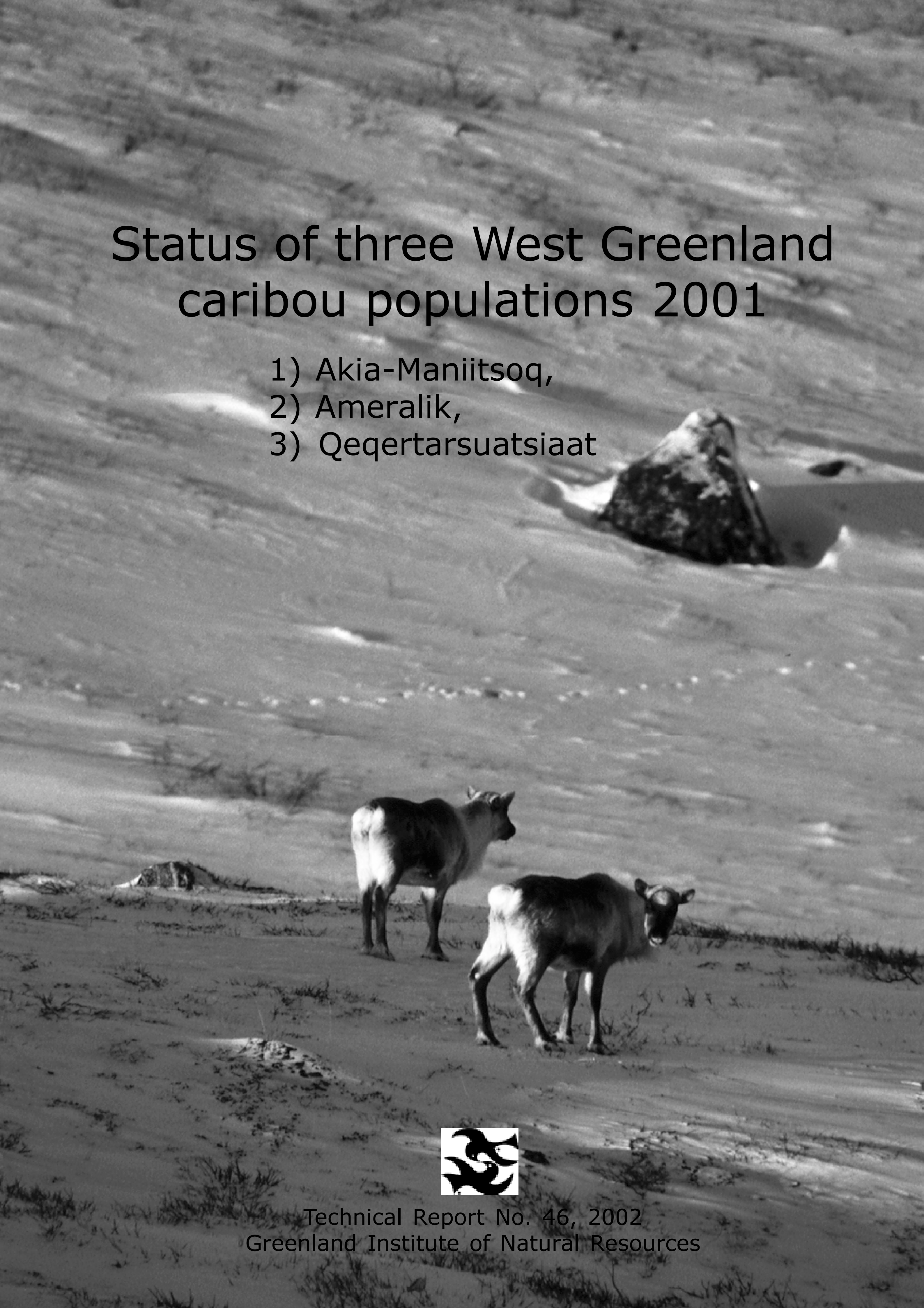
Status of three West Greenland caribou populations 2001

1) Akia-Maniitsoq,
2) Ameralik,
3) Qeqertarsuatsiaat



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Status of three West Greenland caribou populations 2001

1) Akia-Maniitsoq,
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by

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Sammenfatning

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Summary

In March 2001 aerial survey by helicopter for caribou abundance and herd structure was completed for 3 populations. The first was the Akia-Maniitsoq caribou population in region Central. The last two were populations in region South, the Ameralik and Qeqertarsuatsiaat herds. Flight height was 15 metres, flight speed averaged 80 km/hr, and strip width was 300 metres to either side of the helicopter, for a total of 600 metres. During March-April of 1998 and 2000, snowmobile ground surveys for herd structure were also completed in region Central. Both aerial and ground surveys gave annual recruitment estimates.

Akia-Maniitsoq herd – region Central

The estimate for pre-calving population size of Akia-Maniitsoq herd of region Central in March 2001 is c. 46,236 caribou (37,115 - 55,808; 80% CI). Winter range destruction has been observed. A decrease in herd size is advisable to prevent further destruction of the range. Therefore a large female harvest is needed. Neither halting population growth nor herd size reduction can be effectively achieved through hunter harvest unless females make up a large proportion of the animals taken.

Caribou density in 2001 was 4.0 caribou per km^2 in the high-density stratum, and 1.1 caribou per km^2 in the low-density stratum. The former is high and considered a threat to vegetation. Mean group size declined from 6.4 in 1998 to 3.2 in 2001. Calf percentage also declined from 25% in 1998 to 17% in 2001. Similarly annual recruitment was 65 calves/100 cows in 1998 but only 31 in 2001. The high 1998 recruitment could have promoted rapid increase in population size, specifically since there are no natural predators. The present substantial drop in calf recruitment may indicate a population already in decline. The bull to cow ratio was about one bull to every 1.72 cows, which is not unusual. If natural mortality is between 8 and 10% then on a herd this size between 3,700 and 4,600 animals may be expected to die annually.

The Akia-Maniitsoq caribou herd may have been steadily increasing in number since the 1950's. It is probable that herd size did increase substantially during the 1990's, given the initial 2-year ban on hunting, the following 5 years of low harvest quotas, the rich lichen range described by several authors, and the high recruitment observed in 1998. Recently caribou have been using the Davis Strait seacoast range, most noticeably the spring of 2001, when they were numerous on the north shorelines of the Godthåbsfjord along Akia/Nordlandet. Since utilization of coastal range occurs during population peaks, the present estimate may be a maximum for the region. The density of 4 caribou/km^2 appears to support this. The herd size estimate in 2001, which is larger than all previous estimates need not mean a continued increasing number of caribou in the Akia-Maniitsoq herd, since calf recruitment dropped and is now poor. The improved sampling design produced a high population estimate, but the herd may be in decline or on the brink of decline. Support for this hypothesis is found in the present remarkably low recruitment value and observed current range degradation. This situation underlines the importance of monitoring and managing each herd separately in the future.

Ameralik Herd – northern area of region South

The Ameralik herd may have steadily increased since the 1940's until a possible recent peak in the late 1990's. These caribou

have been using the seacoast heavily since 1997/98, which indicates both food limitation elsewhere on the range and a peak in animal numbers. The present high caribou density and range degradation supports this suggestion. This study's estimate for the pre-calving population size of the Ameralik herd in region South in March 2001 is c. 31,880 caribou (24,721 – 39,305; 80% CI). The large estimate need not mean a continued increasing number of caribou in the Ameralik herd. The herd may be in decline, given the poor calf recruitment, range degradation, and probable high population numbers over the past 5 years.

Caribou density in 2001 was 3.7 caribou/km^2. Range destruction has been observed. Given that there are no predators, calf percentage is a low 18% and recruitment only 40 calf/100 cows. This may signal a herd already in decline. The relatively even bull to cow ratio suggests that harvests since 1995, although male-biased, have been too small to affect the population, e.g., herd size was likely large. If natural mortality is between 8 to 10% then between 2,500 and 3,200 animals may be expected to die annually.

Once again halting further population growth and decreasing herd size is advisable to prevent further destruction of the range. Preserving the range will ensure the future of the caribou herd. As with the Akia-Maniitsoq herd a large female harvest is needed to effectively halt population growth or reduce herd size.

Qeqertarsuatsiaat Herd – southern area of region South

The 2001 Qeqertarsuatsiaat caribou herd size estimate of c. 5,372 caribou (2,864 – 8,244; 80% CI) is coupled with an excellent late winter calf recruitment (61 calf/100 cow) and reasonable caribou density (1.1 caribou/km^2). With the high calf recruitment an increase in number is probable unless regulated by hunter harvest. The herd produces large animals for the harvest and present herd size does not appear to represent a threat to range condition. However, little is known about lichen range in the area. For every bull there are 1.4 cows. If natural mortality is between 8 to 10% then between 400 and 550 animals may be expected to die annually.

Harvests should be about half female, so as to protect genetic variability in this relatively small population and promote female fecundity. A harvest strategy, which maintains the herd at its current size estimate, may be sustainable for both herd and range.

Introduction

Estimates of herd size, herd structure and recruitment are important for caribou management decisions. Harvest regulation in west Greenland began in earnest during the 1990's with caribou herd size as the sole foundation. Animal abundance estimates are central to management in Greenland. Alone however, an estimate tells nothing about body condition, fertility, or recruitment, which are also relevant to management decisions, and can often explain the causes behind population fluctuations. The 1990's aerial surveys in west Greenland, specifically 1995 and 1996, had the best method design up to their time. Yet surveys are subject to uncertainty and typically underestimate numbers (Thomas 1998). Therefore it is critical to further improve methods if the resulting estimate is to accurately reflect population size. Recently three caribou populations in West Greenland were investigated; Akia-Maniitsoq, Ameralik and Qeqertarsuatsiaat.

Akia-Maniitsoq caribou: region Central

The Akia-Maniitsoq caribou population of region Central (Figure 1) is composed of native west Greenland caribou (*Rangifer tarandus groenlandicus*) genetically mixed with feral semi-domestic reindeer (*Rangifer tarandus tarandus*) (Jepsen 1999), which were introduced to the Godthåb/Kapisillit area in 1952 (Figure 2). Ear-marked escaped reindeer were already being harvested in region Central, specifically Qussuk, during the 1970's (Kristian Egede pers. comm.). As with all regions in west Greenland there are no natural predators. Region Central may contain sub-populations of caribou, but results from satellite collared individuals (Cuyler & Linnell in press) suggest that the caribou of the region may be considered one population.

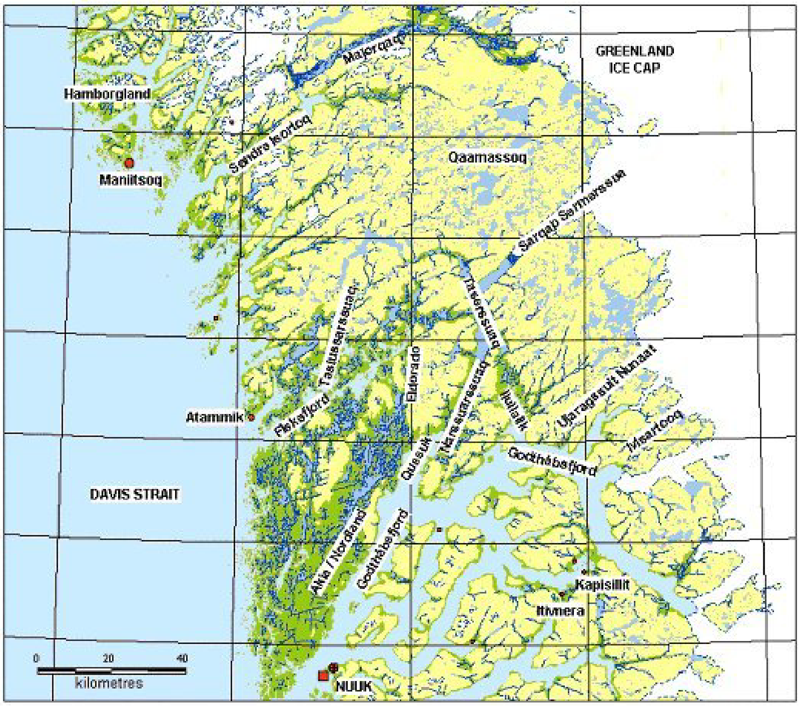

Figure. 2. Place names in region Central.

Figur 1 ind her

Figure 1. Caribou regions of West Greenland.

Historical perspective on population estimates & harvests

Caribou have been hunted in region Central for at least 3,500 years (Meldgaard 1986). Prehistoric caribou hunting structures are concentrated in the inland, and were used primarily only in summer/autumn, which suggests that caribou have always been most common close to the Ice Cap (Meldgaard 1986). Much of the last two centuries' reported caribou trade and harvest were presented in Meldgaard (1986). As with other regions in west Greenland, trade & game statistics suggest a high number of caribou present from 1825 to 1850. Trade dropped after 1850, which may indicate a decrease in caribou number in region Central at that time. Caribou number appears to have remained low for about 100 years. However a small peak is suggested by the game statistics at the beginning of the 20th Century, when harvesting may have been between 500 and 1,000 caribou annually. The harvest until 1950 was typically below 400 caribou annually. Between 1950 and 1983 the reported harvests generally rose steadily, with a spike to over 6,000 caribou in the 1970's. Harvest statis-

Table 1. Previous mean population size estimates for the 3 caribou herds of region Central and South (95% CI included when available).

	Region Central	Region South	
Year	Akia-Maniitsoq herd	Ameralik herd	Qeqertarsuatsiaat herd
1977	5,300[1]		
1978	4,100[1]		
1980	2,000[1]	350[1]	400[5 & 6]
1982	6,700[1]	1,500[1]	300[1]
1983		2,100[2]	
1985		2,000 to 2,500[3]	
1990	6,155[3]	1,504[3]	146[3]
1993	3,505[4]	1,160 (556 – 2,379)[4]	181 (80 - 411)[4]
1994	3,080[4]	1,385 (712 – 2,695)[4]	73 (17 – 306)[4]
1995	6,408[4]	4,046 (2,353 – 6,955)[4]	507 (225 – 1,143)[4]
1996	6,806[4]	4,458 (43,020 – 6,580)[4]	

References: [1] Strandgaard et al. 1983; [2] Meldgaard 1983; [3] Thing & Falk 1990; [4] Ydemann & Pedersen 1999; [5] Reimers 1980; [6] Aastrup 1983.

Table 2. Annual harvest quotas for 3 caribou herds in West Greenland, 1993 – 2000.

Year	Akia-Maniitsoq (region Central)[1]	Ameralik & Qeqertarsuatsiaat (region South)[1]	Total harvest quota West Greenland[2] (5 regions)
1993	0	0	0
1994	0	0	0
1995	c. 745	c. 745	2,000
1996	c. 647	c. 647	2,600
1997	c. 760	c. 760	3,111
1998	c. 909	c. 909	3,680
1999	c. 1,000	c. 1,000	4,450*
2000	c. 3,000	c. 3,000	13,260

[1] Uncertainty due to quotas allocated by municipality and not by caribou region or herd.
[2] These are the total harvest quotas and apply to five caribou regions.
* In 1999 an additional quota of 1,142 animals (above the 4,450) was given specifically for the reindeer-herding district of Kapisillit, situated at the head of Godthåbsfjord.

tics were unfortunately discontinued in 1984, when annual harvest was over 2,000 caribou. Caribou harvest up until 1993 was regulated by bag-limit, but not by quota.

Population estimates between 1977 and 1996 generally portrayed a herd low in number (Table 1). Note that the 1980 survey was inadequate and the result underestimated herd number (Strandgaard et al. 1983, Thing pers comm). There were no sharp drops in numbers despite heavy hunting pressure (Thing & Falk 1990, Strandgaard et al. 1983), which was c. 1,000 to 2,000 caribou annually at that time (Meldgaard 1986). Meldgaard (1986) proposed that population size peaked around 1980. Following a helicopter survey in 1990, Thing & Falk (1990), however, considered the Akia-Maniitsoq herd had been relatively stable between 1975 and 1990, with the exception of a localized increase at Ujaragssuit Nunaat in 1990. In 1993, however, a new aerial survey estimated an alarmingly low population size, c. 3,000 caribou (Ydemann & Pedersen 1999), and a two year hunting prohibition began. By 1995-96 the estimate was c. 6,000 - 7,000 animals (Ydemann & Pedersen 1999). Low quota-regulated harvesting was permited (Table 2), however this was neither herd nor region specific. Reported harvests between 1995 and 1998 were 90% male-biased for all herds in west Greenland (Loison et al. 2000).

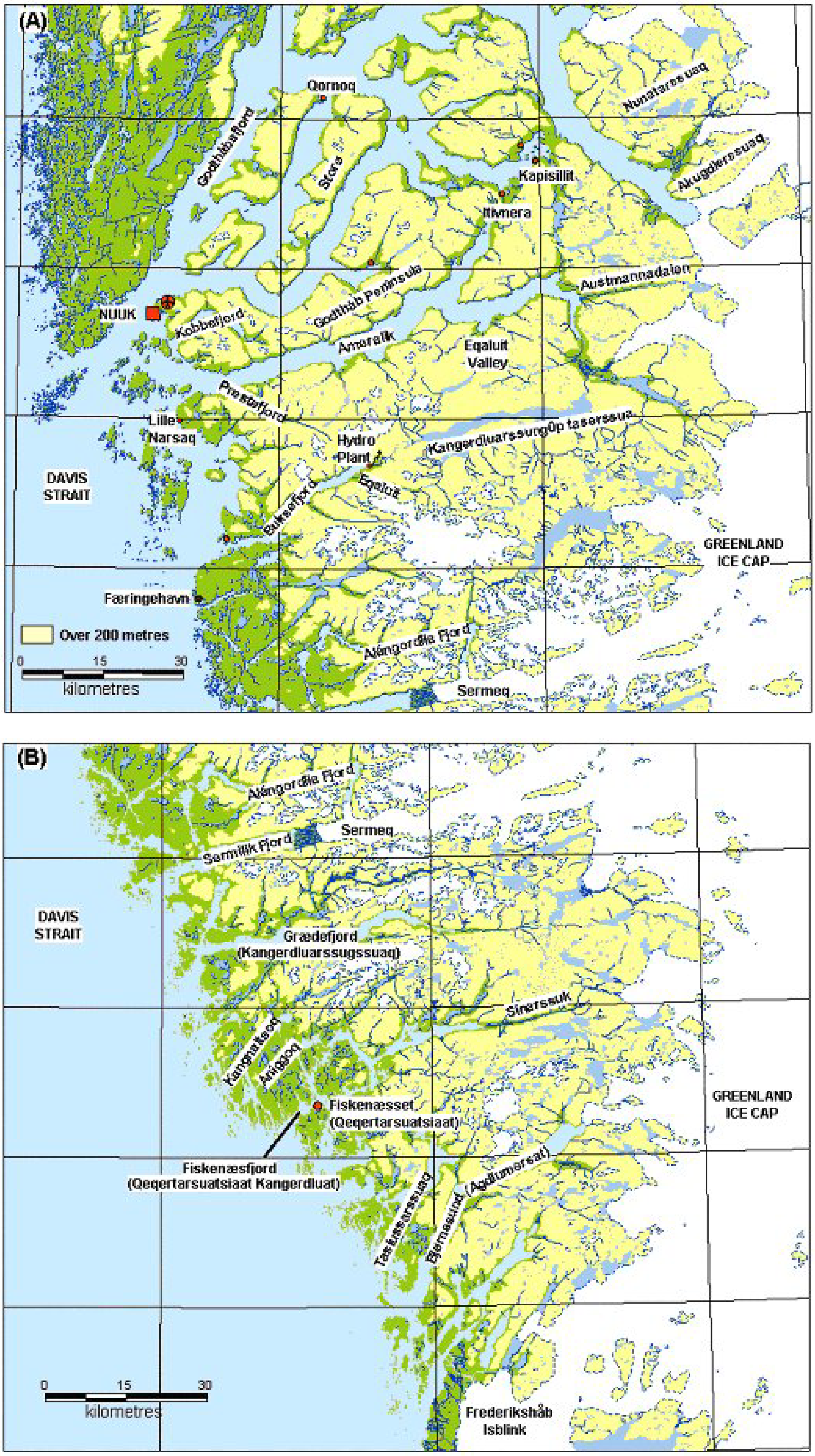

Figure. 3. Place names in region South: (A) northern area & (B) southern area.

Local knowledge perspective on animal abundance

Local knowledge suggests that the Akia/ Maniitsoq caribou herd number has increased steadily with each decade since the 1950's, when they were extremely scarce, until present day with no marked peaks or drops. The growth began during the 1970's and by the 1990's caribou were common. In December 2000 and again in the spring of 2001 there was an extraordinary abundance of caribou observed on the north shores of Godthåbsfjord (Appendix 1).

Ameralik caribou: region South

Rugged terrain and the Sermeq glacial tongue from the Ice Cap bisect region South (Figure 3). Two sub-populations of different herd size have been apparent in every survey since 1982, and in the mid-1990's differences in herd structure were also observed (Strandgaard et al. 1983, Ydemann & Pedersen 1999). This report divides the region into two sub-populations, the large Ameralik herd to the north, and to the south the small Qeqertarsuatsiaat herd. Similar to Akia-Maniitsoq, the Ameralik caribou are a genetic mix of indigenous animals and feral semi-domestic reindeer (Jepsen 1999; Strandgaard et al. 1983; Thing & Falk 1990). The Kapisillit reindeer herding district was immediately to the north and ear-tagged escaped reindeer were often observed moving past the head of Buksefjord in the 1990's (Jack Frederiksen pers. comm.).

Historical perspective on population estimates & harvests

Trade in caribou skins was brisk from 1825 to 1850, which suggests a high number of caribou (Meldgaard 1986). Trade dropped to almost zero after 1850, which likewise suggests a drastic decrease in caribou number. Caribou number appears to have remained low for about 100 years. However a small peak is suggested by the game statistics at the beginning of the 20th Century, when harvesting may have been between 500 and 1,000 caribou annually. Sources in Meldgaard (1986) describe caribou as being plentiful south and east of Ameralik fjord prior to 1921, and that they were numerous on the nunataks, Nunatarssuaq & Akugdlerssuaq, which are just east of the Kapisillit settlement. Still, the reported harvest until 1950 was typically below 400 caribou annually. Between 1950 and 1983 the reported annual harvests generally rose steadily. Meldgaard (1986) proposed a peak population size in 1980. Harvest statistics were unfortunately discontinued in 1984, and at that time the annual harvest for this region was c. 2,000 caribou. The level of hunting pressure was considered high during the 1980's and 1990 (Strandgaard et al. 1983; Thing & Falk 1990). Still in 1990 the Ameralik herd was considered stable, healthy and under range capacity (Thing & Falk 1990). All harvest until 1993 was regulated by bag-limit but not by quota. In 1993 the herd was estimated at only about 1,200 animals (Ydemann & Pedersen 1999) and a 2-year ban on hunting began. By 1995-96 the estimate was c. 4,000-4,500 animals (Ydemann & Pedersen 1999) and hunting was permited.

Local knowledge perspective

Generally local knowledge suggests Ameralik caribou number was low 60 years ago, rose steadily through the 1980's with no marked peaks or drops, and attained a high during the mid to late 1990's, when the common opinion was there were too many caribou, i.e., caribou were plentiful everywhere, not just at the inner fjord coastlines, but also on the islands and coast of the Davis Strait. Previously nonexistant caribou paths became visible, vegetation showed signs of overgrazing, animals could be shot from the beaches and rump fat, which indicates body condition, decreased. The most recent local observations are supported by hunter report data, 1996 –1998, which observed poor body condtion in region South relative to the other caribou regions of west Greenland (Loison et al. 2000).

Qeqertarsuatsiaat caribou: region South

Historical perspective on population estimates and harvests and local knowledge

The Qeqertarsuatsiaat caribou are a relatively small population in the southern portion of region South. Historical records cited in Meldgaard (1986) suggest that Qeqertarsuatsiaat caribou were relatively numerous between 1820 and 1845, with 50 to 200 caribou traded annually. However after 1850 trade dwindled to nothing suggesting that numbers declined rapidly thereafter. The herd increased towards the turn of the 20th Century and then fell from 1915 to 1925, but may have been becoming more plentiful since the 1960's. During the late 1970's and early 1980's caribou hunters found many dead calves and adult caribou in the inland areas and harvests decreased (Meldgaard 1986). The herd was considered stable or perhaps decreasing in early 1980's (Meldgaard 1986) and the same in 1990 (Thing & Falk 1990). Due to uncertainty in the surveys the herd size drop from 1980 to 1990, c. 400 down to c. 150 caribou in Table 1, was not likely a decrease in herd size (Thing & Falk 1990). In 1990 the Qeqertarsuatsiaat herd was considered stable at c. 150 animals, and at or just below the range capacity (Thing & Falk 1990). In 1993 the herd size was estimated at below 200 animals (Ydemann & Pedersen 1999), and similar to the other herds hunting was banned for 2 years. By 1995 the estimate was c. 500 animals (Ydemann & Pedersen 1999) and hunting was again allowed.

All traditional hunting structures are concentrated in the inland (Meldgaard 1986), suggesting that the herd typically occupies the inland area only. Hunting pressure in the region was high during the 1980's and 1990 (Strandgaard et al. 1983; Thing & Falk 1990). Before 1990, hunting pressure from the nearby town of Qeqertarsuatsiaat/Fiskenæsset was high year round, which kept the herd low in number (Thing & Falk 1990). Traditionally only hunters from the Qeqertarsuatsiaat/Fiskenæsset community harvest these caribou (Strandgaard et al. 1983). Local knowledge sources have been few. Caribou were seldom observed south of Bjørnesund, however, these were big and fat during 2000 (Birger Knudsen pers. comm.).

Estimating population size

Since the 1970's Greenland surveys have delivered various estimates, which have generally been low, of caribou population size for the 3 herds of regions Central and South. Failure to detect caribou can be a major source of negative bias during a survey and the correction factor of 1.25 was initially adopted by Canadian caribou surveys (Thomas 1969; Heard 1985). This was found to be inadequate, since reexamination showed that the appropriate factor lay between 1.4 and 3.7 depending on the survey (Thomas 1998). During the west Greenland surveys of the 1990's, variable snow cover was acknowledged to greatly affect sight-ability of caribou (Ydemann & Pedersen 1999), however, Greenland estimates were never corrected for failure to detect caribou. The low estimates of the 1980's went uncontested. This was likely because no management actions were taken. In contrast, the 1993-1996 estimates of caribou population size, met heavy debate and scepticism, because they were used first to initiate an unpopular two-year hunting prohibition, 1993-1994, and later to keep harvest quotas low from 1995 to 1999. Local hunters were of the opinion that caribou number had increased steadily with each decade since the 1940's with no marked peaks or drops. The result was local rejection of the 1990's survey results and low credibility for biologists.

This report provides new estimates for population size, structure and recruitment of three herds; Akia-Maniitsoq in region Central, Ameralik and Qeqertarsuatsiaat in region South.

Methods

In March 2001 aerial transect surveys were completed for 3 caribou populations in two regions; Akia-Maniitsoq (region Central), Ameralik (region South) and Qeqertarsuatsiaat (region South).

Survey design and field methods

Areas defined included islands, lakes and rivers, but deleted Ice Caps and glaciers. Region Central was stratified into an area of low and high caribou density prior to the assignment of random transects (Appendix 2). This stratification was based on the observed densities from the earlier 1990s' aerial surveys (Ydemann & Pedersen 1999). Transect location and directions were randomly generated. Transect length was 7.5 kilometres.

All surveys were by helicopter, which could follow terrain features, while maintaining a constant altitude above ground level. Experience gained during the 2000 surveys (Cuyler et al. 2002, unpublished) allowed method improvement to increase caribou sightability and further reduce the negative bias due to missed caribou on a transect line, i.e., further decrease flight height, flight speed and strip width. Flight speeds were between 40 and 110 km/hour, and averaged c. 80 km/hour. Wind direction and speed determined and changed necessary flight speeds to remain airborne. A constant altitude of 15 metres (50 feet) was used. Transect strip width was 300 metres to either side of the helicopter, for a total strip width of 600 metres. To ascertain the 300 metre strip width mark for each observer, Leica distance-finder binoculars with laser were used. While hovering at the specified altitude and aided by the binoculars, each observer individually marked the strip width on the helicopter window. Solar glare reflecting off the snow surface may reduce sightability of caribou, hence transects were typically flown in a direction placing the sun behind the observers' field of view. March was chosen because caribou group size variability is low and less than 6 animals in late winter (Ydemann & Pedersen 1999). The low variability reduces sampling error and aids precision. March also has an optimal day length and snow cover, and patchy snow cover is known to reduce sightability (Ydemann & Pedersen 1999). Further, caribou movement is relatively low in March. Straight line caribou movements averaged under 1 km per day and did not exceed 5 km per day, however, in April movement can increase to a mean of under 3 km per day and a maximum of c. 12 km per day (Cuyler & Linnell in press).

During transect surveys 3 observers were in the helicopter, of whom two counted on the left side of the helicopter and one on the right side. Observers counted caribou independently of each other, with no verbal or other contact between observers while a transect was being flown. To make observations of the left side observers comparable, the left front seat observer kept to a side-viewing "window", which was similar to that of the left rear seat observer. Manual click-counters were used to log the number of caribou seen on a specific transect by each observer. The number counted by each observer was recorded immediately following each transect, after which click-counters were zeroed. A computer data-logger was used to record the GPS position, helicopter altitude, date, time and taped voice message for each observation, with each observers recorded separately.

Failure to detect caribou was considered the most important source of bias (inaccuracy). Left front-seat observer ability, i.e., mean

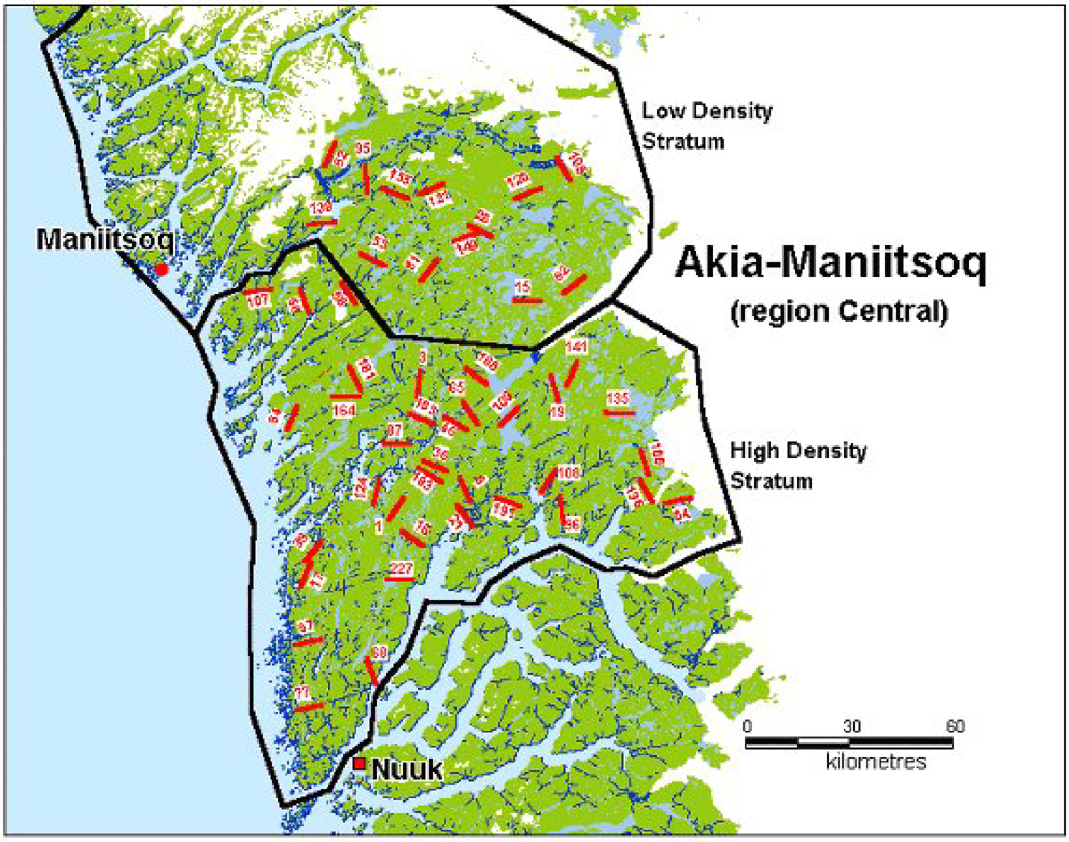

Figure 4. Aerial helicopter survey of the Akia-Maniitsoq caribou population in region Central.

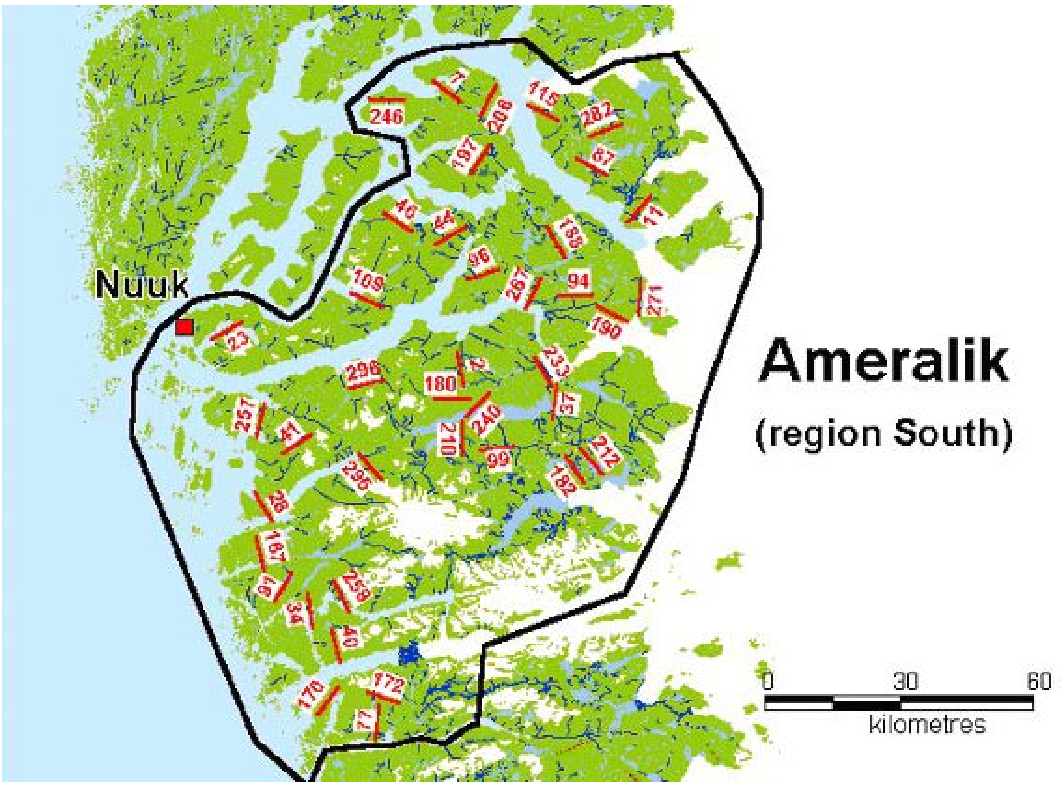

Figure 5. Aerial helicopter survey of the Ameralik caribou population in region South.

missed caribou per transect, was calculated from the results of the 2000 survey in region North (Cuyler et al. 2002). Rear seat (left and right) observer ability, however, was initially unknown. Therefore the rear seat observers alternated seat position, so each sat on the same side as the known-ability observer at least once. Also several observers were used. It was assumed that this spread the bias risk over an average of several individuals' ability rather than risk the possibility of a poor observer, sitting in the right rear seat, causing high negative bias.Details specific to each caribou population studied are given below in the order in which the surveys were completed.

Akia-Maniitsoq caribou population (region Central)

The aerial survey of region Central occurred 12-16 March 2001. Region Central encompasses approximately 15,362 km^2. The 47 random transect lines were divided between 2 strata, one high and one low caribou density stratum (Figure 4). The high-density stratum involved c. 10,037 km^2, while the low-density stratum encompassed c. 5,325 km^2. 34 transects were allocated to the high caribou density stratum and 13 transects to the low caribou density stratum. Herd structure and recruitment counts were flown on 5 transects, and over large areas in both the high and low caribou density strata.

Ameralik caribou population (region South)

The aerial survey of the Ameralik herd occurred 12-21 March 2001. Region South encompasses approximately 13,473 ice-free km^2, however the Ameralik area involves about 8,377 km^2. 40 random transect lines were allocated to the latter (Figure 5). Herd structure and recruitment counts were flown on 4 of the transects, and also over areas where caribou were numerous.

Qeqertarsuatsiaat caribou population (region South)

The aerial survey of the Qeqertarsuatsiaat herd occurred 21-22 March 2001, and used 21 random transect lines (Figure 6). Region South encompasses approximately 13,473

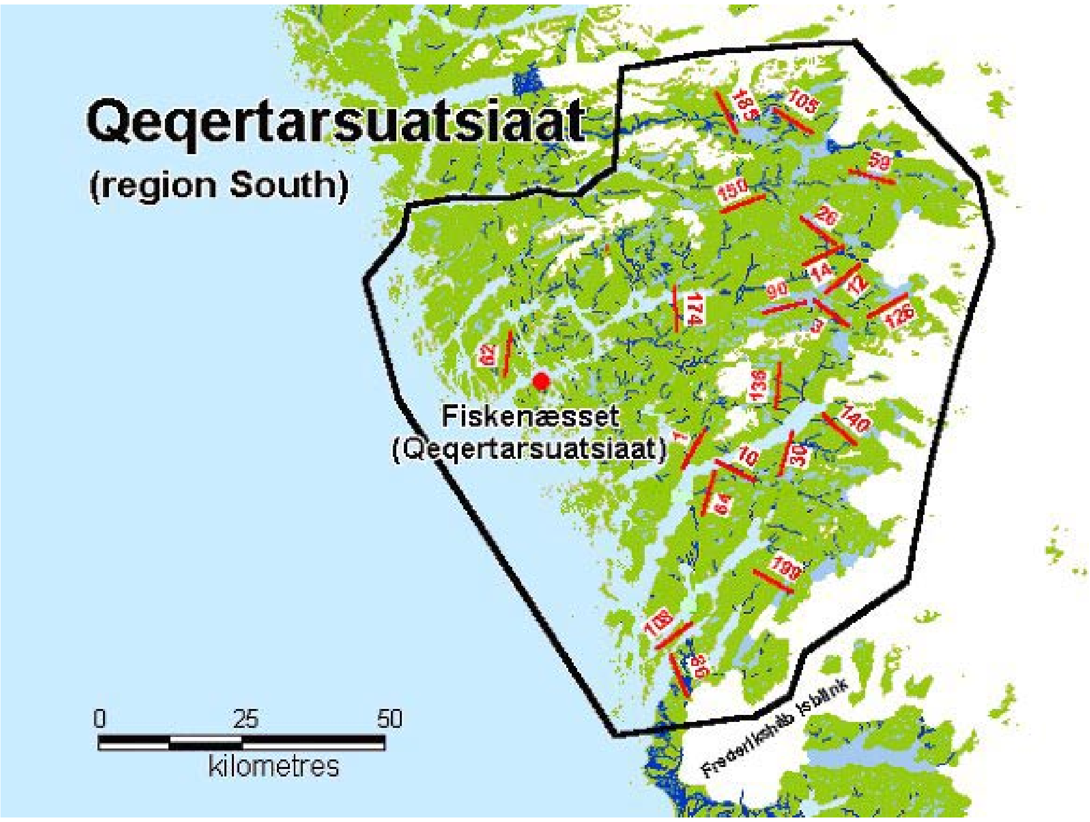

Figure 6. Aerial helicopter survey of the Qeqertarsuatsiaat caribou population in region South.

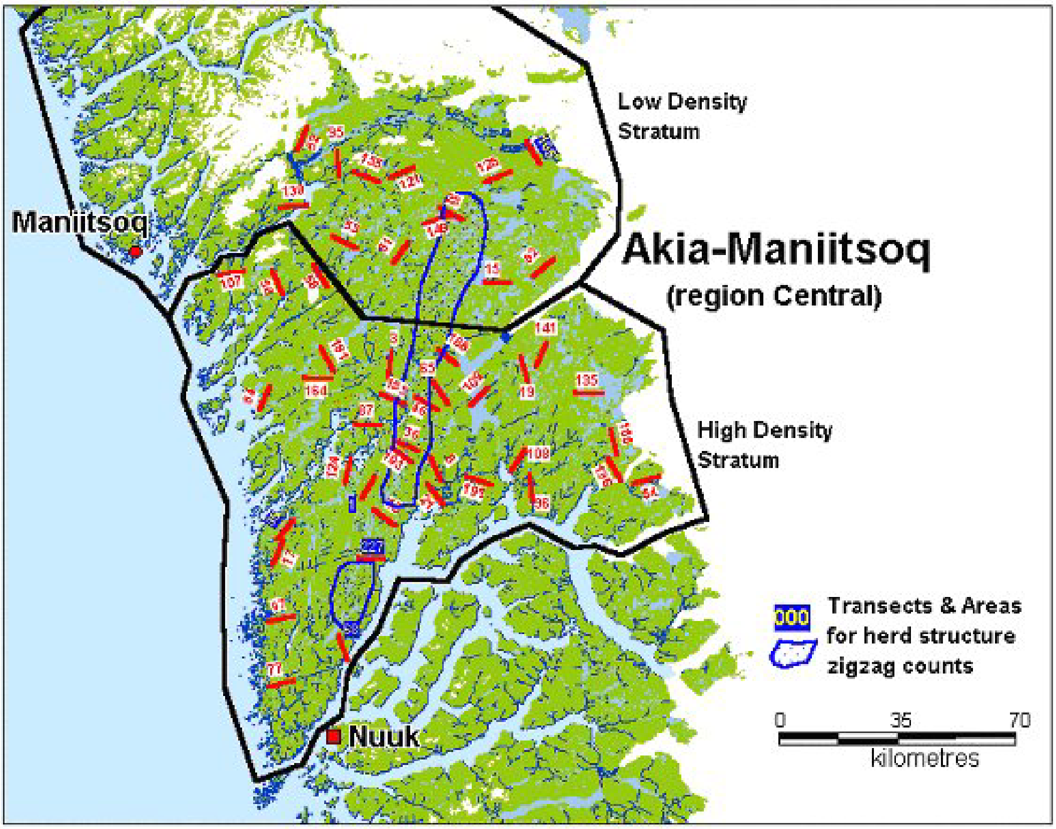

Figure 7. Akia-Maniitsoq herd structure zigzag overflights.

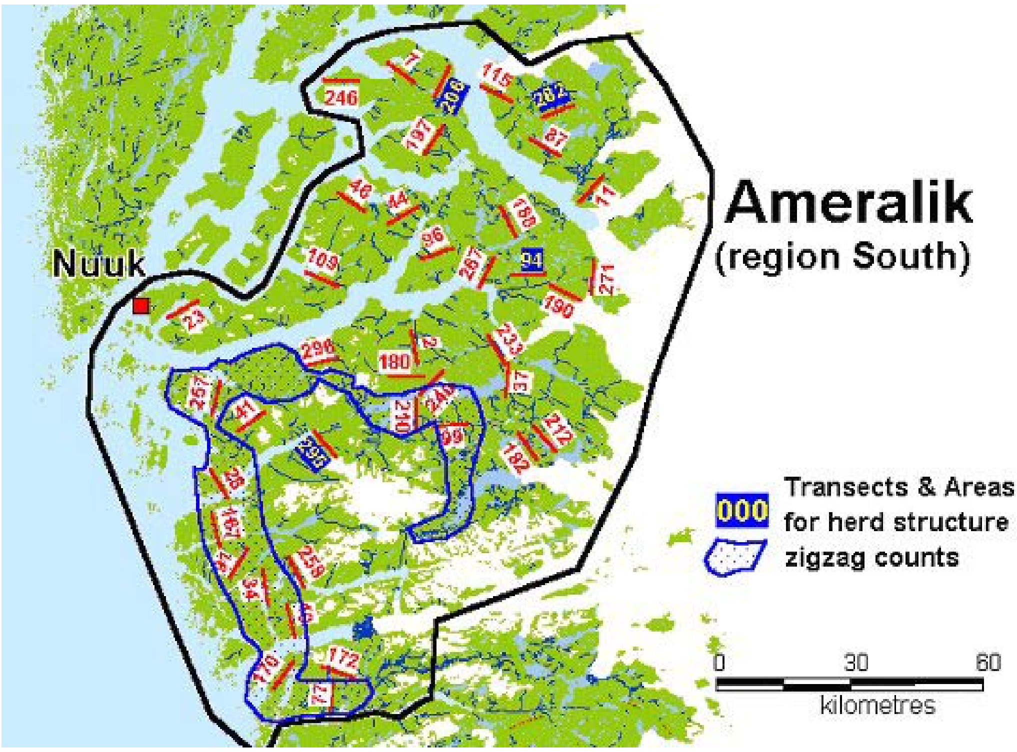

Figure 8. Ameralik herd structure zigzag overflights.

ice-free km^2, however the Qeqertarsuatsiaat area involves about 5,096 km^2. Herd structure and recruitment counts were flown throughout the region over large areas, where caribou were numerous.

Estimating abundance

Population estimates for the 3 caribou populations investigated and the minimum number for the missed animals were calculated according to Cuyler et al. (2002) (Appendices 3 & 4). The standard method when each missed animal is identified follows Pollock & Kendall (1987).

Herd structure & calf recruitment

During aerial surveys, herd structure and recruitment counts were obtained by backtracking transects in a zigzag flight pattern, never flying more than c. 2 kilometres from the transect line (Figures 7, 8 & 9). Alternately, areas of high caribou density were chosen. Choice of a transect or area depended on how many caribou were present, since the goal was to maximize the number of caribou, sexed and aged, for herd structure and recruitment. Akia-Maniitsoq transect numbers 1, 39, 68, 105 & 227 were backtracked, as were Ameralik transect numbers 94, 206, 282 & 295. There was close communication between all observers and pilot during this exercise. All caribou sighted were sexed and aged (< or > 1 year old) following a brief overpass with the helicopter.

Sex was determined by the presence or absence of a vulva and/or urine patch on the rump. This reliably indicated a female on both adults and calves. No other method was 100% certain, e.g., antler size, shape, presence or absence, were not used, as the presence of antlers on female caribou is highly variable in western Greenland. Age was determined by body size. Calves of both sexes were considerably smaller than all other age classes at this time of year. There were two age classes used in subsequent analyses, i.e., calf (≥ 9-10 months old)

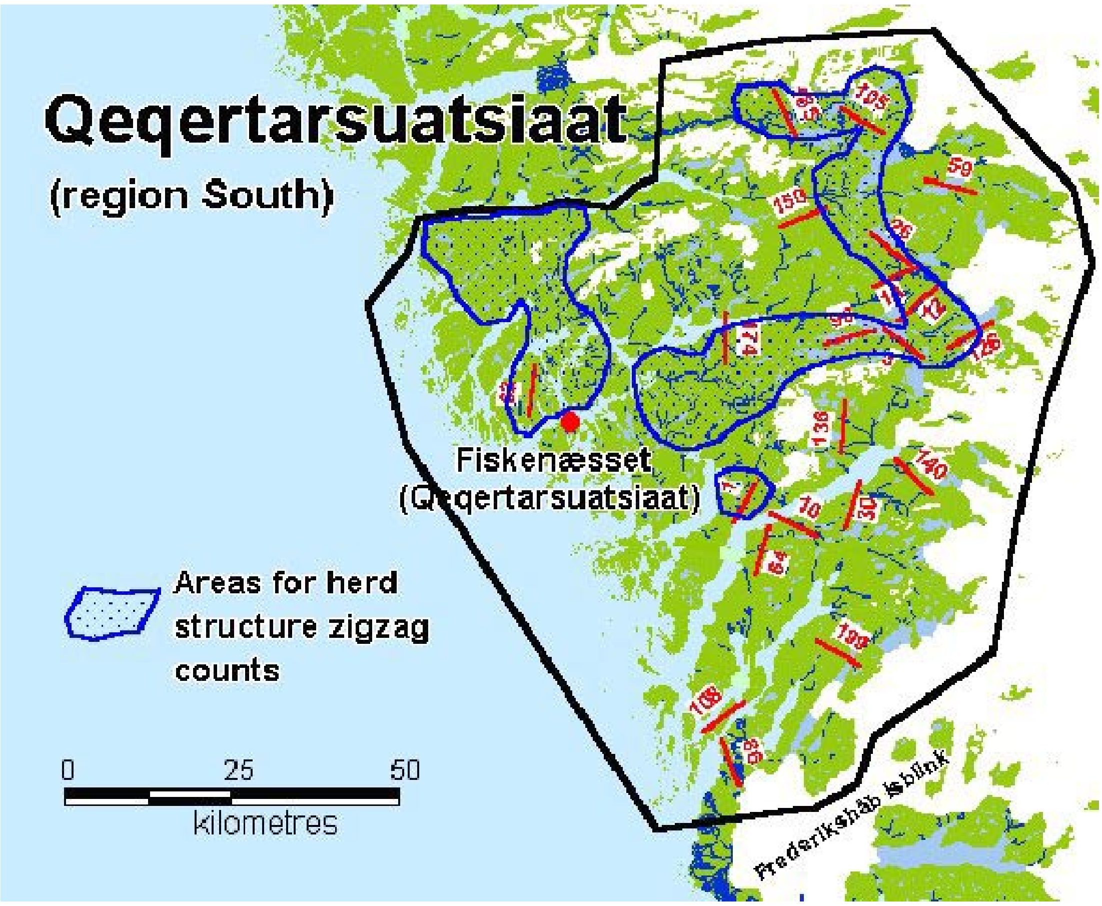

Figure 9. Qeqertarsuatsiaat herd structure zigzag overflights.

and adult (> 1 year). Calf percentage given is the percentage of the total number of caribou seen. Calf recruitment is the late-winter calf/100 cow ratio.

Group size was based on proximity and group cohesion during possible flight response, e.g., three cow/calf pairs, separated by several hundred metres, would not be regarded as a group of six.

The sex and age structure of the Akia-Maniitsoq herd, region Central, were also investigated by ground survey, between 25 March – 3 April 1998, and 29 March – 9 April 2000 (Figure 10). Areas were counted only once and rapid terrain coverage was used to avoid the possibility of double counting. Binoculars and Leica spotting scopes were used to sex and age animals observed.

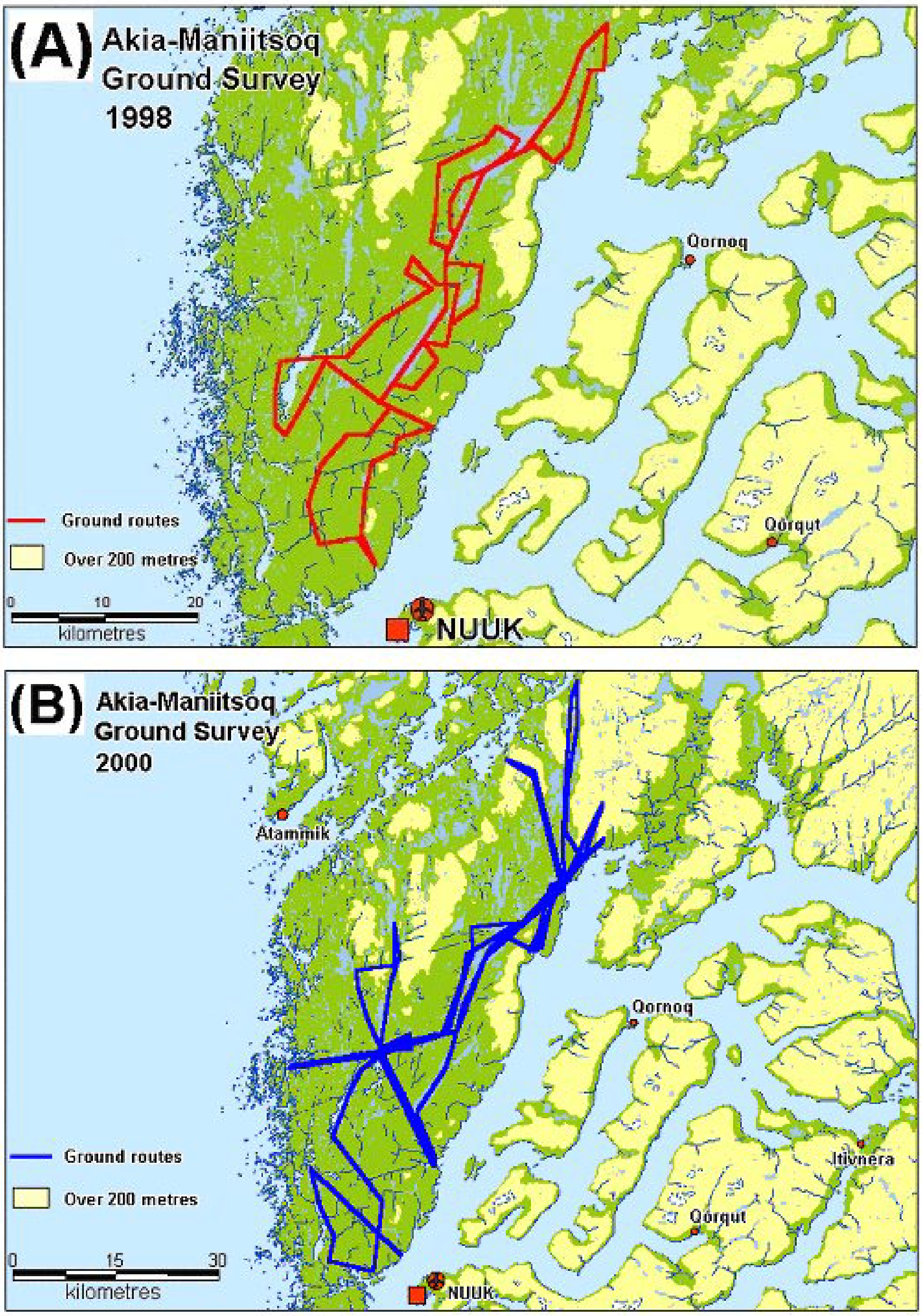

Figure 10. Akia-Maniitsoq herd structure ground survey, routes taken region Central: (A) 1998 & (B) 2000.

Local involvement

Local hunters and hunting officers participated in the surveys as caribou observers, and professional hunters were chosen by the Greenland Association of Commercial Hunters (KNAPK) and Greenland Directorate for Fisheries Hunting and Municipalities (DFFB). Local professional hunters Aslak Jensen, Johannes Egede, Niels Olsen, and Rink Heinrich participated in the helicopter survey 2001. The Maniitsoq wildlife officer, Jakob Heilmann, participated in the region Central snowmobile ground survey for herd structure assessment 2000, while local recreational hunter Jacob Poulson participated in 1998.

Description region Central

Region Central encompasses approximately 15,362 km^2, and caribou utilise much of this area over the course of a year. The regions boundaries reflect geographic features. To the north is the Sukkertoppen Ice Cap, to the north west is Søndre Strømfjord, to the west is the Davis Strait, to the south is Godthåbsfjord and to the east the Greenland inland Ice Cap. Today, the largest human settlement within the region is the city of Maniitsoq, with 2,929 inhabitants, while a further 796 people live in smaller settlements (Grønlands Statistisk Årbog 2000). Only a few kilometres south lies Greenland's capital city, Nuuk, with c. 13,445 inhabitants, and the Kapisillit settlement, with c. 115. Most cities and settlements are located on the Davis Strait seacoast. Vast portions of region Central are readily accessible to Greenland's technologically modern and mobile hunters due to the natural fragmentation of the landscape by fjord, lake and river systems.

The northern third of region Central, specifially the inland named Qaamassoq, can be described as high mountain plateau with a miriad of lakes sprinkled throughout. The area receives plenty of precipitation year round, and in winter this can create deep snow conditions that drive caribou out of this area, east to the borders of the Ice Cap, south towards Fiskefjord, or west towards the Davis Strait coast (Thing & Falk 1990, Strandgaard et al. 1983). Snow cover is typically good until May-June. In 1999 this area was still snow covered on the 25th of June. Although lichen range was good during the 1970's, twenty years later it was overgrazed (Thing & Falk 1990).

The southwest portion of region Central is Akia/Nordland, and lies between Fiskefjord to the north and Godthåbsfjord to the south. The landscape is monotonous fissured rocky lowlands with a myriad of lakes and rivers. There is a central mountain ridge, which runs SW-NE. The climate is wet and maritime with typically deep snow in winter, and previously caribou concentrations have been found on the south shores of Fiskefjord and in the mountain region north of Qussuk but elsewhere on Akia almost none at all (Thing & Falk 1990). This area contained some of the best lichen range in west Greenland, without evidence of overgrazing (Thing & Falk 1990; Lund et al. 2000). During the early 1980's lichens stood 2 to 3 cm high in near coastal areas (Strandgaard et al. 1983). This area currently represents favoured wintering range for the Akia-Maniitsoq herd (Cuyler & Linnell in press). During summer of 2000 several Nature Institute staff noticed independently that vegetation was trampled or overgrazed in the Qussuk area of Akia/Nordlandet, which only 3 years previously had been good lichen heaths. Lichen ranges closer to the Davis Strait coast have also been reduced over the last few years (Tittus Egede pers. comm.).

The southeastern area, Ujaragssuit Nunaat, which is south of the Sarqap Sermerssua glacial tongue and east of the lake Tasersssuaq and fjord Iluljalik, is dominated by high mountainous terrain, proximity to the inland Ice Cap and a continental climate, which means little precipitation annually and light snow depths in winter. Caribou have been known to prefer this area, but the winter lichen range was overgrazed in 1990 (Thing & Falk 1990). Even in the early

1980's lichens here were described as overgrazed and in some places consisting only of dead lichen mats (Strandgaard et al. 1983).

The coast north of Fiskefjord up to Søndre Strømfjord is varied. Mountainous terrain is typical and much of the area is divided by deep long valleys running SW-NE. There are several alpine ice caps. Snow cover can be deep and total, and at the high elevations snow cover can remain until mid-July.

Description region South

Region South encompasses approximately 13,473 ice-free km^2. The region's boundaries reflect geographic features. To the north is Godthåbsfjord, to the east is the Greenland inland Ice Cap, to the south is Frederikshåb Isblink, and to the west the outer coast along the Davis Strait. The region is characterized by a geographically fragmented landscape. Steep sided fjords penetrate deeply towards the inland Ice Cap and glacial tongues of the Ice Cap often begin at the fjord heads. Today, the largest human settlement within the region is Greenland's capital city of Nuuk, with 13,445 inhabitants, while a further 388 people live in smaller settlements (Grønlands Statistisk Årbog 2000). Also using region South for hunting, specifically the Grædefjord area, are hunters from region Paamiut, 2,085 inhabitants.

Ameralik

This 8,377 km^2, area includes all ice-free land and islands. This area between the Godthåb and Sermilik fjords (and Sermeq glacial tongue) has a sharply contrasting landscape. There are low coastal flatlands on the Davis Strait coast and high sharp mountain peaks with alpine glaciers elsewhere. The large lake, Kangerdluarssungûp taserssua, and the Ameralik fjord dominate in the centre, running generally east-west across the region. Snow is typically deep at the coast and decreases steadily towards the east until almost nothing close to the inland Ice Cap (Thing & Falk 1990). The terrain east of 50°30'W sees little precipitation, while west of that receives plenty, e.g. snow depths are commonly 1.5 metres at 51°W during winter (Jack Frederiksen pers. comm.). However for at least the past 2 decades, the windblown coastal lowlands at the seacoast seldom can keep any snow cover to speak of during winter (Göran Lindmark pers. comm.).

Historically the lichen ranges in Ameralik were excellent. Knud Rasmussen (1910) investigated Godthåbsfjord-Ameralik area with Saami during 1905. He described a range covered extensively with rich deep reindeer-lichen heaths, reaching even up to 1,000 m ASL in places. He wrote that the range was better suited for reindeer than anywhere in Scandinavia at that time. Lichens were still rich during the 1940's along the Davis Strait coastline from Lille Narsaq down to Buksefjorden and all along the shores of Buksefjorden. These ranges are now overgrazed (Tittus Egede pers. comm.).

Ameralik had good quality winter range during the early 1980's (Aastrup 1983, 1984), and lichen ranges were generally assumed of good quality in the early 1980's, due to observations of body condition (Thing 1982a; Strandgaard et al. 1983). However lichen ranges near the Ice Cap were poor relative to further west (Strandgaard et al. 1983). Lichen ranges on the Nunatarssuaq, east of Kapisillit were overgrazed in late 1980's (Nikolaj Heinrich pers. comm.). Ameralik in 1990 still contained some of the best lichen range in west Greenland, second only to Akia in region Central, being relatively good in many areas but again overgrazed near the Ice Cap (Thing & Falk 1990). The average lichen cover in 1984 for the land between Ameralik and Kangerdluarssungûp taserssua was 45-55% (Aastrup 1986). However, the entire south shore of the Ameralik fjord was overgrazed by the late 1990's (Jens Bjerge pers comm). In 1998 the lichens mats of the Eqaluit valley were observed overgrazed and trampled (GN unpublished). Between 1985 and 2000 the lichen heaths were severely overgrazed and trampled (Lund et al. 2000).

Qeqertarsuatsiaat

This 5,096 km^2, area includes all ice-free land and islands. The area is naturally fragmented to a severe degree by steep sided fjords and glacial tongues from the inland Ice Cap. Half the region is alpine, being greater than 700 metres ASL (Thing & Falk 1990), but there are low coastal flatlands and islands along the Davis Strait coast. Snow cover can be total from Davis Strait coast to the inland Ice Cap. Although not examined, Thing & Falk (1990) assumed the winter lichen range in this area was overgrazed and in poor condition, because the 1990 survey estimated a low caribou population size. Other explainations are possible. For example a heavy hunting pressure could have kept caribou numbers low, despite good range conditions. Alternately, the population size might have been underestimated, and have nothing to do with range condition. Hence range condition was unknown.

Table 3. Estimates of caribou abundance 2001 for 3 herds in West Greenland. Corrected for missed caribou as follows Cuyler et al. (2002).

Region	Population	Estimate	80% Confidence Interval[1]
Central	Akia-Maniitsoq	46,236	37,115 – 55,808
South	Ameralik	31,880	24,721 – 39,305
South	Qeqertarsuatsiaat	5,372	2,864 – 8,244

[1] non-parametric (bootstrap) CI's.

Table 4. Caribou density 2001 for 3 herds in West Greenland. Corrected for missed caribou as follows Cuyler et al. (2002).

Region	Population	Low density area	High density area
Central	Akia-Maniitsoq	1.1 / km^2	4.0 / km^2
South	Ameralik	-	3.8 / km^2
South	Qeqertarsuatsiaat	-	1.05 / km^2

Table 5. Late winter herd structure parameters for 3 caribou herds in West Greenland.

	Region Central			Region South	
	Akia-Maniitsoq			Ameralik	Qeqertarsuatsiaat
Year	2001	2000	1998	2001	2001
Method	Aerial	Ground	Ground	Aerial	Aerial
Total sexed & aged	758	590	575	555	107
Average group size	3.2	3.6	6.4	4.3	2.9
Maximum group size	18	17	36	28	6
Bull (>1 year)	232 (30.6%)	236 (40.0%)	206 (35.8%)	207 (37.3%)	33 (30.8%)
Cow (>1 year)	400 (52.8%)	237 (40.2%)	224 (39.0%)	249 (44.9%)	46 (43.0%)
Calf	126 (16.6%)	117 (19.8%)	145 (25.2%)	99 (17.8%)	28 (26.2%)
Recruitment (calf/cow*)	0.31	0.49	0.65	0.40	0.61

* all cows >1 year old

Results

Caribou population size & herd structure

Incorporating a correction for missed caribou (Cuyler et al. 2002), population size estimates for the 3 caribou populations investigated are, 1) Akia-Maniitsoq c. 46,236 caribou, 2) Ameralik c. 31,880 caribou, and 3) Qeqertarsuatsiaat c. 5,372 caribou (Table 3), while mean densities ranged up to 4 caribou/km^2 (Table 4). Herd structure and calf recruitment varied substantially among the 3 caribou populations (Table 5).

Distribution changes were observed for both the Akia-Maniitsoq and Ameralik caribou populations. Unusually large numbers of Akia-Maniitsoq caribou were observed on the Davis Strait coast and the northern shorelines of Godthåbsfjord. A large portion of the Ameralik caribou population was observed in the extreme south of their range and bordering on the Qeqertarsuatsiaat caribou range.

Akia-Maniitsoq caribou distribution

Within the high-density stratum, large numbers, i.e. high densities, of caribou were present all along the south-facing slopes of the hilly north shore of Godthåbsfjord. The favoured Akia/Nordland wintering range just north of these hills, was also densely populated. For example, transect line 68 had a density of c. 23 caribou/km^2, and half of transect line 227 had a density of c. 20 caribou/km^2 (Appendix 5).

Coastal areas along the Davis Strait were also full of caribou. Coastal transect line 39, which was at the mouth of Fiskefjord, south side, had a density of c. 15 caribou/km^2, while transect lines 97, 17 and 77 had densities of c. 3, 2 and 2 caribou/km^2 respectively. Further north the Davis Strait coastline was still supporting substantial numbers of caribou. Transect lines 84, 56 and 107 had densities of c. 5, 4 and 4 caribou/km^2 respectively.

Also areas further inland had high densities. Transect 1 had a density of c. 7 caribou/km^2. Inside a narrow inland valley, which lies on a N-S orientation, 197 caribou were sexed and aged. We named this valley "Eldorado" because its caribou density was c. 30 caribou/km^2. This valley was an observed April migration route for south to north movement of the Akia-Maniitsoq herd during the 1998 and 2000 ground surveys.

Areas furthest inland by the Ice Cap, i.e., the Ivisartoq and Ujaragssuit Nunaat areas, were also well populated though not as excessively as elsewhere within the high-density stratum. Densities typically lay above 2 caribou/km^2, while lines 166, 108, and 96 had densities of 4.4, 4 and 3.8 caribou/km^2 respectively.

Although the low-density stratum in the northern portion of region Central typically had few caribou, transect line 105 beside the inland Ice Cap was an exception. It had a density of c. 17 caribou/km^2. Transect lines 53 and 61 in the mid-interior had densities of 1.6 and 2 caribou/km^2 respectively.

Large tracts where few caribou were present were also noted. The area between transect lines 18 and 193 were little used for other than "bee-line" migration trails heading due north through there. This pattern was also noticed during the ground counts of 1998 and 2000. There were seven transects in the high-density stratum where zero or one caribou only were sighted. These were transects 3, 18, 58, 65, 136, 181 and 186. There were four transects in the low-density stratum with zero caribou sighted. These were transects 15, 52, 95 and 126.

Ameralik caribou distribution

With the exception of the Godhåb Peninsula, high concentrations of caribou occurred along the Davis Strait coast. Coastal transect 40 had the highest count of caribou, 94 animals, which gave a local density of 20 caribou/km^2. The nearby transects 34, 167, 170, 91, 258, had densities of c. 11, 10, 7, 5 and 5 caribou/km^2 respectively. Further to the north both transects 257 and 41 had a density of c. 6 caribou/km^2, while line 295 had 8/km^2.

Another relatively densely populated area was the inland within a c. 25 km radius of Kapisillit. Transects 94, 267, 206, and 282 had densities of 8, 7, 6, and 5 caribou/km^2 respectively. Uneven distribution occurred. Transect lines 46, 44, 190 and 7 had densities of ≤ 2 caribou/km^2, while transects 109 and 271 had zero animals. Other transects lay somewhere inbetween.

The area around the Kangerdluarssungûp taserssua lake was not as heavily populated. Densities of only 3 caribou/km^2 were observed on lines 212 and 37, and all other transects had densities ≤ 2 caribou/km^2, with 2 transects, 233 and 182, having zero caribou.

On the 12th of March while flying past Storø, which is an island just north east of Nuuk within the Godthåbsfjord system, a single group of about 30 caribou were sighted on the northern end. There were remarkably few caribou around and behind lille Narsaq, which is at the mouth of Ameralik Fjord. Plenty of caribou were observed using high elevations beside & crossing mini-ice caps high in the mountains.

Two caribou "highways", having an enormous volume of caribou moving south, were observed. The first was a north to south crossing on the Sermeq glacial tongue in inner Alángordlia fjord. The second was over the sea/fjord ice at the mouth of Sermilik fjord between Kavssaq and just east of Issaussat Nunaat, which roughly corresponds to the south end of transect line 40 and the north end of transect 170. A total of 125 animals were observed just on the 600 m width of those two transects. These two observations led to including these areas in the range for the Ameralik herd. Otherwise, there was a total lack of caribou tracks in the rugged terrain between the Ameralik and Qeqertarsuatsiaat herd.

Qeqertarsuatsiaat caribou distribution

Within the Qeqertarsuatsiaat range caribou trails were visible in the new snow. It was apparent that the caribou were making a "bee-line" migration in a WSW to ENE direction, i.e., moving from their winter range (many observed craters and animals) on the mainland uplands east of the town of Fiskenæsset/Qeqertarsuatsiaat and returning to the inland near the Ice Cap for the spring. Movement appeared to have already been under way for some time when the area was surveyed 21-22 March 2001.

This relatively small population uses only a small portion of the area available. Of the 21 transects flown, 13 had zero caribou. The greatest densities were observed inland near the Ice Cap. Specifically transect 26 had 6 caribou/km^2, while transects 3, 14, 126, each had 3 caribou/km^2, and transects 59, 12 each had 2 caribou/km^2. No animal tracks were seen on the coastal flats near Fiskenæsset/Qeqertarsuatsiaat or to the north.

Although no caribou were sighted, some tracks were observed in the Tasiussarssuaq fjord area, and many north of Bjørnesund, while almost none were seen south of it. In the extreme southern portion of region South, with the exception of one old single caribou track, there was no evidence of caribou on transect lines 86, 108 and 140 or the areas between. The mountain ridge, comprising the mid-portion of the south shore of Bjørnesund, possessed thick deep expansive lichen heaths on the snow-free south-facing apline slope. These heaths appeared totally untouched by caribou, and no caribou trails were present in the area immediately south of Bjørnsund.

Natural mortality

No dead caribou were observed in region Central. In region South one sickly caribou, a female, and one dead caribou were observed. The dead caribou lay on the fjord ice directly below a steep rock face, which was covered in lichen. It was assumed the animal had fallen to its death.

Snow / Ice cover

Region Central

Overall, region Central had ^{3} 90%snow cover. The low-density stratum typically had deep snow with full cover, however the high-density stratum was more variable. Several random transect lines flown had as little as 40% snow cover, others somewhat more in a gradient up to 80%. The low flight altitude and speed, plus the narrowed strip width, were necessary for detecting caribou under these conditions.

Region South

Snow conditions on the Amerlik herd's range were extremely variable, even along the length of a single transect. At the coast snow cover ranged from 55-90%, but could reach lows of 10-25%. The area around Kangerdluarssungûp taserssua lake ranged from 25-99% and then became almost nonexistent in proximity to the inland Ice Cap east of the lake.

Snow cover on the Qeqertarsuatsiaat herd's range also spanned from c. 10-90%. Within the Qeqertarsuatsiaat range, just south of Sermeq glacial tongue, there was a large area, which was also surrounded by lesser alpine glaciers and another glacial tongue from the Ice Cap. This area was thoroughly covered in severely deep snow. There were no caribou tracks or any evidence of caribou activity in this area.

Atypically, there was no fjord ice on Buksefjord. Sermilik fjord had only half the usual ice cover (Ulf Østerlund pers. comm.). Grædefjord (Kangerdluarssugssuaq) was $3/4^{ths}$ ice covered and there were caribou tracks crossing the ice everywhere over this fjord. Kaangnaitsoq fjord was $2/3^{rds}$ ice covered. Although usually totally covered with ice, Aniggaq and the "square" of fjord waters surrounding the island of Qeqertarssuatsiaq were all ice free. Tasiussarssuaq fjord had ice only in the inner most head of the fjord. Bjørnesundfjord usually has ice right out to the sea coast. It was 99% ice-free. This year there was no ice until the head of the fjord, and even that ice was thin and grey coloured. Where a river spilled into the fjord head there was no ice at all. Ikaatoq fjord was perhaps half covered with ice, again only in the inner head of the fjord.

Aerial survey logistics

This survey used about 18 hours of flying time. The AS 350 helicopter employed, could fly approximately 2.5 hours before needing to refuel. Although an aged datalogger was used for 7 days, it functioned only 1.5 days. Problems included, wiring, lack of GPS connection, failure to record data when button depressed and arbitrary shut-downs during flight. This would have led to a loss of data if it were not for the manual "click-counters" used by all observers to record number of caribou seen on a strip.

Numbers of caribou seen by the best back seat observers were never significantly ($p < 0.05$) better or worse than the front seat observer. Observer ability to see caribou varied little during this survey, and all were competent, i.e., good at sighting caribou.

Ground survey logistics

Spring ground fogs in April often immobilized field teams, and spring melt began already in late March. The latter often resulted in flooding over river and lake ice, which commonly was dangerously hidden under deep snow.

Discussion

Survey method & design

Reducing negative bias by increasing sight-ability of caribou on transects

This survey incorporated several differences in methods over previous surveys (Table 6), which reduced the negative bias associated with observers failing to detect caribou actually within the transect strip. The obvious changes were the lower and slower flying at a constant height over the gound, and the narrow short strips. Not so obvious was that the sun was usually kept behind the observers, in contrast to the 1993-96 surveys where the sun was normally in observer's eyes at least half the time, often over a 100 kilometre long transect. The new 2000–01 methods promoted full observer concentration and reduced observer fatigue. Together, these improvements served to increase the sight-ability of caribou, thereby reducing the bias associated with violation of the assumption that all caribou within the strip are observed. In the 1993-96 surveys, the long transects, flown at high speed and altitude, regardless of sun direction likely increased observer fatigue and provided poor observation conditions. All would increase negative bias and decrease accuracy of the calculated population estimate.

Acknowledging how difficult it is to estimate animal abundance, the present survey methods reduced bias. Further, with 2 people observing the same side of each transect, a correction for missed caribou was possible. Both increased survey accuracy. Negative bias, however, was not eradicated. Caribou present on a strip could still be missed because they were hidden behind terrain features. On occasion in the event of hills or gullies, the low flight height of 15 metres prevented a full strip width visibility to either or both sides of the helicopter. Therefore the present estimates may be considered underestimates.

Caribou population size estimates for 2001

The March 2001 population estimates were 1) Akia-Maniitsoq population c. 46,236

Table 6. Method and design for the 1993, 1996, 2000 & 2001 aerial surveys.

Year	2001	2000	1996	1993
Aircraft type	Helicopter	Helicopter	Fixed-wing	Fixed-wing
Total strip width (m)	600 (2 x 300)	1.000 (2 x 500)	1,400 (2 x 700)	1,400 (2 x 700)
Mean flight speed (km/hr)	80	100	167	167
Flight altitude (m (feet))	15 (50)	100 (328)	152 (500)	152 (500)
Strip type	Transects	Transects	Transect nets	Transect nets
Strip length (km)	7.5	7.5	Variable; c. 8 to 100	Variable; c. 8 to 110
Strip selection	Random	Random	Uniform spacing	Variable spacing
Strip alignment	Random	Random	North - South	Variable
Observers	3	3	2	2
Time of year	March	March	April	April
Correction missed caribou	Yes	Yes	No	No

(37,115 – 55,808; 80% CI), 2) Ameralik population c. 31,880 (24,721 – 39,305; 80% CI) and 3) Qeqertarsuatsiaat c. 5,372 (2,864 – 8,244; 80% CI). The present herd size estimates are larger than all recent previous estimates for these herds, and habitat degradation is evident for Akia-Maniitsoq and Ameralik. Since 1993 population growth would have been probable, given the initial 2 year hunting ban, subsequent low quotas, male-biased harvesting, lack of predators, and the 1990's high calf recruitment and good range condition. Still, the current numbers may not reveal so much an enormous increase in population size since 1996, but more accurate and precise estimates of caribou number actually present in a region. The status for the Akia-Maniitsoq caribou herd in 2001 may actually be of a herd already in a decline, or on the brink of one, since annual recruitment rate has dropped since 1998. The status of the Ameralik caribou herd in 2001 may be of a herd in decline, since winter range degradation is evident, annual recruitment is low, density is high, and local knowledge suggests that peak herd number occurred already c. 1997-1998. The status of the Qeqertarsuatsiaat caribou herd may be good, since this herd has excellent recruitment, and reasonable density, but no information about range quality is available.

Herd Structure

Akia-Maniitsoq, Ameralik & Qeqertarsuatsiaat herds

The bull to cow ratios are female skewed. This is not abnormal. Akia-Maniitsoq's especially skewed 2001 value may reflect the better area coverage achieved by the aerial versus the ground surveys. The Akia-Maniitsoq 2001 ratio was about one bull to every 1.7 cows, while the Ameralik bull to cow ratio 2001 was 1.2 females for every bull, and the Qeqertarsuatsiaat bull to cow ratio was 1.4 females for every bull. These figures can be interpreted as better than the typical ratio for herds not exploited by selective sport hunting, which can be 1.8 females for every bull (Parker 1972). The current bull to cow ratios are similar to the Kaminuriak barren-ground caribou herd of North American, although higher proportions of bulls may occur in Alaskan herds with greater first year calf survival (Parker 1972). Since selective hunting for bulls, 90%, has been prevalent in Greenland from 1995-98 (Loison et al. 2000), when quotas were c 2,000 to 4,000, today's relatively even sex ratio suggests that those low harvests had little effect on the population's sex ratio. If male-skewed harvesting persists, the current large quotas may have great effect on sex ratio.

Herd structure appears to have been variable since 1993 (Tables 5, 7, 8). Still, the Akia-Maniitsoq 2001 values of 17% calves and recruitment of 31 calves/100 cows are low, considering there are no predators. These values are half of what they were in 1998, when the calf percentage of 25.2%, and late winter recruitment of 65 calves/100 cows would have promoted rapid increase in population. The number of calves in the Ameralik population is also low. Inside the

Table 7. Herd structure parameters in late winter for the Akia-Maniitsoq caribou herd, region Central, 1982 – 1996.

NB! Mangler der ikke nogle numre her?????

Parameter	1996	1995	1994	1993	1990	1982
High density (caribou/km²)	0.7	0.6	0.3	0.3	2.0	
Low density (caribou /km²)	0.2	0.3	0.1	0.2	0.2	
Average group size	2.5	3.2	3.4	2.8	5.2	3.5
Calf %	21.0	16.1	27.2	3.5	25.3	
# sexed/aged	1,511	961	475	536	495	
Reference	3	3	3	3	2	1

1. Thing 1982, 2. Thing & Falk 1990, 3. Ydemann & Pedersen 1999.

Alángordlia fjord only one calf was observed out of c. 300 caribou during the autumn of 1999 (Birger Knudsen pers. comm.). The Ameralik 2001 survey values of 18% calves and recruitment of 40 calf/100 cows are also low, again considering there are no predators. Only the Qeqertarsuatsiaat herd had high 2001 values, 26% calves and late winter recruitment of 61 calves/100 cows. These would promote rapid herd increase. The Qeqertarsuatsiaat calf percentage is also generally much larger than those from the 1993-1995 surveys (Table 9), and rapid increase is possible.

Although the 2001 recruitment values are generally higher than for studies from North America and Scandinavia, which report late winter recruitments of 20 calves, 22 calves and 41 calves/100 cows (Dzus 1999; Parker 1972; Fancy et al. 1994 respectively), these populations have predators. A comparison with the Southampton Island herd, which like Greenland has no predators shows late winter recruitments varying between 22 and 77 calves/100 cows (Heard & Ouellet 1994). Variable climate may be a factor involved in the latter's unstable recruitment.

Causes for the low recruitment observed in the Akia-Maniitsoq and Ameralik herds are unknown, but density-dependant effects of intra-specific competition brought about by too many caribou on the range can increase juvenile mortality (Skogland 1985). Climate may also have a role. The Qeqertarsuatsiaat recruitment value is higher than for studies from North America and Scandinavia, which is to be expected given the lack of predators.

Caribou Density

Akia-Maniitsoq herd

Today, caribou density is 4.0 caribou per km^2 in the high-density stratum and 1.1 caribou per km^2 in the low-density stratum. Caribou densities of 2 caribou/km^2 are considered high, a threat to vegetation, and to result in dispersal thought due to competition for food (Haber & Walters 1980), and even the latter has been considered too high for range recovery in region North (Thing

Table 8. Herd structure parameters in late winter for the Ameralik caribou herd, region South, 1982 - 1996.

Parameter	1996	1995	1994	1993	1982
Density (caribou /km^2)	0.9	0.8	0.3	0.2	
Average group size	3.5	5.3	5.4	3.9	8.5
Maximum group size					52
Calf %	16.2	14.5	21.8	3.1	
# sexed/aged	989	604	209	229	
Reference	3	3	3	3	1

1. Thing 1982, 3. Ydemann & Pedersen 1999.

Table 9. Herd structure parameters in late winter for the Qeqertarsuatsiaat caribou herd, region South, 1993 - 1995.

Parameter	1995	1994	1993
Density	0.09	0.01	0.03
Average group size	3.5	6.0	1.9
Calf %	11.3	25.0	14.8
# sexed/aged	80	12	27
Reference	3	3	3

3. Ydemann & Pedersen 1999.

1981). In northern Finland a density of 4 caribou/km^2 of effective lichen heath has been shown to be too high to sustain a lichen heath in optimal condition (Helle et al. 1990). The caribou density in the present study refers to all area and not just to the effective area of lichen heath, which will be smaller. Overgrazed or trampled lichens take perhaps 30 to 40 years to recover to depths of 0.5 to 2 cm (Vibe 1967). Recovery following overgrazing may actually be longer. On St. Matthews Island 22 years after overgrazing the lichens had recovered only to 10% of original value (Klein 1987).

Ameralik & Qeqertarsuatsiaat herds

Today, caribou density is 3.7 caribou/km^2 for the Ameralik herd. Lichen heaths around Ameralik fjord were once plentiful and second only to those found in region Central (Thing & Falk 1990). The lichen heaths of the Ameralik area have already been damaged by overgrazing and trampling during the late 1990's (Lund et al. 2000). The Ameralik caribou herd density has likely been too high for their range for several years.

Today, caribou density is 1.1 caribou/km^2 for the Qeqertarsuatsiaat herd. This density refers to the entire area and not just to the effective area of lichen heath, which will be smaller. Any calculation using effective areas will increase density values to more realistic estimates. The present density should not be permitted to give a false sense of security about the Qeqertarsuatsiaat herd. The condition of the lichen range in Qeqertarsuatsiaat is generally unknown, although it appeared healthy south of Bjørnesund and caribou have been scarce there for decades.

Caribou distribution

Akia-Maniitsoq herd

The literature documents that when caribou numbers are high then animals appear along the Davis Strait seacoast. Local knowledge from the Maniitsoq area tells that during the caribou population high of 1825-1850, the Akia-Maniitsoq herd expanded its range into the coastal regions even as far as Hamborgerland island, which is north of the city of Maniitsoq, further that when the population decreased, 1850-1950, the herd retreated to areas near the inland Ice Cap (in Meldgaard 1986).

Meldgaard (1986) gives sources, which describe region Central caribou distribution 100 years ago. Caribou were numerous between the lake, Taserssuaq, and the inland Ice Cap and were also common between lake Taserssuaq and the Søndre Isortoq river. Caribou only occurred west of the Sukkertoppen Ice Cap when the population was large (Meldgaard 1986). Thing (1982a) observed no caribou along the outer Davis Strait coast, instead most animals occurred in the south central and south eastern portion of the region, which is considered their traditional wintering range, i.e., from Tasiussarssuaq fjord and Quagssugtarssuaq mountain in the east, down to Qugssuk fjord and east over to lake Taserssuaq and to Ujaragssuit Nunaat and Ivisartoq by the inland Ice Cap. There were also some caribou between Majorqaq and Sukkertoppen Ice Cap. Winter surveys of the 1980's found most caribou concentrated on either side of lake Taserssuaq and Ilulialik fjord (Strandgaard et al. 1983). The highland northern third of region Central was thought to be a calving area during the late 1970's and early 1980's (Strandgaard et al. 1983). This has since been confirmed by Cuyler & Linnell (in press). The 1995 and 1996 surveys again confirmed low caribou densities in the northern third of region Central (Ydemann & Pedersen 1999).

During the 1990's caribou began using the Davis Strait seacoast. Although the 1995-1996 surveys did not observe many caribou along the Davis Strait coastline, local knowledge knew that caribou were occupying that coastline and islands, and had been since the early 1990's. Further that this had never occurred before. Specifically since 1997 increasing numbers of caribou used the islands and coasts of the Davis Strait in the Atammik area. The present study also observed high densities of caribou along the Davis Strait seacoast.

Further inland, along the inner Godthåbsfjord coasts, caribou are also now noticeable at shorelines. Since 1996, and until this study, more caribou have been present, than ever remembered, near the coasts of region Central and hunters could make easy kills by just cruising the fjords. The present study also observed high densities of caribou along the Godthåbsfjord coasts.

Caribou in west Greenland use seacoast areas when caribou numbers are high (Grønnow et al. 1983; Meldgaard 1986). Caribou also move when food is in short supply (Haber & Walters 1980). The greater the lack of food the greater the caribou will move (Baskin 1990). Coupled with the present population size estimate, the above distribution data strongly suggests that the Akia-Maniitsoq herd has been increasing for several years, and were particularly abundant in March 2001. Food supply may have begun to be a limiting factor.

Ameralik herd

Caribou number in the northern portion of region south was low for years. Meldgaard (1986) gives sources, which describe region South Ameralik caribou herd's distribution 100 years ago. It was good on the nunataks, Nunatarssuaq & Akugdlerssuaq, which are east of the settlement Kapisillit. The population south and east of Ameralik fjord was then described as "large". During the early 1980's few caribou used the western half of the region, but concentrated themselves in the northeastern corner (Thing 1982a). Winter caribou distribution in the early 1980's was concentrated primarily in the areas north and south of the lake Kangerdlusarssungûp, with calving occurring in the continental inland area near the Ice Cap (Thing 1982a, Strandgaard et al. 1983). Summer found the animals dispersed. Then towards winter the animals followed their old trails westward to their coastal wintering range (Meldgaard 1986; Aastrup 1984). During the winter of 1990, caribou still occupied the land north of the lake Kangerdluarssungûp taserssua since range quality south of the lake was poor (Thing & Falk 1990). The above describes the Ameralik caribou herd's distribution when numbers were low.

Recently caribou number increased. Range expansion has been evident during the 1990's. Before the 1990's caribou paths were nonexistant on the outer Godthåbs peninsula or in the Ameralik/Buksefjord area, however by the late 1980's and during the 1990's both paths and animals became noticeable. Currently the Ameralik caribou population appears to be using seacoast areas and moving away from the northern portion of region South, which is overgrazed (Lund et al. 2000), and colonizing little-used coastal range further south, which borders on the Qeqertarsuatsiaat caribou range.

Since caribou movement is proportional to food scarcity and Greenland caribou use seacoast areas during population peaks, the above suggests that Ameralik herd size has been high for several years already and that range condition is already a limiting factor. The present population size estimate and documented overgrazing makes further caribou movement probable. Range degradation at new locations may follow.

Although this survey observed no caribou tracks between the actual Ameralik and Qeqertarsuatsiaat herds, given the southward movement of the Ameralik caribou, mingling of these two sub-populations may occur in future.

Qeqertarsuatsiaat herd

Qeqertarsuatsiaat caribou are generally found in the inner reaches between the heads of the major fjords and the inland Ice Cap, i.e., heads of the fjords, Grædefjord, Qeqertarsuatsiaat kangerdluat, and Bjørnesund (Agdlumersat) (Meldgaard 1986). Distribution during the autumn hunting season was locally known to be best in the inland areas close to the inland Ice Cap (Meldgaard 1986). This was also the case during an air survey in 1982 (Strandgaard et al. 1983). Local knowledge tells that shifts in distribution have occurred in the past (Meldgaard 1986). Large concentrations can in some years be found around the fjord head of Grædefjord (Kangerdluarssugssuaq) and other years around the fjord head of Bjørnesund (Agdlumersat), although caribou are seldom observed south of Bjørnesund. Annual movements include moving to low lying coastal wintering areas in September-October and in spring moving inland to calving grounds and summer ranges (in Meldgaard 1986).

The present study found a similar distribution of caribou to that described above. No caribou were found near the Davis Strait seacoast. This may have been due to the lack of sea ice on the fjords. Caribou may be reluctant to swim cold fjords in late winter, if lichen range was adequate where they were. Given that Greenland caribou use the seacoasts during population peaks and move greatly when range is poor (Haber & Walters 1980; Grønnow et al. 1983; Meldgaard 1986; Baskin 1990), their present distribution suggests that their herd size is not near a peak and further that their range is adequate for the present density. Most animals were in the rugged uplands just east of the town of Fiskenæsset/Qeqertarsuatsiaat. Surprisingly the spring migration to the inland had begun at the time of this survey. The area where migration movement occurred was surveyed in under 2 hours and against the flow of movement, which removed the possibility of double counting. Further, the observed maximum straight line movement for west Greenland caribou in March was under 5 km per day (Cuyler & Linnell in press).

Expected natural mortality

Adult natural mortality for caribou in 5 North American herds without natural predators is 4-6% annually (Bergerud 1967; 1971; Skoog 1968; Kelsall 1968), which corresponds to a life expectancy of 17 to 25 years. Adult annual natural mortality has been c. 8% on Southampton Island (NWT, Canada), which is also without predators (Heard & Ouellet 1994), and Thing (1982b) suggested a natural mortality of 7% for adult caribou of region North in west Greenland. Actual natural mortality values for Greenland caribou appear around 8-10%, given the general life expectancy of 10 to 12 years found in Loison et al. (2000) and Cuyler & Østergaard (2002). It should come as no surprise to find a number of dead caribou in the terrain over the course of each year. During a lifetime of hunting, Kristian Egede (pers. comm.) found about 10 dead caribou a year while out in the terrain.

Using a natural mortality of 8-10% and the current population estimate of c. 46,236 (37,115 – 55,808; 80% CI) caribou for the Akia-Maniitsoq herd, equates to an expected natural mortality of between c. 3,700 and 4,600 caribou each year in region Central. Similarly, the expected natural mortality is between 2,500 and 3,200 caribou each year for the Ameralik population and between 400 and 550 caribou for the Qeqertarsuatsiaat population.

Implications for caribou harvest

Akia-Maniitsoq & Ameralik herds

Given the 2001 herd size estimate of c. 46,236, observed caribou densities and distribution, and local knowledge on range expansion, it is possible that the Akia-Maniitsoq caribou herd is now a threat to its range. The herd may even have reached peak numbers, given its present seacoast distribution, low calf recruitment and evidence of range degradation. The situation is similar for the Ameralik caribou herd, which appears to have been abundant for several years already, given the expanded distribution to the seacoast, local knowledge accounts, and documented range destruction of the late 1990's. Today the 2001 herd size estimate of c. 31,880 (80% CI: 24,721 – 39,305) caribou coupled with the observed high density, low calf recruitment and poor range suggest a herd primed for a decline.

Preventing further destruction to the range is necessary if healthy herds of reasonable size are to be maintained in future. Caribou density likely needs to be reduced to prevent range destruction. Thus the herds should not be allowed to increase further, rather a decrease from present numbers is advisable. Maintaining a low caribou density for several decades could allow sustainable lichen heaths. A target density of under 2 caribou/km^2 is suggested as a management goal to be reached by 2006. Given the nearby large number of potential hunters, regulated harvest pressure could be a useful management tool influencing herd size, density and herd structure.

Since 1995 the caribou harvests have been severely (90%) sex-biased towards males (Loison et al 2000). Highly male-biased sex ratios in harvesting can lead to greatly reduced female fecundity and population collapse (Ginsberg & Milner-Gulland 1994), and may even endanger the genetic variability of a population (Ryman et al 1981). Because of this and the need to reduce herd size, more females in the harvest are needed. Neither halting population growth nor herd size reduction can be effectively achieved through hunter harvest unless females make up a large proportion of the quota taken.

Qeqertarsuatsiaat herd

Today the 2001 Qeqertarsuatsiaat caribou herd size estimate of 5,372 (80% CI: 2,864 – 8,244) caribou is coupled with an excellent calf recruitment and reasonable caribou density for the area. The present size of the herd appears to promote large healthy animals, while not representing a threat to range quality. However, little is known about lichen range in the area. Maintaining the herd at its current size estimate through wise harvesting may be sustainable for both herd and range.

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Appendix 1
Local knowledge on animal abundance

Local knowledge sources have been plentiful regarding the Ameralik caribou population, fewer for the Akia-Maniitsoq herd and only a single source was available for the Qeqertarsuatsiaat caribou population. This reflects the haphazard collection of local knowledge, rather than a definite lack of sources. Future work would benefit from a more systematic approach for identifying good sources of local knowledge.

Akia-Maniitsoq caribou population – region Central

Despite the survey estimates from 1977-1996, local knowledge suggests that the Akia / Maniitsoq caribou herd number has increased steadily with each decade since the 1950's until present day with no marked peaks or drops (Kristian Egede & Jacob Poulsen pers. comm.). Prior to the 1950's caribou on Akia/Nordlandet were very scarce (Bjørn Rosing & Kristian Egede pers. comm.). By the 1990's caribou were commonly seen on Akia/Nordlandet (Bjørn Rosing pers. comm.). Further, Jacob Poulsen (pers. comm.) describes the following. During the 1970's it would take 3 to 4 men one week to hunt 6 to 8 caribou, however during the 1980's 4 men could easily take 14 caribou in one day and another 4 to 5 more over the next 2 days for a total of 5 caribou per man. Since the early 1990's caribou have been observed along the Davis Strait coastline and islands, further that this had never occurred before (Jacob Poulsen, Victor McGregor, Tittus Egede & Kristian Egede pers. comm.).

Ameralik caribou population – region South

Generally local knowledge suggests Ameralik caribou number was low 60 years ago, rose steadily through the 1980's, and attained a high during the late 1990's. Local knowledge suggests that the Ameralik caribou population abundance was high just prior to this study.

The Ameralik caribou numbers were low during the 1940's and increased steadily since the 1940's, i.e., no marked peaks or drops, (Tittus Egede & Kristian Egede pers. comm.). In 1997 the caribou of Ameralik were described as too many (Jack Frederiksen, Jens Bjerge, Bjørn Rosing, Tittus Egede & Nikolaj Heinrich pers. comm.). By 1998 caribou were plentiful everywhere, not just at the inner fjord coastlines, but also on the islands and coasts of the Davis Strait (Tittus Egede & Nikolaj Heinrich pers. comm.). There are always caribou in the northeastern corner (between Kangerdluarssungûp taserssua/Maeragdla/Naujat kûat) of region South, because this area receives little snow (Jens Bjerge pers. comm.).

Bjørn Rosing (pers. comm.) described the situation as follows. Hunter effort decreased steadily from the 1940's until present day, e.g., long hikes inland and up to one week were needed to get 1 or 2 caribou during the 1940's. By the 1970's hunting was easier, but one still had to walk far inland. The same applied to the 1980's, but by then one could see plenty of animals. Already during the hunting ban, 1993-94 there was a noticeable increase of caribou occurrence on the low coastal flatlands at the mouth of Buksefjord during both summer and winter, and also along the coast north to Lille Narsaq and Ameralik. Caribou were first seen at Lille Narsaq in 1994 or 1995, and caribou presence on the coast increased steadily thereafter. Since 1995, one no longer needed to go into the traditional inland hunting areas. A 1 km walk from your boat would obtain all the caribou wanted. Finally by the late 1990's animals could be taken from the beaches. Behaviour has changed in recent years. Prior to the hunting prohibition in

1993 the caribou were wary, which meant hunters had to sneak up to them. However since the hunting ban was lifted in 1995 the caribou are no longer wary, e.g. they now wander close to cabins and hunters. Hunting became easier after the hunting ban (Morten Jørgen Heilmann pers. comm.).

Geologist Victor McGregor (pers. comm.) describes a similar picture. In 1968-69 there were no caribou anywhere in the vicinity of Lille Narsaq (abandoned village) or Prestefjorden. During the 1970's there were no caribou paths, or caribou to speak of, on the south shores of Ameralik fjord. By the mid-1980's and early 1990's, however, there were definitely more caribou and caribou paths could be seen everywhere, and the vegetation was showing signs of overgrazing. Esmar Bergstrøm (pers. comm.) hunted and fished in the area between Ameralik and Sermilik fjords since 1970. 1985 was the first year he observed caribou there. Until then there were none. Now he sees them even at the coast near Færingshavn, e.g., 15 caribou were on a nearby tiny island during July 2000.

Since the late 1990's caribou have been observed year round on the low coastal flatlands between Buksefjord and Sermilik fjord. October 1998 saw exceedingly large numbers of caribou at Lille Narsaq and along the seacoast between Ameralik fjord and Buksefjord, when c. 2000 caribou were observed, and there were noticeably more caribou in 1998 than there had been in 1997 (Lars Mathiasen pers. comm.). During mid-October of 1998 Jens Bjerge & Jack Frederiksen (pers. comm.) noticed that the Ameralik caribou were numerous, in large groups and on the move. There were c. 100 at the head of Buksefjord, c. 300 at the mouth of Eqaluit, 5 km west, and c. 500 in Præstefjorden. There had been only 150 to 200 caribou in Præstefjorden the previous year (Jacob Rhode pers. comm.). All tracks led to the Davis Strait sea coast, where pilot Göran Lindmark (pers. comm.) observed, over 200 caribou in October/November 1998. That autumn the Greenland Institute of Natural Resources counted just under 1,000 caribou along the shoreline in the vicinity of Lille Narsaq (GNI unpublished data). Large numbers of caribou reoccurred in the autumn of 1999 (Tittus Egede pers. comm.). In the autumn 2000 a group of c. 50 caribou were seen at Lille Narsaq (Hans Henrik Skott pers. comm.).

On the Godthåbs peninsula, which defines the north side of Ameralik fjord, Morten Jørgen Heilmann (pers. comm.) observed that before 1975 there were no caribou paths on the outer Godthåbs peninsula (last 20 km), however, more caribou were first noticed in the late 1980's and now caribou paths are present. Further, since 1996 there has been a small number of caribou, c. 20, every autumn near the Kobbefjord ski centre. Larger groups have been seen by others. A caribou group of 55 animals was observed on the north side of Kobbefjord, only c. 17 km east of Nuuk in 1998 (Atle Dahl pers. comm.) and later c. 30 caribou were observed in the same place (Arild Landa pers. comm.).

The large numbers seen along the shoreline during 1998 and 1999 were not seen even during Melgaard's (1983) suggested peak population size of the early 1980's, never in memory were so many animals to be seen at the coastlines (Bjørn Rosing, Minik Møller Lund, & Kristian Egede pers. comm.). The late 1990's saw caribou heavily using the Davis Strait coast between Ameralik fjord and Buksefjord, and even swimming out to the islands, Utorgarmiut and specifically Qeqertat timerdlît igdlue, at the mouth of Buksefjord (Lars Mathiasen & Nikolaj Heinrich pers. comm.). Hunters from Paamiut commonly sailed up to Sermilik fjord and entered Alángordlia fjord to take caribou, because animals could be shot from the beaches (Birger Knudsen pers. comm.).

Body condition has deteriorated in recent years. At present and since the late 1990's, caribou around Ameralik have had poorer body condition, i.e., thinner (Nikolaj Heinrich & Tittus Egede pers. comm.). Spring

2000 saw 15 to 20 caribou of poor condition in the vicinity of Lille Narsaq (Jan Kleinschmidt pers. comm.). Caribou taken in Alángordlia fjord in 1997 were large, but the harvests of 1999 and 2000 yielded thin animals (Birger Knudsen pers. comm.). The caribou seem too numerous and are trampling the range and pulling up bushes (Birger Knudsen pers. comm.), and the caribou were already coming out to the fjord shorelines and Davis Strait seacoast in late 1990's because their pastures were overgrazed in the inland (Nikolaj Heinrich pers. comm.).

Qeqertarsuatsiaat caribou population – region South

Few caribou have ever been observed south of Bjørnesund, however, those seen and the 5 shot in 2000 were big and fat (Birger Knudsen pers. comm.).

Appendix 2

Region Stratification & Transect Allocation

Region Central

Region Central was divided into two strata, one with high caribou density and one with low density (Figure 4). 34 transects were allocated to the high caribou density stratum, and 13 transects were allocated to the low density. Optimal allocation of transects between strata is governed as follows: the number of transects in each stratum must be proportional to the product of the stratum's area and the standard deviation of the caribou density within the stratum.

How many transects are needed?

One of the most important questions that have to be answered before undertaking any survey is whether the survey will yield data of a sufficient quality to answer the question that the survey attempts to answer; animal abundance. A related question is the choice of sample size. In a helicopter survey, where flight hours in Greenland are very expensive, this question becomes very important.

An idea of the expected variance is necessary. In flight surveys the variance is intimately related to the density of animals. The prior information available before the surveys was relative densities from a previous survey in 1996 and densities found in region North in 2000. The assumption made was that although the 1996 surveys used a radically different methodology, the relative densities would remain fairly constant. Implicit in that assumption is the expectation that the caribou populations in all regions have had similar growth rates since 1996 despite that they form clearly distinct populations with different demographics.

A simulation experiment was performed in the following fashion. The highest density area in the 1996 survey was the high-density area of region North, the density of the other areas was known as a fraction of the density of that high density area. For each simulated transect the number seen is found as follows. A random transect from the high-density area in region North is chosen

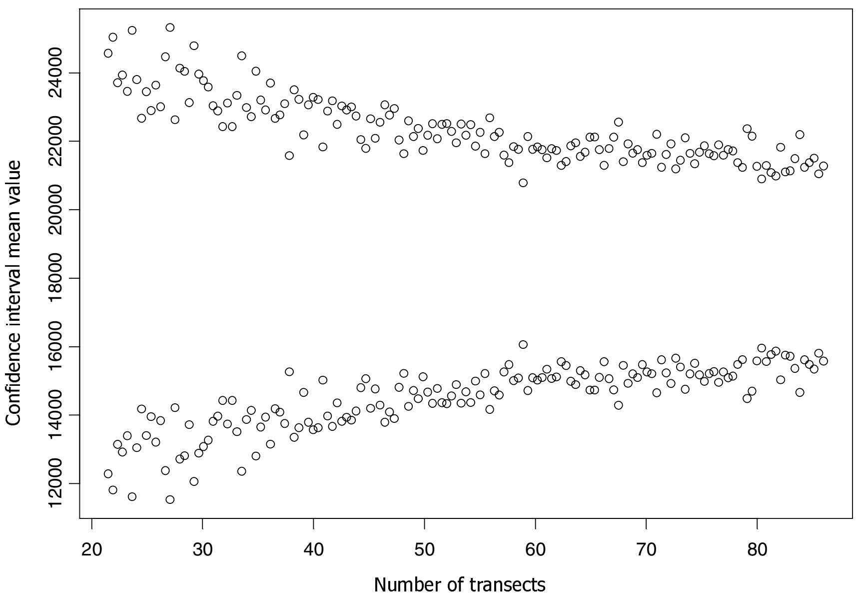

Figure 11. How many transect lines needed for a relatively accurate and precise survey of region Central. Simulation of confidence interval mean values versus the number of transects used.

and the number seen there is called "*s*". If *r* is the relative density of the area in question and *w* is the relative width of the transects then a number seen can be simulated as a binomial:

$$Binomial(s, r \cdot w)$$

Once a simulation was done, the resulting data was analyzed using standard parametric methods, and a confidence interval found. The procedure was repeated for different total numbers of transects. The data was then plotted by taking all the confidence intervals, centering these on their common mean and plotting them against the total number of transects (Figure 11).

From the graph it is obvious that an effort smaller than 40 lines will result in a wide confidence interval, whereas a number larger than 60 will be a waste of resources. The result is similar for region South. Note that the picture here is slightly misleading since it takes into account only the width of the confidence interval around the grand mean of the estimates. In reality the means will jump around less for higher sample sizes. For economic reasons the final number of transect lines was set to 48.

Transect allocation

Since region Central is divided into two strata with different expected densities, transect allocation must be decided. Here a simple mathematical method was used for allocating transects to each strata. The standard method for allocation of transects to strata is to allocate proportional to the product of the area and the expected standard deviation of each strata.

If: A_i is the area of strata i
d_i is the expected density of strata i

then the best allocation is proportional to

$$A_i \cdot d_i^{\alpha}$$

where: $\alpha = 0.5$ corresponds to the square root of the expected density.

Note that it is sufficient to have the expected relative densities and areas. For areas {1,..,i} the proportions of transects allocated to area 1 will be.

$$p_1 = \frac{A_1 \cdot d_1^{\alpha}}{\sum_i A_i \cdot d_i^{\alpha}} = \frac{1}{\sum_i \frac{A_i \cdot d_i^{\alpha}}{A_1 \cdot d_1^{\alpha}}} = \frac{1}{\sum_i \frac{A_i}{A_1} \cdot \frac{d_i^{\alpha}}{d_1^{\alpha}}} = \frac{1}{\sum_i \left(\frac{A_i}{A_1}\right) \cdot \left(\frac{d_i}{d_1}\right)^{\alpha}}$$

There are several ways of choosing a. For animals that tend to be in groups the question centres around whether they tend to increase the group size when the density is higher. If the group size is the same regardless of density then a = 0.5. If on the other hand the group size tends to go up with higher density without the number of groups changing then a = 1. In this case we chose a = 0.75 as a compromise solution.

The allocation assumed that the relative densities remained unchanged since last survey of 1996. The stratification was not the same as in the last survey, but was altered based on the observed densities in 1996. Region Central was divided into two strata, with the area northeast of Maniitsoq considered the low density stratum.

On the basis of the above mentioned formulas 13 transects were allocated to the low density area and 34 transects were allocated to the high density area.

Region South

Previous surveys have been unable to clarify distribution of caribou densities in region South. Survey stratification was therefore not possible. Region South contains two distinct caribou herds, the Ameralik and the Qeqertarsuatsiaat. If the region had contained only one herd the allocation scheme would have been similar to region Central. It is necessary, however, to make separate harvest recommendations for each herd. Therefore, a much simpler allocation scheme was chosen. The allocation was made according to the relative sizes of the two areas, so that each received identical coverage.

On this basis, 40 transects were allocated to the area of the Ameralik herd, and 21 to the area of the Qeqertarsuatsiaat herd.

Appendix 3

Survey field method and statistical design

Accuracy equates to the population size calculated being close to the true value. Bias, which makes the calculated population size depart from reality, results in inaccuracy. There can be bias in your counting, sampling design or even analysis. Precision is the measure of variation in the numbers of caribou on each of the transects. Poor precision can result from sampling errors, e.g., if group size and distribution were highly variable within a stratum.

Field methods

Reducing negative bias: Sightability of caribou on transect

To reduce the negative bias associated with violation of the assumption that all caribou within the strip are observed the following improvements in survey field methods, i.e., over those described in Cuyler et al. (2002), were used.

- Narrowed strip width, 300 x 2 metre versus 500 x 2 metre,
- Slower flying speed, c. 80 kilometre/hour versus 100 kilometre/hour,
- Several different observers, whom rotated seat positions, rather than the same observers in constant seat position for entire survey.

Statistical design

Caribou population estimates can be calculated as follows:
For each stratum we have:

$$\hat{N}_j = A_j \cdot \frac{\sum_i y_i}{\sum_i A_i} = \frac{A_j}{\overline{A}} \cdot \overline{y} \qquad (0.1)$$

Where

$\hat{N}_j$ Is the estimated total in the j^{th} strata

y_i Is the total number of caribou observed in strip i

A_j Is the total area of strata j

A_i Is the area of strip i

$\overline{A}$ Is the mean area of the strips in the stratum

Because the area of each strip is constant the calculation of variance is.

$$Var(\hat{N}_j) = Var(\frac{A_j}{\overline{A}} \cdot \overline{y}) =$$

$$\left(\frac{A_j}{\overline{A}}\right)^2 Var(\overline{y}) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot Var(\frac{\sum_i y_i}{n}) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n} Var(\sum_i y_i) =$$

$$\left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n^2} Var(\sum_i y_i) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n^2}(n \cdot Var(y_i)) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{Var(y_i)}{n}$$

$$\hat{V}ar(y_i) = s^2 = \frac{1}{n-1}\sum_i (y_i - \overline{y})^2$$

Since the total number of caribou in the area is the sum of the totals in each stratum the variance of the total will be the sum of the variances in the strata.

$$\hat{N} = \sum_j \frac{A_j}{\overline{A}} \cdot \overline{y}_j$$

$$Var(\hat{N}) = \sum_j \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{Var(y_i)}{n}$$

Appendix 4

Increasing the accuracy of aerial counts of caribou in western Greenland

Most aerial surveys of animal abundance are negatively biased because animals within the sample unit are over-looked by observers. Various double-count methods have been developed to generate survey specific correction factors. However, these methods require that observations can be attributed to specific individuals or groups, which is not always possible. We present a simple method for generating a minimum estimate of the number of overlooked animals based on the total number of animals seen by double observers on one side of the aircraft. In addition, we describe aspects of survey design that have been used in caribou *Rangifer tarandus* surveys in west Greenland to further reduce bias.

The extent to which animals are overlooked can be influenced by many factors such as aircraft design, flying speed, flight height, light conditions, vegetation density, topographic complexity, and observer experience/fatigue (Caughley 1974; Samuel, Garton, Schlegel & Carson 1987; Aastrup & Mosbech 1993). Early attempts to correct for this bias focused on determining a factor from a series of controlled trials, and using this as a blanket correction factor for all further surveys (Caughley 1974; Caughley, Sinclair & Scott-Kemmis 1976; Samuel et al. 1987; Pollock & Kendall 1987; Aastrup & Mosbech 1993). However, because conditions vary from survey to survey there have been attempts to develop survey-specific correction factors, especially using the double-count methodology (Pollock & Kendall 1987; Graham & Bell 1989; Rivest, Couturier & Crepeau 1995). In this process, at least one side of the aircraft has two observers. Using the numbers of animals or groups seen by the first observer only, the second observer only, or by both observers it is possible to apply capture-mark-recapture methodology to calculate the number of animals seen by neither observer (Pollock & Kendall 1987). However, this requires that observations from the two observers can be attributed specifically to each animal or group observed. While such results may be achieved using double-track tape recorders (Marsh & Sinclair 1989) or GPS/data logger technology, there are always situations whereby technology fails, is unavailable or cannot be applied practically. We present an extension of the normal double-count statistics to estimate the correction factor for the proportion of animals unseen using the total number of animals counted by each observer within a given sample strip. In many ways this is similar to the aims of Caughley & Grice (1982), but is designed for species that occur at a higher density.

Accounting for overlooked animals

In the cases where there are more than one observer in one side of the aircraft and it is possible to know which animals have been seen or not seen by each observer it is possible to estimate the probability that a visible animal has been observed. The method is thoroughly discussed in Pollock and Kendall (1987) and will be slightly elaborated upon here. We will use the following nomenclature similar to the one used by Graham & Bell (1989).

B	is the number of animals observed by both observers
S_f	is the number of animals observed by the front seat observer only.
S_r	is the number of animals seen by the rear seat observer only.
M	is the number of animals not seen by either observer
p_f	is the probability that a visible animal is seen by the front seat observer
p_r	is the probability that a visible animal is seen by the rear seat observer
N	is the total number of visible animals in the transects

Then

$$N = S_f + S_r + B + M$$

In a conventional double-count set up where animals or groups can be individually identified for comparison between observers the following procedure is often used;

B can be estimated as $E(B) = p_f \cdot p_r \cdot N$

Therefore $N = \frac{E(B)}{p_f \cdot p_r}$

In the same manner S_f can be estimated as

$$E(S_f) = p_f \cdot (1 - p_r) \cdot N$$

By substitution

$$E(S_f) = p_f \cdot (1 - p_r) \cdot \frac{E(B)}{p_f \cdot p_r}$$

$$E(S_f) = (1 - p_r) \cdot \frac{E(B)}{p_r}$$

$$E(S_f) \cdot p_r = E(B) - E(B) \cdot p_r$$

$$(E(S_f) + E(B)) \cdot p_r = E(B)$$

$$p_r = \frac{E(B)}{E(B) + E(S_f)}$$

In the same manner p_f can be estimated as

$$p_f = \frac{E(B)}{E(B) + E(S_r)}$$

Thereby the proportion of animals overlooked by both the front and the rear seat observer is

$$(1 - p_f) \cdot (1 - p_r)$$

therefore, the number of observed animals in the left side of the helicopter should be multiplied with

$$\frac{1}{1-(1-p_f)\cdot(1-p_r)} = \frac{1}{1-(1-\frac{B}{B+S_r})\cdot(1-\frac{B}{B+S_f})} = \frac{(B+S_f)\cdot(B+S_r)}{B\cdot(B+S_f+S_r)}$$

Or equivalently

$$\hat{N} = (B + S_f + S_r) \cdot \frac{(B+S_f)\cdot(B+S_r)}{B\cdot(B+S_f+S_r)} = \frac{(B+S_f)\cdot(B+S_r)}{B}$$

And, under the assumption that the left and right rear seat observers have the same probability of observing a visible animal, the right side observations should be multiplied by

$$\frac{1}{p_r} = \frac{B + S_f}{B}$$

This method does not take into account the variance in the estimates of p_f and p_r. The easiest way to find confidence intervals is to use a bootstrap procedure (Effron & Tibshirani 1993).

The estimates of p_f and p_r are equivalent to the Petersen estimate. Although this estimate is biased, the bias can be eliminated using Chapman's correction.

$$\hat{N}_{left} = \frac{(B+S_f+1)\cdot(B+S_r+1)}{B+1} - 1$$

(Graham & Bell 1989)

Then $\frac{\hat{N}}{S_r + B}$ will be an estimate of $\frac{1}{p_r}$

Hence the estimate of the number of animals on the right side of the aircraft is

$$\hat{N}_{right} = S_{right} \cdot \frac{(B+S_f+1)\cdot(B+S_r+1)-(B+1)}{(B+1)\cdot(S_r+B)}$$

However, if we don't know which specific animals or groups have been seen by each observer but have the total number of animals observed within each strip for each observer then we can calculate maximum values for p_f and p_r

If for each strip i

f_i is the number of animals seen by the observer in the front seat

r_i is the number of animals seen by the rear seat observer

Then we can define

$$B^* = \sum_i Min(f_i, r_i)$$

$$S_f^* = \sum_i Max(0, f_i - r_i)$$

$$S_r^* = \sum_i Max(0, r_i - f_i)$$

And observe that

$$B^* \geq p_f \cdot p_r \cdot N$$

$$S_f^* \leq p_f \cdot (1 - p_r) \cdot N$$

$$S_r^* \leq p_r \cdot (1 - p_f) \cdot N$$

leading to

$$N \leq \frac{B^*}{p_f \cdot p_r}$$

$$S_f^* \leq p_f \cdot (1 - p_r) \cdot N \leq p_f \cdot (1 - p_r) \cdot \frac{B^*}{p_f \cdot p_r}$$

$$p_r \leq \frac{B^*}{B^* + S_f^*}$$

Similarly

$$p_f \leq \frac{B^*}{B^* + S_r^*}$$

Since we here are dealing with maximum values of p_f and p_r the corresponding values for overlooked animals will be minimum values. Accordingly the corrected values for the number of animals seen will still be negatively biased. As this methodology gives a lower bound of the probability of observing a visible animal it is instructive to simulate some observations in order to gauge the effectiveness of the method.

Since we are assuming that for each transect line the number seen by both observers is equal to the lowest number seen, it would be reasonable to assume that the method works best for small observation numbers and large observation probabilities. This assumption can be tested using a simulation study. In this simulation a number of virtual surveys were set up, each with 100 transect strips. For each assumed level of detection probability (0.6; 0.7; 0.8; 0.9) a mean number of animals per strip was chosen between 1 and 10. The number of animals on each transect strip was chosen as a Poisson random variable. The number of animals seen by each observer was then chosen as a binomial random variable. The resulting estimates of the sighting probabilities were then plotted against the mean number of animals per strip. As expected (Figure 12) the estimated detection probabilities tended to be too high, particularly when the number of animals per strip is high.

Reducing bias through survey design

The overriding concern with the survey design has been to minimise the number of overlooked animals by flying closer to the ground and concentrating the effort in a narrow strip close to the aircraft. In addition, observer fatigue was minimised by flying many short transect strips, rather than fewer longer strips. It is possible to evaluate the effectiveness of the different experimental protocols by comparing p_f and p_r between years. In addition, it is instructive to see how large a difference accounting for overlooked animals makes in each case (Table 10).

In the 2000 survey (with the higher flight altitude and wider strip) for the Kangerlussuaq-Sisimiut region there was still a large bias that needed to be corrected. In contrast, the 2001 surveys (lower altitude, narrower strip) in the other three regions resulted in a much smaller bias (Table 10).

Discussion

The above example clearly supports a wealth of previous studies and demonstrates that failing to take overlooked animals into account during aerial surveys will produce an underestimate (inaccurate) of true population size. While we appear to have been able to reduce bias through improved survey design (lower flight altitude, narrower strip) our methodology provides a simple procedure to establish a survey specific correction factor provided that double observers are available for at least one side of the aircraft. Our approach does not require that observations by the double observers can be attributed to specific groups and is therefore suitable to situations where the technology for such cross-referencing does not exist, or where it is difficult to attribute animals to specific groups.

When our experience is taken together with the experience reported in the scientific literature it would appear that the aerial surveys performed in the 1993-96 period (Linnell et al. 2000) produced severe underestimates of population size. The use of a fixed-wing aircraft rather than helicopter, higher flying speeds and altitudes, wider strip widths and longer transects are all likely to increase the proportion of overlooked animals. In addition their analysis failed to correct for uncounted animals. The resulting conflict over caribou management in Greenland (Linnell et al. 2000) shows the importance of addressing bias in aerial surveys.

Even after applying our correction methodology, the resulting estimate is still an underestimate of true population size. This is because (1) we assume maximum values of and (2) there will always be animals that are present in the strip but are hidden from both observers by vegetation or topography, i.e. they have a null sighting probability. This effect is most likely to be pronounced in forested areas (Samuel et al. 1987; Rivest et al. 1998). Even though our surveys all occurred on treeless tundra, the topographic complexity may have obscured some caribou from both observers, especially at the lower flying altitudes. The statistical approach presented by Rivest et al. (1998) offers one potential approach to account for the issue should further experiments show that the effect is substantial.

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Table 10. Results of the caribou surveys conducted in four regions of western Greenland (2000-2001), highlighting the differences in sighting probability by the double observers, the effect that correcting for visibility bias has on the estimated population size and the effect of reducing flying height and strip width.

Area	Kangerlussuaq-Sisimiut	Akia	Ameralik	Qeqertarsuatsiaat
Altitude	100 m	17 m	17 m	17 m
Strip width	1,000 m	600 m	600 m	600 m
p_f	0.94	0.89	0.88	0.89
p_r	0.68	0.85	0.92	0.82
80 % CI uncorrected	36,000-52,800	35,000-51,700	23,300-37,900	2,800-7,900
80 % CI corrected	42,700-61,500	37,000-55,800	24,700-39,300	2,900-8,200

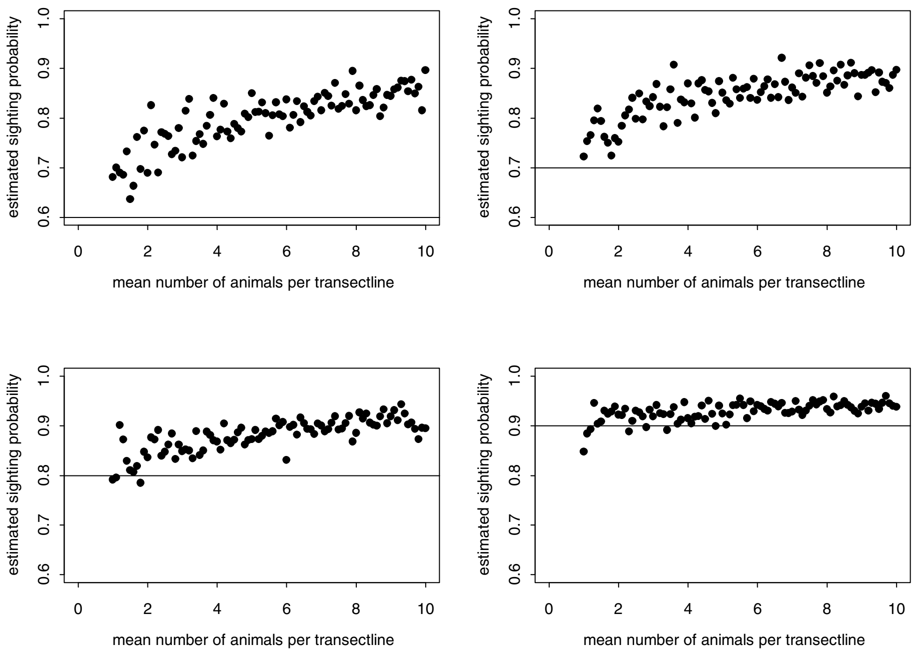

Figure 12. Simulations of the effects of number of animals encountered per transect strip on the estimated sighting probability (bias adjustment) at four different levels of detection probability (the horizontal line at 0.6, 0.7, 0.8 and 0.9).

Appendix 5

Aerial survey 2001 data for 3 caribou herds in west Greenland

Table 11. Aerial survey Akia-Maniitsoq caribou herd, region Central, March 2001.

	High density stratum	Low density stratum	Total
Area size[1] (km²)	10,037	5,325	15,362
Number strips (*n*)	34	13	47
Length of each strip (km)	7.5	7.5	
Total strip width (metres)	2 x 300	2 x 300	
Area covered (km²)	153	58.5	211.5
Flight height (metres)	15 (50 feet)	15 (50 feet)	
Flight speed (km/hr)	40 to 110	40 to 110	Mean 80
Total caribou seen	570	61	631

[1] includes islands, lakes & rivers, but deletes ice caps and glaciers

Table 12. Aerial survey Ameralik & Qeqertarsuatsiaat caribou herds, region South, March 2001.

	Ameralik	Qeqertarsuatsiaat
Area size[1] (km²)	8,377	5,096
Number strips (*n*)	40	21
Strip length (km)	7.5	7.5
Total strip width (metres)	2 x 300	2 x 300
Area covered (km²)	180	94.5
Flight height (metres)	15 (50 feet)	15 (50 feet)
Flight speed (km/hr)*	40 to 110	40 to 110
Total caribou seen	632	96

[1] includes islands, lakes & rivers, but deletes fjords, ice caps & glaciers
* mean 80 km/hr

Appendix 6

Ground surveys 1998 & 2000 Akia-Maniitsoq caribou herd

Table 13. Raw data aerial survey Akia-Maniitsoq caribou herd, region Central, March 2001.

Date ddmmyy	Transect number	Density stratum	Number caribou observed on transect			Rear seat observers	
			Left front (CC)	Left rear	Right rear	Left	Right
12.03.01	68	High	17	15	63	LR	CCh
12.03.01	227	High	3	1	32	LR	CCh
12.03.01	18	High	0	0	0	LR	CCh
12.03.01	1	High	17	13	13	LR	CCh
12.03.01	124	High	8	4	6	LR	CCh
12.03.01	87	High	12	1	20	LR	CCh
12.03.01	21	High	13	17	5	CCh	NO
12.03.01	8	High	8	10	5	CCh	NO
12.03.01	36	High	20	20	20	CCh	NO
12.03.01	193	High	10	13	10	CCh	NO
12.03.01	191	High	15	13	10	CCh	NO
12.03.01	108	High	10	13	5	CCh	NO
12.03.01	96	High	11	14	3	CCh	NO
13.03.01	77	High	5	0	4	JE	MR
13.03.01	97	High	13	13	2	JE	MR
13.03.01	17	High	5	5	4	JE	MR
13.03.01	39	High	22	27	21	JE	MR
13.03.01	84	High	2	5	19	JE	MR
13.03.01	58	High	0	0	0	JE	MR
13.03.01	56	High	12	12	7	JE	MR
13.03.01	107	High	14	14	4	JE	MR
13.03.01	181	High	0	0	0	MR	JE
13.03.01	164	High	0	0	3	MR	JE
13.03.01	3	High	1	1	0	MR	JE
13.03.01	183	High	4	5	5	MR	JE
13.03.01	46	High	8	8	2	MR	JE
13.03.01	65	High	0	0	0	MR	JE
13.03.01	186	High	0	0	1	MR	JE
13.03.01	19	High	6	6	0	MR	JE
13.03.01	141	High	6	6	4	MR	JE
15.03.01	135	High	0	1	7	AJ	CCh
15.03.01	166	High	6	11	9	AJ	CCh
15.03.01	136	High	0	0	0	AJ	CCh
15.03.01	64	High	5	5	3	AJ	CCh
16.03.01	15	Low	0	0	0	RH	MR
16.03.01	92	Low	4	6	0	RH	MR
16.03.01	105	Low	25	19	0	RH	MR
16.03.01	126	Low	0	0	0	RH	MR
16.03.01	121	Low	2	2	1	RH	MR
16.03.01	155	Low	3	3	0	RH	MR
16.03.01	95	Low	0	0	0	RH	MR
16.03.01	52	Low	0	0	0	RH	MR
16.03.01	139	Low	2	2	0	RH	MR
16.03.01	53	Low	5	3	2	MR	RH
16.03.01	61	Low	5	3	4	MR	RH
16.03.01	149	Low	2	0	0	MR	RH
16.03.01	28	Low	2	0	2	MR	RH
Totals				**335**	**296**		

Akia-Maniitsoq survey observers: (CC) Christine Cuyler, (LR) Lotte Rasmussen, (CCH) Casper Christoffersen, (NO) Niels Olsen, (JE) Johannes Egede, (MR) Michael Rosing, (AJ) Aslak Jensen, and (RH) Rink Heinrich.

Table 14. Raw data aerial survey Ameralik caribou herd, region South, March 2001.

Date	Transect	Number caribou observed on transect			Rear seat observers	
ddmmyy	number	Left front (CC)	Left rear	Right rear	Left	Right
12.03.01	246	8	11	0	CCh	NO
12.03.01	23	0	0	0	CCh	NO
15.03.01	115	1	2	6	AJ	CCh
15.03.01	282	2	3	19	AJ	CCh
15.03.01	87	5	6	9	CCh	AJ
15.03.01	11	6	3	10	CCh	AJ
15.03.01	271	0	0	0	CCh	AJ
15.03.01	190	0	0	3	CCh	AJ
15.03.01	94	25	25	12	CCh	AJ
15.03.01	188	2	8	4	CCh	AJ
15.03.01	267	10	8	22	CCh	AJ
15.03.01	96	5	5	7	CCh	AJ
15.03.01	44	2	2	0	CCh	AJ
15.03.01	197	0	0	0	AJ	CCh
15.03.01	206	11	14	15	AJ	CCh
15.03.01	7	0	1	7	AJ	CCh
15.03.01	46	0	2	0	AJ	CCh
15.03.01	109	0	0	0	AJ	CCh
20.03.01	257	24	13	4	NO	CCh
20.03.01	41	2	4	23	NO	CCh
20.03.01	28	0	4	2	NO	CCh
20.03.01	167	24	27	16	NO	CCh
20.03.01	91	14	11	9	NO	CCh
20.03.01	34	38	37	12	NO	CCh
20.03.01	40	39	48	46	NO	CCh
20.03.01	258	7	7	16	NO	CCh
20.03.01	295	33	31	3	NO	CCh
20.03.01	77	0	0	7	CCh	NO
20.03.01	172	0	0	0	CCh	NO
20.03.01	170	27	28	3	CCh	NO
21.03.01	296	0	1	2	MR	CCh
21.03.01	180	0	0	3	MR	CCh
21.03.01	2	0	0	5	MR	CCh
21.03.01	240	10	10	0	MR	CCh
21.03.01	37	2	1	11	MR	CCh
21.03.01	233	0	0	0	MR	CCh
21.03.01	212	8	8	6	MR	CCh
21.03.01	182	0	0	0	MR	CCh
21.03.01	99	0	0	3	MR	CCh
21.03.01	210	0	0	4	MR	CCh
Total caribou seen		**343**		**289**		

Ameralik survey observers: (CC) Christine Cuyler, (CCH) Casper Christoffersen, (NO) Niels Olsen, (AJ) Aslak Jensen, and (MR) Michael Rosing.

Table 15. Raw data aerial survey Qeqertarsuatsiaat caribou herd, region South, March 2001.

Date ddmmyy	Transect number	Number caribou observed on transect			Rear seat observers	
		Left front (CC)	Left rear	Right rear	Left	Right
21.03.01	185	0	0	0	CCh	MR
21.03.01	105	0	0	0	CCh	MR
21.03.01	59	5	5	6	CCh	MR
21.03.01	150	3	3	0	CCh	MR
21.03.01	26	24	15	5	CCh	MR
21.03.01	14	8	6	7	CCh	MR
21.03.01	12	8	10	0	CCh	MR
21.03.01	126	9	13	2	CCh	MR
21.03.01	3	5	5	7	CCh	MR
21.03.01	90	0	0	0	CCh	MR
21.03.01	174	0	0	0	CCh	MR
21.03.01	62	0	0	0	CCh	MR
22.03.01	86	0	0	0	JE	CCh
22.03.01	108	0	0	0	JE	CCh
22.03.01	199	0	0	0	JE	CCh
22.03.01	140	0	0	0	JE	CCh
22.03.01	30	0	0	0	JE	CCh
22.03.01	10	0	0	0	JE	CCh
22.03.01	64	0	0	0	JE	CCh
22.03.01	1	0	0	1	JE	CCh
22.03.01	136	0	0	0	JE	CCh
Total caribou seen		**68**		**28**		

Qeqertarsuatsiaat survey observers: (CC) Christine Cuyler, (CCH) Casper Christoffersen, (MR) Michael Rosing and (JE) Johannes Egede.

Table 16. Random transects for aerial survey Akia-Maniitsoq caribou herd, region Central, March 2001.

Date ddmmyy	Direction flown	Transect number	Transect start		Transect end	
			Latitude	Longitude	Latitude	Longitude
12.03.01	S – N	1	64° 47.14'	51° 32.91'	64° 50.49'	51° 27.56'
13.03.01	N – S	3	65° 09.80′	51° 21.80′	65° 05.79′	51° 22.96′
12.03.01	S - N	8	64° 49.86′	51° 03.41′	64° 53.51′	51° 07.52′
16.03.01	W – E	15	65° 20.68′	50° 47.81′	65°20.52′	50°38.12′
13.03.01	S - N	17	64° 36.97′	52° 04.81′	64° 40.68′	52° 01.00′
12.03.01	S –N	18	64° 43.05′	51° 20.32′	64° 45.39′	51° 28.05′
13.03.01	N – S	19	65° 09.15′	50° 34.45′	65° 05.24′	50° 31.98′
12.03.01	S – N	21	64° 46.09′	51° 02.62′	64° 49.33′	51° 08.32′
16.03.01	SE-NW	28	65° 30.11′	50° 55.63′	65° 31.96′	51° 04.32′
12.03.01	S – N	36	64° 54.46′	51° 11.98′	64° 56.09′	51° 20.72′
13.03.01	S – N	39	64° 40.85′	52° 03.31′	64° 43.95′	51° 57.21′
13.03.01	NW-SE	46	65° 02.89′	51° 12.83′	65° 00.80′	51° 04.61′
16.03.01	S – N	52	65° 40.79′	51° 56.24′	65° 44.54′	51° 52.55′
16.03.01	NW-SE	53	65° 27.61′	51° 42.92′	65° 25.81′	51° 34.19′
13.03.01	S - N	56	65° 18.61′	52° 01.44′	65° 22.37′	52° 05.01′
13.03.01	S - N	58	65° 19.84′	51° 44.91′	65° 23.29′	51° 49.99′
16.03.01	SW-NE	61	65° 23.39′	51° 21.39′	65° 26.66′	51° 15.66′
15.03.01	W – E	64	64° 50.56′	49° 43.96′	64° 49.53′	49° 53.16′
13.03.01	SE-NW	65	65° 01.78′	51° 01.07′	65° 05.11′	51° 06.50′
12.03.01	S – N	68	64° 22.11'	51° 37.73'	64° 25.95'	51° 40.69'
13.03.01	W - E	77	64° 18.99′	51° 57.18′	64° 18.11′	52° 06.29′
13.03.01	S – N	84	65° 00.67′	52° 10.06′	65° 04.40′	52° 06.31′
12.03.01	E – W	87	64° 58.55′	51° 25.42′	64°58.78′	51° 34.97′
16.03.01	SW-NE	92	65° 21.48′	50° 30.04′	65° 24.06′	50° 22.56′
16.03.01	S – N	95	65° 36.87′	51° 40.90′	65° 40.92′	51° 41.22′
12.03.01	S – N	96	64° 46.69′	50° 30.23′	64° 50.72′	50° 31.05′
13.03.01	E - W	97	64° 28.06′	52° 06.60′	64° 29.03′	51° 57.48′
16.03.01	S – N	105	65° 38.69′	50° 27.48′	65° 42.25′	50° 32.19′
13.03.01	E - W	107	65° 21.66′	52° 24.97′	65° 22.37′	52° 15.41′
12.03.01	S – N	108	64° 51.34′	50° 38.18′	64° 54.72′	50° 32.96′
16.03.01	NE-SW	121	65° 38.27′	51° 13.44′	65° 36.60′	51° 22.38′
12.03.01	S – N	124	64° 49.51′	51° 38.92′	64° 53.44′	51° 36.66′
16.03.01	NE-SW	126	65° 37.47′	50° 38.29′	65° 36.02′	50° 47.44′
15.03.01	W – E	135	65° 03.43′	50° 14.72′	65° 03.25′	50° 05.14′
15.03.01	N – S	136	64° 53.40′	50° 02.64′	64° 49.88′	49° 57.96′
16.03.01	E – W	139	65° 31.92′	52° 02.11′	65° 32.39′	51° 52.4′
13.03.01	S – N	141	65° 07.52′	50° 28.98′	65° 11.23′	50° 25.13′
16.03.01	SW-NE	149	65° 29.47′	51° 09.85′	65° 30.74′	51° 00.58′
16.03.01	SE-NW	155	65° 35.85′	51° 26.31′	65° 37.49′	51° 35.26′
13.03.01	E - W	164	65° 05.72′	51° 43.85′	65° 05.81′	51° 53.45′
15.03.01	N – S	166	64° 57.85′	50° 01.89′	64° 53.92′	49° 59.59′
13.03.01	N – S	181	65° 10.39′	51° 47.28′	65° 06.81′	51° 42.78′
13.03.01	NW-SE	183	65° 03.25′	51° 25.54′	65° 01.64′	51° 16.74′
13.03.01	NW-SE	186	65° 10.27′	51° 04.97′	65° 07.62′	50° 57.69′
12.03.01	N – S	191	64° 50.56′	50° 54.21′	64° 49.24′	50° 45.21′
12.03.01	N – S	193	64° 54.99′	51° 21.95′	64° 52.77′	51° 13.97′
12.03.01	E – W	227	64° 37.95'	51° 24.53'	64° 38.00'	51° 33.97'

Table 17. Random transects for aerial survey Ameralik caribou herd, region South, March 2001.

Date ddmmyy	Direction flown	Transect number	Transect start		Transect end	
			Latitude	Longitude	Latitude	Longitude
21.03.01	S – N	2	64° 03.30′	50° 27.78′	64° 07.29′	50° 29.33′
15.03.01	SE-NW	7	64° 36.38′	50° 28.59′	64°38.98′	50° 35.83′
15.03.01	S – N	11	64° 22.34′	49° 43.68′	64° 25.41′	49° 37.58′
12.03.01	NE-SW	23	64° 10.78′	51° 27.77′	64° 08.79′	51° 35.85′
20.03.01	NNW-SSE	28	63° 51.02′	51° 24.10′	63° 47.51′	51° 19.54′
20.03.01	N – S	34	63° 39.08′	51° 09.81′	63° 35.08′	51° 08.49′
21.03.01	S – N	37	63° 59.41′	50° 03.76′	64° 03.44′	50.02.78′
20.03.01	N – S	40	63° 35.05′	51° 03.50′	63° 31.13′	51° 01.22′
20.03.01	SW-NE	41	63° 55.42′	51° 16.78′	63° 57.73′	51° 09.22′
15.03.01	SW-NE	44	64° 19.89′	50° 35.79′	64° 21.79′	50° 27.54′
15.03.01	NW-SE	46	64° 23.58′	50° 49.45′	64° 21.21′	50° 41.87′
20.03.01	S – N	77	63° 22.12′	50° 51.44′	63° 26.15′	50° 50.58′
15.03.01	N – S	87	64° 29.99′	49° 57.17′	64° 27.81′	49° 49.27′
20.03.01	SW-NE	91	63° 38.14′	51° 19.09′	63° 41.52′	51° 14.06′
15.03.01	E – W	94	64° 13.81′	50° 02.19′	64° 13.93′	49° 52.88′
15.03.01	E – W	96	64° 15.74′	50° 26.94′	64° 16.98′	50° 18.07′
21.03.01	E – W	99	63.55.88′	50° 23.52′	63° 56.31′	50° 14.37′
15.03.01	NW-SE	109	64° 14.15′	50° 58.05′	64° 12.56′	50° 49.49′
15.03.01	W – E	115	64° 36.12′	50° 10.24′	64° 34.14′	50° 02.02′
20.03.01	N – S	167	63° 45.73′	51° 23.67′	63° 41.79′	51° 21.61′
20.03.01	SW-NE	170	63° 25.19′	51° 07.12′	63° 28.36′	51° 01.50′
20.03.01	SE-NW	172	63° 26.36′	50° 45.12′	63° 27.71′	50° 53.65′
21.03.01	W – E	180	64° 01.86′	50° 26.17′	64° 01.82′	50° 35.41′
21.03.01	S – N	182	63° 52.03′	49° 55.05′	63° 55.35′	50° 00.31′
15.03.01	S – N	188	64° 18.39′	50° 00.62′	64° 21.88′	50° 05.34′
15.03.01	SE-NW	190	64° 10.74′	49° 43.36′	64° 12.64′	49° 51.57′
15.03.01	S – N	197	64° 28.05′	50° 26.06′	64° 31.40′	50° 20.77′
15.03.01	S – N	206	64° 34.78′	50° 23.33′	64° 38.37′	50° 18.99′
21.03.01	S – N	210	63° 52.95′	50° 28.25′	63° 59.28′	50° 28.21′
21.03.01	S – N	212	63° 52.95′	49° 49.88′	63° 56.02′	49° 55.89′
21.03.01	S – N	233	64° 03.32′	50° 03.68′	64° 06.68′	50° 08.85′
21.03.01	SW-NE	240	63° 59.75′	50° 27.49′	64° 02.59′	50° 20.90′
12.03.01	W – E	246	64° 36.77′	50° 53.28′	64° 36.71′	50° 43.84′
20.03.01	S – N	257	63° 57.00′	51° 24.00′	64° 01.24′	51° 21.40′
20.03.01	S – N	258	63° 37.18′	50° 58.55′	63° 40.68′	51° 03.13′
15.03.01	N – S	267	64° 15.90′	50° 07.09′	64° 12.31′	50° 11.37′
15.03.01	N – S	271	64° 15.52′	49° 39.83′	64° 11.48′	49° 40.51′
15.03.01	W – E	282	64° 33.86′	49° 45.24′	64° 32.36′	49° 53.98′
20.03.01	SE-NW	295	63° 52.37′	50° 50.03′	63° 55.46′	50° 55.96′
21.03.01	W – E	296	64° 04.00′	50° 49.48′	64° 03.06′	50° 58.47′

Table 18. Random transects for aerial survey Qeqertarsuatsiaat caribou herd, region South, March 2001.

Date	Direction	Transect	Transect start		Transect end	
ddmmyy	flown	number	Latitude	Longitude	Latitude	Longitude
22.03.01	SSW-NNE	1	62° 56.89′	50° 10.86′	63° 00.40′	50° 06.42′
21.03.01	SE-NW	3	63° 09.89′	49° 37.02′	63° 12.30′	49° 44.23′
22.03.01	SE-NW	10	62° 55.81′	50° 04.06′	62° 57.61′	50° 04.06′
21.03.01	NE-SW	12	63° 15.57′	49° 35.00′	63° 12.89′	49° 41.72′
21.03.01	NE-SW	14	63° 17.15′	49° 38.18′	63° 15.47′	49° 46.36′
21.03.01	NW-SE	26	63° 19.83′	49° 46.79′	63° 17.32′	49° 39.73′
22.03.01	SW-NE	30	62° 56.35′	49° 51.16′	63° 00.22′	49° 48.53′
21.03.01	E – W	59	63° 22.87′	49° 28.02′	63° 24.04′	49° 36.67′
21.03.01	S – N	62	63° 05.32′	50° 46.84′	63° 09.34′	50° 45.76′
22.03.01	SSW-NNE	64	62° 52.73′	50° 06.93′	62° 56.60′	50° 04.29′
22.03.01	SSE-NNW	86	62° 36.03′	50° 09.64′	62° 39.78′	50° 12.95′
21.03.01	E – W	90	63° 11.06′	49° 54.53′	63° 12.07′	49° 45.84′
21.03.01	NW-SE	105	63° 29.69′	49° 51.97′	63.27.53′	49° 44.31′
22.03.01	SW-NE	108	62° 40.44′	50° 16.14′	62° 42.84′	50° 09.05′
21.03.01	NE-SW	126	63° 12.78′	49° 25.17′	63° 10.74′	49° 32.93′
22.03.01	SSW-NNE	136	63° 02.39′	49° 51.73′	63° 06.42′	49° 51.04′
22.03.01	SE-NW	140	62° 59.15′	49° 35.60′	63° 01.89′	49° 42.16′
21.03.01	E – W	150	63° 20.24′	50° 02.82′	63° 21.74′	49° 54.44′
21.03.01	S – N	174	63° 09.38′	50° 12.00′	63° 13.43′	50° 12.20′
21.03.01	NNW-SSE	185	63° 31.05′	50° 03.93′	63° 27.47′	49° 59.70′
22.03.01	SE-NW	199	62° 45.60′	49° 48.48′	62° 47.60′	49° 56.17′

Table 19. Raw data aerial survey herd structure Akia-Maniitsoq caribou herd, region Central, March 2001.

Date ddmmyy	Transect number / Stratum density	Group size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
12.03.01	68	4		2	2
12.03.01	68	2		1	1
12.03.01	68	3		2	1
12.03.01	68	5		3	2
12.03.01	68	4		1	3
12.03.01	68	2		1	1
12.03.01	68	8	2	3	3
12.03.01	68	2		1	1
12.03.01	68	2		1	1
12.03.01	68	2	1	1	
12.03.01	68	5		3	2
12.03.01	68	2	1	1	
12.03.01	68	2		1	1
12.03.01	68	2		1	1
12.03.01	68	4	2	1	1
12.03.01	68	6	2	3	1
12.03.01	68	3		1	2
12.03.01	68	1		1	
12.03.01	68	3	1	2	
12.03.01	68	7	4	2	1
12.03.01	68	2	2		
12.03.01	68	8	4	2	2
12.03.01	68	2	2		
12.03.01	68	1	1		
12.03.01	68	5	1	1	3
12.03.01	68	3	3		
12.03.01	68	2		1	1
12.03.01	227	3		3	
12.03.01	227	1		1	
12.03.01	227	1		1	
12.03.01	227	2		2	
12.03.01	227	2		2	
12.03.01	227	3	3		
12.03.01	227	7	2	2	3
12.03.01	227	1	1		
12.03.01	227	2		1	1
12.03.01	227	3	1	2	
12.03.01	227	2		2	
12.03.01	227	5		5	
12.03.01	227	5	2	2	1
12.03.01	227	2	2		
12.03.01	227	2	1	1	
12.03.01	227	1		1	
12.03.01	227	2		2	
12.03.01	1	1		1	
12.03.01	1	2		1	1
12.03.01	1	6		6	
12.03.01	1	4		3	1
12.03.01	1	1		1	
12.03.01	1	6		4	2
12.03.01	1	4	3	1	
12.03.01	1	4	1	3	
12.03.01	1	2		1	1
12.03.01	1	3			3

Date ddmmyy	Transect number / Stratum density	Group size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
13.03.01	97	3		2	1
13.03.01	97	5	1	3	1
13.03.01	97	2		1	1
13.03.01	17	4	4		
13.03.01	39	2		1	1
13.03.01	39	4		2	2
13.03.01	39	4	2	1	1
13.03.01	39	1	1		
13.03.01	39	5	5		
13.03.01	39	4	4		
13.03.01	39	2		1	1
13.03.01	39	7	7		
13.03.01	39	2		1	1
13.03.01	39	4	1	2	1
13.03.01	39	4	1	3	
13.03.01	39	1	1		
13.03.01	39	6	5	1	
13.03.01	39	2		1	1
13.03.01	39	6	6		
13.03.01	39	2	1	1	
13.03.01	39	5	3	2	
13.03.01	39	6	4	2	
13.03.01	84	2		1	1
13.03.01	56	2		1	1
13.03.01	107	4		2	2
13.03.01	46	2		1	1
13.03.01	46	3		2	1
13.03.01	141	1	1		
15.03.01	166	2		1	1
15.03.01	166	2		1	1
15.03.01	64	5	2	3	
15.03.01	64	2		1	1
16.03.01	105	10	2	5	3
16.03.01	105	2		1	1
16.03.01	105	2		1	1
16.03.01	105	2		1	1
16.03.01	105	1			1
16.03.01	105	3	1	2	
16.03.01	105	4	1	1	2
16.03.01	105	1		1	
16.03.01	105	1	1		
16.03.01	105	1		1	
16.03.01	105	3		3	
16.03.01	105	1		1	
16.03.01	105	2		1	1
16.03.01	105	2		2	
16.03.01	105	2	1	1	
16.03.01	105	3		2	1
16.03.01	105	7		6	1
16.03.01	105	1	1		
16.03.01	105	1		1	
16.03.01	105	3		3	
16.03.01	155	3		3	
16.03.01	53	2		1	1
16.03.01	61	2		1	1
16.03.01	28	2		1	1
16.03.01	28	2	1	1	

Date ddmmyy	Transect number / Stratum density	Group size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
16.03.01	Low density stratum	1		1	
16.03.01	Low density stratum	1	1		
16.03.01	Low density stratum	1		1	
16.03.01	Low density stratum	3	1	2	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	3		2	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	3		2	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2	2		
16.03.01	High density stratum	5		4	1
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	5	1	3	1
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	3		2	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	10	3	6	1
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	4		4	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	5	2	3	
16.03.01	High density stratum	3		2	1
16.03.01	High density stratum	3		2	1
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	11	5	6	
16.03.01	High density stratum	3	1	2	
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	6	3	3	
16.03.01	High density stratum	4	1	3	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	13	2	10	1
16.03.01	High density stratum	4	1	3	
16.03.01	High density stratum	5	2	2	1

Date ddmmyy	Transect number / Stratum density	Group size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	4		3	1
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	7	2	5	
16.03.01	High density stratum	7	1	6	
16.03.01	High density stratum	9	4	5	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	5	1	3	1
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	3	3		
16.03.01	High density stratum	2	2		
16.03.01	High density stratum	3	3		
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	8	4	4	
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	3	1	1	1
16.03.01	High density stratum	12	5	7	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	4	3	1	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	1		1	
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	4		2	2
16.03.01	High density stratum	15	9	5	1
16.03.01	High density stratum	3	1	2	
16.03.01	High density stratum	4	1	2	1
16.03.01	High density stratum	14	6	6	2
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	13	2	11	
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	5	5		
16.03.01	High density stratum	3	1	1	1
16.03.01	High density stratum	7	1	3	3
16.03.01	High density stratum	4	1	2	1
16.03.01	High density stratum	3	1	1	1
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	18	8	8	2
16.03.01	High density stratum	2		2	
16.03.01	High density stratum	7	4	2	1
16.03.01	High density stratum	6	2	3	1

Date ddmmyy	Transect number / Stratum density	Group size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
16.03.01	High density stratum	3		3	
16.03.01	High density stratum	2			2
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	2	1	1	
16.03.01	High density stratum	9	5	3	1
16.03.01	High density stratum	2		1	1
16.03.01	High density stratum	1	1		
16.03.01	High density stratum	9	4	2	3
16.03.01	High density stratum	8	7	1	
Totals		**758**	**232**	**400**	**126**

Table 20. Raw data aerial survey herd structure Ameralik caribou herd, region South, March 2001.

Date ddmmyy	Transect number / Area description	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
15.03.01	282	4		3	1
15.03.01	282	2		2	
15.03.01	282	1	1		
15.03.01	282	6	1	4	1
15.03.01	282	2		2	
15.03.01	282	5	1	4	
15.03.01	282	2	1	1	
15.03.01	282	2		1	1
15.03.01	282	1	1		
15.03.01	282	4	1	3	
15.03.01	94	7	7		
15.03.01	94	2		1	1
15.03.01	94	5	4	1	
15.03.01	94	3		2	1
15.03.01	94	3	2	1	
15.03.01	94	6	1	3	2
15.03.01	94	7	2	3	2
15.03.01	94	18	6	10	2
15.03.01	94	11	4	5	2
15.03.01	94	9	2	4	3
15.03.01	94	6		4	2
15.03.01	188	2		1	1
15.03.01	267	2		1	1
15.03.01	267	1			1
15.03.01	267	2		1	1
15.03.01	206	3	1	1	1
15.03.01	206	6		5	1
15.03.01	206	4		4	
15.03.01	206	3	1	2	
15.03.01	206	4		3	1
15.03.01	206	2	2		
15.03.01	206	2	1		1
15.03.01	206	3		3	
15.03.01	206	1		1	
15.03.01	206	4		4	
15.03.01	206	3		3	
15.03.01	206	3		3	
15.03.01	206	1		1	

Date ddmmyy	Transect number / Area description	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
15.03.01	44	2		1	1
20.03.01	257	2		1	1
20.03.01	257	3		2	1
20.03.01	28	2		1	1
20.03.01	91	2		1	1
20.03.01	34	3		2	1
20.03.01	34	3		2	1
20.03.01	34	3	3		
20.03.01	40	2		1	1
20.03.01	258	2	1	1	
20.03.01	258	5		4	1
20.03.01	295	15	3	9	3
20.03.01	295	9		7	2
20.03.01	295	6		5	1
20.03.01	295	5	4	1	
20.03.01	Coast	4	4		
20.03.01	Coast	2		1	1
20.03.01	Coast	3		3	
20.03.01	Coast	8	4	3	1
20.03.01	Coast	9	4	4	1
20.03.01	Coast	20	11	6	3
20.03.01	Coast	2		1	1
20.03.01	Coast	5		3	2
20.03.01	Coast	6	2	4	
20.03.01	Coast	3	1	1	1
20.03.01	Coast	7		4	3
20.03.01	Coast	8	3	4	1
20.03.01	Coast	6	1	2	3
20.03.01	Coast	6	1	2	3
20.03.01	Coast	7	1	5	1
20.03.01	Coast	4		2	2
20.03.01	Coast	3		3	
20.03.01	Coast	11	5	4	2
20.03.01	Coast	2		1	1
20.03.01	Coast	2		1	1
20.03.01	Coast	2			2
20.03.01	Coast	3	2	1	
20.03.01	Coast	2		1	1
20.03.01	Coast	1		1	
20.03.01	Coast	3	3		
20.03.01	Coast	1			1
20.03.01	Coast	5	5		
20.03.01	Coast	5	5		
20.03.01	Coast	2		1	1
20.03.01	Coast	1		1	
20.03.01	Coast	3		2	1
20.03.01	Coast	3	2	1	
20.03.01	Coast	3	2		1
20.03.01	Coast	1	1		
20.03.01	Coast	7		4	3
20.03.01	Coast	2	2		
20.03.01	Coast	5	3	1	1
20.03.01	Coast	4	1	2	1
20.03.01	Coast	3	1	2	
20.03.01	Coast	6	1	2	3
20.03.01	Coast	7	4	3	
20.03.01	Coast	1	1		

Date ddmmyy	Transect number / Area description	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
20.03.01	Coast	2	2		
21.03.01	296	2		1	1
21.03.01	2	1	1		
21.03.01	37	4		4	
21.03.01	37	2		1	1
21.03.01	212	2		1	1
21.03.01	212	2		1	1
21.03.01	Coast	2	2		
21.03.01	Coast	4	4		
21.03.01	Coast	7	7		
21.03.01	Coast	7	3	4	
21.03.01	Coast	3	2	1	
21.03.01	Coast	4		2	2
21.03.01	Coast	3	2	1	
21.03.01	Coast	13	12	1	
21.03.01	Coast	24	22	1	1
21.03.01	Coast	1	1		
21.03.01	Coast	1	1		
21.03.01	Coast	4	4		
22.03.01	Mid-inland	2	2		
22.03.01	Mid-inland	1	1		
22.03.01	Mid-inland	4		3	1
22.03.01	Mid-inland	6		4	2
22.03.01	Mid-inland	2		1	1
22.03.01	Mid-inland	4	1	2	1
22.03.01	Mid-inland	4	4		
22.03.01	Mid-inland	6	4	2	
22.03.01	Mid-inland	6	2	3	1
22.03.01	Mid-inland	11	6	5	
22.03.01	Mid-inland	5		5	
22.03.01	Mid-inland	2		2	
22.03.01	Mid-inland	1	1		
22.03.01	Mid-inland	2		1	1
22.03.01	Mid-inland	4	2	1	1
22.03.01	Mid-inland	3	1	1	1
Totals		**555**	**207**	**249**	**99**

Table 21. Raw data aerial survey herd structure Qeqertarsuatsiaat caribou herd, region South, March 2001.

Date ddmmyy	Transect number / Area description	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
22.03.01	150	3		2	1
22.03.01	26	2		1	1
22.03.01	26	2		1	1
22.03.01	12	2		1	1
22.03.01	12	2		1	1
22.03.01	126	2		1	1
22.03.01	3	2		2	
22.03.01	1	5	5		
22.03.01	1	1	1		
22.03.01	136	2		1	1
22.03.01	Upland plateau	2		1	1
22.03.01	Upland plateau	2	1	1	
22.03.01	Upland plateau	4		1	3
22.03.01	Upland plateau	3	1	2	
22.03.01	Upland plateau	2		1	1
22.03.01	Upland plateau	6	2	3	1
22.03.01	Mid- to inland	2	1		1
22.03.01	Mid- to inland	2	2		
22.03.01	Mid- to inland	6	3	2	1
22.03.01	Mid- to inland	2		2	
22.03.01	Mid- to inland	5	1	3	1
22.03.01	Mid- to inland	3		2	1
22.03.01	Mid- to inland	3	1	2	
22.03.01	Mid- to inland	4	4		
22.03.01	Mid- to inland	1	1		
22.03.01	Mid- to inland	2	1	1	
22.03.01	Mid- to inland	5		3	2
22.03.01	Mid- to inland	3		1	2
22.03.01	Mid- to inland	3		2	1
22.03.01	Mid- to inland	4		2	2
22.03.01	Mid- to inland	2		1	1
22.03.01	Mid- to inland	2		1	1
22.03.01	Mid- to inland	4	3	1	
22.03.01	Mid- to inland	4	4		
22.03.01	Mid- to inland	3	1	1	1
22.03.01	Mid- to inland	3	1	1	1
22.03.01	Mid- to inland	2		2	
Totals		**107**	**33**	**46**	**28**

Appendix 6

Ground surveys 1998 & 2000 Akia-Maniitsoq caribou herd

Table 22. Raw data ground survey herd structure Akia-Maniitsoq caribou herd, region Central, March/April 1998.

Date ddmmyy	Group size	Females > 1 year	Calves < 1 year	Males > 1 year	Sex unknown
26.03.98	1			1	
26.03.98	3	2		1	
26.03.98	2			2	
26.03.98	6	2	1	3	
26.03.98	1			1	
26.03.98	7	3	1	2	1
26.03.98	6			6	
29.03.98	1			1	
29.03.98	3	1		2	
29.03.98	4	1	1	2	
29.03.98	2	2			
29.03.98	2			2	
29.03.98	3	1	1	1	
29.03.98	4	1		3	
29.03.98	5			5	
29.03.98	3	2		1	
29.03.98	4	1	1	2	
29.03.98	4		1	3	
29.03.98	2			2	
29.03.98	1			1	
29.03.98	2				2
29.03.98	5	2		3	
29.03.98	3		3		
29.03.98	5		1	4	
29.03.98	6	4		2	
29.03.98	1	1			
29.03.98	2			2	
29.03.98	5	2	1	2	
29.03.98	6				6
29.03.98	4	2		2	
29.03.98	2			2	
31.03.98	8	3	4	1	
31.03.98	5	1	2	2	
31.03.98	4	1	1	2	
31.03.98	14	3	3	8	
31.03.98	1	1			
31.03.98	3	2	1		
31.03.98	2	1	1		
31.03.98	1			1	
31.03.98	1		1		
31.03.98	10	3	1	6	
31.03.98	1			1	
31.03.98	2	1	1		

Date ddmmyy	Group size	Females > 1 year	Calves < 1 year	Males > 1 year	Sex unknown
31.03.98	5	2	3		
31.03.98	2		2		
31.03.98	3	1	1	1	
31.03.98	7	2	2	3	
31.03.98	3		1	2	
31.03.98	36	4	4	23	5
31.03.98	6	2	2	2	
01.04.98	11	2	2	7	
01.04.98	2	1		1	
01.04.98	3	1		2	
01.04.98	1		1		
01.04.98	11	5	5	1	
01.04.98	5	4		1	
01.04.98	5	2	3		
01.04.98	1			1	
01.04.98	35	17	12	6	
01.04.98	3	1	2		
01.04.98	3	2		1	
01.04.98	18	4	8	6	
02.04.98	12	2	5	5	
02.04.98	17	9	3	5	
02.04.98	3	3			
02.04.98	9	6	1	2	
02.04.98	16	8		8	
02.04.98	10	7		3	
02.04.98	3	2		1	
02.04.98	1	1			
02.04.98	2	1		1	
02.04.98	35	19	8	8	
02.04.98	22	9	6	7	
02.04.98	5	5			
02.04.98	6	3	2	1	
02.04.98	9	4	4	1	
02.04.98	6	4	2		
02.04.98	9	2	5	2	
02.04.98	2	1	1		
02.04.98	14	4		10	
02.04.98	1		1		
02.04.98	5	2	3		
03.04.98	17	2	7	8	
03.04.98	2	1	1		
03.04.98	4	3		1	
03.04.98	12	7	5		2
03.04.98	10	4	5	1	
03.04.98	2	1	1		
03.04.98	10	4	5	1	
03.04.98	7	6	1		
03.04.98	7	4	3		
03.04.98	14	7	2	5	
Totals	**589**	**224**	**145**	**206**	**16**

Table 23. Raw data ground survey herd structure Akia-Maniitsoq caribou herd, region Central, March/ April 2000.

Date	Group	Females	Calves	Males			Sex	GPS position	
ddmmyy	size	> 1 year	< 1 year	> 1 year	> 2 year	> 3 year	?	Lat.	Long.
29.03.00	2	1	1					64°14.1'	51°52.4'
29.03.00	4	4						64°15.1'	51°54.4'
29.03.00	2	1			1			64°16.7'	52°00.3'
30.03.00	3				3			64°15.0'	51°51.6'
30.03.00	4			1	3			64°15.2'	51°51.4'
30.03.00	1				1			64°15.4'	51°51.4'
30.03.00	4			3	1			64°16.5'	51°50.3'
30.03.00	4	2	1	1				64°16.5'	51°50.3'
30.03.00	3	1	2					64°15.8'	51°51.1'
30.03.00	4				2	2		64°16.8'	51°51.1'
30.03.00	3	1	1	1				64°18.1'	51°51.3'
30.03.00	3	1	1	1				64°18.8'	51°52.7'
30.03.00	4	2	1	1				64°18.8'	51°52.7'
30.03.00	5	2	1	2				64°19.5'	51°54.1'
30.03.00	1	1						64°20.6'	51°55.6'
30.03.00	4	1	1			2		64°20.9'	51°56.0'
30.03.00	2	1	1					64°20.9'	51°56.0'
30.03.00	1			1				64°21.6'	51°58.0'
30.03.00	2	1	1					64°22.7'	51°37.8'
30.03.00	2				1	1		64°25.9'	51°54.2'
30.03.00	3	2	1					64°26.4'	51°53.9'
30.03.00	2	2						64°26.6'	51°53.1'
30.03.00	5	2	3					64°27.1'	51°52.6'
30.03.00	3	2	1					64°28.9'	51°50.4'
30.03.00	2	1	1					64°14.1'	51°52.4'
30.03.00	3						3	64°14.1'	51°52.4'
30.03.00	3						3	64°29.9'	51°51.3'
30.03.00	3						3	64°29.9'	51°51.3'
30.03.00	3	2		1				64°30.9'	52°06.4'
30.03.00	6						6	64°30.9'	52°06.4'
30.03.00	2			1	1			64°32.7'	52°02.1'
30.03.00	2	1	1					64°32.8'	51°58.4'
30.03.00	1				1			64°32.5'	51°58.2'
30.03.00	1					1		64°32.5'	51°58.2'
30.03.00	10	2	1	2			5	64°32.5'	51°58.2'
30.03.00	2			1	1			64°32.5'	51°58.2'
30.03.00	2					2		64°32.0'	51°58.8'
30.03.00	1	1						64°30.7'	51°51.8'
31.03.00	6	2	2				2	64°32.2'	51°50.8'
31.03.00	2	2						64°32.8'	51°50.7'
31.03.00	1	1						64°34.1'	51°50.4'
31.03.00	1			1				64°34.3'	51°50.3'
31.03.00	2		1	1				64°34.2'	51°49.8'
31.03.00	7				7			64°35.0'	51°49.5'
31.03.00	5				1	4		64°35.0'	51°49.5'
31.03.00	6		1	1	4			64°35.0'	51°49.5'
31.03.00	4						4	64°35.0'	51°49.5'
31.03.00	2						2	64°35.0'	51°49.5'
31.03.00	3	2	1					64°36.3'	51°49.0'
31.03.00	5	2	2	1				64°36.7'	51°49.0'
31.03.00	2	1			1			64°38.4'	51°48.6'
31.03.00	2						2	64°39.4'	51°49.1'
31.03.00	4	2	2					64°39.4'	51°49.1'
31.03.00	2	1					1	64°39.5'	51°49.5'
31.03.00	5	2	2	1				64°39.8'	51°49.3'
31.03.00	3	1	2					64°41.7'	51°51.1'
31.03.00	4	2		1	1			64°42.1'	51°51.4'
31.03.00	4	2	2					64°42.1'	51°51.4'
31.03.00	1	1						64°36.1'	51°54.7'
31.03.00	1	1						64°36.1'	51°54.7'

Date	Group	Females	Calves	Males			Sex	GPS position	
ddmmyy	size	> 1 year	< 1 year	> 1 year	> 2 year	> 3 year	?	Lat.	Long.
31.03.00	5	2		1			2	64°35.3'	51°54.0'
31.03.00	3	2	1					64°34.1'	51°53.2'
31.03.00	2	1	1					64°33.5'	51°54.7'
31.03.00	8	3	3	1	1			64°33.5'	51°54.7'
31.03.00	10	2		1	7			64°36.0'	51°56.6'
31.03.00	4				2	2		64°35.9'	51°57.5'
31.03.00	8	3	1		4			64°35.6'	51°57.2'
31.03.00	3	1	1	1				64°34.9'	51°56.7'
31.03.00	2						2	64°30.1'	51°52.4'
31.03.00	7						7	64°30.1'	51°52.4'
31.03.00	7						7	64°30.1'	51°52.4'
02.04.00	2			2				64°29.1'	51°51.2'
02.04.00	3	2		1				64°29.0'	51°50.5'
02.04.00	1				1			64°29.8'	51°48.5'
02.04.00	6	1	1	3	1			64°29.8'	51°48.5'
02.04.00	9	3	2	3	1			64°29.8'	51°47.9'
02.04.00	2	1	1					64°31.0'	51°46.5'
02.04.00	10	4	1	4	1			64°29.8'	51°48.7'
02.04.00	17	4	2	5	2		4	64°31.5'	51°46.0'
03.04.00	2					2		64°31.2'	51°50.6'
03.04.00	2		0					64°31.5'	51°50.0'
03.04.00	1		0					64°31.5'	51°50.0'
03.04.00	2	1	1					64°31.4'	51°48.3'
03.04.00	1	1						64°31.4'	51°48.3'
03.04.00	3	1	2					64°31.7'	51°47.2'
03.04.00	3	2	1					64°31.7'	51°47.2'
03.04.00	10	5	2	1	1	1		64°31.7'	51°47.2'
03.04.00	2	1	1					64°31.7'	51°47.2'
03.04.00	4			3		1		64°31.8'	51°44.0'
03.04.00	6	5	1					64°32.0'	51°42.8'
03.04.00	3				1	2		64°32.0'	51°42.8'
03.04.00	2				1	1		64°32.0'	51°42.8'
03.04.00	1					1		64°40.3'	51°29.2'
03.04.00	2	1	1					64°39.1'	51°35.8'
03.04.00	1				1			64°37.2'	51°40.8'
04.04.00	4	2	2					64°28.6'	51°50.7'
04.04.00	2	1	1					64°27.6'	51°48.9'
04.04.00	2				2			64°22.3'	51°40.3'
05.04.00	2	1	1					64°31.2'	51°47.5'
05.04.00	2	1	1					64°32.1'	51°46.1'
05.04.00	4	2	2					64°32.1'	51°46.1'
05.04.00	6				2		4	64°32.1'	51°46.1'
05.04.00	2	2						64°31.9'	51°45.1'
05.04.00	4	1	1	2				64°41.8'	51°18.5'
05.04.00	3	2	1					64°44.2'	51°18.8'
05.04.00	8	5			2		1	64°48.1'	51°27.2'
05.04.00	1	1						64°48.1'	51°27.2'
05.04.00	11	6	3	2				64°48.9'	51°27.5'
05.04.00	4	2	2					64°49.0'	51°27.8'
05.04.00	2	1	1					64°48.9'	51°24.1'
05.04.00	6	5	1					64°49.8'	51°25.1'
05.04.00	2	1	1					64°49.8'	51°25.1'
05.04.00	1				1			64°51.1'	51°24.4'
05.04.00	2	1	1					64°51.1'	51°24.4'
05.04.00	8	3	3	1	1			64°51.5'	51°23.9'
05.04.00	8	6	2					64°51.5'	51°23.9'
05.04.00	6	2	4					64°51.3'	51°21.9'
05.04.00	1	1						64°51.3'	51°21.9'
05.04.00	8	4	3	1				64°51.3'	51°21.9'
05.04.00	3	1	2					64°46.8'	51°24.8'
06.04.00	4	2	1	1				64°44.2'	51°16.7'
06.04.00	3					3		64°45.1'	51°16.3'
06.04.00	1					1		64°45.7'	51°14.7'
06.04.00	2				1	1		64°46.3'	51°12.8'

Date	Group	Females	Calves	Males			Sex	GPS position	
ddmmyy	size	> 1 year	< 1 year	> 1 year	> 2 year	> 3 year	?	Lat.	Long.
06.04.00	4			2	2			64°46.5'	51°12.5'
06.04.00	6	4	2					64°46.7'	51°12.3'
06.04.00	1	1						64°46.7'	51°12.3'
06.04.00	1	1						64°47.9'	51°12.4'
06.04.00	3						3	64°48.7'	51°11.3'
06.04.00	4	2	1		1			64°48.5'	51°11.6'
06.04.00	5	2			2	1		64°47.8'	51°12.4'
06.04.00	2		1		1			64°47.8'	51°17.9'
06.04.00	1	1						64°47.8'	51°17.9'
06.04.00	1					1		64°48.9'	51°18.6'
06.04.00	3					3		64°49.1'	51°18.6'
06.04.00	3	3						64°51.7'	51°20.7'
06.04.00	3	3						64°52.3'	51°20.9'
06.04.00	5	3	1		1			64°52.0'	51°18.7'
06.04.00	12	4	3	1	2	2		64°52.0'	51°18.6'
06.04.00	4	1	1	1	1			64°51.8'	51°17.8'
06.04.00	8	3	1	2	1	1		64°51.8'	51°17.8'
06.04.00	4	1	1	2				64°51.8'	51°17.8'
06.04.00	4	4						64°53.1'	51°16.9'
06.04.00	9	4	2		3			64°53.1'	51°16.9'
06.04.00	5	3	2					64°53.1'	51°16.9'
06.04.00	2	2						64°53.1'	51°16.9'
06.04.00	5	3			1	1		64°53.1'	51°16.9'
06.04.00	5						5	64°53.1'	51°16.9'
06.04.00	2	1			1			64°51.6'	51°17.1'
06.04.00	3	2	1					64°51.3'	51°16.7'
06.04.00	2	1	1					64°51.1'	51°16.2'
06.04.00	3	2	1					64°51.1'	51°16.2'
06.04.00	1	1						64°50.8'	51°16.4'
06.04.00	3	2	1					64°50.5'	51°17.5'
06.04.00	6	3		1	2			64°50.2'	51°18.2'
06.04.00	2			2				64°38.5'	51°21.8'
06.04.00	5						5	64°38.5'	51°21.8'
06.04.00	2	2						64°41.1'	51°20.5'
07.04.00	2					2		64°44.4'	51°15.2'
07.04.00	3				1		2	64°46.3'	51°12.9'
07.04.00	1	1						64°46.3'	51°12.9'
07.04.00	8	2				6		64°46.6'	51°11.0'
07.04.00	5	2	2		1			64°46.9'	51°09.8'
07.04.00	7	1			1	5		64°46.4'	51°08.2'
07.04.00	3			1	1	1		64°46.4'	51°08.2'
07.04.00	1	1						64°47.0'	51°09.3'
07.04.00	1					1		64°45.6'	51°15.7'
07.04.00	1			1				64°44.0'	51°17.2'
07.04.00	2					2		64°37.5'	51°24.2'
07.04.00	1	1						64°38.3'	51°25.2'
07.04.00	2	1	1					64°38.3'	51°25.2'
07.04.00	4	2	2					64°38.3'	51°25.2'
07.04.00	2	1	1					64°38.3'	51°25.2'
07.04.00	11	2	1	4	4			64°38.3'	51°25.2'
07.04.00	1				1			64°38.5'	51°26.8'
07.04.00	1						1	64°38.5'	51°26.8'
07.04.00	5				2	3		64°40.8'	51°20.7'
09.04.00	6	5		1				64°26.4'	51°42.8'
09.04.00	5			2	3			64°24.9'	51°44.2'
09.04.00	1	1						64°23.1'	51°43.5'
09.04.00	2					2		64°23.1'	51°43.5'
09.04.00	7				2	5		64°22.1'	51°40.8'
09.04.00	6	3	1	1	1			64°22.3'	51°41.7'
Totals	**590**	**237**	**117**	**76**	**97**	**63**	**74**		

Appendix 7
List of terms

Accuracy – how well a survey estimate for animal numbers reflects the true population size.

Annual – occurring, or done every year.

Bias – describes how far the average value of the estimator is from the true population value. An unbiased estimator centers about the true value for the population. Bias is the extent to which an estimate is systematically wrong. Bias decreases the accuracy of a survey. In popular terms, negative bias in surveys moves the final estimate to below the true population size and positive bias can move it above the true population size.

Body condition – pertaining to amount of fat present, i.e., plenty of fat equals excellent body condition.

Confidence interval – statistical term for when the SE is combined with a probability (P) level to yield confidence limits (CL) and their interval, the confidence interval (CI). For example: at a $P = 0.90$ (alpha = 0.1) then assuming no bias a 90% CI is likely to contain the true population size in 90% of surveys of the same type and intensity. NOTE: it is incorrect to state that there is a 90% chance that the actual number of caribou in a survey area is within the CI.

Criteria – standards set on which judgement can be made, i.e. the sex or age of a caribou.

Density – the number of caribou per square kilometre of land area.

Estimate – a calculation as to the likely or approximate size of the caribou population.

Fecundity – related to fertility and is the potential level of reproductive performance of a population, which is usually much greater than the realised reproduction (fertility). However, fecundity and fertility are often used inconsistently and even interchangeably in the literature.

Fertility – of a population is the number of live births over a time period, usually a year, e.g., the number of live births per female, or the number of female young born per female. To calculate fertility we need to know the average litter size, average number of litters produced per time interval (year) and the sex ratio at birth (Caughley 1977).

Fertility index – see also under *recruitment*. Ratio of calves to females or calves to adults.

Herd – see also under *population*. Indigenous Greenlandic caribou seldom or never aggregate into large coherent groups. Group size typically stays under 4 animals, with groups scattered throughout a large area.

Herd structure – this is the sex and age distribution of the animals within a given population/herd.

Logistics – the obtaining, distribution, maintenance and replacement of field equipment and personnel.

Management – e.g., wildlife management, which is the act of manipulating, directing, controlling, regulating and/or administrating a wildlife resource and any number of the factors affecting that wildlife resource.

Natural mortality – all mortality due to factors other than hunting (disease, accident, starvation, predation, parasites, etc.).

Net recruitment – or rate of increase of the herd is determined by subtracting the adult mortality rate from the gross recruitment.

Population – see also under *herd*. All the animals of the same species living in a specific region, which do not mix with animals from other regions, i.e., they are reproductively isolated. A population is a demographic unit distinct by virtue of its unique density, distribution, birth & death rate, sex & age structure, immigration and emigration rates, and other demographic parameters.

Population status – states a wildlife species' occurrence and abundance, i.e., where and how many.

Population analysis – attempts to determine herd structure (sex & age) and the forces controlling the composition of the population/herd.

Population dynamics – in any analysis of herd structure and status the parameters are seldom if ever static, therefore the term population *dynamics*.

Precision – is a measure of the quality of the survey estimate for animal number, i.e., how close you could expect the estimate to approximate its expected value. Precision refers to the variation in repeated measurement of the same quantity. Precision is determined primarily by the variation in the population and the size of the sample. An indicator of the precision of an estimate is the confidence interval.

Range – the extent of the land area on which the caribou wander and graze. The land area used during foraging/calving/rutting by the caribou, e.g., summer and winter ranges. The word is often synonymous with pasture or habitat, however, the term range brings vegetation to mind rather than for example topography.

Recruitment – see also under *fertility index*. The late winter (March) value for calves/100 cows, which indicates the increment in caribou number for a specific population/herd from one year to the next.

Sightability – the probability of actually seeing a caribou present within the strip flown.

Standard Error (SE) – standard error is the standard deviation (SD) divided by the square root of sample size (n) or (n-1) if SD is calculated using n and not n-1. Sampling error would be zero if the same number of caribou were seen on each transect flown.

Strata – (plural of stratum) in this report refers to the division of region Central according to expected caribou density.

Terrain – refers to the land or ground, usually in conjunction with a description of topography, e.g., rough terrain, mountainous terrain, etc.

Variance – statistical term for the amount of variation in measurements. Variance is the expected square deviance regardless of the distribution. Its square root is standard deviation (SD). Note: variance is distribution independent. It is simply the expected square deviation.

Appendix 8

Recommendations for future

Aerial Survey method & design

Since survey methodology is complex, collaboration of biologists and biometricians experienced in aerial survey design was considered a prerequisite to success. Methods were planned in accordance with later analysis needs. Reducing the bias (missed caribou) was prioritised over lowering the variance. A correction for undetected caribou was also applied. The result was a population size estimate which we consider of an acceptable accuracy and precision. Future surveys are recommended to take the same measures.

Survey effort

47 transects were used in the present survey of region Central at the cost of approximately a quarter of a million Danish kroner. As a rule of thumb, new surveys of the same effort can detect a change in population size, which is equal to the sum of the previous confidence interval, e.g., a new estimate for the Akia-Maniitsoq herd would have to drop below 28,000 or rise above 65,000 caribou before a survey with the same effort could show a difference. Regardless of the effort, it will not be possible to detect a change for Akia-Maniitsoq that falls within the present confidence interval, which is 18,693. However, a series of surveys yield much more information than the sum of the individual surveys. With a suitable plan it would be possible to design a series of surveys that could serve to adjust the quota system over a period of time. It is important that the surveys are done in a manner comparable to the surveys done previously in the same area and with a clear objective. Repeating surveys every five years may be enough.

Stratification

Further refinement of the stratification of Akia-Maniitsoq can be based on the densities found in this and earlier surveys, and would reduce the variance thus improving precision. Perhaps transects with zero or few caribou (transects 3, 58, 65, 181 and 186), could be included in the low-density stratum.

Field methods

Overall snow cover was highly variable in both Ameralik and Qeqertarsuatsiaat. This survey's low flight altitude and speed, plus the narrowed strip width, were necessary for detecting caribou under these fluctuating conditions.

Future aerial surveys would be well advised to continue the use of low flight altitudes. This survey flew at 50 feet, an altitude, which can make many pilots cringe, but which permitted excellent sight-ability of caribou on the strip. However, a height of 100 to 150 feet may be just as suitable. The extra height would make virtual ground speed appear slower (giving more time to observe the same terrain) and could make the entire 2 x 300 metre strip visible in hilly terrain. Altitudes over 150 feet are not recommended. Even at an altitude of 50 feet many caribou just stood and looked at the helicopter without reacting. It is difficult to detect non-moving caribou even at 50 feet regardless of snow cover or terrain features.

It is advised to continue using flight speeds averaging 80 km/hr or less and a strip width of 2 x 300 metres. Observers are able to detect most of the caribou present at distances ≤ 300 metres from the helicopter. Accuracy of any survey depends on reducing the bias incurred by observers failing to detect the caribou present in their strip. A narrower strip where most caribou are detected is better than a wide strip where untold numbers of caribou may be missed.

Random transects of short length erased observer fatigue and promoted 100% concentration during actual transects. These should be continued.

Observers
Using local hunters with caribou experience as observers can lead to more caribou being seen. Since initially their actual ability was unknown it was an advantage to use several and change their seating position. This allowed an average of the individuals' abilities rather than risking the possibility of a one poor observer seated constantly in the same position causing a high negative bias. Since only one observer counted caribou from the right seat position, a stationary poor observer here could cause underestimating of population size.

Numbers of caribou seen by the best back seat observers were never significantly ($p < 0.05$) better or worse than the front seat observer. This may occur if a) there is no intrinsic sighting advantage for the front-seat observer, or b) if a sighting advantage exists, the best rear-seat observer was better than the front seat observer. In future these two alternatives could be tested by rotating the front seat observer.

Using a minimum of three observers on each transect is recommended. Caribou counts were consistent between front and rear seats, giving confidence to the observed numbers. A further improvement would be at least two observers for each side of the helicopter. Local involvement will continue to be encouraged, and future surveys would do well by continuing to employ methods for finding local hunters best able to perform the task.

Equipment
The computer data-logger used was antiquated and unreliable. Thus it was impossible to record caribou group number or size on each transect. A new data logger is necessary to record the number groups observed and their size per transect in order to allow a calculation of survey precision. Regardless, continued use of manual "click-counters", as back-up, would be wise considering the ever-present possibility of technology breakdown in the field. Owing to terrain difficulties in Greenland, helicopters are better suited to surveying caribou populations than fixed-wing aircraft for surveys.

Ground survey logistics
In region Central snowmobile ground surveys should begin early March and finish before April, because April ground fogs can immobilize field teams, and spring break-up may occur even in late March.

More of region Central's caribou population could be monitored for herd structure if temporay winter camps were used. The ground surveys of 1998 and 2000 used permanent camps, so backtracking was a daily necessity. Tenting at a new location each night would facilitate a continuous path through the region and increase the total area covered. Herd structure data representing the entire region's caribou population would be possible.

Technical reports from Greenland Institute of Natural Resources

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Nr. 13 Kalaallit Nunaata kitaani saattussat (*Chionoecetes opilio*) amerlassusaasa naatsorsorneqarnerat 1997-imi/Bestandsstatus af krabber (*Chionoecetes opilio*) ved Vestgrønland 1997. Burmeister, A.D., 1997.

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Nr. 16 Nunatsinni timmissat aamma miluumasut nunamiut imarmiullu – pisuussutit uumassusillit pingaarnerit pillugit nalunaarut 1. oktober 1998/ Grønlandske fugle, havpattedyr og landpattedyr – en status over vigtige ressourcer, oktober 1998. Born, E. et al., 1998.

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