SEX AND AGE CLASSIFICATION SURVEYS

OF MUSKOXEN ON BANKS ISLAND,

1985-1998: A REVIEW

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ABSTRACT

Sex and age classification surveys of muskoxen were conducted annually on Banks Island from 1985 to 1998. Most surveys were in June, but surveys were as early as 27 April and as late as 15 August. Most surveys had aerial support. Survey areas and objectives differed between years. In 1989 Banks Island was divided into 8 strata, based upon geographic areas and muskox density, to increase accuracy in the population estimates, and therefore improve the assessment of the rate of increase in the muskox population and the impact of harvest. We compiled all available sex and age classification data from surveys completed between 13 June and 15 August from 1985 to 1998. All classified groups were assigned into the appropriate stratum resulting in 37 surveys of different strata over a 13 year period. For each of the 37 surveys we calculated the ratios of calves and yearlings:100 adult ($\geq$2 year-old) females, the percentages of calves and yearlings in the survey sample, the ratio of adult females:adult ($\geq$2 year-old) males, the number of non-calves in the survey sample, and the non-calf percentage of the estimated total population. These 7 measures were compared between years and strata. There were significant ($P < 0.05$) year effects for yearlings:100 adult females and percent yearlings; both were lower in years following severe winters. There were significant stratum effects for the number of non-calves sampled; the number was higher in strata with larger populations. The range of calves:100 adult females and yearlings:100 adult females on Banks Island is similar to those found in other circumpolar muskox populations. We estimated calf production for 13 years, range 31.3 (1995) to 56.3 (1996) calves per 100 adult females. Production from 1986-1992 was generally higher than from 1993-1998. We estimated overwinter survival of calves for 12 years. Overwinter survival ranged from 23% (1988-89) to 83% (1991-92) when defining adult females as $\geq$ 2 years-old and from 27-98% for

the same years when defining adult females as $\geq$ 3 years-old. Overwinter survival of calves was higher from 1986-87 to 1992-93 than from 1993-94 to 1997-98. Both production and overwinter survival were higher during a period with documented severe winter weather and were lower during a period with mild winters.

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INTRODUCTION

Spring and/or summer sex and age classification surveys (composition surveys) of wildlife populations are often conducted by wildlife managers as part of regular inventory programs. Numbers of each sex and age group can provide valuable information pertaining to population productivity, recruitment, survival, age structure, and sex structure (Caughley, 1974; 1977), depending upon: i) how surveyed animals were sampled from the population, ii) the number of years of sampling, and iii) population size estimates.

Muskox numbers on Banks Island increased steadily from 1972, when the population was estimated at 3, 800 $\geq$1 year-old animals (Nagy *et al.*, 1996) to 64,608 (SE 2,009) in 1996 (Larter and Nagy, 1997). The most recent population estimate (July 1998) was 45,833 (SE 1938) $\geq$1 year-old animals (J. Nagy and M. Branigan, unpubl. data). Since the 1980's, increasing muskox numbers have been a concern of Sachs Harbour residents, especially since Peary caribou numbers decreased on the island during the same time period (Nagy *et al.*, 1996; J. Nagy and M. Branigan, unpubl. data). Annual sex and age classification surveys of muskoxen were begun in April 1985 to address the concern of the increasing muskox population. Surveys during the 1980's and early 1990's were intended to provide baseline levels of sub-adult (calf and yearling) survival, adult ($\geq$3 year-old) sex ratios, and group size, and to provide estimates of productivity and recruitment. (B. McLean, A. Gunn, and P. Fraser, unpubl. data.). Surveys conducted since 1992 were intended to assess annual variation in productivity and recruitment in areas of high muskox density and in areas where commercial harvesting occurred. Summer island-wide population estimates of muskoxen were obtained in 1972, 1982, 1985, 1989, 1991, 1992, 1994, and 1998.

This report compiles, reviews, and assesses all data from sex and age classification surveys of muskoxen conducted on Banks Island. We document annual variation in ratios of calves and yearlings:100 $\geq$2 year-old females in areas of high and low muskox density and present the best estimates of calf production and overwinter survival of calves for the Banks Island population. We discuss these results in the context of original survey objectives, population changes both island-wide and within each strata, and commercial harvesting. We compare our findings with data from other muskox populations.

METHODS

Sex and Age Classifications

Muskox on Banks Island generally calve during April and early May with most calves born by mid-May (Latour, 1987; pers. obs.). Body size, pelage, and horn development are sufficiently different between the sexes to identify sex and age of the first three cohorts of muskox in the field (Tener, 1965; Henrichsen and Grue, 1980; Olesen and Thing, 1989). As many as 13 sex and age classes were variously identified during the 37 surveys. Not all surveys identified all 13 classes, however, all surveys identified calves, yearlings, 2 year-old and/or older females and 2 year-old and/or older males. Surveys prior to 1993 generally defined adult females as $\geq$3 years-old. Female muskoxen on Banks Island can conceive as yearlings and calve in their second year (Nagy and Larter, unpubl. data). Therefore, females $\geq$2 years-old were defined as adults.

Types of Classification Surveys

Sex and age classification surveys were conducted annually in various parts of Banks Island from 1985 to 1998 (Table 1.). Most surveys were conducted using a Bell 206B or 206L helicopter so as to maximize coverage within the study area. Muskox groups of $\leq$10 animals were sometimes classified from the air. Larger groups were located from the air and the survey crew, generally an observer and a data recorder, was positioned by helicopter. To minimize disturbance, the helicopter landed 0.5-1.5 km downwind and preferably behind a ridge or hill to be out of the animals' line-of-sight. The survey crew walked to a position where they could view the animals with a spotting scope.

Snowmobiles were used for 2-4 day ground-based surveys in 1985. In those surveys, muskox were observed with spotting scopes and binoculars. The July 1990 survey was done opportunistically on foot as part of a larger field operation. Muskox groups that were encountered were classified with spotting scopes or binoculars whenever possible. In both August 1987 and 1990 the aerial surveys were supplemented with opportunistic ground-based observations. The helicopter survey classified the majority of the groups in the combined ground/air survey and was done on the final day of the 6-10 day field trip.

Locations of all classified groups was recorded starting in 1991. The locations of groups were recorded on 1:250,000 maps during surveys in 1991 and 1992 and were later transcribed into latitude and longitude. After 1992, the locations of groups were recorded using a global positioning system.

Excluding and Partitioning Raw Classification Data

We reviewed the raw data from each survey and then transcribed the data into computer spreadsheets for analyses. April and May (1985) surveys were excluded from our analyses because they were conducted during the calving season. We used classification data from surveys conducted between 13 June and 15 August in our analyses. We acknowledge that calf mortality occurs during this period and will bias the results of mid-August surveys more than in mid-June. However, we deemed surveys conducted during this 2-month period as suitably comparable. All survey data are provided in Appendix 2.

In 1989 Banks Island was divided into 8 separate strata: A, B, C, D, Egg, Masik, Thomsen, and Parker (Figure 1.). Stratification was based upon geographic area and muskox density, to increase accuracy in the population estimates, and therefore improve the assessment of the rate of increase in the muskox population and the impact of harvest (Nagy *et al.*, 1996). All groups classified and used in our analyses were assigned into the appropriate stratum. For each classification survey in each stratum we calculated the following 7 measures: 1) calves per 100 adult ($\geq$2 year-old) females, 2) yearlings per 100 adult females, 3) adult females to adult ($\geq$2 year-old) males, 4) percent calves, 5) percent yearlings, 6) number of non-calves, and 7) the non-calf percentage of the estimated total population. Groups containing unclassified animals were removed from the analysis. Data from groups containing adult ($\geq$2 year-old) muskoxen which had not been classified by sex were used only in calculating percent calves, percent yearlings, and number of non-calves. Some groups of muskoxen were classified only into the number of calves and the number of adults. Data from these groups were only used for calculating percent calves and non-calf numbers.

Population estimates per stratum were determined from islandwide surveys during summers 1985, 1989, 1991, 1992, 1994 and 1998 (Nagy *et al.*, 1996; Larter and Nagy, 1997; J. Nagy and M. Branigan, unpubl. data). For those years between population surveys we estimated population size from the instantaneous rate of growth (*r*) between two successive surveys (Appendix 1).

Best Estimates of Calf Production

We determined the total number of calves per 100 $\geq$2 year-old females reported from each stratum surveyed during a particular year. For years when there was >1 survey within the same stratum we used the data from the earliest survey. The only exception to this was for the Parker stratum in 1986. Because the survey days were 30, 31 July and 1 August we lumped the data and included it in the 1986 calculations. Most calculations are based upon data collected in June or July. We realize that these data do not address neonatal mortality, but we believe they provide the best estimates of calf production.

Estimating Overwinter Survival of Calves

We determined the total number of yearlings per 100 ≥2 year-old females reported from each stratum surveyed during a particular year. As above with multiple surveys/stratum we used data from the earliest survey and lumped the Parker July and August 1986 data. Because we were concerned that survival of 2 year-old females may be more affected than that of ≥3 year-old females by severe winter weather events we also determined the total number of yearlings per 100 ≥3 year-old females reported from each stratum during a particular year. We estimated overwinter survival of calves in the population by: 1) dividing the number of yearlings per 100 ≥2 year-old females by the previous years' number of calves per 100 ≥2 year-old females, and 2) dividing the number of yearlings per 100 ≥3 year-old females by the previous years' number of calves per 100 ≥2 year-old females. The values used for the calculations are found in Table 2.

Statistical Analyses

We pooled each of the seven measured parameters and used the Kruskal-Wallis test to determine if stratum or year explained any of the variability in the ratio of calves:100 adult females, the ratio of yearlings:100 adult females, the ratio of females (≥2 years-old):males (≥2 years-old), the percent calves, the percent yearlings, the number of non-calves, and the non-calf percentage of the estimated total population. When Kruskal-Wallis tests indicated significant

(P<0.05) results, multiple comparisons (Gibbons, 1985) were conducted on the mean class ranks to identify significantly different subsets of years. We used an overall significance level of 0.25 for multiple comparisons. We used the Mann-Whitney U test to determine if calf production prior to 1993 was different from that from 1993 to present and if overwinter survival prior to 1993-94 was different from overwinter survival from 1993-94 to present.

RESULTS

Classification Data

During the 14 year period from 1985-1998, 37 classification surveys that were conducted in different strata on Banks Island provided adequate data for analyses, all those from 1986-1998. There were significant year effects in yearlings:100 adult ($\geq$ 2 year-old) females ($P=0.010$) and percent yearlings ($P=0.021$). Ratios of yearlings per:100 adult females were significantly lower in 1995 and 1996 than in 1986 and were significantly higher in 1990 than 1986. Similarly, percent yearlings were significantly lower in 1995 and 1996 than in 1986 and were significantly higher in 1990 than 1986 (Appendix 2). There were significant stratum effects in the number of non-calves ($P=0.012$); significantly more non-calves were surveyed in the higher density strata (Thomsen and Masik). The other 4 measures varied between years and among strata showing no significant ($P>0.05$) main effects (Appendix 2).

Best Estimates of Calf Production

Estimates were calculated for 13 consecutive years from 1986-1998 and ranged from a low of 31.3 (1995) to a high of 56.3 (1996) calves per 100 $\geq$2 year-old females (Table 2). Calf production during 1986-1992 (median 45.8 calves per 100 $\geq$2 year-old females) was similar ($P>0.05$) to calf production from 1993-1998 (median 38.5 calves per 100 $\geq$2 year-old females).

Best Estimates of Overwinter Survival

Estimates were calculated for 12 consecutive winters from 1986-87 to 1997-98.

Overwinter survival estimates of calf muskoxen based upon the subsequent years ratio of yearlings per 100 ≥2 year-old females ranged from a low of 23 (1988-89) to a high of 83% (1991-92) (Table 3). Overwinter survival estimates of calf muskoxen based upon the subsequent years ratio of yearlings per 100 ≥3 year-old females ranged from a low of 27 (1988-89) to a high of 98% (1991-92) (Table 3). Overwinter survival during 1986-87 to 1992-93 was significantly greater ($P=0.05$, 1-tailed) than during 1993-94 to 1997-98 regardless of whether survival estimates were calculated using ≥2 year-old females (medians 77 versus 40%) or using ≥3 year-old females (medians 82 versus 44%).

DISCUSSION

Classification Data

In order to best address productivity and overwinter survival of calves a biased subset of the population must be classified - mixed sex and age groups. Classification of bull-only groups does not provide information to address productivity or overwinter survival of calves. Flying time spent classifying bull-only groups is lost from classifying mixed sex and age groups and could reduce sample size of classified animals. Classification surveys wanting to address productivity and overwinter survival of calves should be conducted after the calving period.

Surveys prior to 1993 generally had lower adult female: adult male ratios, percent calves and percent yearlings than those conducted since 1993. These lower values are indicative of a random selection of groups for classification. Surveys during the 1980's and early 1990's attempted to collect data on a wide range of topics: group size, adult sex ratios, productivity, and overwinter survival of calves. A completely random sample of all group types and animals provides data to best address group sizes and adult sex ratios, but likely increased variability in the estimates of productivity and overwinter survival of calves. However, for effective management adult sex ratio and group size data are less applicable than estimates of productivity and overwinter survival of calves, especially with an increasing population.

It is not surprising that the non-calf number of animals classified showed a stratum effect. In areas of high muskox density it is easier to classify a larger number of animals in a given amount of time. More surveys were conducted in strata with high densities of muskoxen than in strata with low densities of muskoxen.

Severe winter weather is believed to cause the fluctuations in population dynamics of muskox (Parker *et al.*, 1975; Miller *et al.*, 1977; Gray, 1987; Gunn, 1990). For example, the ratios of calves and yearlings:100 adult female muskox in Alaska's Arctic National Wildlife Refuge are generally lower in summers following severe winters than in summers following more normal winters (Reynolds, 1998). The ratio of calves:100 adult ($\geq$2 year-old) females on Banks Island showed little variation around the median (43.8), however the ratio of yearlings:100 adult females and the percent yearlings surveyed showed substantial variation around their respective median values (24.2 and 10.2%) and had significant year effects. Severe winter weather caused die-offs of Peary caribou during winters 1987-88, 1988-89, and 1990-91 (Nagy *et al.*, 1996). Severe icing conditions were also documented during winter 1993-94 however there was no accompanying die-off of caribou (Larter and Nagy, 1994). The lowest ratios of yearlings:100 adult females and percent yearlings were found in 1988 and 1994, both summers following severe winter weather.

The ratios of calves and yearlings:100 adult females documented from Banks Island muskoxen are similar to those in other circumpolar muskox populations (Table 4). The ratios of calves:100 adult females range from *ca.* 0-70, and the ratios of yearlings:100 adult females range from *ca.* 5-50. Where multiple years of data are available the similarities are evident. The Jameson Land population and the Nunivak Island population in the 1930's and 1940's likely have somewhat inflated ratios because these data were derived from adult females defined as those $\geq$3 years. During the 1930's and 1940's the Nunivak Island founder population was $<$150 animals and there is some indication that females bred in alternate years. Alternate year breeding is likely responsible for this population having the greatest range in the ratio of calves:100 adult females

(R. Kacyon, pers. comm.). The lowest ratio of yearlings:100 adult females from Banks Island (6.3) resulted from a sample of 1 group; the next lowest ratio (9.4) is likely more realistic of the lower bound.

Calf Production

The population of Banks Island muskox ($\geq$1 year-old) increased steadily (r=0.07) from an estimated 29,168 (SE 2,104) in 1985 to peak at an estimated 64,608 (SE 2,009) in 1994 (Nagy *et al.*, 1996; Larter and Nagy 1997). Between 1994 and 1998 the population decreased (r=-0.09) and was estimated at 45,833 (SE 1,938) (Nagy and Branigan, unpubl. data). The ratio of calves:100 adult $\geq$2 year-old females represents a conservative index of productivity or fecundity. Fecundity is influenced by the health and condition of females. If access to high quality summer forage is restricted females may be unable to gain enough body mass to come into estrous (White *et al.*, 1997). Low fecundity would be reflected by low calf production the following year.

The muskox population peaked in 1994 and has subsequently declined (Figure 2). The sedge component of the summer diet of muskox in both low and high density areas decreased from 1993-1996 while the willow component generally increased (N. Larter and J. Nagy, unpubl. data). There were no 1 year-old females pregnant during the 1997 commercial muskox harvest unlike in commercial harvests from 1990-1993 (J. Nagy and M. Branigan, unpubl. data). Although calf production during 1986-1992 was not significantly different from calf production from 1993-1998, the median for the latter period was *ca.* 7 calves:100 adult females lower (Table 2, Figure 2). Possibly calf production decreased in response to high muskox density. Lower annual calf production is associated with years immediately prior to and following peak population density

(Figure 2). This association is more obvious when broken down by strata. The higher density Masik strata showing a more exaggerated decrease in calf production immediately prior to and following peak population density (Figure 3).

Calf production of muskox in the Arctic National Wildlife Refuge (ANWR) was greatest (87 calves:100 $\geq$3 year-old females) when the population was increasing (r=0.24) between 1977 and 1980. Calf production subsequently declined as the rate of population increase slowed (1983-86), decreased (1987-90), and possibly stabilized (1991-95), being 61, 49, and 38 calves:100 $\geq$3 year-old females for each time period respectively. Low calf production in ANWR was also associated with more severe winters, snow depth in particular (Reynolds, 1998).

On Banks Island calf production was generally higher and less variable when the population was increasing, during a 7 year period with 3 severe winters, than when the population peaked and started to decline, during the 5 year period with one severe winter. Recent high calf production may be a response to mild winters, especially 1996-97 and 1997-98. During these winters snow depths, densities, and hardness were some of the lowest recorded from 1992-1998 (N. Larter, unpubl. data).

Overwinter Survival

Overwinter survival of calves is typically calculated by dividing the number of yearlings per 100 adult females by the previous years' number of calves per 100 adult females. However, our classification data includes an age breakdown of the adult female and males classes. Therefore, in a method comparable to Reynolds (1998), we calculated a second estimate of overwinter survival which attempts to remove added variability by following the same cohort in both the numerator and denominator of each measure. This estimate was derived by dividing the number of yearlings per 100 $\geq$3 year-old females by the previous years' number of calves per 100 $\geq$2 year-old females. The pattern and yearly ranking of overwinter survival did not change regardless of which calculation was used. If anything high overwinter survival was exaggerated (Figure 4).

Reynolds (1998) found overwinter survival of calf and yearling muskox in ANWR was negatively correlated with snow depth and snow disappearance dates. Calf overwinter survival from 1983-84 to 1995-96 ranged from *ca.* 40-99% and was lower in years when the muskox population was decreasing than when the population was increasing. Similarly, we found overwinter survival of calves was greater when the population was increasing than when the population was decreasing and that severe winter weather had a negative effect on survival (Figure 4). Between 1986-87 and 1997-98 calf overwinter survival on Banks Island ranged from *ca.* 27-98%, using the same calculation as Reynolds (1998).

Even though we have 3 documented severe winters prior to 1993 and only 1 documented severe winter after 1993, overwinter survival was higher in years prior to 1993, when the population was increasing. The 1988-89 winter was the severest recorded (Nagy *et al.*, 1996) and the second consecutive severe winter. This winter obviously had a major impact on overwinter calf survival during the period of population increase (Figure 4). If we compare overwinter survival of calves during population increase (1986-87 to 1992-93) with survival during population peak and decrease (1993-94 to 1997-98) the difference is significant ($P<0.012$, 1-tailed). Survival is much higher during the population increase period (median 88.5%) than during the population peak and decrease period (median 44%). Survival neared 100% for three consecutive years during the period of population increase. Survival has rebounded recently, likely in response to some of the mildest winters recorded (1996-97 and 1997-98), and possibly due to lower population density, but has not reached levels seen during the mid-1980's to early 1990's when the population was increasing and at comparable levels to 1998.

Commercial Harvesting

Large scale commercial harvests (>500 animals) of muskox were conducted in both the Masik and the Egg strata from 1991 to 1993 and again in 1997: total animals harvested were 2031, 1798, 738, and 1300 respectively. Approximately half of the animals were harvested from each stratum. In general, all animals located were rounded up and harvested. Occasionally old males were let go. The impact of these harvests does not appear to have had a major effect on population size. Calf production has been similar to median levels in years following commercial harvests (Figure 2). Overwinter survival of calves was high when the first 3 commercial harvests were conducted. Reduced overwinter survival since 1993-94 and the commercial harvest in 1997 have been factors in the population decreasing from peak levels in 1994. It could be argued that population density has had more of a direct effect on calf production and overwinter survival of muskox calves than severe winter weather. Quite possibly reduced population density, to levels seen between 1989 and 1991, would result in increased calf production, and overwinter survival thus continue to provide the opportunity of commercial harvesting at levels similar to 1991-1993.

RECOMMENDATIONS

1) The classification survey should be designed to address specific *a priori* questions. Surveys that are designed to address a number of different questions should be avoided because they tend to provide inferior information to address most questions.

2) If the main goal of a classification survey is to address productivity and overwinter survival, an aerial survey should be used which focuses on mixed sex/age groups.

3) Classification surveys addressing productivity and overwinter survival should be conducted in June. Every attempt should be made to classify $\geq$5% of the estimated non-calf population.

4) Classification surveys to address productivity and overwinter survival of muskoxen in the Egg and Masik strata should be conducted annually, and given the 1998 population estimates, classification surveys in the Thomsen strata may be warranted.

5) It may be more appropriate to calculate overwinter survival of calves by dividing the number of yearlings per 100 $\geq$3 year-old females by the previous years' number of calves per 100 $\geq$2 year-old females.

6) It is important to have regular estimates of population size and rate of increase in order to make accurate interpretations of classification data. The use of classification survey data to gauge population increase is redundant.

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Figure 1. Banks Island delineated into the 8 separate strata used for the analyses.

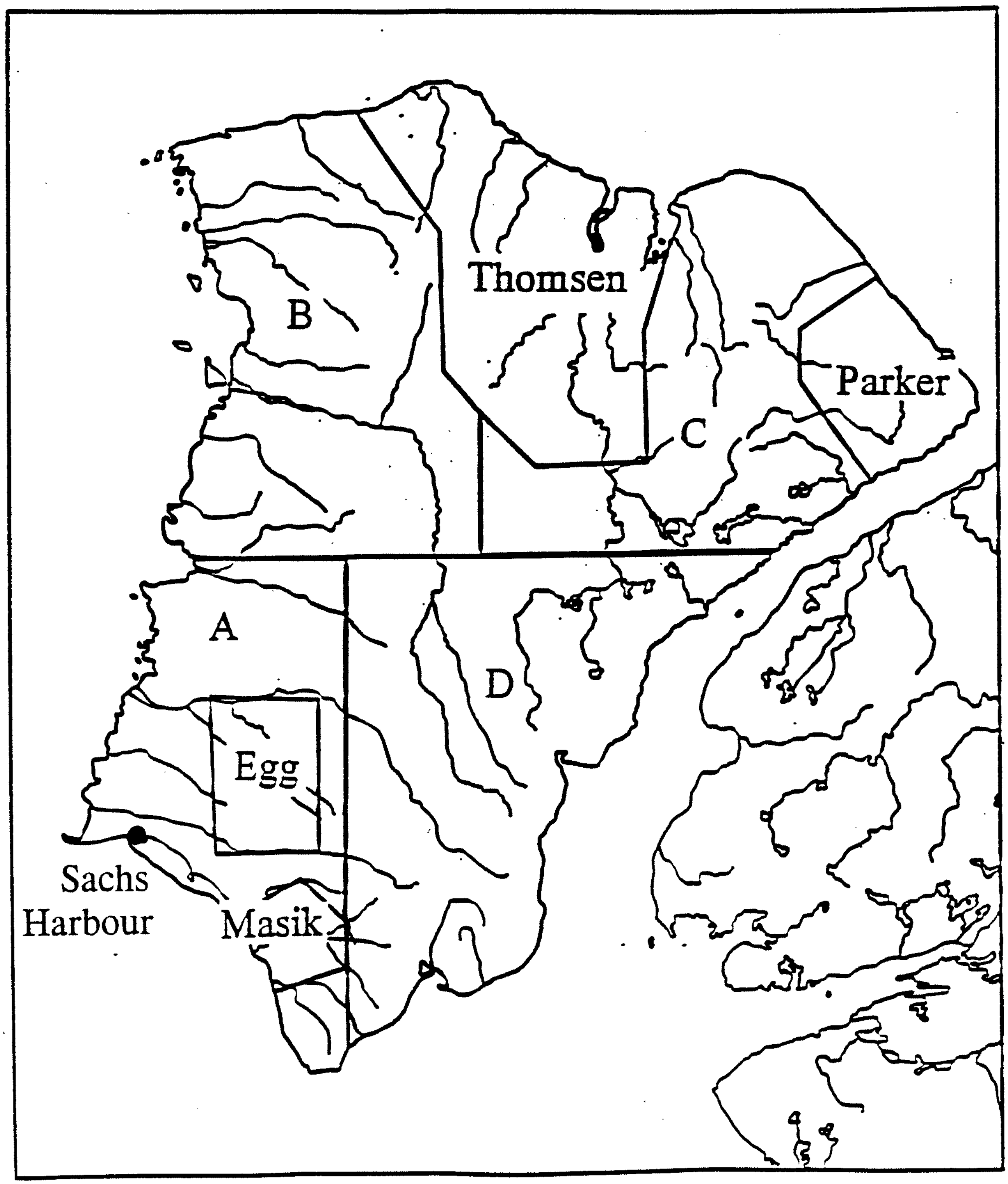


Figure 2. Annual muskox calf production (ratio of calves:100 ≥2 year-old females) and estimated muskox (≥ 1 year-old) population on Banks Island from 1986 to 1998.

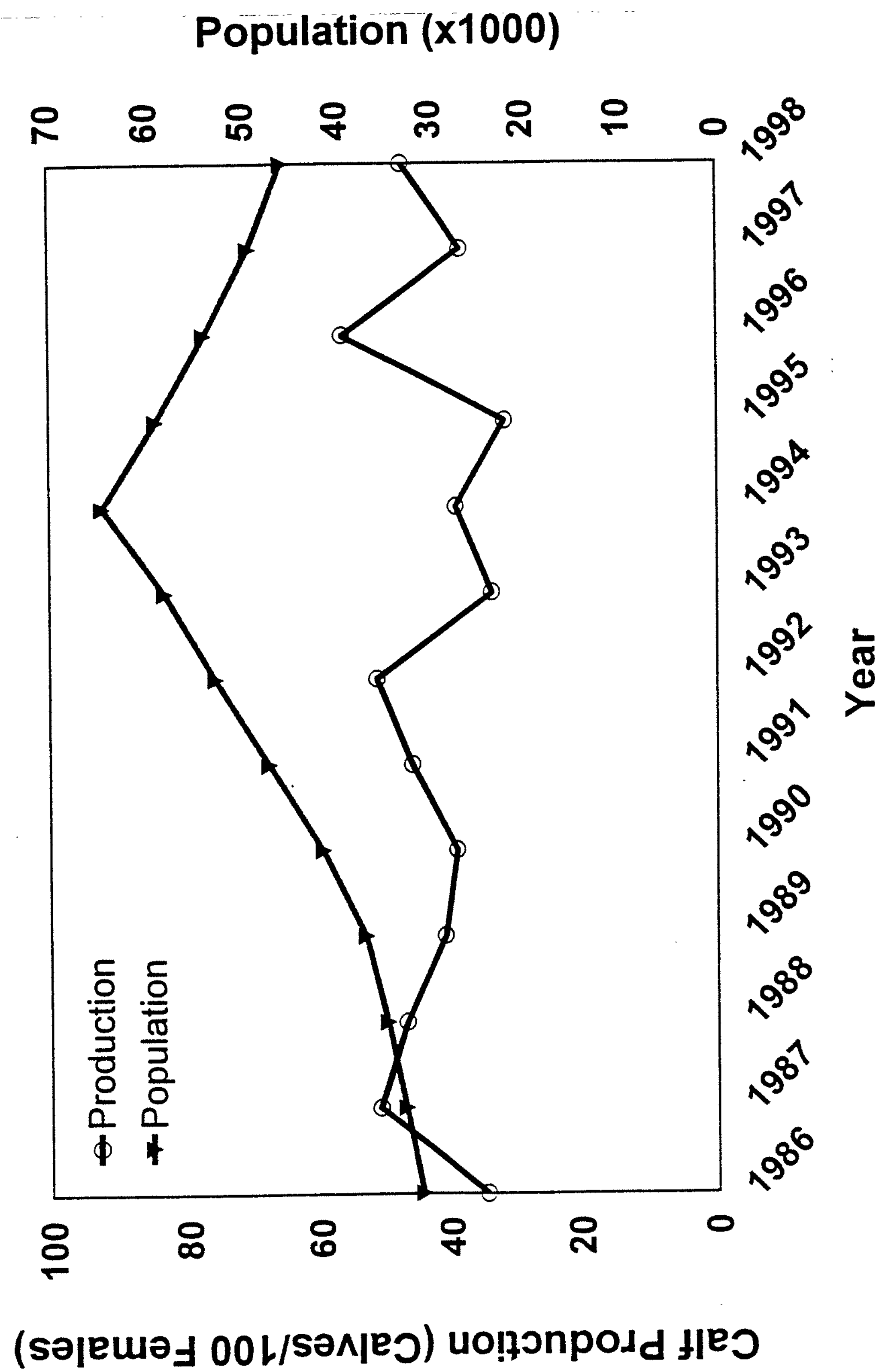
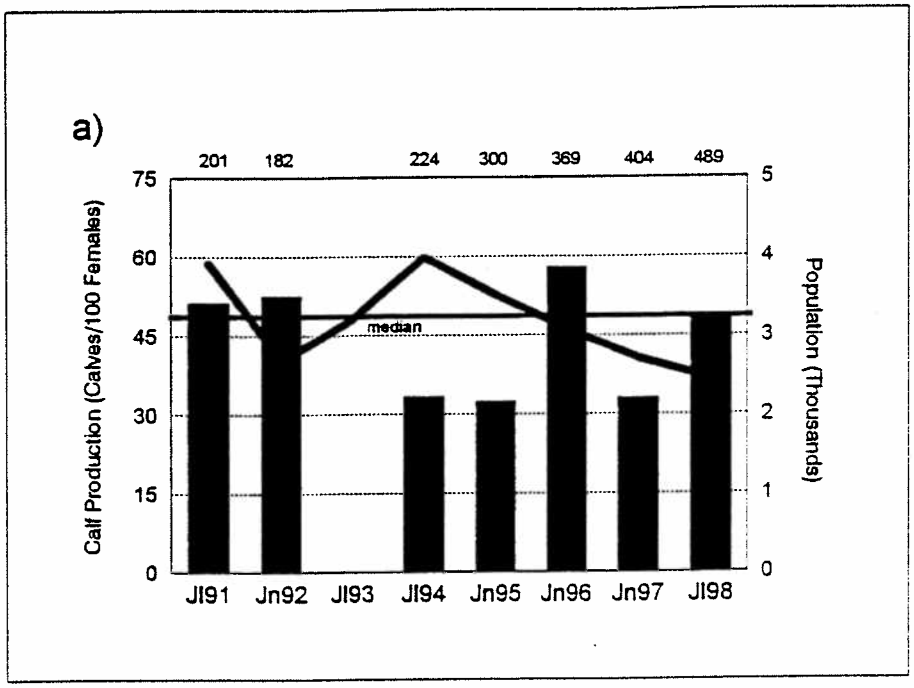


Figure 3. Calf production (ratio of calves:100 $\geq$2 year-old females) and estimated population ($\geq$1 year-olds) for the a) Masik stratum and b) Egg stratum. Values above the histobars are the number of $\geq$1 year-olds classified.



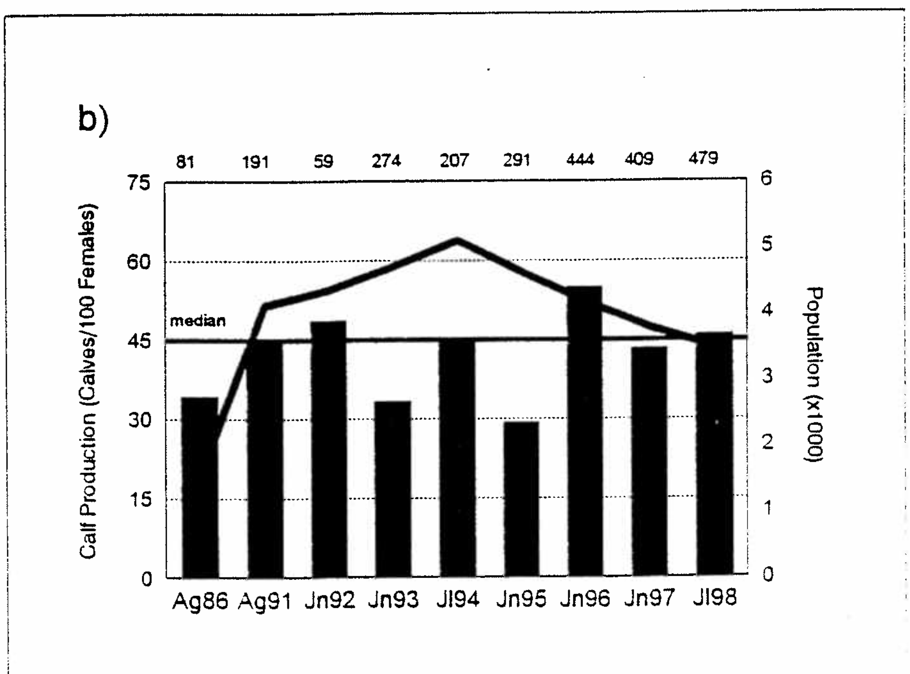


Figure 4. Estimated overwinter survival of calves and estimated population (≥ 1 year-olds) of Banks Island muskox from 1986-87 to 1997-98. The bold bars indicate documented severe winters. The methods of estimating survival based upon 2+ and 3+ females are described in the text.

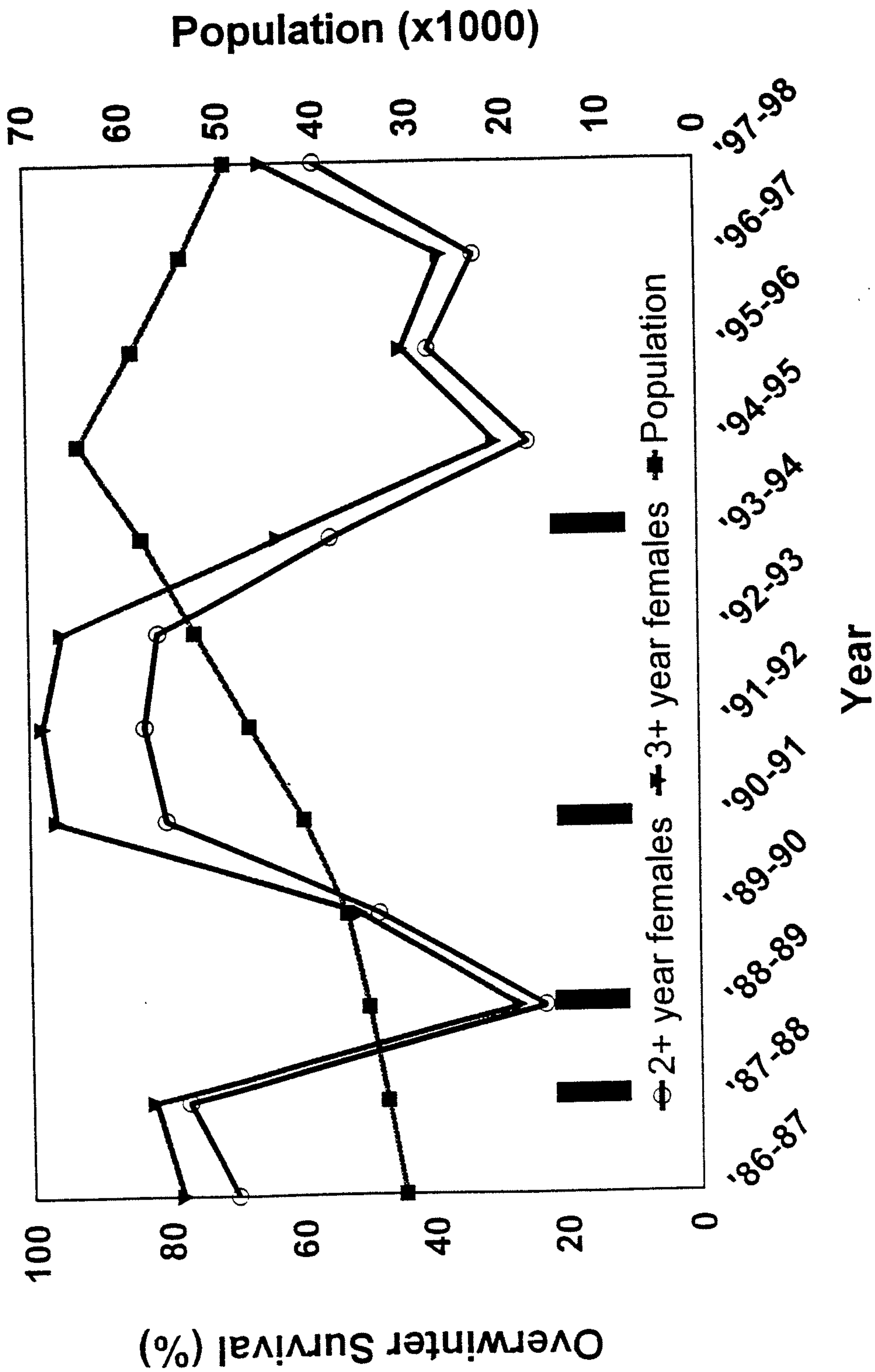


Table 1. Survey dates, survey type (ground, air, or both), stratum surveyed, the number of groups surveyed, and the total number of animals classified.

Date(s)	Survey Type	Stratum	Number Groups	Total Animals
27-28 April, 1985[1]	Ground	A	12	146
10-13 May, 1985[1]	Ground	M, E	11, 6	134, 149
24-31 July, 1986	Air	T, P, C, D	218, 133, 87, 80	1580, 780, 574, 470
1 August. 1986	Air	B, A, E, D	14, 13, 12, 7	93, 140, 94, 83
17-23 June, 1987	Air	T, C	168, 25	930, 176
9-15 August, 1987	Both	T, C	96, 28	771, 190
12 August, 1988	Air	T	100	815
15 June, 1989	Air	T	63	464
14-31 July, 1990	Ground	T	56	393
1-14 August, 1990	Both	T	96	777
31 July, 1991 [2]	Air	M	22	228
1 August, 1991[2]	Air	M	1	16
1 August, 1991	Air	A, E	8, 19	91, 233
20 June, 1992	Air	A, M, E	24, 26, 6	144, 213, 75
18-19 June, 1993	Air	E	32	314
13-15 June, 1994	Air	E, M	20, 20	263, 271
22-23 June, 1995	Air	E, M	25, 24	378, 355
21-22 June, 1996	Air	E,M	31,29	613, 515
18-20 June, 1997	Air	E,M	31, 31	523, 490
14-15 July, 1998	Air	E, M	33, 34	619, 632

[1] Survey data were not included in the analyses because surveys were conducted during the calving period.

[2] Both surveys were combined and treated as July for the analyses.

Table 2. Best estimates of annual calf production (Ca:Cow), the ratio of yearlings:100 ≥2 year-old females (Yr:2+Cow), and the ratio of yearlings:100 ≥3 year-old females (Yr:3+Cow) for Banks Island muskox.

Year	Ca:Cow	Yr:2+Cow	Yr:3+Cow
1986	34.2	29.3	32.9
1987	50.8	23.9	26.6
1988	46.7	39.3	41.8
1989	40.7	10.7	12.7
1990	38.8	19.7	20.7
1991	45.8	30.8	37.3
1992	51.2	38.0	45.0
1993	33.3	41.7	48.5
1994	38.9	18.5	20.9
1995	31.3	9.8	11.8
1996	56.3	12.7	13.8
1997	38.1	18.7	21.6
1998	47.2	21.8	24.7

Table 3. Estimated overwinter survival (%) of calf muskoxen during different winters on Banks Island based upon two different measures: 1) dividing the ratio of the following years yearlings:100 ≥2 year-old females by the current years calves:100 ≥2 year-old females, and 2) dividing the ratio of the following years yearlings:100 ≥3 year-old females by the current years calves:100 ≥2 year-old females.

Year	Survival Estimate 1	Survival Estimate 2
1986-87	70	78
1987-88	77	82
1988-89	23	27
1989-90	48	51
1990-91	80	96
1991-92	83	98
1992-93	81	95
1993-94	55	63
1994-95	25	30
1995-96	40	44
1996-97	33	38
1997-98	57	65

Table 4. The range of ratios of calves and yearlings per 100 ≥ 2 year-old females from various muskox populations.

Population/Location	Date(s)	Ca:100 Fem	Yr:100 Fem	Reference
Banks Island, NWT	1985-96	28.6-66.1	6.3-47.5	This study
Victoria Island, NWT	1986	50.8-61.4	26.1-43.0	McLean, unpublished data
Rae-Richardson, NWT	1987	22.8	20.2	Gunn, 1995
ANWR, Alaska[1,2]	1983-95	30-76	36.5	Reynolds, 1998; personal communication
Seward Peninsula, Alaska	1992	59.6	24.3	Machida, unpublished data
Jameson Land, Greenland[2]	1982-90	28-67	7-45	P. Aastrup, personal communication
Nunivak Island, Alaska[2]	1937-48	0.0-76.9	n/a	Kacyon, unpublished data
Nunivak Island, Alaska	1994-96	43.1-50.5	21.6-35.7	Kacyon, unpublished data

[1] Mean Yr:100 Fem for the period are reported.
[2] Adult females were considered as ≥ 3 year-old for this area.

APPENDICES

Appendix 1. The estimated non-calf population size and density (non-calf muskox/km^2) for each stratum on Banks Island from 1985 to 1998.

Year	Stratum A	Stratum B	Stratum C	Stratum D	Egg	Masik	Parker	Thomsen
1985[1]	2288 (0.22)	3957 (0.27)	3613 (0.31)	1727 (0.09)	1342 (0.50)	933 (0.68)	2650 (0.88)	12883 (1.51)
1986	2656 (0.26)	4226 (0.29)	3767 (0.33)	2172 (0.12)	1539 (0.58)	1165 (0.85)	2525 (0.84)	12449 (1.46)
1987	3083 (0.30)	4513 (0.31)	3927 (0.34)	2730 (0.15)	1764 (0.66)	1455 (1.06)	2405 (0.80)	12029 (1.41)
1988	3579 (0.35)	4819 (0.33)	4094 (0.35)	3433 (0.19)	2022 (0.76)	1817 (1.32)	2291 (0.76)	11624 (1.37)
1989[1]	4353 (0.42)	5191 (0.36)	4282 (0.37)	4835 (0.26)	2411 (0.91)	2524 (1.84)	2193 (0.73)	11257 (1.32)
1990	5964 (0.58)	5625 (0.39)	3401 (0.29)	4528 (0.25)	3057 (1.15)	3081 (2.25)	2836 (0.94)	12080 (1.42)
1991[1]	9128 (0.88)	6136 (0.43)	2837 (0.24)	4258 (0.23)	4120 (1.55)	3923 (2.86)	3940 (1.31)	13030 (1.53)
1992[1]	7157 (0.69)	6637 (0.46)	5560 (0.48)	7546 (0.41)	4354 (1.64)	2684 (1.96)	2929 (0.97)	15737 (1.85)
1993	8238 (0.80)	6879 (0.48)	5872 (0.51)	5926 (0.32)	4701 (1.77)	3217 (2.34)	3680 (1.22)	18607 (2.19)
1994[1]	9683 (0.94)	7138 (0.50)	6220 (0.54)	4912 (0.27)	5105 (1.92)	3994 (2.91)	4890 (1.62)	22665 (2.66)
1995	9271 (0.90)	7154 (0.50)	5888 (0.51)	5138 (0.28)	4617 (1.73)	3507 (2.56)	3717 (1.23)	18930 (2.22)
1996	8876 (0.86)	7169 (0.50)	5575 (0.48)	5374 (0.29)	4177 (1.57)	3079 (2.24)	2825 (0.94)	15810 (1.86)
1997	8497 (0.82)	7185 (0.50)	5277 (0.46)	5622 (0.31)	3778 (1.42)	2703 (1.97)	2147 (0.71)	13205 (1.55)
1998[1]	8167 (0.76)	7202 (0.49)	5025 (0.44)	5905 (0.33)	3484 (1.30)	2452 (1.73)	1873 (0.63)	11726 (1.39)

[1] Whole island population surveys were completed during summer of these years.

Appendix 2. The ratio of calves:100 adult females (ca:cow), yearlings:100 adult females (yr:cow), number of groups classified (n), the total number of animals classified (N), the ratio of adult females to adult males (fem:mal), the percent calves in the classified sample (%ca), the percent yearlings in the sample (%yr), the number of non-calves in the sample (nonca), and the percent of the total non-calf population (%totN) for each survey month and stratum combination of Banks Island muskoxen. Values in parentheses for n and N indicate the numbers used to determine the percent calves, percent yearlings, and number of non-calves. See text for explanation. The 1985 survey data is presented for completeness, because it was collected during the calving period the data were not included in the analyses.

Date	Stratum	ca:cow	yr:cow	n	N	fem:mal	%ca	%yr	nonca	%totN
Apr-85	Thomsen	31.5	25.9	12 (14)	146 (210)	0.89	11.0	12.9	187	1.5
Jul-86	Thomsen	28.8	21.3	218 (220)	1580 (1605)	1.25	12.5	9.2	1404	11.3
Jun-87	Thomsen	55.0	24.5	168 (178)	930 (1138)	0.65	17.5	7.2	939	7.8
Aug-87	Thomsen	66.1	29.2	96 (97)	771 (800)	0.74	20.1	8.5	639	5.3
Aug-88	Thomsen	46.7	39.3	100 (112)	815 (1013)	1.00	16.2	12.1	849	7.3
Jun-89	Thomsen	40.7	10.7	63 (69)	464 (596)	0.91	18.0	3.5	489	4.3
Jul-90	Thomsen	38.8	19.7	56 (80)	393 (722)	0.92	16.8	4.6	601	5.0
Aug-90	Thomsen	41.6	10.4	96 (239)	777 (2067)	1.17	17.0	4.1	1715	14.2
May-85	Masik	37.3	21.6	11 (16)	134 (246)	0.96	13.8	6.9	212	22.7
Jul-91	Masik	51.2	31.0	23 (24)	244 (281)	0.92	17.8	9.3	231	5.9
Jun-92	Masik	52.5	47.5	26	213	0.62	14.6	13.1	182	6.8
Jul-94	Masik	33.3	13.5	20	271	2.20	17.3	7.0	224	5.6
Jun-95	Masik	32.4	10.6	24	355	1.52	15.5	5.1	300	8.6

Date	Stratum	ca:cow	yr:cow	n	N	fem:mal	%ca	%yr	nonca	%totN
Jun-96	Masik	57.9	15.5	29	515	3.23	28.3	7.6	369	12.0
Jun-97	Masik	33.0	14.6	31	490	2.49	17.6	7.8	404	15.0
Jul-98	Masik	48.5	23.4	34	632	2.36	22.6	10.9	489	19.9
May-85	Egg	64.2	37.7	6 (14)	149 (465)	1.26	19.4	9.7	375	27.9
Aug-86	Egg	34.2	31.6	12 (14)	94 (118)	1.23	15.3	11.0	100	6.5
Aug-91	Egg	44.7	31.9	19	233	1.40	18.0	12.9	191	4.6
Jun-92	Egg	48.5	24.2	6	75	1.83	21.3	10.7	59	1.4
Jun-93	Egg	33.3	41.7	32	314	1.15	12.7	15.9	274	5.8
Jun-94	Egg	45.2	24.2	20	263	2.34	21.3	11.4	207	4.5
Jun-95	Egg	29.3	9.4	23	344	1.95	15.4	4.9	291	6.3
Jun-96	Egg	54.9	10.4	31	613	2.96	27.6	5.2	444	10.6
Jun-97	Egg	43.2	22.7	31	523	3.11	21.8	11.5	409	10.8
Jul-98	Egg	45.9	20.3	32	619	2.72	22.6	10.2	479	13.8
Jul-86	C	36.8	32.1	87 (89)	574 (604)	1.31	15.1	13.2	513	13.6
Jun-87	C	36.6	22.0	25	176	1.78	17.0	10.2	146	3.7
Aug-87	C	62.7	18.7	28	190	1.39	24.7	7.4	143	3.6
Jul-86	D	43.5	37.7	80	470	1.54	17.7	15.3	387	17.8
Aug-86	D	55.9	26.5	7	83	1.62	20.4	10.8	64	2.9
Aug-86	A	56.6	34.0	13 (15)	140 (170)	1.36	20.6	12.4	135	5.1

Date	Stratum	ca:cow	yr:cow	n	N	fem:mal	%ca	%yr	nonca	%totN
Aug-91	A	36.1	27.8	8 (9)	91 (101)	1.13	14.9	10.9	86	0.9
Jun-92	A	51.4	35.1	24	144	0.49	13.2	9.0	125	1.7
Jun-95	A	43.8	6.3	2	34	1.60	20.6	2.9	27	0.3
Jul-86	Parker	20.9	39.2	133	780	1.01	8.1	15.1	717	28.4
Aug-86	B	63.9	30.6	14	93	1.57	24.7	11.8	70	1.7