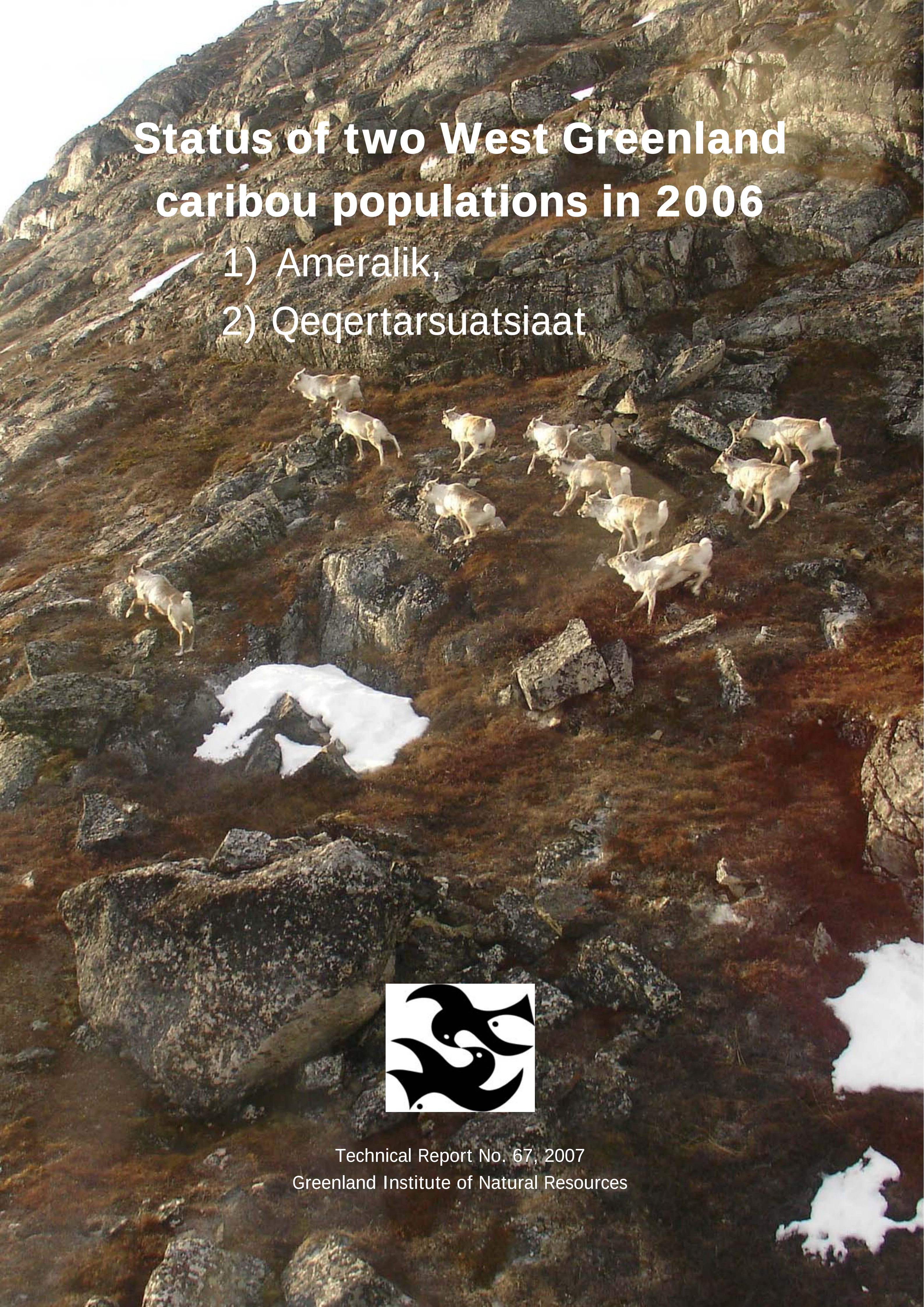

Status of two West Greenland caribou populations in 2006

1) Ameralik,

2) Qeqertarsuatsiaat

Technical Report No. 67, 2007
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Status of two West Greenland caribou populations in 2006

1) Ameralik,
2) Qeqertarsuatsiaat

By

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Summary

In March 2006 two caribou populations, Ameralik and Qeqertarsuatsiaat, which are south of the capital city of Nuuk, were surveyed by helicopter for abundance and herd structure. Methods and analysis repeated the surveys of 5 years earlier. Combining the estimates for both populations gives a total of ca. 15,000 caribou with a coefficient of variance of 13%. Although there are far fewer animals than 5 years ago, caribou remain relatively plentiful in the South region. Furthermore, a portion of the Ameralik population appears to be continuing its movement /dispersal south into Qeqertarsuatsiaat. Increased mixing of these two populations may be expected in future.

Relatively rapid rise and fall cycles of abundance in West Greenland caribou populations have been noted since the 1700s, with the periods of abundance being infrequent and short-lived. This suggests that high abundance might be the greatest threat to population stability, provoking a new decline. Perhaps owing in part to overgrazed ranges and subsequent possible density-dependent forage limitation. Past records indicate that once an extreme low abundance is reached, the better part of a century goes by before caribou again increase in number. Today we have become accustomed to relatively high caribou abundance in West Greenland. However, high caribou abundance, as experienced since the 1990's, likely cannot be maintained by any management scheme with that goal in mind. In addition to protracted decline brought on by density-dependent forage limitation, disastrous weather events or even trends may be of major importance. One catastrophic winter with deep snows and severe thaw-freeze icing events restricting access to forage could be enough to cause abrupt herd collapse.

The Ameralik herd in West Greenland has declined in abundance since 2001. Harvest pressure was the major factor. Sound management for conservation of a declining population is extremely difficult, because hunting can worsen a situation where population size is changing unpredictably in response to catastrophic weather events, as these may result in near total mortality across age classes. Although catastrophic weather events have not occurred to date, we should be alert to their possibility. Meanwhile, annual caribou harvests have been large since 2000. Because hunters may be harvesting the most reproductively valuable individuals (i.e., females and males in prime reproductive age), the effect on the entire herd could be greater than the total number caribou killed suggests, and perhaps diminish herd survival/resilience in the face of catastrophic weather events or negative trends. Close monitoring of population size and herd structure with flexible rapid adjustments to hunting pressure can diminish this threat to caribou populations, e.g., should mass die-offs, or even loss of an entire calf cohort be observed. The present level of knowledge about caribou in West Greenland, however, may not be sufficiently detailed to strike the right balance. In general harvest pressure on most West Greenland caribou populations remains high because several herds are still far above the recommended target density, and this high abundance threatens herd stability (through overgrazing) regardless

of possible disastrous weather events or trends in future. However, owing to the conclusion that the decrease in Ameralik herd size over the past 5 years was the result of hunting, the precautionary principle was applied conservatively to the Ameralik population. Harvest recommendations included a shortened season length (September) and cancellation of the winter 2007 (January-February) commercial hunt, while maintaining an open harvest. The open harvest was assumed permissible, as adverse weather can prevent hunters from leaving town for much of a short season. Further, in the South region elevation changes are extreme and since winter arrives later and later each autumn this makes many of the caribou inaccessible. Warm temperatures delay the mass movement of animals out of the high elevations until at least mid-September (or later) in the South region. Qeqertarsuatsiaat received the same recommendation, because 1) mixing of the two populations is strongly suspected as the cause of the observed abundance stability in the Qeqertarsuatsiaat population estimate, and 2) current estimated hunting exceeds the replacement yield.

Ameralik herd – South region

This population, which is a mix of semi-domestic reindeer and indigenous caribou, occurs between Godthåbsfjord and Grædefjord in hunting area 4 of the South region. Since the last survey in 2001, two major changes have occurred. The recommended stocking density for the Ameralik caribou population has been attained because the population is currently about 1/3 the size it was 5 years ago ($P < 0.01$). The change in animal abundance was due to the success of the past 5 years of recommended high hunting pressure, which aimed at reducing population size and density. The average hunt since 2000 was ca. 2950 caribou per annum. For the period between 2001 and 2006, the herd decreased about 20% per year ($\lambda = 0.79$), while the exponential rate of increase (r) was - 0.24. If unchanged, at this rate of decrease the current number of Ameralik caribou will be halved by 2009.

The estimate for pre-calving population size of Ameralik herd of the South region in March 2006 is ca. 9,680 caribou (6,515 – 13,147; 90% CI, CV=21%). Caribou density was 1.16 caribou per km^2. Mean group size was 5.4 ± 3.06 S.D. The 2006 calf percentage and recruitment were better than in 2001, while the once even ratio of bulls to cows appears to have decreased. Late winter calf percentage was 24.8%, with good annual recruitment of 59.8 calves per 100 cows. The mature bull (age > 4 year) to cow ratio was 55 males per 100 females, while for bulls (age > 1 year) the ratio was 81 males per 100 females. If natural mortality is between 8 and 10% then on a herd this size between 500 and 1,300 animals may be expected to die annually of natural causes.

Present estimated densities are close to the recommended conservative target value of $1.2/km^2$, which may permit sustainable caribou grazing on the vegetation. In contrast 5 years ago the density was ca. 4 $caribou/km^2$. Thus current competition between individuals for available food resources is likely less. Keep in mind, however, that the Ameralik range has been heavily grazed for about a decade, and therefore may not be able to support even the recommended target density of caribou. Still, the relatively good 2006 late-winter calf recruitment suggests that the current caribou population density may allow sustainable use of the current vegetation resources. This does not, however, rule out the possibility of population crashes should adverse stochastic events occur (e.g. icing, extreme snow depths, etc.). Therefore accurate predictions about future herd trends are impossible. To understand approaching developments the caribou and their range must be studied within the wider context of global warming and associated climate change.

Qeqertarsuatsiaat herd – South region

This population of indigenous caribou occurs between Grædefjord and Frederikshåb Isblink in hunting area 5 of the South region. The 2006 size and density of the Qeqertarsuatsiaat population are stable since the 2001 survey ($P > 0.5$). For the period between 2001 and 2006, the herd decrease was only about 1% per year ($\lambda = 0.99$), while the exponential rate of increase (r) was - 0.006. At face value, these numbers would suggest no change. However, in contrast to the stable abundance estimate, the ratio of adult males to females is now disproportionally weighted towards males, the average group size has increased and calf recruitment is ½ that of 5 years ago. Further, hunter harvests have increased each year since 2000 and estimates of harvest and replacement yield show the former is double the latter, so this population is expected to decline unless hunting restrictions are implemented.

The estimate for pre-calving population size of Qeqertarsuatsiaat herd of the South region in March 2006 is ca. 5,224 caribou (2,831 – 7,881; 90% CI, CV=29%). Caribou density was 1.02 caribou per km^2. Mean group size was 5.2 ± 3.28 S.D. Herd structure observations revealed a low (8%) late winter calf percentage, however annual recruitment was 32 calves per 100 cows. While the latter is reasonable, recruitment was double 5 years ago when it was 61 calves per 100 cows. Furthermore, the mature bull (age > 4 year) to cow ratio was a high 211 males per 100 females, and the bull (age > 1 year) ratio was 275 males per 100 females. The skewed sex ratio favouring adult males was the result of the many male-only groups observed in the Qeqertarsuatsiaat areas in proximity to Grædefjord (which had a high density of Ameralik animals) and possibly the slightly female biased harvesting since 2000. If natural mortality is between 8 and 10% then for a herd this size between 200 and 800 animals may be expected to die annually of natural causes.

The stability in population number combined with 1) the heavily skewed sex ratio towards males, 2) the reduced calf recruitment, 3) the increased group size, and 4) increasing harvests, which exceed replacement yield, suggests that Ameralik males immigrated into Qeqertarsuatsiaat. If true, this immigration may have maintained the Qeqertarsuatsiaat estimate, thus concealing possible reduced abundance in the Qeqertarsuatsiaat population.

Resume *(Danish)*

I marts 2006 blev bestandstætheden og flokstrukturen af rensdyrbestandene Ameralik og Qeqertarsuatsiaat syd for Nuuk bestemt ved helikopter-optælling. Metoder og analyser var de samme som blev brugt i helikopter-tællingen for fem år siden. Antallet af dyr i de to bestand tilsammen var ca. 15.000 rensdyr med en varians koefficienten af 13%. Rigtig mange dyr, men alligevel færre end for 5 år siden. En del af Ameralik bestanden fortsætte tilsyneladende med at bevæge sig længere syd over ind i Qeqertarsuatsiaat. Derfor kan man forvente en øget opblanding af de to bestande.

Relativt hurtige svingninger i størrelsen af de Vestgrønlandske rensdyrbestande har været bemærket siden 1700-tallet, og perioder med mange rensdyr er sjældne og kortvarige. Dette antyder at store bestande muligvis kan udgøre den største trussel mod bestandsstabilitet, med efterfølgende bestands nedgang, måske på grund af overgræsning og efterfølgende tæthedsafhængig fødebegrænsning. Tidligere dokumenter antyde at når vi har nået det laveste antal rensdyr i en cyklus kan det tage næsten et helt århundred før de igen er talrige. I dag er vi vant til at der er mange rensdyr i Vestgrønland. Men det høje antal rensdyr vi har oplevet siden 1990'erne kan sandsynligvis ikke opretholdes uanset hvilke forvaltningstiltag der taget i brug. Udover en relativ langstrakt bestands nedgang grundet tæthedsafhængig fødebegrænsning, er det sandsynligt at ekstreme vejrforhold kan have betydning. En kraftig vinter med enorme sne mængder og/eller en kraftig kombination af tøv og frost, ville kunne hindre adgang til vigtige føde områder og muligvis forsage en brat bestands nedgang.

Ameralik bestanden i Vestgrønland er gået tilbage i siden 2001, først og fremmest på grund af et højt jagttryk. Det kan være meget svært at forvalte en bestand i tilbagegang, idet fangsten kan forværre en situation hvor bestanden i forvejen ændre sig uforudsigeligt som respons til ekstremt vejr, som kan forårsage en nærmest total udslettelse over alle aldersklasser. Selv vi har ikke har oplevet ekstreme vintre siden 1990'erne, bør vi være opmærksomme på denne mulighed. Imens har den årlig rensdyrfangst været høj siden 2000. Da fangerne måske nedlægger tyre og køer i den bedste kønsmodne alder kan effekten på hele bestanden være større end antydet af antallet af skudte dyr, og dette kan måske reducere bestandens modstandsdygtighed mod ekstremt vejr. En løbende overvågning af bestands størrelse og flokstruktur sammenholdt med en fleksibel og hurtig justeringer af fangsttrykket kan sandsynligvis reducere denne trussel mod rensdyrbestandene, f.eks., hvis der blive observeret masse dødelighed eller tab af en hel kalve årgang. Dagens viden om rensdyr i Vestgrønland er desværre ikke detaljeret nok til at finde den rigtig balance. Generelt bør fangsttrykket for de fleste Vestgrønlandske rensdyrbestandene forblive højt da flere af bestandene stadigvæk er langt over det anbefalede mål for tæthed, og da disse høje tætheder true bestandsstabiliteten (gennem overgræsning) uafhængigt af evt. ekstremt vejr eller fremtidige klimaændringer. Imidlertid, da der er konstateret nedgang i Ameralik bestandsstørrelse over de sidste 5 år på grund af fangst, er dette forsigtigheds princip blevet anvendt konservativt for Ameralik bestanden. Fangst rådgivningen anbefalede blandt andet

en kortere jagtsæson (september) og aflysning af erhvervsmæssigt vinterfangst 2007 (januar-februar), mens åben fangst stadigvæk var tilladt. Den åben fangst var antaget at være forsvarlig da dårligt vejr kan forhindre fangere i tage af sted for meget af tiden hvis sæson er kortvarig. Herudover har Syd en meget stor topografisk højdeforskel og da vinteren ankommer senere og senere hvert efterår er mange rensdyr utilgængelige. De varme efterår forsinke rensdyrenes vandring ned fra fjeldhøjderne til efter midten september (eller senere) i region Syd. Den samme rådgivning har været anvendt på Qeqertarsuatsiaat fordi opblandingen af de to bestandene højst sandsynligt er grunden for stabiliteten i Qeqertarsuatsiaats bestanden , og da fangsten er større end den estimerede rekruttering.

Ameralik-bestanden – Region Syd

Denne bestand er en blanding af tamren og oprindelige rener mellem Godthåbsfjord og Grædefjord, og udgør jagtområdet 4 i Region Syd. Siden den sidste optælling i 2001 er to store ændringer indtruffet. Den anbefalede tæthed er opnået idet bestandsstørrelsen nu er 1/3 af hvad den var for 5 år siden ($P < 0{,}01$). Denne ændring er endvidere forsaget af det høje fangsttryk over de sidste 5 år, et jagttryk der havde til formål at reducerede bestanden til den ønskede tæthed. Siden 2000 er der i gennemsnit nedlagt ca. 2.950 rensdyr årligt. For perioden 2001-2006 er bestanden faldet med ca. 20% per år ($\lambda = 0{,}79$), hvilket svarer til en eksponentiel vækstrate (r) på –0,24. Hvis dette fortsætter vil det nuværende antal af rensdyr i Ameralik være halverede i 2009.

Ameralik -bestanden i Region Syd blev i marts 2006 optalt til ca. 9.680 rener (6.515 – 13.147; 90% KI) før kælvning. Rensdyrtætheden var i 2006 på 1,16 rener pr. km^2. Den gennemsnitlige flokstørrelse var 5,4 ± 3,06 SD. Andelen af kalve og rekrutteringen til bestanden er forbedret siden 2001, men der ses et fald i antallet af tyre i forhold til køer. Senvinter-andelen af kalve var 24,8%, med en god årlige rekruttering på 59,8 kalve pr. 100 ko. Forholdet mellem tyre (alder > 4 år) og køer var på 55 tyr pr. 100 ko, mens forholdet for tyre (alder > 1 år) var på 81 tyr pr. 100 ko. Ved en naturlig dødelighed på 8-10%, vil man i en flok på denne størrelse kunne forvente at se en naturlig dødelighed på mellem 500 og 1.300 dyr om året.

Den estimerede tæthed i 2006 er næsten lig det anbefalet mål på 1,2 rener pr. km^2, hvilket anses for at være en bæredygtige tæthed for rensdyrs set i forhold til udnyttelsen af vegetationen. Det er derfor sandsynligt at der nu er mindre konkurrence mellem renerne end for fem år siden hvor tætheden var ca. 4 rener pr. km^2. Men det er vigtigt at huske at Ameralik området har været græsset meget i løbet af de sidste ca. 10 år, og dermed er det mulig at græsningsarealet alligevel ikke kan opretholde den anbefalede tæthed. Den relativt gode senvinter-andel af kalve i 2006 giver derimod grund til at håbe at den nuværende tæthed er i ligevægt med vegetations udnyttelsen. Faren for bestands kollaps er desværre stadig tilstede på grund af uforudsigelig vejr (f.eks. isning, sne dybden etc.). Dermed er nøjagtige forudsigelser om bestandens fremtidige udvikling ikke muligt. Skal vi øge forståelse af den fremtidige udvikling, må rensdyrene og deres græsningsarealer studeres i en bredere sammenhæng, der også omfatter den globale opvarmning og de medfølgende klimaforandringer.

Qeqertarsuatsiaat-bestanden – Region Syd

Denne bestand er en oprindelig bestand af rener der findes i jagt område 5, mellem Grædefjord og Frederikshåb Isblink i Region Syd. Bestandsstørrelsen og tætheden i 2006 er stabil i forhold til optællingen i 2001 ($P > 0,5$). I perioden 2001-2006 har der blot været en nedgang i bestanden på omkring 1% per år ($\lambda = 0,99$), hvilket svarer til en eksponentiel vækstrate (r) på – 0,006. Der er dog et misforhold mellem kønnene med mange flere tyre per ko, gruppestørrelsen er desuden forøget og kalve rekruttering er kun halvdelen af hvad den var for 5 år siden. Herudover er fangsten i Qeqertarsuatsiaat øget for hvert år siden 2000 og estimater af fangst versus rekruttering viser at fangsten nu er det dobbelte af rekrutteringen. Dermed må det forventes at bestanden i Qeqertarsuatsiaat vil gå tilbage hvis der ikke foretages yderligere begrænsninger af fangsten.

Qeqertarsuatsiaat-bestanden blev i marts 2006 optalt til ca. 5.224 rener (2.831 – 7.881; 90 % KI) før kælvning. Rensdyrtætheden var i 2006 på 1,02 rener pr. km^2 og den gennemsnitlige gruppestørrelse var 5,2 ± 3,28 SD. Flokstruktur observationer gav en lav (8%) senvinter-andelen af kalve, men den årlige rekruttering var 32 kalve pr. 100 ko. Selvom 32:100 er en ok rekruttering, var rekrutteringen det dobbelte for 5 år siden, hvor der var 61 kalve pr. 100 ko. Endvidere er forholdet mellem tyre og køer meget skævt, med 211 tyre pr. 100 køer for tyre over 4 år, og 275 tyre pr. 100 køer for tyre over 1 år. Dette skyldes de mange tyre grupper der er observeret i nærheden af Grædefjorden hvor der var en høj tæthed af dyr fra Ameralik området, og muligvis den svage overvægt af køer i fangsten siden 2000. Ved en naturlig dødelighed på 8-10%, vil man i en flok på denne størrelse kunne forvente at se en naturlig dødelighed på mellem 200 og 800 dyr om året.

Den nærmest uændret bestandsstørrelse i kombination med 1) den skæve kønsfordeling mod tyre, 2) den reducerede rekruttering, 3) den forhøjede gruppestørrelse, og 4) den øgede fangst der nu er større end rekrutteringen antyder at det specielt er tyre fra Ameralik der er immigreret til Qeqertarsuatsiaat. Hvis dette er sandt kan immigrationen have opretholdt bestanden i Qeqertarsuatsiaats og dermed skjult en mulige nedgang i selve Qeqertarsuatsiaat bestanden.

Imaqarniliaq *(Greenlandic)*

Marts 2006-imi tuttut immikkoortut marluk, Amerallup Qeqertarsuatsiaatsiaallu tuttui, tassa tamarmik illoqarfiit pingaarnersaata Nuup kujataaniittut, qulimiguulik atorlugu amerlassusii qanorlu katitigaaneri misissuiffigineqarput. Periaatsit paasisanillu misissueqqissaarnerit ukiut tallimat tamatuma siorna atorneqartut atoqqinneqarput. Tuttut immikkoortut taakku marluk ataatsimut 15.000-inik amerlassuseqartutut, 13%-imik nikingassuteqarsinnaasumik, missingerneqarput. Naak ukiut tallimat matuma siornaniit tuttut ikinnerungaaraluarlutik taamaattoq kujasinnerusup tuttui suli amerlapput. Aammattaaq Amerallup tuttui suli Qeqertarsuatsiaat tungaannut ingerlaartut/siammariartortut malunnarpoq. Tuttut taakku immikkoortut siunissami suli akulerussuunnerulernissaat naatsorsuutigineqarsinnaavoq.

Kalaallit Nunaata kitaata tuttuisa pilertortumik amerlisarlutillu ikilisarnerat 1700-ikkunnili maluginiarneqarsimavoq. Amerlisarnerat sivikitsuinnaasarpoq qaqutigullu pisarluni. Tamatumuunakkut malunnarpoq amerlisarnerat tuttut aalaakaasumik amerlassuseqarnerannut navianartorsiortitsisut annersarigaat ikiliartoqqilernerannut aallarniutaasarami. Nuna nerivallaarsinnaasarpaat aammalu amerlassusiat apeqqutaalluni neriarfissaat killeqalersinnaasarluni. Qangaanerusut allattugaasarsimasut naapertorlugit ikinnerpaaffissartik nallereeraangamikku ukiut untritillit tulliit amerliartoqqilersarsimapput. Massakkut Kalaallit Nunaata kitaani amerlakuluttarnerat sungiusimavarput. Taamaattorli amerlassusiat 1990-ikkunnili takusimasarput amerlaannarnissaat siunertaralugu piniarnermik aqutsinikkut attattuaannarneqarsinnaagunanngilaq. Amerlassusiat apeqqutaalluni neriarfissaata killeqarnera pissutigalugu ikiliartulernerat, silap ajutoortitsisarnera imaluunniit amerlassusiisa allanngoriartornerat pingaartorujussuusinnaapput. Aputilissuulluni aammalu issangiarujussuariarluni sermerluni ukiorluunera ataaseq tuttut ikilipiloorujussuarnerannik kinguneqarsinaavoq.

Kitaani Amerallup tuttui 2001-imili ikiliartulersimapput. Piniagaanerat annerpaamik ikiliartuutaavoq. Tuttut ikiliartortut ikiliartorunnaarsinniarlugit piniagaanerannik aqutsininiarneq ajornakusoortorujussuuvoq silapiluunera pissutigalugu amerlassusiisa siumut naatsorsorneqarsinnaanngitsumik allanngorarnerat pissutigalugu piniagaanerat ajoqutaaginnarsinnaammat allaallu tuttut ukioqatigiinngittukkuutaat tamarmik tamakkerlutik toqussutigisinnaammassuk. Naak suli sila pissutigalugu ullumimut ikilipiloorujussuarsimanngikkaluartut taama pisoqarsinnaanera eqqumaffigisariaqarparput. Taamaattorli 2000-imili amerlaqisut pisarineqartarput. Piniartut kinguaassiorluarsinnaanerpaanik (tassa kulavannik pannernillu norrisinnaallualeruttortunik) pisaqartarsinnaanerat tuttunut ataatsimoortunut tamanut sunniuteqarnerusinnaavoq pisassat amerlanerpaaffissaasa pisarineqarneranniit, aammalu sila pissutigalugu ajutoorsinnaanerat imaluunniit ikiliartulernerat eqqarsaatigalugu annassinnaassusiannut / ataniarsinnaassusiannut ajoqutaasinnaalluni. Amerlassusiisa malinnaaffigilluarneratigut taamaaqataanillu piniagaanerisa allanngorteriataarneqarsinnaaneratigut tuttut navianartorsiorsinnaanerat tamanna annikillisinneqarsinnaavoq, tassa toqorarujussualernerat imaluunniit tuttuaqqat tamarmik toqunerat malinnaaffigineqarsinnaasariaqarput. Taamaattorli Kalaallit Nunaata kitaata tuttui pillugit ilisimasat oqimaaqqatigiissitsiniarnissamut naammanngillat. Kalaallit Nunaata kitaani tuttut pisarineqartartut suli amerlaqaat amerlassuserilersinniarneqartunit suli amerlaneroqimmata, aammalu taama amerlatiginerat silamit pissuteqartumit imaluunniit ikiliartulernerminnit navianartorsiortinneqarsinnaanerat apeqqutaatinnagu tuttut aalaakaasumik amerlassuseqarnerannut navianartorsiortitsisinnaammat (nunamik nerivallaarnermikkut). Taamaattorli Amerallup tuttuisa ukiut kingulliit tallimat piniarneqarnermikkut ikiliartulersimanerat pissutigalugu Amerallup tuttui mianersuunneqartariaqalersimapput. Piniagaanerat pillugu inassutigineqartunut ilaapput piffissap piniarfiusup sivikillineqarnera (septemberi) aammalu 2007-imi ukiuunerani (januar-februar) piniarneqarfissaagaluata atorunnaarsinneqarnera, tuttulli pisarineqarsinnaasut amerlassusii killilersornagit. Piniarneqarsinnaasut amerlassusiinik killilersuinnginnissaq akuerineqarsinnaasutut isumaqarfigineqarpoq piffissap piniarfiusup sivikillineqarneratigut piniartut silamik pissuteqarlutik piniarianngitsoortarsinnaammata. Aamma kujasinnerusumi tuttut tiffasinnerusaqaat qutsinnerusaqalutillu aammalu ukioq takkutiaannginnerusaleqimmat tuttut tikinneqarsinnaaneq ajorput. Silap kiannera pissutigalugu kujasinnerusumi tuttut amerlasoorsuullutik septemberip qeqqata missaani (kingusinnerusukkulluunniit) aatsaat sinerpartilersinnaapput. Qeqertarsuatsiaat pillugit inassuteqaatit aamma taamaapput, pissutigalugu 1) Qeqertarsuatsiaat eqqaata tuttuisa missingerneqartut aalaakaasumik amerlassuseqarneratigut tuttut taakku akulerussuunnerat ilimanaateqaqimmat, aamma 2) ullumikkut pisarineqartartut inunngortartuniit amerlanerummata.

Amerallup tuttui - Kujataa

Tuttut taakku, tuttunit nujuitsunit nujuartanillu akusaasut, Nuup Kangerluata Amerallullu akornanniipput piniarfimmi Kujallermi 4-miillutik. Misissuinermit kingullermit 2001-imi pisumit allannguutit annerit marluk pisimapput. Ameralimmi tuttunut akulikissuseritinniarneqartoq tassa ukiut tallimat matuma siorna amerlassuserisaminniit pingajorarterutinngornissaat ($P < 0,01$) anguneqarsimavoq. Amerlassusii inassutigineqartutut ukiut kingulliit tallimat annertuumik piniartitsinikkut, ikilisinneqarnissaanik siunertaqarfiusukkut, anguneqarsinnaasimavoq. 2000-imiilli ukiumut pisarineqartartut agguaqatigiissillugit 2.950-it missaannik amerlassuseqartarput. 2001-imiit 2006-imut amerleriaataat killilik (λ) ukiumut 0,79 (r)-iusarsimavoq, eksponentialimilli amerlassusiisa allanngoriartornerat piffissami tassani – 0,24-iusimalluni. Taama ikiliartornerat ingerlaanassappat Amerallup tuttui 2009-imi affaanarmik amerlassuseqalersimassapput.

Amerallup tuttui suli norrinngitsut marsimi 2006-imi 9.680-inik amerlassuseqartutut missingerneqarput (6.515 – 13.147; 90% CI, CV=21%). Km^2 –imut tuttut 1,16-inik akulikissuseqartarput. Ataatsimoortut amerlassusii 5,4 ± 3,06 S.D. 2006-imi norraat inunngortut aammalu toqusartut peereerlugit amerleriaataat 2001-imiit amerlanerupput, kisiannili kulavaat pannerillu amerlaqatigiikkaluarnerat allanngorsimalluni. Ukiorissilluarnerani tuttuarartaat 24,8%-iupput, kulavaallu 100-iugaangata norraat toqusut peereerlugit ukiumut 59,8-iusarlutik. Pannerit inerluarsimasut (> 4 ukiut) kulavannut sanilliullugit kulavaat 100-iugaangata 55—iusarput, panneeqqalli (> 1 ukiut) 81-iusarput kulavaat 100-iuagaangata. Nammineerlutik toqusartut 8 aamma 10%-inik amerlassuseqarsimappata taava tuttut taama amerlassusillit akornanni tuttut 500-it aamma 1.300-it akornanni ukiumut nammineerlutik toqusarsimassapput.

Massakkut akulikissuserisaat amerlanaarnaveersaarlugit 1,2/km^2-imik amerlassuseqartinniarneqarnerannut qanippoq, nunalu nerigaluarunikku ikiliartuutigilernaviarnagu. Ukiut tallimat matuma siornanut sanilliukkaanni taamani 4 km^2-imut tuttut sisamat missaannik amerlassuseqartarput. Massakkut nerisassalerngusaattarnissaat ilimanarpallaanngilaq. Eqqaamasariaqarporli Amerallup eqqaa ukiut qulit ingerlaneranni nerruviusimaqimmat, taamaammat tuttut amerlassuseritinniarneqartutut amerlassuseqaraluarutulluunniit nerisassaqartissinnaassagunanngimmagit. 2006-imili ukiuunerani kingusissukkut tuttuaqqat amerlaalunneratigut malunnarpoq neriniarfiat ilumut tuttunik nerisassaqartitsisinnaasoq. Taamaakkaluarpalluunniit toqorarujussuartoqarsinnaanera (sermernera, aperujussuarnera allallu pissutigalugit) tamatumuunakkut pinngitsoortinneqarsinnaanngilaq. Taamaammat siunissami tuttut amerlassusiisa qanoq allanngoriartornissaat eqqoqqissaartumik siulittuutigineqarsinnaanngilaq. Tuttut qanoq iliartuaarnerat siammarsimaffiisalu allanngoriartuaarnerat silarsuup kiatsikkiartornera, tamatumalu malitsigisaa silap allanngoriartornera aallaavigalugit annertunerusumik misissuiffigineqartariaqarpoq.

Qeqertarsuatsiaat tuttui – Kujataa

Tuttut taakku Kalaallit Nunaata tuttugisai Amerallup Paamiullu kujataanni Sioqqap akornanniipput piniarfimmi kujallermi 5-imiillutik. 2006-imi Qeqertarsuatsiaat tuttuisa amerlassusii akulikissusiilu 2001-imi misissuinermut sanilliullutik aalaakaasimapput ($P > 0,5$). Piffissami 2001-imiit 2006-imut amerleriaataat killilik ukiumut tuttunik (λ) 0,99-inik annertussuseqartarpoq, amerleriaataalli eksponentialiusoq (r) – 0,006-iusimalluni. Kisitsisit taamaakkamik allanngortoqarneranik takutitaqanngillat. Taamaakkaluartorli amerlassusiat aalaakaagaluartoq pannerit kulavanniit amerlanerulersimaqaat, ataatsimoortut amerlanerulersimallutik norraallu pinngortartut ukiut tallimat matuma siornanut sanilliullutik affaananngorsimallutik. Kiisalu piniartut pisarisartagaat 2000-imiilli amerlanerulersimapput, taamaammallu pisat piaqqiaasuninngaaniit marloriaatinngorsimallutik, taamalu piniarnermik killilersuisoqalinngippat tuttut taakku ikiliartulernissaat naatsorsuutigisariaqarpoq.

Qeqertarsuatsiaat tuttui piaqqiorneq sioqqullugu marsimi 2006-imi 5.224-it missaannik amerlassuseqartutut missingerneqarput (2.831 – 7.881; 90% CI, CV=29%). Tuttut akulikissusiat 1,02/ km^2. Ataatsimoortut agguaqatigiissillugu amerlassuseqartarput 5,2 ± 3,28 S.D. Tuttut katitigaanerat takugaanni paasinarpoq ukiuunerani norraat ikittuinnaasartut (8%), ukiumullu toqusut ilanngaatiginereerlugit kulavaat 100-iugaangata norraat 32-it pinngortarput. Kingulleq taaneqartoq naammaginaraluartoq taamaattoq ukiut tallimat matuma siorna kulavaat 100-iugaangata norraat 61-it pinngortaraluarput. Aammattaaq pannerit inerluarsimasut (utoqqaassuseq> 4 ukiut) 211-iugaangata kulavaat 100–iusarput, aammattaaq panneeqqat (utoqqaassuseq > 1 ukiut) 275-iugaangata kulavaat 100-iusarput. Suiaassutsimikkut agguataarnerat equngasoq, pannerit amerlanerullutik, Qeqertarsuatsiaat tuttoqarfianni Amerallup (tamaanittut tuttut amerlaqalutik) eqqaani pannerpassuit katersuussimanerannik takuneqartumik pissuteqassangatinneqarpoq kiisalu 2000-imiit kulavaanerusut piniarneqartarnerannik. Nammineerinnarlutik toqusartut 8-iniit 10%-inut amerlassuseqartarpata tuttut taama amerlatigisut akornanni toqusartut ukiumut 200-iniit 800-inut amerlassuseqartarnissaat naatsorsuutigisariaqarpoq.

Tuttut aalaakaasumik amerlassusiisa aalaakaanerat 1) pannerit amerlavallaarneranik ilallugu 2) tuttuaqqat ikiliartornerannik, 3) eqimattakkuutaartut amerlinerannik, aammalu 4) pisat amerliartornerannik, tassa ukiumut pinngortartunit amerlanerusunik, ilagaanni paasinarpoq Amerallup tuttuisa pannertaat Qeqertarsuatsianut nuussimasut. Tamanna ilumoorsimappat nuunnerat Qeqertarsuatsiaani missingikkanik aalaakaaginnarsitsisinnaavoq taamalu Qeqertarsuatsiaani tuttut ikiliartulernerannik malunnarunnaarsitsisimasinnaalluni.

Introduction

The Ameralik and Qeqertarsuatsiaat (Figure 1) populations in the South region of West Greenland were last surveyed by helicopter in March 2001, when the density of the Ameralik population exceeded and density of the Qeqertarsuatsiaat was similar to the recommended target density of 1.2 caribou per km². The Ameralik population is a genetic mix of indigenous caribou (*Rangifer tarandus groenlandicus*) and feral semi-domestic reindeer (*Rangifer tarandus tarandus*) (Jepsen 1999, et al. 2002), while the Qeqertarsuatsiaat population is indigenous caribou.

The 2001 estimates exceeded over 6-fold the caribou abundance estimates of the 1990's (Ydemann & Pedersen 1999). Given the methods employed in the 1990's (high speed, high altitude, wide strip width, long transect length, inability to maintain constant altitude, etc.) and factors such sun glare and observer fatigue, a large number of caribou were likely not detected, and subsequently population size was underestimated (Cuyler et al. 2002, 2003, 2005). The 2001 surveys employed new methods designed to reduce the negative bias of missed caribou (significantly slower flight speeds, lower and constant flight altitudes, narrowed strip width, and shorter transects, correction for missed caribou, etc.).

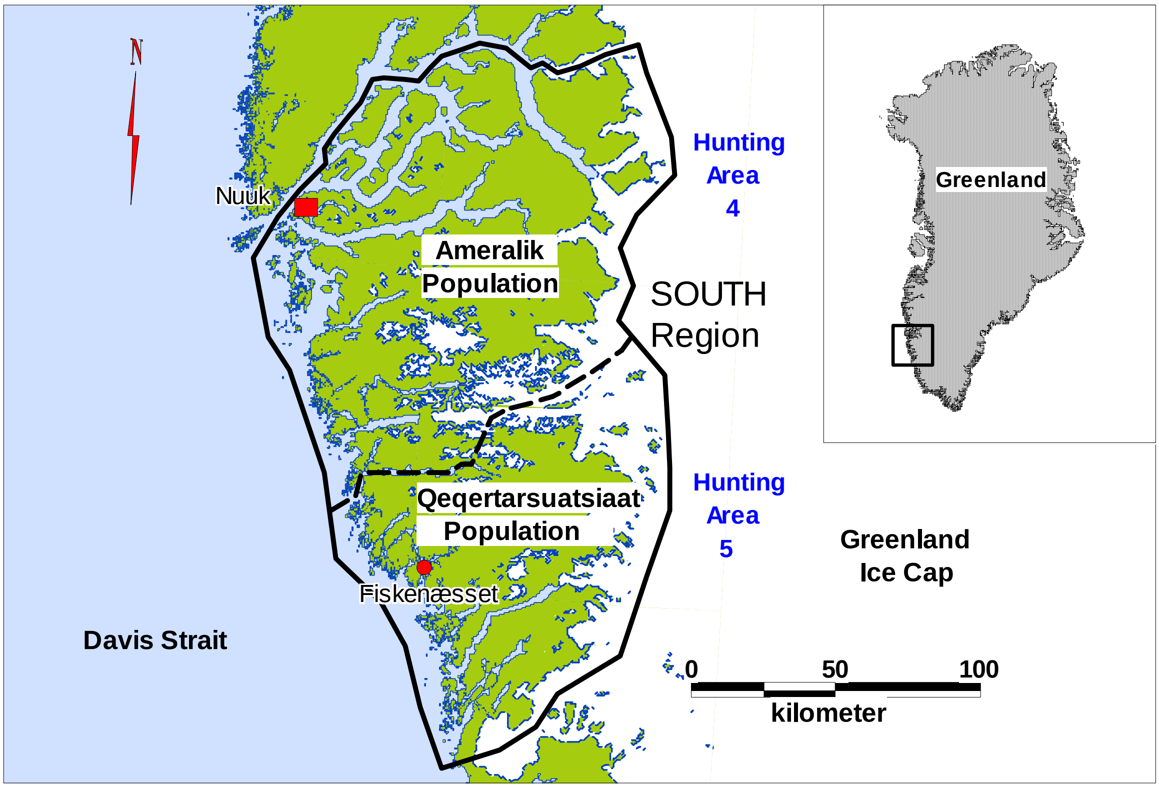


Figure 1. Locations of the two West Greenland caribou populations, Ameralik and Qeqertarsuatsiaat, in the South region, which correspond to hunting areas 4 and 5 respectively.

Background - Ameralik population

This mix of semi-domestic reindeer and indigenous caribou occurs between Godthåbsfjord and Grædefjord in hunting area 4 (for details see Appendix 7). The 2001 pre-calving population estimate was ca. 31,880 caribou (24,721-39,305; 80% C.I.) for the Ameralik population, and seven times the previous 1996 population estimate (ca. 4,500), and 27 times the 1993 estimate (ca. 1,200). The high caribou number in 2001 meant that densities had reached almost 4 caribou per sq km (Table 1). Qualitative observations on range condition and apparent grazing pressure and trampling suggested reduced forage quality and quantity by the late 1990's (Cuyler et al. 2003). Meanwhile calf percentage was 18% and recruitment was 40 calves per 100 cows. Although not low, these values were far below the 26% and 68 calves per 100 cows in the Kangerlussuaq-Sisimiut herd in 2000 (Cuyler et al. 2002). Given the Ameralik population's 2001 large herd size, high density, calf recruitment, observed poor range, and southward movement / dispersal into previously unused areas Cuyler et al. (2003) suggested that this population may have peaked around 1997-98, and likely had been overstocked for several years. A decline in abundance since 2001 was suspected. Rink Heinrich & Jens Bjerge (pers comm) reported markedly fewer caribou in the 2004-05 hunting seasons, where earlier caribou had been numerous, i.e., Ameralik, Buksefjord, Sermilik and Alángordlia fjords (Figure 2). Local knowledge (Appendix 1) further supported a general decline. Relative to the 1990's, when caribou were "everywhere", animals are typically more difficult to find in the Godthåbsfjord, Ameralik and Buksefjord areas. However, high abundance clusters are being observed in localized areas further and further south where caribou were once scarce, e.g., in 2006, large numbers appeared in Grædefjord and Qeqertarsuatsiaat (Fiskenæsset) Fjord (Appendix 1).

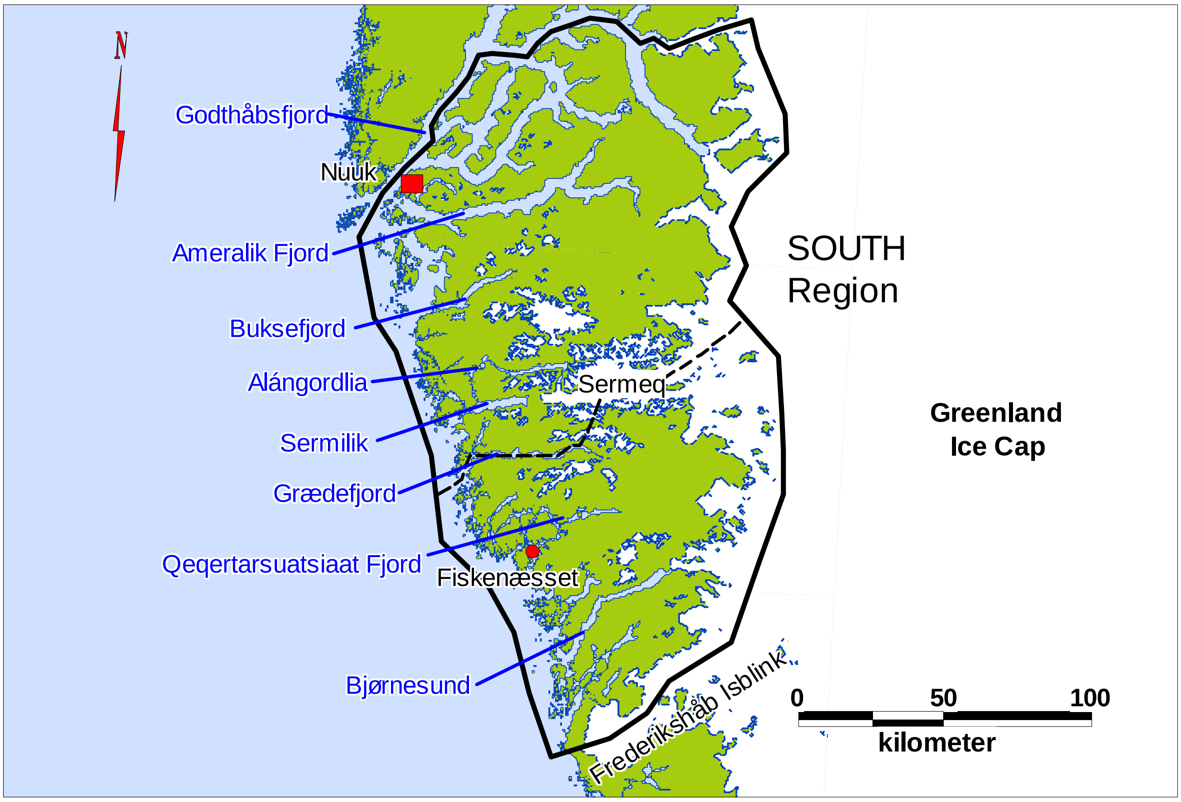


Figure 2. *The South region fjord names used to delineate areas of caribou abundance. Elevation is not shown.*

Background - Qeqertarsuatsiaat population

These indigenous caribou occur between Grædefjord and Frederikshåb Isblink in hunting area 5. The 2001 pre-calving population estimate was ca. 5,372 caribou (2,864-8,244; 80% C.I.), and was 30 times greater than the 1993 estimate (ca. 181). No estimate was calculated for Qeqertarsuatsiaat caribou in 1996. Although the 2001 mean density was 1.1 caribou per sq. km, the calf percentage and recruitment were high (Cuyler et al. 2003), which could promote abundance. Local knowledge from the 2005 hunting season reported markedly greater numbers of caribou where earlier there had been few or none, i.e., inside and at the head of Grædefjord as well as on the mainland southeast for the town of Fiskenæsset (Rink & Nikolaj Heinrich pers comm).

Further historical backgrounds for the Ameralik and Qeqertarsuatsiaat caribou are in Cuyler et al. (2003).

Table 1. *Recent late winter herd parameters of the Ameralik and Qeqertarsuatsiaat populations in West Greenland (Cuyler et al. 2003).*

Parameter	1993	1996	2001
Ameralik caribou population – South region (4)			
Herd size estimate			31,880
Mean group size ± SD	3.9	3.5	4.3 ± 3.65 SD
Density per sq km	0.2	0.9	3.7
Calf percentage	3.1	16.2	17.8 %
Recruitment (Calf / 100 Cow)			40
Sex ratio (Bull > 1 year / 100 Cow)			83
Qeqertarsuatsiaat caribou population – South region (5)			
Herd size estimate		-	5,372
Mean group size ±SD	1.9	-	2.9 ± 1.29 SD
Density per sq km	0.03	-	1.1
Calf percentage	14.8	-	26.2 %
Recruitment (Calf / 100 Cow)		-	61
Sex ratio (Bull > 1 year / 100 Cow)		-	72

Harvest management since 2001

Given the large population estimates of 2001, recommendations to the Greenland Home Rule government advised against allowing further population increase for the Ameralik herd and suggested reducing population abundance and density through increased hunter harvest (Linnell et al. 2001, Kingsley & Cuyler 2002). Out of concern for preserving the vegetation and to promote sustainable use, we advised that caribou density on the range be kept below a density that might threaten forage quality and availability. Despite the lack of studies of carrying capacity on West Greenland ranges, in the 2002 harvest advice an imprecise target density of 1.2 caribou per sq km was suggested. The target is based on studies of carrying capacity elsewhere and associations between observed densities and changes in caribou productivity, dispersal or the condition of the range. At densities of 1.03 to 1.41 reindeer per km^2, females become sexually mature and conceive for the first time when just over 1-year old, which suggests this density is compatible with optimal range (Reimers et al. 1983). In contrast, a density of 4 reindeer per km^2 is too high to sustain lichen heath at optimal condition in Finland (Helle et al. 1990). Observations from Svalbard (Norway) support this. Fifteen reindeer introduced on the Brøggerhalvøya peninsula (Svalbard) at an initial density of 0.25 per km^2 increased over 15 years to 400, or 6.7 per km^2, and the once lush preferred macro-lichens *Cetraria nivalis* and *Cladonia mitis* had disappeared (Staaland et al. 1993). In a single winter icing event, the population crashed to 100 (Jacobsen & Wegener 1995), but animals had already begun to leave the peninsula (Staaland pers. comm.). Skogland (1985) observed that recruitment fell sharply at densities over 2.5 per km^2 owing to a decline in calf productivity of the sub-adult females, but that calf productivity of females 3-years old and older also fell slightly even at densities of 2 per km^2. When caribou reach densities exceeding 2 per km^2, movement / dispersal increases and distribution can be unpredictable (Skoog 1968, Baskin 1990). Although possibilities are limited, dispersal has been observed in the Ameralik population (Cuyler et al. 2003). Population dispersal or movement shifts to new range could delay the effects of food shortage in limiting numbers and Messier et al. (1988) suggested that caribou populations could overshoot range capacity because of these delays. Although the target density of 1.2 per km^2 is not now based on studies of carrying capacity on West Greenland ranges, it may favour the preservation of vegetation quantity, quality and availability, which will benefit caribou populations and the sustainability of future harvests. A halt to population increase, or a reduction in numbers, would give time for more precise target densities to be derived from appropriate studies.

To reduce caribou number and density, before natural forces did so, harvest pressure was increased. In 2001, the Greenland government issued 5,000 and 900 caribou licences to Ameralik and Qeqertarsuatsiaat respectively for the summer-autumn hunt. Similarly in 2002 this increased to 12,289 and 1,100 issued licences, which in practice became an open (unlimited) harvest. Actual quotas in 2002 were 7,400 and 700 for Ameralik and Qeqertarsuatsiaat respectively. A winter season was also first permitted in 2002 with 1,300 licences. Open harvests began in 2003, and continued in 2004, 2005 and 2006. The winter hunt begun in 2002 was also continued in all subsequent years.

Traditionally most caribou hunting occurred in August and September, and the majority of animals harvested were males (Loison et al. 2000). Harvesting a greater number of females was recommended to achieve target reductions in abundance and density. A female-only harvest could not be implemented, because harvest supervision/inspection is not currently possible. Instead, since rutting males are considered inedible, the hunting season was extended into the October rut and sometimes into November. Furthermore, it was permitted to take the calf with the female.

Hunting season was lengthened three to seven-fold. From 1996 until 1999 the length of the hunting season never exceeded 27 days, 15 August to 10 September, for both sport and commercial hunters. In contrast, by 2004 the autumn season was 92 days for both commercial and sport hunters, with commercial hunters receiving an additional 90-day winter season. The season began 1 August 2004, paused for the month of November, and finished at the end of February 2005. In 2005 the season began 1 August and finished 15 November for both sport and commercial hunters, while the latter were permitted a winter harvest 1 January – 28 February.

Present survey

Had the management strategies implemented since 2001 reduced caribou abundance or density in the Ameralik population or changed the Qeqertarsuatsiaat population? In March 2006 an aerial survey by helicopter examined the Ameralik and Qeqertarsuatsiaat caribou populations of the South region to determine whether population size or demographic rates (e.g., calf:cow ratio) had changed significantly. This report presents current abundance and herd structure for caribou in the South region.

Methods

Survey design and field methods

In March 2006 we completed helicopter transect surveys for the Ameralik and Qeqertarsuatsiaat caribou populations in the South region. These surveys repeated the design and methods employed during the 2001 surveys, i.e., no survey stratification owing to unclear distribution of caribou densities in the region, thus transect allocation was made according to relative size of the two areas, so that each received identical coverage (Cuyler et al. 2003). Areas surveyed included islands, lakes and rivers, omitting Ice Caps and glaciers. Transect location and directions were randomly generated. Transect length was 7.5 km.

To permit detecting caribou present while flying a transect, the methods described in Cuyler et al. (2003, 2005) were repeated, i.e., low slow helicopter flight at constant altitude, while concentrating on a narrow strip width, with short length transects.

We used an Air Greenland AS350 helicopter (OY-HGO), which could follow terrain features, while maintaining a constant altitude above ground level. We flew at 46-65 km/hour. Ambient wind direction and speed determined the necessary flight speed to remain airborne. We maintained a constant altitude of 15 metres (50 feet). Transect strip width was 300 metres to either side of the helicopter, for a total strip width of 600 metres. Before departing the airport we ascertained the 300 metre strip width using distance-finder binoculars, i.e. hovering at the 15 m altitude, we measured a distance of 300 m to the broadside of the airplane hanger wall. Observers marked their window with masking tape at the point at which the hangar wall met the tarmac. The tape functioned as a guide for the 300 m strip width while flying transects.

Solar glare reflecting off the snow surface may reduce sightability of caribou and cause observer fatigue. Thus it was important that observers did not look directly into the sun when flying a transect, and flight direction was chosen accordingly. During overcast conditions solar glare was not a problem and transects could be flown in either direction. March was selected because in other Greenland studies group size variability is low and less than 6 animals in late winter (Roby & Thing 1985, Thing 1982, Thing & Falk 1990, Ydemann & Pedersen 1999, Cuyler et al. 2002, 2003, 2005), and distribution or spacing of groups, i.e., density, is typically uniform within a region, or stratum (not used this survey) regardless of topography (Cuyler et al. 2002, 2003, 2005). The low variability reduces sampling error, permitting less survey coverage (Heard 1989). This was important, as given financial constraints survey coverage in this study was 2% of the total area. March was also chosen for its optimal day length and typically good snow cover. Patchy snow cover is known to reduce sightability (Ydemann & Pedersen 1999). Furthermore, Greenland caribou movement is relatively low in March. Straight line caribou movements averaged < 1 km per day and did not exceed five kilometres per day, however, in April movement can increase to a mean of 3 km per day and a maximum of ca. 12 km per day (Cuyler & Linnell 2004).

In addition to Greenland Institute of Natural Resources research biologist, Christine Cuyler, the Greenland Association of Commercial Hunters (KNAPK) provided three experienced professional hunters from Nuuk as observers; Rink Heinrich, Johannes Egede and Lars Mathæussen. Three observers were in the helicopter. Two counted on the left side and one on the right side. Counts were independent. There was no verbal or other contact between observers while a transect was being flown. We used manual click-counters to log the number of caribou seen on a specific transect by each observer. The number counted by each observer was written down immediately following each transect, after which click-counters were zeroed. If the counts from the two observers on the left side differed, the larger value was accepted as the number of caribou and the difference being the number missed by the other observer.

Failure to detect caribou was considered the most important source of bias (inaccuracy). A correction for missed caribou was applied to estimates of abundance. Left front-seat observer ability, i.e. mean missed caribou per transect, was known from the results of the 2000-2001 surveys (Cuyler et al. 2002, 2003). Rear seat (left and right) observer ability, was calculated thereafter, by alternating seat position. Rear seat observers each sat on the same side as the known-ability observer several times. Survey details specific to each caribou population are given below.

Ameralik caribou population (South region, hunt area 4)

The South region is ca. 13,473 permanent ice-free km^2, however the Ameralik area is ca. 8,377 km^2. The aerial survey used 40 random transect lines and occurred 11-14 March 2006 (Figure 3). Herd structure and recruitment counts were flown over 14 of these transects.

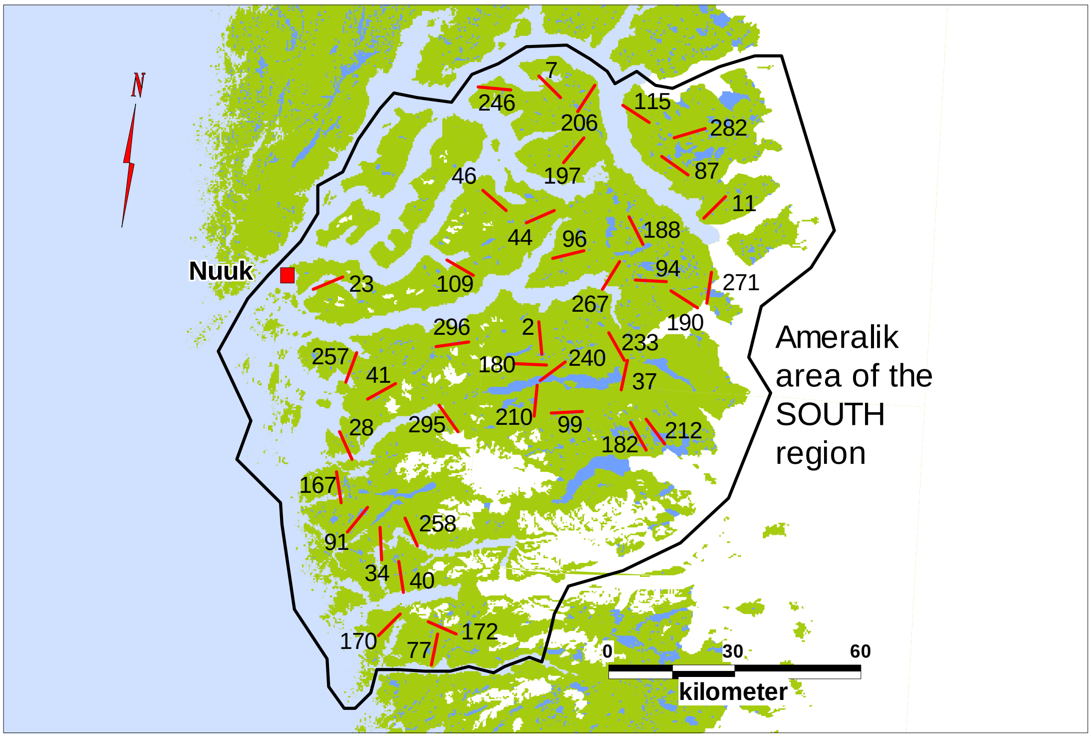


Figure 3. *Forty transect lines, with ID numbers used for the 2006 aerial survey of the Ameralik caribou population in the South region. Elevation is not shown.*

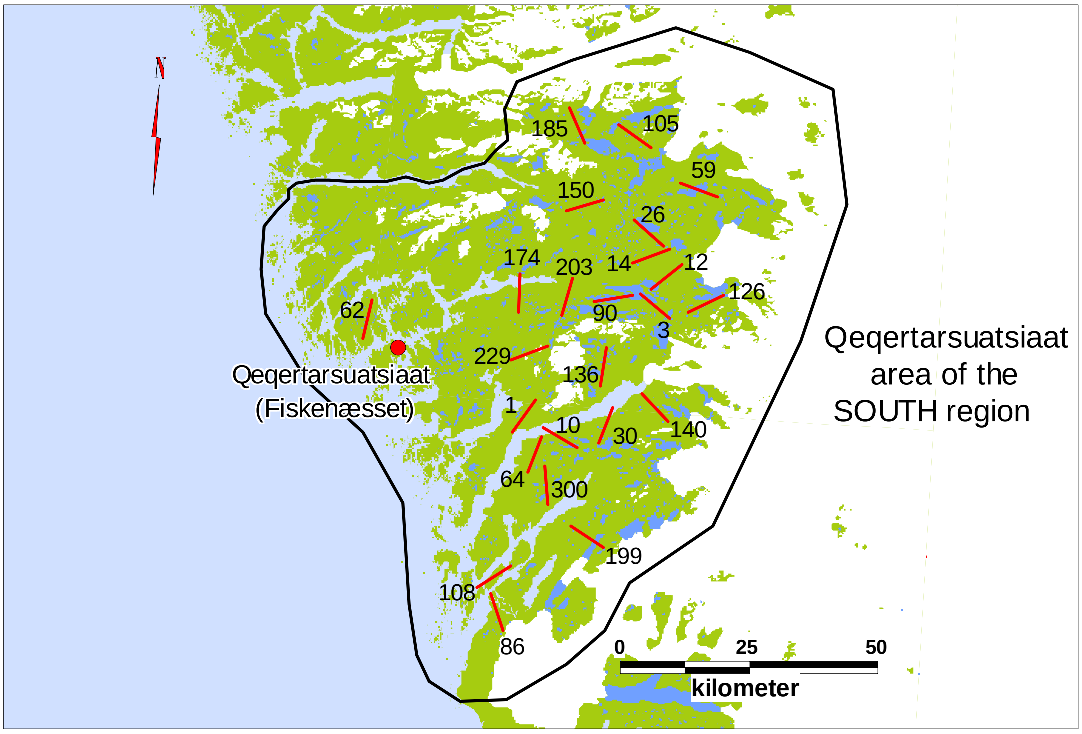


Figure 4. *Twenty-four transect lines, with ID numbers used for the 2006 aerial survey of the Qeqertarsuatsiaat / Fiskenæsset caribou population in the South region. Elevation is not shown.*

Qeqertarsuatsiaat caribou population (South region, hunt area 5)

The South region is ca. 13,473 permanent ice-free km^2, however the Qeqertarsuatsiaat area is ca. 5,096 km^2. The aerial survey used 24 random transects and occurred 14-15 March 2006 (Figure 4). Herd structure and recruitment counts were flown on 7 of those 24 transects and over large areas throughout the region.

Estimating abundance

The aerial helicopter survey was designed as a strip transect count. Each transect had three observers, of which two counted the same strip area, i.e. both counted on the left side of the helicopter. Population estimates for the two caribou populations investigated and the minimum number for the missed animals were calculated according to Cuyler et al. (2002, 2003). The standard method when each missed animal is identified follows Pollock & Kendall (1987). For details see appendix 1. As no useful 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). Calculating the standard deviation of the bootstrapped values and dividing by the mean value obtained a coefficient of variance.

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 ca. two kilometres from the transect line, by zigzagging over areas of high caribou density, or by opportunistic observations while flying a transect (Figures 5 and 6). Choice of a transect or area for zigzagging 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. There was close communication between all observers and the pilot during zigzagging. 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 and polled females are the norm in some populations. 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) and adult (> 1 year). Calf percentage is the percentage of calves in the total number of caribou seen. Calf recruitment is the late-winter calf per 100 cow ratio. Group size was based on proximity and group cohesion during possible flight response.

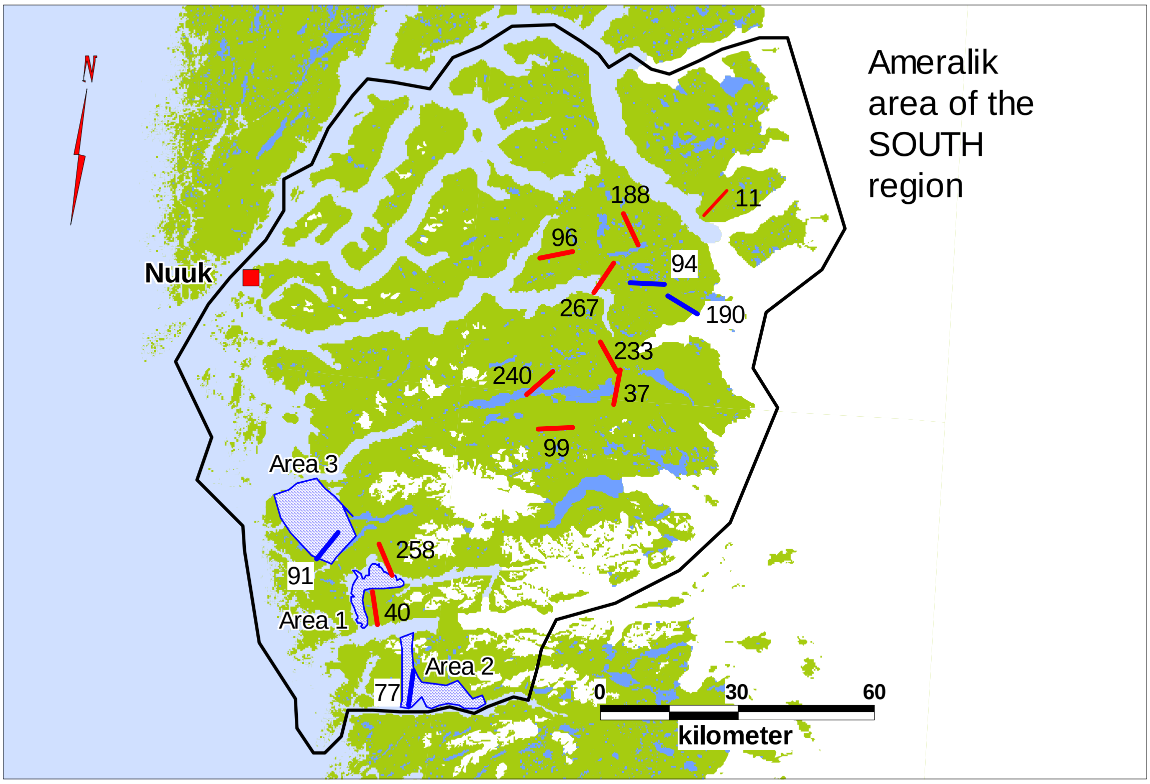


Figure 5. South region: Ameralik herd structure zigzag overflight areas (indicated by blue cross-hatching) and transects (the blue transects with ID number highlighted were zigzagged; the red transects indicate where opportunistic observations where obtained). Elevation is not shown.

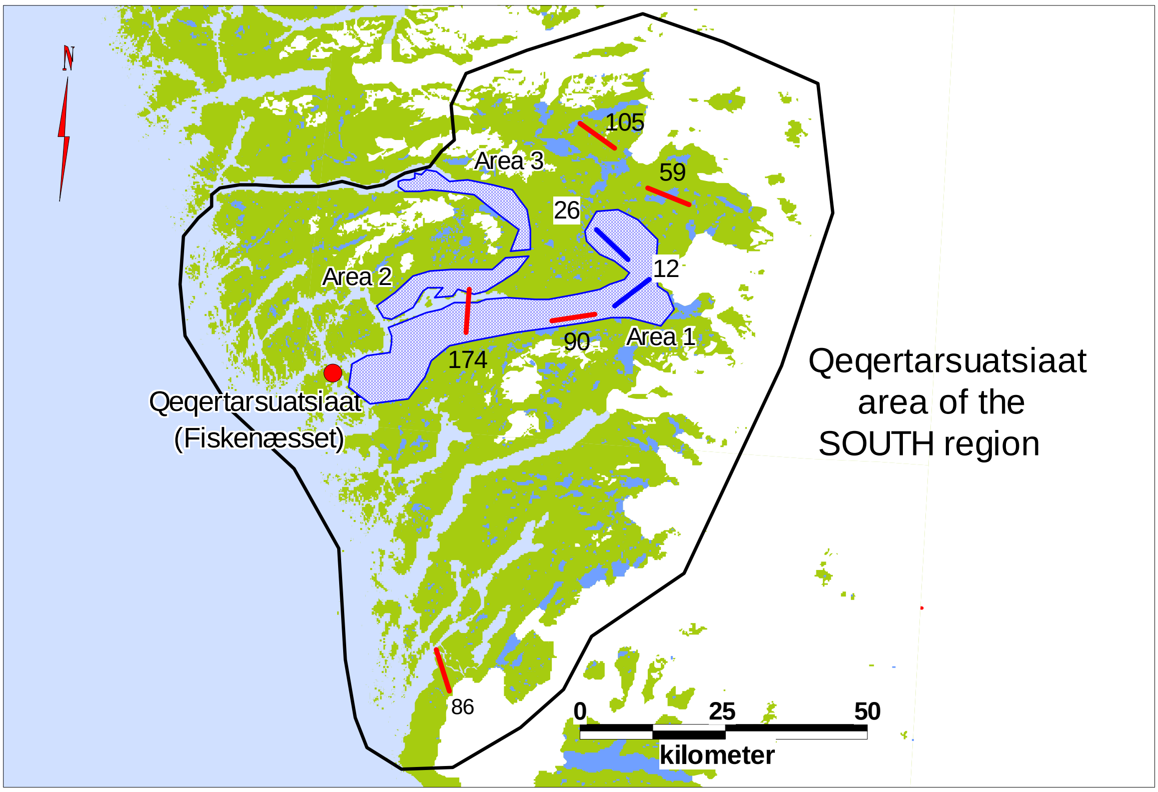


Figure 6. South region: Qeqertarsuatsiaat herd structure zigzag overflight areas (indicated by blue cross-hatching) and transects (the blue transects with ID number highlighted were zigzagged; the red transects indicate where opportunistic observations where obtained). Elevation is not shown.

Estimating rate of change

The finite rate of population change (λ) and the actual exponential rate of increase (r) since the 2001 aerial surveys were calculated following Krebs (1972),

$$\lambda = e^{rm} \text{ (per individual per year).}$$

Where e is the base of natural logarithms and the constant, 2.71828, while r_m is the intrinsic exponential rate of increase. The actual exponential rate of increase can be calculated as follows.

$$r = \frac{ln \text{ herd size } t_2 - ln \text{ herd size } t_1}{\text{Time period in years}}$$

An estimate of the number of years it will take a population to double may be calculated by dividing the constant 0.6931 by the exponential rate of increase r (Caughley 1977), and if the r is negative then the equation reflects halving time for population size.

Mortality rate

Age distributions in West Greenland in 1996–97 after a period of light hunting pressure showed rather flat age distributions out to about 12 years of age (Cuyler & Østergaard 2002), as though age-independent mortality were small and age-dependent mortality roughly equivalent to 8% per annum. Observations from the 1995 harvest indicated that the general life expectancy was about 10 years (Loison et al. 2000), equivalent to an annual mortality of ca. 10%. Annual adult mortalities for North American herds without predators have lain between 4 and 8% (Bergerud 1967, 1971, Skoog 1968, Kelsall 1968, Heard & Ouellet 1994), and natural density-independent factors (e.g., weather) can dramatically alter survival (Gates et al. 1986). Bergerud (1980) proposed a standard adult mortality rate of 10% for North American caribou. Therefore the mortality rate for caribou in West Greenland was assumed between 8 and 10% (Kingsley & Cuyler 2002).

Results

The surveys of Ameralik and Qeqertarsuatsiaat populations used ca. 26 hours of flying time, or ca. 14.5 and 13.5 hours respectively. Weather conditions between the 11 and 15 March 2006 were excellent for strip visibility. At the flight altitude used (15 m), however, "dead" ground is common on transects, i.e. terrain features prevent seeing the entire 300 metre strip width. Caribou may be missed because they are hidden from view. Dead ground is a source of negative bias and contributes to under estimating population size. This source of error gave confidence that our helicopter surveys did not overestimate population size.

As with the helicopter surveys of 2000, 2001 and 2005, again movement was not the only key for detecting animals present on a transect, as animals may remain lying down or standing/grazing without overt reactions to the helicopter fly-by. Detecting caribou shape or colouring was necessary or animals would be missed. The March 2006 snow cover conditions in the South region (Appendices 9, 10, 13) gave exceptional camouflage to the caribou and made detection difficult, which underlined once again the value of the survey's low flight altitude, low speed, and narrow strip width. Snow cover was never full and typically ranged from patchy to absent. Often a light dusting of snow or frost resulted in a "salt & pepper" background into which the caribou blended almost perfectly. Caribou sightability was further compromised by considerable variation in snow cover conditions along an individual transect. This also contributes a negative bias to the estimates, i.e., our estimates probably underestimate the actual abundance.

As in the 2000, 2001 and 2005 helicopter surveys, more caribou were observed on the left side of the helicopter than on the right, 165 and 142 respectively in March 2006 but the difference was not significant ($P > 0.5$). No dead caribou were observed.

For the combined caribou populations in the Ameralik+Qeqertarsuatsiaat areas, we observed a total of 307 caribou, from 64 transects, which were well dispersed across the region surveyed with area coverage of 2%. Caribou were absent on over half the transects, i.e., 34 out of the 64. The raw data (Appendices 3, 4) gave a pre-calving population estimate of ca. 14,871 caribou, with a density of ca. 1.1 caribou per sq km (Table 2). The coefficient of variance (CV) obtained by calculating the standard deviation of the bootstrapped values and dividing by the mean value, was 13%.

Ameralik population, South region

Estimated population size 2006

We observed a total of 198 caribou on 40 transects, which provided 2% coverage. The raw data gave an uncorrected pre-calving population estimate of ca. 9,215 caribou, with a density of ca. 1.1 caribou per sq km. After incorporating a correction for missed caribou (Cuyler et al. 2002), the pre-calving population size estimate became ca. 9,680 (90% CI: 6,515 – 13,147), and density remained relatively unchanged at 1.16 caribou per sq km. The CV was 21%. The finite rate of change (λ) from 2001 to 2006 was 0.79 per caribou per year, which corresponds to a negative 21% change per annum for that period. The actual exponential rate of increase (r) was -0.24. At this rate of decrease we expect the current number of Ameralik caribou to drop 50% by 2009.

Density was not evenly distributed throughout the region. Caribou were few or absent over large areas and abundant in others (Figure 7), e.g. were absent (zero observed) on 20 out of 40 transects (Appendix 3). Specifically the Alángordlia/Sermilik and Grædefjord (Kangerdluarssugssuaq) areas had relatively high concentrations of caribou. While zigzagging for herd structure, 44 caribou were observed near transect 40 and 10 were actually observed on the transect strip. Furthermore, 65 animals were observed on the north shore of Grædefjord, while 35 were observed on transects 77 and 172. Two males were a marked overall dark brown colouration suggesting semi-domestic reindeer heritage. The general area between the head of Ameralik Fjord and the Ice Cap was also plentiful with animals.

Herd structure, recruitment & natural mortality

In the March 2006 zigzag counts, 43 groups of caribou totalling 234 animals were assigned to sex and age classes in the Ameralik population (Table 3). Mean group size was significantly higher than 5 years earlier ($P = 0.04$). Calf percentage increased by 40% and calf recruitment 50% over the same time period (Table 1, 3), while the bull (> 1 year) to cow ratio remained essentially unchanged at just above 80 bulls per 100 cows. Stochastic events and density dependent effects notwithstanding, using an assumed natural mortality of 8-10% and the current population estimate, the calculated natural mortality is between ca. 500 and 1,300 caribou annually for the Ameralik population.

Miscellaneous observation: Ameralik population

South of Buksefjord in the area of transect 167, were abundant snowmobile tracks paired with fleeing caribou tracks. The snowmobiles appeared to have pursued the caribou. The tracks led to two Yamaha snowmobiles found at ca. 63° 45.77′ N; 51° 20.29′W, and "hidden" ca. 100 metres from the open fjord inlet, which opens into salt-water Lake Tasiussarssuaq. Footprints between the inlet shore and snowmobiles indicated recent use when this observation was made, 15 March 2006. The winter hunting season ended 28 February 2006 and hunting from snowmobile is prohibited in Greenland. The significance of out-of-season harvest or chasing caribou with snowmobiles has not been studied.

Qeqertarsuatsiaat population, South region

Estimated population size 2006

We observed a total of 109 caribou on 24 transects, which provided 2% coverage. The raw data gave an uncorrected pre-calving population estimate of ca. 5,143 caribou, with a density of ca. 1.0 caribou per sq km. After incorporating a correction for missed caribou (Cuyler et al. 2002), the pre-calving population size estimate became ca. 5,224 (90% CI: 2,831 – 7,881), while densities remained basically unchanged at 1.02 caribou per sq km. The CV was 30%. The finite rate of change (λ) was 0.99 per caribou per year, and the actual exponential rate of increase (r) was –0.006. At face value, these rates suggest little change in population size over the next decade.

As in 2001, density was not evenly distributed throughout the Qeqertarsuatsiaat region, i.e., caribou appeared few or absent over large areas and abundant in others (Figure 8), e.g. were absent (zero observed) on 14 out of 24 transects (Appendix 4). In contrast to 2001, no caribou were observed in the mainland upland area east of the town of Qeqertarsuatsiaat. With the exception of three bulls seen just north of the glacial tongue, Frederikshåb Isblink, all animals were observed far inland and north of the head of Bjørnesund (Agdlumersat). Zigzagging for herd structure revealed an abundance of caribou along the north shore and valleys of the innermost east-reaching arm of the Qeqertarsuatsiaat fjord, i.e., between Qeqertarsuatsiaat Island to west and the Sinarssuk Quvnerssuaq River valley to the east. Transect line 174 touches a small portion of this area and 14 were observed, however, while zigzagging for herd structure 51 animals were seen.

Herd structure, recruitment & natural mortality

In the March 2006 zigzag counts, 22 groups of caribou totalling 114 animals were assigned to sex and age classes in the Qeqertarsuatsiaat population. Mean group size was significantly higher than 5 years earlier ($P = 0.004$). There was also an almost 4-fold rise in the bull (> 1 year) to cow ratio, from 72 per 100 cows in 2001 to 275 per 100 cows in 2006. In contrast calf percentage dropped 3-fold from 26% to 8%, and recruitment was halved, i.e., 61 calves per 100 cows in 2001 reduced to 32 calves per 100 cows by 2006. Stochastic events and density dependent effects notwithstanding, using an assumed natural mortality of 8-10% and the current population estimate, the calculated natural mortality is between ca. 200 and 800 caribou annually for the Qeqertarsuatsiaat population.

Table 2. *Survey information and preliminary raw and corrected population size estimates for Ameralik-Qeqertarsuatsiaat caribou, South region, 11-15 March 2006.*

Parameter	Ameralik	Qeqertarsuatsiaat	Totals
Area size	8,377 km^2	5 096 km^2	13 473 km^2
Number strip transects	40	24	64
Length of each strip transect	7.5 km	7.5 km	7.5 km
Total strip width	2x 300 m	2x 300 m	2x 300 m
Area covered	180 km^2	108 km^2	288 km^2
Survey coverage	2%	2%	2%
Flight height	15 metres	15 metres	15 metres
Flight speed (km/hr)	46 to 65	46 to 65	46 to 65
Total caribou seen (n)	198	109	307
Raw Density (caribou / km^2)*	1.1	1.0	1,1
Raw estimate herd size*	9,215	5,143	14,362
Corrected Density (caribou / km^2)**	**1.16**	**1.02**	**1.11**
Corrected estimate herd size**	**9,680 caribou**	**5,224 caribou**	**14,871 caribou**
90% Confidence Interval (CI)	(6,515 – 13,147)	(2,831 – 7,881)	(11,689 – 18,231)
Standard Error (SE)	2015.805	1534.954	1988.45
Coefficient of Variance (CV)	0.208 (21%)	0.294 (29%)	0.134 (13%)

* Population size estimate from raw data with no correction for missed caribou.

** Population size estimate after correction for missed caribou has been made.

Table 3. *Herd Structure of Ameralik and Qeqertarsuatsiaat caribou populations, South region, 11-15 March 2006.*

Parameter	Ameralik Caribou Population	Qeqertarsuatsiaat Caribou Population	Both Populations Combined Total
Method	Helicopter	Helicopter	Helicopter
Number of groups observed	43	22	65
Average group size	5.4 ± 3.06 S.D.	5.2 ± 3.28 S.D.	5.4 ± 3.11 SD
Maximum group size	15	14	15
Minimum group size	1	1	1
Total sexed & aged (*n*)	234 (100 %)	114 (100 %)	348 (100 %)
Bull (> 1 year)	79 (33.76 %)	77 (67.54 %)	156 (44.82 %)
Bull (> 1 year & < 4 years)	26 (11.11 %)	18 (15.79 %)	44 (12.64 %)
Bull (> 4 years)	53 (22.65 %)	59 (51.75 %)	112 (32.18 %)
Cow (> 1 year)	97 (41.45 %)	28 (24.56 %)	125 (35.92 %)
Calves from 2005	58 (24.79 %)	9 (7.89 %)	67 (19.25 %)
Recruitment (calf / 100 cow)	59.8	32.14	53.6
Sex ratio (Bull >1 year / 100 Cow)	81	275	125
Sex ratio (Bull >4 year / 100 Cow)	55	211	90

Discussion

Ameralik population

Similar to 2001, consider the 2006 abundance a conservative estimate, as a negative bias of caribou missed remains, owing to patchy snow cover, "salt & pepper" backgrounds, and "dead" ground. Further, the 2006 observed uneven distribution (density) compounded with the low (2%) coverage would cause inaccuracy and underestimate abundance (Heard 1989). Future surveys could stratify this region to counteract the problem of uneven distribution. The corrected pre-calving March 2006 Ameralik population estimate is ca. 9,680 caribou (6,515 – 13,147; 90% CI; CV 21%). In contrast, the 2001 survey estimate was ca. 31,880 caribou (24,721 – 39,305; 80% C.I.; CV 18%). As methods between the surveys of 2001 and 2006 did not differ, confidence intervals do not overlap, and mean estimates are significantly different ($P < 0.01$), these results reflect a ca. 2/3 decrease in abundance over the past 5 years. Despite this reduction, the 2006 estimate of ca. 9,680 caribou remains a large number of animals. However, the exponential rate of population change r was - 0.24, which gave a halving time of under 3 years for this population, as calculated by 0.6931/r (Caughley 1977), i.e., by 2009 the Ameralik population may contain under 5000 animals.

Stocking density has declined to 1.16 caribou per sq km, which is similar to the recommended target density, (1.2/km^2), considered sustainable. While this reduction may be the result of harvest combined with density dependent factors, there have been no observations of high natural winter mortality, i.e. mass die-offs or loss of entire calf cohorts. Weather records, which might otherwise have aided interpretation of fecundity or calf survival, are not available. Almost without exception, Greenland weather stations are seacoast locations and of little relevance for caribou. An analysis of the harvest rate revealed that the strong decline was the result of the hunt, with an average of ca. 2950 caribou per year since 2000 (Witting & Cuyler 2007). The suggestion that the 2006 population size and density is in better alignment with the vegetation carrying capacity of the Ameralik area is supported by: 1) current late winter calf percentage and recruitment being highest observed between 1993 and 2006 (Thing 1982, Ydemann & Pedersen 1999, Cuyler et al. 2003); and 2) this population appears to have a stable and healthy sex ratio of bulls (> 1 year) to 100 cows (> 1 year), which were 83:100 in 2001 and 81:100 in 2006. Furthermore, local knowledge (Appendix 1) sources observed in autumn 2006 that abundance and calf production rose in certain areas.

The reduced density recorded in 2006 may be the cause of the observed improved late winter calf recruitment. In 2001 when the density was 3.7 caribou per sq km the late winter calf recruitment was 40 calves per 100 cows. The current figure is ca. 60 calves per 100 cows. Although shooting female caribou could have influenced this ratio, the reasonable herd structure (41.45% female, 33.76% male, 24.79% calves) suggests no scarcity of adult females in the population.

Although the 2006 density is similar to the recommended target, 1.2 caribou per sq km and late winter calf recruitment has risen, it is unknown whether current density is compatible with the quality and quantity of the range now available. Owing to possible overstocking/ overgrazing in the past, current range condition may not be able to sustain grazing pressure even at the target density. Thus further decline in this population may occur from natural density dependent causes and may be inevitable.

Depleted range causes caribou movement /dispersal to new areas. Over the past two decades a portion of the Ameralik population has consistently moved south exploiting fresh ranges (Cuyler et al. 2003). Some are now well established inside Grædefjord, and are therefore on the threshold of the Qeqertarsuatsiaat population. This was evidenced by the large group sizes typical for the descendants of semi-domestic reindeer but not typical for indigenous caribou (Figure 9), and observations of animals with an overall brown pelage, which may indicate feral reindeer descent. Mixing of the two populations is suspected, and we recommend DNA testing, which could be accomplished by an analysis of fecal pellets.

Despite the overall reduced Ameralik population size in 2006, the mean group size increase was unchanged between 2001 and 2006, 4.3 ± 3.65 SD to 5.4 ± 3.06 S.D. respectively. As group size may increase with increased population size, this result might contradict the reduced population estimate, however, local knowledge attests to there being fewer animals and the difference in group size from 2001 to 2006 was not significant (P = 0.04). Furthermore, there was less variation in group size during the 2006 survey. The animals were scarce over large areas of the region and then locally abundant at a few select localities.

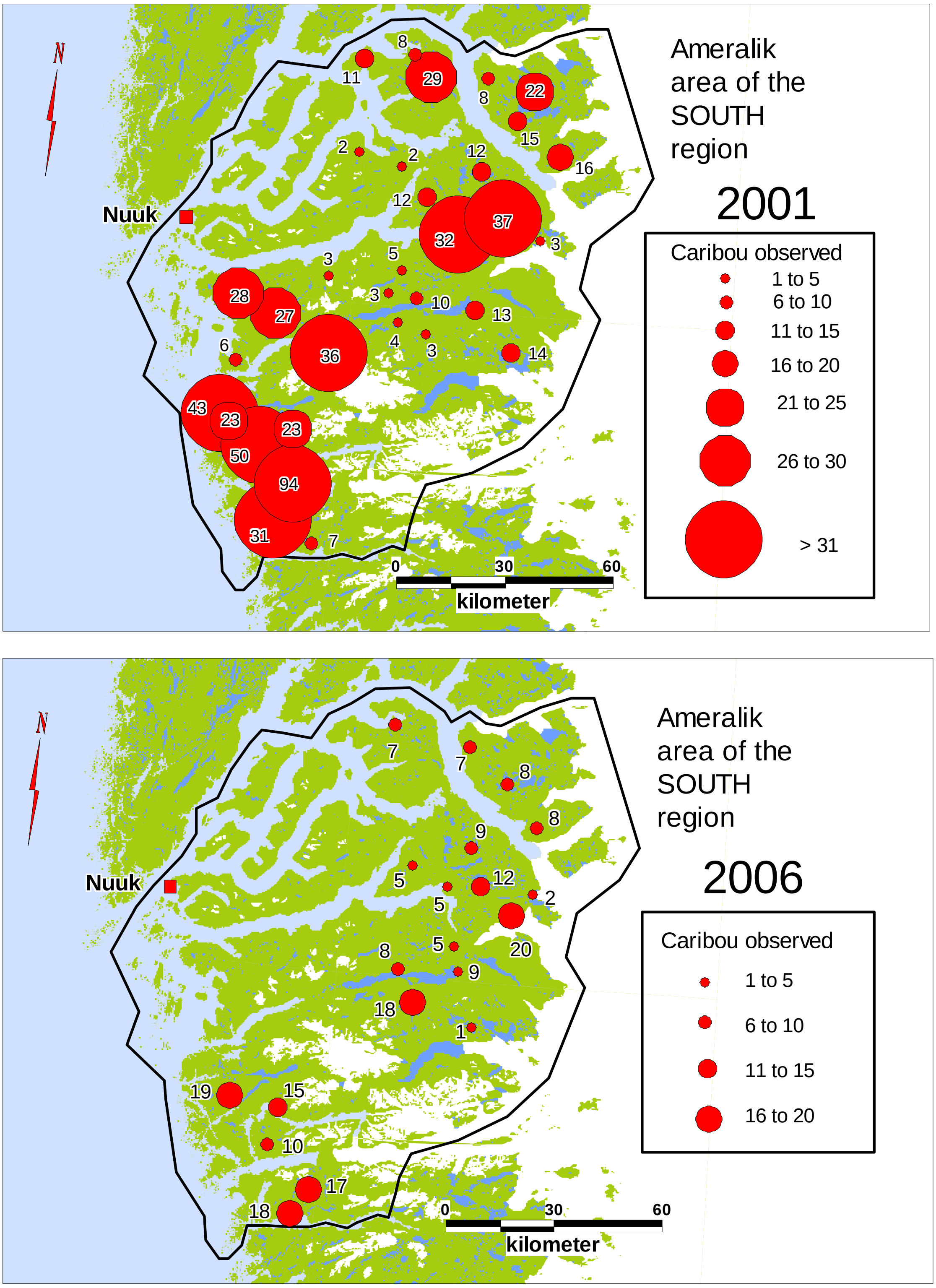
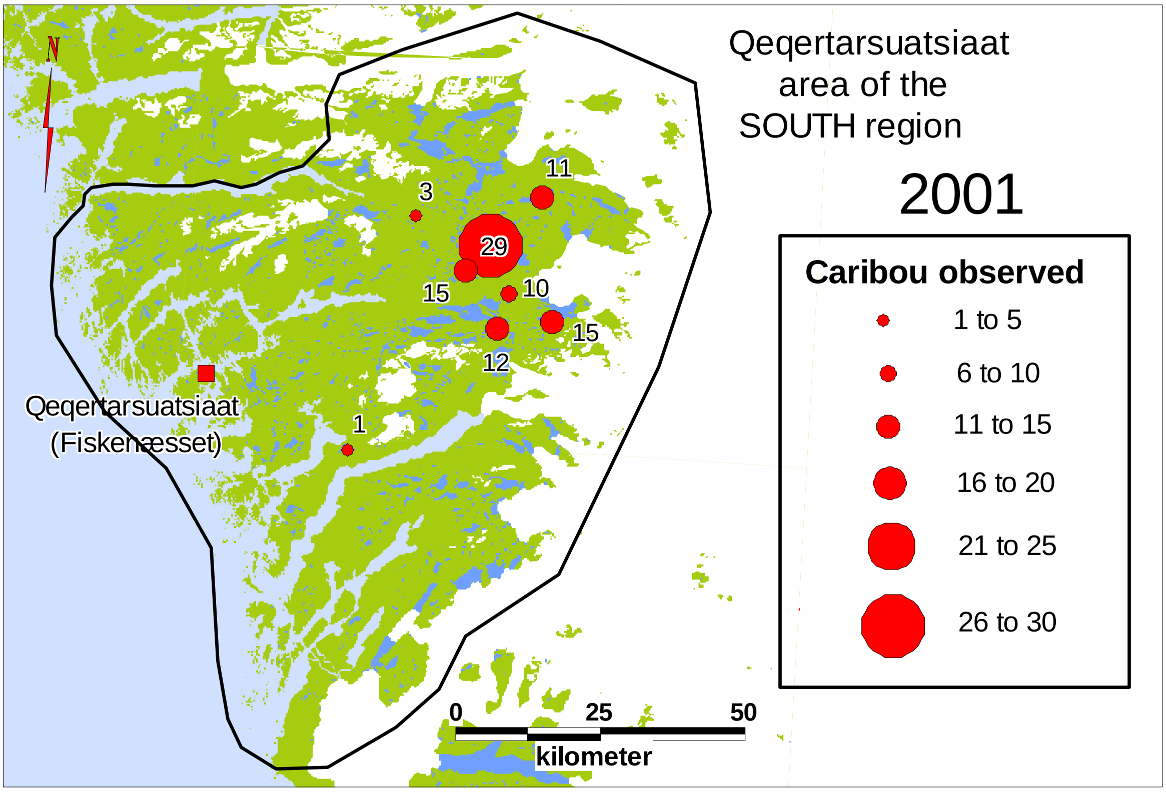


Figure 7. *Ameralik population - South region: relative distribution of caribou as per observations from the transect surveys in 2001 and 2006. Actual number observed given beside or inside the observation. Elevation is not shown.*



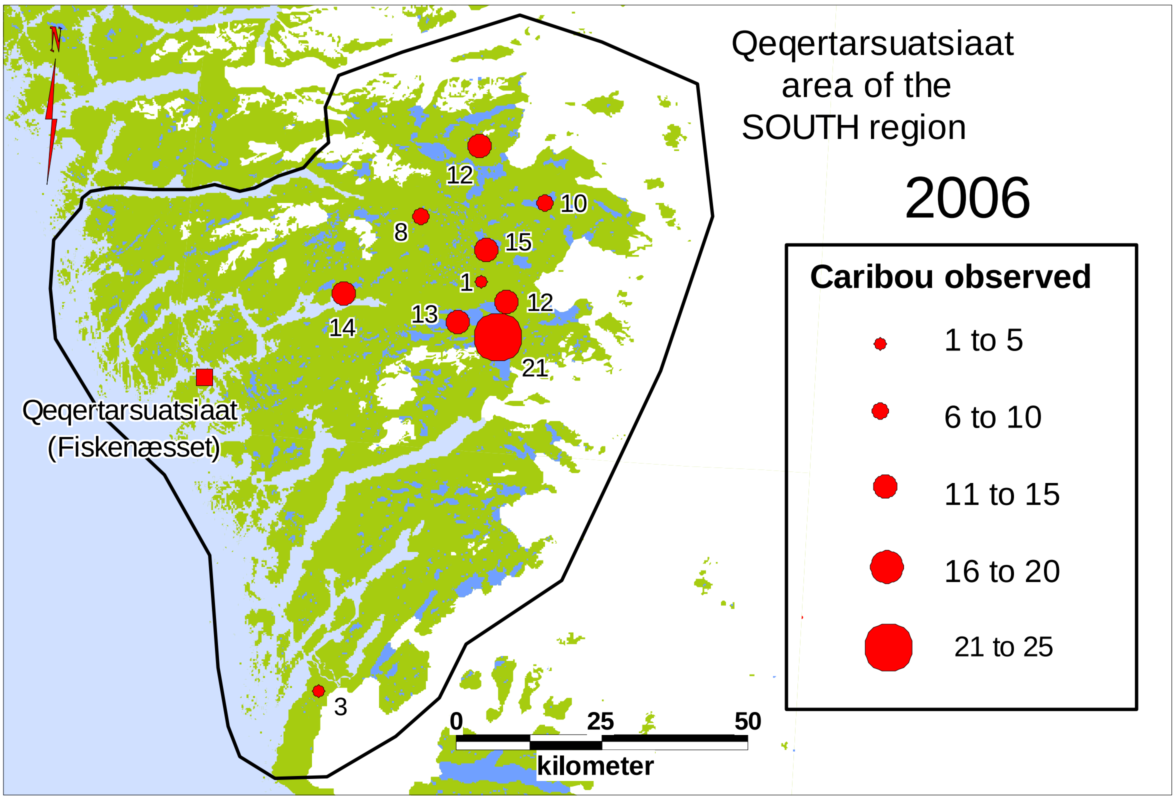


Figure 8. *Qeqertarsuatsiaat population - South region: relative distribution of caribou as per observations from the transect survey. Actual number observed given beside the observation. Elevation is not shown.*

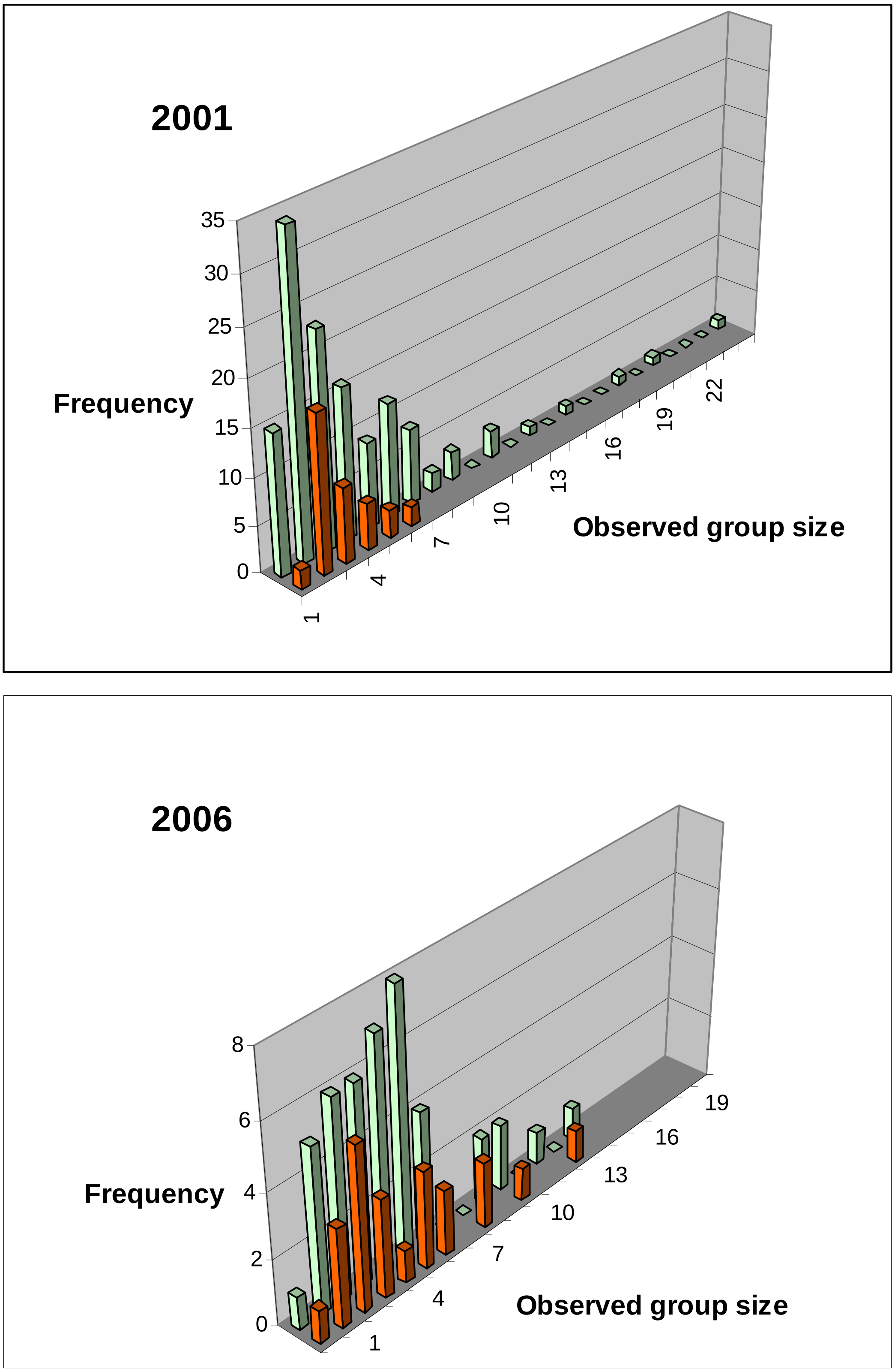


Figure 9. The 2001 and 2006 observed group size and frequency. The Ameralik population, which includes feral reindeer, is light green ( ), and the indigenous Qeqertarsuatsiaat population is orange (!) (Cuyler et al. 2003, this study). The difference in group size between the two populations was significant in 2001 but not in 2006 (P = 0.0004 and P= 0.76, respectively).

This is atypical of indigenous caribou in West Greenland in late winter, and the clumped distribution resulted in a lower CV than expected. Local knowledge confirmed that animals are now generally scarce, but clusters of abundance occur and are found at specific sites. The above suggests that caribou densities remain high at select locations, which may deplete forage. Alternately, there is the small possibly that the mean group size increase reflects smaller groups being overlooked, as these would have been difficult to spot in the patchy and "salt & pepper" camouflage backgrounds typical of the entire region during this survey (see Appendices 9 & 10).

Qeqertarsuatsiaat population

The only difference between the 2001 and 2006 surveys was the addition of three transects, which could not be flown in 2001 owing to financial constraints. The additional transects in 2006 served only to reduce the still considerable CV by 10% and would not have affected the population size estimate. Similar to the 2001 surveys, consider the 2006 abundance a conservative estimate, as a negative bias of caribou missed remains, owing to patchy snow cover, "salt & pepper" backgrounds, and "dead" ground. Further, uneven distribution (density) observed both in 2001 and 2006 compounded with the low (2%) coverage would cause inaccuracy and underestimate abundance (Heard 1989). Stratification in future surveys could reduce the problem of uneven distribution.

The 2001 to 2006 trend for Qeqertarsuatsiaat population size is stable. The corrected pre-calving March 2006 Qeqertarsuatsiaat population estimate is ca. 5,224 caribou (2,831 – 7,881; 90% CI), which is similar to the 2001 estimate of ca. 5,372 caribou (2,864 – 8,244; 80% C.I.). Since methods between the surveys of 2001 and 2006 did not differ, confidence intervals do overlap, and mean estimates are not significantly different ($P > 0.5$), the present results suggest a stable animal abundance over the past 5 years. The exponential rate of population change r was - 0.006, which implies that abundance will not change rapidly. As abundance was stable so was density, being now 1.0 caribou per sq km, which coincides with the recommended target density. However, analysis of the harvest impacts since 2000 showed that the number of Qeqertarsuatsiaat caribou taken increased each year since 2000 and current harvests exceed replacement yield, therefore the Qeqertarsuatsiaat population is expected to decline to 3,900 individuals by 2012 unless restrictions are applied (Witting & Cuyler 2007).

Unexpectedly, there were a lack of females and calves in the 2006 herd structure observations. Furthermore, the late winter calf recruitment dropped almost 50%, from 61 calves per 100 cows in 2001, to only 32 calves per 100 cows in 2006. The current figure is reflected in a skewed herd structure (67.54% male, 24.56% female, 7.89% calves), which is predominated by males. The greater number of males may have resulted from an unusual and greater than expected sex-segregated clumping of animals during the 2006 survey, i.e., that we chanced upon primarily male groups with our random transects. Still, the reduced calf recruitment suggests the possibility of elevated calf mortality or decreased fecundity of adult females or both. Alternately, the changed herd structure may also reflect a shift in hunter preference. In the past harvests have been heavily male-skewed in Greenland (Loison et al. 2000), but the current altered herd structure may be the result of the slightly female-skewed harvesting, mean 54.3% ± 1.29 S.D., in the Qeqertarsuatsiaat population since 2000 (Witting & Cuyler 2007). Reduced recruitment and a sex ratio biased against females means less replacement is occurring, i.e. there are fewer individuals in the next generation. This situation is cause for concern because it lowers the resilience of a population. Without sufficient recruitment it will not be able to provide a sustainable annual harvest and could be susceptible to a decline or a crash in abundance, specifically if adverse and widespread stochastic events occur. Investigations on fecundity and calf mortality are needed.

Given the unaltered herd size, the mean group size increase is puzzling, 2.89 ± 1.29 SD to 5.18 ± 3.28 SD, 2001 and 2006 respectively. The difference is significant ($P = 0.004$), and in 2006 there was greater variation in group size. We suggest that the greater group size is because either population size is larger than the survey result, or feral reindeer from the Ameralik population, which possess high group cohesiveness, were present on many of the transects surveyed in the Qeqertarsuatsiaat area.

We suspect that the primary cause of increased group size and stable abundance observed was mixing of the Qeqertarsuatsiaat and Ameralik populations. The immigration of caribou/ feral reindeer from the Ameralik area could have maintained the Qeqertarsuatsiaat population size despite increasing harvest pressure or a declining native population. Furthermore the mixed descendants are exhibiting the semi-domestic reindeer tendency to aggregate into groups larger than 10, which is typical of the mixed Ameralik population but not indigenous Greenland caribou. The presence of large numbers of Ameralik animals in Grædefjord, which is in close proximity to the Qeqertarsuatsiaat population, supports this suggestion.

Management implications

A central question arises from the survey results of 2006. Why is the Ameralik population now 1/3 the size it was 5 years ago? We did not observe any carcasses in the terrain during the survey, nor does local knowledge (Appendix 1) report unusual natural mortality, i.e., above and beyond the assumed 8-10%, in either herd over the past 5 years. The period 2000-2006, however, saw sharply increased quotas the first three years and unlimited harvests for the last four years, when for the first time long hunting seasons were also permitted. The management goal was to reduce the size of the caribou populations before natural forces did so. The Greenland National Commercial Hunter's Union (KNAPK) says that 80% of the commercial caribou harvest brought into the Nuuk market comes from the South region, i.e. from Ameralik Fjord and southwards (Lars Mathæussen & Nikolaj Heinrich pers comm.). An analysis of the impact of hunter harvest concluded that the strong decline was the result of the increased hunting pressure since 2000 (Witting & Cuyler 2007). The harvest analysis did not consider the contribution of a possible loss of Ameralik animals owing to dispersal into Qeqertarsuatsiaat, which we have suggested in this study given circumstantial evidence. Dispersal would have resulted in a net loss to the Ameralik population size and a net gain to the Qeqertarsuatsiaat. However, given that the 2006 mean population estimate for Qeqertarsuatsiaat is only ca. 5,000 caribou, the number of Ameralik animals suggested to be among them is assumed to be relatively modest compared to the Ameralik population decline of ca. 22,000 animals. Hunting stands as the primary cause.

Between 2001 and 2006, hunter harvest reduction of Ameralik population size was the management goal to protect the range from overgrazing and trampling. Where the range has been compromised, caribou numbers may decline regardless of our efforts. Where caribou densities are above that recommended, hunting may be used to reduce caribou abundance and thus preserve some of the range for an earlier recovery than if left to natural grazing induced caribou-vegetation cycles, which can be compounded by weather cycles, i.e., local knowledge reported that extreme dryness in summer 2004 affected plant growth (Appendix 1). By increasing the 2001-2006 harvests, management hoped to reduce overgrazing (or potential for such) on winter ranges. In contrast to 2001, now with fewer animals competing for forage and other resources the overall situation appears to have improved for this population, i.e., the calf recruitment has increased while the sex ratio remains normal. However, there remains concern for this herd because hunting was responsible for the steep reduction in abundance. Also, the animals now congregate in high abundance in relatively few small areas, which could make them easy to hunt. Further these clumped concentrations could relatively quickly deplete forage resources at those localities. Given its past history of overgrazing previous pastures, the Ameralik herd must not be permitted to increase in number from its current size.

Following a continual period of overall population growth and high abundance, caribou populations can undergo a lengthy steady decline over a series of years, e.g. a decade, owing to density-dependent responses associated with overgrazing (Miller et. al 2005). Depletion of winter lichen ranges can press a population into a phase of density-dependent forage-limitation with consequences to follow in subsequent years (Miller et al. 2005). Given the degree of overstocking (which causes overgrazing) prevalent in West Greenland for more that a decade, it is possible that we may soon experience a transition into a long period of low caribou abundance.

Relatively rapid rise and fall cycles of abundance in West Greenland caribou populations have been noted since the 1700s (Figure 10), with periods of abundance being infrequent and short-lived. This suggests that high abundance might be the greatest threat to population stability, provoking a new decline, specifically when ranges are overgrazed. Past records indicate that once an extreme low abundance is reached, the better part of a century goes by before caribou again increase in number.

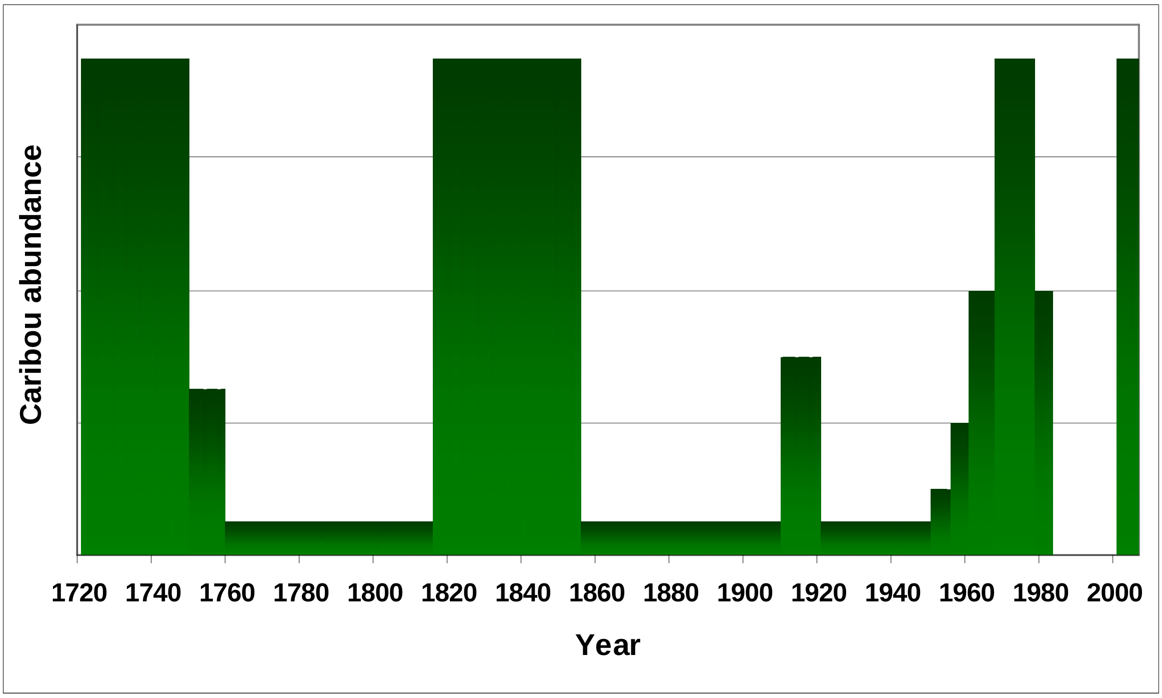


Figure 10. *Historical rise and fall cycles of relative caribou abundance in west Greenland based on Vibe (1967), Meldgaard (1986) and the 2001 abundance estimate. Only general trends are illustrated, since the caribou populations in west Greenland do not cycle in absolute synchrony (Meldgaard, 1986), and estimates were unavailable except for in 2001. During periods of low abundance, records suggest caribou disappear almost entirely. No harvest records were available from 1983 to 1995.*

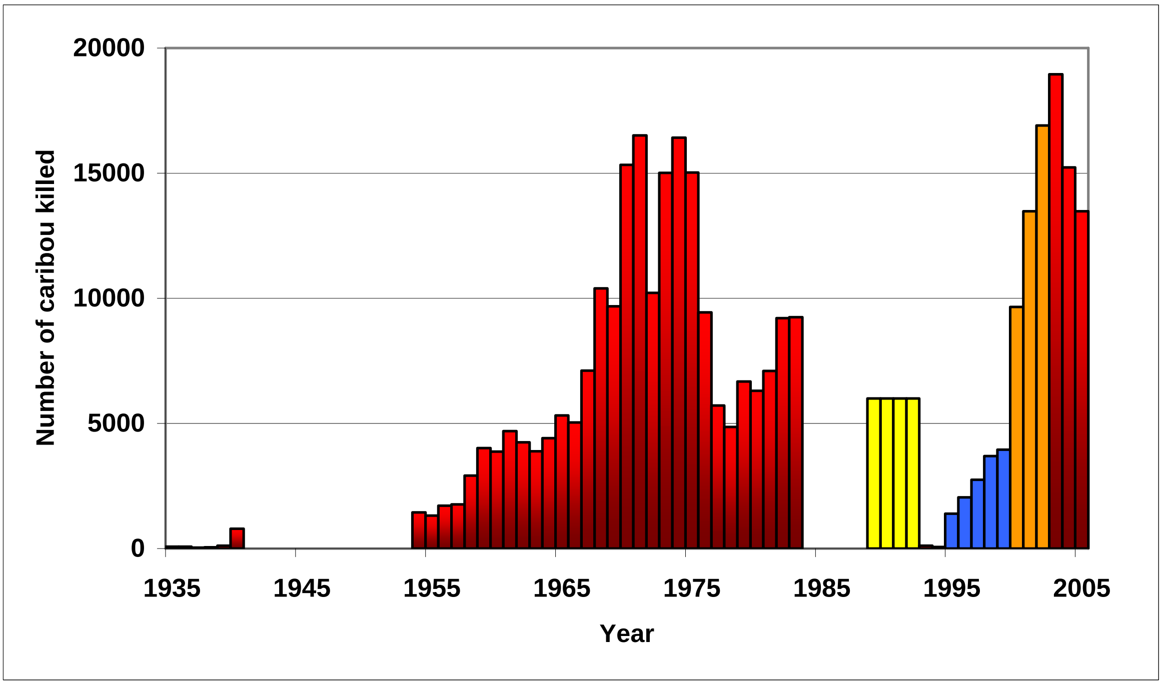


Figure 11. *Caribou harvest records 1935 – 2005 (Anon: Grønlands fangstlister, Piniarneq). No records were kept between 1983 and 1995. Red columns are open harvest. Yellow columns, 1989-1992, are assumed harvest level (Peter Nielsen pers comm). Blue columns, 1995-1999, are harvests attained when legal quotas were low. Orange columns, 2000-2002, are harvests attained when legal quotas were dramatically increased.*

The harvest data for West Greenland (Figure 11) indicates that a rise in caribou abundance may have begun in the late 1960's and extended into at least the early 1980's, when harvest statistics were discontinued. Alternately, the harvest increase of the 1970's may reflect an increase in overall hunting effort and increased efficiency through better firearms and speedboats. Regardless, a caribou boom in the past decade is clear from local knowledge and the 2000 to 2006 population estimates. Combined they suggest a period of caribou abundance covering most of the past 35 years.

Today the public are accustomed to high caribou abundance, which past history indicates cannot last. What does the public expect regarding present and future caribou abundance in West Greenland? The pubic must be informed, so that they may understand and accept that the large numbers of caribou observed and available since the 1990's in West Greenland likely cannot be maintained by any management scheme with that goal in mind.

The difference between minimums and maximums in West Greenland caribou abundance is on the scale of a mouse to an elephant (Meldgaard 1986). Although evidence is lacking, over the centuries, over-harvesting typically was blamed for the disappearance of caribou following a period of abundance (Meldgaard 1986), although Greenlanders were few in number and implements of harvest primitive when the abrupt caribou population crashes of ca. 1750 and 1850 occurred. Instead, the role of unfavourable weather or disastrous weather events may have been of major importance, and climate may be central to explaining the caribou cycles observed in Greenland (Vibe 1967, 1982, 1984, Meldgaard 1986) as well as the extinction of *Rangifer tarandus eogroenlandicus* in Northeast Greenland around 1900 (Degerbøl 1957). In this report we make no reference to the NAO (North Atlantic Oscillation) effect on caribou population cycles in West Greenland, although this subject has received theoretical treatment recently by Post & Forchhammer (2002), as there is debate in the literature (Vik et al. 2004). Further in our experience Greenland caribou (and muskox) population abundance data from the past are suspect (Cuyler 2007) and harvest reporting mere guidelines. Post & Forchhammer (2002) reportedly used raw hunting statistics with an unknown relationship to population dynamics. Also, harvests may have been influenced by socio-economic factors unrelated to the herds or the NAO. Further investigation using robust databases for abundance estimates and regional climate is needed and may yet show an unequivocal relationship between large herbivore population dynamics in Greenland and the NAO or AO (Arctic Oscillation).

In contrast to protracted population declines over many years in response to density-dependant factors, a population crash is defined as a sudden reduction in numbers, ≥ 30%, in a single year event, while an extreme population crash would be ≥ 50% (Miller et al. 2005). Regardless of population status (increasing, stable, declining) a severe winter event, e.g., thaw-freeze, deep snow, can cause premature and abrupt crashes in caribou numbers (Miller et al. 2005, Jacobsen & Wegner 1995).

Climate change in West Greenland is expected to cause increased temperatures and precipitation (Rysgaard et al. 2003), which could increase the frequency of severe stochastic weather events. Extreme conditions restricting access to forage, e.g. winter thaw-freeze icing or excessively deep snows have been known to result in near total mortality across age classes in caribou (Miller 1990, Jacobsen & Wegener 1995). Although catastrophic weather events have not occurred in recent years, we should be alert to their possibility, as in addition to population trends, these could play a major role in the future abundance of West Greenland caribou. In Greenland where caribou are limited in their ability to disperse to new ranges, how many animals survive a catastrophic weather event will depend on the event's severity, extent and duration. Collapse of affected caribou populations in a single year event is possible.

Sound management for conservation of a declining population is therefore extremely difficult, because hunting can worsen a situation where population size is changing unpredictably in response to catastrophic weather events or perhaps just unfavourable weather trends. If caribou are low in abundance then excessive harvesting may cause over-depletion that may unnecessarily postpone a future population recovery. Furthermore, the majority of caribou taken in a hunter harvest are likely the most reproductively valuable individuals (males and females in their prime) rather than the young, sick or old. Therefore, the effect on the entire herd could be greater than the total number caribou killed would suggest. Close monitoring of population size and demographics coupled with flexible rapid adjustments to hunting pressure can diminish this threat. The present level of knowledge about caribou in West Greenland, however, may not be sufficiently detailed to strike the right balance. Therefore we recommend that caribou management build population resilience, e.g., a sex and age structure favouring abundance recovery.

Recommendations for the 2006 harvest

As a result of hunter harvest, the Ameralik population declined from about 32,000 in 2001 to about 10,000 animals in 2006 (Witting & Cuyler 2007), and KNAPK assessed the Ameralik harvest pressure as 80% of the total Nuuk catch. Should a large and effective harvest be allowed to continue on the Ameralik population? There are fewer animals and these are unevenly distributed across the region, but calf recruitment is good. If the present range status (i.e., vegetation type, quality, quantity, availability) can support the current density, which is compatible with the recommended target density, then further reduction in population size is unnecessary. On the other hand, we advise against the Ameralik herd being allowed to increase in size, and in summer 2006 local knowledge sources again observed females with two calves at heel (twinning), indicating a capacity for rapid herd growth. Combining the Ameralik & Qeqertarsuatsiaat populations represents ca. 15,000 caribou in the South region. They may sometimes seem few-and-far-between because they are spread over a ca. 13,500 sq km area. In contrast to other populations, their tendency to clump into large and accessible aggregations during the autumn rut (Sept-Oct) also makes them sparse over large areas and locally abundant in others. Once an aggregation is found, however, harvesting a large number of animals over a short period is possible.

As the decrease in Ameralik herd size over the past 5 years was the result of hunting, the precautionary principle was applied conservatively to the Ameralik population in an attempt to strike a balance between harvesting enough but not too few. The 2006 recommendation was for an open harvest of only one month (September) and no winter hunt. The latter would benefit gestating females. We recommended September, primarily because it may promote the harvest of an equal number of males and females. Ameralik males with their semi-domestic reindeer heritage may enter the rut in the latter half of September, which makes them unpalatable and females preferable. At present, implementation and enforcement of sex and age specific caribou licences are not possible in Greenland. Furthermore, the arrival of winter has been increasingly delayed in recent years, and in general the West Greenland caribou have been coming down out of the high elevations at ever later and later dates, i.e. September, October and even November. Although the hunting season in West Greenland has begun on 1 August for many years, given recent warming in West Greenland, if hunting season length on the Ameralik herd is only 1 month, then September may permit larger harvests than a harvest in August. The open harvest was assumed permissible, as the difficult high terrain elevations of Ameralik provide natural protection from hunters for the majority of the animals, which remain in the high mountains in the current warm autumns, e.g. 2005-2006, and are thereby unobtainable. Additional protection comes from the typically unpredictable sailing weather, which can keep hunters in harbour and limits hunting success if the season is short.

The Ameralik recommendation was extended to the Qeqertarsuatsiaat population because mixing of these herds is suspected in maintaining the Qeqertarsuatsiaat 2006 abundance estimate, and population decline is expected as catch otherwise increases each year and current harvests exceed replacement yield. Given the Qeqertarsuatsiaat skewed sex ratio against females, shooting females was no longer encouraged. Recommendations for other caribou populations remained essentially unchanged from the 2005 season.

Subsequent to the above recommendation, the Greenland Home Rule government made the following management decisions for the autumn 2006 – winter 2007 hunting season on the Ameralik and Qeqertarsuatsiaat populations: Summer harvest remained open (no quotas) from 1 August to 10 September 2006. Winter January-February harvest 2007 was cancelled. Management decisions for the autumn 2007 – winter 2008 hunting season altered season period to 15 August –30 September 2006, while all else remained unchanged.

Hunter harvest reports

The Witting & Cuyler (2007) harvest analysis was handicapped by the fact that few Nuuk commercial hunters report their harvest, e.g. in 2005 only eight commercial hunters and 124 caribou (89 Ameralik; 35 Qeqertarsuatsiaat) were reported killed. In contrast, the roughly estimated 2005 harvests[1] were ca. 2,300 and 340 caribou for Ameralik and Qeqertarsuatsiaat respectively. Population specific harvest statistics would greatly assist management. For example, the expected decline in caribou abundance in the South region is easily understood if one considers that the combined harvest is ca. 18% of the combined population estimate, and once the 8-10% natural mortality is added (i.e. 26% to 28%) it becomes apparent that the combined calf recruitment of 19% is insufficient to maintain current population size.

[1] The Witting & Cuyler (2007) annual harvests from each population were estimated using detailed harvest databases based on hunter reports as follows. Individual county estimates for each herd, were obtained by comparing the total annual catch for all herds for a specific county to the relative distribution of catches between the different hunting areas for all received hunter reports for that county. The individual estimates of caribou killed per population by each county were then summed to obtain an estimated total annual harvest from each caribou population.

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Appendix 1

Local knowledge

On 20 November 2006, Jens Bjerge was interviewed. He has been an employee at the Buksefjord Hydro Power Plant since 1989 and is an avid sport hunter and observer of the Ameralik caribou/feral reindeer population.

On 30 January 2007 four Nuuk commercial hunters, KNAPK (Greenland National Commercial Hunter's Union), Nikolaj Heinrich, Anthon Egede, Lars Mathæussen and Job Heilmann, were interviewed together regarding the Ameralik caribou population.

On 12 March 2007 Qeqertarsuatsiaat commercial KNAPK hunter, Karolus Steffani, was interviewed regarding the Ameralik and Qeqertarsuatsiaat caribou populations.

Ameralik caribou / feral reindeer

General

Relative to the 1990's, when caribou were "everywhere", there are now fewer animals in the northern portion of this range, but high abundance was observed at one locality in the late autumn of 2006. Although abundance is declining to the north, since the 1990's localized areas of high abundance are observed further and further south where caribou were once scarce. In the autumn of 2006, large numbers appeared in Grædefjord and Qeqertarsuatsiaat (Fiskenæsset) Fjord.

The month of August was too warm for hunting in 2006, because most of the animals remained in the high elevations, which made hunting difficult, and the insect harassment was awful.

Buksefjord Hydro Power Plant: catchment area & power line

Jens Bjerge gave the following information regarding the land area between Ameralik Fjord and Buksefjord. In brief, the difference in caribou/ feral reindeer abundance from 1998 to 2006 is enormous. In 1998 there were animals everywhere you looked. Now there are few.

Already in 2002 and 2003 Jens noticed fewer animals along the shores of the long lake, Kangerdluarssungup taserssua and also on the road joining the west end of the lake and the power station at the head of Buksefjord. Each year since 2003, there are fewer and fewer. In the autumn of 2005 there were almost no animals about the hydro station buildings until the day after the last hunting day. That day, the 16th of November 2005, about 40 animals came past the hydro station buildings. In late November 2006 there came only about 10 animals.

Generally there are fewer caribou/ feral reindeer in 2006. Jens, sails the length of Kangerdluarssungup taserssua lake by boat several times each summer to check the hydro station's dam at the east end of the lake. He is always on the look out for caribou/feral reindeer. There were noticeably fewer animals observed along his route in June, July and early August 2006 relative to the summer of 2005. He pointed out, that the difference could have been because the period of observation in summer 2005 was only in August and early September and there were also fewer sailings in 2005. For 4-6 weeks in June-July 2006, Jens and several Power station co-workers worked at the Kangerdluarssungup taserssua dam at east end of the lake. Only one single cohesive group of 50-60 caribou/feral reindeer meandered about in the valley below (i.e., northeast) the dam during the entire period. In August-September 2006, helicopter work in the area immediately south of the Power station to the Equaluit valley revealed fewer than eight caribou/feral reindeer. Later at the end of September 2006, Jens and Minik Møller-Lund had helicopter work over an extensive area south of the Kangerdluarssungup taserssua lake (i.e., from Power station to "drainage Lake" (Appendix 12)). Although both Jens and Minik kept a sharp lookout for caribou/ feral reindeer, they observed only a single group of 6 to 8 animals at high elevation. This group was just east of the alpine glaciers, which are ½ way between Kangerdluarssungup taserssua Lake, and Isortuarssup tasia Lake. Admittedly the helicopter flew low and fast, but they agreed caribou/feral reindeer were now fewer in this region. On the road joining the west end of the lake and the power station at the head of Buksefjord, Jens has almost not seen a single caribou/feral reindeer since January 2006. Specifically the summer period 2006 was noticeable for the absence of animals and lack of tracks. By the time of his interview, 20 November 2006, there were finally about 10 caribou/feral reindeer grazing in the vicinity of the Hydro station buildings at the head of Buksefjord.

There are also fewer observations of caribou/ feral reindeer along the hydropower line between the Power station and Nuuk. In the late 1990's under regular winter checks of the hydropower line by helicopter, Jens always observed many animals and tracks along the line. Today, he observes few tracks in the snow and still fewer, if any, animals. In mid-August 2006, Jens worked a continuous 2 weeks along this hydro-power line, but saw only one group of three animals, which were at ca. 700 metres elevation and in terrain accessible only by helicopter.

Jens Bjerge had the following comments regarding the heavy erosion trails present along the shores of Kangerdluarssungup taserssua lake and in the valley to the east of the dam. The erosion trails in the valley to the east and northeast of the Kangerdluarssungup taserssua lake dam, were already present by the late 1990's. Furthermore, many of these trails are no longer freshly trodden although still very visible. This applies to trails on both shores of the lake. Heavy erosion trails of Kangerdluarssungup taserssua, as photographed in Appendix 11, are also present in the large alpine area between Kangerdluarssungup taserssua lake, and Isortuarssup tasia lake.

Abundance, distribution & lichen pasture

Anton Egede gave the following information. Prior to the 1970's there were no caribou around Nuuk and they always sailed north to Kangerlussuaq (North region) for autumn hunting. In early 1980's, he stopped sailing north because large fat caribou could be hunted at the head of Ameralik/Ameragdla Fjord, specifically at Naujat Kuuat. He continued hunting here into the 1990s. Hunting was prohibited in 1993-94. When hunting resumed in summer 1995 the caribou were so numerous they could be shot from a boat cruising the Ameralik/Ameragdla fjord shoreline. Before the hunting prohibition, the largest and fattest animals were always taken in the area south and southeast of Naujat Kuuat, which is at the head of Ameralik/Ameragdla Fjord. After the prohibition the animals continued to be large, however, there were few or no calves. Owing to changes in caribou distribution, after 1995 he began hunting further and further south. From 2001 to 2006 he hunted the area between Buksefjord and Sermilik Fjord, where females typically had two calves at heel. By summer 2006 females often had no calf or only one calf at heel. Recently caribou have been seen even at the fishing station of Færingehavn. In 2006 from 1 August until 10 September, caribou, both large and small, were again plentiful in the inner Ameralik/Ameragdla Fjord at Naujat Kuuat, and it was easy to hunt many each trip. This Naujat Kuuat area in summer 2004 was extremely dry, the vegetation died of drought, and the caribou did poorly. By contrast, in 2005 and 2006 there was plenty of grass and the caribou appeared to be doing well and were becoming more numerous than in recent years. In August and September of 2006, he saw many calves and females with two calves at heel were not uncommon. Still lichen (*qajuusat*: Greenlandic) abundance is reduced in the Ameralik area.

Karolus Steffani has very occasionally observed cows with two calves at heel, in the Alángordlia / Grædefjord areas north of Qeqertarsuatsiaat (Fiskenæsset).

Nikolaj Heinrich, Anthon Egede and Lars Mathæussen agreed that in 1995 when August-September hunting began again following the 1993-94 prohibition, there were phenomenal numbers of caribou observed by hunters along the coast between the mouth of Ameralik fjord and Buksefjord, i.e., from Lille Narsaq to Agpaanguit iluat Bay. Furthermore, before 1995 crowberries were plentiful around the Egede's hunting cabin in Agpaanguit iluat Bay. After the enormous influx of caribou / feral reindeer following 1995, there were no crowberries owing to trampling by the animals.

Nikolaj Heinrich gave the following information. Since 1987 he has hunted in Alángordlia-Sermilik Fjord area in August-September. In 1993 there were unbelievable numbers of caribou at the Sioralik river valley on the north shore of the inner Alángordlia Fjord. Many caribou were also taken at head of Ikaatoq Sangujat Fjord. By summer 2006, however, there were no caribou at all in these places. He believes there are too many boats coming to hunt these areas now. From 2001 to 2006 Nikolaj Heinrich observed that during the autumn hunting season caribou were fewer than just prior to 2001.

By late autumn 2006, however, caribou were extremely abundant along most of the north shore of Alángordlia fjord (Karolus Steffani pers comm). Furthermore, in August-September 2006 caribou were plentiful in, the higher elevations and valleys around the Taserssuatsiait Lake, a small portion of the north shore of Alángordlia fjord, the east shore of Amitsuarssuagssuaq Fjord, north shore and a portion of the south shore of Sermilik Fjord, and the entire length of the north shore and head of Grædefjord (Anthon Egede & Nikolaj Heinrich, pers comm).

Karolus Steffani gave the following information. In the 1970s he and other hunters from the town of Qeqertarsuatsiaat (Fiskenæsset) would sail to the north shore of Grædefjord and head deep into the Kugssuup alángua River valley to hunt caribou. In the 1970s lichen pastures were good in the Kugssuup alángua River valley. They used snowmobile in winter or a combination of rubber dinghies and walking in summer. They always had to penetrate deep into the Kugssuup alángua River valley before finding caribou, even up until 1995. After 1995, the lichen pasture began to appear overgrazed, and Karolus thought there were too many caribou. Today the lichen pasture is poor. In autumn 2006 the caribou were so numerous that hunters needed only to enter the mouth of the valley to be successful. These animals have larger antlers, longer legs and less meat and rump fat than the caribou at Frederikshåb Isblink.

In 2006, however, more animals than ever before were observed in the entire Grædefjord area even into the month of November 2006 (Nikolaj Heinrich), specifically caribou were extremely abundant in the Kugssuup alángua River valley on north shore of Grædefjord (Karolus Steffani). The Qeqertarsuatsiaat hunters went there in 2006 for hunting because there were so many caribou (Nikolaj Heinrich).

Caribou were scarce at the head of Godthåbsfjord in autumn 2006. Caribou were not observed in several locations within the Nunatarsuaq area after the hunting season closed. Even after 10 September 2006, the Sarqarssuaq valley and mountainsides showed no sign of caribou or tracks, and this unusual situation repeated itself the following day in the Akugdlerssuaq area (Anthon Egede).

Karolus Steffani observed that caribou have always been present to some degree on the Marraq peninsula area (i.e., where US military once maintained a dirt airstrip), even today.

Natural mortality

In the winter of 1991, Nikolaj Heinrich, observed several places below the mountains of Ameralik Fjord where caribou had fallen off the cliffs and died. In the late 1990s to about 2000, Karolus Steffani observed winter caribou mortality in the general coastal area between Buksefjord and Sermilik fjord. Specifically in Sermilik fjord, it appeared that the caribou had died falling down the mountainsides where they'd been feeding. Jens Bjerge also remembers the winter 1997-98 for several observations of natural mortality. Dead animals were found on the Buksefjord sea ice, and elsewhere in the Ameralik area. Jens has not observed any natural mortality from 2001 to 2006.

Hunting season 2006 ended too early

Karolus Steffani observed that the rugged mountain topography north of Qeqertarsuatsiaat (Fiskenæsset) makes hunting strenuous. It is difficult or impossible to access large areas at the high elevations where the caribou are. Therefore Karolus thinks there will always be caribou there, because the hunters cannot reach them.

Karolus Steffani has observed that when the weather is warm, the caribou remain in the high elevations, and descend to the lowlands only when the weather turns cold and snow covers the high elevations. In the 1 August to 10 September 2006 hunting season, the weather remained warm until after the season ended, which made the majority of the caribou inaccessible, as they remained at high elevations. The heat in August also made the mosquito harassment extremely bothersome for the hunters. In October 2006 colder weather came, and the caribou came down to the lowlands in great numbers, but the hunters could only look at them. Owing to the unusually warm weather in 2006, the 10th of September was too early to end the hunting season. The caribou are abundant and need to be harvested or they will overgraze their pastures. He is worried that the caribou will become overabundant in the Qeqertarsuatsiaat area.

Anthon Egede agreed that caribou remain at high elevation if the weather is warm. In August 2006, to shoot caribou in the Ameralik portion of the South region he had to go into the high elevations.

Qeqertarsuatsiaat caribou

The following local knowledge for the Qeqertarsuatsiaat caribou comes solely (unless indicated otherwise) from commercial (KNAPK) hunter Karolus Steffani.

General

Karolus Steffani usually hunts just to the north of the Frederikshåb Isblink and sometimes on the delta area around the front. The caribou there have shorter legs but larger robust bodies with more meat and rump fat, than caribou harvested to the north of Qeqertarsuatsiaat (Fiskenæsset), i.e. the Ameralik population. Karolus has not noticed any difference in pelt colouration between the two areas, but the Frederikshåb Isblink caribou have smaller antlers. In contrast to the Ameralik caribou population, Karolus has never observed females with two calves at heel, in the Frederikshåb Isblink area. The caribou around Frederikshåb Isblink move back and forth between the area north of the Isblink and Qassit, which is in Paamiut region. They wander over the delta flats in front of the Isblink. The low-lying terrain just to the north of the Frederikshåb Isblink and the delta area around the front allow easy access for hunting.

Abundance & distribution
Prior to 1960 there were few caribou in the Qeqertarsuatsiaat area. Karolus Steffani and other hunters would always successfully take a few caribou in the coastal areas between Qeqertarsuatsiaat (Fiskenæsset) and Grædefjord, but the caribou were not abundant. It was after the hunting prohibition of 1993-1994 that he noticed an increase in caribou number. Ever since 1995, the caribou are everywhere and increasing in number.

Between 2001 and 2006 there has been a slow steady increase in the number of caribou in the Qeqertarsuatsiaat area. In August 2006 Karolus Steffani took 2 caribou on the mainland shore only a few kilometres east of town, and both these animals had, the much prized, deep layer of rump fat. In autumn 2006 caribou were extremely abundance in the inner Qeqertarsuatsiaat Kangerdluat fjord east of Qeqertarsuatsiaat (Fiskenæsset). Today hunters sail this fjord shoreline slowly, easily spotting caribou that are within shooting range. Nikolaj Heinrich and Anthon Egede agreed with this observation. Nikolaj Heinrich proposed that this meant that the Ameralik caribou were moving south into the area of the Qeqertarsuatsiaat caribou population.

Caribou may also be taken in the valleys at the head of Bjørnesund. These come from the Qeqertarsuatsiaat inland by the Ice Cap.

In Karolus Steffani ʻs lifetime there have never been caribou on the island where the town of Qeqertarsuatsiaat (Fiskenæsset) is situated, or on the large islands immediately north and west.

Miscellaneous Observations

North region
Nikolaj Heinrich remembers that in the spring of 1971 a large number of caribou drowned out on the sea ice west of Sisimiut (Holsteinsborg, North Region) when a hard storm hit the region breaking up the ice and drowning the animals.

Central region
Anthon Egede, remembers that when he was a young boy, they had to sail up to the North region (Kangerlussuaq area) to hunt caribou because there were none around Nuuk. By the 1980's, however, caribou could be seen near the coastal towns of Napatsoq and Atammik as they sailed north, and so they no longer had to sail all the way to Kangerlussuaq to catch caribou.

Job Heilmann observed that caribou on Akia-Nordlandet have become noticeably fewer with each year over the past few years, specifically in the Narsarssuaq Valley at head of Qugsuk

Fjord (Godthåbsfjord), which is the area he typically hunts. In January 2007 he saw first three groups of caribou (7, 5 & 4 animals) in the bay north of Terte

Paamiut region

There were many caribou at Qassit in the autumn of 2006.

South region: Semi-domestic reindeer

Caribou parasites

1952 semi-domestic reindeer came to Godthåbsfjord and brought the warble fly parasites with them (Nikolaj Heinrich pers comm).

Movement/ Dispersal into North region

In 1971 Nikolaj Heinrich shot a female wearing a bell collar at the Isortog River north of the town of Sisimiut in the North region. He assumed this was a semi-domestic reindeer that had come north from the reindeer herding station at Itivnera in Godthåbsfjord.

Movement / Dispersal of feral reindeer from Itivnera/Godthåbsfjord to Ameralik and further

There is abundant local knowledge observing the steady southward movement of semi-domestic reindeer from Godthåbsfjord down into Ameralik, Buksefjord and further south (Cuyler et. al. 2003). Further to these are the following.

In the autumn of 1988 or 1989, Anthon Egede shot a reindeer calf with an ear tag [which suggests possibly a yearling] at the mouth of Buksefjord on the south shore. This animal could only have come from the reindeer herding station at Itivnera in Godthåbsfjord, which is a distance of ca. 135 km by land. [Caribou and reindeer are capable of covering short distances like this easily in one season (C. Cuyler).]

In summer 2004 Anthon shot an unusually large bull with ear tags and deformed antlers on the far eastern shore of Taserssuatsiait Lake, which is between Buksefjord and Alángordlia Fjord. Anthon believed people had castrated the bull, i.e., testicles were missing, which suggested to him that this animal came from the reindeer herding station at Itivnera in Godthåbsfjord. This station closed permanently in 1998, after several years of neglect.

Muskox

Observations

In summer 2006 at the head of Godthåbsfjord, Anthon Egede saw seven muskox in the Sarqarssuaq valley, which separates the Nunatarssuaq and Akugdlerssuaq highlands. He has photo of these.

Possible introduction at Qeqertarsuatsiaat
Karolus Steffani in 1984 Qeqertarsuatsiaat (Fiskenæsset) almost received permission to introduce muskox to the area just north of Frederikshåb Isblink. In 2006 the town of Qeqertarsuatsiaat (Fiskenæsset) has applied again for permission to have muskox in this area.

Observed in Austmannadalen?
Anthon Egede says he has never heard of or seen muskox in Austmannadalen. There are, however, both black and white sheep there in 2006, and suggested that someone may have mistaken black sheep from a distance for muskox.

Lake draining rapidly (see Appendix 12)
Nikolaj reported that the last time the lake emptied rapidly was in 2002, and he expects it to empty again in 2010. Jens Bjerge was at this same lake in late September 2006 and observed that it looked similar to the March 2006 photos in Appendix 12, and therefore did not appear to be filling-up as usual.

Ice Cap / glacial melt
Anthon Egede reported that prior to 2005 he always needed a boat to get across the Austmannadalen River. In the summers of 2005 and 2006 he could cross the Austmannadalen River in rubber boots, because the Ice Cap had receded, which substantially reduced the amount of water flowing in the river.

Anthon Egede reported that by summer 2006, the alpine ice north and east of the Taserssuatsiait Lake (between Buksefjord and Alángordlia fjord) has receded noticeably. The alpine glaciers to the north are almost completely gone, while the tongue of the mini-icecap recedes with each year.

Karolus Steffani reports that if there is any shrinkage of the Frederikshåb Isblink it is not readily visible, although he thinks it is shrinking slowly.

Seal Hunting
Karolus Steffani reports that seal hunting is good in the waters off the front of Frederikshåb Isblink

Information for local knowledge sources interviewed

Jens Bjerge
Tel: (+299) 32 64 17 p / 32 14 08 work / 35 98 22 Buksefjord
Born 1965
He has been employed at the Nuuk Hydro Power station in Buksefjord since 1989, and has noted caribou population changes in the areas monitored by the hydro plant since then.

Nikolaj Heinrich, KNAPK
Tel: (+299) 55 59 79 mobile / 32 49 86 home
Born 1938
Originally from Qeqertarsuatsiaat area but has lived in Nuuk for some decades.

Anthon Egede, KNAPK
Tel: (+299) 54 86 56 mobile
Born 1956
Family has hunting cabin in the Agpaanguit iluat Bay area, which is just north of the mouth of Buksefjord.

Lars Mathæussen, KNAPK
Born 1956
Tel: (+299) 24 17 88

Job Heilmann, KNAPK
Born 1965
He is a resident of Nuuk resident, and hunts in the Narssarssuaq valley of Qugsuk
Tel: (+299) 25 82 91 mobile / 32 48 85 home

Karolus Steffani, KNAPK
Born 1948,
Qeqertarsuatsiaat resident and hunts there
Tel: (+299) 29 52 31

Appendix 2

Survey statistical design

Although the public requests unbiased estimates of the "true" abundance of caribou present, all surveys are plagued by inherent biases and errors, and must adher to what is logistically possible within the financing available.

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. In order to account for missed animals we used the method described below. Instead of a parametric variance calculation we found a bootstrapped confidence interval. Precision is the measure of variation in the numbers of caribou on each transect. Poor precision can result from sampling errors, e.g., if group size and distribution were highly variable within a stratum. We attempt to increase precision by having as many sample units (transects) as possible.

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 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 and 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 $N = \dfrac{E(B)}{p_f \cdot p_r}$

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 and 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.

Then the corrected values for observed animals are then:

$$N = \sum_i \frac{\max(f_{i,left}, r_{i,left})}{(1-(1-p_f)\cdot(1-p_r))} + \frac{r_{i,right}}{p_r}$$

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.

Table 4. 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-Maniitsoq	Ameralik	Qeqertarsuat-siaat
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

Data taken from Cuyler et al. 2002, 2003.

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 4).

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 4).

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 p_r 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.

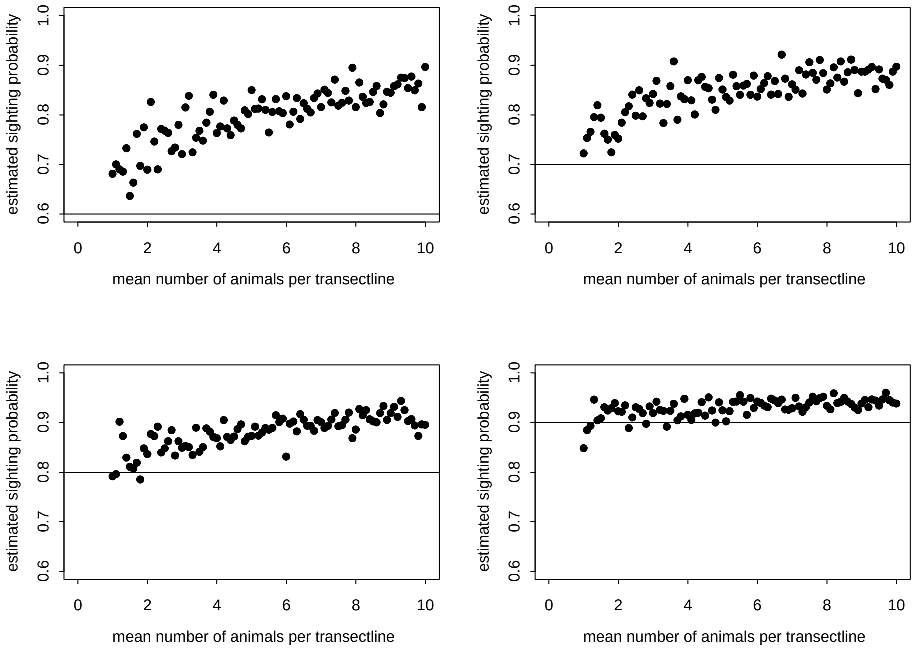

Figure 12. Simulations of the effects of number of animals encountered per transect strip on the estimated sighting probability (bias adjustment) at four different levels of detection probability (the horizontal line at 0.6, 0.7, 0.8 and 0.9).

Appendix 3

Aerial helicopter survey 2006 of the Ameralik caribou population, in the South region of West Greenland

Table 5. *Raw data aerial survey Ameralik caribou herd, South region, March 2006. Survey observers: (CC) Christine Cuyler, (RH) Rink Heinrich and (JE) Johannes Egede, (LM) Lars Mathæussen.*

Date ddmmyy	Transect number	Stratum	Number Caribou observed on transect			Rear Seat Observers	
			Left front (CC)	Left rear	Right rear	Left	Right
11.03.06	246	Ameralik	0	0	0	JE	RH
11.03.06	7	Ameralik	7	7	0	JE	RH
11.03.06	206	Ameralik	0	0	0	JE	RH
11.03.06	115	Ameralik	5	7	0	JE	RH
11.03.06	282	Ameralik	0	0	0	JE	RH
11.03.06	87	Ameralik	7	5	1	JE	RH
11.03.06	11	Ameralik	0	0	8	JE	RH
11.03.06	271	Ameralik	2	2	0	JE	RH
11.03.06	190	Ameralik	17	17	3	JE	RH
11.03.06	188	Ameralik	9	3	0	JE	RH
11.03.06	94	Ameralik	7	7	5	RH	JE
11.03.06	267	Ameralik	5	5	0	RH	JE
13.03.06	109	Ameralik	0	0	0	LM	RH
13.03.06	46	Ameralik	0	0	0	LM	RH
13.03.06	44	Ameralik	0	0	0	LM	RH
13.03.06	197	Ameralik	0	0	0	LM	RH
13.03.06	96	Ameralik	5	5	0	LM	RH
13.03.06	296	Ameralik	0	0	0	LM	RH
13.03.06	41	Ameralik	0	0	0	LM	RH
13.03.06	28	Ameralik	0	0	0	LM	RH
13.03.06	167	Ameralik	0	0	0	LM	RH
13.03.06	257	Ameralik	0	0	0	LM	RH
13.03.06	23	Ameralik	0	0	0	LM	RH
13.03.06	210	Ameralik	0	0	0	RH	LM
13.03.06	240	Ameralik	4	4	4	RH	LM
13.03.06	2	Ameralik	0	0	0	RH	LM
13.03.06	180	Ameralik	0	0	0	RH	LM
13.03.06	99	Ameralik	5	5	13	RH	LM
13.03.06	182	Ameralik	0	0	1	RH	LM
13.03.06	212	Ameralik	0	0	0	RH	LM
13.03.06	37	Ameralik	0	4	0	RH	LM
13.03.06	233	Ameralik	0	0	5	RH	LM
13.03.06	295	Ameralik	0	0	0	RH	LM
13.03.06	258	Ameralik	0	11	4	RH	LM
13.03.06	40	Ameralik.	4	4	6	RH	LM
13.03.06	34	Ameralik.	0	0	0	RH	LM
13.03.06	91	Ameralik	16	16	3	RH	LM
14.03.05	170	Ameralik	0	0	0	LM	RH
14.03.05	172	Ameralik.	0	0	17	LM	RH
14.03.05	77	Ameralik.	0	0	18	LM	RH
TOTAL			**198 caribou** (110 left side + 88 right side)				

Table 6. *Random transects aerial survey Ameralik caribou, South region, March 2006.*

Direction flown	Transect number	Transect start		Transect end	
		Latitude	Longitude	Latitude	Longitude
SSE-NNW	2	64º 07.29'	50º 29.33'	64º 03.30'	50º 27.78'
NW-SE	7	64º38.98'	50º 35.83'	64º 36.38'	50º 28.59'
NE-SW	11	64º 22.34'	49º 43.68'	64º 25.41'	49º 37.58'
SW-NE	23	64º 08.79'	51º 35.85'	64º 10.78'	51º 27.77'
SSE-NNW	28	63º 51.02'	51º 24.10'	63º 47.51'	51º 19.54'
NW-SE	34	63º 39.08'	51º 09.81'	63º 35.08'	51º 08.49'
SSW-NNE	37	63º 59.41'	50º 03.76'	64º 03.44'	50º 02.78'
NW-SE	40	63º 35.05'	51º 03.50'	63º 31.13'	51º 01.22'
NE-SW	41	63º 55.42'	51º 16.78'	63º 57.73'	51º 09.22'
SW-NE	44	64º 19.89'	50º 35.79'	64º 21.79'	50º 27.54'
SE-NW	46	64º 23.58'	50º 49.45'	64º 21.21'	50º 41.87'
S-N	77	63º 22.12'	50º 51.44'	63º 26.15'	50º 50.58'
NW-SE	87	64º 29.99'	49º 57.17'	64º 27.81'	49º 49.27'
SW-NE	91	63º 38.14'	51º 19.09'	63º 41.52'	51º 14.06'
W-E	94	64º 13.81'	50º 02.19'	64º 13.93'	49º 52.88'
SW-NE	96	64º 15.74'	50º 26.94'	64º 16.98'	50º 18.07'
W-E	99	63º 55.88'	50º 23.52'	63º 56.31'	50º 14.37'
NW-SE	109	64º 14.15'	50º 58.05'	64º 12.56'	50º 49.49'
NW-SE	115	64º 36.12'	50º 10.24'	64º 34.14'	50º 02.02'
SSE-NNW	167	63º 45.73'	51º 23.67'	63º 41.79'	51º 21.61'
SW-NE	170	63º 25.19'	51º 07.12'	63º 28.36'	51º 01.50'
NW-SE	172	63º 27.71'	50º 53.65'	63º 26.36'	50º 45.12'
W-E	180	64º 01.82'	50º 35.41'	64º 01.86'	50º 26.17'
SE-NW	182	63º 55.35'	50º 00.31'	63º 52.03'	49º 55.05'
SE-NW	188	64º 21.88'	50º 05.34'	64º 18.39'	50º 00.62'
SE-NW	190	64º 12.64'	49º 51.57'	64º 10.74'	49º 43.36'
SW-NE	197	64º 28.05'	50º 26.06'	64º 31.40'	50º 20.77'
SW-NE	206	64º 34.78'	50º 23.33'	64º 38.37'	50º 18.99'
S-N	210	63º 55.23'	50º 28.25'	63º 59.28'	50º 28.21'
SE-NW	212	63º 56.02'	49º 55.89'	63º 52.95'	49º 49.88'
SE-NW	233	64º 06.68'	50º 08.85'	64º 03.32'	50º 03.68'
SW-NE	240	63º 59.75'	50º 27.49'	64º 02.59'	50º 20.90'
W-E	246	64º 36.77'	50º 53.28'	64º 36.71'	50º 43.84'
SW-NE	257	63º 57.00'	51º 24.00'	64º 01.24'	51º 21.40'
NW-SE	258	63º 40.68'	51º 03.13'	63º 37.18'	50º 58.55'
SW-NE	267	64º 12.31'	50º 11.37'	64º 15.90'	50º 07.09'
S-N	271	64º 11.48'	49º 40.51'	64º 15.52'	49º 39.83'
SW-NE	282	64º 32.36'	49º 53.98'	64º 33.86'	49º 45.24'
SE-NW	295	63º 55.46'	50º 55.96'	63º 52.37'	50º 50.03'
ENE-WSW	296	64º 03.06'	50º 58.47'	64º 04.00'	50º 49.48'

Table 7. *Raw survey data on herd structure of the Ameralik caribou, South region, March 2006.*

Date ddmmyy	Transect number / Area Flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
11-Mar-06	11	3	1	1	1
11-Mar-06	190	11	3	4	4
11-Mar-06	190	2	0	1	1
11-Mar-06	188	6	0	3	3
11-Mar-06	94	5	0	3	2
11-Mar-06	94	2	0	1	1
11-Mar-06	94	6	0	3	3
11-Mar-06	94	6	0	4	2
11-Mar-06	267	5	5	0	0
13-Mar-06	96	5	0	4	1
13-Mar-06	240	4	0	2	2
13-Mar-06	240	4	0	2	2
13-Mar-06	99	2	0	1	1
13-Mar-06	99	3	1	1	1
13-Mar-06	37	4	1	2	1
13-Mar-06	233	5	2	2	1
13-Mar-06	258	4	0	3	1
13-Mar-06	40	4	0	2	2
13-Mar-06	40	6	1	3	2
13-Mar-06	Area 1	1	0	1	0
13-Mar-06	Area 1	6	3	3	0
13-Mar-06	Area 1	6	1	5	0
13-Mar-06	Area 1	2	0	2	0
13-Mar-06	Area 1	7	0	5	2
13-Mar-06	Area 1	10	0	7	3
13-Mar-06	Area 1	2	0	1	1
13-Mar-06	91	3	0	2	1
13-Mar-06	91	7	0	4	3
13-Mar-06	91	6	0	3	3
14-Mar-06	77	15	5	9	1
14-Mar-06	77	3	0	2	1
14-Mar-06	77	5	0	3	2
15-Mar-06	Area 2	3	3	0	0
15-Mar-06	Area 2	5	5	0	0
15-Mar-06	Area 2	10	10	0	0
15-Mar-06	Area 2	5	5	0	0
15-Mar-06	Area 2	4	4	0	0
15-Mar-06	Area 2	11	11	0	0
15-Mar-06	Area 2	13	11	1	1
15-Mar-06	Area 2	7	7	0	0
15-Mar-06	Area 2	7	0	4	3
15-Mar-06	Area 3	3	0	0	3
15-Mar-06	Area 3	6	0	3	3
	TOTALS	**234**	**79**	**97**	**58**

Appendix 4

Aerial helicopter survey 2006 of the Qeqertarsuatsiaat caribou, in the South region of West Greenland

Table 8. *Raw data aerial survey Qeqertarsuatsiaat caribou herd, South region, March 2006. Survey observers: (CC) Christine Cuyler, (RH) Rink Heinrich, (JE) Johannes Egede, and (LM) Lars Mathæussen.*

Date ddmmyy	Transect number	Area	Number Caribou observed on transect			Rear Seat Observers	
			Left front (CC)	Left rear	Right rear	Left	Right
14.03.05	150	Qeqertar.	0	0	8	LM	RH
14.03.05	185	Qeqertar.	0	0	0	LM	RH
14.03.05	105	Qeqertar.	0	0	12	LM	RH
14.03.05	59	Qeqertar.	9	10	0	LM	RH
14.03.05	229	Qeqertar.	0	0	0	RH	LM
14.03.05	174	Qeqertar.	7	7	7	RH	LM
14.03.05	203	Qeqertar.	0	0	0	RH	LM
14.03.05	90	Qeqertar.	9	7	4	RH	LM
14.03.05	3	Qeqertar.	0	0	21	RH	LM
14.03.05	126	Qeqertar.	0	0	0	RH	LM
14.03.05	12	Qeqertar.	11	11	1	RH	LM
14.03.05	14	Qeqertar.	0	0	1	RH	LM
14.03.05	26	Qeqertar.	15	15	0	RH	LM
14.03.05	62	Qeqertar.	0	0	0	RH	LM
15.03.05	86	Qeqertar.	3	3	0	JE	RH
15.03.05	108	Qeqertar.	0	0	0	JE	RH
15.03.05	199	Qeqertar.	0	0	0	JE	RH
15.03.05	300	Qeqertar.	0	0	0	JE	RH
15.03.05	64	Qeqertar.	0	0	0	JE	RH
15.03.05	10	Qeqertar.	0	0	0	JE	RH
15.03.05	30	Qeqertar.	0	0	0	JE	RH
15.03.05	140	Qeqertar.	0	0	0	JE	RH
15.03.05	136	Qeqertar.	0	0	0	JE	RH
15.03.05	1	Qeqertar.	0	0	0	JE	RH
TOTAL			**109 caribou** (55 left side + 54 right side)				

Table 9. *Random transects aerial survey Qeqertarsuatsiaat caribou, South region, March 2006.*

Direction flown	Transect number	Transect start		Transect end	
		Latitude	Longitude	Latitude	Longitude
NE-SW	1	62º 56.89'	50º 10.86'	63º 00.40'	50º 06.42'
NW-SE	3	63º 12.30'	49º 44.23'	63º 09.89'	49º 37.02'
NW-SE	10	62º 57.61'	50º 04.06'	62º 55.81'	49º 56.09'
SW-NE	12	63º 12.89'	49º 41.72'	63º 15.57'	49º 35.00'
NE-SW	14	63º 15.47'	49º 46.36'	63º 17.15'	49º 38.18'
NW-SE	26	63º 19.83'	49º 46.79'	63º 17.32'	49º 39.73'
SW-NE	30	62º 56.35'	49º 51.16'	63º 00.22'	49º 48.53'
NW-SE	59	63º 24.04'	49º 36.67'	63º 22.87'	49º 28.02'
SSW-NNE	62	63º 05.32'	50º 46.84'	63º 09.34'	50º 45.76'
SW-NE	64	62º 52.73'	50º 06.93'	62º 56.60'	50º 04.29'
SSE-NNW	86	62º 39.78'	50º 12.95'	62º 36.03'	50º 09.64'
SW-NE	90	63º 11.06'	49º 54.53'	63º 12.07'	49º 45.84'
NW-SE	105	63º 29.69'	49º 51.97'	63.27.53'	49º 44.31'
SW-NE	108	62º 40.44'	50º 16.14'	62º 42.84'	50º 09.05'
SW-NE	126	63º 10.74'	49º 32.93'	63º 12.78'	49º 25.17'
SSW-NNE	136	63º 02.39'	49º 51.73'	63º 06.42'	49º 51.04'
SE-NW	140	63º 01.89'	49º 42.16'	62º 59.15'	49º 35.60'
SW-NE	150	63º 20.24'	50º 02.82'	63º 21.74'	49º 54.44'
S-N	174	63º 13.43'	50º 12.20'	63º 09.38'	50º 12.00'
SE-NW	185	63º 31.05'	50º 03.93'	63º 27.47'	49º 59.70'
NW-SE	199	62º 47.60'	49º 56.17'	62º 45.60'	49º 48.48'
SSW-NNE	203	63º 09.42'	50º 01.98'	63º 13.37'	50º 00.09'
SW-NE	229	63º 04.40'	50º 12.64'	63º 06.10'	50º 04.53'
SSE-NNW	300	62º 53.58'	50º 02.95'	62º 49.58'	50º 01.54'

Table 10. *Raw survey data on herd structure of the Qeqertarsuatsiaat caribou, South region, March 2006.*

Date ddmmyy	Transect number / Area Flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
14-Mar-06	105	3	1	1	1
14-Mar-06	59	2	1	1	0
14-Mar-06	59	2	0	1	1
14-Mar-06	174	7	6	1	0
14-Mar-06	90	7	0	4	3
14-Mar-06	90	4	4	0	0
14-Mar-06	26	1	1	0	0
14-Mar-06	26	3	2	1	0
14-Mar-06	26	6	6	0	0
14-Mar-06	26	5	0	5	0
14-Mar-06	26	6	0	6	0
14-Mar-06	12	9	3	4	2
14-Mar-06	12	3	3	0	0
15-Mar-06	86	3	3	0	0
15-Mar-06	Area 1	0	0	0	0
15-Mar-06	Area 2	3	3	0	0
15-Mar-06	Area 2	4	4	0	0
15-Mar-06	Area 2	11	11	0	0
15-Mar-06	Area 2	14	11	1	2
15-Mar-06	Area 2	9	9	0	0
15-Mar-06	Area 2	6	6	0	0
15-Mar-06	Area 2	4	1	3	0
15-Mar-06	Area 3 (S side Grædefjord)	2	2	0	0
	TOTALS	**114**	**77**	**28**	**9**

Appendix 5

Recommendations for future

Aerial survey methods & design

Stratification is necessary. In 2006 both the Ameralik and Qeqertarsuatsiaat herds evidenced pronounced clumped distributions (zero caribou on half or more of the transects) and group sizes were relatively large. Thus the assumption that density was uniform throughout the region was false. This makes the population estimates less accurate. Figures 7 & 8 could be the guidelines for a future stratification.

Increasing survey coverage on future surveys would also promote accuracy. If financially possible more transects are recommended to increase the area coverage, as present coverage is low (2%), which leads to underestimating abundance.

To ensure that caribou can be spotted and reduce the bias of missed caribou, the methods described in this report are recommended for future aerial surveys.

The window design on the helicopter available during this and last year's surveys is not optimal for side viewing (Fig. 13). The rear windows are too small and those forward are cluttered with barriers to vision. If possible a helicopter with windows better suited to viewing is desirable.

Figure 13. *Window design on helicopter currently available for caribou surveys; left and right sides.*

Move the time period for aerial surveys forward to late February, or at least to the first week in March. Although mid-March has been the period chosen for surveys because, in addition to greater day length, almost full snow cover is expected, the onset of early spring melt in recent years, i.e., 2005 and 2006, has caused partial or complete loss of snow cover over much of the surveyed areas. The result is poor sightability conditions for caribou. The patchy snow cover or "salt & pepper" background of new snow makes detection of caribou present on transects difficult and contributes a negative bias to the estimates.

Owing to recent early onsets of spring melt, we recommend changes be made to those transects, which cross over fjords. In the past fjords would be frozen over with ice and thereby utilized by caribou, making them valid survey areas in March. However, fjords are now typically ice-free and not utilized by caribou during the survey period. We suggest altering these transects for future surveys. Aiming to alter survey design as little as possible, two potential changes include, shortening the length of the affected transects by removing the fjord segment, or, removing the distance out over fjord and applying this length to the opposite terrestrial end of the same transect. The transect remains in place but now all 7.5 km are over land.

Sighting caribou

Although seldom significant ($P < 0.05$), fewer caribou are observed on the right side of the helicopter (Cuyler et al. 2002, 2003, 2005, this study), where only one observer was present relative to the left side of the helicopter, where two observers independently counted animals. We suggest that a subconscious element of competition existed between the two left side observers, since their results will be compared against each other. This sharpened their concentration and more caribou present on transects were spotted. Competition, real or imaginary, may be a method to further reduce the number of missed caribou on a survey. For details see Appendix 6 in Cuyler et al. (2005). To obtain a double count on selected transects, a second helicopter flying simultaneously with first and counting from higher flight altitude than 15m height might be employed. Alternately, video footage on selected transects may be useful.

Herd structure count

While zigzagging for herd structure the principal observer in the front left seat of the helicopter has the dual tasks of observing and writing down caribou sex and age. Eye contact with the animals is broken while writing. This makes observations of large groups difficult, because the animals are in flight and shift positions often, and results in more time required sorting out individuals. We recommend that one of the back seat observers writes down the sex and age, as called out by the front left seat observer. Thus enabling the latter to keep an eye on the animals at all times, while these are running and mixing in flight.

Area (km^2) calculation

Areas given in this report are "flat", and do not reflect the topographical complicity of the regions or the random transects flown. If a GIS digital terrain model could be created for the regions and also the transects, then this would increase the accuracy of the estimated caribou densities, and allow better calculation of the actual area "seen" (dead ground could be excluded). Population estimates would improve.

NDVI (Normalized Difference Vegetation Index: or greenness index)

As weather records with relevance for interpreting caribou fecundity or calf survival are not available, study of remote sensing NDVI data would give an idea of weather effect on vegetation, and possibly allow comparisons of vegetation before and after climate change and correlations to caribou dynamics.

Logistics Tips

Book the time period for helicopter use well in advance (minimum two months) and check as to whether Air Greenland has other plans for their helicopter or pilot during the time period for the intended survey. One year, Air Greenland neglected to inform us that their pilot was obliged to participate in an Air Greenland pilots training course. This interrupted the survey when weather was optimal.

Prior to takeoff:

- Make sure the helicopter has a SATELLITE TELEPHONE. For safety reasons helicopter pilots must call-in by radio to Air Greenland every half-hour and give their position. Since radio contact is impossible at the 15 m flight altitudes used during the survey, the pilot must drop what he's doing and gain altitude until contact is made. This causes delays and can result in wasted time, i.e. extra expense, for the surveys. With a satellite telephone the pilot can make contact with Air Greenland regardless of where we are in the terrain.
- To pick out inevitable discrepancies, check transect "start" and "end" GPS points keyed-into the helicopter GPS by the pilot against your own printout of the correct points. Correct any errors found.
- Check from helicopter GPS that all transects entered have length 7.5 km.
- Check that all transects to be used that day are actually in helicopter GPS. The number of data points may exceed memory of helicopter GPS. All initial transects entered can be erased for want of available of memory and no warning will be given.

While flying:

- Always carry your original print-out of transect "start" and "end" points with you in helicopter for consultation in case the above still does not catch all human errors.
- Refuelling is not always possible between 09:00 and 17:00, Monday to Friday, specifically at Sisimiut airport, which can close early, e.g. 14:00, and possibly also at Maniitsoq. Telephone on the specific day to obtain update on whether refuelling is possible and when.
- Refuelling in Kapisillit or Qeqertarsuatsiaat (Fiskenæsset) is only possible if fuel barrels are already there, and pilot has pumping gear onboard. Refuelling may take up to two hours if conditions are adverse or equipment functions poorly.
- All airports are closed for Sundays and holidays, unless your project is willing to pay to keep them open.
- Helicopter pilots are prohibited from flying more than 7 hours per day. Safety considerations would suggest that less than 7 hours is better when flying the low slow transects used in the caribou surveys.
- Bring totally non-scratch cloths, which are approved by Air Greenland Helicopter Charter department to wipe condensation off the inside of the helicopter's front window.

Appendix 6

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 centres 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.

Coefficient of Variance (CV) – statistical term for an index of precision that is derived by dividing the standard error (SE) by the mean estimated abundance.

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 deviation (SD) – standard deviation is the square root of the variance.

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 the North region 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. Note: variance is distribution independent, and is simply the expected square deviation.

Appendix 7

Names and locations of Greenland caribou populations & their corresponding hunting regions

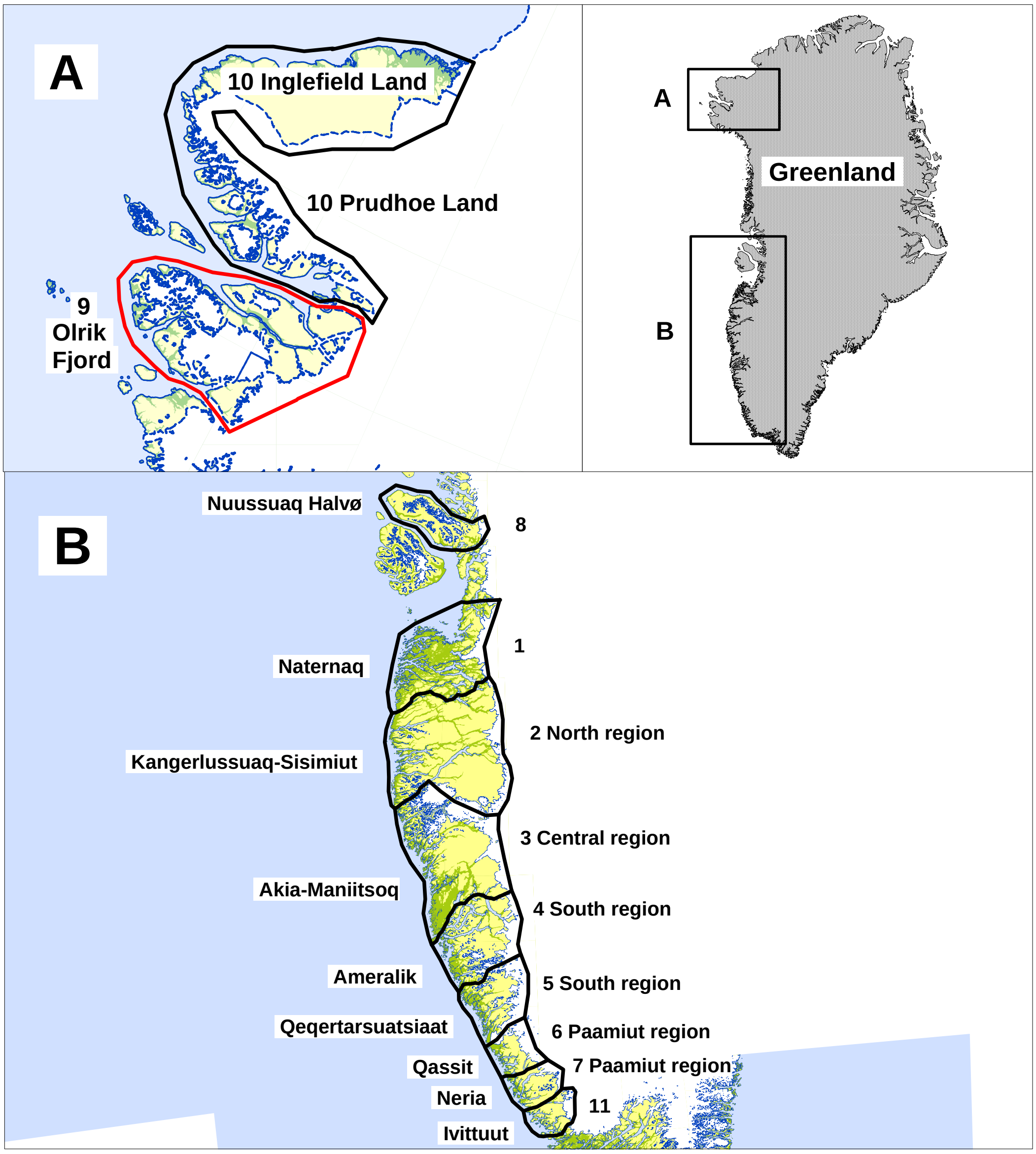

Figure 14. *Names and locations of Greenland caribou / feral reindeer populations in 2006, with their corresponding hunting region number and where applicable a region name.*

Prior to 1999, the Greenland caribou on the west coast were harvested and managed as one continuous population. New assessment and data allowed the definition of specific populations based on geographic regions (Linnell et al. 1999, 2001; Cuyler et al. 2002, 2003, 2004). The complex geography of the west coast creates topographical barriers or filters, which make large-scale exchange of individuals unlikely along a north-south axis (Linnell et al. 2000). Although not impossible, north-south dispersion between regions has never been supported by satellite telemetry (Cuyler & Linnell 2004) and suggested by locals only once

(Appendix 1). Documented seasonal movements, when these occur, are on an east–west axis (Vibe 1967, Strandgaard et al. 1983, Cuyler & Linnell 2004). Further, genetic analysis using microsatellites confirmed relatively distinct herds coinciding to geographic regions (Jepsen 1999, et al. 2002). Therefore beginning in 1999, to facilitate population specific harvest management and reporting (e.g., quotas, season length, etc. or the sex/age and body condition of animals harvested respectively) the geographical regions corresponding to single populations were assigned hunting area numbers and typically names.

Appendix 8

Greenland caribou population estimates & minimum counts

Table 11. Winter population estimates and minimum counts of wild caribou / reindeer in Greenland. All population size estimates are approximate[1].

Caribou / Reindeer Population	Region No.	Region Name	1977 /78	1993	1994	1995	1996	1999	2000	2001	2002	2005	2006
Inglefield Land	10	-	-	-		100		2,260	-	-	-	-	-
Olrik Fjord	9	.	-	-		-				38*	-	-	-
Nuussuaq Halvø	8	-	170	-		400				400	1,164*	-	-
Naternaq	1	Naternaq	100	80		271				-	-	-	-
Kangerlussuaq-Sisimiut	2	North	17,900	3,788	7,727	6,196	10,869		51,600**	-	-	90,464**	-
Akia-Maniitsoq	3	Central	5,300	3,506	3,080	6,408	6,806		-	46,236	-	35,807	-
Ameralik	4	South	-	1,341	1,458	4,553	4,458+		-	31,880	-	-	9,680
Qeqertarsuatsiaat	5	South	-						-	5,372	-	-	5,224
Qassit	6	Paamiut	-	-		-			196*	-	-	-	
Neria	7	Paamiut	-	-	181	407			1,600 (332*)	-		-	
Total Estimate for Greenland	-	-	-	**9,000** (6865–10559)	**13,000** (10105–15530)	**18,000** (14761–21558)	**ca. 22,000** (19581–25027)		-	**ca. 140,000[2]**	-	-	**ca. 140,000[3]**

[1]Estimates from 2000 to 2006 were obtained using survey methods and design unlike those employed from 1993 to 1999. Therefore herd size differences between these two time periods are not assumed readily comparable.

[2] Rough sum of population estimates from 1999, 2000 and 2001.

[3] Rough sum of population estimates from 2005 and 2006.

*Minimum counts.

**Kangerlussuaq-Sisimiut estimates from 2000 and 2005 were obtained using somewhat dissimilar methods, i.e. the 2005 survey reduced flight altitude by 85 m, speed by ca. 45 km/hr, and strip width by 400 m. The two estimates are therefore not assumed readily comparable and should not be interpreted as indicating population trend for this herd.

Sources: Ydemann & Pedersen 1999, Linnell et al. 1999, Landa et al. 2000, Cuyler et al. 2002, 2003, 2004, 2005 and current study.

Table 12. Indices of precision, standard error and coefficient of variance, for the surveys completed since 2000.

Year	Mean estimate of Abundance & (CI)	Width 1	Width 2	Confidence Interval (CI)	Percentile	Standard Error (SE)	Coefficient of Variance (CV)
NORTH Region *Kangerlussuaq-Sisimiut*							
2000	51,600 (40,400 – 62,800)	11,200	11,200	90%	1.645	6808.511	**0.131948**
2005	90,464 (70,276 – 113,614)	20,188	23,149	90%	1.645	13172.34	**0.145609**
CENTRAL Region *Akia-Maniitsoq*							
2001	46,236 (37,115 – 55,808)	9,121	9,572	80%	1.28	7301.953	**0.157928**
2005	35,807 (27,474 – 44,720)	8,333	8,913	90%	1.645	5241.945	**0.146394**
SOUTH Region *Ameralik*							
2001	31,880 (24,721 – 39,305)	7,159	7,425	80%	1.28	5696.875	**0.178697**
2006	9,680 (6,515 – 13,147)	3,165	3,467	90%	1.645	2015.805	**0.208244**
SOUTH Region *Qeqertarsuatsiaat*							
2001	5,372 (2,864– 8,244)	2,508	2,872	80%	1.28	2101.563	**0.391207**
2006	5,224 (2,831 – 7,881)	2,393	2,657	90%	1.645	1534.954	**0.293827**
SOUTH Region *Combined Ameralik + Qeqertarsuatsiaat*							
2001							
2006	14,871 (11,689– 18,231)	3,182	3,360	90%	1.645	1988.45	**0.133713**