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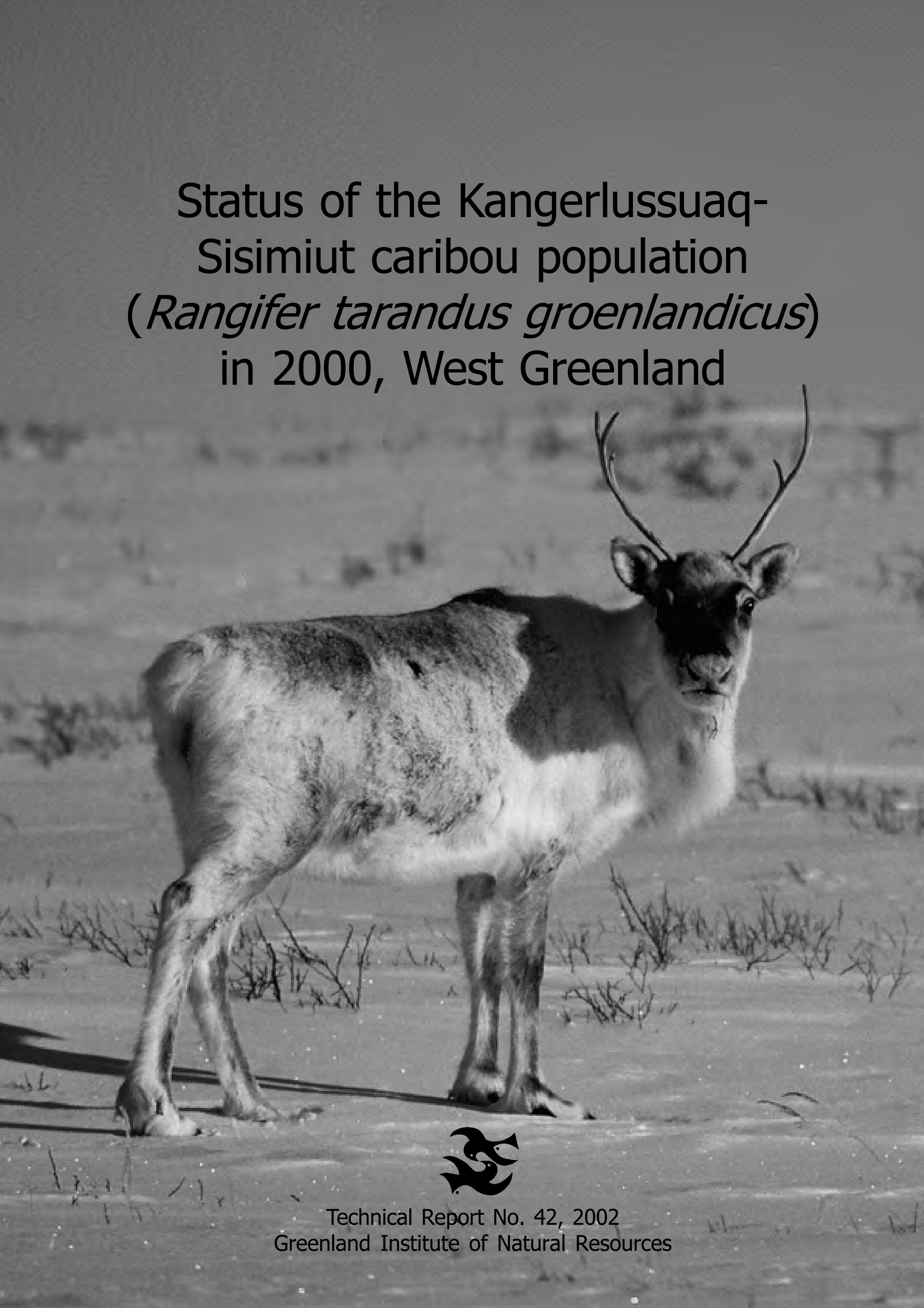

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Status of the Kangerlussuaq-Sisimiut caribou population (*Rangifer tarandus groenlandicus*) in 2000, West Greenland

by

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Eqikkaaneq

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Naatsorsuinikkut tagginneqarpoq Kangerlussuup Sisimiullu akornanni tuttut, piarangortussat eqqarsaatigissanngikkaanni, marts 2000-mi 51.600-uusut ± 11.200 (90% C.I.) (11.200-nik ikinnerusinnaallutik amerlanerusinnaallutilluunniit). Taamaammat 2000 august-septemberimi sumiffimmi Avannani piniarneqarsinnaasutut innersuussutigineqartut 7.000-nik amerlineqarput piniartullu kajumissaarneqarput kulavannik amerlanerusunik pisaqaqqullugit. 2001-mi innersuussutigineqartut 10.000-nik amerlineqarput kajumissaarutigineqarluni pisat affaat kulavaasariaqartut, tassa tuttut suli amerliartornissaat pinngitsoorneqassappat. Tuttut amerliartornerat killilersimaarneqarsinnaanngilaq kulavaat pisarineqartartut amerlinngippata.

Kangerlussuup Sisimiullu akornanni tuttut sukkasuumik amerliartorsinnaapput. Eqqoriaanerit naapertorlugit 1996-miit 2000-p tungaanut tuttut tallimariaammik amerlisimapput uumasoqatigiit taakku eqqarsaatigissagaanni aatsaat taama amerlatigissallutik. Ilimanarpoq tuttut ingerlaarfitsik annertusitissimagaat, pasitsaanneqarporlu toqusartut amerliartortut tuttullu peqqippallaanngitsut. Uumasoqatigiit amerlavallaalernerat taamatullu nerisaasa innarlernequarnerat pinngitsoortinneqassappat piniakkat amerlinerat aqqutissaavoq.

Sammenfatning

Oplysninger om rensdyrenes bestandsstørrelse og flokstruktur og estimater af rekruttering er vigtige som grundlag for beslutninger vedrørende forvaltningen. I marts 2000 gennemførte Naturinstituttet en helikoptertælling i området Kangerlussuaq-Sisimiut for at få oplysninger om antallet af rensdyr samt flokstrukturen. Flyvehøjden var 100 meter, hastigheden var ≤ 100 km/t og bredden af transekten var 500 meter på hver side af helikopteren. I 1998 og 2000 gennemførte instituttet også tællinger af rensdyrenes flokstruktur fra snescooter i februar-marts måned. Både helikopter- og snescootertællingerne gav estimater af den årlige tilvækst.

Den gennemsnitlige gruppestørrelse var 2,7 rensdyr fra lufttællingerne og 3,1 fra de to tællinger udført på jorden. Disse gruppestørrelser er sammenlignelige med tidligere opgørelser og typiske for grønlandske rensdyrbestande. Tætheden af rensdyr var 2,76 pr. km^2 i høj-tæthedsområdet og 1,19 pr. km^2 i lav-tæthedsområdet. 2,76 rensdyr pr. km^2 kunne anses for en trussel mod vegetationen og selv 1,19 rensdyr pr. km^2 er før blevet anset for at være for højt til at vegetationen kan restituere sig. Kalveprocenten for hele bestanden var 26,5 %. Fertilitetsindekset for sen-vinter samt det årlige rekrutteringsindex var ca. 68 kalve pr. 100 simler (hunner). Denne høje rekrutteringsrate vil give mulighed for en hurtig vækst i bestanden, specielt fordi der ingen rovdyr er. Forholdet mellem antallet af tyre og simler var ca. 1 tyr for hver 1,2 simle og det er ikke usædvanlig sammenlignet med nordamerikanske bestande. Hvis den naturlige dødelighed er mellem 4 og 7 % så vil der sandsynligvis dø mellem 2.000 og 3.600 rensdyr af naturlige årsager hvert år med den nuværende bestandsstørrelse.

Dette studies beregning af størrelsen på førkælvingsbestanden af rensdyr i området Kangerlussuaq-Sisimiut i marts 2000 er ca. 51.600 rensdyr ± 11.200 rensdyr (90% C.I.) Den anbefalede jagt i region Nord blev derfor øget til 7.000 dyr for jagten i august-september 2000, og jægerne blev opfordret til at skyde flere simler. Anbefalingen blev øget til 10.000 rensdyr for jagten i 2001 med den anbefaling at halvdelen af kvoten skulle allokeres til simler hvis yderligere stigning i bestanden skulle undgås. Tilvæksten i bestanden kan ikke standses gennem jagt hvis ikke andelen af nedlagte simler bliver større.

Bestanden i området Kangerlussuaq-Sisimiut er på nuværende tidspunkt i stand til hurtigt at vokse i antal. Det nuværende estimat for 2000 er ca. fem gange så stort som estimatet for 1996 og større end noget andet estimat har været for denne bestand. Yderemere er der en mulighed for at bestanden har udvidet sit leveområde og der er ting der peger på at den naturlige dødelighed er steget og at dyrene er i dårlig stand. En øget jagt i denne region vil derfor muligvis kunne forhindre en kraftig stigning i bestandsstørrelsen og deraf følgende skade på vegetationen.

Summary

Caribou herd size, herd structure, and recruitment estimates are important for management decisions. In March 2000 an aerial survey by helicopter for caribou abundance and herd structure was completed in Kangerlussuaq – Sisimiut. Flight height was 100 metres, flight speed was ≤ 100 kilometre/hour and strip width was 500 metres to either side of the helicopter. In 1998 and 2000, snowmobile ground surveys for herd structure were also conducted in February-March. Both aerial and ground surveys gave annual recruitment estimates.

Mean group size was 2.7 caribou from the aerial herd structure count and averaged 3.1 from the two ground counts. These group sizes are similar to previous findings and typical for Greenland caribou populations. Caribou density was 2.76 per km^2 in the high-density stratum and 1.19 per km^2 in the low-density stratum. The former could be considered a threat to vegetation, and even the latter has previously been considered too high for range recovery. The calf percentage to the total herd was 26.5%. The late winter fertility index and annual recruitment estimate was c. 68 calves per 100 female caribou. This high recruitment rate will promote rapid increase in the population, specifically since there are no predators. The bull to cow ratio was about one bull to every 1.2 cows, and is not unusual compared with North American herds. If natural mortality is between 4 and 7%, then on the present herd size between 2,000 and 3,600 animals may be expected to die annually.

This study's estimate for the pre-calving population size of the Kangerlussuaq-Sisimiut caribou herd in region North in March 2000 is c. 51,600 caribou ± 11,200 (90% CI). The recommended harvest quota for region North was increased to 7,000 caribou for the August-September hunt 2000, and hunters were asked to shoot more females. The recommendation was increased to 10,000 caribou for the 2001 hunt, with the stipulation that half the quota should be allocated to females only, if further population growth was to be halted. Halting population growth cannot be effectively achieved through hunter harvest unless females make up a large proportion of the harvest.

The Kangerlussuaq-Sisimiut caribou herd is presently capable of increasing rapidly in number. The present estimate for 2000 is approximately five times the 1996 estimate and larger than any previous estimate for this herd. In addition, there is the possibility that the herd has expanded its range, and some suggestion of increased natural mortality and animals in poor condition. Increasing the caribou harvest for this region may avert a possible rapid increase in herd size and subsequent range damage.

Introduction

An estimate of population size is often used as the most important foundation for managing caribou populations. When combined with data on herd structure, calf recruitment, and ecology (Thomas 1998) it is possible for managers to attempt to set sustainable hunting quotas. The caribou (*Rangifer tarandus groenlandicus*) of region North (Kangerlussuaq – Sisimiut (Figure 1)) are native to west Greenland, and at present are untainted by genetic mixing with introduced semi-domestic reindeer (*Rangifer tarandus tarandus*) as has occurred in some other regions (Jepsen 1999). At present, all caribou within region North are considered one population on the basis of their genetic similarity (Jepsen 1999). Although estimates of population size are among the most important foundations for managing caribou, estimates themselves are plagued by uncertainty as to how well they reflect reality for the population in question. In North America there is scepticism regarding caribou herd size estimates, for although counts have been done often and over several decades the results typically lack public support and too often are later found to have been underestimates (Thomas 1998).

Historical perspective on population estimates for region North

Caribou have been hunted in region North for c. 4000 years, and archaeological excavation evidence from several large hunting camps shows that hunting pressure has been heavy for the last 800 years, especially in inland areas (Meldgaard 1986). Until recently quantified estimates of caribou population size were not obtainable, however, there are written historical records containing subjective observations of relative abundance. Extreme caribou scarcity and poor hunting success, which resulted in human starvation, was first recorded for the years 1761-1770 (Vibe 1967, Meldgaard 1986). In 1815 an increase in caribou numbers was noticed, and numbers may have remained high for the next 35 years. A peak in caribou number appears to have occurred between 1845 and 1850, when c. 6,000+ caribou were hunted annually in region North (Vibe 1967, Meldgaard 1986). Numbers declined rapidly during the 1850's and reached a minimum in 1860 (Vibe 1967, Meldgaard 1986). Caribou remained scarce in region North until the 1950's. Between 1910 and 1920 typically only c. 300 caribou were reported in annual harvest statistics in region North, with even fewer taken up until the 1950's (Vibe 1967).

After the 1950's, caribou numbers increased steadily as did number harvested (Meldgaard 1986). There were always plenty of caribou for hunting between 1955 and 1976 (Kristian Egede pers. comm.). Well remembered was an infamous "Red" Sunday around Easter-time during the late 1960's when a large number of caribou swarmed into the coastal town of Sisimiut/Holsteinsborg (Steen Malmquist pers. comm.). Caribou moved about in large groups during the autumns of late 1960's and early 1970's, and hunters could take their time to pick out the fattest animals (Bjørn Rosing pers. comm.). The number of caribou around the Kangerlussuaq airport in 1963 was overwhelming, but by the 1970's a noticeable decrease in number had begun (Steen Malmquist pers. comm.). The highest reported numbers of caribou ever taken in this area (6,000+) occurred in 1974 and 1975, but following years gave somewhat declining hunter harvest (Grønlands Fangstlister, Meldgaard 1986).

Since the 1970's, there have been a series of aerial surveys to count or estimate the size

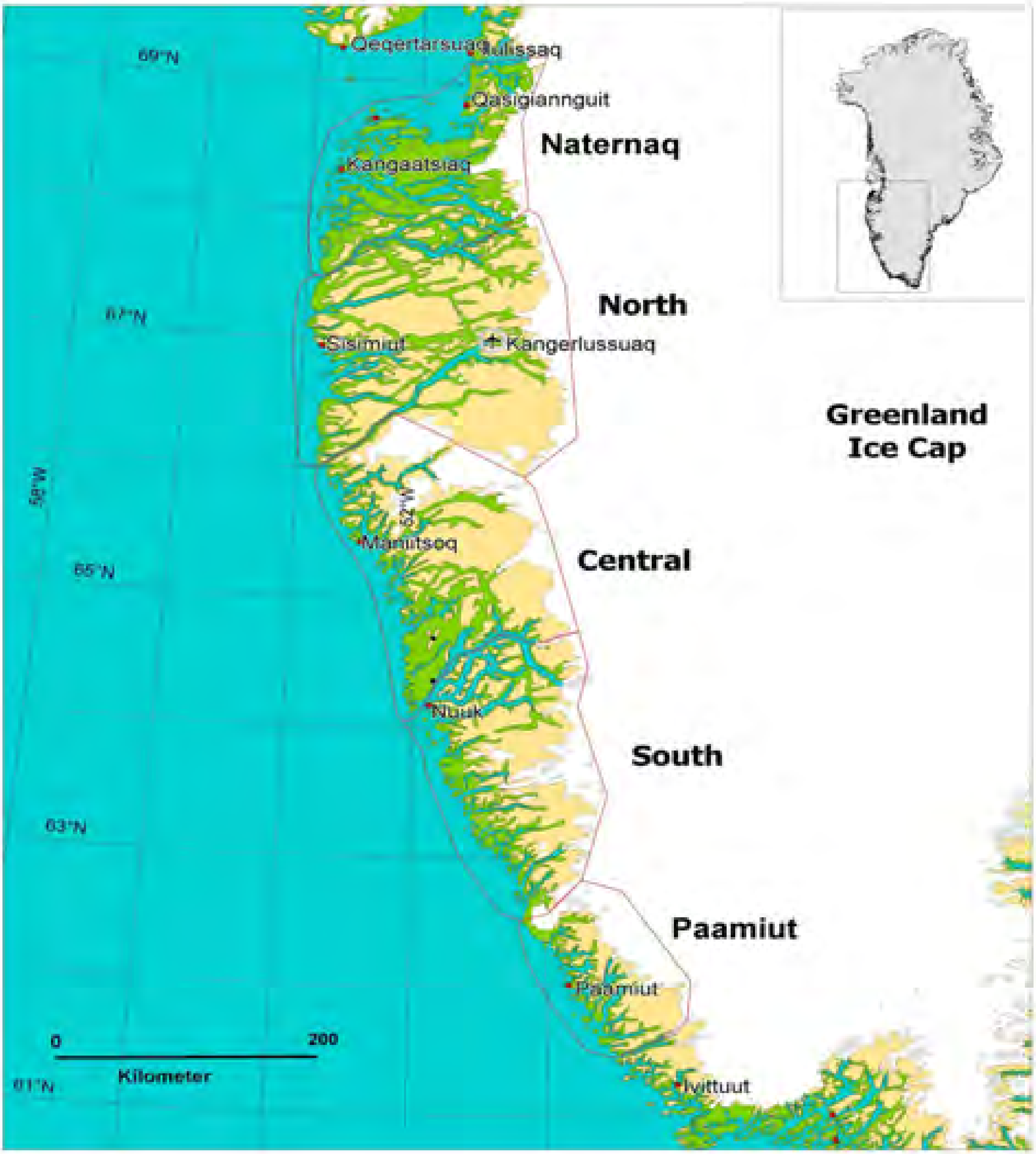

Figure 1. Caribou regions of west Greenland.

of the population. These surveys were conducted by various biologists and used a variety of different techniques (Table 1). All methods have a series of intrinsic errors and biases, and there has been public controversy about the accuracy of the 1990s' estimates. Based on general knowledge of the methods used during previous surveys it is highly likely that they all underestimated, by an unknown extent, the true size of the population. In this report we present new surveys of the size and structure of the region North caribou population, using improved methods.

Table 1. Caribou population size estimates for region North.

Year	Number of caribou[1]	Method	Reference
1977	18,350	minimum count	Strandgaard et al. 1983
1978	16,000	minimum count	Clausen et al. 1980, Roby & Thing 1985
1978	11,400	minimum count	Strandgaard et al. 1983
1980	3,000	minimum count	Strandgaard et al. 1983
1982	5,300	minimum count	Strandgaard et al. 1983
1990	8,874	minimum count	Thing & Falk 1990
1993	3,813	transect estimate	Ydemann & Pedersen 1999
1994	7,727	transect estimate	Ydemann & Pedersen 1999
1995	6,196	transect estimate	Ydemann & Pedersen 1999
1996	10,869	transect estimate	Ydemann & Pedersen 1999

[1] Sum of sub-area estimates within region, hence no confidence intervals. For details see reference.

Methods

Study area and caribou distribution

Region North encompasses approximately 26,000 km^2. The region's boundaries reflect both geographic and to an extent also biological units. It includes all the area between Nordre Strømfjord in the north down to Sukkertoppen Ice Cap in the south, and all land between the coast in the west and the Greenland Ice Cap to the east. All terrain in region North could be described as open or alpine tundra. Today, the largest human settlement within the region is the city of Sisimiut, with 5,127 inhabitants, while a further 244 people live in smaller settlements (Grønlands Statistisk Årbog 2000). The country's largest international civil airport is located on the far eastern side of the region near the inland Ice Cap.

The Kangerlussuaq-Sisimiut caribou herd has been described as having marked seasonal migrations between the inland and coast (Vibe 1967, Strandgaard et al. 1983). However, locals in 1981 told that most caribou kept to the inland all winter with no movement to the coasts, and surveys in March of 1981 and 1982 found that ¾ of the all observed caribou were within 30 kilometres of the inland Ice Cap (Strandgaard et al. 1983). Results from satellite-collared caribou found modest annual movement, with animals staying in the vicinity of the Ice Cap year round (Cuyler & Linnell in prep). Aerial surveys during the 1990's observed that high caribou densities occurred within inland areas and low densities further west towards, and at the coast (Ydemann & Pedersen 1999).

The inland areas were therefore considered to contain high caribou density relative to the coastal areas. During March the caribou of region North typically are scattered in small groups of less than 4 animals (Roby & Thing 1985, Thing 1982, Thing & Falk 1990, Ydemann & Pedersen 1999). The most critical calving area lies close to the inland Ice Cap between the Kangerlussuaq airport and Isortoq River (Thing 1981).

Aerial Survey objectives

The major objectives were to obtain up-to-date estimates of caribou abundance, herd structure and recruitment (number of calves per 100 females). Given the doubt surrounding previous surveys, estimating population trend was not an objective. Subordinate objectives included comparing ground and aerial survey methods for herd structure, and obtaining an overview of caribou distribution in the region.

Aerial survey design and field methods

An aerial survey of region North was conducted between the 15 to 17 March 2000. Helicopters were used, since in addition to slow flight capabilities, these can follow abrupt terrain features accurately.

The area was divided into two strata, one with a high caribou density and one with a low density (Figure 2) based on the observed densities from the earlier 1990s' aerial surveys (Ydemann & Pedersen 1999). The high-density stratum was 8,000 km^2, and the low-density stratum 18,000 km^2.

Sixty transect lines were used. Transect location and directions were randomly generated. 40 transects were allocated to the high caribou density stratum, and 20 transects were allocated to the low-density stratum. The optimal allocation of transects

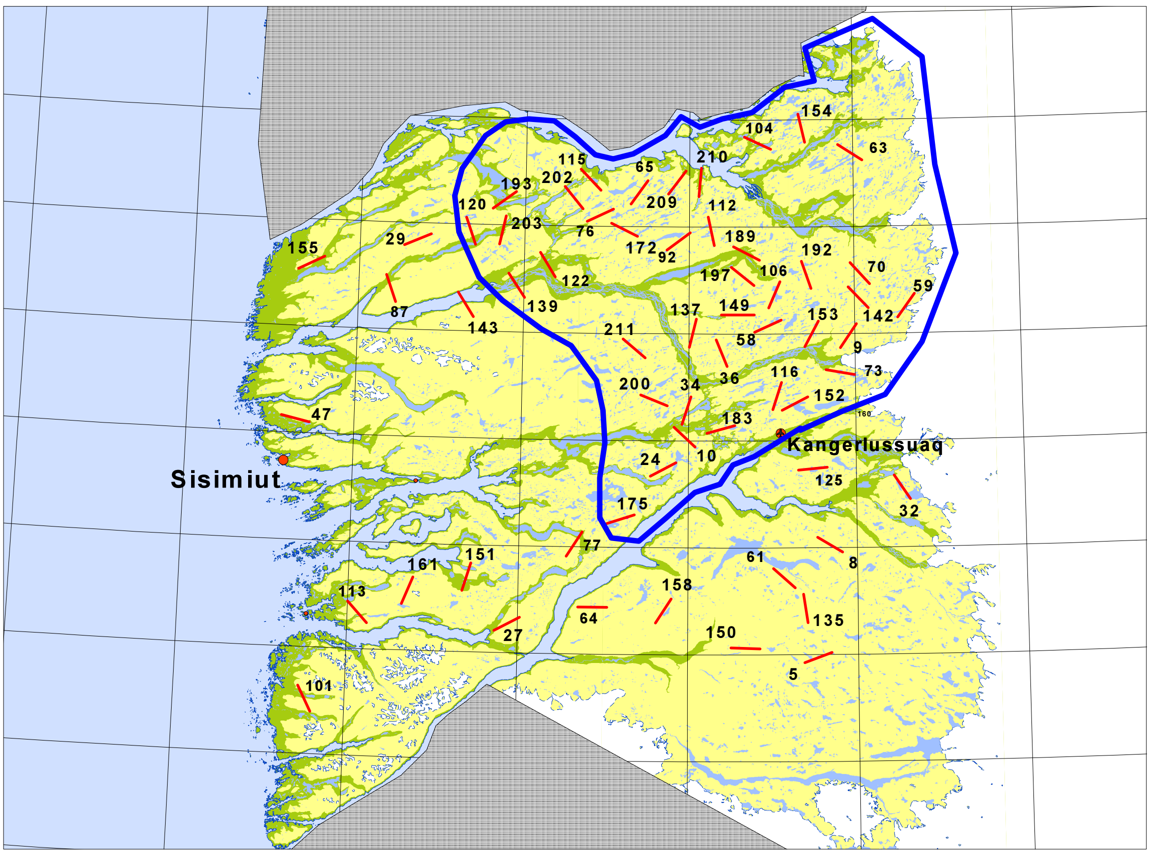

Figure 2. Transect lines and stratification used during aerial survey of region North. The high caribou density stratum included all land area inside the blue outline.

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.

One of the main problems in the earlier survey designs was that not all caribou present on a transect flown by the aircraft/helicopters were seen. This led to negatively biased population estimates. While it is difficult to completely overcome this bias, it can be minimised through careful design. To increase the sightability of caribou in our survey, several methods were employed. March was chosen for its optimal day length and snow cover, since patchy snow cover is known to reduce sightability (Ydemann & Pedersen 1999). Flight speed averaged 100 km/hour, which was a speed reduction compared to earlier surveys in Greenland. This allowed the observers more time to scan the strip area for caribou. To prevent observer fatigue/loss of concentration transects were kept to a length of 7.5 kilometres. 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. Altitude above the ground was c. 100 metres for the entire transect. The constant altitude provided even strip-width coverage for all transects. Strip width was reduced to 500 metres on either side of the helicopter, for a total strip width of 1 kilometre. To ascertain the 500 metre mark for each observer, Leica distance-finder binoculars with laser were used. Aided by the binoculars, each observer individually marked different coloured lines on the helicopter window at distances of 200, 300 and 500 metres.

There were 3 observers in the helicopter. Their positions were the left front seat, the left rear seat and the right rear seat. All 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 the left rear seat observer. Manual click-counters were used to log the number of caribou seen on a specific transect by each observer. Simultaneously a computer data-logger was used to record the GPS position, helicopter altitude, date, time and taped voice message for each observation, with each observer recorded separately. Additionally, transect characteristics (sun angle, cloud cover, snow coverage, topography and snow surface glare) were given by the front-seat observer while flying the transect. The number counted by each observer was recorded immediately following each transect, after which click-counters were zeroed for the next transect.

On 35 of the transects (16 in the low density stratum and 19 in the high density stratum) herd structure and recruitment counts were also flown (Figure 3). Choice generally depended on how many caribou were present during the initial transect flight, since the goal was to maximise the number of caribou, sexed and aged, for herd structure and recruitment. The helicopter backtracked the transect in a zig-zag flight pattern, never flying more than c. 2 kilometres from the transect line. There was close verbal contact 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.

Statistical design

The aerial helicopter survey was designed as a stratified strip transect count. Each transect had 3 observers, of which two counted the same strip area, i.e. both counted on the left side of the helicopter. A method to calculate a minimum number for the missed animals was developed. The standard method when each missed animal is identified was as follows Pollock & Kendall (1987). For details see appendices 1 & 2.

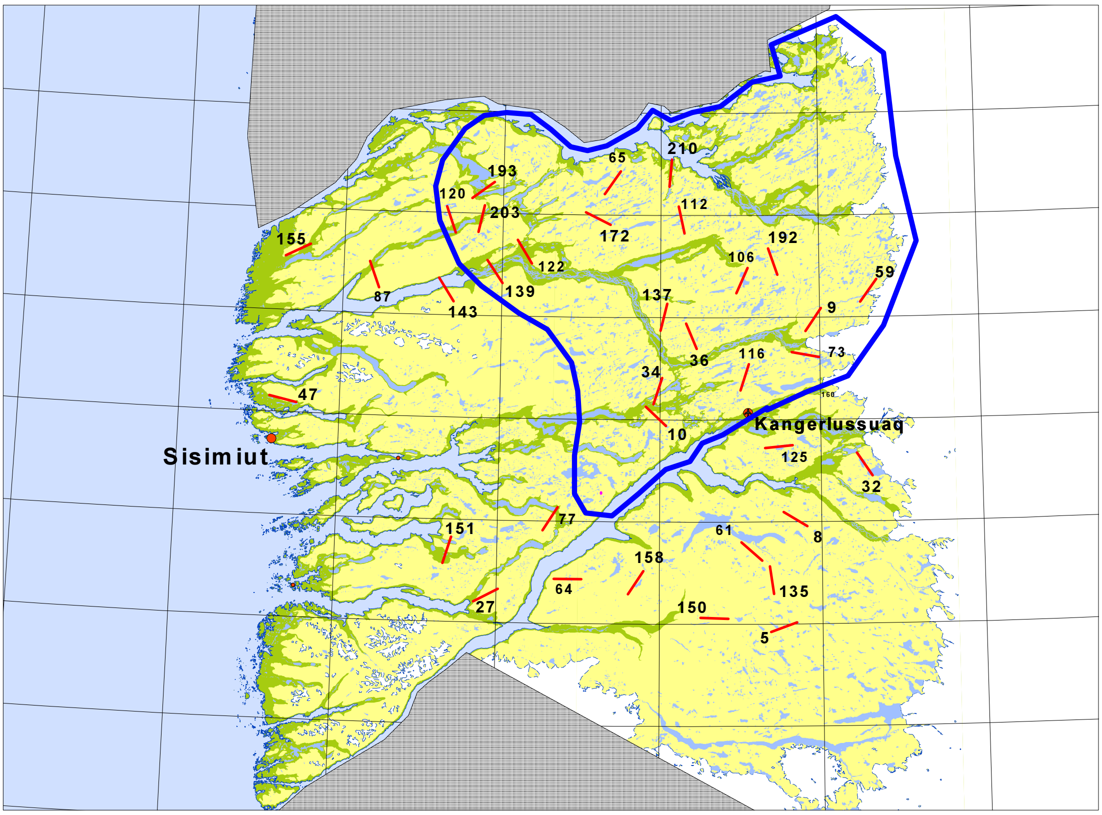

Figure 3. The 35 transect lines which also received zig-zag coverage for herd structure and recruiment counts during the aerial survey of region North. Blue outline encloses the high caribou density stratum.

Ground survey design and field methods

The sex and age distribution of the Kangerlussuaq-Sisimiut herd was investigated by ground survey of region North. Observations were made between 19 February-4 March 1998, and 28 February-9 March 2000. Inland areas were ground surveyed in 1998, while both inland and coastal areas were ground surveyed in 2000. The use of February-March optimised both snow cover and the amount of daylight. The terrain is well suited for snowmobiles. Caribou observations, approximate routes and area covered are shown in Figure 4. Areas were covered only once and rapid terrain coverage was used to avoid the possibility of double counting. Binoculars (10 x magnification) and/or a Leica spotting scope (60 x magnification) were used to sex and age animals observed.

Sex and age criteria

These criteria were applied during both ground and aerial surveys. Sex was determined by presence or absence of a vulva and/or urine patch on the rump. This reliably indicated a female on both adults and calves, and using the 60x scope sex could be ascertained at great distances. 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. There were two age classes used in subsequent analyses, calf (≤ 9-10 months old) and adult (> 1 year). Age was determined by body size. Calves of both sexes were considerably smaller than all other age classes at this time of year. Group size was based on proximity and group cohesion during possible flight response. Three cow/calf pairs, separated by several hundred metres, would not be regarded as a group of six.

Local involvement

Local observers from the Maniitsoq community were chosen by the Greenland Directorate for Industry (DE) and the Greenland Association of Commercial Hunters (KNAPK). Local professional hunter, Franz Petersen (KNAPK), and hunting officer, Jacob Heilman (DE) participated in the aerial survey. Local professional hunter, Hanseraq Olsen (KNAPK) participated in the snowmobile ground survey 2000.

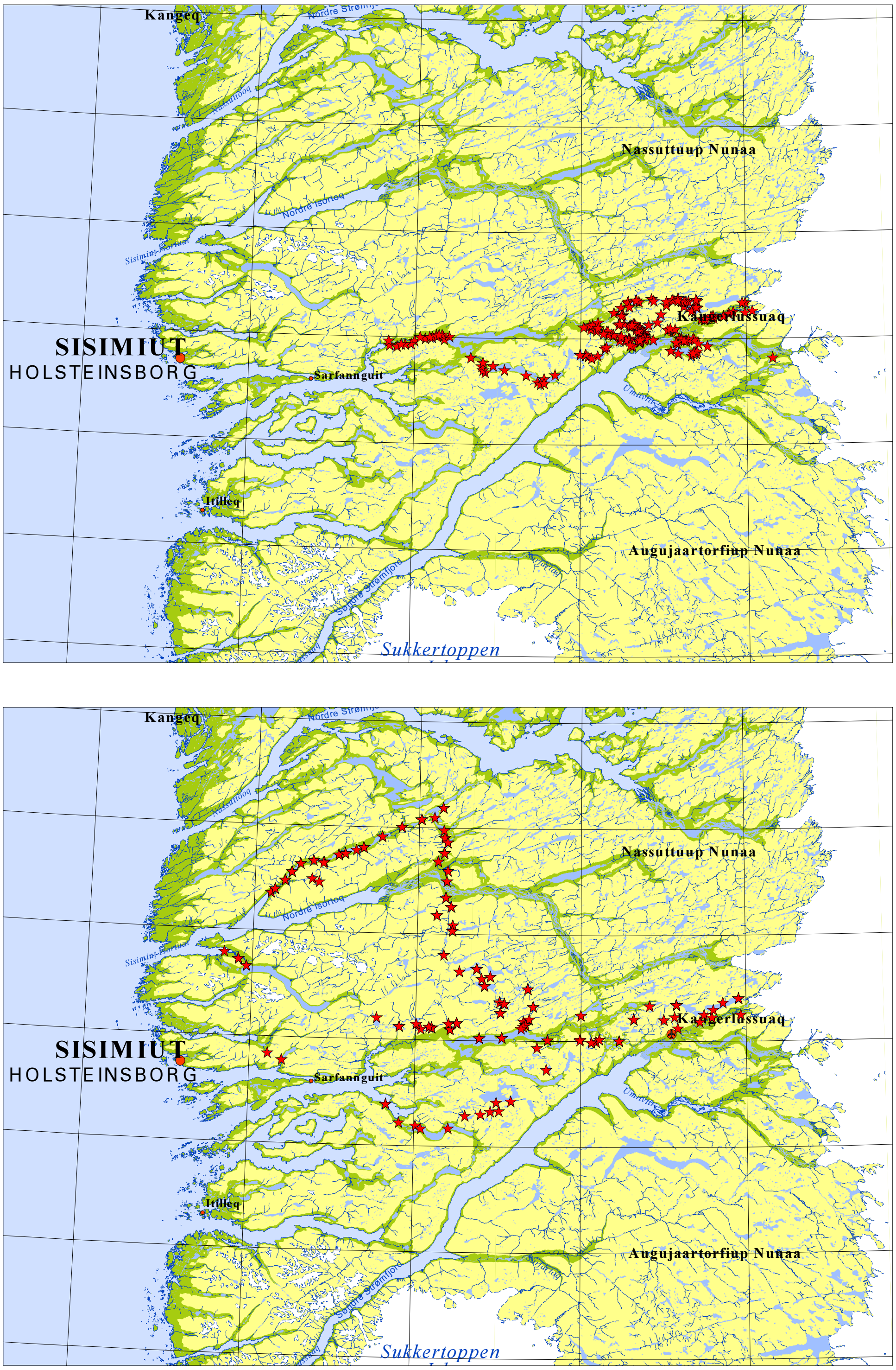

Figure 4. Observation sites for caribou during snowmobile ground survey 1998 (top) and 2000 (bottom) in region North.

Results

Region North caribou population size & distribution

Initial analysis of the data gave a preliminary estimate of population size in region North of c. 43,413 caribou ± 10,532 90% confidence interval (CI). The initial value was too low, because the lack of correction for missed caribou during the transect survey. The revised value is 51,600 ± 11,200 (Table 2), when accounting for animals present on transect but not seen by the observers. The correction calculation accounted for different correction factors for each stratum. Since no good method is available which could include the variance of a correction factor, the confidence intervals were instead calculated using a bootstrap method (Effron & Tibshirani 1993).

Caribou were scarce along the coast of region North during March. Of the five transects flown at or near the coast (no.'s 155, 47, 161, 113 and 101) only one had 4 caribou present and the rest none. Transects in the low density stratum generally had few caribou as expected. In contrast, seven of the 20 low density transects had between 11 and 36 caribou present. Four of these tran-

Table 2. Preliminary and revised caribou population size estimates, region North, March 2000.

	High density	Low density	Preliminary totals	Revised & final totals
Area size	8,000 km^2	18,000 km^2	26,000 km^2	26,000 km^2 *
Number strips	40	20	60	60
Length of each strip	7.5 km	7.5 km		
Total strip width	1 km	1 km		
Area covered	300 km^2	150 km^2	450 km^2	450 km^2
Flight height	100 metres	100 metres		
Flight speed (km/hr)	90 to 100	90 to 100		
Total caribou seen (n)	827	178	1,005	1,005
Mean number per strip	21	9		
Mean number per km^2	3	1		
Total	**22,053**	**21,360**	**43,413**	**c. 51,600**
Lower 90% CI			**32,880**	**40,400**
Upper 90% CI			**53,946**	**62,800**

* Correction not necessary.

sects (no.'s 125, 61, 135 and 158) were in Angujaartorfiup Nunaa (area enclosed by Søndre Strømfjord, Sukkertoppen and the Ice Cap). These transects had 23, 11, 30 and 21 caribou present respectively.

Transects in the low density stratum averaged 8.9 caribou ± 11.1 Standard deviation (SD). Transects in the high density stratum averaged 20.7 ± 13.5 (SD) caribou. Maximum caribou observed on any one transect was 61 caribou. This occurred on transect no. 73, which was tight beside the Ice Cap.

Herd structure & recruitment

Two methods were employed to examine herd structure. The first was by air and the other by ground survey. Total number of caribou sexed and aged from the air (Table 3) was higher than the total number of caribou seen on the 2 x 500 metre wide transect strip (Table 2) as more caribou were seen during the zig-zagging procedure (see methods).

Aerial survey logistics

The data-logger functioned poorly and fitfully, and no useful data could be collected. The manual click-counter animal counts from each observer for each transect provided the results for the aerial survey of caribou abundance. Observers sighted most caribou between 0-300 metres from the helicopter. Few were sighted beyond 300 metres, although animals were just as likely to be present in that strip area. Some observers could only detect moving caribou and missed stationary caribou, those lying down or standing still. This survey used about 22 hours of flying time.

The ability to see caribou varied among observers. On the left side of the helicopter there were two observers. The front-seat observer saw 595 caribou, while the same side rear-seat local observer saw 431 caribou. On the right side rear-seat of the helicopter the lone observer saw 386 caribou. Handling each transect separately and summing the maximum number of caribou seen on either side per transect, yielded the total number of 1,005 caribou seen on the strip transects.

Table 3. Herd Structure for caribou in region North, March 2000 and 1998

Date	15-17 March 2000	28 Feb-9 March 2000	19 Feb-4 March 1998
Method	Helicopter	Snowmobile	Snowmobile
Total sexed & aged (*n*)	1,130	1,006[1]	438
Density (high stratum)	2.76 / km^2		
Density (low stratum)	1.19 / km^2		
Average group size	2.8	3.98	2.3
Maximum group size	17	21	10
Bull (> 1 year)	387 (34.3%)	383 (38.1%)	161 (36.8%)
Cow (> 1 year)	443 (39.2%)	413 (41.1%)	187 (42.7%)
Calf	300 (26.6)	210 (20.8%)	90 (20.5%)
Recruitment (calf/cow*)	0.68	0.51	0.48

* all cows >1 year old.
[1] 85 unsexed yearlings not included.

Discussion

Caribou population size estimate

The final March 2000 population estimate was c. 51,600 caribou ± 11,200 (90% CI). This is best considered a conservative estimate, because although present methodology was improved a negative bias of caribou missed remains. The estimate of 51,600 caribou exceeds the previous 1996 survey estimate by a factor of five (Table 1) and is greater than any previous estimate from the 20th century. An interpretation of this result is difficult since methods differed. Regardless, it is likely that caribou abundance has been increasing since the 1996 estimate. It does not necessarily follow that region North is at a caribou population maximum, only that the present survey reflects animal abundance in 2000.

Caribou distribution

The distribution of caribou within region North appears to have expanded in recent years. The present study's stratification of the region into one area for low and one for high caribou density was based on caribou distributions observed during the 1990's surveys. Present results suggest changed distribution since the area of high caribou density appears to have expanded, specifically in Angujaartorfiup Nunaa and also to some extent further west of the stratification line used. An enlarged distribution is supported by local knowledge.

In recent years, increasing numbers of caribou have been seen in areas previously uninhabited by caribou (Ammunnguaq Jonathansen & Lars Inusugtoq pers. comm.). At the coast where caribou were once few in late summer, they are now numerous and come earlier (Ammunnguaq Jonathansen & Arkalunnguaq Mikaelsen pers. comm.). Caribou have expanded their summer range distribution also in the northern portion of region North during the past 6 years (Mogens Marker, Villiam Henriksen, Svend Jerimiassen pers. comm.). During geological studies in 1994, along a west to east gradient created by the south shore of Nordre Strømfjord, Marker seldom met caribou until nearly adjacent to the Greenland Ice Cap in the east. Subsequently, caribou number and frequency of caribou increased noticeably. During summer 2000, about 10 caribou could be observed in one's field-of-view from any position along the entire length of Nordre Strømfjord's south shore (Mogens Marker pers. comm.), and during the autumn there were caribou observed on Qeqertaussaq Island, which lies in the middle of Nordre Strømfjord (Hans Henrik Skott pers. comm.).

20 years ago local hunters knew that caribou behaviour changed with the size of the herd and that animals moved into coastal areas during population maximums (Grønnow et al. 1983, Meldgaard 1986). Locals now observe animals near the coast, but perceive no increase in caribou number. This leads to speculation. With a herd size around 52,000 animals, where on the population growth curve is this population today, and what herd sizes or densities are first necessary for locals to discern "too" many caribou in region North?

Caribou density

Reindeer move when food is in short supply, the greater the lack of food the more the movement (Baskin 1990). Densities of 2 caribou/km^2 in the Yukon and Alaska are considered high and result in dispersal thought due to competition for food (Haber & Walters 1980). Region North had a density of 2.76 caribou/km^2 in the high-density stratum. The area used in the calculation of density included all elevations. However, elevations over 700 metres contain minimal vegetation (Feilberg 1980) and may be of little importance as caribou food sources.

Density dependent affects can be acting within a population long before drastic effects are apparent. These may manifest themselves through winter food limitation, and severe weather could affect recruitment through decreased juvenile survival (Skogland 1985). Effects might include die-offs or animals in poor body condition. Thin caribou were observed along the shores of Søndre Strømfjord/Kangerlussuaq fjord in November 2000 (Hans Kreutzmann pers. comm.). During august 2001 an increased number of dead caribou relative to previous years were observed along the coasts, mainly on the south shores of Nordre Strømfjord, which is the northern border of region North (Ammunnguaq Jonathansen, Arkalunnguaq Mikaelsen, Hans Mølgaard, Jørgen Inuusuttoq, Svend Jerimiassen & Villiam Henriksen pers. comm.). All carcasses were within 1 km of the fjord shoreline with starvation as the likely cause of death (Hans Mølgaard pers. comm.). This local information combined with the aerial survey's observed high caribou density suggests the possibililty of overgrazing on the range. In the early 1980's even the present low-density stratum's 1.2 caribou/km^2 was considered too high for range recovery in region North (Thing 1981).

Herd structure

The two snowmobile ground survey results appear comparable (Table 4). Any differences may be due to the inclusion of coastal areas during the 2000 survey, e.g., group sizes are known to be greater in coastal areas (Roby & Thing 1985). The doubling of maximum group size observed during the

Table 4. Overview of herd structure parameters during late winter for the Kangerlussuaq-Sisimiut caribou herd, region North.

	2000 aerial	2000 ground	1998 ground	1996	1995	1994	1993	1990	1979	1978	1977
Density (high)	2.76			0.96	0.51	0.8	0.38	0.61			
Density (low)	1.19			0.16	0.09	0.06	0.06				
Group size	2.8	4	2.3	2.5	2.6	3.2	2	2.6	c. 2.2	c. 2.2	c. 2.2
Bull% (> 1 yr)	34.3	38.1	36.8						13	28	32
Cow% (> 1 yr)	39.2	41.1	42.7						55	52	45
Calf %	26.6	20.8	20.5	17.3	13.2	16.0		23.7	28	17	22
Calf/100 cows	68*	51	48						c. 24	c. 24	c. 24
n	1,130	1,006	438	2,337	1,131	837	484		7,223	2,851	6,153
Reference	4	4	4	2	2	2	2	3	1	1	1

*Cows over 1 year old.
[1] Thing 1982
[2] Ydemann & Pedersen 1999 unpublished
[3] Thing & Falk 1990
[4] present study

2000 ground survey relative to the 1998 survey was also mirrored in the aerial survey 2000. The higher values for calf% and calf/100 cows from the aerial survey may reflect better the actual situation for the population, since more of the herd's range was covered during aerial survey than could be covered by ground survey. There is a significant difference between the herd structures found by air and by both snowmobile counts ($p < 0.05$), but no significant difference between the snowmobile structure counts done in 1998 and in 2000 ($p > 0.8$). The bull to cow ratio was about one bull to every 1.2 cows, and is not unusual compared with studies on barren-ground and woodland caribou in North American (Parker 1972).

Recruitment

Recruitment in the Kangerlussuaq-Sisimiut herd (average 56 calves/100 cows in late winter) is high compared to other herds. Studies from North America and Scandinavia report late winter 41 calves/100 cows (Fancy et al. 1994), 20 calves/100 cows (Dzus 1999) and 22 calves/100 cows (Parker 1972). However, some of these populations typically have predators. Still a comparison to 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). The Kangerlussuaq-Sisimiut caribou herd late winter recruitment of between 51 and 68 calves/100 cows in 2000 suggests a population capable of increasing rapidly in number.

Expected natural mortality

Natural adult mortality for caribou in 5 North American herds without natural predators has been estimated at 4-6% annually (Bergerud 1967, 1971, Skoog 1968, Kelsall 1968). Thing (1982) estimated 7% died annually in region North. With the 2000 population estimate of c. 51,600 ± 11,200 caribou in region North, and using both 4% and 7%, this would equate to a potential natural mortality of between 2,000 and 3,600 caribou each year in region North.

Implication for caribou harvest

Kangerlussuaq-Sisimiut caribou population Caribou harvest was either prohibited or quotas given were small (Table 5) following the low population size estimates of the 1990's aerial surveys (Table 1). At present the Kangerlussuaq-Sisimiut caribou herd may be increasing in number, given the large 2000 herd size estimate, high calf recruitment rate, almost a decade of low harvesting, and local knowledge on range expansion. The harvest recommendation for region North in 2000 was 7,000 and for 2001 it is 10,000 caribou.

Hunter reports are still essential to the data foundation on which harvest recommendations are made and therefore continued hunter reporting is necessary regardless of the size of future quotas. The harvest quota recommendation for 2001 has again been increased due to acknowledged large herd size, substantial calf recruitment, high caribou density on range and the present concern for probable range degradation. Calf production appears to be approximately 9-10,000 calves at present. A harvest quota of this magnitude for region North may prevent further growth in population size.

Since 1995 the harvests have been severely (90%) sex-biased towards males (Loison et al. 2000). Highly male-biased sex ratios in harvesting can potentially lead to reduced

Table 5. 10-year overview of harvest quotas for region North Kangerlussuaq-Sisimiut caribou herd.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Harvest quota	X[1]	X[1]	X[1]	0	0	705	856	1,120	1,350	1,920

[1] harvest regulated by bag-limits for each hunter rather than an overall population specific quota.

female fertility and population collapse in extreme cases (Ginsberg & Milner-Gulland 1994). Sex-skewed harvesting may even endanger the genetic variability of a population (Ryman et al. 1981). However, in the context of west Greenland caribou, the most likely short-term negative consequence of a skewed sex ratio lies in the creation of a female dominated population with a high growth rate relative to population size. Such a population with high growth rate can rapidly become too large for the range to support, potentially resulting in a population crash and/or long term degradation of the range. Therefore the recommendation for 2001 harvest in region North included the stipulation that half the harvest quota must be female, which would assist halting population growth.

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Appendix 1

Survey method & design

This survey attempted to improve both accuracy and precision in method and design. A further analysis of the survey method can be found in Appendix 3.

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.

Reducing negative bias: Sightability of caribou on transect

This survey reduced the negative bias associated with observers missing caribou that were actually within the transect strip, and hence is more accurate than previous surveys. The improvements in survey design over those described in Ydemann & Pedersen (1999) are listed below.

- Helicopter used versus fixed-wing aircraft.
- Strip width was narrower, only 500 metre to each side versus 700 metre.
- Slower flying speed, 100 kilometre/hour versus 167 kilometre/hour.
- Lower altitudes, 100 metre versus 152 metre.
- Sun typically behind observers, versus sun often in observer's eyes.
- Short transect length promoted full observer concentration and reduced observer fatigue, 7.5 kilometres versus typically c. ≥ 100 kilometres
- Statistical correction for missed caribou.

Together, these improvements served to reduce the bias associated with violation of the assumption that all caribou within the strip are observed. In the 1993, 94, 95 & 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.

Precision

Precision can be improved in two ways, increasing the number of transect lines and improving on the stratification and allocation of transect lines between strata. In this case the stratification was changed based on the observed densities from the previous surveys. It is difficult to assess the contribution of the stratification to the precision but it is possible to assess the contribution of the transect allocation to the precision. The allocation during the 2001 survey was not optimal.

The allocation used during this survey gave 40 transects to the high-density area and 20 transects to the low-density area. A better allocation would have been the exact opposite (in retrospect, i.e., knowing the relative size of the variances and the size of the areas), 20 to the high-density area and 40 to the low-density area. The difference in precision was a parametric 90% CI of ± 10,500, where the optimal allocation would have given a 90% CI of ± 8,750.

Statistical design

The total population estimate for caribou in region North 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

is the total number of caribou observed in strip i

is the total area of strata j

is the area of strip i

is the mean area of the strips in the stratum

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

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

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 2

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 overlooked by observers. Various doublecount 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 et al. 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 et al. 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 doublecount methodology (Pollock & Kendall 1987, Graham & Bell 1989, Rivest et al. 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 doublecount 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 & 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
is the number of animals observed by the front seat observer only
is the number of animals seen by the rear seat observer only
is the number of animals not seen by either observer
is the probability that a visible animal is seen by the front seat observer

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

In a conventional doublecount setup where animals or groups can be individually identified for comparison between observers the following procedure is often used:

B can be estimated as

Therefore

In the same manner can be estimated as

By substitution

In the same manner can be estimated as

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 . The easiest way to find confidence intervals is to use a bootstrap procedure (Effron & Tibshirani 1993).

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

(Graham & Bell 1989)

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

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

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

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

is the number of animals seen by the rear seat observer

then we can define

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

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

and

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

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 5) 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 6).

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 6).

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 p_f and 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.

Table 6. 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.

P_f

P_r

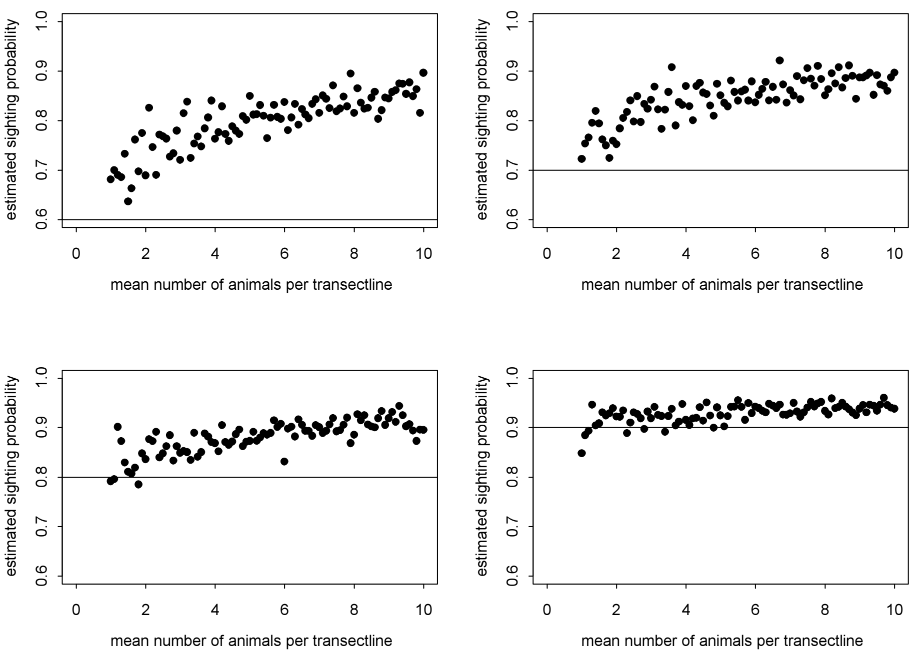

Figure 5. Simulations of the effects of number of animals encountered per transect strip on the estimated sighting probability (bias adjustment) at four different levels of detection probability (the horizontal line at 0.6, 0.7, 0.8 and 0.9).

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Appendix 3

Aerial survey 2000 data for Kangerlussuaq-Sisimiut caribou population in West Greenland

Table 7. Aerial survey Kangerlussuaq-Sisimiut caribou herd, region North, March 2000.

	High Density Stratum	Low Density Stratum	Total
Area size[1] (km^2)	8,000	18,000	26,000
Number strips (n)	40	20	60
Length of each strip (km)	7.5	7.5	
Total strip width (metres)	2 x 500	2 x 500	1,000
Area covered (km^2)	300	150	450
Flight height (metres)	100	100	
Flight speed (km/hr)	90 to 100	90 to 100	
Total caribou seen	827	178	1,005

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

Table 8. Raw data aerial survey Kangerlussuaq-Sisimiut caribou herd, region North, March 2000.

Date ddmmyy	Transect number[1]	Density Stratum	Number Caribou observed on transect		
			Left front[2] (CC)	Left rear (JH)	Right rear (FP)
15.03.00	77	Low	34	26	2
15.03.00	27	Low	0	0	0
15.03.00	151	Low	3	7	6
15.03.00	161	Low	0	0	0
15.03.00	113	Low	0	0	0
15.03.00	101	Low	0	0	0
15.03.00	47	Low	0	0	4
15.03.00	87	Low	7	5	5
15.03.00	155	Low	0	0	0
15.03.00	29	Low	0	0	0
15.03.00	120	High	13	15	6
15.03.00	193	High	27	21	19
15.03.00	203	High	38	25	9
15.03.00	139	High	9	5	16
15.03.00	143	Low	5	2	0
16.03.00	125	Low	9	2	14
16.03.00	32	Low	3	3	0
16.03.00	8	Low	0	0	3
16.03.00	61	Low	7	6	4
16.03.00	135	Low	11	14	19
16.03.00	5	Low	2	2	0
16.03.00	150	Low	2	1	2
16.03.00	158	Low	10	14	7

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Date ddmmyy	Transect number[1]	Density Stratum	Number Caribou observed on transect		
			Left front[2] (CC)	Left rear (JH)	Right rear (FP)
16.03.00	64	Low	8	5	0
16.03.00	175	High	5	1	6
16.03.00	152	High	2	4	1
16.03.00	116	High	9	4	11
16.03.00	73	High	31	23	30
16.03.00	9	High	15	14	15
16.03.00	153	High	7	6	1
16.03.00	142	High	5	3	2
16.03.00	59	High	15	3	26
16.03.00	70	High	4	3	4
16.03.00	192	High	22	12	3
16.03.00	189	High	6	4	3
16.03.00	197	High	11	1	6
16.03.00	106	High	17	12	8
16.03.00	58	High	3	1	18
17.03.00	183	High	0	1	0
17.03.00	10	High	10	11	0
17.03.00	24	High	3	0	6
17.03.00	34	High	19	11	10
17.03.00	200	High	9	6	8
17.03.00	211	High	6	2	1
17.03.00	137	High	25	15	11
17.03.00	149	High	2	0	4
17.03.00	112	High	22	23	9
17.03.00	92	High	14	14	11
17.03.00	36	High	24	18	14
17.03.00	63	High	0	1	3
17.03.00	154	High	9	8	3
17.03.00	104	High	11	6	0
17.03.00	210	High	7	9	6
17.03.00	209	High	2	5	19
17.03.00	65	High	15	11	12
17.03.00	115	High	21	18	3
17.03.00	202	High	19	5	8
17.03.00	76	High	6	0	6
17.03.00	172	High	22	18	1
17.03.00	122	High	9	5	1
Individual totals			**595 (CC)**	**431 (JH)**	**386 (FP)**
Totals			**Left side 619**		**Right side 386**
Grand total			**1,005 caribou observed**		

Kangerlussuaq-Sisimiut aerial survey observers: (CC) Christine Cuyler, Greenland Institute of Natural Resources; (JH) Jakob Heilman, Maniitsoq hunting officer; (FP) Franz Petersen, KNAPK hunter.

[1] Transects are presented in the order flown.

[2] Indicates seat position in helicopter.

Table 9. Random transects for aerial survey Kangerlussuaq-Sisimiut caribou herd, region North, March 2000.

Date ddmmyy	Direction flown	Transect number	Transect start DD mm.m		Transect end DD mm.m	
			Latitude	Longitude	Latitude	Longitude
15.03.00	NE-SW	77	66° 47.1'	51° 52.8'	66° 43.7'	51° 58.3'
15.03.00	NE-SW	27	66° 35.0'	52° 14.4'	66° 33.1'	52° 23.3'
15.03.00	SSE-NNW	151	66° 38.6'	52° 34.9'	66° 42.5'	52° 31.9'
15.03.00	SSE-NNW	161	66° 36.5'	52° 56.1'	66° 40.3'	52° 52.3'
15.03.00	SE-NW	113	66° 33.7'	53° 08.1'	66° 36.6'	53° 15.1'
15.03.00	SSE-NNW	101	66° 21.0'	53° 26.8'	66° 24.6'	53° 31.4'
15.03.00	ESE-WNW	47	67° 01.5'	53° 31.1'	67° 02.4'	53° 41.2'
15.03.00	S - N	87	67° 18.8'	53° 01.6'	67° 22.6'	53° 05.2'
15.03.00	SW-NE	155	67° 22.9'	53° 37.2'	67° 24.8'	53° 27.9'
15.03.00	SW-NE	29	67° 26.8'	52° 59.0'	67° 28.5'	52° 49.3'
15.03.00	SE-NW	120	67° 27.1'	52° 33.1'	67° 30.9'	52° 36.6'
15.03.00	SW-NE	193	67° 32.3'	52° 27.0'	67° 34.7'	52° 18.5'
15.03.00	NE-SW	203	67° 31.2'	52° 22.1'	67° 27.3'	52° 24.4'
15.03.00	NW-SE	139	67° 23.2'	52° 20.7'	67° 19.9'	52° 14.9'
15.03.00	NW-SE	143	67° 20.4'	52° 38.9'	67° 17.0'	52° 33.2'
16.03.00	W - E	125	66° 56.3'	50° 25.5'	66° 55.9'	50° 35.8'
16.03.00	SE-NW	32	66° 51.7'	49° 56.0'	66° 55.1'	50° 01.7'
16.03.00	SE-NW	8	66° 44.4'	50° 20.4'	66° 46.5'	50° 29.2'
16.03.00	SE-NW	61	66° 39.4'	50° 37.2'	66° 42.1'	50° 44.8'
16.03.00	S - N	135	66° 34.5'	50° 32.9'	66° 38.5'	50° 34.3'
16.03.00	NE-SW	5	66° 30.3'	50° 24.5'	66° 28.9'	50° 34.0'
16.03.00	E - W	150	66° 30.9'	50° 49.8'	66° 31.0'	50° 59.9'
16.03.00	SW-NE	158	66° 34.4'	51° 26.5'	66° 37.8'	51° 21.0'
16.03.00	W - E	64	66° 36.6'	51° 53.9'	66° 36.6'	51° 43.7'
16.03.00	SW-NE	175	66° 48.3'	51° 44.0'	66° 49.6'	51° 34.3'
16.03.00	NE-SW	152	67° 06.2'	50° 32.3'	67° 04.3'	50° 41.5'
16.03.00	SW-NE	116	67° 04.4'	50° 44.9'	67° 08.2'	50° 41.7'
16.03.00	WNW-ESE	73	67° 09.9'	50° 25.6'	67° 09.2'	50° 15.4'
16.03.00	SW-NE	9	67° 13.0'	50° 20.4'	67° 16.4'	50° 14.4'
16.03.00	SW-NE	153	67° 13.2'	50° 33.2'	67° 16.8'	50° 28.2'
16.03.00	SE-NW	142	67° 18.6'	50° 10.2'	67° 21.5'	50° 17.4'
16.03.00	SW-NE	59	67° 17.2'	49° 59.5'	67° 20.5'	49° 53.3'
16.03.00	SE-NW	70	67° 21.9'	50° 09.6'	67° 24.9'	50° 16.6'
16.03.00	SE-NW	192	67° 21.4'	50° 30.8'	67° 25.5'	50° 34.3'
16.03.00	SE-NW	189	67° 25.4'	50° 49.5'	67° 27.2'	50° 58.9'
16.03.00	SE-NW	197	67° 21.8'	50° 51.6'	67° 24.3'	50° 59.8'
16.03.00	NE-SW	106	67° 22.4'	50° 42.1'	67° 18.6'	50° 46.3'
16.03.00	WSW-ENE	58	67° 15.3'	50° 51.3'	67° 16.9'	50° 41.8'
17.03.00	WSW-ENE	183	67° 01.1'	50° 08.6'	67° 02.2'	50° 58.6'
17.03.00	SE-NW	10	66° 59.1'	51° 12.8'	67° 01.9'	51° 20.3'
17.03.00	NE-SW	24	66° 56.9'	51° 19.6'	66° 55.0'	51° 28.7'
17.03.00	SSW-NNE	34	67° 02.3'	51° 17.5'	67° 06.2'	51° 14.3'
17.03.00	SE-NW	200	67° 04.9'	51° 22.7'	67° 06.4'	51° 32.4'
17.03.00	SE-NW	211	67° 11.6'	51° 30.9'	67° 14.2'	51° 38.9'
17.03.00	SSW-NNE	137	67° 13.2'	51° 15.0'	67° 17.1'	51° 12.5'
17.03.00	W - E	149	67° 17.7'	51° 02.7'	67° 17.7'	50° 52.2'

Continues...

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Date ddmmyy	Direction flown	Transect number	Transect start DD mm.m		Transect end DD mm.m	
			Latitude	Longitude	Latitude	Longitude
17.03.00	SSE-NNW	112	67º 27.4'	51º 06.0'	67º 31.4'	51º 08.2'
17.03.00	NE-SW	92	67º 29.2'	51º 14.7'	67º 26.8'	51º 23.2'
17.03.00	NW-SE	36	67º 14.2'	51º 05.3'	67º 10.5'	51º 01.3'
17.03.00	SE-NW	63	67º 39.3'	50º 11.7'	67º 41.5'	50º 20.7'
17.03.00	SSE-NNW	154	67º 41.9'	50º 32.8'	67º 45.8'	50º 35.2'
17.03.00	SE-NW	104	67º 40.9'	50º 45.4'	67º 42.6'	50º 55.0'
17.03.00	SSW-NNE	210	67º 34.3'	51º 11.7'	67º 38.3'	51º 10.7'
17.03.00	SW-NE	209	67º 34.6'	51º 22.8'	67º 37.9'	51º 16.4'
17.03.00	SW-NE	65	67º 33.1'	51º 36.5'	67º 36.5'	51º 30.4'
17.03.00	SE-NW	115	67º 35.1'	51º 47.6'	67º 38.0'	51º 55.0'
17.03.00	NW-SE	202	67º 35.5'	52º 00.8'	67º 32.4'	51º 54.0'
17.03.00	SW-NE	76	67º 30.7'	51º 52.5'	67º 32.4'	51º 49.9'
17.03.00	NW-SE	172	67º 30.5'	51º 43.6'	67º 28.7'	51º 34.1'
17.03.00	NW-SE	122	67º 26.2'	52º 09.4'	67º 22.8'	52º 03.8'

Table 10. Raw data aerial survey herd structure Kangerlussuaq-Sisimiut caribou herd, region North, March 2000.

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
15.03.00	77	4	1	2	1
15.03.00	77	2	1	1	0
15.03.00	77	2		1	1
15.03.00	77	3	1	1	1
15.03.00	77	5	3	1	1
15.03.00	77	4	1	3	0
15.03.00	77	2	2		0
15.03.00	77	6	3	1	2
15.03.00	77	5	2	2	1
15.03.00	77	2	2		0
15.03.00	77	2	1		1
15.03.00	77	3	1	2	0
15.03.00	151	2	1	1	0
15.03.00	151	4	2	2	0
15.03.00	151	2	2		0
15.03.00	151	1	1		0
15.03.00	151	6	2	4	0
15.03.00	151	1	1		0
15.03.00	151	1	1		0
15.03.00	151	4	2	2	0
15.03.00	151	1	1		0
15.03.00	151	4	1	3	0
15.03.00	151	1		1	0
15.03.00	151	2	1	1	0
15.03.00	47	2		1	1
15.03.00	47	5	2	3	0
15.03.00	47	6	4	1	1
15.03.00	87	3	1	2	0
15.03.00	87	5	4		1
15.03.00	87	2	2		0

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
15.03.00	87	2	1	1	0
15.03.00	87	2	2		0
15.03.00	155	6	4		2
15.03.00	120	4	1	3	0
15.03.00	120	4	2		2
15.03.00	120	2	2		0
15.03.00	120	4	2		2
15.03.00	120	5	3		2
15.03.00	120	1	1		0
15.03.00	120	1		1	0
15.03.00	120	2	2		0
15.03.00	193	2		2	0
15.03.00	193	4	3	1	0
15.03.00	193	3	3		0
15.03.00	193	2			2
15.03.00	193	3	3		0
15.03.00	193	5	3	2	0
15.03.00	193	1		1	0
15.03.00	193	1	1		0
15.03.00	193	2	2		0
15.03.00	193	2	2		0
15.03.00	193	3	2	1	0
15.03.00	193	2	2		0
15.03.00	193	2	2		0
15.03.00	193	7	7		0
15.03.00	193	7	5	2	0
15.03.00	193	4			4
15.03.00	193	3			3
15.03.00	193	2	2		0
15.03.00	193	7		3	4
15.03.00	203	6		5	1
15.03.00	203	7	1	3	3
15.03.00	203	5	1	2	2
15.03.00	203	1		1	0
15.03.00	203	5	5		0
15.03.00	203	1	1		0
15.03.00	203	4	4		0
15.03.00	203	3	3		0
15.03.00	203	1	1		0
15.03.00	203	1	1		0
15.03.00	203	8	7		1
15.03.00	203	7	3	3	1
15.03.00	139	1		1	0
15.03.00	139	2			2
15.03.00	139	1	1		0
15.03.00	139	1		1	0
15.03.00	139	2	2		0
15.03.00	139	1			1
15.03.00	139	3		2	1
15.03.00	139	2		1	1
15.03.00	139	3	1	1	1
15.03.00	139	1	1		0
15.03.00	139	3		1	2
15.03.00	139	5	2	2	1
15.03.00	139	1	1		0
15.03.00	139	1		1	0

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
15.03.00	139	1	1		0
15.03.00	139	4	1	2	1
15.03.00	139	4	4		0
15.03.00	139	3	1	2	0
15.03.00	139	1	1		0
15.03.00	139	3	1	1	1
15.03.00	139	1	1		0
15.03.00	139	5	2	2	1
15.03.00	143	2	1	1	0
15.03.00	143	2	2		0
15.03.00	143	3	3		0
15.03.00	143	1	1		0
16.03.00	125	4	3	1	0
16.03.00	125	3		1	2
16.03.00	125	4		3	1
16.03.00	125	6	3	3	0
16.03.00	125	3	2	1	0
16.03.00	125	3	1	2	0
16.03.00	125	1		1	0
16.03.00	32	2	1	1	0
16.03.00	32	2		1	1
16.03.00	61	1	1		0
16.03.00	61	1			1
16.03.00	61	2			2
16.03.00	61	1	1		0
16.03.00	61	3		1	2
16.03.00	61	1			1
16.03.00	61	2	1	1	0
16.03.00	61	1	1		0
16.03.00	61	2	2		0
16.03.00	135	3	1	2	0
16.03.00	135	2		1	1
16.03.00	135	6	1	3	2
16.03.00	135	1		1	0
16.03.00	135	1		1	0
16.03.00	135	3	3		0
16.03.00	135	1			1
16.03.00	135	1		1	0
16.03.00	135	3	2	1	0
16.03.00	135	17	10	7	0
16.03.00	135	3	3		0
16.03.00	135	3	2	1	0
16.03.00	135	1		1	0
16.03.00	5	1		1	0
16.03.00	5	2		1	1
16.03.00	150	1		1	0
16.03.00	150	2		1	1
16.03.00	150	2		1	1
16.03.00	158	6	3	3	0
16.03.00	158	7	2	5	0
16.03.00	158	1			1
16.03.00	158	1			1
16.03.00	158	2			2
16.03.00	158	1		1	0
16.03.00	158	10	2	2	6

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
16.03.00	158	4	2	1	1
16.03.00	158	2	2		0
16.03.00	158	4		1	3
16.03.00	158	2			2
16.03.00	158	1		1	0
16.03.00	64	1	1		0
16.03.00	64	4	3	1	0
16.03.00	64	2		2	0
16.03.00	64	4	1	2	1
16.03.00	64	5	2		3
16.03.00	116	5			5
16.03.00	116	3		2	1
16.03.00	116	5	1	4	0
16.03.00	116	6	6		0
16.03.00	116	2		1	1
16.03.00	116	2	2		0
16.03.00	116	2	2		0
16.03.00	73	2		1	1
16.03.00	73	2		1	1
16.03.00	73	3	2		1
16.03.00	73	3	1	1	1
16.03.00	73	3		3	0
16.03.00	73	2		1	1
16.03.00	73	5		4	1
16.03.00	73	5		3	2
16.03.00	73	4	2	2	0
16.03.00	73	2		1	1
16.03.00	73	2		1	1
16.03.00	73	3		2	1
16.03.00	73	3		2	1
16.03.00	73	7		4	3
16.03.00	9	2	1	1	0
16.03.00	9	2	2		0
16.03.00	9	2	2		0
16.03.00	9	4	1	3	0
16.03.00	9	2		1	1
16.03.00	9	1		1	0
16.03.00	9	4	2	2	0
16.03.00	9	4	1	3	0
16.03.00	9	2		1	1
16.03.00	9	5		3	2
16.03.00	9	1		1	0
16.03.00	9	2		2	0
16.03.00	9	2		1	1
16.03.00	59	5	3	1	1
16.03.00	59	1	1		0
16.03.00	59	2		1	1
16.03.00	59	4	1	1	2
16.03.00	59	4		2	2
16.03.00	59	4		3	1
16.03.00	59	2			2
16.03.00	59	1	1		0
16.03.00	192	2			2
16.03.00	192	2		2	0
16.03.00	192	1			1
16.03.00	192	2	1	1	0

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
16.03.00	192	3	1	1	1
16.03.00	192	2	1	1	0
16.03.00	192	2		1	1
16.03.00	192	4		2	2
16.03.00	192	2		1	1
16.03.00	192	2		2	0
16.03.00	192	2	1		1
16.03.00	192	7	1	6	0
16.03.00	192	2		2	0
16.03.00	192	4		1	3
16.03.00	192	4		4	0
16.03.00	192	3		3	0
16.03.00	192	1		1	0
16.03.00	192	3		2	1
16.03.00	192	2		1	1
16.03.00	106	3		1	2
16.03.00	106	6	3	3	0
16.03.00	106	4		4	0
16.03.00	106	1			1
16.03.00	106	5		2	3
16.03.00	106	3	3		0
16.03.00	106	3		2	1
16.03.00	106	2			2
16.03.00	106	3	1	2	0
16.03.00	106	7	1	3	3
16.03.00	106	3		1	2
16.03.00	106	2		1	1
16.03.00	106	4		4	0
16.03.00	106	6		4	2
16.03.00	106	2		1	1
16.03.00	106	1		1	0
16.03.00	106	4			4
17.03.00	10	2		1	1
17.03.00	10	2		2	0
17.03.00	10	3	1	1	1
17.03.00	10	1			1
17.03.00	10	1	1		0
17.03.00	10	5			5
17.03.00	10	2		1	1
17.03.00	10	1		1	0
17.03.00	10	1			1
17.03.00	10	1			1
17.03.00	10	3		3	0
17.03.00	10	2	1	1	0
17.03.00	10	4	1	1	2
17.03.00	10	1			1
17.03.00	34	5		3	2
17.03.00	34	1		1	0
17.03.00	34	1			1
17.03.00	34	1		1	0
17.03.00	34	1		1	0
17.03.00	34	4		4	0
17.03.00	34	4		3	1
17.03.00	34	2			2
17.03.00	34	1			1
17.03.00	34	3	2		1

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
17.03.00	34	2		2	0
17.03.00	34	1		1	0
17.03.00	34	3	1	2	0
17.03.00	34	3	1	1	1
17.03.00	34	6		5	1
17.03.00	34	4		3	1
17.03.00	34	1		1	0
17.03.00	137	2		1	1
17.03.00	137	4	1		3
17.03.00	137	1		1	0
17.03.00	137	3		3	0
17.03.00	137	3		1	2
17.03.00	137	4	2		2
17.03.00	137	1			1
17.03.00	137	1	1		0
17.03.00	137	2	1	1	0
17.03.00	137	3	1	1	1
17.03.00	137	1		1	0
17.03.00	137	6		2	4
17.03.00	137	2	2		0
17.03.00	137	4	1	3	0
17.03.00	137	4		2	2
17.03.00	137	2	1	1	0
17.03.00	137	3	1	1	1
17.03.00	137	1		1	0
17.03.00	137	2	1	1	0
17.03.00	112	9		4	5
17.03.00	112	7	4	1	2
17.03.00	112	4		4	0
17.03.00	112	3		2	1
17.03.00	112	6	2	4	0
17.03.00	112	2	1	1	0
17.03.00	112	5		4	1
17.03.00	112	6	1	4	1
17.03.00	112	3	3		0
17.03.00	112	1	1		0
17.03.00	112	1	1		0
17.03.00	112	1			1
17.03.00	112	1	1		0
17.03.00	112	2		1	1
17.03.00	112	2		1	1
17.03.00	112	1			1
17.03.00	112	1			1
17.03.00	112	1	1		0
17.03.00	112	2			2
17.03.00	112	7	2	4	1
17.03.00	112	1		1	0
17.03.00	112	3		3	0
17.03.00	112	2		2	0
17.03.00	112	5		5	0
17.03.00	112	1		1	0
17.03.00	36	4	1	1	2
17.03.00	36	2			2
17.03.00	36	2	2		0
17.03.00	36	2		1	1

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
17.03.00	36	3	1	2	0
17.03.00	36	2		1	1
17.03.00	36	2		1	1
17.03.00	36	4		1	3
17.03.00	36	5		3	2
17.03.00	36	2		2	0
17.03.00	36	1	1		0
17.03.00	36	4	3	1	0
17.03.00	36	1	1		0
17.03.00	36	1	1		0
17.03.00	36	5	2	2	1
17.03.00	36	2		1	1
17.03.00	36	4		1	3
17.03.00	36	2			2
17.03.00	36	4	1		3
17.03.00	36	6	1	3	2
17.03.00	36	3		3	0
17.03.00	36	5	1	2	2
17.03.00	36	3		2	1
17.03.00	36	2	1	1	0
17.03.00	210	2		1	1
17.03.00	210	1	1		0
17.03.00	210	3	3		0
17.03.00	210	1	1		0
17.03.00	210	1			1
17.03.00	210	2	2		0
17.03.00	210	1	1		0
17.03.00	210	4	2	2	0
17.03.00	210	2			2
17.03.00	210	3	1	2	0
17.03.00	210	3	3		0
17.03.00	210	4	2	2	0
17.03.00	210	3	2	1	0
17.03.00	210	2	1		1
17.03.00	210	1	1		0
17.03.00	210	1	1		0
17.03.00	210	1	1		0
17.03.00	210	1	1		0
17.03.00	210	3			3
17.03.00	210	1		1	0
17.03.00	210	1		1	0
17.03.00	210	1	1		0
17.03.00	210	2	1		1
17.03.00	210	2		1	1
17.03.00	210	2	1		1
17.03.00	210	1	1		0
17.03.00	210	2	2		0
17.03.00	210	2	1	1	0
17.03.00	65	2			2
17.03.00	65	4	4		0
17.03.00	65	3	2	1	0
17.03.00	65	2	1	1	0
17.03.00	65	2	2		0
17.03.00	65	2	1	1	0
17.03.00	65	4	2		2

Continues...

Continued...

Date ddmmyy	Transect number Zig-Zag flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
17.03.00	65	1	1		0
17.03.00	65	2	2		0
17.03.00	65	2	2		0
17.03.00	65	1	1		0
17.03.00	65	2	2		0
17.03.00	65	5	1	2	2
17.03.00	65	3	1		2
17.03.00	65	2			2
17.03.00	65	9	2	6	1
17.03.00	65	7	2	1	4
17.03.00	65	3			3
17.03.00	65	2	2		0
17.03.00	65	3	1	2	0
17.03.00	65	2		1	1
17.03.00	65	6	2	4	0
17.03.00	172	5		4	1
17.03.00	172	3	1	2	0
17.03.00	172	4			4
17.03.00	172	2	2		0
17.03.00	172	1		1	0
17.03.00	172	3	1	2	0
17.03.00	172	6	2	4	0
17.03.00	172	2			2
17.03.00	172	1	1		0
17.03.00	172	2		1	1
17.03.00	122	3	2		1
17.03.00	122	1	1		0
17.03.00	122	1	1		0
17.03.00	122	2			2
17.03.00	122	2			2
17.03.00	122	3			3
17.03.00	122	1		1	0
17.03.00	122	2		2	0
17.03.00	122	2	2		0
17.03.00	122	2			2
17.03.00	122	2	1		1
17.03.00	122	4	1		3
17.03.00	122	4	1	3	0
Totals		**1,130 All**	**387 Males**	**443 Females**	**300 Calves**

Appendix 4

Ground surveys 1998 & 2000; Kangerlussuaq-Sisimiut caribou population in West Greenland

Table 11. Raw data ground survey herd structure Kangerlussuaq-Sisimiut caribou herd, region North, 19 February – 4 March 1998.

Date ddmmyy	Group Size	Females > 1 year	Calves < 1 year	Males > 1 year
19.02.98	1	1		
19.02.98	2	1	1	
19.02.98	2	1	1	
19.02.98	1			1
19.02.98	2			2
19.02.98	1			1
19.02.98	3	2	1	
19.02.98	3			3
19.02.98	2	1	1	
19.02.98	2			2
19.02.98	2		2	
19.02.98	2	1		1
19.02.98	2	1	1	
19.02.98	4	1	2	1
19.02.98	2			2
19.02.98	4	4		
19.02.98	1	1		
19.02.98	2		2	
19.02.98	2	2		
19.02.98	1			1
19.02.98	2	1	1	
21.02.98	4	2	1	1
21.02.98	2			2
21.02.98	2	1	1	
21.02.98	1			1
21.02.98	2	1	1	
21.02.98	2			2
21.02.98	2	1	1	
21.02.98	2	1		1
21.02.98	1			1
21.02.98	1	1		
21.02.98	2	1	1	
21.02.98	2	1	1	
21.02.98	4	2		2
21.02.98	4	2		2
21.02.98	1	1		
21.02.98	3	1		2
21.02.98	4			4
21.02.98	5	2	3	
21.02.98	2	2		
21.02.98	2	1	1	

Continues...

Continued...

Date ddmmyy	Group Size	Females > 1 year	Calves < 1 year	Males > 1 year
21.02.98	4	2	2	
21.02.98	4	2	2	
21.02.98	3	2	1	
21.02.98	3			3
21.02.98	2	1	1	
21.02.98	10	4	4	2
21.02.98	2	1	1	
21.02.98	1			1
21.02.98	5	4	1	
21.02.98	1			1
21.02.98	1	1		
21.02.98	2	1	1	
21.02.98	1			1
21.02.98	1	1		
21.02.98	2	2		
21.02.98	2	2		
21.02.98	1	1		
21.02.98	3	1	2	
21.02.98	2	2		
21.02.98	1	1		
21.02.98	1			1
21.02.98	1	1		
21.02.98	2	2		
21.02.98	2	1	1	
21.02.98	2	2		
22.02.98	2	1	1	
22.02.98	1			1
22.02.98	2			2
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	1	1		
22.02.98	3			3
22.02.98	9	4		5
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	2	1	1	
22.02.98	6	1		5
22.02.98	2	1		1
22.02.98	2			2
22.02.98	3	1		2
22.02.98	2	1		1
22.02.98	1	1		
22.02.98	1			1
22.02.98	1			1
23.02.98	3	1		2
23.02.98	2		1	1
23.02.98	1			1
23.02.98	1	1		
23.02.98	2	1	1	
23.02.98	2	1	1	
23.02.98	2			2
23.02.98	3	1		2

Continues...

Continued...

Date ddmmyy	Group Size	Females > 1 year	Calves < 1 year	Males > 1 year
23.02.98	1		1	
23.02.98	1	1		
23.02.98	3	3		
23.02.98	1	1		
23.02.98	1	1		
23.02.98	1	1		
23.02.98	2			2
23.02.98	2	1	1	
23.02.98	2	1	1	
23.02.98	2	1	1	
23.02.98	1	1		
23.02.98	1			1
23.02.98	1			1
23.02.98	1			1
23.02.98	2	1	1	
26.02.98	2	1	1	
26.02.98	7	1		6
26.02.98	2	2		
26.02.98	1			1
27.02.98	2	1	1	
27.02.98	1			1
27.02.98	2			2
27.02.98	1	1		
27.02.98	1	1		
27.02.98	1			1
27.02.98	1			1
27.02.98	5			5
27.02.98	8			8
27.02.98	5	1	1	3
27.02.98	5			5
27.02.98	1		1	
27.02.98	3			3
27.02.98	3	3		
27.02.98	2			2
27.02.98	2			2
27.02.98	4			4
27.02.98	2	2		
27.02.98	1			1
27.02.98	1			1
27.02.98	1			1
27.02.98	2	1	1	
27.02.98	2			2
27.02.98	1	1		
27.02.98	1	1		
27.02.98	4		2	2
27.02.98	3	1	1	1
27.02.98	3	1	1	1
27.02.98	2	1		1
27.02.98	2	1		1
27.02.98	3			3
27.02.98	4	1	1	2
04.03.98	2	1	1	
04.03.98	1			1
04.03.98	3	3		
04.03.98	1	1		

Continues...

Continued...

Date ddmmyy	Group Size	Females > 1 year	Calves < 1 year	Males > 1 year
04.03.98	3	2		1
04.03.98	8	4	1	3
04.03.98	5	3	2	
04.03.98	1	1		
04.03.98	3			3
04.03.98	2		2	
04.03.98	3	2	1	
04.03.98	1		1	
04.03.98	1		1	
04.03.98	3	3		
04.03.98	2	1	1	
04.03.98	4	2	1	1
04.03.98	6	2	2	2
04.03.98	2	1	1	
04.03.98	3	2		1
04.03.98	2	1	1	
04.03.98	2	1	1	
04.03.98	2	1	1	
04.03.98	4	2	2	
04.03.98	1	1		
04.03.98	2	2		
04.03.98	3			3
04.03.98	1	1		
04.03.98	3	1		2
04.03.98	1			1
04.03.98	2	1	1	
04.03.98	3	3		
04.03.98	2	1	1	
04.03.98	1	1		
04.03.98	2	1	1	
04.03.98	3			3
04.03.98	4	4		
04.03.98	2	1	1	
04.03.98	1	1		
04.03.98	3	3		
04.03.98	3	3		
04.03.98	2	1		1
04.03.98	4	1	2	1
Totals	**438 All**	**187 Females**	**90 Calves**	**161 Males**
			Total sexed & aged 438	

Ground survey observers were Christine Cuyler, Greenland Institute of Natural Resources and Joseph Patrick McCullough, sport hunter from Nuuk.

Table 12. Raw data ground survey herd structure Kangerlussuaq-Sisimiut caribou herd, region North, 28 February – 9 March 2000.

Group-size	Females	Calves < 1 year	Males	Sex unknown (yearlings)	GPS position DD.ddd	
					Latitude	Longitude
10			10		66.848	52.422
8	4	4			66.848	52.422
12	3	1	8		66.848	52.422
3	1			2	66.805	52.342
5	2	1	2		66.798	52.242
1			1		66.792	52.210
6	1	1	4		66.793	52.045
2	1			1	66.823	51.945
4	2	1		1	66.827	51.852
1			1		66.833	51.793
6	3		3		67.052	52.488
6	2		3	1	66.835	51.742
3			2	1	66.855	51.758
5			4	1	66.858	51.670
4	1		2	1	66.858	51.670
5	1		4		67.047	50.530
1			1		67.057	50.457
2			2		67.057	50.457
4	2	2			67.057	50.457
3	2	1			67.057	50.457
10	5	3		2	67.063	50.282
3			2	1	67.102	50.295
7	2	1	3	1	67.102	50.295
11	2	1	7	1	67.102	50.295
3	1	1	1		67.092	50.390
4	3	1			67.075	50.448
1	1				67.063	50.505
5	3	2			67.062	51.250
10	9			1	67.062	51.250
2			1	1	67.087	50.672
6	2	2	2		67.087	50.672
6	2	2	2		67.087	50.672
6	4		2		67.087	50.672
3	2			1	67.087	50.672
3	2	1			67.087	50.672
3	2	1			67.087	50.672
5	2		2	1	67.087	50.672
2	2				67.058	50.683
2	1	1			67.052	50.748
7	4	2	1		67.052	50.748
2		2			60.047	50.693
6	6				67.032	50.663
2			2		67.002	51.018
1			1		67.002	51.018
3			3		67.002	51.018
3		2		1	67.002	51.018
3		1	1	1	67.002	51.018
3	2	1			67.000	51.158
3	3				67.000	51.158
1		1			67.005	51.138
1	1				66.998	51.187
2	1	1			66.998	51.187
2	1	1			66.998	51.187

Continues...

Continued...

Group-size	Females	Calves < 1 year	Males	Sex unknown (yearlings)	GPS position DD.ddd	
					Latitude	Longitude
2				2	66.998	51.187
9	7	2			67.005	51.255
3	1	1	1		67.003	51.257
6	5	1			67.084	50.834
2	1	1			67.084	50.834
2	2				67.053	50.931
3	1	2			67.053	50.931
2	1	1			67.053	50.931
3	2	1			67.053	50.931
3	2	1			67.053	50.931
1			1		67.053	50.931
3			3		67.003	51.452
17	9	5	1	2	67.003	51.452
1	1				67.003	51.452
4	2	2			67.003	51.452
1			1		67.008	51.728
5	3	2			67.008	51.728
1			1		67.008	51.728
1			1		67.007	51.865
3			3		67.007	51.865
2	1	1			67.007	51.865
1			1		67.007	51.865
3	1	1	1		67.007	51.865
4	1	1	2		67.027	52.042
4	1		3		67.027	52.042
3		1	2		67.027	52.042
9	4	3	2		67.027	52.042
1	1				67.027	52.042
3	1		2		67.042	52.002
1			1		67.042	52.002
1			1		67.042	52.002
1	1				67.042	52.002
3	1	2			67.042	52.002
3	1	1	1		67.042	52.002
3			3		67.042	52.002
1			1		67.042	52.002
1			1		67.042	52.002
7			7		67.042	52.002
3			3		67.042	52.002
4	3	1			67.042	52.002
4	2	2			67.042	52.002
9	3	3	2	1	67.040	52.052
5			5		67.040	52.052
1		1			67.040	52.052
8	6	2			67.030	52.153
3	2		1		67.030	52.153
1			1		67.030	52.153
3	2	1			67.030	52.153
2			2		67.030	52.153
4	2	2			67.030	52.153
2				2	67.030	52.153
1			1		67.030	52.153
1			1		67.030	52.153
4			4		67.030	52.153
3	1	1	1		67.032	52.170
2		1		1	67.032	52.170

Continues...

Continued...

Group-size	Females	Calves < 1 year	Males	Sex unknown (yearlings)	GPS position DD.ddd	
					Latitude	Longitude
2	1	1			67.027	52.220
4	1	1	2		67.038	52.247
21	8	7	2	4	67.038	52.247
1				1	67.032	52.350
5	1	3		1	67.032	52.350
2	1			1	67.032	52.350
4	2	2			67.165	53.287
2				2	67.165	53.287
6	2	1		3	67.182	53.337
5	3	2			67.182	53.337
5	3	2			67.182	53.337
2	1	1			67.182	53.337
4	1	1	2		67.182	53.337
6	3	2		1	67.182	53.337
13	4	2	5	2	67.197	53.423
3	1	2			67.340	53.152
3			3		67.340	53.152
3	2			1	67.348	53.127
3			3		67.348	53.127
2			2		67.348	53.127
1			1		67.348	53.127
1			1		67.370	53.067
1			1		67.370	53.067
2	1	1			67.370	53.067
1				1	67.370	53.067
3	1		2		67.370	53.067
5	2	1	1	1	67.370	53.067
9	4	2	3		67.390	53.027
5	4	1			67.390	53.027
4	2	2			67.390	53.027
3	2	1			67.390	53.027
1			1		67.390	53.027
17	10	4	1	2	67.410	52.975
4			4		67.410	52.975
4	2	1	1		67.410	52.975
5	3	2			67.418	52.895
1			1		67.418	52.895
3	2	1			67.415	52.832
3	2	1			67.415	52.832
5	2	1	2		67.415	52.832
5			5		67.415	52.832
2	1	1			67.433	52.742
1				1	67.433	52.742
1				1	67.433	52.742
6	2	1		3	67.433	52.742
6	2	1	1	2	67.437	52.702
2	1	1			67.437	52.702
3			3		67.437	52.702
6			6		67.437	52.702
2	1	1			67.437	52.702
4	1	1	1	1	67.445	52.635
1				1	67.452	52.590
15	6	5	2	2	67.452	52.590
4	2	1		1	67.452	52.590
5	1		3	1	67.452	52.590
19	9	5	4	1	67.452	52.590

Continues...

Continued...

Group-size	Females	Calves < 1 year	Males	Sex unknown (yearlings)	GPS position DD.ddd	
					Latitude	Longitude
6			6		67.452	52.590
8			8		67.452	52.590
11	3	3	5		67.478	52.477
2	1	1			67.478	52.477
2	1	1			67.478	52.477
2			2		67.502	52.357
2			2		67.502	52.357
1			1		67.502	52.357
0					67.520	52.237
5			5		67.520	52.237
8	1		6	1	67.520	52.237
2			2		67.520	52.237
3	1		1	1	67.520	52.237
2			2		67.520	52.237
2			2		67.478	52.092
1				1	67.478	52.092
2	1	1			67.478	52.092
1	1				67.478	52.092
2	1	1			67.478	52.092
1		1			67.478	52.092
2			2		67.478	52.092
3				3	67.467	52.073
2	1	1			67.467	52.073
5	2	1	2		67.467	52.073
6			6		67.467	52.073
2				2	67.467	52.073
2	1		1		67.442	52.093
3			3		67.442	52.093
3			2	1	67.442	52.093
4	1	1	2		67.442	52.093
2	1	1			67.442	52.093
3	1	2			67.442	52.093
1			1		67.442	52.093
6	6				67.422	52.130
2	2				67.422	52.130
6	3	3			67.375	52.075
14	8		6		67.375	52.075
6	2	2	2		67.337	52.080
1		1			67.337	52.080
1	1				67.337	52.080
1			1		67.337	52.080
5	3	1		1	67.315	52.047
9	4	2	3		67.315	52.047
5			4	1	67.315	52.047
3	2		1		67.315	52.047
11	4	1	6		67.315	52.047
3			3		67.295	52.133
2	1			1	67.295	52.133
16	7	1	8		67.295	52.133
4	2		2		67.272	52.035
1			1		67.272	52.035
4	1		2	1	67.258	52.037
1			1		67.258	52.037
1			1		67.202	52.087
4	2	1	1		67.163	51.990
5	3	1	1		67.163	51.990

Continues...

Continued...

Group-size	Females	Calves < 1 year	Males	Sex unknown (yearlings)	GPS position DD.ddd Latitude	Longitude
1	1				67.170	51.885
1				1	67.170	51.885
1			1		67.170	51.885
4	4				67.170	51.885
8	4	2	2		67.147	51.855
2	1		1		67.130	51.837
1			1		67.130	51.837
1	1				67.152	51.802
2	2				67.152	51.802
2	1			1	67.092	51.743
8	4		4		67.092	51.743
1				1	67.092	51.743
5	4		1		67.088	51.715
2			2		67.088	51.715
2			2		67.088	51.715
2	1	1			67.088	51.715
1		1			67.067	51.738
2			2		67.067	51.738
3	1	1	1		67.067	51.738
1	1				67.123	51.573
2			2		67.123	51.573
1	1				67.123	51.573
2	1			1	67.123	51.573
1		1			67.123	51.573
6	2		4		67.082	51.540
4	3		1		67.082	51.540
2	2				67.082	51.540
2	1	1			67.052	51.563
6	1	2	3		67.052	51.563
1			1		67.038	51.585
4	2		2		67.038	51.585
2	2				67.038	51.585
1			1		67.038	51.585
1				1	67.035	51.600
1		1			67.030	51.612
9	1	1	7		67.525	52.157
6	2	3	1		67.375	52.902
10	1	1	8		67.368	52.858
5			5		67.413	52.835
9	5	2	2		67.548	52.103
17	7	2	8		67.548	52.103
3	3				67.548	52.103
5	3	2			67.548	52.103
6	2	2	2		67.548	52.103
5	4	1			67.548	52.103
2	1	1			67.495	52.097
9	4		5		67.400	52.070
7		7			67.047	51.598
14	5	3	4	2	66.985	51.515
6	2	2		2	66.933	51.458
5	1	1	1	2	54.200	51.478
9	5		4		66.947	53.055
5	3	2			66.962	53.142
1,091 All	**383 Females**	**413 Calves**	**210 Males**	**85 Unknown**		
	1,006 Sexed & aged					

Ground survey observers were Torsten Ingerslev, Greenland Institute of Natural Resources and Hanseraq Olsen, KNAPK hunter from Sisimiut. No dates were provided in original data report.

Appendix 5

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.

Bootstrapping - statistical tool to arrive at confidence intervals without knowledge of the distribution of the parameter in question.

Confidence interval - statistical term for when the standard error (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*. 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 of the same species 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 & 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 North according to caribou density present.

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 6

Recommendations for the future

Aerial survey design & field methods

Future aerial surveys could further improve caribou sightability by using even lower flight altitudes, slower flight speeds and a further narrowing of the strip width. Results indicate observers are able to detect caribou typically at distances ≤ 300 metres from the helicopter. Caribou were seldom sighted in the 300 to 500 m zone. To increase sightability and further reduce negative bias for missed caribou, future surveys should narrow the strip width to 300 metres.

Throughout the duration of this survey the same observers were used and they kept the same seats. This procedure is not recommended for future surveys. Although the results of the present survey suggest a possible intrinsic sighting advantage for the front seat observer, later surveys suggested no advantage existed (Cuyler et al. 2002, Cuyler et al. unpublished). When you don't know observer ability, by changing observers and their positions it is possible to spread the bias risk over an average of individuals' abilities rather than risking the possibility of a poor observer causing high negative bias. Recommended for future surveys is the use of several different rear seat observers, plus changing their seating from left to right rear seat, as it is then possible to measure observer quality and to select for the best observers, given that the front seat observer is of known and acceptable observer quality.

Ground survey design & field methods

Future ground surveys could be improved by establishing a systematic program of fixed routes to collect data annually or bi-annually. Routes chosen should provide a broader coverage of both inland and coastal areas. The season and timing of the survey could remain February-March. A time series of ground surveys could provide an index of caribou herd structure, recruitment and minimum count for region North. Index changes could reflect changes in the caribou population.

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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. 24 Flytællinger af fugle og havpattedyr i Vestgrønland 1998. Heide-Jørgensen, M.P., M. Acquarone & F.R. Merkel 1999.

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