of caribou on the calving ground, we multiplied the visual estimates from strata 5, 7, and 8 by 3.0, to correct for sightability bias, and added the products to the photographic estimate from strata 1 through 4 (Table 3).

The visual estimate from stratum 6 was not added to the total because caribou appeared to have moved into that area, primarily from stratum 3 but also from stratum 4, only after strata 3 and 4 had been photographed. Stratum 3 was photographed on 16 June and stratum 4 on 17 June. When the survey strata were set up on 16 June (Appendix 1) there were no caribou in the area which was eventually to become stratum 6. It was only during the visual census on 18 June that it was noted that some caribou had apparently moved to stratum 6 from strata 3 and 4.

The number of caribou on the Bathurst calving ground in 1986 was estimated at 285,400 ± 17,300 (Table 4).

The proportion of parturient females in the 4 photographed strata ranged from 9% in stratum 5 to 86% in stratum 4 (Table 5). In spite of the late spring and relatively unusual calving location, neonatal survival appeared to be good. Eighty-eight

percent of the cows with udders (159,000/180,000) were accompanied by calves. Some cows with udders but no calves were likely still pregnant as 25% still carried at least one antler while only 6% of cows accompanied by calves still carried at least one antler.

The total herd size was estimated to be 472,000 ± 72,900 assuming a sex ratio of 60% females (Appendix 4).

The accuracy of the extrapolation of the calving ground estimate of parturient females to total herd size depends on the accuracy of both the sex ratio and pregnancy rate estimates. We assumed a sex ratio 60% (66 males:100 females) based on the average of in six other surveys of NWT caribou herds. In 1978, D.C.H. estimated the herd sex ratio to be 53% females which is low relative to most caribou herds. Females usually make up about 64% (57 males:100 females) of the one year old and older caribou (Bergerud 1980). It would also be reasonable to assume that the proportion of females in the Bathurst herd in 1986 was lower than average, as was found in 1978. High caribou survival rates usually results in a sex ratio closer to 50:50 (Heard and Calef 1986, Heard in press) and the high rate of increase in the Bathurst herd since 1980 suggests that survival has been high. We chose the more conservative estimate.

Because age specific pregnancy rates are relatively constant (Bergerud 1980), Bathurst caribou were assumed to have average age structure and age specific pregnancy rates even though few data have been collected from Bathurst caribou.

We found 8 dead neonates during this survey. Four were killed by wolves and not eaten, 3 died of unknown causes, but not predation, 2 when less than a day old and one 4-7 days old, and 1 died of unknown causes where predation could not be excluded.

We observed 10 wolves in 5 groups (1, 1, 1, 2, and 5), three single grizzly bears, and 23 groups of muskoxen totalling 166 individuals (typical and mean group sizes were 20.2 and 7.2 respectively, range 1 to 45).

ACKNOWLEDGEMENTS

North West Survey Corporation International Ltd., took the photographs and Dendron Resource Surveys Ltd., counted the caribou on the photographs. Anne Gunn helped with the calving ground composition work and Polar Continental Shelf Project provided helicopter support. We thank Ron Graf, Susan Fleck, Francis Jackson, Heather Myers, and Joseph Tikhak for suffering through many days of cribbage and sport eating, waiting for suitable weather to carry out this survey, while D.C.H. stayed home to coach through the birth of his daughter (who, by the way, was not called Beverly).

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Table 1. The number of caribou estimated in strata 1-8 of the Bathurst caribou herd's calving ground in June 1986 based on the visual strip transect survey

Stratum	Stratum Area (km^2)	Estimate	Density (caribou/km^2)	Variance	SE	CV
1	632	5,785	9.15	1129597		.184
2	603	22,044	36.56	2831029		.076
3	1566	21,811	13.93	5673160		.109
4	2170	23,282	10.73	4481434		.091
5	1179	6,650	5.64	14852783		.580
6	426	9,593	22.52	4315722		.217
7	1472	12,058	8.19	58697551		.635
8	3938	2,087	0.53	776985		.528
Totals		103,310		93204755	9654	.093

Table 2. The number of caribou estimated in strata 1-4 of the Bathurst caribou herd's calving ground in June 1986 based on the photographic strip transect survey

Stratum	Estimate	Density (caribou/km^2)	Variance	SE	CV
1	16,683	25.86	35416442		.357
2	71,611	111.03	47007850		.096
3	51,554	61.89	51175820		.139
4+6	82,806	38.07	92463072		.116
Totals	222,654		226063184	15035	.068

Table 3. The number of caribou estimated in strata 5, 7, and 8 of the Bathurst caribou herd's calving ground in June 1986 based on an visual counting of caribou on transect strips and the sightability correction factor determined from areas that were covered by both aerial photography and visually counted transect strips.

Stratum	Visual Estimate		Sightability Correction Factor		Corrected Population Estimate	Variance x 10^6§	CV
5	6,700	x	3.0	=	20,100	14.9	.192
7	12,100	x	3.0	=	36,300	58.7	.211
8	2,100	x	3.0	=	6,300	1.2	.173
Totals	20,900				62,700	74.8	.138

§ assuming no variance in the sightability correction factor

Table 4. The number of caribou estimated on the Bathurst calving ground in 1986.

Location	Estimate	Variance	SE	CV
Strata 1-4+6	222,700	226,100,000		
Strata 5, 7, and 8	62,700	74,800,000		
Totals	285,400	300,900,000	17,300	.061

Table 5. Composition of one year and older caribou classified in strata 1 through 6 of the Bathurst herd's calving ground in June 1986

Classification	Number of caribou Stratum 1	2	3	4	5	6
Parturient cows with a calf and;	59	801	286	432	2	604
- 2 antlers	1		11		0	
- 1 antler	0		10		0	
- 0 antlers	58		265		2	
Parturient cows without a calf but with an udder	40	72	30	57	18	66
- 2 antlers	5		9		4	
- 1 antler	0		3		1	
- 0 antlers	35		18		13	
Barren cows	48	77	5	29	65	157
-no udder, 2 antlers	1		0		1	
-no udder, 1 antler	1		0		1	
-no udder, 0 antlers	46		5		63	
Yearlings	110	92	49	51	122	261
Bulls	2	0	3	0	2	20
Total	259	1042	373	569	209	1108
Proportion of parturient cows	.382	.838	.847	.859	.096	.605
SE	.0296	.0112	.0184	.0144	.0202	.0145
CV	.0775	.0134	.0217	.0168	.2104	.0240

Table 6. The estimated number of parturient female caribou on the Bathurst herd's calving ground in June 1986 based on composition counts and the stratum population estimates.

Stratum	Estimate		Parturient Proportion		Females Estimated number	Variance x 10^6 *	SE
1	16,683	x	.382	=	6,400	5.47	
2	71,611	x	.838	=	60,000	33.82	
3	51,554	x	.847	=	44,700	39.55	
4+6	82,806	x	.785[1]	=	65,000	58.27	
5	20,100	x	.096	=	1,900	0.23	
7	36,300	x	.605[2]	=	22,000	23.35[3]	
8	6,300	x	.605[2]	=	3,800	0.49[3]	
Totals	285,400				203,800	161.18	12,700

* Variance in each stratum is equal to the number of parturient females (the product) squared, times the sum of the squares, of the CV's of the estimates that were multiplied together to get that product (Heard 1987b) eg., $6,400^2 \times [(0.357)^2 + (0..0775)^2 = 5,466,327$

[1] Composition estimate and its variance weighted in proportion to the visual estimates from strata 4 and 6 (e.g., proportion of parturient females is 0.785 = (23282/32875)(.859) + (9593/32875)(.605) with a standard error and CV of 0.0144 and 0.0183 respectively)

[2] No effort was made to estimate composition is these strata. This value represents the unweighted mean proportion of breeding females present in strata 1 through 6.

[3] Assuming a CV of the proportion of parturient females of 0.061; the unweighted mean of the 6 CV's in Table 5.

Appendix 1. Survey notes and schedule

5 and 6 June - Set up camp.

7 June - Weather out.

8 June - Half day of recon flying then weather out again.

9 June - Half day of recon flying; low ceilings and very difficult to navigate.

10 June - Weather out in morning. Systematic recon in afternoon. Weather out (snowing) in evening.

11 - 14 June - Weather good at Waller Lake camp but out where caribou were around Bathurst Inlet.

15 June - Weather out in morning. Systematic recon in afternoon.

16 June - Systematic recon and data analysis completed. Delivered flight maps to photo crew in Cambridge Bay [but realized when returned to camp one stratum on photo flight maps had missed being plotted]. Chopper arrived in camp. Photo crew began flying.

17 June - Photography completed except for missing stratum. Composition work and visual census begun.

18 June - Visual census completed. Composition work continued.

19 June - Composition work completed. Packed up camp and went to Cambridge Bay.

20 June - Returned to Yellowknife.

Appendix 2. Caribou counted on each photographic transect of the Bathurst herd's calving ground June 1986.

Transect No.	Area	Caribou Counted
Stratum 1		
1	16.2	252
2	16.2	333
3	16.2	208
4	15.0	852
Totals	63.6	1645
Stratum 2		
1	14.0	1154
2	15.0	1595
3	15.4	1172
4	16.2	2083
5	16.2	1247
6	16.2	1430
7	16.2	1532
8	16.2	3364
9	16.2	3353
10	15.0	1015
11	16.2	2144
12	16.2	530
13	16.2	2199
14	16.2	1763
Totals	221.4	24581

Transect No.	Area	Caribou Counted
Stratum 3		
1	10.2	659
2	14.0	753
3	11.6	462
4	14.2	370
5	12.6	274
6	17.4	532
7	18.4	2388
8	18.4	1559
9	17.8	1931
10	17.8	771
11	17.0	785
Totals	169.4	10484
Stratum 4		
1	17.0	156
2	14.2	107
3	15.6	293
4	16.4	1173
5	17.4	536
6	17.4	231
7	15.6	471
8	12.2	968
9	15.6	567
10	12.2	972
11	17.6	1231
12	17.8	965
13	16.4	764
14	17.8	387
15	17.8	630
16	17.4	737
17	16.8	434
Totals	279.0	10622

Appendix 3. Composition of one year old and older caribou by transect on the Bathurst herd's calving ground in June 1986.

	Transect no.	Number of parturient cows	Number of other caribou
Stratum 1	1	2	43
	2	22	40
	3	57	45
	4	18	28
	5	0	4
Total		99	160
Stratum 2	1	119	74
	2	65	3
	3	247	29
	4	226	36
	5	216	27
Total		873	169
Stratum 3	1	62	19
	2	133	11
	3	20	7
	4	101	20
Total		316	57

	Transect no.	Number of parturient cows	Number of other caribou
Stratum 4	1	39	13
	2	138	7
	3	102	9
	4	96	13
	5	114	38
Total		489	80
Stratum 5	1	1	3
	2	3	24
	3	5	19
	4	5	50
	5	6	93
Total		20	189
Stratum 6	1	4	133
	2	8	45
	3	570	173
	4	88	21
	5	0	66
Total		670	438

Appendix 4. The extrapolation of the 1986 calving ground survey data to an estimate total herd size.

Survey data	Estimate	SE	CV
Number of caribou on the calving ground (Table 4)	285,400	17,300	.061
Number of parturient females on the calving ground (Table 6)	203,800	12,700	.062
Proportion of females in the entire herd	.60		.1[a]
Proportion of 1.5 year old and older females pregnant	.72		.1[a]
Total population[b]	472,000	72,900	.154

[a] no data; value only a guess

[b] - total population = number of parturient females / proportion of females in the population / proportion of females pregnant eg., 203,800 / .60 / .72 = 472,000

- for SE calculations see Table 6 and (Heard 1987b)
- CV = SE / total population eg., 72,900/472,000 = 0.154

APPENDIX D. Bathurst calving ground survey, June 1990. Douglas C. Heard and T. Mark Williams. Department of Renewable Resources. Government of the Northwest Territories. 1991.

ABSTRACT

In June 1990, the number of caribou on the Bathurst caribou herd's calving ground was estimated using a stratified transect strip survey where caribou were counted on aerial photographs. The survey resulted in an estimate of 212,000 ± 35,300 (SE) caribou one year old and older on the calving ground. Based on the reproductive condition of a sample of animals classified from a helicopter, the number of parturient (pregnant and post-partum) females on the calving ground was estimated to be 152,000 ± 25,800 which extrapolates to a total population estimate of 352,000 ± 77,800. The number of parturient females in 1990 was lower than in 1986 (207,000 vs 152,000) and the corresponding decline in the estimate of total herd size was from 470,000 to 350,000 but neither change was statistically significant. Because recruitment between 1986 and 1990 was high (suggesting the decline may have been less severe than the estimates indicate) and because the 1990 estimate exceeds 300,000 animals, we suggest that no management changes need be made.

INTRODUCTION

This report describes the results of the 1990 census of the Bathurst caribou herd and interprets the result in relation to previous herd size estimates.

METHODS

Reconnaissance flights were flown between 2 and 10 June 1990 to locate the general distribution of calving cows. On 11 June, transects spaced 10km apart, the systematic survey were flown over the entire calving distribution as determined by the reconnaissance. Both the reconnaissance and systematic surveys were flown in a Cessna 185 aircraft. During the systematic survey, observers counted all caribou except neonates within a 400m strip on each side of the aircraft. Transects were flown at 120m above ground level at approximately 170-180 kph.

Caribou densities determined from the systematic survey were then used to divide the calving ground into 4 strata of similar densities (Fig 1). A population estimate was generated from the systematic survey counts based on post-census stratification. Stratum density estimates were also used to determine the optimal allocation of survey effort (flight lines) that would maximize

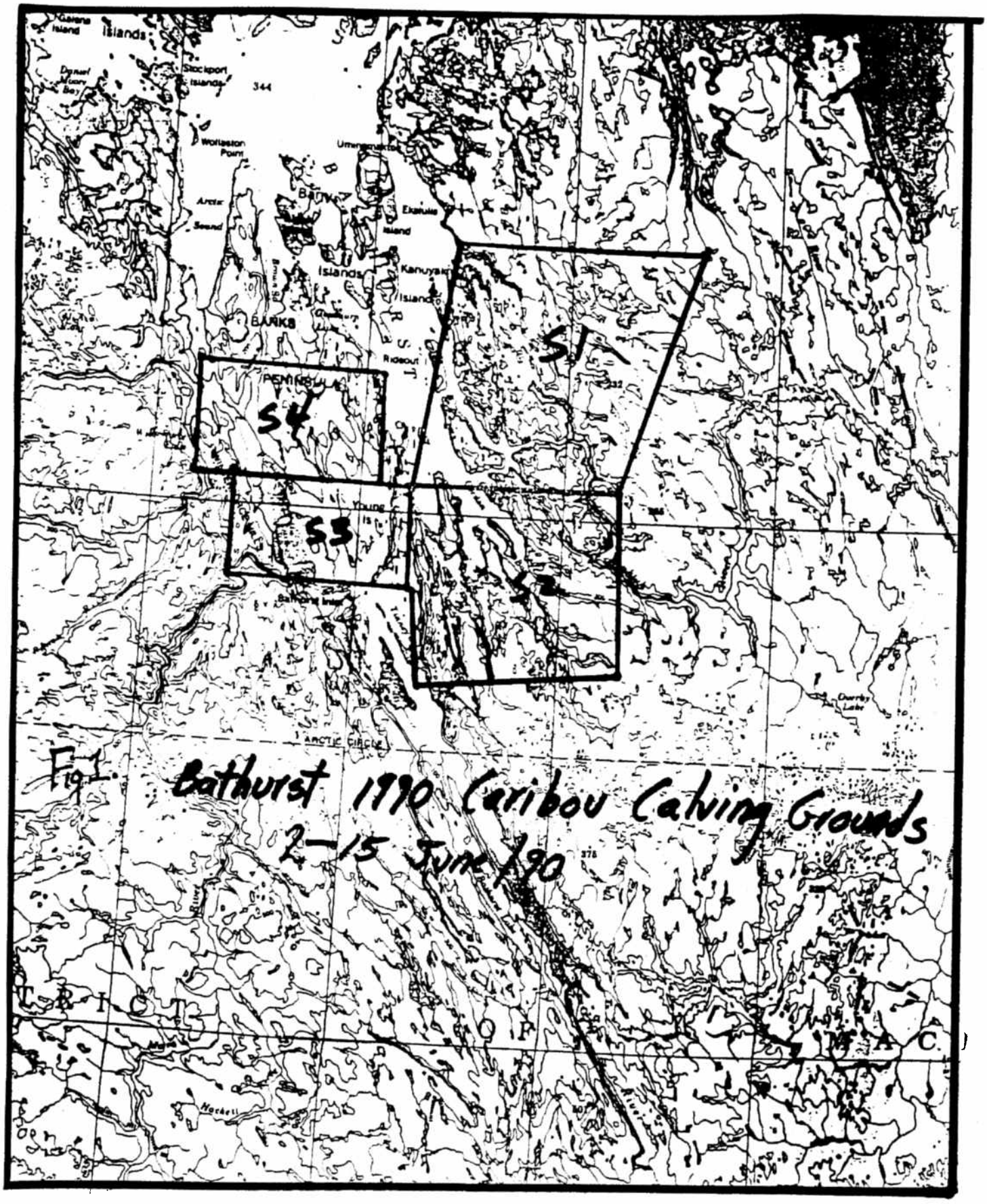

Fig 1. Bathurst 1990 Caribou Calving Grounds
2–15 June 90

the precision of the population estimate (Heard 1987a) for the subsequent photographic survey. We combined strata 3 and 4 for the photographic survey which was completed on 14 and 15 June.

Two thousand four hundred and fifty-nine photographs (black and white,230cm x 230cm, Agfa Panchromatic 150 film) were taken from 600m above ground level to provide an average image scale of 1:4000. Scale varied because ground elevation changes were too rapid for the aircraft to parallel, but we assumed scale was 1:4000 for caribou density calculations. The camera was a Ziess RMK A 15 with a forward motion compensator. Photographs had 60% forward overlap. Caribou were counted on the photographic contact prints using a stereoscope by Paul Roy.

Between 11 and 14 June, the age, sex and reproductive condition of all caribou observed from a Bell Jet Ranger 206B helicopter were recorded while flying along arbitrary flight lines within all 4 strata (Fig 2). The helicopter was flown at about 50m and 100 kph although speed and height were variable. Caribou were classed as neonates, yearlings, two year old and older males, and two year old and older cows. Parturient females, pregnant and post-partum cows, were identified by the presence of an udder. The proportion of parturient females in each stratum was the weighted mean and its variance was calculated using the binomial (Snedecor and Cochran 1967:514).

The proportion of parturient females was multiplied by the population estimate to obtain an estimate of the number of parturient females within each stratum. Stratum population estimates were based on the number of adult caribou recorded on photographs taken during the photographic strip transects. Total herd size was calculated by dividing the estimate of the number of parturient females by the sex ratio of the population (66 males: 100 females; the mean of 6 fall composition estimates available from different NWT caribou herds) and by the proportion of females in a caribou herd that are usually pregnant.

RESULTS AND DISCUSSION

Calving occurred adjacent to the south and east shores of Bathurst Inlet, the second time calving has been documented that far west since 1950 (Heard and Williams 1991) but incidental observations suggest that the herd may have calved here every year since 1985 (Page Burt pers comm). Calving usually occurs around Brichta Lake and the Ellice River over 100km further east. Caribou may have calved in the relatively snow-free lower

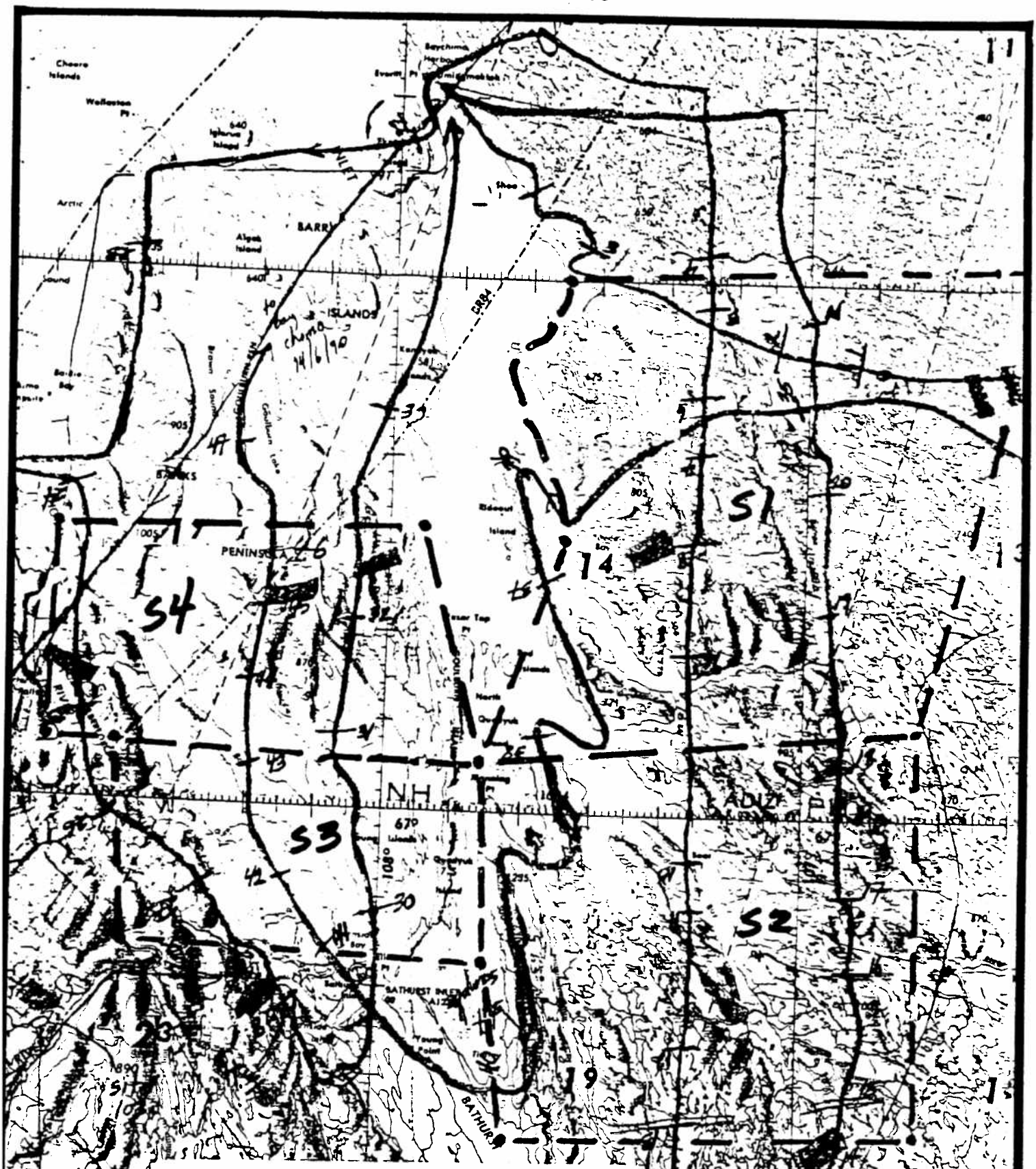

Figure 2. Classification flight lines, Bathurst 1990 calving ground survey 2-15 June 1990.

elevations around Bathurst Inlet in 1986 when snow melt was extremely late but snow melt appeared normal in 1990.

The visual census estimate of 92,000 ± 18,800 caribou on the calving ground was only 43% of the photo estimate of the same area (92,148/211,898; Table 1, 2). The difference represents sightability bias, the magnitude of which is consistent with past surveys (Heard 1985).

A total of 31,027 caribou was counted on the photographs. The number of caribou estimated from the photographic survey was 212,000 ± 35,300 (Table 2).

The proportion of parturient females in the four strata ranged from 49 to 82% (Table 5). There was more variation in the composition on individual days (Table 3, 4) but the only major difference was the estimate of only 7% in a small sample from stratum 5 on 11 June. Neonatal survival appeared to be good because most uddered cows were accompanied by a calf and those that were not carried at least one antler and were likely still pregnant (Table 5).

The estimate of parturient females was 152,000 ± 25,800 and the total herd size was estimated to be 350,000 ± 77,800 (Table 6, 7).

The number of parturient females in 1990 was lower than in 1986 (207,000 vs 152,000) and the corresponding decline in the estimate of total herd size was from 470,000 to 350,000 but neither change was statistically significant (Table 8). Because recruitment between 1986 and 1990 (Table 9) was high (suggesting the decline may have been less severe than the estimates indicate) and because 1990 the estimate exceeds 300,000 animals, we suggest that no management changes need be made.

In addition to caribou we saw 91 muskoxen in 11 groups (typical group size = 23.5 and mean group size = 8.3, range = 1-32) on 11, 14 and 15 June 1990 (Table 10). We also observed 8 grizzly bears in 4 groups (typical and mean group sizes = 2.5 and 2.0 respectively, range 1-3) and 1 wolf on 9 June and 2 at a den on 11 June.

We found 4 dead neonates. The cause of death could not be determined for any but none appeared to have died as a result of predation and all had lived 2 to 4 days. One may have died of exhaustion in the lake edge slush.

ACKNOWLEDGEMENTS

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PERSONAL COMMUNICATIONS

Page Burt, Biologist, Bathurst Inlet Lodge, Bathurst Inlet , NWT

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Table 1. The number of caribou estimated in strata 1-4 of the Bathurst caribou herd's calving ground in June 1990 based on the visual strip transect survey

Stratum	Stratum Area (km^2)	Estimate	Density (caribou/km^2)	Variance x 10^6	SE	CV
1	2251	33188	14.74	123.4		
2	1836	29599	16.12	45.0		
3	786	5834	7.42	1.8		
4	841	23527	27.97	184.9		
Totals		92148		355.1	18844	.204

Table 2. The number of caribou estimated in strata 1-3 of the Bathurst caribou herd's calving ground in June 1990 based on the photographic strip transect survey.

Stratum	Estimate	Density (caribou/km^2)	Variance x 10^6	SE	CV
1	103902	46.16	785.1		.27
2	48042	26.17	21.9		.10
3[1]	59954	36.85	435.6		.35
Totals	211898		1,242.6	35,300	0.166

[1] Visually surveyed strata 3 and 4 were combined for the photographic survey.

Table 3. Composition of one year and older caribou classified in strata 1 through 4 of the Bathurst herd's calving ground on 11 June 1990.

Classification	Number of caribou Stratum 1	2	3	4	Total
Parturient cows with a calf and;					
2 antlers	207	149	42	2	400
1 antler	15	5	0	0	20
0 antlers	101	88	25	0	214
Parturient cows without a calf but with an udder					
2 antlers	104	80	15	2	201
1 antler	6	0	0	0	6
0 antlers	18	11	15	0	44
Barren cows					
no udder, 2 antlers	0	5	1	0	6
no udder, 1 antler	0	0	0	0	0
no udder, 0 antlers	20	35	22	20	97
Yearlings	85	126	61	33	305
Bulls	4	1	2	4	11
Total	560	500	183	61	1304
Proportion of parturient cows	.81	.67	.53	.07	.68
SE	.017	.021	.037	.033	.013
CV	.020	.031	.070	.467	.019

SE=sqrt(pq/n); fpc ignored

Table 4. Composition of one year and older caribou classified in strata 1 through 4 of the Bathurst herd's calving ground on 14 June 1990.

Classification	Number of caribou Stratum 1	2	3	4	Total
Parturient cows with a calf and;					
2 antlers	135	61	23	58	277
1 antler	9	7	0	8	24
0 antlers	157	269	8	108	542
Parturient cows without a calf but with an udder					
2 antlers	42	14	1	20	77
1 antler	0	1	1	2	4
0 antlers	15	17	3	12	47
Barren cows					
no udder, 2 antlers	0	0	0	1	1
no udder, 1 antler	0	0	0	0	0
no udder, 0 antlers	8	16	8	30	62
Yearlings	59	60	42	92	253
Bulls	1	1	4	0	6
Total	426	446	90	331	1293
Proportion of parturient cows	.84	.83	.40	.63	.75
SE	.018	.018	.052	.027	.012
CV	.021	.021	.129	.042	.016

Table 5. Composition of one year and older caribou classified in strata 1 through 4 of the Bathurst herd's calving ground on 11 and 14 June 1990.

Classification	Number of caribou Stratum 1	2	3	4	Total
Parturient cows with a calf and;					
2 antlers	342	210	65	60	677
1 antler	24	12	0	8	44
0 antlers	258	357	33	108	756
Parturient cows without a calf but with an udder					
2 antlers	146	94	16	22	278
1 antler	6	1	1	2	10
0 antlers	33	28	18	12	91
Barren cows					
no udder, 2 antlers	0	5	1	1	7
no udder, 1 antler	0	0	0	0	0
no udder, 0 antlers	28	51	30	50	159
Yearlings	144	186	103	125	558
Bulls	5	2	6	4	17
Total	986	946	273	392	2597
Proportion of parturient cows	.82	.74	.49	.54	.71
SE	.012	.014	.030	.025	.009
CV	.015	.019	.062	.047	.013

Table 6. The estimated number of parturient female caribou on the Bathurst herd's calving ground in June 1990 based on composition counts and the stratum population estimates.

Stratum	Estimate		Parturient Females Proportion		Estimated number	Variance x 10^6 *	SE	CV
1	103,902	x	.82	=	85,200	530.8		
2	48,042	x	.74	=	35,551	13.1		
3	59,954	x	.52	=	31,176	122.0		
Total	211,898				151,927	665.9	25,805	.170

Table 7. Extrapolation of the 1990 calving ground survey data to an estimate of total herd size.

Survey data	Estimate	SE	CV
Number of caribou on the calving ground (Table 2)	211,898	35,300	.166
Number of parturient females on the calving ground (Table 6)	151,927	25,805	.170
Proportion of females in the entire herd	.60		.1[a]
Proportion of 1.5 year old and older females pregnant	.72		.1[a]
Total population[b]	351,683	77,769	.22

[a] no data; value only a guess

[b] - total population = number of parturient females / proportion of females in the population / proportion of females pregnant eg., 151,927 / .60 / .72 = 351,683 (see Heard and Williams 1991 for details).

- for SE calculations see Heard (1987b)
- CV = SE / total population

Table 8. T-tests of the differences between the 1986 and 1990 parturient and total population estimates

Year	Parturient females	Total population
1986	207,100	479,000
1990	152,000	352,000
	t = 1.94	t = 1.20
	0.05 < P < 0.1	P > 0.1
	df = 33	df = 33

Table 9. Calf:cow ratios in March 1987-1990 in the Bathurst caribou herd.

Year	Calf:cow ratio (sd)	Estimated per cent calves in herd	Number of groups classified
1987	37 (2.6)	18	30
1988	58 (14.1)	26	13
1989	36 (2.0)	18	16
1990	33 (2.2)	18	15

Table 10. Muskox and Grizzly Bear Sightings, 11 to 15 June 1990.

Date	Location	No.	Description
Muskox sightings			
11/6	67°25'N X 106°29'W	2	
	67°24'N X 106°35'W	1	
	66°41'N X 106°55'W	17	12 adults + 5 calves
	66°49'N X 108°16'W	2	
14/6	67°25'N X 104°52'W	28	26 adults + 2 calves
	67°22'N X 106°23'W	5	
	67°21'N X 106°26'W	1	
15/6	65°57'N X 111°00'W	1	
	66°52'N X 109°15'W	1	
	66°53'N X 109°10'W	32	26 adults + 6 calves
	67°07'N X 108°47'W	1	
Total		91	
Grizzly Bear sightings			
8/6	67°41'N X 104°54'W	1	
11/6	67°15'N X 107°20'W	3	1 sow+2 cubs of the year
	67°14'N X 108°02'W	1	
14/6	67°13'N X 108°15'W	3	
	1 sow + 2 yearlings		
Total		8	

Appendix 1. Survey notes and schedule

2 and 3 June - First reconnaissance flights over calving area.
4 to 7 June - Weather out.
8 June - Set up camp.
9 June - Half day of spaghetti reconnaissance flying then TMW to Cambridge to arrange chopper fuel.
10 June - Too windy to fly 10km transects but D. Melton and DCH did some behaviour observations and enough reconnaissance to justify calling in the photo plane.
11 June - Completed the systematic reconnaissance in two long flights. Photo plane arrived. TMW began composition work in helicopter. Weather out (snowing) in evening. Prepared photo flight maps.
12 June - DCH went to Cambridge with maps for photo crew but too windy (to 118kph) to fly photo or composition.
13 June - Weather out.
14 June - Photo begun [DCH in photo plane], composition work completed by TMW and camp packed up and removed to Cambridge while the C185 went to YK.
15 June - TMW to Contwoyoto Lake from Cambridge Bay, and return, in helicopter to locate bulls and for fecal pellet sampling.
- photo completed with Melton in photo plane, DCH returned to YK in photo plane
16 June - TMW return to YK on scheduled airline

Appendix 2. BATHURST 1990 CALVING GROUND CENSUS: NUMBER OF CARIBOU COUNTED ON THE PHOTOGRAPHS ON EACH TRANSECT IN EACH STRATUM.

STRATUM 1	N=53	Z=2251
TRANSECT	AREA	COUNT
1	40.7	1965
2	41.4	2285
3	43.2	5565
4	40.9	2342
5	38.6	438
6	39.1	1014
7	35.4	717
8	38	320
TOTALS	317.3	14646

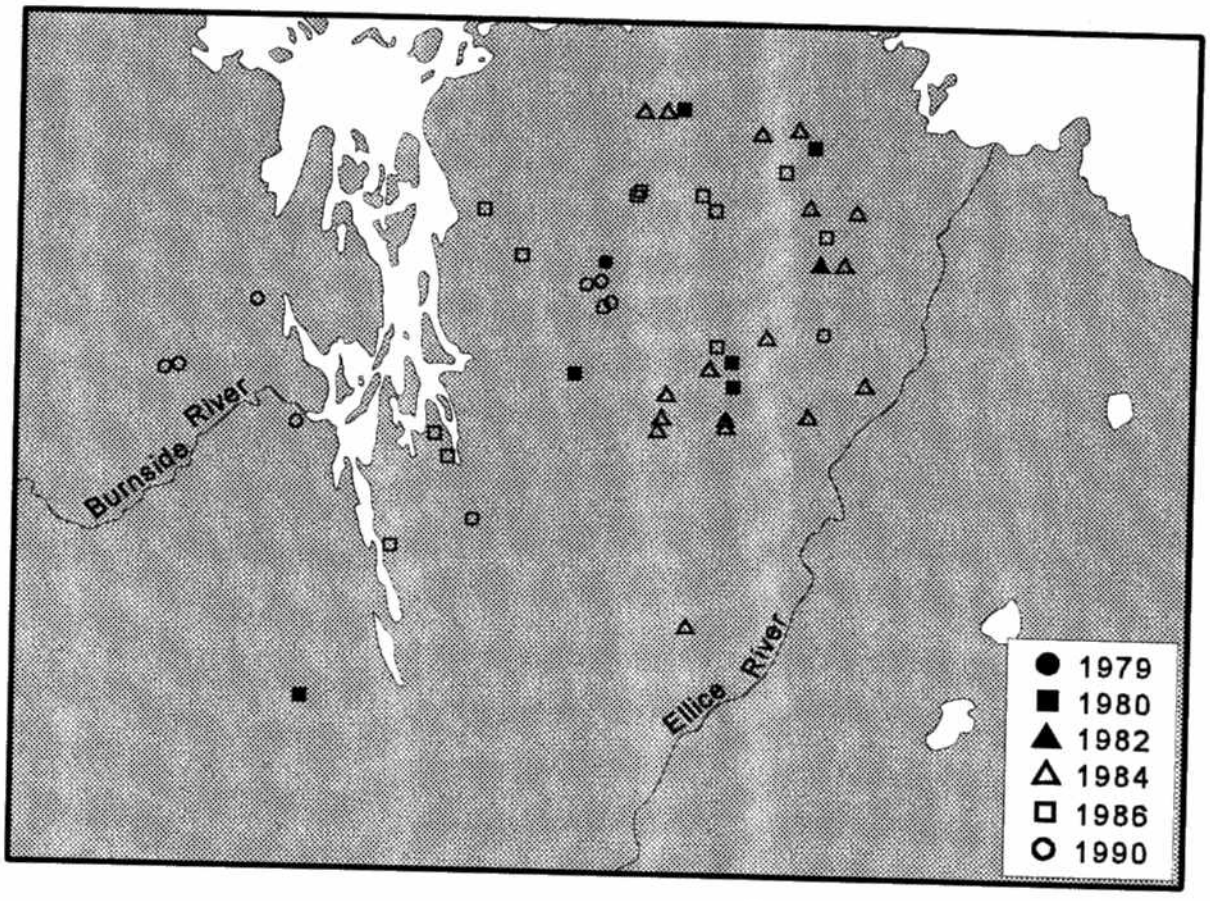
STRATUM 2	N=45	Z-1836
TRANSECT	AREA	COUNT
1	38.4	1489
2	37.5	939
3	43.5	1030
4	41.4	1045
5	41.9	1256
6	40.3	1109
7	44.2	647
TOTALS	287.2	7515

STRATUM 3	N=49	Z=1627
TRANSECT	AREA	COUNT
1	23.7	102
2	37.4	485
3	40.7	3780
4	40.3	897
5	42.3	2671
6	27.4	621
7	28.8	310
TOTALS	240.6	8866

APPENDIX E. Muskox groups observed during Bathurst calving ground surveys, 1979-1986 (for flight lines see Sutherland and Gunn 1996). Observations compiled by Sue Fleck, Douglas C. Heard and T. Mark Williams.

Date	Number Seen	Latitude	Longitude
1979			
7 June	4	67 28	106 30
1980			
31 May	25 (2 blond)	67 55	105 15
1 June	3	67 09	106 30
	20	66 05	107 44
	12	67 13	105 24
2 June	22 (same as 31 May)	67 66	106 14
	3 (2 bulls)	67 17	105 27
1982			
5 June	35	67 36	105 00
1984			
3 June	12	67 57	105 23
	2 (bulls)	67 55	105 38
	1 (bull)	67 55	106 20
	3 (bulls)	67 54	106 30
	40	67 40	105 51
4 June	20	67 18	104 30
	1 (bull)	66 32	105 19
	3	67 06	105 23
	10	67 06	105 23
	3	67 06	105 23
5 June	3	67 07	105 23
	2	67 07	105 23
	1	67 07	105 23
	12	67 37	104 50
	5	67 22	105 15
	1	67 05	105 50
	18	67 09	105 50
	1	67 03	105 50
	9	67 15	105 35
	1	67 11	105 50
	7	67 45	105 10
	3	67 46	104 50
1986			
9 June	2	67 40	106 24
	20	67 43	105 57
	5+ 3 calves	67 50	105 24
	4	67 41	106 23
10 June	3	67 19	105 35
	4	67 41	105 00
	20+ 5 calves	67 41	105 50

Date	Number Seen	Latitude	Longitude
16 June	5	67 32	107 25
17 June	1	66 53	107 20
	1	66 50	107 12
	2	67 26	107 05
18 June	45	66 33	107 25
1990			
11 June	2	67 25	106 29
	1	67 24	106 35
	17	66 41	106 55
	2	66 49	108 16
14 June	26+2	67 25	104 52
	5	67 22	106 23
	1	67 21	106 26
15 June	1	65 57	111 00
	1	66 52	109 15
	32	66 53	109 10
	1	67 07	108 47



APPENDIX F. Detecting numerical changes in numbers of breeding females from calving ground surveys of Bathurst caribou, 1990-96.

Introduction

We conduct calving ground surveys of barren ground caribou to determine abundance of breeding females on an annual calving ground. By comparing results between subsequent surveys, we determine trend in the number of breeding females; this is a useful index to population trend.

Trend analysis is the assessment of numerical change over time and may involve either regression analysis (see Gerrodette 1987) when there are many data points, or a simple t-test (see Gasaway *et al.* 1986) when comparing two data points. In the latter case, a proper test of the null hypothesis, *i.e.,* that there is no significant difference between surveys, requires an objective assessment of the power of the test. This is especially true when the null hypothesis is not rejected (Toft and Shea 1983, Peterman 1990).

Based on our results from a calving ground survey of Bathurst caribou in June 1996 (this report), we accepted the null hypothesis that the number of breeding females was not significantly different from the estimate in June 1990. Here we assess power of the test given variability in results of the calving ground surveys. We designed a spreadsheet using formulas in Chapters 3 and 4 of Gasaway *et al.* 1986. Our purpose was to understand the implications of survey precision on power to detect numerical changes in abundance of breeding females.

Methods

We used a two-tailed *t*-test to determine whether the estimate of breeding females in June 1996 was significantly different from the June 1990 estimate. We estimated degrees of freedom (v_o) for each calving ground survey using the formula provided in Section 3.7.2.3 (page 39) of Gasaway *et al.* 1986

$$v_o = \frac{[V(\hat{T}_o)]^2}{\frac{[V(\hat{T}_h)]^2}{n_h - 1} + \frac{[V(\hat{T}_m)]^2}{n_m - 1} + \frac{[V(\hat{T}_l)]^2}{n_l - 1}} \qquad (1.0)$$

where: $V(T_o)$ = $\sum$ variances of all strata estimates;

$V(T_h)$, $V(T_m)$, $V(T_l)$ = variances of estimates within high-, medium-, and low-density strata respectively;

n_h, n_m, and n_l = number of transects surveyed within high-, medium-, and low-density strata respectively.

We calculated the *t*-statistic (*t'*) using the following formula (from Section 4.2.1.2, page 62, Gasaway *et al.* 1986).

$$t' = \frac{\hat{T}_{1996} - \hat{T}_{1990}}{\sqrt{V(\hat{T}_{1990}) + V(\hat{T}_{1996})}} \qquad (2.0)$$

where:

T_{1996} and T_{1990} = population estimate of breeding females from calving ground surveys in June 1996 and 1990 respectively;

$V(T_{1990})$ and $V(T_{1996})$ = variances of population estimates (breeding females) from calving ground surveys in June 1990 and 1996 respectively.

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

$$v_t = \frac{[V(\hat{T}_{1996}) + V(\hat{T}_{1990})]^2}{\frac{V(\hat{T}_{1996})^2}{v_{o1996}} + \frac{V(\hat{T}_{1990})^2}{v_{o1990}}} \qquad (3.0)$$

where:

$V(T_{1996})$ and $V(T_{1990})$ = variances of population estimates (breeding females) from calving ground surveys in June 1996 and 1990 respectively;

v_{o1996} and v_{o1990} = degrees of freedom from calving ground surveys in June 1996 and 1990 respectively (derived from formula 1.0 above).

To calculate critical *t*-values (t^o) for Type II error (β), we used the following formula (see Section 4.2.1.2, page 63, Gasaway *et al.* 1986).

$$t^o = \frac{CD - \sqrt{V(\hat{T}_{1996}) + V(\hat{T}_{1990})} \; x \; t_{\alpha, v_t}}{\sqrt{V(\hat{T}_{1996}) + V(\hat{T}_{1990})}} \qquad (4.0)$$

where:

CD = the consequential difference of interest, *i.e.*, the minimum change in population size that would probably cause some change in management strategy; or the minimum detectable difference between population means (p. 134, Zar 1984);

$V(T_{1996})$ and $V(T_{1990})$ = variances of population estimates (breeding females) from calving ground surveys in June 1996 and 1990 respectively;

$t_{\alpha, vt}$ = critical *t*-value for a two-tailed test at α probability, t and v degrees of freedom.

We incorporated the formulas into a simple spreadsheet model in Quattro Pro 6.0© . The spreadsheet allowed us to change one of three parameters singly or in combination: a) Coefficient of Variation (CV) of one or both surveys; b) Consequential Difference (CD) between surveys; and c) α (probability of a Type I error). By varying any one of the parameters, we iteratively determined the effect on statistical power, *i.e.*, β, the probability of a Type II error (Equation 4.0). To evaluate the effect of survey precision (CV) on detectable differences between survey estimates (CD), we assigned probabilities for α and β at 0.10 and 0.20 respectively.

Results

The estimate of breeding female caribou from the calving ground survey in June 1990 was 151 927 $\pm$ 25 712 (Standard Error). The survey was comprised of three strata with 8, 7, and 7 transects respectively; this resulted in 10 degrees of freedom for that survey. The survey in June 1996 resulted in an estimate of 151 393 $\pm$ 35 145 (SE). The 1996 survey results were based on two survey strata with 10 and 13 transects respectively; and 10 degrees of freedom. We accepted the null hypothesis that there was no significant change in number of breeding female caribou between surveys ($t_{(2)}$ = 0.012, 18 df, $p > 0.50$).

Using the respective levels of precision for the June 1996 (CV = 0.23) and June 1990 (CV = 0.17) surveys, we determined that we could have only detected a 75% change in numbers of breeding females (Table 1).

The spreadsheet model showed that increasing precision of survey estimates would decrease minimum detectable differences. Given an optimum example where comparative surveys had *CV's* of 0.10 respectively, we could be 80% confident of detecting a 37% change in number of breeding females (Table 2).

Table 1. A spreadsheet model designed to assess statistical power of a two-tailed *t*-test of calving ground surveys.

1) Comparison of breeding females from calving ground surveys

	Bathurst June 1990 (T1)				Bathurst June 1996 (T2)	
T1	Var(T1)	CV(T1)	CD (% of T1)	T2	Var(T2)	CV(T2)
151927	659237935	***0.169***	***0.75***	151393	1233641397	***0.232***
			113945			

2) Critical Values (2-tailed t-test with 18 d.f.)

	ALPHA			BETA	
tcalc	tcrit(.05)	tcrit(.10)	tcrit(.20)	tocalc	
-0.072	2.101	1.734	1.330	*0.885*	

Set Alpha ***1.734***

Critical values of "to" to achieve Power (@ 18df)

60%	70%	80%	85%	90%	95%
0.257	0.534	0.862	1.067	1.330	1.734

3) Degrees of Freedom (df) for the estimate of Breeding Females in a survey (Section 3.7.2.3; pg 39)

	Bathurst June 1990			Bathurst June 1996	
Estimate	151927	Transects	**Estimate**	151393	Transects
VAR 1	529516067	8	**VAR I**	1199372066	10
VAR 2	12440399	7	**VAR III**	35764462	13
VAR 3	119126495	7	**VAR sum**	1235136528	
VAR sum	661082960		**SE**	35145	
SE	25712		df	10	
df (vo)	10				

4) Degrees of Freedom (df) for a 2-tailed t-test of two calving ground surveys (Section 4.2.1.2.; pg 62)

df (vt)	18

Table 2. The effect of survey precision on minimum detectable differences.

1990 Survey *(CV)*[a]	1996 Survey *(CV)*	α[b]	β[c]	CD[d]
0.17	0.23	0.10	0.20	0.75 (113 945)
0.20	0.20	0.10	0.20	0.74 (112 426)
0.15	0.15	0.10	0.20	0.55 (83 560)
0.10	0.10	0.10	0.20	0.37 (56 213)

[a] Coefficient of Variation
[b] Alpha (Type I Error)
[c] Beta (Type II Error)
[d] Consequential Difference or minimum detectable difference as a proportion of the 1990 estimate of breeding females. Number in parentheses represents the absolute value.

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