Population demography of the muskoxen in Jameson Land, 1982-1990

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Abstract: Studies of the Jameson Land muskox population in Northeast Greenland were conducted 1982-1990 in conjunction with an oil exploration. A population monitoring program consisted of one yearly aerial survey in late winter and a ground survey for population composition in August. The estimated unadjusted minimum average population size was approximately 4000 with a maximum size of 4700 and a minimum of 2800 muskoxen. The monitoring program was adequate to detect an annual change of about 10%. Population composition data proved to be essential. The only indication of a negative impact from oil exploration was detected in the fraction of yearlings. The average calf proportion was roughly 18% and about half of the calves died during their first year. The population density and composition was similar to the Banks Island muskox population in Canada and to the West Greenland population although the latter population had a higher productivity. Seismic operations and/or climatic conditions may have had a negative impact on the calf survival during 1986-1989, when fractions of yearlings were significantly lower than before and after the exploration.

Key words: Greenland, monitoring, muskox, population composition, population size, population trend, seismic surveys.

Rangifer, 20 (4): 229–238

Introduction

Muskoxen (*Ovibos moschatus*) have a stronghold in Jameson Land, part of Scoresby Land in north-east Greenland (Boertmann *et al.,* 1992). From 1982 to 1990 the population was monitored through annual counts and sex-age classifications to assess impacts of oil exploration (Aastrup, 1988; 1990; Aastrup & Mosbech, 1988). During this period, extensive oil exploration occurred within the study area and hunters from local settlements hunted the population. The community mostly relies on hunting of marine mammals and does not subsist on muskoxen.

Literature is sparse on the effects of seismic operations on muskox at the population level. Miller & Gunn (1979) studied responses of caribou and muskoxen to helicopter harassment and found that cows and calves were most responsive and that the response increased the lower the altitude of the helicopter. They recommended minimum flying heights to protect the muskoxen from stress induced by disturbance. Olesen (1986) studied immediate responses of muskoxen when passed by seismic vehicles and concluded that the activity budget was greatly affected during disturbance. Cameron (1983) reviewed impacts from petroleum development in Prudhoe Bay, Alaska, on caribou (*Rangifer tarandus*). He concluded that despite losses of habitat, no adverse effects on herd productivity could be documented. Cameron *et al.* (1992; 1995) in a later study reported that calving caribou in the Prudhoe Bay area were redistributed relative to a road through a caribou calving area and that female caribou avoided the network of production and support facilities during summer. In a recent study Cronin *et al.* (1998) reported that during postcalving caribou were largely unrelated to distance from infrastructure in the Prudhoe Bay area. Maier *et al.* (1998) recommended, based on studies of caribou responses to overflights by low-altitude jet aircraft, that such should be curtailed during calving and postcalving. Other authors have argued that human development has had no or only small effects. Bergerud *et al.* (1984) discussed caribou and human developments and concluded that there are no examples where physical features of corridors or associated disturbances affected numbers or productivity of caribou.

Analyses of time series of muskox demography have been reported by Nagy *et al.* (1996) for muskoxen on Banks Island, NWT, 1982-1992, and by Pedersen & Aastrup (2000) for an introduced muskox population in West Greenland during the period 1986 to 1996. The Banks Island population increased from about 30 000 to about 53 000, production not being balanced by hunting or other factors, while the West Greenland population was stabilised by hunting. Reynolds (1998) studied an introduced muskox population in northern Alaska and found high variance in the rate of population increase and decrease in calf production during 1977 to 1996.

We present a time series of population composition, size, reproduction and mortality in Jameson Land and analyse the population parameters in relation to disturbances from seismic exploration for oil. Our conclusions may assist both harvest management initiatives, and environmental impact assessments for muskox populations.

Study area

The western and southern part of Jameson Land (Fig. 1) is a plateau ranging from sea level to the west up to 5-600 m above sea level. The majority of the plateau is relatively level, but intersected by numerous rivers with deep valleys. The total study area is about 10 500 km^2.

Western Jameson Land (<200 m.a.s.l.) is dominated by continuous dwarf scrub. Valleys are characterised by moist dwarf scrub offering excellent foraging habitats for muskoxen (Thing *et al*, 1987; Thing, 1984). Marsh vegetation, ponds and lakes are concentrated in the western part of Jameson Land and in Ørsted Dal (Fig. 1) in the north (Mosbech & Hansen, 1994). Sparse vegetation or barren areas dominate the eastern portion of the study area.

Jameson Land is situated in the intermediate region between low and high arctic zones. Coastal areas are high arctic with mean July temperature less than 5 °C, while inland areas are low arctic with mean July temperature as high as 9.3 °C. The yearly mean temperatures vary between -10 °C and -6 °C (GFU, 1989). Annual precipitation is about 400 mm/year.

About half of the precipitation in Jameson Land falls as snow. The snow cover usually persists from late September to the beginning of May. During winter strong northerly winds redistributes the snow exposing windward slopes and plateaus and forming snowdrifts on south facing slopes. Snow depths on sparse dry heath scrub, often used by muskoxen in winter, average 25 cm. More luxuriant vegetation types (e.g. moist dwarf scrub heath) have more than 100 cm snow cover, making them inaccessible to foraging muskoxen (Bay & Holt 1986). Average snow depths vary regionally (Hansen & Mosbech 1994), and the muskox concentrations were highest in areas with relatively thin snow cover during March-April aerial surveys. Snow melt starts in May and is usually finished by late June. In snow-rich years many snowdrifts last until July or August (Hansen & Mosbech, 1994).

Hunting

Inuit from Ittoqqortormiut (Scoresbysund), Kap Tobin and Kap Hope (total about 500) hunt in Jameson Land (Sandell & Sandell, 1991; 1998). From 1937 until mid 1970s legal hunting was restricted to 40 muskoxen annually. From mid 1970s to 1987 160 muskoxen were reported taken annually (Sandell & Sandell, 1991). From 1988, the Greenland Home Rule Government allocated an annual quota of 140-180 muskoxen.

Illegal hunting is common but the numbers taken are largely unknown. Thing *et al.* (1987) estimated that 300-500 muskoxen might have been hunted each year during the 1980s, which would be about 10% of the estimated population size.

During the 1970s, when hunting increased, only a few straggling muskoxen occurred near the small

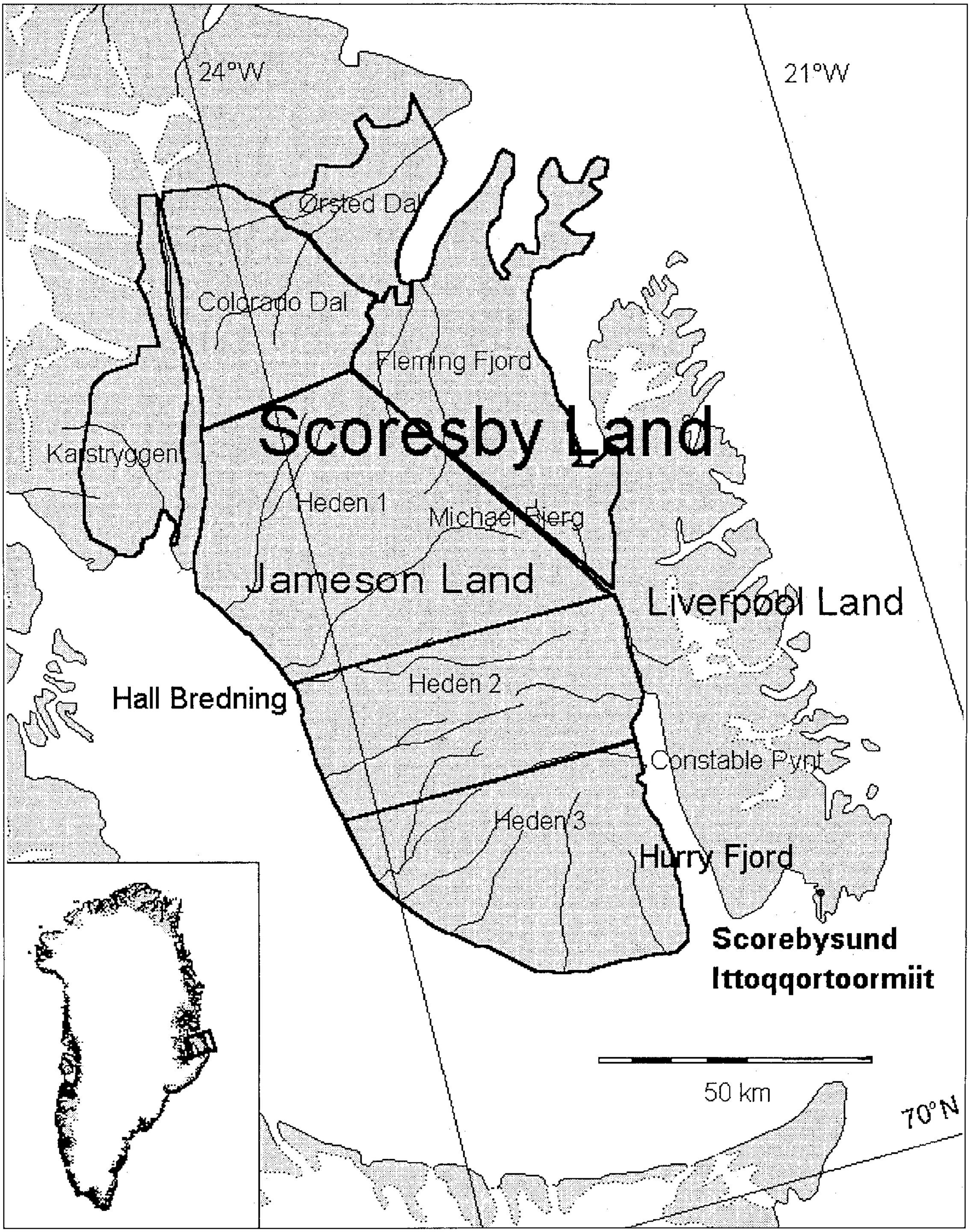

Fig. 1. Study area.

settlements in Liverpool Land and on the western coast of Hurry Fjord so hunters had to travel longer distances to get the muskoxen (Sandell & Sandell, 1991; 1998).

The winter hunt mainly occurs during dog sledge trips in the central part of Jameson Land around Michael Bjerg, while hunting in August mostly occurs along the eastern coast of Jameson Land. The area around Colorado Dal is more or less undisturbed year round as hunters only rarely travel that far. Occasionally wolves are observed in Jameson Land but their predation on the muskoxen apparently was small during the study period.

Seismic work

During summer (from June to September) 1987-1989 a total of 1070 km of seismic line were surveyed using helicopter, while 735 km of seismic line were surveyed based on tracked vehicles and other equipment during 1985-86 and 1987-88. Seismic surveys in the summer period relied largely on 6 helicopters (i.e., 4 Bell 212 and 2 Bell 206) operating 8-10 h/day from mid-June to late September. Helicopters moved personnel between the base camp at Constable Pynt and the seismic lines each day and all equipment was moved along lines and between lines with helicopters. Ferry flights between survey areas and the base camp were mostly done above 1500 feet while the work on the lines was done mostly below 500 feet above ground level. The seismic survey lasted 2-3 weeks along each part of the seismic line and included approx. 40 low altitude helicopter flights. The summer operation had the potential to cause disturbance in a vast area.

Helicopters are generally 10 dB noisier than fixed-winged aircrafts of similar size. Estimated source level for the dominant tone (22 Hz tone) for a Bell 212 helicopter cruising at 152 m altitude is 123 dB (re 20μPa at 1 m), while the received level (at ground) is 83 dB (re 20 μPa) at 152 m altitude and 75 dB (re 20 μPa) at 610 m altitude (inferred from Richardson *et al.*, 1995). Noise levels are about 5-15 dB higher during take-off and climb than during cruise or approach, resulting in very high noise levels during the many take-off's with sling load on the seismic line.

The winter seismic operations took place in lowland areas from late November. The operations were based on tracked vehicles and trailers supplemented by snowmobiles and helicopters and the personnel lived in a trailer camp moving along the seismic lines. In the first winter season 333 km were covered and during the second season 402 km were covered. The winter operations were localised along the seismic lines and potentially disturbing activities were mostly from tracked vehicles in a localised area. Hunting by the seismic personnel was not allowed, and there was neither evidence nor rumours of any violations.

Material and methods

Aerial surveys were conducted in March or April 1982 to 1990 when snow cover was nearly complete and the muskoxen should be relatively easy to spot. The 1984 survey was performed in January, and was affected by poor weather conditions. Therefore 1984 was omitted from the present analysis.

Each survey was completed within a 5 day period. Muskoxen exhibit a rather sedentary behaviour during March and April, and therefore movements between transects and census zones were considered minimal. We usually counted individuals as the aircraft approached a group of muskoxen; that is before the individuals gathered in a close defensive circle.

We flew 200 to 300 m above ground at approx. 200 km/hr. Surveys were conducted using various types of fixed-wing aircrafts (e.g. Cessna Skymaster and Partenavia Observer). Two or three observers recorded observations and 7-8 different observers were used. The front seat observer recorded time and locations on a map. The data sampling procedure as well as the method of population estimation was gradually modified. The data therefore were quite heterogeneous in regard to aircraft used, personnel and flight routes.

In the present analysis of data the number of observed muskoxen per km was used to estimate density on the assumption that the width of the surveyed area was 4500 m. This is too wide to allow detection of all groups. For comparability it was decided, however, to use this width as all data sampled 1982 to 1987 were sampled on this premise. Distance data were not available for counts performed 1982 to 1987 so truncation according to distance from transect line is not possible. Aastrup & Mosbech (1993) found by a double observer experiment that 25% of the muskoxen present in the southern flat area were missed. A further elaboration on these data showed that about 40% of the muskoxen were missed corresponding to a adjustment factor of 1.6 (Aastrup, unpubl.). No corrections were made for missed groups in the present study, so estimates of density and population size therefore should be regarded as minimum estimates.

The study area was subdivided into the strata shown in Fig. 1. In the valleys, Karstryggen, Colorado Dal, Ørsted Dal and Fleming Fjord, the flight routes followed the topography and it was assumed that the valleys were covered in all their width. In Heden 1, Heden 2 and Heden 3 parallel transects were flown from 1985 while less well defined zigzag shaped routes were followed before 1985.

The composition of the population was studied in summer in August 1982 to 1990, except 1985, during ground based surveys in the Ørsted Dal/Colorado Dal/Major Paars Dal-area (see Fig. 1). Large numbers of muskoxen stay in the Colorado Dal area both summer and winter, and it was assumed that the population composition in this area was representative for the whole population. Direct comparison of data from 1982 from different locations including Colorado Dal showed no locality-related differences in population composition (Thing & Lassen, 1984). Each individual in all muskox groups were classified as calf, yearling, subadult (2+3 year old), adult cow or adult bull based on Olesen & Thing (1989). Calf/cow and yearling/cow ratios were computed based on the numbers of classified calves, yearlings and cows observed. The number of animals classified was much smaller from 1986 to 1990 than from 1982 to 1984 (Table 2) when data was from a larger area. However, it was assumed that population composition data from the survey areas were representative of the whole population composition (Thing & Lassen, 1984).

The mortality of calves was calculated as the ratio between the fraction of calves in August and the fraction of yearlings in August the following year, when the calves were about 15 months old. Early calf mortality (from parturition until 3 month) was unknown.

The trend of population estimates was investigated according to Gerrodette (1987) , who presented a method for power analysis for detecting trends and developed a computer program, Trends (Gerrodette, 1993). This program analyses the relations between 1) the precision of abundance estimates, 2) the number of sampling occasions, 3) the nature and magnitude of the actual rate of change in abundance, 4) the asymmetry between upward and downward trends and 5) the levels of Type 1 and Type 2 statistical errors. The program allows calculation of any one parameter when all other parameters are known. The following parameters are needed for calculations: n, the number of samples; r, the rate of change of population size; CV, the initial coefficient of variation; and α and β the probabilities of Type 1 and 2 errors. Normally the growth of animal populations is exponential and log-transformed regression based on the population estimates was used to find r. CV was calculated as the ratio of the mean population size to the standard deviation of population sizes. The $CV(A_i)$ for strip transects is proportional to $1/(A_i)^2$, Gerrodette (1987; 1993).

Results

The overall winter density of muskoxen in Jameson Land vatied between 0.19 and 0.44 muskoxen per km^2, with an average of 0.28 muskoxen per km^2 (unadjusted for survey efficiency). The density was highest in the north-western part of Jameson Land, in Colorado Dal, in Karstryggen and in Heden 1 where densities varied between 0.5 and 1.2 muskoxen/km^2. In the southern part of Jameson Land (Heden 2 and Heden 3), and in the Fleming Fjord area densities of muskoxen ranged between 0 and 0.3 muskoxen per km^2.

Table 1. Number of muskoxen in Jameson Land, Northeast Greenland, 1982-1990.

	Heden 1 2900 km^2	Heden 2 1800 km^2	Heden 3 1700 km^2	Karstryggen 500 km^2	Colorado Dal 1000 km^2	Ørsted Dal 900 km^2	Fleming Fjord 1700 km^2	TOTAL 10 500 km^2
1982	2121	278	253	306	938	193	148	4237
1983	2286	65	0	253	661	246	0	3511
1984	-	-	-	-	-	-	-	-
1985	2841	158	115	401	863	301	0	4679
1986	2087	373	323	277	472	120	0	3652
1987	1764	249	190	145	461	62	0	2871
1988	1296	431	246	601	630	64	15	3285
1989	2011	288	15	503	871	240	0	3928
1990	1699	179	156	542	77	349	0	3001
Average	2269	386	201	393	598	211	2	4060

Table 2. Population composition in Jameson Land.

	Calves	Yearlings	Subadults	Cows	Bulls	Calf/100 cows	Yearling /100cows	% Calf mortality	Total n
1982	19.8	12.3	14.4	34.2	19.3	58	36	-	1439
1983	20.4	12.6	10.4	32.3	24.2	63	39	36	1370
1984	12.9	14.1	13.9	31.6	27.6	41	45	31	1277
1985	-		-	-	-	-	-	-	-
1986	23.5	3.5	5	48	20	49	7	-	314
1987	14.4	8.3	2.3	52.2	22.8	28	16	65	164
1988	14.0	5.0	5.0	50.0	26.0	28	10	65	254
1989	27.9	6.6	1.1	41.5	22.9	67	16	53	220
1990	14.6	14.0	5.6	37.9	27.6	39	37	50	301
Average*	18.4 (5.0)	9.6 (4.0)	7.2 (4.8)	41 (7.7)	23.8 (3.0)	46.6 (14.0)	25.8 (14.0)	50.0 (14.3)	

* Standard deviation is shown in brackets.

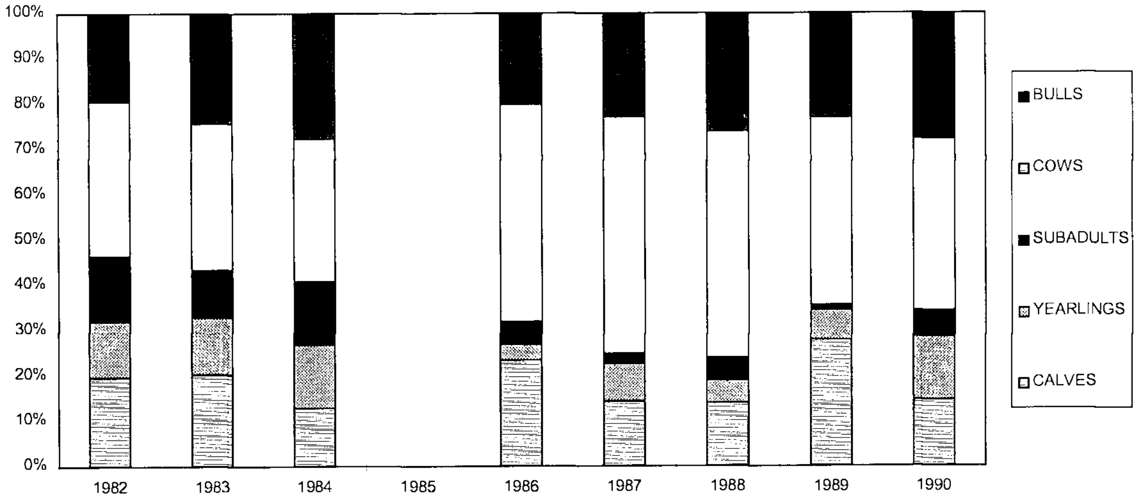

Fig. 2. Composition of muskox population in Jameson Land, Northeast Greenland, 1982 to 1990.

Winter population size estimates (Table 1) fluctuated between roughly 2800 and 4700. Data suggest an increase in population size until 1985 when the estimated population size peaked. A regression of log-transformed population estimates gave a weak, not significant negative trend with a rate of decrease, r=-0.0309 (R^2=0.27, pr > F=0.19).

The coefficient of variance, CV was 0.163. Putting these values into "Trends" gave a power of 0.17 for detecting a true (α=0.05) negative trend in population size. In other words the probability of detecting a true negative trend was only 0.17. Furthermore, a power of 0.95 would have required 16 censuses. On the other hand "Trends" showed that the monitoring program would have been sufficient to detect a trend of 10% change per year in population size.

Population composition data are summarised in Table 2 and Fig. 2 as percentage of individuals in each sex and age group encountered during each year. The largest fraction was cows, which in average was about 40% of the population followed by bulls, 24%, and calves, 18%. The average proportion of yearlings was 9%, half the proportion of calves. The average proportion of subadults was 8%. On the average about half of the cows had a calf and there was one yearling per four cows.

The proportion of cows was largest in 1987 while the proportion of bulls fluctuated during the study. The proportion of yearlings and subadults was largest in 1984 and then fell to a relatively low level from 1986 to 1989. The proportion of calves fluctuated from 14% to 28% during the study period. The calves/100 cows -ratio varied between 28 and

67 with an average of 47 while the ratio of yearlings/100 cows varied between 7 and 45 with an average of 26. The average calf mortality over all years was 50%. During years with seismic activities (1986-1989) the calf mortality averaged 61%, while it was 39% during years without seismic activity (1983-85, 1990).

A Fisher exact test (Zar, 1984) showed that the average calf proportion was not significantly lower ($0.1<P<0.20$) during years with seismic activity (1986-1989) than in years without seismic activity (1982-1988 and 1990). The yearling proportion, however, was significantly lower ($0.001<P<0.01$) in years with seismic activities than in years without seismic activities.

Discussion

It is ambiguous to compare muskox densities because of differences in survey techniques, and because topography and definitions of muskox habitat area, forage, and climatic conditions vary among muskox ranges. However, the average densities of 0.19 and 0.44 muskoxen per km^2 and densities in local areas of 0.93 and 1.2 muskoxen per km^2 observed in Jameson Land population seems to be similar to those found in other well established muskox populations in the circumpolar range. Olesen (1993) found an overall density of 0.40 muskoxen per km^2 and a density of 1.8-2 muskoxen per km^2 in the core area of the introduced muskox population in Angujaartorfiup Nunaat near Kangerlussuaq. In a recent analysis of the same population Pedersen & Aastrup (2000) found an average density between 0.3 and 0.4 from 1987 to 1996. Nagy *et al.* (1996) reported overall densities between 0.42 and 0.69 muskoxen per km^2 on Banks Island, N.W.T; locally, densities varied between 0.09 and 1.85. Thomas *et al.* (1981) reported densities of 0.6-1 muskoxen in a restricted area in the Bailey Point region. Other ranges have considerably lower densities; On Queen Elizabeth Islands (NWT), Miller & Russell (1975) reported densities from 0.018 up to 0.072 muskoxen per km^2. In high arctic northern Greenland Aastrup *et al.* (1986) found extremely low densities between 0.0002 and 0.023 muskoxen per km^2.

The density of muskoxen in late winter in Jameson Land was generally highest in the northern valleys and lowest in mountainous areas and in the southern part of Jameson Land (Fig. 3). Heden 1 and Colorado Dal held a large stock throughout the study period. This pattern may result from a combination of poor forage conditions and high hunting pressure in areas close to the settlement of Scoresbysund.

The estimated average population size was roughly 4000 with a maximum size of about 4700 in 1985 and a low of about 2900 muskoxen in 1987 (see Table 1) but the true population size must have been higher as these estimates have not been adjusted for missed observations. True population size may have been 25-40% higher (Aastrup & Mosbech, 1993).

Earlier estimates were 3000 in the early 1930s (Pedersen & Mikkelsen cited by Jennov, 1945),

Table 3. Earlier estimates of calf fractions in Northeast Greenland.

Area	% calves	Year	Reference
Scoresbysund	14.0	1869-70	Koldewey (after Jennov, 1945)
Shannon-Scoresby Land	4.0	1899	Pedersen (after Jennov, 1945)
Scoresbysund	6.0	1899	Nathorst (after Jennov, 1945)
Scoresbysund	13.0	1900	Jensen & Kolthoff (after Jennov, 1945)
Northeast Greenland	5.0	1900	Mikkelsen (after Jennov, 1945)
Northeast Greenland	20.0	1930	Mikkelsen (after Jennov, 1945)
Jameson Land	27.6	1961	Hall (after Pedersen, 1974)
Scoresby Land	5.6	1962	Hall (after Pedersen, 1974)
Scoresbysund Distrikt	12.7	1969	Pedersen, 1974
Rypefjord/Rødefjord	20.4	1970	Pedersen, 1974
North Greenland	7.5	1985	Aastrup *et al*, 1986
Angujaartorfiup Nunaat, W. Greenland	25.0	1988-90	Olesen, 1990
Average	13.4		

Table 4. Selected population parameters in Angujaartorfiup Nunaat (West Greenland) and Jameson Land.

Population parameter (average)	Angujaartorfiup Nunaat (Olesen, 1993; Olesen *et al.*, 1994)	Jameson Land (present study)
Fraction of calves	24.7	18.4
Calves/100 cows	100	46
Calf mortality, winter	probably < 10%	43%
Age at first birth	1 year	3-4 years
Average Body Weight; Bulls > 4 years	321 (11) (summer)	290 (32) (winter)
	286 (30) (summer)	220 (41) (winter) - Thing *et al.*, 1987
Yearly population increase	32.9 (before official hunting was initiated)	Weak decrease (hunted population)
Population density	40-50/100 km^2	38/100 km^2 (average 9 years)

4500 (including some adjacent areas) in 1945 (Jennov, 1945) and 5000 in 1969-70 (Pedersen, 1974) seem to suggest, that the population has been fluctuating within rather stable limits through the 1900s; however with gaps of 12-24 years between estimates some major peaks or lows may have been missed by this record. The available data (1930s until today) suggest stability within the Jameson Land population, which is in contrast to the populations in northern Greenland where fluctuations probably were caused by climatic conditions (Forchhammer & Boertmann, 1993).

The proportion of calves in northern Jameson Land in summer averaged 18.4% of the total population. Table 4 summarises some earlier estimates of calf fraction in different parts of Greenland. In North Greenland in 1985 the proportion of calves varied between 1.8% and 20.6% with an average of 7.5% calves (Aastrup *et al.,* 1986). In the introduced population in Angujaartorfiup Nunaa (AN) in West Greenland, Olesen (1993) found around 25% calves through several years. Nagy *et al.* (1996) found an average calf proportion of 18.3% on Banks Island, NWT, in Canada. The Jameson Land proportion of calves is comparable with that of Banks Island and it is not as variable as in northern Greenland.

The proportion of yearlings averaged about 9% of the total population and the yearling to one hundred cows ratio was 26 in Jameson Land. This is also similar to Banks Island where the number of yearlings per one hundred cows averaged 25.9 during 1982-1992 (Larter, pers. comm.).

The calf to one hundred cows ratio in Jameson Land varied between 28 and 67 with a mean of 42 calves per 100 cows, which is similar to 44.3 calves per 100 cows on Banks Island (Larter, pers. comm.). Olesen (1993) found that the number of calves per 100 cows was almost 100 in West Greenland through several years.

Data from Banks Island, Canada are remarkably similar to those from Jameson Land. The West Greenland population has a higher reproduction rate although the overall densities are similar. The West Greenland population was increasing during the 1970s and 1980s after the introduction in 1963 and 1965. The production in West Greenland has been high since quota based harvesting that matched the annual production was initiated in 1987 (Pedersen & Aastrup, 2000).

Differences in population parameters of the muskox population in Jameson Land (JL) and the introduced population in West Greenland (Table 4) are apparent except for the overall population density. The West Greenland population in Angujaartorfiup Nunaat lives in a much more productive habitat and may still be increasing; the better habitat conditions in West Greenland seem to result in greater production and body weight (Olesen *et al.,* 1994). Probably the West Greenland overall population density is now limited only by hunting (Pedersen & Aastrup, 2000), while the Jameson Land population is limited in part by hunting and in part by natural mortality. The apparent stability of the Jameson Land population size over 60 years suggest that mortality factors including hunting equalled production during this time period. We suggest, that the population stability may be caused by density dependent hunting pressure.

The seismic operations 1987-1989 may have affected the muskox population. Significantly lower yearling fractions during the years of the seismic operations indicate an increased winter mortality of calves. We can not assess whether this was a consequence of the disturbances or some other factor was involved. We examined some climatic parameters (temperature, freeze-degree days and wind) but the validity of available climatic parameters to the muskox population in Jameson Land is questionable. Seismic operations occurred all over the area and disturbances may have reduced the feeding time and increased energy expenditures. Olesen (1986) found that time spent standing and walking was increased six fold while time spent lying was halved during seismic disturbance within 1 km from muskoxen in Jameson Land.

The population monitoring program was not sufficient to detect small decreases in population size that may have been related to oil exploration. On the other hand a more severe decrease in population size would have been detected; calculation by "Trends" showed that a decrease in a minimum order of 10% per year could have been detected with a power of 0.95. The magnitude of changes in reproduction that a monitoring program should be able to detect is open to discussion. Because some negative effect on the survival of calves during their first winter was detected during this study it is concluded, that population composition data are essential and that a longer monitoring period is needed to detect effects of demographic change on population size. Another important point is that more precise surveys where observers focus on narrow strip would have given a much better power of detection of population changes.

We cannot conclude that the seismic operations had a significant negative effect on the calf survival although this may have occurred. During the seismic operations helicopter flights were prohibited below 500 m above ground level during the calving period and in spring in the areas with highest densities of muskoxen. A possible negative effect on the muskox population seems to have been temporary during years with seismic exploration. It can not be excluded, however, that climatic factors were involved. On Banks Island, for instance, the rate of increase varied much in the absence of seismic operations (Nagy *et al.,* 1996).

Acknowledgement

We would like to thank the observers, Sigga Joensen and Jørgen B. Andersen and, not least, the pilot of OY-CAG, Leif Petersen. Christine Cuyler, Mike Ferguson, Jørgen Rabøl, Frank Riget and two anonymous reviewers are all thanked for valuable comments of earlier drafts.

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Manuscript received 18 January, 1999
accepted 11 July, 2000