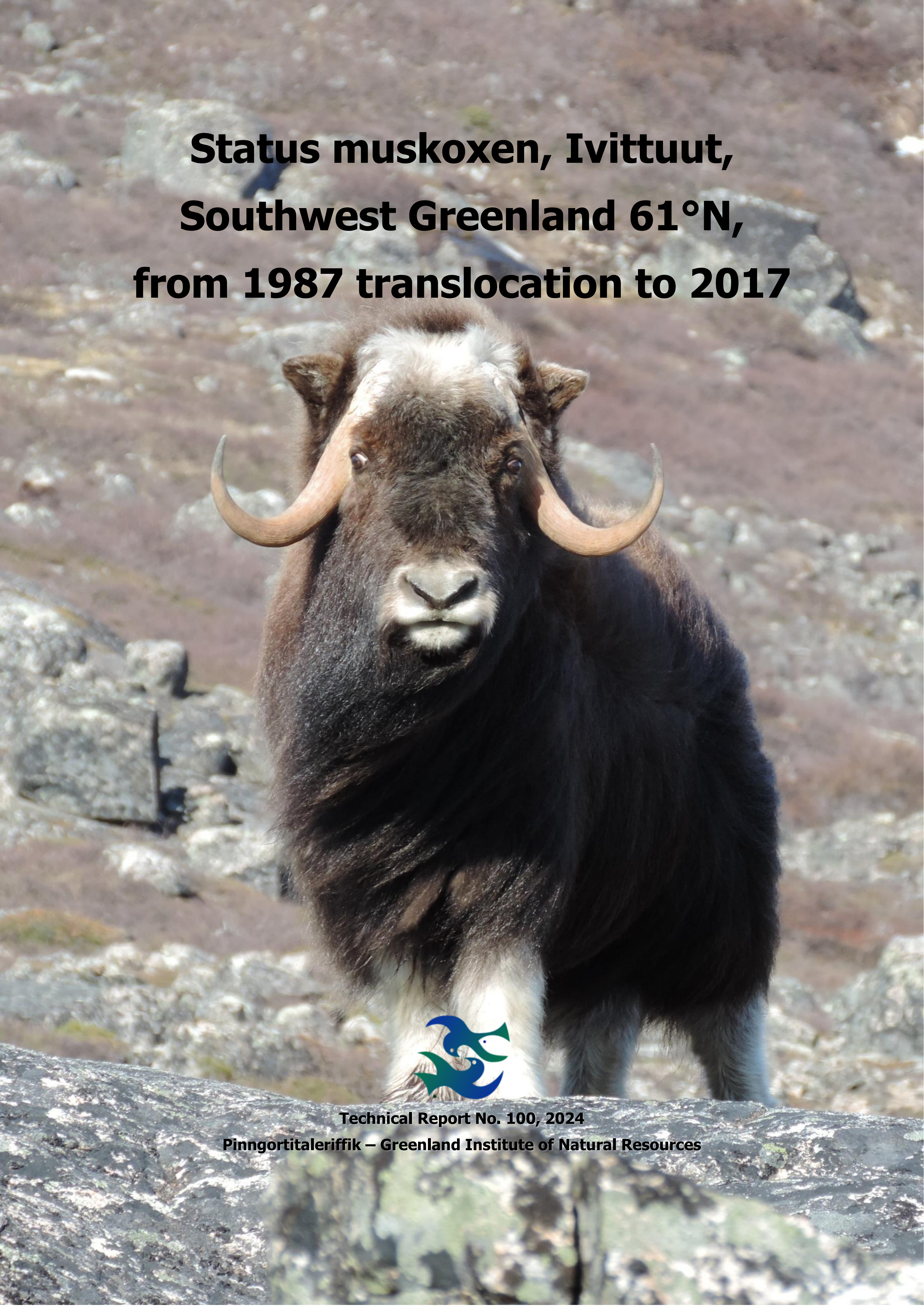

Status muskoxen, Ivittuut, Southwest Greenland 61°N, from 1987 translocation to 2017

Technical Report No. 100, 2024

Pinngortitaleriffik – Greenland Institute of Natural Resources

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Status muskoxen, Ivittuut, Southwest Greenland 61°N, from 1987 translocation to 2017

By

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Summary (English)
The muskox (*Ovibos moschatus*) population on the Ivittuut peninsula (ca. 61°N, 48°W, area 432 km^2) began in 1987 when 15 yearlings were translocated from the Maniitsoq population at Kangerlussuaq (Søndre Strømfjord) to the remote and optimal habitat of the Ivittuut peninsula. Initial population growth was unhindered given ample forage, no large predators, no hunting, and absence of large herbivore competitors. Natural mortality was low. The maximum observed age was a 25-year-old cow, which was one of the original 15 ear-tagged animals. Hunting, regulated by quotas and seasons, began in 1995. Initially, suggested goals for maximum population size ranged from 150 to 300 muskoxen. Counts over time illustrated that harvests were insufficient to prevent population growth beyond those goals.

The peninsula area is relatively small, thus the resources available (i.e. the vegetation) could rapidly become a limiting factor for population growth. Habitat could deteriorate if muskox abundance became too high. The counts illustrate that population size grew each year until 2009 and thereafter fluctuated, due to possible limitation of resources. In a population limited by resource availability, maximum growth rate, i.e. maximum proportional change in population size from one year to the next, typically occurs at about half of the potential carrying-capacity (i.e. muskox density at which the number of births equals deaths). The maximum population growth rate occurred from 2004 to 2005, when the population size reached 508. This suggests that the initial carrying-capacity for Ivittuut was twice the 508 muskoxen. This was possibly reached in 2009, when ca. 900 muskox were counted and gave a density of ca. 2.1 muskox/km^2.

Maximum population growth is also generally considered to coincide with maximum sustainable yield (MSY) for hunter harvests. Given 2005, a muskox population size of 400-500 with a density at ca. 1/km^2 may be optimal and sustainable for the Ivittuut peninsula habitat, albeit half of the peninsula is dominated by barren ground that is very sparsely vegetated. Since 2009, however, muskox densities have been 2-3 per km^2. Those high densities combined with the heavy herbivory observed in the 2015-2017 period and that now another large herbivore, feral reindeer, inhabits the region, suggests that damage to the vegetation has potentially reduced the resources available. This is supported by calf production values. Pre-2009 calf percentage was from 24% to 32%, but this changed. In 2016, the calf percentage was ca. 11% and coincided with what appears to be the beginning of a decline in population size. For future management strategies, a muskox density ≤ 1/km^2 for the entire peninsula is worth considering and might allow for a balance between vegetation regeneration, herbivory, and good body condition among muskoxen. Climate warming may create more plant biomass and increase

carrying-capacity, i.e. the muskox density that the Ivittuut peninsular can sustainably contain.

A reduction in muskox density might be achieved through careful management and supervision of the harvest. Since past harvests have been predominantly juveniles and bulls, changing just the annual quota will likely be insufficient action taken if a population crash has occurred since 2017. Further, even at a muskox density ≤ 1/km^2, natural fluctuations in population abundance may still occur and may be in response to factors beyond management control, e.g. catastrophic stochastic events, including extreme weather and pathogen outbreaks.

Counts cannot detect all muskoxen present, hence the name 'minimum' count. Owing to fewer undetected animals, multi-day counts are preferrable to rapid one-day counts. Undetected muskoxen could be 13% more than the number counted on the former and 16%-28% on the latter. We encourage these annual counts to continue, potentially augmented by demographic data collected from newer technologies, i.e. unmanned aerial vehicles. Strengthening the detail and accuracy of the demographic data would assist predictions of population trends.

Eqikkaaneq (kalaallisut)

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Resumé (dansk)

Moskusoksebestanden (*Ovibos moschatus*) på Ivittuut-halvøen (ca. 61°N, 48°V; areal 432 km^2) blev grundlagt i 1987, da 15-årige dyr blev flyttet fra Maniitsoq-bestanden ved Kangerlussuaq (Søndre Strømfjord) til det afsides og optimale habitat på Ivittuut-halvøen. Bestandsstilvækst var til at begynde med uhindret, da der var rigeligt foder, ingen store rovdyr, ingen jagt og ingen konkurrerende store planteædere. Den naturlige dødelighed var lav. Det ældste observerede individ er en 25-årig ko, som var et af de oprindelige 15 øremærkede dyr. Kvote- og sæsonreguleret jagt begyndte i 1995. Den oprindeligt foreslåede maksimale populationsstørrelse var mellem 150 og 300 moskusokser. Optællinger gennem årene viste, at jagten var utilstrækkelig til at forhindre bestandstilvækst ud over disse niveauer.

Halvøen er relativt lille, og derfor kan de tilgængelige ressourcer (dvs. vegetationen) hurtigt blive en begrænsende faktor for bestandstilvæksten. Habitatet kan forringes, hvis tætheden af moskusokser bliver for høj. Optællingerne viser, at bestandsstørrelsen steg hvert år frem til 2009, hvorefter den fluktuerede – muligvis på grund af ressourcebegrænsning. En dyrebestand, der begrænses af tilgængelige ressourcer, opnår typisk sin højeste vækstrate – dvs. den forholdsmæssigt maksimale størrelsesændring

fra det ene år til det næste – når bestanden er halvt så stor som den bestand, området potentielt kan bære. Den største tilvækst i Ivittuut-bestanden fandt sted fra 2004 til 2005, hvor bestandsstørrelsen nåede 508 individer. Området burde altså kunne bære en bestand på ca. det dobbelte af 508 moskusokser. Det niveau blev muligvis nået i 2009, hvor der blev talt ca. 900 moskusokser svarende til ca. 2,1 moskusokse/km^2.

Den maksimale bestandsvækst anses generelt for også at falde sammen med det maksimale bæredygtige jagtudbytte (**M**aximum **S**ustainable **Y**ield). I lyset af 2005-tællingen kan en moskusoksebestand på 400-500 individer med en tæthed på ca. 1 individ/km^2 være optimal og bæredygtig for Ivittuut-halvøen, selvom halvdelen af området domineres af et goldt, tyndt bevokset landskab. Siden 2009 har tætheden af moskusokser dog været 2-3 individer/km^2. Disse høje tætheder kombineret med den massive græsning, der blev observeret i perioden 2015-2017, og introduktionen af en anden stor planteæder, vildtlevende rensdyr, tyder på, at skader på vegetationen kan have reduceret de tilgængelige ressourcer. Dette understøttes af kalveproduktionen: Før 2009 var kalveprocent fra 24 til 32, men det ændrede sig. I 2016 var kalveprocenten ca. 11 og faldt sammen med, hvad der ser ud til at være begyndelsen på et fald i bestandsstørrelsen. I fremtidige forvaltningsstrategier er en moskusoksetæthed på ≤ 1 individ/km^2 på hele halvøen værd at overveje. Det kan give mulighed for en balance mellem græsning, regenerering af vegetationen og god fysisk tilstand hos moskusokserne. Opvarmning pga. klimaændringer kan tilvejebringe mere plantebiomasse og øge den moskusoksetæthed, som Ivittuut-halvøen kan bære.

En reduktion af moskusoksetætheden kan opnås ved omhyggelig forvaltning og overvågning af jagtudbyttet. Da der tidligere overvejende er blevet nedlagt ungdyr og tyre, vil en ændring af den årlige kvote sandsynligvis være utilstrækkelig, hvis bestanden er styrtdykket siden 2017. Selv ved en moskusoksetæthed på ≤ 1 individ/km^2 kan der forekomme naturlige udsving i bestandstætheden, som kan skyldes faktorer uden for forvaltningens kontrol, f.eks. tilfældige katastrofale hændelser som ekstremt vejr og sygdomsudbrud.

Optællinger kan ikke påvise alle tilstedeværende moskusokser, deraf betegnelsen ”minimumtælling”. På grund af færre uopdagede dyr er tællinger over flere dage at foretrække frem for hurtige endagstællinger. Uopdagede moskusokser kan udgøre 13 % mere end det observerede antal under en tælling over flere dage og 16-28 % mere for endagstællingers vedkommende. Grønlands Naturinstitut opfordrer til, at disse årlige tællinger fortsætter, eventuelt suppleret med demografiske data indsamlet med nyere teknologier som droner. En styrkelse af detaljegraden og nøjagtigheden af de demografiske data vil bidrage til forudsigelser af bestandsudviklingen.

Introduction

Greenland muskox populations

In Greenland, native muskoxen (*Ovibos moschatus* Zimmermann) occur only in the North and Northeast (Fig. 1), where no towns existed until 1925, when a single small coastal settlement was established, Ittoqqortoormiit, which today numbers ca. 350 inhabitants. As most of Greenland's human population have always resided on the south and southwest coasts of the country, historically muskoxen have not been central to Greenlandic hunting traditions and culture. Since the 1960's, however, there have been several muskox translocations to new ranges on the west coast of Greenland. Most resulted in now well-established muskox populations (Fig. 1). Currently, both native and translocated muskox populations are an important source of wild game. Further, over the past two decades, specifically the translocated populations have also provided economic opportunities for commercial/recreational hunters, as well as the trophy hunting and qiviut industries. Today, the Government of Greenland's Department of Fisheries & Hunting (APN) manages harvest where applicable, for 13 populations of muskoxen within the APN muskox harvest management regions (Table 1).

Table 1. Government of Greenland, Department of Fisheries & Hunting (APN) muskox management areas from north to south as per 2020, with population names, user communities, harvest area number & whether permitted.

Muskox harvest management area	Muskox population name	Primary communities utilizing population	Harvest area no.	Harvest
		Western Greenland		
Qaanaaq	Inglefield- & Prudhoe Land	Qaanaaq	-	Yes
	Cape Atholl		-	Yes
Uummannaq/Upernavik	Sigguk/Svartenhuk	Uummannaq/Upernavik	-	Yes
Naternaq	Naternaq/Lersletten	Diverse[1]	-	Yes
Sisimiut	Sisimiut	Sisimiut / Diverse[2]	-	Yes
Maniitsoq	Maniitsoq	All communities	1, 3, 4	Yes
			2	Yes / No
-	Nuuk	-	-	No
Ivittuut	Ivittuut	Ivittuut / Diverse[2]	-	Yes
Nanortalik	Nanortalik	Nanortalik	-	No
		North and Northeast Greenland		
Washington Land	Washington Land	Washington Land	-	No
National Park	National Park	National Park	-	No
Ittoqqortoormiit	Jameson- & Liverpool Land	Ittoqqortoormiit	-	Yes
	Inner Kangertittivaq / Scoresbysund Fjord		-	Yes

[1]Diverse includes Aasiaat, Qasigiannguit, Kangaatsiaq, Ilulissat and Qeqetarsuaq.
[2]Diverse includes Kangerlussuaq and Kangaatsiaq.
[3]Diverse includes Nuuk, Qeqertarsuatsiaat, Qaqortoq, Narsaq and Narsarssuaq.

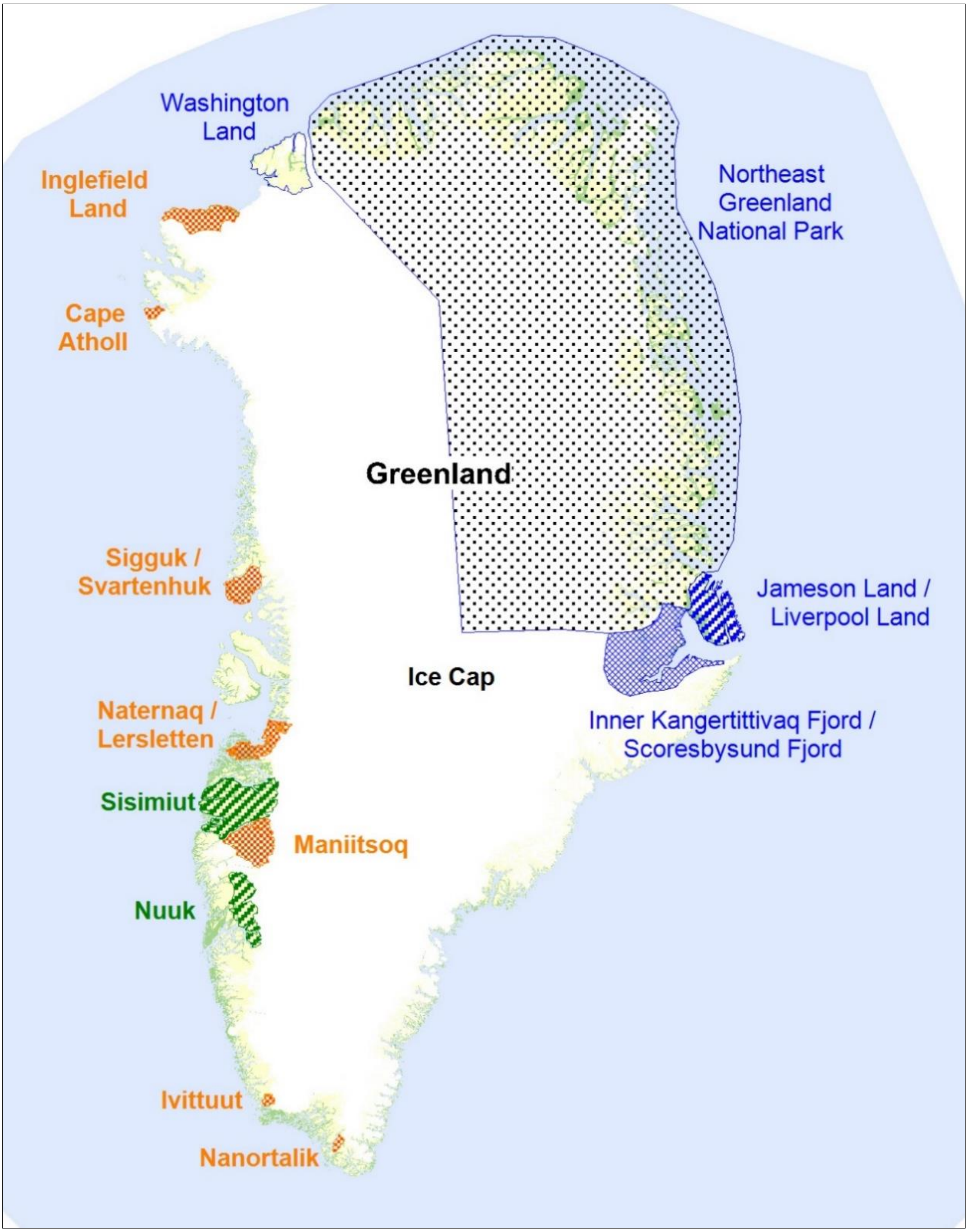

Figure 1. Muskox populations in Greenland. Native populations (blue) are in North and Northeast Greenland. The west has several translocated populations (orange) or those resulting from natural range expansion (green). Population borders are approximations and size does not reflect animal abundance. National Park in northeast Greenland is indicated with stippling. Currently, regulated harvest is permitted on most populations, with four exceptions where hunting prohibited: Washington Land, National Park, Nanortalik and Nuuk.

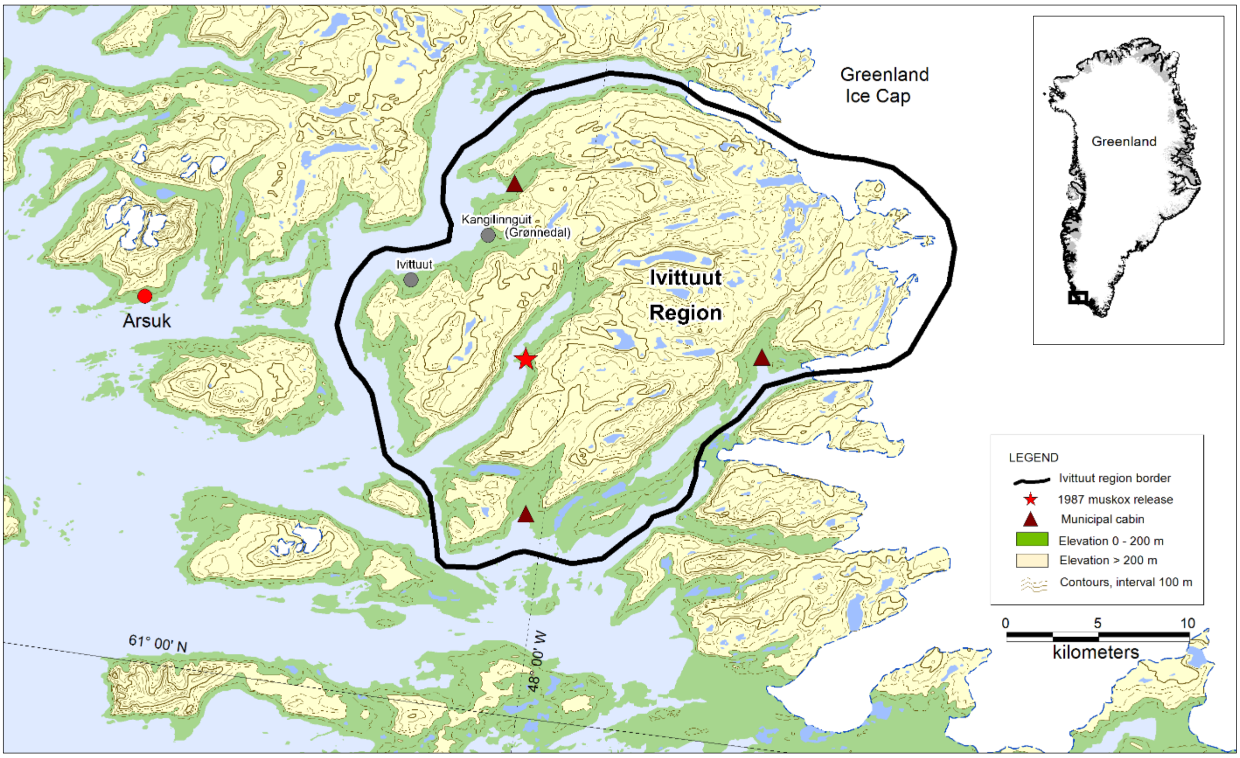

Figure 2. Map of the peninsula, which is the Ivittuut region, an area of 431 km² in southwest Greenland. 15 translocated muskoxen arrived in the summer of 1987. Elevations below 200 m comprise 95.3 km², those above 200 m elevation, 336.4 km².

Muskox translocation to Ivittuut

The Ivittuut peninsula (ca. 61°N, 48°W), located in the southwest of Greenland, is one of many sites for successful muskox translocation. Historically, Ivittuut was inhabited by native caribou (*Rangifer tarandus groenlandicus*). Greenlanders harvested caribou in the inner Arsuk Fjord from ca. 1860 to 1880 and shooting coverts attest to caribou hunting in prehistoric times. The caribou, however, extirpated in the Ivittuut area at the end of the 19th century (Winge 1902). Almost a century later, still lacking caribou, the Ivittuut municipality desired a large ungulate they could hunt. Further north up the west coast, a 1960's translocation of muskoxen to Kangerlussuaq (Søndre Strømfjord) (ca. 67°N, 51°W) had established the successful Maniitsoq muskox population (Cuyler et al. 2022).

To create a muskox population on the Ivittuut peninsula, in 1987, animals were taken from that Maniitsoq population. 15 yearling muskoxen (ten females and five males, born spring 1986) were live-captured 06 July, placed into transport crates and flown by Dash-7 to Narsarsuaq in southern Greenland. The following day, 07 July 1987, the muskoxen were translocated to the Ivittuut peninsula by S-61 helicopter (Fig. 2) (Ivittuut Kommune et al. 1996). All 15 juveniles received ear tags and were released on the east side of Snævringen, which is midway into Ikka Fjord (Figs. 2, 3). Details of their capture and release can be found in Clausen & Hansen (1987), Clausen et al. (1989) and to a lesser extent in Atuagagdliutit/Grønlandsposten (1987) and Ivittuut Kommune et al. (1996). The translocation of 15 muskoxen to the Ivittuut peninsula was the decision of the Ivittuut municipal council (Ivittuut Kommune et al. 1996) and the Ivittuut municipality financed the capture, transport, and release of the 15 yearlings. Following discussions in 1986 with the then Premier of Greenland, Jonathan Motzfeldt, the original plan was to establish a muskox farm (Atuagagdliutit/Grønlandsposten 1987). Nevertheless, the Home-Rule government of Greenland, Department for Industry (Erhvervsdirektoratet) vetoed the farm plan but permitted the translocation, if the goal was to establish a wild muskox population, which could provide hunting opportunities in the future.

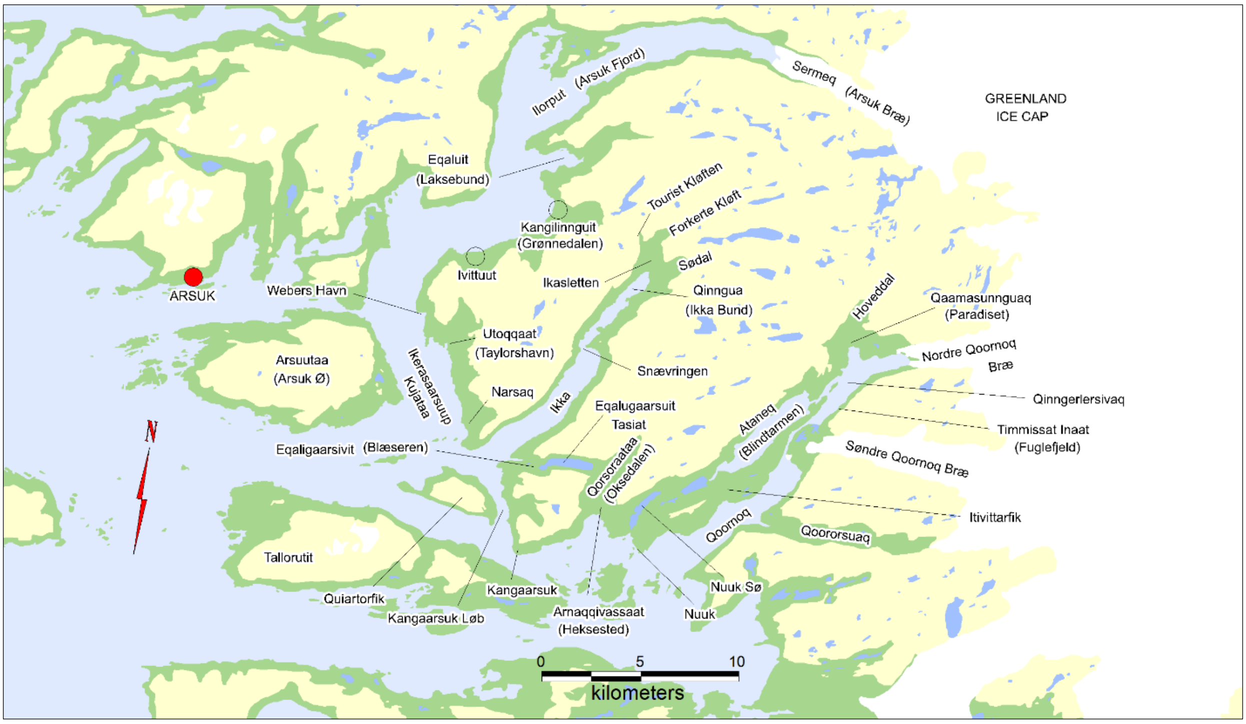

Figure 3. Common place names (unofficial & official) used in Ivittuut region (further names Appendix 1). Official names found here: https://www.arcgis.com/apps/View/index.html?appid=c5c7d9d52a264980a24911d7d33914b5

Ivittuut range before arrival of muskoxen

Prior to the 1987 release of the 15 yearling muskoxen, a vegetation map for the Ivittuut peninsula was prepared (Appendix 2) and provided an assessment of available range. Meanwhile, local consensus thought Ivittuut pasture quality was good because, whether wild or domestic, large mammalian herbivores, had not foraged that range for about a century. Although sheep farming is extensive in south Greenland, because high densities of sheep had already altered vegetation there, it had never been permitted within the neighboring Ivittuut municipality, (Ivittuut Kommune et al. 1996). The newspaper, Atuagagdliutit/Grønlandsposten (1987) described the Ivittuut summer pasture as lush, although there was concern about winter pastures since excessive snowfalls were common in winter. Resulting snow depths > 1m might prevent the muskoxen from accessing food resources in the Ivittuut region. Although the 1987 consensus was that lowlands were well vegetated, the results of the vegetation mapping illustrated lowland habitat was scarce. Just 95.3 km^2 (22%) of the Ivittuut range is below 200 m elevation (Fig. 2). Further, the 1987 map indicates that half of the 431 km^2 Ivittuut range is dominated by barren ground, which involves the region's highest elevations. Regardless of the 1987 designation that the barrens lacked vegetation, it is known that areas classified as barrens can be sparsely vegetated (Walker et al. 2005).

Muskoxen are characteristically sedentary and generally forage in low lying valleys and coastal areas (Nellemann & Reynolds 1997, Reynolds et al. 2002, Gustine et al. 2011, Nellemann 2011, Anderson & Fergusen 2016, Schmidt et al. 2016). Thus, not surprisingly, Ivittuut's "parent" Maniitsoq population, were known to remain in areas below 400 m elevation year-round (Olesen 1993). Optimal muskoxen habitat appears to be below 200 m elevation, with elevations below 100 m supporting the highest densities of muskoxen (Thomas et al. 1981). Given the vegetation mapping for Ivittuut, it appears just ca. 216.6 km^2 is vegetated, of which 40% is thinly vegetated. Meanwhile sparsely vegetated barrens make up the other ca. 216.6 km^2. Clearly, from the beginning, the Ivittuut range had its constraints regarding the number of muskoxen it could sustain.

Early population growth

In the beginning, given excellent range conditions in the lowlands, absence of large predators, lack of large herbivore competitors and a hunting prohibition for the first eight years, as expected the muskox population grew. Initially, muskoxen numbers were monitored ad hoc. In 1990, just three years after the introduction of 15 juveniles, the Ivittuut population had more than doubled. Two groups totaling 42 muskoxen were observed in the valleys about the naval base, Kangilinnguit (Skolemose, pers. comm. *In* Boertmann et al. 1992). This number was as expected, given the uncertainty in theoretical calculations for exponential population growth and mortality (Thing 1994). Similarly in 1995, although 136 was the expected population size, a minimum of 150 muskoxen were observed. Thus, the Ivittuut municipal council and Arsuk town council became concerned for the general sustainability of the natural resources on the Ivittuut peninsula (Ivittuut Kommune et al. 1996). At this time, Per Nukaaraq Hansen, Ivittuut hunting officer, Greenland Fisheries Licensing and Control (GFLK), noted that some juvenile 2-year-old cows produced calves. This suggests high reproduction supported by high forage quality, both of which have been documented in the early stages of other translocated muskox populations (Alendal 1971, Jingfors & Klein 1982, Olesen 1993, Olesen et al. 1994). On the advice of the Danish Polar Center regarding observed early population growth, the Ivittuut council decided that their muskox population should not exceed the 150 animals observed in 1995. Thus, hunting began in 1995 but only to remove selected animals deemed "unnecessary" for the future of the population (Ivittuut Kommune et al. 1996). Reported harvest from 1995 to 2000, suggests "unnecessary" animals were primarily juvenile and adult bulls and secondarily, juvenile cows. However, towards the end of the period, this became primarily juveniles of both sexes and secondarily adult bulls. (Note: Juvenile bulls require four years to mature, so this group includes animals of ≤ 1 age < 5 years. Juvenile cows require two years to mature, so this group includes animals of 1 ≤ age < 3 years.) The Ivittuut hunting officer oversaw and handpicked each animal harvested. During this period, many almost-known-by-name ear tagged muskoxen were observed still present in the population.

Despite Ivittuut municipality's desire that their muskox population remain under 150 animals, this was not achieved. The following years' annual muskox counts by Ivittuut hunting officer, indicated that abundance rose steadily (P.N. Hansen pers. comm.). In 2001, the Ivittuut municipality petitioned the Home-Rule central government to permit a population of up to 300 muskoxen, which was based on local opinion that vegetation was yet unchanged (Slettemark 2001). In late 2003, the Greenland Institute of Natural Resources (GINR) acknowledged that at 300 muskoxen, density would be high, relative to the area with vegetation cover, and might impact/alter existing vegetation landscapes (Cuyler 2003). To conserve existing resources, GINR recommended the population be stabilized at ≤ 300 muskoxen, achieved by harvesting 100-160 animals annually. Annual harvests, however, generally remained under 100 muskoxen for the next five years. Meanwhile, muskox sightings grew increasingly common throughout the Ivittuut region (Fig. 4).

Figure 4. Recently mature bull muskox (horns still have sharp black tips, thus age ≥ 5-years) looking in window of summer cottage, Ivittuut 2004. Photo Per Nukaaraq Hansen.

Harvest

The Ivittuut municipality had a trial harvest of one bull in 1991, then two bulls in 1992 and three in 1994, but it was first in 1995, that regulated hunter harvests began (Appendix 3). Concurrently, three Arsuk commercial hunters were trained in the trophy hunting industry and began guiding foreign hunters for trophy bull harvest. Initially, annual quotas were conservative (Fig. 5). In the 2006-2010 period, annual harvest quotas of at least 200 animals were recommended (Chemnitz 2014), and quotas rose rapidly from 2005 to 2010. Until at least 2010, trophy hunts were supervised by the Ivittuut hunting officer. Regardless of the year, according to the reported harvest, quotas were seldom filled (Fig. 5). This difference between permitted harvest quota and reported number killed became more pronounced after 2005. This was not because muskoxen were few. For specifically the 2006-2010 period, Ivittuut was described as having muskoxen everywhere and ca. 200 calves were born annually (P.N. Hansen pers. comm.).

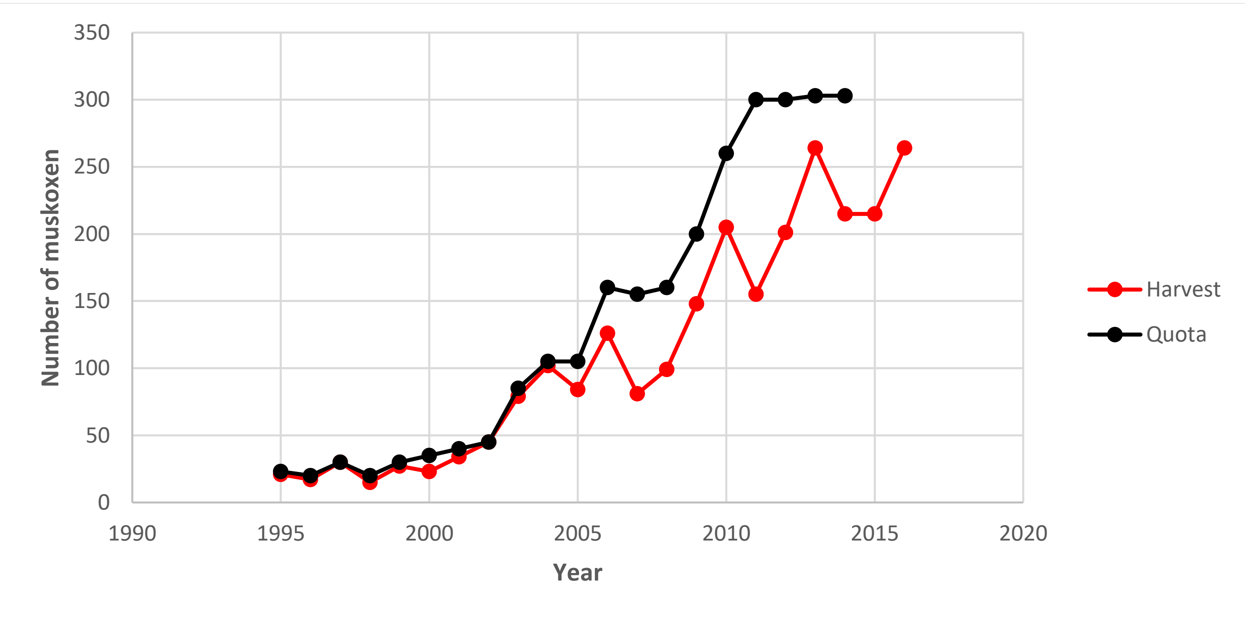

Figure 5. Ivittuut annual quotas and reported number of muskoxen harvested in the 1995-2016 period, which includes all legal and the known illegal harvest and muskoxen that died after crippling by hunters.

From 1991 to 2016, a total of 2,441 muskoxen were legally harvested (Appendix 3). This illustrates the importance of the Ivittuut muskox population for meat security in the Arsuk community. Further, this population has been a valuable source of income, through commercial sale of meat, and the lucrative trophy bull and qiviut industries. Meanwhile, whether hunters were locals from Arsuk or from outside the Ivittuut region, harvests were bull-biased and predominantly juveniles (Figs. 6, 7, details Appendix 3).

Juvenile bulls require twice as many years to mature than juvenile cows, i.e. four years compared to two years, respectively. Thus, in Figures 6 and 7, the sum of juvenile bulls includes two more years. Similarly for adult cows and bulls, only here it is the cows that include two more years. To avoid misinterpretation, remember that the number of years summed over in each category (except calf) differs.

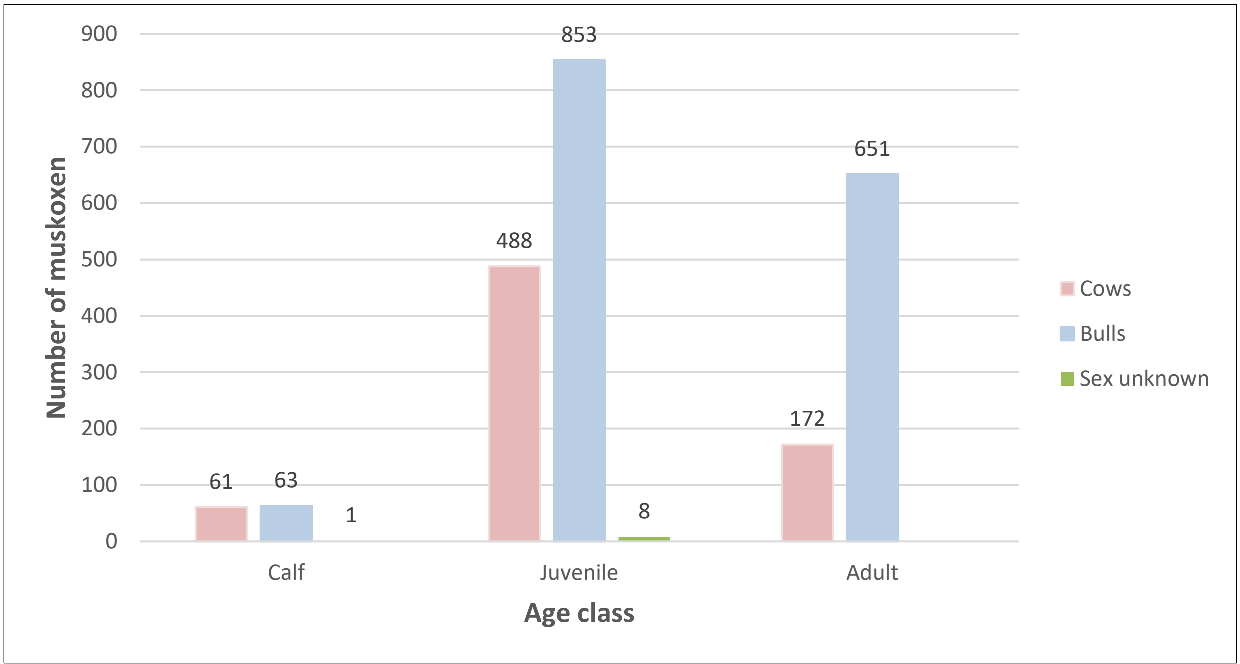

Figure 6. Total number of muskoxen harvested legally on the Ivittuut peninsula from 1991 to 2016. Age classes are given in years; calf age < 1, juvenile cow 1 ≤ age < 3, juvenile bull 1 ≤ age < 5, adult cow age ≥ 3, adult bull ≥ 5. Note: excepting 'calf', the number of years summed over for each age class differs.

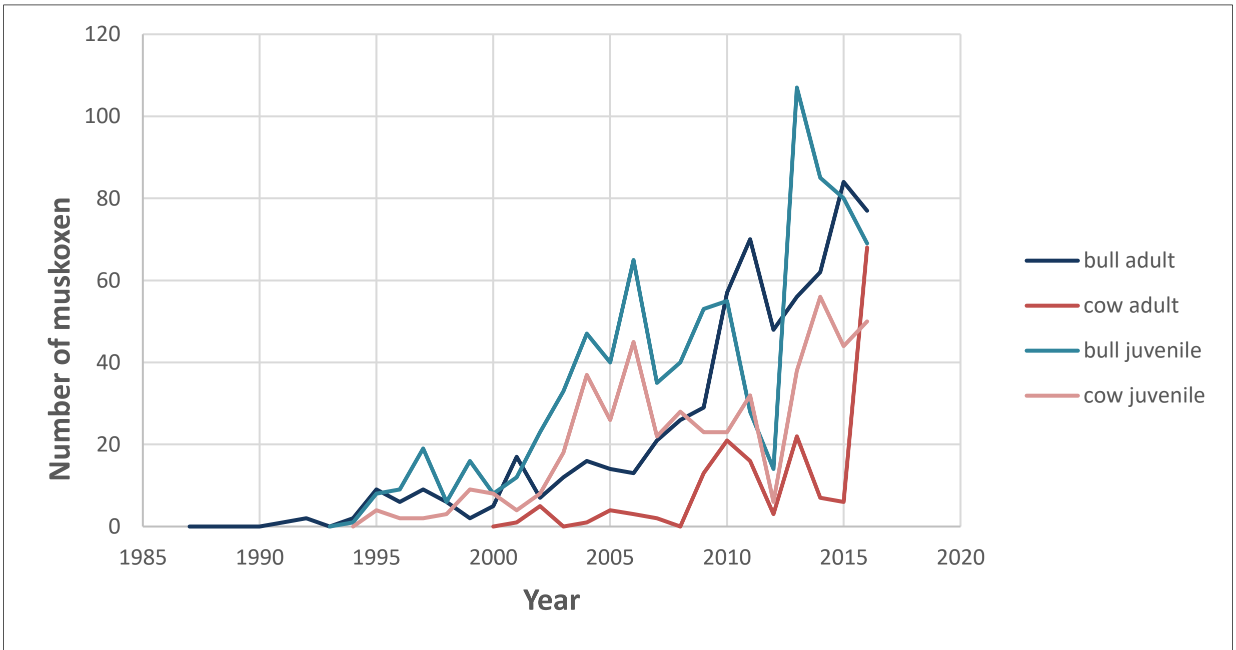

Figure 7. Reported harvest of muskoxen on the Ivittuut peninsula from 1991 to 2016. The minimal harvest of calves and animals of unknown sex is not included. Age classes are given in years; adult bull age ≥ 5, adult cow age ≥ 3, juvenile bull 1 ≤ age < 5, juvenile cow 1 ≤ age < 3. Note: excepting 'calf', the number of years summed over for each age class differs.

Present study
This report presents the status of the muskox population in the Ivittuut region from translocation of 15 yearlings in summer of 1987 through to June 2017. Principally, the report covers annual minimum counts of muskoxen present in the region and calf production. Focus is on the minimum counts of 2015, 2016, and 2017, which for the first time included detailed demographics. Secondarily, we provide a summary of the ad hoc observations of mortality/longevity, reproduction, changing vegetation landscape, and range expansion by muskoxen and semi-domestic reindeer. There follows a discussion of possible muskox population sizes/densities for the Ivittuut region. Topics also covered include the reliability of muskox counts and the risk of stochastic events.

Methods

Study area
The Ivittuut region is a peninsula with a land area of approximately 432 km^2, which excludes ice and lakes (an area of ca. 19 km^2). Elevations from 0 to 200 m cover 95 km^2 of the Ivittuut area. The remaining area, 336 km^2, is above 200 m elevation. Specifically, elevations between 200 and 700 m cover 270 km^2, while elevations above 700 m cover 66 km^2 (Appendix 1). The highest point is 1015 m elevation. The topography of the 432 km^2 peninsula is highly varied, which provides diverse habitat conditions.

The Ivittuut region was mapped for vegetation in 1987 (Appendix 2). At that time, just 216.7 km^2 possessed vegetation cover, which were divided into seven vegetation categories: shrub heath (41.8 km^2 (19,3%)), shrub/moss/lichen heaths (50 km^2 (23.1%)), shrub/grasses/forbs (succulents)/sedge heaths (12.2 km^2 (5,6%)), scrub forest (3.5 km^2 (1.6%)), scrub forest with shrub heath (12.8 km^2 (5.9%)), lichen and moss heaths (8.4 km^2 (3.9%)), and the largest category, thinly vegetated mountains (87.4 km^2 (40.3%)). The area designated in 1987 as having no vegetation was 215 km^2, which is half the entire peninsula. Barrens, however, can be sparsely vegetated (Walker et al. 2005). Whatever sparse forage is present, given the barrens are all above 200 m elevation, forage quality may be poor.

The peninsula is bounded to the west and north by the Ikerasaarsuup Kujataa [Strait] and Ilorput (Arsuk) Fjord, with the latter ending at the Greenland Ice Cap's Sermeq (Arsuk) glacial tongue (Fig. 3). To the south is the Kangaarsuk Løb [Strait], and to the east is the Greenland Ice Cap and the Qoornoq fjord, which after the 'narrows' becomes Qinngerlersivaq, which ends at the Greenland Ice Cap with the Nordre Qoornoq Bræ glacial tongue. In winter, the outer coasts remain ice-free open water, however, the inner fjords are usually ice covered from November to May (Buchardt et al. 2001). In summer, icebergs are common in the fjords and straits. Many arise from the Sermeq (Arsuk) glacial tongue of the Greenland Ice Cap. Others, often larger, arrive with the East Greenland Current, which bends around the southern tip of Greenland and continues northward up the west coast passing Ivittuut (Buchardt et al. 2001).

Climate on the Ivittuut peninsula is low arctic and relative to most of Greenland is mild (Fristrup 1971). Mean summer (June, July, August) temperature is ca. 8°C, and mean winter (December, January, February) is ca. -1°C, while summer highs average ca. 12°C and winter lows average -10°C. Annual precipitation is 1000–1200 mm.

Currently, there are no permanent human habitations on the Ivittuut peninsula. The nearest settlement is the small village, Arsuk (population < 80), which is located about 14 km west of the Ivittuut peninsula. A Danish naval base, Kangilinnguit (Grønnedal), decommissioned in 2012, is located on the northwestern shore of the Ivittuut peninsula, and while uninhabited in 2017 all infrastructure remained. Immediately southwest of Kangilinnguit is the abandoned community, Ivittuut, which mined cryolite from 1854 until 1987. Today, some homes are still used as summer cottages. Further, there are at least three coastal cabins, which are maintained and managed by the local Arsuk Council. For a small fee, these may be rented and used as a base for diverse activities, e.g. hunting, fishing, hiking, qiviut collection and counting muskoxen. Beyond the roads inside Kangilinnguit and Ivittuut and those few within their immediate vicinity and between them, no roads exist on the Ivittuut peninsula. Transportation possibilities are limited to boats, hiking, and in winter, snowmobiles. Permission must be obtained for the latter. There are no nearby airports, so air access is limited to helicopters and seaplanes.

Aside from the now established translocated population of muskoxen, native wild mammals present in the Ivittuut region are the arctic hare (*Lepus arcticus* Rhoads) and arctic fox (*Vulpes lagopus* Linnaeus). Recently, feral semi-domestic reindeer (*Rangifer tarandus tarandus*) have expanded into the region, from the Isortoq reindeer husbandry district, which is neighboring area immediately south. As with the rest of the southwest coast, large mammalian predators are absent.

Ikaite Tufa Towers

Although not relevant to the terrestrial habitat, it is worth noting that the Ivittuut region contains the only known marine environment in the world where the rare carbonate mineral "Ikaite" forms submarine Ikkaitter (Ikaite Tufa Towers), whose large columns sometimes reach 18 m tall (Buchardt et al. 2001). These occur only in the Ikka/Qinngua Fjord, and a submarine reserve has been designated. Prohibitions to prevent damage to the Ikkaitter include not sailing over top of them with boats whose hull or motor reaches more than 1.30 m deep, (setting fishing nets or taking "souvenirs" is also prohibited). For hunters using the typical open outboard motorboats, the submarine reserve is not a barrier to accessing the inner Ikka Fjord and the Ikasletten.

Field methods

Muskox counts from 1998 to 2014

To provide an index of muskox abundance, in 1998, annual minimum counts began. These were completed by Ivittuut hunting officer, Per Nukaaraq Hansen, Greenland Fisheries Licensing and Control (GFLK). Most counts occurred in June or the autumn months of September and October. Winter counts were seldom.

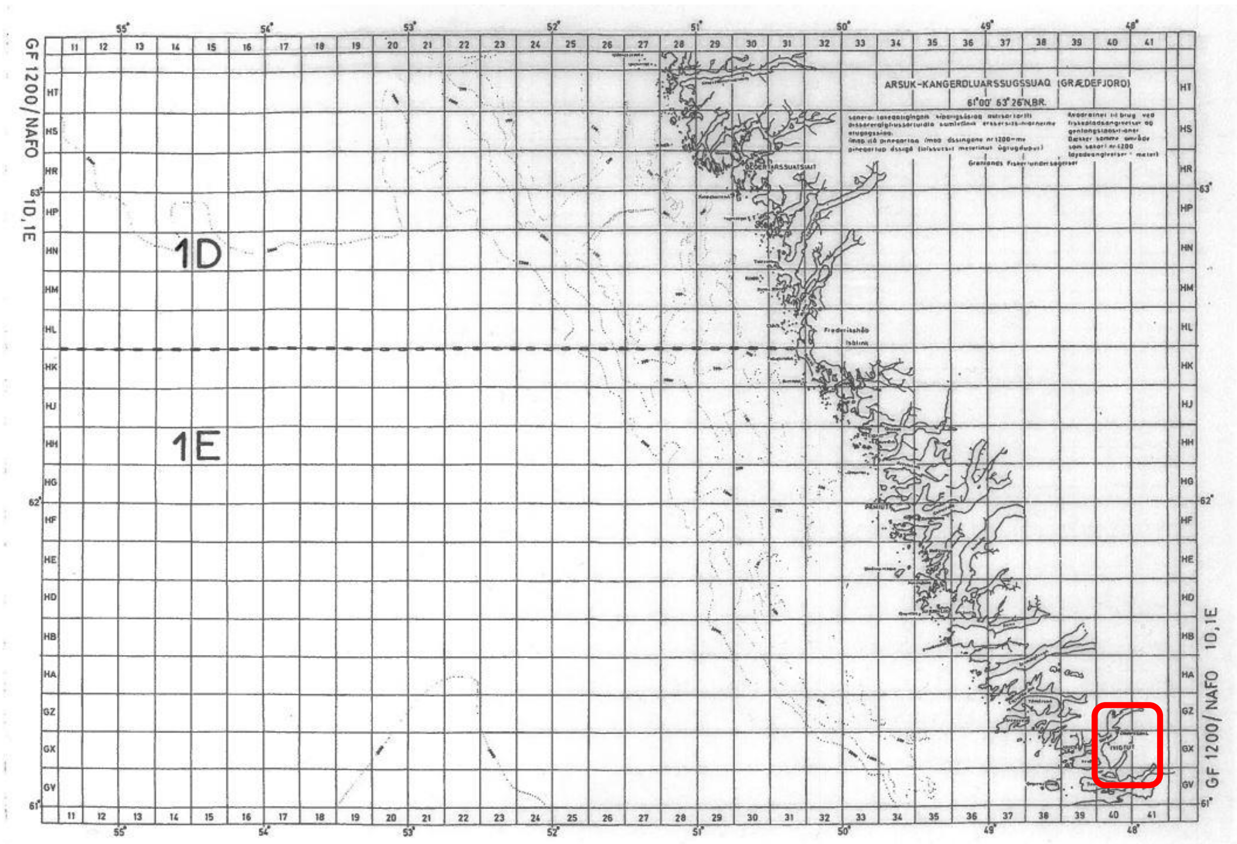

Figure 8. Marine grid map sometimes used to provide location information for muskox observations in the 1987 to 2014 period. Portions of the Ivittuut region (rounded red rectangle in lower right) occur in only six of the grid cells.

Detecting muskoxen was aided by binoculars (8x magnification). These early muskox counts did not always provide an observation location. When they did, observations were summarized for each location examined, i.e. as the total number of muskoxen observed in the vicinity of a place name location and a general Geographical Positioning System (GPS) coordinate, e.g. Laksebunden (61°15.62′N; 48°04.01′W), Taylershavn (61°09.98′N; 48°10.40′W), Paradiset (61°09.20′N; 47°50.85′W), Blindtarm (61°08.29′N;

47°52.17′W), Blindtarm west (61°07.36′N; 47°55.57′W), Itivittarfik (61°07.01′N; 47°54.00′W), Oksedalen (61°08.11′N; 47°48.42′W), Heksestedet (61°61.06′N; 48°10.40′W), Quassuk (61°05.10′N; 47°56.04′W) and Ikka (61°12.78′N; 47°59.16′W). Occasionally, until 2014, muskox location was designated using a marine grid cell map (Fig. 8). This map's large cell size provided scant information about muskox distribution on the peninsula. Fortunately, the latter was seldom used and the primary manner to designate location remained place names.

Figure 9. A mature cow at the Arsuk fjord shore observed from open outboard boat, 4 June 2015. Photo C. Cuyler.

Cruising slowly in open outboard boats alongside the entire Ivittuut coastline was standard procedure for counts, as the steeply rising coastal terrain made spotting muskoxen possible (Fig. 9). Inland areas were covered on foot by hiking into principal valleys (Fig. 10). High elevation points were often used as lookout vantage points. Which areas were covered varied among years, usually owing to poor weather or snow on the ground (Table 2). Winter (January-March) counts involved snowmobiles. The occasional one-day summer counts were accomplished by just cruising the coastline.

The 1998-2014 demographics collected were simple. There were the four basic categories, i.e. calves, cows, bulls, and unknowns. The latter occurred when sex and age of animals older than calves could not be determined. This was usually caused by too great a distance between muskoxen and observer using binoculars. Calves were not sexed. There were no age classes for cows. Bulls, however, were further sub-divided into three age classes, i.e. age 2-3 years, 4-5 years and those ≥ 6-years. Horn development, shape and size were the deciding criteria for determining sex and aging (Olesen & Thing 1989).

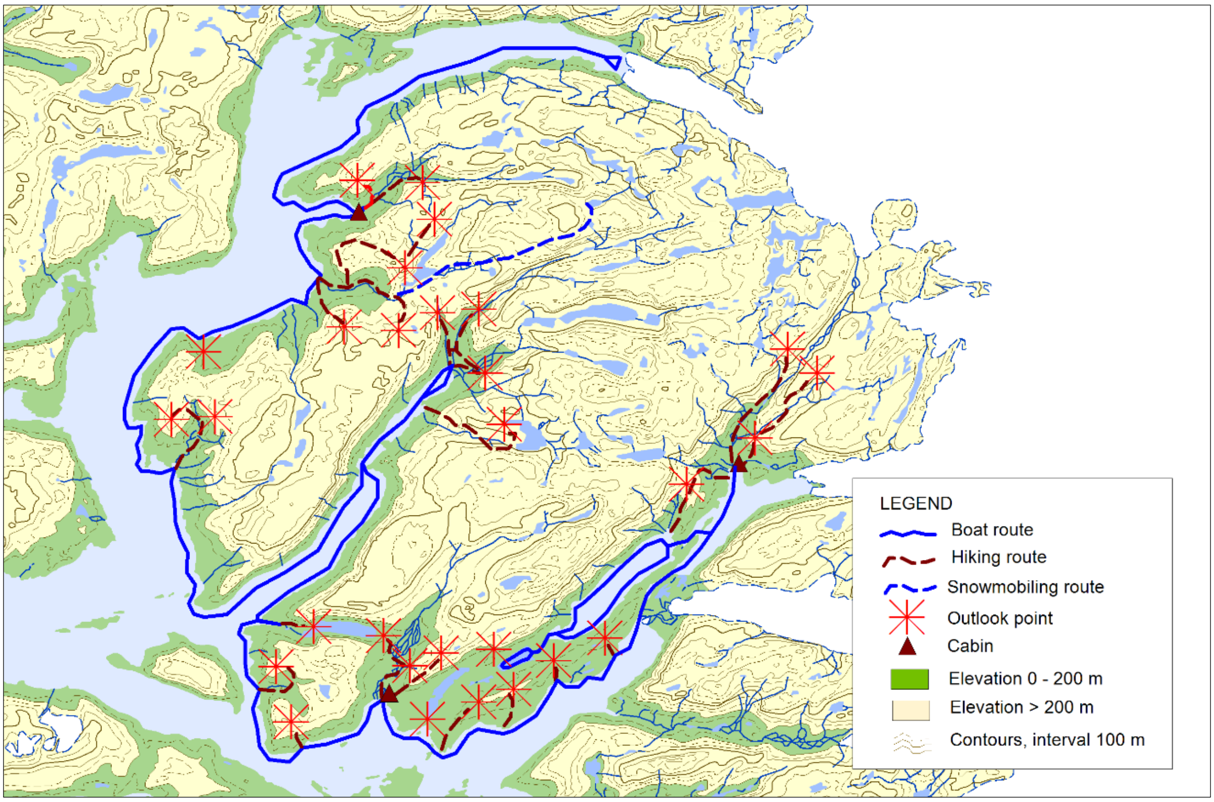

Figure 10. Overview of routes used for the 1998-2014 minimum counts of muskoxen in the Ivittuut region.

Muskox counts from 2015 to 2017

Annual monitoring from 2015 to 2017 of muskox number, including calf number, involved several members of the Arsuk Resource Management Council, led by the Ivittuut hunting officer, Per Nukaaraq Hansen (GFLK) and collaborating with research scientist, Dr. Christine Cuyler (Greenland Institute of Natural Resources (GINR)). Morten Lyberth, also with GFLK, participated on all three counts. Participating Arsuk Council members brought local expert ecological knowledge to the annual muskox minimum counts and received training in demographics data (sex, age) collection. Routes used were like earlier counts and used open outboard motorboats to cruise the entire coastline, while principal valleys were surveyed on-foot. Once again, routes hiked on-foot varied among years (Table 2).

Since animal movement may occur, we made the following preventive efforts to avoid counting animals twice. There was rapid (relative to normal muskox movement) terrain coverage over few days, weather permitting. Terrain features limiting animal movement were used to delimit an area to survey on a specific day. When possible, adjacent areas were surveyed on consecutive days. Muskoxen are seldom frightened by a motorboat sailing past. When hiking, however, muskoxen often fled the approaching observers, running farther into a valley where they mixed with other groups. Therefore, to avoid double counting when hiking, the count and demographics did not begin until the furthest destination inside a valley was reached. Then, counting began and continued until return to the boats/coastline. Similarly, to avoid double counting, a coast/fjord area was only begun if it was possible to finish the entire length of shore within a few hours on the same day. Finally, if doubt existed of possible double counting a muskox group, then it was not counted. Also noted were the location and number of observed feral semi-domestic reindeer, arctic hare, arctic fox, white-tailed eagle (*Haliaeetus albicilla*), falcon (*Falco* unspecified), seals (unspecified), common eider (*Somateria mollissima*) and harlequin (*Histrionicus histrionicus*) ducks.

Unlike earlier counts, the 2015, 2016 and 2017 counts collected demographics on each muskox group observed and that information increased in detail over the three-year period. Binoculars (10x magnification, Leica) and/or a spotting scope (32x-60x magnification, Leica) were used to determine sex and age of detected animals. Observations of groups of muskoxen were assigned a date and a grid map cell location (Fig. 11). We recorded the number of groups seen, the approximate elevation, the total number of animals in each group, and when circumstances permitted, detailed sex and age of individuals within a group (Appendix 4).

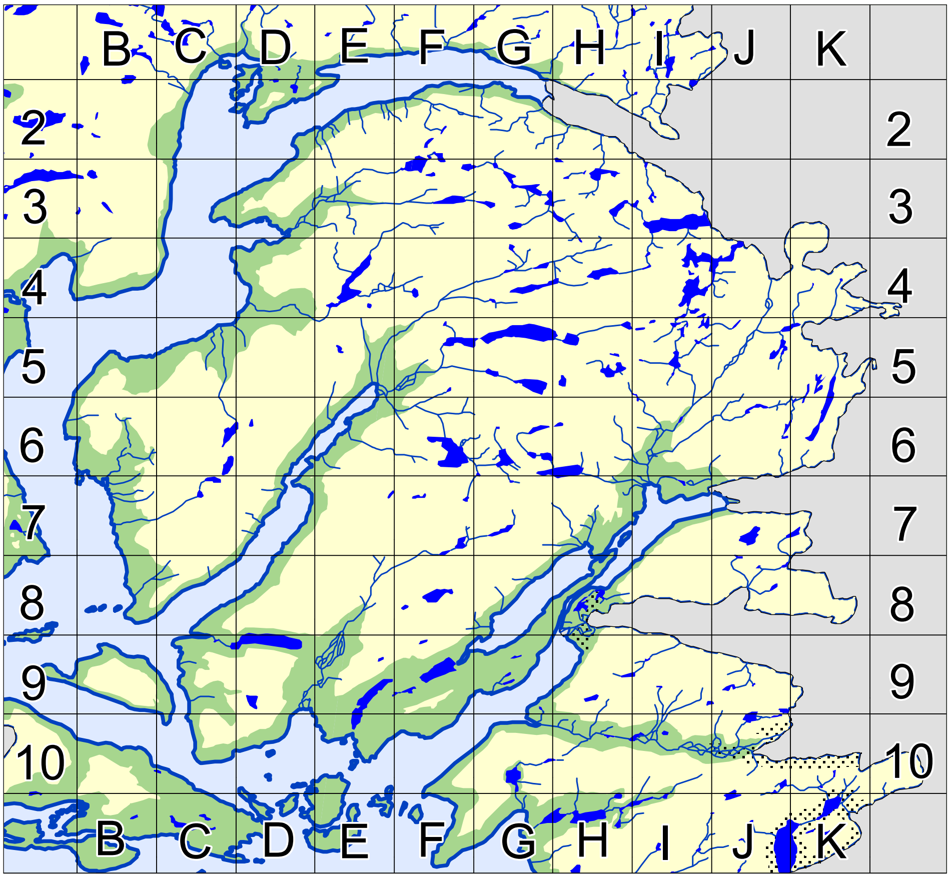

Figure 11. Grid map with 3x3 km cells used to provide location information for each muskox observation in the 2015, 2016, and 2017 counts.

Table 2. Record of variation of inland areas covered by Ivittuut muskox counts. Excepting Blindtarmen, the inland areas were done by hiking on-foot. Outer coastlines are not included, as cruised past in all counts. Data were not available about areas covered before 2001 and for 2003, 2004, 2006, 2009, and 2010.

Location	2001	2002	2005	2007	2008	2011	2012	2013	2014	2015	2016	2017
Arsuk Fj/Bræ											x	
Laksebunden	x	x	x	x	x	x		x	x	x	x	x
Grønnedalen		x	x	x	x	x	x	x	x	x	x	x
Ivittuut							x	x	x	x	x	x
Taylershavn	x	x		x	x		x	x	x	x	x	x
Turistkløften			x		x	x		x		x		
Forkertekløft					x	x		x		x		
Sødalen					x	x		x	x	x	x	x
Blæseren		x	x	x	x	x	x	x		x	x	x
Qaqqatsiat		x						x				
Heksested	x	x	x	x	x	x	x	x	x	x	x	x
Oksedalen	x	x	x	x	x	x		x	x	x	x	x
Nuuk		x		x	x	x	x		x	x	x	x
Quassuk	x	x	x		x	x			x	x	x	x
Itivittarfik	x	x		x	x			x	x			x
Blindtarmen	x		x		x	x	x		x	x	x	x
Paradisdalen	x	x	x	x	x	x	x	x	x	x	x	x
Hoveddalen		x	x	x	x	x	x		x	x	x	x
Nordre Q. Bræ			x		x			x		x	x	x
Kuuki										x		
Laksfjeldet[2]					x	x		x				
Hesteskosøen					x							
Qoororsuaq[3]											x	x

[2] Laksefjeldet mountain (elevation 1091m) north of Laksefjeldsøer (Appendix 1: Fig. 36), reached by snowmobile.

[3] This valley is outside, and southeast of, the Ivittuut region.

Age categories and sex were determined by horn development, shape, and size (Olesen & Thing 1989, Holst 1990, Appendix 5). Exact animal ageing (years) was either by animal's possession of ear tag issued at translocation (1987) and for some instances of natural mortality when mandibles were available, using cementum age of extracted incisor teeth (Reimers & Nordby, 1968). Body size was used to place animals of unknown sex into age categories (calf, 1-year, 2-years, and adults ≥ 3-years) since calves were small, yearlings were ca. twice calf size, and 2-year-olds were half adult size (Fig. 12, see also *Muskox sex and age field guide* in Appendix 5).

Figure 12. Mature adult cow (age ≥ 3 years) with her calf-at-heel (age 1-2 months). Photo C. Cuyler

As in earlier counts, the herd structure for 2015-2017 counts contained four basic categories; calves (not sexed), cows, bulls, and animals of unknown sex and age (≥ 1-year). Unlike earlier counts, cows were further sub-divided into three age classes, 1-year-old, 2-year-old, and adult (age ≥ 3-years). Also, bulls were sub-divided into six age classes, 1, 2, 3, 4, 5-9 and ≥ 10-years-old.

Results

Counts from 1998 to 2014 often took three to six days to complete. Summer counts were most often in 01-15 June period, and autumn counts in 01-15 September period. Month for annual count varied, with some years receiving more than one count, i.e. 2009, 2011, 2012, 2013 and 2016 (Table 3).

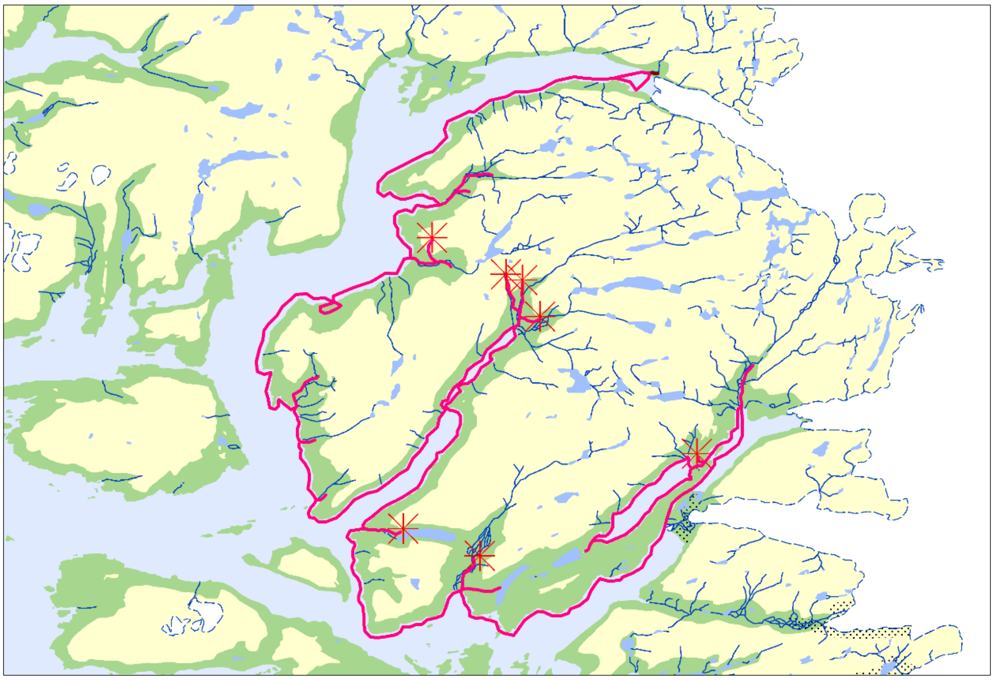

Figure 13. Boat and hiking routes taken, plus lookout points (✳), June 2015 muskox count of Ivittuut region.

The three counts from 2015 to 2017 were always in the late spring/early summer. The 2015 count was from 04 to 12 June, the 2016 count from 23 June until 02 July, and 2017 count from 08 to 13 June (Table 4). Although in those periods, Ivittuut fjords are typically ice-free. In 2015, Blindtarm was ice covered and it was several days before passable. Similarly, the bottom of Ikka fjord was ice covered in 2015. Passage required using a Nuumit-19 boat with a double reinforced hull and a 150 HP (horsepower) outboard motor. Cruising the entire coastline by boat was possible in all three years, albeit gale force winds often created difficult sailing conditions. Due to environmental conditions, inland areas received little effort and coverage varied over the years (Figs. 13, 14, 15).

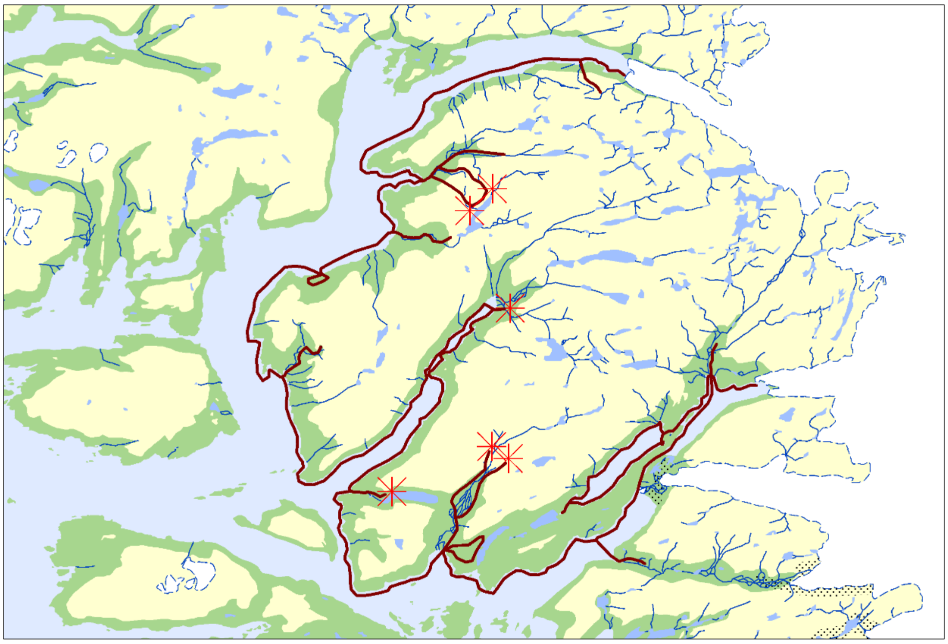

Figure 14. Boat and hiking routes taken, plus lookout points (✳), in June 2016 muskox count of Ivittuut region.

Figure 15. Boat and hiking routes taken, plus lookout points (✳), in June 2017 muskox count of Ivittuut region.

In 2015, 2017 and 2017, each muskox group observed was assigned to a grid cell (Fig. 11). Thus, total muskoxen observed inside each grid cell location was possible and provided the basis for distribution maps for those three years (Figs. 16, 17, 18). The distribution maps provide an index for muskox density but only for the grid cells covered by the count effort. In 2015, the maximum number of muskoxen in one grid cell was 140 animals for a density of 15.6/km^2. This occurred in grid cell I6. Two other grid cells, E5 and E6, had 126 and 128 muskoxen respectively, for a density of ca. 14/km^2.

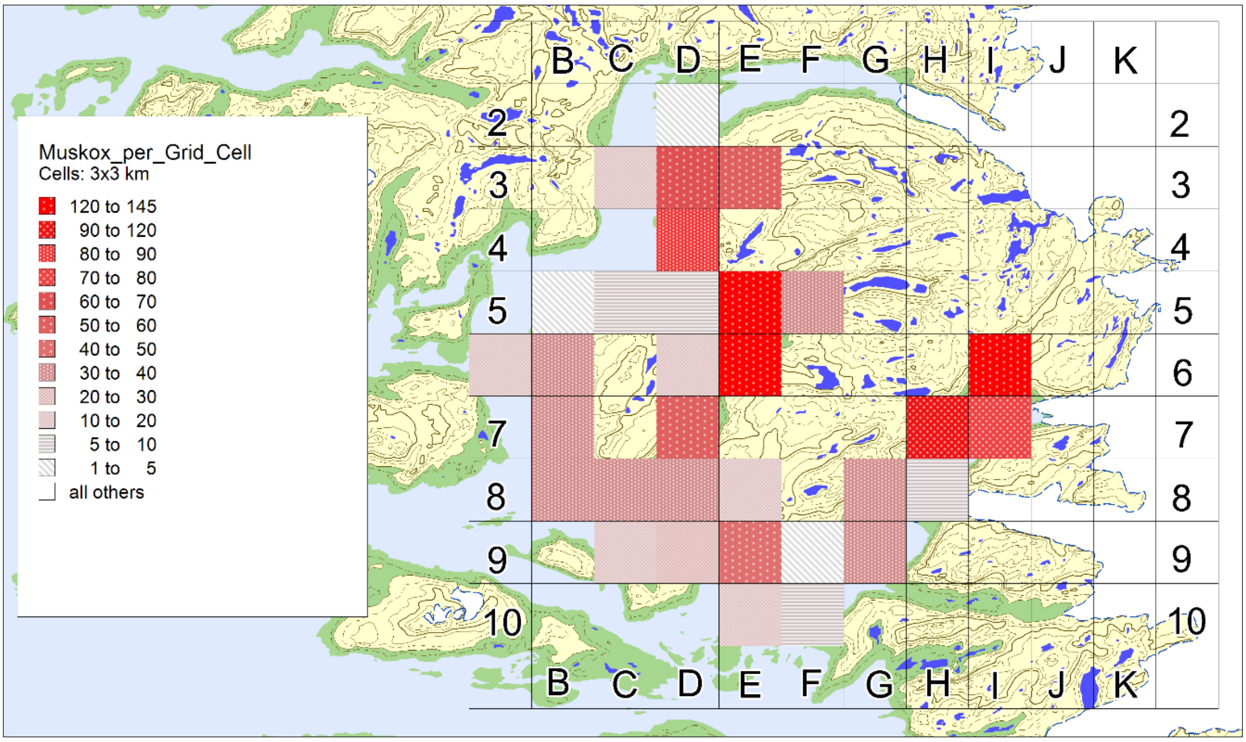

Figure 16. 2015 muskox distribution within the grid cells (3x3 km) covered by count effort.

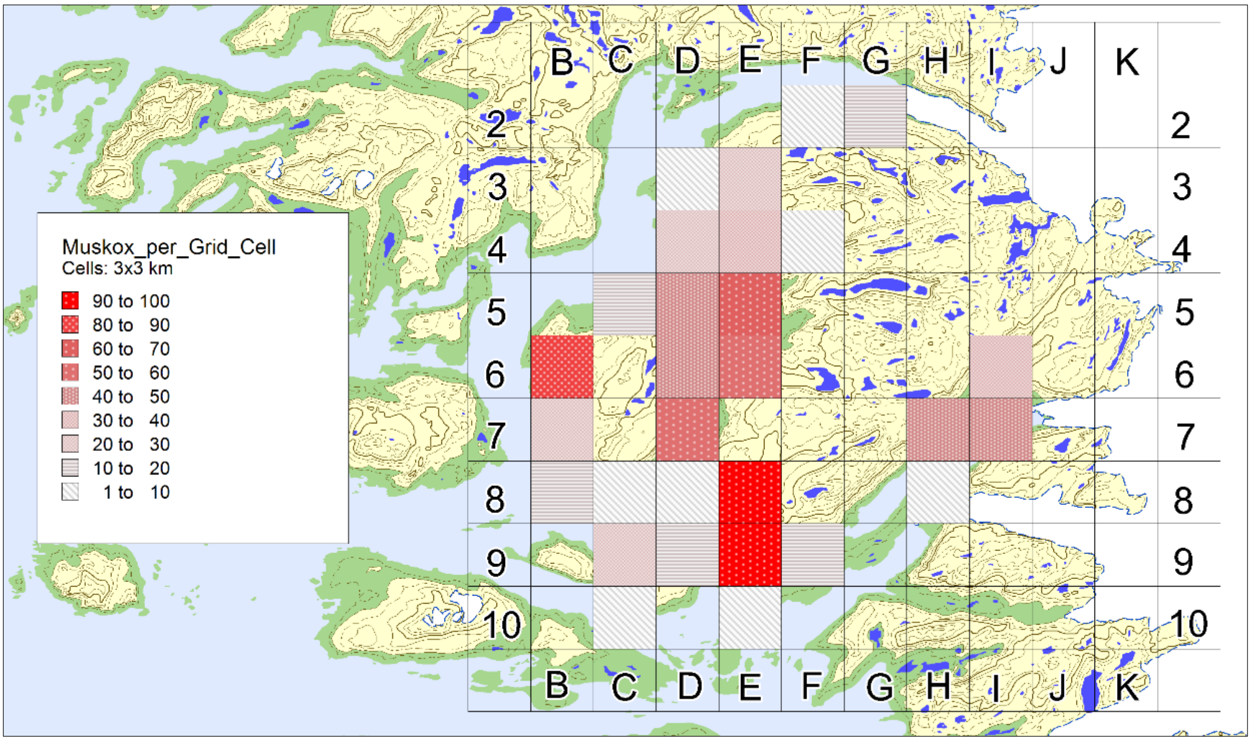

Figure 17. 2016 muskox distribution within the grid cells (3x3 km) covered by count effort.

In 2016, overall fewer muskoxen were observed, and the maximum number in one grid cell dropped to just 95 animals for a density of 10.6/km². (i.e. in grid cell E8). A neighboring cell (E9) had 91 muskoxen and density of 10.1/km² (Fig. 17).

In 2017, the maximum number of muskoxen in one grid cell dropped yet again, this time to 85 animals and a density of 9.4 /km² (i.e. in grid cell E5) (Fig. 18).

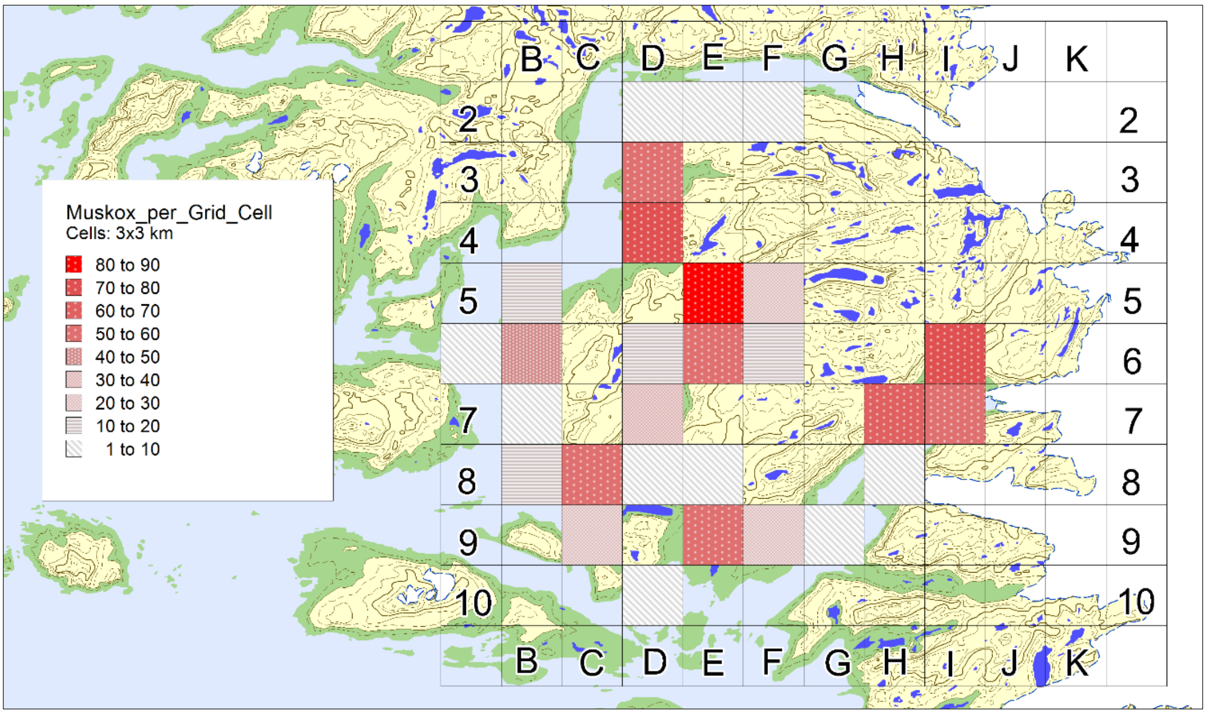

Figure 18. 2017 muskox distribution within the grid cells (3x3 km) covered by count effort.

Muskox distribution varied and density decreased over the 2015-2017 period. In 2015, the highest concentrations of muskoxen were in three areas, Paradiset (cells I6, I7, H7), Ikasletten plus the Ikka/Qinngua fjord (cells E5, E6, D7), and the Lakseelv/Grønnedal area (D3, D4, E3) (see appendix 1 for place names). In 2016, there were fewer muskoxen, and the highest concentration was in Heksested/Oksedalen valley (E8, E9). Meanwhile, the three areas of high muskox density the previous year, 2015, were conspicuous for relatively low numbers in 2016. In 2017, the highest concentration of muskoxen was in Ikasletten (E5) and there were several further cells of relatively high densities.

An index of trend and change in population size and calf number are provided in Table 3 and Figure 19. The muskox counts invariably had a high proportion of unknown animals, of which many could be cows. Thus, table 3 does not include a column for calf recruitment (number of calves per 100 cows). Counts from 2015 to 2017 provided detailed demographics for that period (Table 4, 5). The proportion of unknown animals was less for the 2015-2017 counts but remained a substantial portion of the total number of muskoxen observed.

Table 3. Minimum counts, densities, and rough demographics for muskoxen in the Ivittuut region, 1987 - 2017.

Year	Season / Month	Date	Density[a] per km²	Count	Unknown	Bull		Cow	Calf	Calf %	Bull/Cow Ratio
					Age						
					≥ 1 year	≥ 5-years	3-4 years	≥ 3 years	< 7 months		
1987	Summer		0.0	**15**							
1988	September	18	0.0	**15**							
1990	Summer		0.1	**42**							
1995			0.3	**150**							
1998	Summer/Fall		0.4	**182**	35	15	20	70	42	23.6	0,21
1999	March-May		0.5	**227**					53		
2001	October	10 - 18	0.7	**287**	47	20	45	99	76	26.5	0,20
2002	June	12 - 14	0.8	**341**	229	25			87	25.5	
2003	December		0.9	**373**	266				107	28.7	
2004	July		0.8	**335**							
2005	September	28 - 30	1.2	**508**	341	33			134	26.4	
2006	October	22	1.3	**551**	329	48			174	31.6	
2007	September	10 - 14	1.6	**677**	149	60		288	180	26.6	0,21
2008	September	4 - 7	1.8	**796**	526	65			205	25.7	
2009	September	21 - 25	2.1	**894**	581	85			228	25.5	
2009	December		2.0	**851**							
2010	October	4 - 7	1.7	**748**	163	67		307	211	28.2	0,22
2011	June	22 - 24	1.9	**805**	116	101		372	216	26.8	0,27
2012	April	15	1.6	**581**[b]	519	62					
2012	October	2,4,5	2.1	**897**	258	58		360	221	24.6	0,16
2013	June	26	1.7	**736**	487	82			167	22.7	
2013	October	3 - 6	2.3	**981**	661	97			223	22.7	
2013	October	13 - 15	2.0	**846**	846						
2014	June	1 - 5	2.1	**927**	317	126		303	181	19.5	0,42
2015	June	4,6,9,10,12	2.9	**1256**	424[c]	94	95	430	213	17.0	0,22
2016	June-July	23-30/1-2	2.1	**917**	319[c]	105	47	349	97	10.6	0,30
2016	October	6 - 11	1.4	**620**	521	99					
2017	June	8 - 13	1.9	**805**	313[c]	56	64	234	138	17.1	0,24

[a] Density calculated using the total Ivittuut peninsula area, 432 km².

[b] Although 581 was the April 2012 count by Per N Hansen, he suspected another 100 muskoxen were in the highlands where poor snow conditions prevented survey effort.

[c] In order for 2015, 2016 & 2017 counts to fit pre-2015 table columns, all juveniles, despite known sex, were included in this column for unknowns. For juvenile details see Table 4.

Sources: Boertmann et al. 1992, Ornis Consult letters, Personal communication with Per N. Hansen and Peter Nielsen, Government of Greenland's Directorate for Environment & Nature (DMN) letters and this study.

Table 4. The 2015 – 2017 detailed demographics for muskoxen in the Ivittuut region, 2015 - 2017.

Year	Month	Date	Count	Unknown Sex & Age	Unknown Sex Age (years)				Bull Age (years)						Cow Age (years)			Calf
					1	2	1-2*	>2	1	2	3	4	≥ 5	≥ 10	1	2	≥ 3	
2015	June	4, 6, 9,10,12	**1256**	141			283				62	33	93	1			430	213
2016	June/July	23-30/1-2	**917**	62	27	5	17		53	49	30	17	101	4	77	29	349	97
2017	June	8 - 13	**805**	139	2	1	18	49	10	41	36	28	56	0	31	22	234	138

*Juvenile, exact age not determined, could be either age 1- or 2-years.

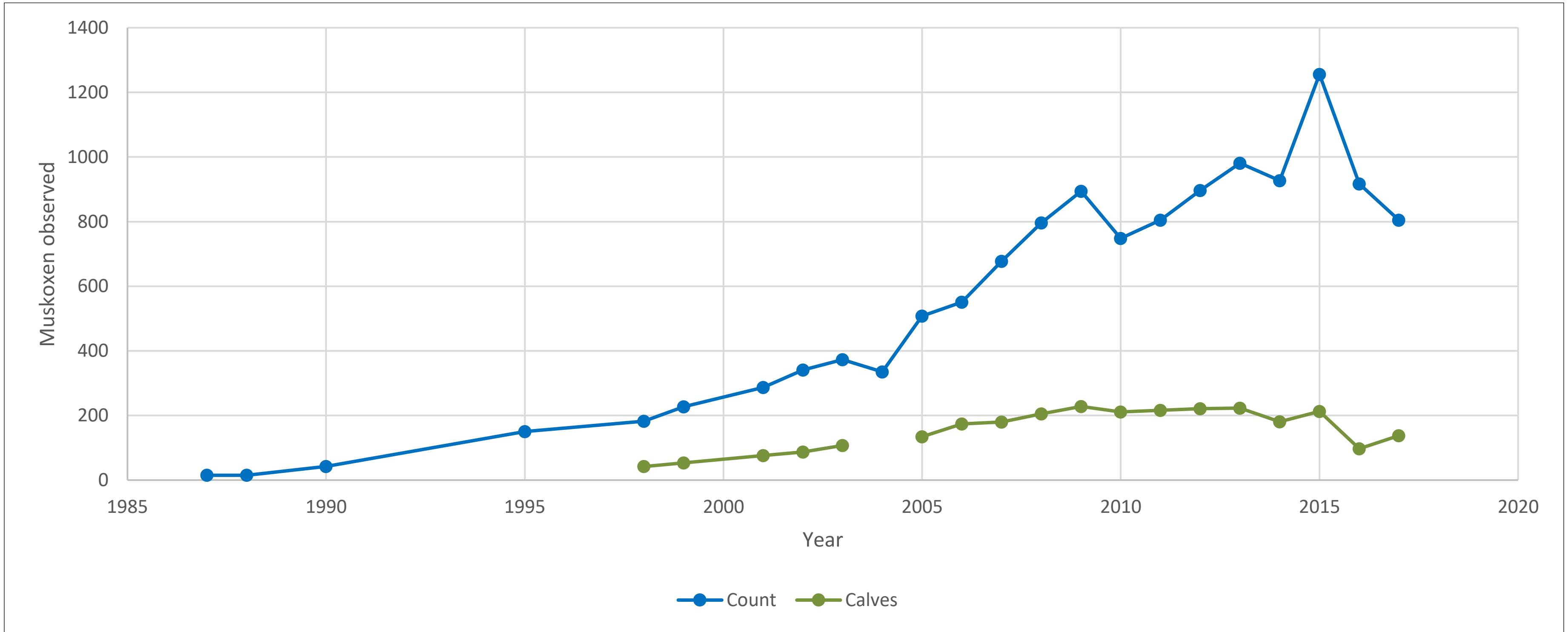

Figure 19. Index for changing muskox abundance and calf number over time in the Ivittuut region, using data from the 1987 to 2017 minimum counts.

Table 5. Muskox population parameters and demographic details from minimum counts in 2015, 2016, and 2017, Ivittuut peninsula, an area of 431 km².

Parameter	Ivittuut muskox population 2015 (04-12 June)		2016 (23 June – 02 July)		2017 (08-13 June)	
Minimum count (Total observed)	1256		917		805	
Approximate density per sq km	2.9		2,1		1,9	
Number of groups observed	227		190		191	
GROUP SIZE						
Mean	5.53		4.83		4.21	
Confidence Interval (95%)	0.8183		0.5901		0.7056	
Standard Deviation	± 6.26		± 4.12		± 4.94	
Standard Error	0.41		0.30		0.36	
Sample Variance	39.14		17.00		24.44	
Median	4		4		3	
Mode	2		1		2	
Maximum	64		26		51	
Minimum	1		1		1	
DEMOGRAPHICS						
Total number individuals sexed and aged	832	100%	806	100%	596	100%
Cow (age > 1-year)	-	-	77	8.40%	31	3.85%
Cow (age > 2-year)	-	-	29	3.16%	22	2.73%
Cow (age ≥ 3-year)	433	34.24%	349	38.06%	234	29.07%
Calf (age < 3 months)	213	16.9%	97	10.58%	138	17.14%
Bull (age > 1-year)	-	-	53	5.78%	10	1.24%
Bull (age > 2-year)	-	-	49	5.34%	41	5.09%
Bull (age > 3-year)	62	4.94%	30	3.27%	36	4.47%
Bull (age > 4-year)	33	2.63%	17	1.85%	28	3.48%
Trophy Bull (age 5-9 years)	93	7.40%	101	11.01%	56	6.96%
Bull (age ≥ 10-year)	1	0.08%	4	0.44%	0	0%
Calf percentage (Total observed/Calf)	17 %		10.6 %		17.1 %	
Recruitment[1] (Calf /100 Cow age ≥ 2-year)	49.5		25.7		53.9	
Sex ratio (Bull age ≥ 5-yr/100 Cow age ≥ 2-yr)	0.22		0.28		0.22	
Demographics miscellaneous						
Both sex & age unknown	-	-	-		139	17.27%
Adults - unknown sex	141	11.23%	62	6.76%	49	6.09%
Sub adults – unknown sex	283	22.53%	49	5.34%	21	2.61%

[1] Any consideration of the above calf recruitment values, must acknowledge that more cows may occur among the relatively high number of adult animals of unknown sex.

The 1998 and 1999 counts observed 42 to 53 newborn calves, respectively. Thereafter calf number increased with each count, to a maximum observed 228 calves in 2009. Calf numbers then basically flattened but from 2015 began to drop (Fig. 19). Meanwhile, calf percentage and recruitment appear to decline after 2010 (Fig. 20). This coincided with relatively large fluctuations of the bull to cow ratio. Note: calf recruitment in Figure 20 did not account for possible cows among animals of unknown sex.

It is important to remember that calf numbers among any count can be underestimated. Owing to their tiny body size, calves were often hidden by dense shrub vegetation, while adults were visible. Calves were also missed when they were lying down in the pocketed terrain or behind larger older muskoxen. Observing calves often required observation periods of over 30 minutes, so that calves stood up and moved about.

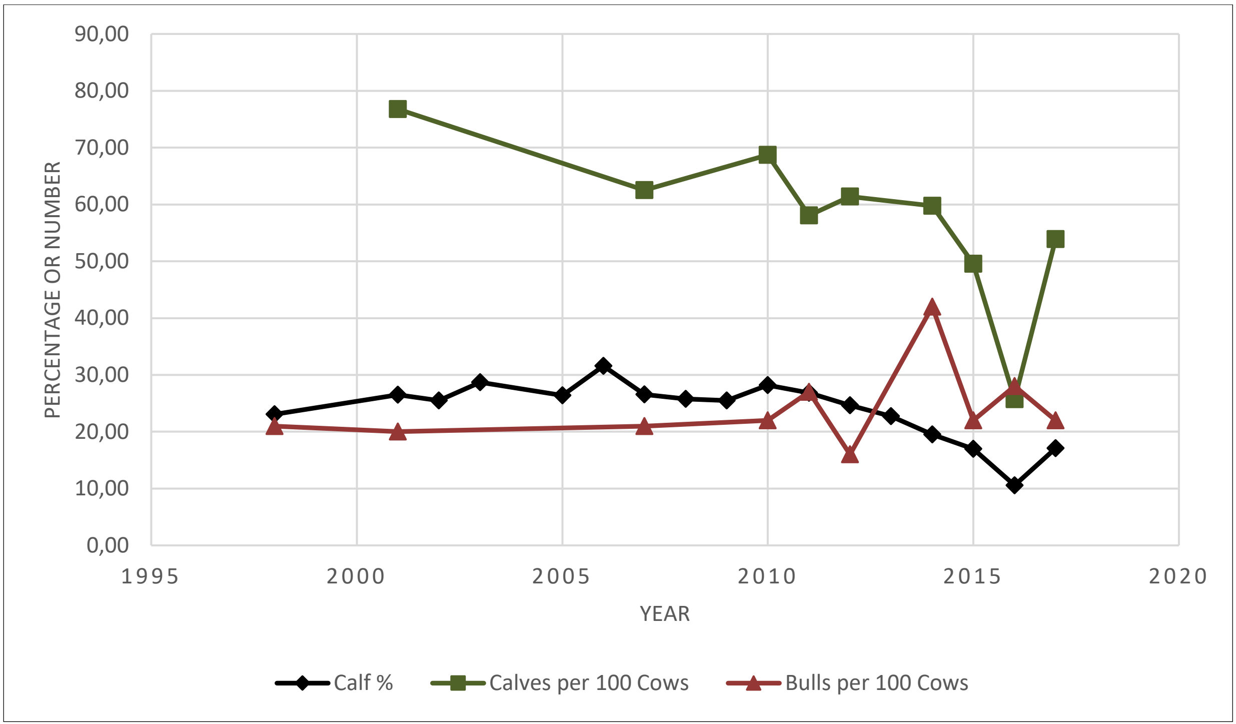

Figure 20. Changes in calf percentage, calf recruitment (calves per 100 cows) and ratio of bulls to cows in the Ivittuut region from 1998 to 2017. Note: calf recruitment did not account for possible cows among animals of unknown sex.

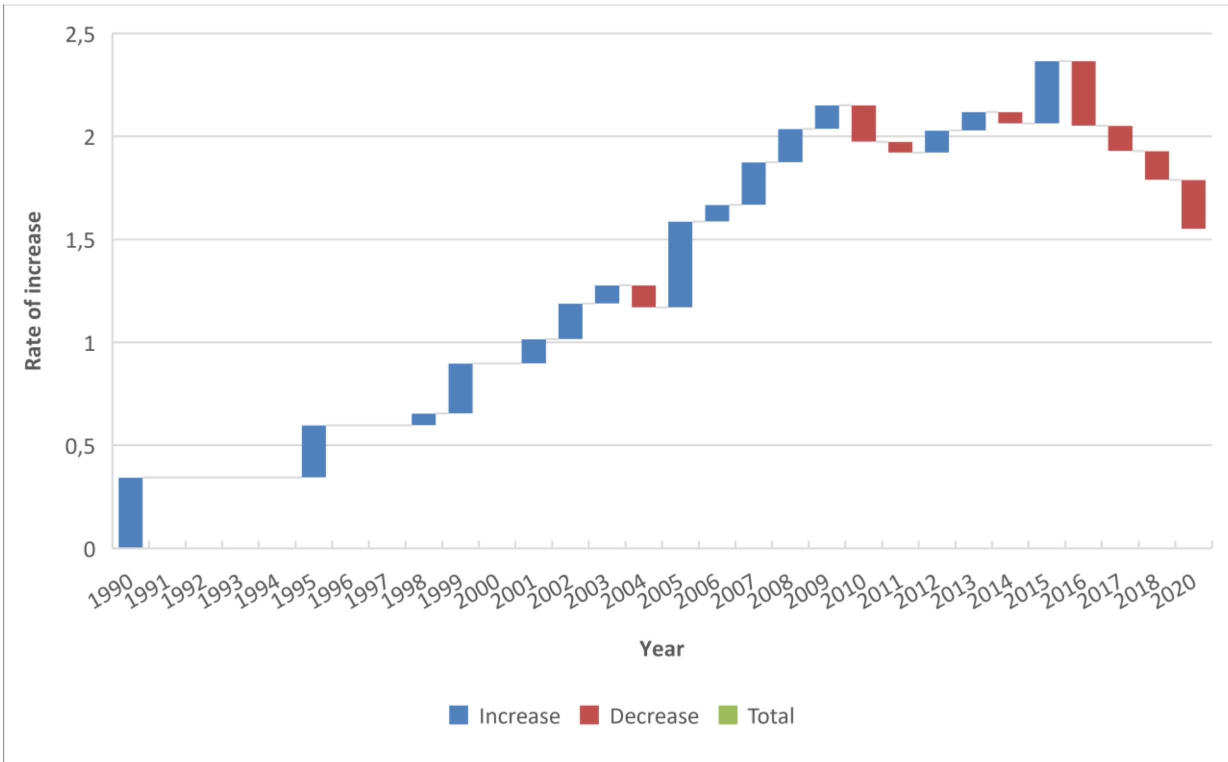

Figure 21. Proportional change, increase/decrease, in population size between two consecutive minimum counts of the Ivittuut muskox population for the 1987-2020 period, available counts for 2018 and 2020 added (Appendix 9).

Typically, for ungulate populations, maximum population growth is assumed to occur when population size (N) is 50%-56% of carrying-capacity (K); $N = K/2$ (McCullough 1979, 1984). If we assume that the 2009 minimum count of 894 muskoxen represents an approximate carrying-capacity for Ivittuut, then maximum population growth would occur with a population of ca. 500 muskoxen. This result is supported by the 2005 rate of increase (Fig. 21), which (ignoring initial spike post-translocation) was the maximum obtained and coincided with a count of 508 muskoxen for that year. Since maximum population growth is generally considered to coincide with maximum sustainable yield (MSY) for hunter harvest, a muskox population size of 400-500 with density at ca. 1/km^2 may be optimal and sustainable for the Ivittuut peninsula habitat. Meanwhile, densities post-2009 were ca. double 1/km^2.

The counts from 2015 to 2017 provided an index for detailed demographics in that period (Figs. 22, 23, 24, details in Appendix 6).

Although figures 22, 23, 24, provide detailed information for each sex and the unknowns, an overview of the observed variation in demographics for the 2015-2017 period are better illustrated using pie-charts (Fig. 25).

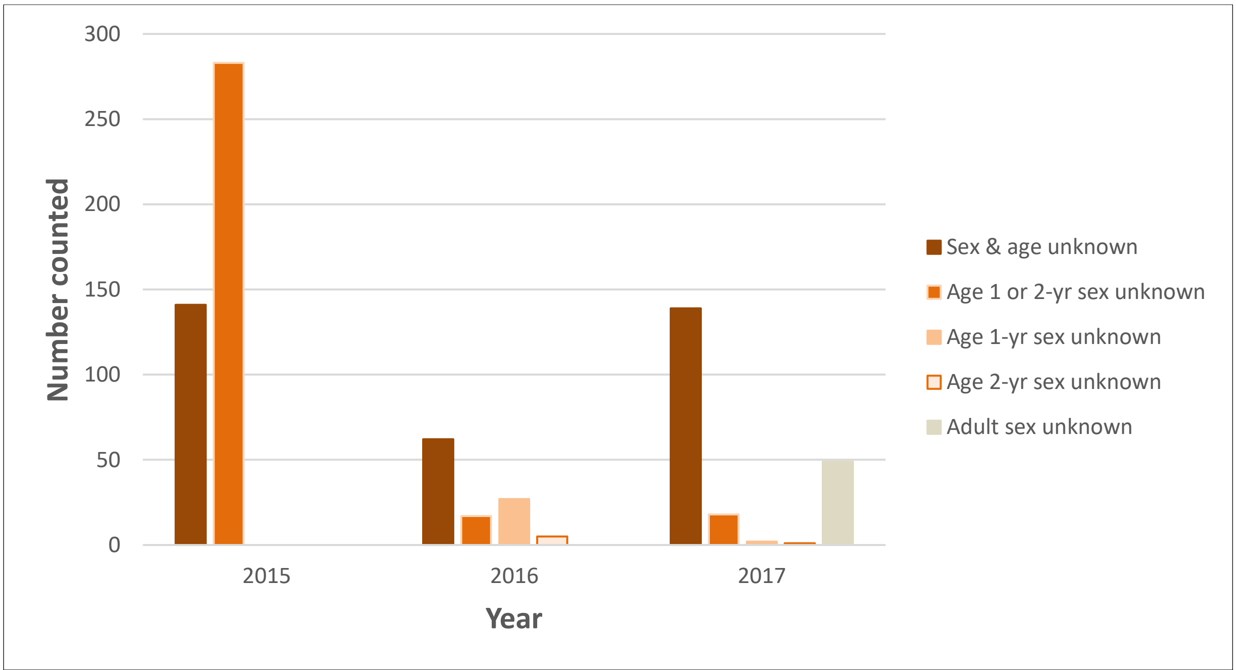

Figure 22. Demographics of unknown sex and/age muskoxen observed on minimum counts in Ivittuut region from 2015 to 2017.

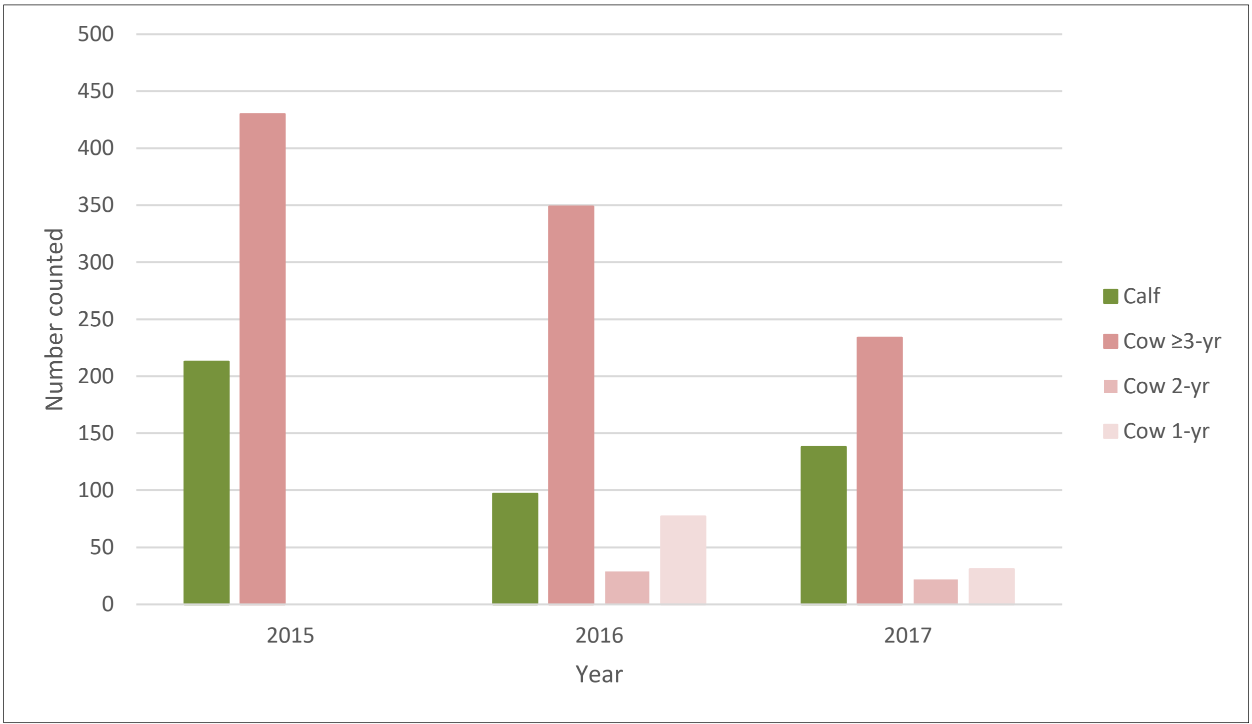

Figure 23. Detailed demographics, specifically calves and cows, from dataset of sexed and aged muskoxen observed on minimum counts in Ivittuut region from 2015 to 2017.

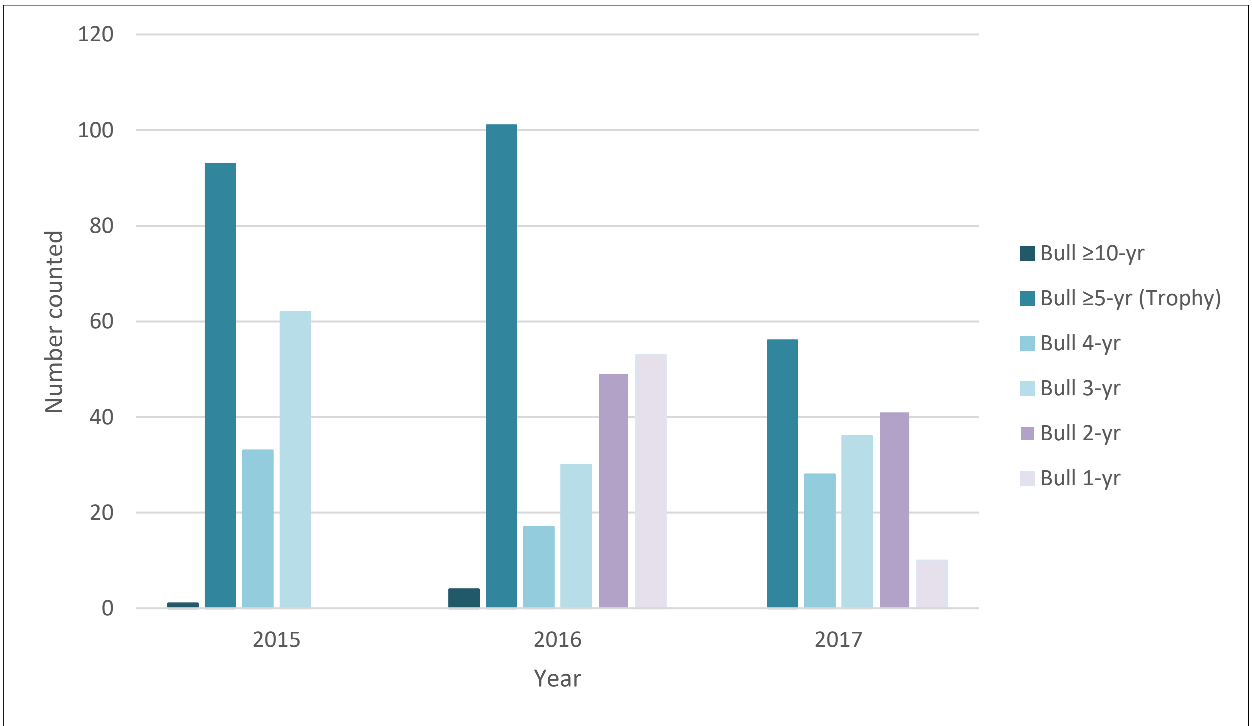

Figure 24. Detailed demographics, specifically bulls, from dataset of sexed and aged muskoxen observed on minimum counts in Ivittuut region from 2015 to 2017.

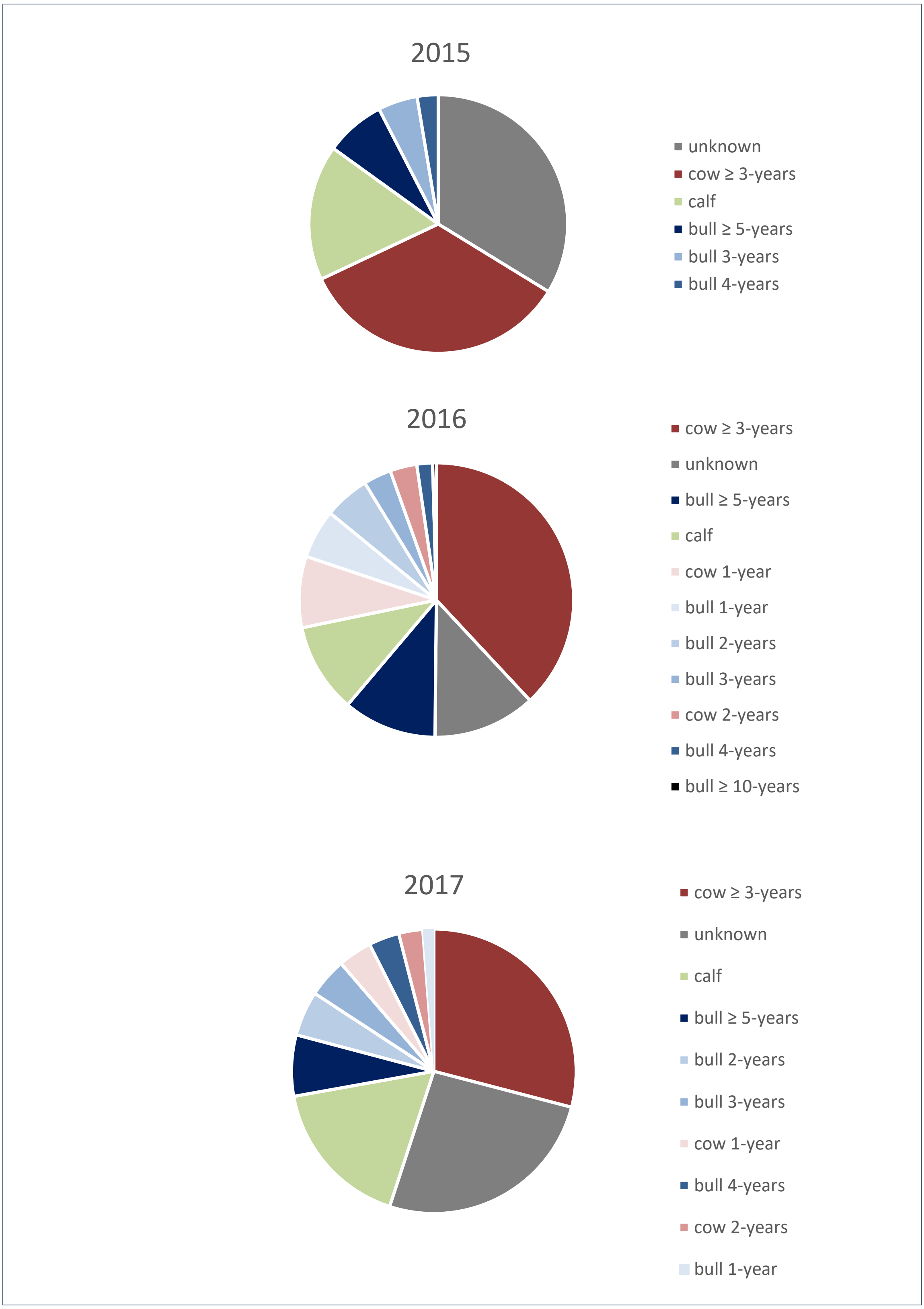

Figure 25. Overview summarizing the demographics of the muskox population on the Ivittuut peninsula, as observed on minimum counts in 2015, 2016 and 2017. Legends and pie-charts rank the categories from largest to smallest proportion of the total observed muskoxen. Animals of unknown sex/age (i.e. age > 1-year) are grey, calves are green (and always of unknown sex), colours for cows and bulls are pink/red and blue, respectively, and darken with age.

Elevation use

Most muskoxen, including most calves, detected during the counts of 2015, 2016 and 2017, were at elevations under 100 m (Table 6). The 2015 and 2017 counts both occurred before the middle of June. The 2016 count occurred at the end of June and into July, and more groups were observed at elevations above 200 m. Specifically, there were several observations of groups at elevations between 300 and 600 m.

Table 6. Elevations where muskox detected in late spring (June through early July) on Ivittuut peninsula, from minimum counts 2015, 2016, and 2017: observed number of groups, total number of muskoxen and calf percentage as per approximate elevation.

Elevation (meters)	Ivittuut muskox population								
	2015 (04-12 June)			2016 (23 June – 02 July)			2017 (08-13 June)		
	Groups	Total	Calf%	Groups	Total	Calf%	Groups	Total	Calf%
< 100 m	179	920	17,5	52	270	14,4	176	761	16.8
< 200 m	44	330	15,8	44	176	8,5	15	44	22.7
< 300 m	2	6	0	41	242	9,1	0	0	-
300< x <600 m	-	-	-	18	90	12,2	-	-	-
No data	-	-	-	35	139	25,2	-	-	-
Total	**225**	**1256**		**190**	**917**		**191**	**805**	

1998-2017 Ad hoc miscellaneous observations

Some of the following ad hoc observations provide facts (e.g. range expansion, longevity, warble fly infection, immigration of semi-domestic reindeer) that are not questioned. Others, however relevant, will require investigation to conclusively document (e.g. mortality, reproduction, timing for calving, twinning, range use & diet, changing plant communities, soil erosion, and calf predation by arctic fox).

Range expansion

Prior to 2015, range expansion by muskoxen, beyond the borders of the Ivittuut region, was observed by Arsuk locals. During the 2015-2017 counts, range expansion was observed twice. Although the emigrated individuals were not included in the data presented in this study's tables and figures for the Ivittuut peninsula, the two observations are described as follows. In 2015, five muskoxen (3 cows, 2 juveniles) were located immediately north of the Ivittuut region. They were near the Sermeq glacier on the north shore of Arsuk Fjord (Ilorput). The group was close to the coast amongst high-growth dense willows, which were under a waterfall. If calves were present, these were impossible to detect owing to the impenetrable willow thicket. In 2017, seven muskoxen were observed immediately southeast of the Ivittuut region. They were in the lowlands of the Qoororsuaq river valley, which runs ESE off Qoorsooq Fjord. The group included one adult bull (age ≥ 10-year), three adult cows (age ≥ 3 years), 1 calf, and two juveniles, which were a cow and a bull, both of age 2-years.

Mortality / Longevity

Prior to 1999, natural mortality was seldom observed among the muskoxen on the Ivittuut peninsula, i.e. only three muskoxen were found dead of natural causes. These were a seven-year-old in May of 1995, a two-year-old in May 1996 (possibly ill), and an ear-tagged 11.5-year-old bull in February 1998.

Since all 15 muskoxen translocated to the Ivittuut region in 1987 were age 1-year and ear-tagged, age determination was possible when the same animals were later observed. Even 13-14 years later, in 1999 and 2000, some ear-tagged individuals were observed annually. Per N. Hansen observed that ear-tagged males disappeared from the population faster than ear-tagged females. No ear-tagged bulls were ever observed following the spring of 1998. This suggests that bulls in the Ivittuut region do not survive much beyond the age 12-years. The oldest ear-tagged bull died in the winter of 1998, age 11.5 years. An incisor tooth sectioned and analyzed for cementum rings confirmed the bull's age at 11.5-years. That bull evidenced severe horn wear, i.e. tips were dull, rounded and totally lacking any black pigment. Tips were the same color as the rest of the horn. Despite advanced age, the bull's mandible teeth evidenced minimal tooth wear.

Figure 26. 2011 photo of 25-year-old cow, one of the original ear-tagged yearlings translocated to Ivittuut in 1987. Note: little remains of horn on left side of head, her shoulders are shaggy with unshed old wool/qiviut, and the cornea of her eye is opaque. Photo by P N Hansen.

Relative to ear-tagged bulls, cows might live up to twice as long. At least four ear-tagged cows survived to age 20-years, since four ear-tagged cows were observed alive both in summer 2004 and 2006. In autumn 2007, two 21-year-old ear-tagged cows were observed with other muskoxen between Oksedalen and Qoornoq fjord. In 2009, there were observed three 23-year-old ear-tagged cows, and for all of them little remained of their horns. 2011 was the last year an ear-tagged cow was observed (Fig. 26). She would have been at age 25-years and her opaque corneas suggest possible eyesight difficulty.

Figure 27. One of two dead cows observed 10 June near the shore of Ikka fjord (NW side). Lack of decomposition indicated recent death of both cows, cause(s) unknown. Photo C. Cuyler.

In June 2015, seven adults, including several cows, were found to have died recently of unknown cause(s) (Fig. 27), i.e. three in Hoveddal (Paradiset), two at Tourist Kloften (Ikka fjord) and two on Ikke fjord shoreline. This was the maximum observed number of dead muskoxen in one year for the 1987-2017 period. Observations of carcasses in the terrain have been few. Unless a recent death, i.e. showing little decomposition (Fig. 27), carcasses were difficult to detect. A decomposing mature bull (Fig. 28) was detected by only one of three observers, all of whom walked within 10 m of the carcass.

Two muskox carcasses were detected in each of 2016 and 2017, during June/July minimum counts. In 2017, one carcass was a juvenile (age 1-year) that had been illegally shot in preceding winter months.

Figure 28. Decomposing carcass of mature bull, 09 June 2015, Hoveddal valley, Paradiset. Cause(s) of death unknown. Photo C. Cuyler.

Reproduction

Parturient cows generally left the larger group to calf and then remained apart for about one month before returning with their calves to the group (P.N. Hansen pers. comm.). Although calving typically occurs in May, in the spring of 2004 some calves may have been born in June, as evidenced by their unusually tiny size.

Elderly cows can be reproductively active. In the post-2000 period, ear-tagged cows of age ≥ 14-years were often observed to have produced calves. In 2001, several ear-tagged 15-year-old cows were observed with a newborn calf-at-heel. Also, of the four 18-year-old ear-tagged cows observed summer 2004, one had a calf-at-heel, which owing to smaller size relative to the other calves-at-heel, may have been born in late June. In June 2014, a tiny calf, assumed age 2-weeks, was rescued from deep inside a rock cleft and successfully reunited with its dam (P.N. Hansen pers. comm.).

Twin calves

Twinning may have occurred among the muskoxen at Ivittuut (Fig. 29). Since 1987, there have been four years where suspected calf twinning has been observed among the muskoxen in the Ivittuut region (P.N. Hansen pers. comm.). In 2001, two pairs of possible twin calves were seen, i.e. two cows were observed each with twin calves-at-heel. In 2009, eight pairs of twins were observed, and one pair in each of 2012, 2013 and 2015. The latter suspected twins were observed during June 2015 muskox minimum count.

Figure 29. Solitary cows accompanied by two calves have been observed, which suggests the possibility of twinning among muskoxen in the Ivittuut region. Photo Per Nukaaraq Hansen.

Muskox range use & diet

Per Nukaaraq Hansen, became hunting officer of Ivittuut region in 1993, and immediately noted that in winter the muskoxen utilized mountain plateaus (elevations 200-700 m), while in summer they grazed in lowland valleys and coastline areas (elevations 0-200 m). One exception occurred. During the December 2003 count, 12 muskoxen, all old bulls (age > 10-12 years) were observed in lowlands, when all other muskoxen had moved up into the mountain plateaus for the winter. These 12 bulls did not move away from the approaching observers and appeared to have slightly overgrown hooves, i.e. were 5-6 cm longer than usual.

Per N. Hansen observed the Ivittuut muskoxen eating lichens in winter and spring seasons, as evidenced by lichens in the mouth and rumen contents of harvested animals. Lichen consumption by muskoxen has also been observed by Thing (unpublished). Further, seaweed appears to be in the diet. June 2015, we observed several mature bulls seemingly eating seaweed from shoreline rocks at low tide (Fig. 30).

Figure 30. Mature bull muskoxen (age ≥ 5-years) appearing to consume seaweed at low tide, small bay at Taylershavn, June 2015. Photo C. Cuyler.

Muskoxen altering the plant landscape

While completing the 2015-2017 minimum counts, we observed grasses/sedges grazed right to the ground by muskoxen. In 2015, the north shore of Ikka Fjord was heavily grazed (Fig. 31). In the inner Grønnedal valley, 2016, all grassy vegetation appeared grazed to the ground. In 2015, bark stripping of willow shrub landscape by muskoxen was noted in three locations, the inner Ikka Fjord, Oksedalen river valley, and Paradiset. Also in 2016, 24 June, in Laksebund/Lakselv river valley, we noted bark stripping of willow shrub landscape by muskoxen (Appendix 7). Although late June with green-up evident for other vegetation, much of the willow shrub had no leaf buds and no green leaves. Further, we noted swaths of ancient willow shrub boughs strewn like bleached bones on the ground (Fig. 32). Laksebund/Lakseelv mountainside willows also evidenced muskox browsing.

Figure 31. Ikka fjord shore grasses/sedges evidencing heavy muskox grazing, 10 June 2015. Photo C. Cuyler

Figure 32. 'Bleached bones' remains of trampled ancient willows by riverside in Laksebund/Lakselv Valley, 24 June 2016. Photo C. Cuyler.

Also in 2016, some willow shrubs in the valley behind Taylershavn evidenced bark stripping. Near Taylershavn summer cabin, however, there was no evidence of muskox bark stripping, trampling, or browsing. In Oksedalen on 29 June 2016, bark stripping by muskoxen was noted, as it was in 2015, but now trampling was also observed. Many willow shrubs may be dead, given lack of green-up despite date and abundance of other green vegetation surrounding them.

In 2017, the status of willow shrubs in the Ivittuut region seemed unchanged from observations in 2015 and 2016.

Muskoxen & soil erosion

In June 2017, as we sailed the coastline of the southwestern innermost small bay of Blindtarmen, soil erosion/exposure was observed on the northeast side. It appeared to be caused by muskoxen, e.g. grazing or gouging. There was no time to go ashore for a closer look, as we were late catching the high tide allowing passage through the narrows. If muskox truly caused soil erosion/exposure, then it is the first reported for the Ivittuut region.

Arctic fox chasing muskox calves

During the 2014 muskox count (01-05 June), there appeared to be unusually many foxes. Some were relentlessly chasing small muskox calves, born spring 2014, albeit the foxes were without observed predation success.

Warble fly larvae

In 2009, subcutaneous warble fly larvae were observed in juvenile Ivittuut muskoxen.

Other species observed

Although no specific effort was made to detect other species, when observed these were noted (Table 7). Details for each observation are available in Appendix 8.

Table 7. Species observed opportunistically during 2015-2017 Ivittuut muskox minimum counts. Blanks indicate no data / observations. Location and group size details in Appendix 8.

Year	Semi-domestic Reindeer	Arctic hare	Arctic fox	White-tailed eagle	Falcon	Eider duck	Harlequin duck	Seal
2015	81 (incl. 16 calf)	11	5	6	1		2	4
2016	27 (incl. 2 calf)	8	2	7				
2017	51 (incl. 14 calf)	2	4	3		many		2

Semi-domestic reindeer range expansion into Ivittuut

Although native Greenland caribou were long since extirpated (i.e. in 1980's) from Ivittuut and muskoxen were becoming firmly established, by the early 2000's residents of Arsuk realized that semi-domestic reindeer had begun a northward expansion into the Ivittuut municipality, and some remained year-round (E. Jakobsen pers. comm.). The reindeer originated from the Isortoq reindeer-herding district, which is immediately south of Ivittuut. Arsuk community members typically considered feral reindeer in their region an annually recurring unwanted intrusion. In 2007 six feral reindeer were shot illegally, i.e. without a license. In 2009, at least 40 reindeer were constantly in the Heksestedet/Oksedalen/Nuuk area and assumed to cause range deterioration (P.N. Hansen pers. comm.). In 2010, a large group of semi-domestic reindeer (mixed sex, age) were observed in the Ivittuut region (Fig. 33). With limited success, the Isortoq reindeer herders attempted to herd these feral semi-domestic reindeer back into their husbandry district. Regardless, every year groups of reindeer are observed in the Ivittuut region, this includes the years of the 2015-2017 minimum counts (Fig. 34, Table 7, Appendix 8). In all years, calves have been present among reindeer groups in Ivittuut.

Figure 33. In 2010, a large group of semi-domestic reindeer was observed inside the Ivittuut region. Photo Per Nukaaraq Hansen.

Figure 34. Eight bull semi-domestic reindeer in the Blæseren Valley, 09 June 2015. Photo C. Cuyler.

Discussion

In a nutshell, the Ivittuut peninsula is small in area (432 km^2). Ultimately, this will limit the number of muskoxen possible on the peninsula. When 15 muskoxen were translocated to the peninsula in 1987, half of the peninsula's area was categorized as completely barren (Appendix 2), which is now better understood as very sparsely vegetated (Walker et al. 2005). On the remaining half, two thirds consisted of poorly vegetated highlands (ca. 121 km^2) and one third well vegetated lowlands (ca. 95 km^2). In 1987, the vegetation had not been grazed by large herbivores for about a century, so pasture condition was likely optimal. By 1998, forage conditions remained good, as evidenced by a bull muskox, age 11.5-years, that had almost no mandibular tooth wear. Not surprisingly, the muskox population grew and so did their density. By the 2008-2017 period, annual counts observed anywhere from ca. 800 to 1200 animals. The initial lush lowland vegetation and relatively mild low arctic climate likely enabled the observed rapid population growth. Eruptive growth is typical of introduced ungulate populations (McNab 1985). Again, for the 2008-2017 period, given the counts and total Ivittuut area, muskox densities were ca. 2-3/km^2. Elsewhere in the Arctic, muskox densities typically average ca. 1 muskoxen per km^2 (Cuyler 2003), which is markedly lower than the densities for the Ivittuut peninsula.

Carrying-capacity

What is the resource-based capacity of the Ivittuut peninsula for muskoxen? What is the carrying-capacity *K*, i.e. density of the muskox population where number of births equals the number of deaths? There is no simple answer, as it is almost impossible to define *K*, which is a moving target owing to several factors, notably weather affecting forage production and availability (Macnab 1985). Eruptive population growth in ungulates typically overshoots carrying-capacity before an obvious crash in abundance occurs (McCullough 1979, 1984). An overshoot, i.e. too many animals, can damage the vegetation resources, which brings the carrying-capacity to a new, permanently lower, value (McCullough 1979, 1984).

Since natural mortality is common in winter, carrying-capacity of arctic ungulates is typically regulated by winter pasture, specifically accessibility to that pasture but also pasture quantity and quality. Ivittuut winter range is at elevations above 200 m owing to deep snow in the lowlands (P.N. Hansen pers. comm.) and is 3½ times more area than summer range. Although we lack knowledge about vegetation productivity in the sparsely vegetated highlands, other muskox populations in the Arctic likely experience similar conditions. To date, vegetation productivity on different muskox pastures around the Arctic remains a knowledge gap. Solving this gap would permit comparisons across pastures and populations.

For the Ivittuut situation, by 2017 the muskox population did not appear to have dramatically overshot their carrying-capacity, because there was not an abrupt excessive crash in abundance, i.e. compared to other introduced ungulate populations (McCullough 1979, 1984). Instead, there was steady muskox population growth from their translocation to Ivittuut in 1987 until 2009 (Table 3, Figures 19, 21). The exception was a slight 2004 drop, which may reflect count conditions that year rather than declining muskox numbers. The steady growth in muskox numbers, density and calf number stopped in 2009, when the count observed 894 animals (Fig. 19). The 2010 decline and subsequent fluctuating population sizes/densities (Fig. 21) combined with declining calf percentages (Fig. 20) suggest that in 2009 muskox abundance had reached a potential carrying-capacity. The density was then ca. $2/km^2$.

Today, carrying-capacity may be lower. Already in late 2009, worn down vegetation was observed at the mouth of Qoornoq fjord and around Nuuk Sø (P.N. Hansen pers. comm.). Since then, muskox herbivory appears to have impacted/changed the vegetation cover (Figs. 31, 32, and Appendix 7). Damaged forage resources result in a long-lasting reduction of carrying-capacity (McCullough 1979, 1984). To complicate matters, muskoxen now share the peninsula's forage resources with a potential competitor species, feral semi-domestic reindeer. Two large herbivores on the same pasture can be expected to decrease the carrying-capacity for each species. Thus, we recommend a muskox density $\leq 1/km^2$ for the Ivittuut peninsula because it might allow for a balance between vegetation regeneration and resource availability for muskoxen.

All the above notwithstanding, fluctuations in ungulate population abundance are natural and their speed and amplitude highly variable. Often, abundance fluctuations are in response to factors beyond management control. In general, expecting entirely stable harvest yields over the long term is unrealistic for wild populations.

To better understand what is currently happening, a new muskox count is required as it is seven years since the last detailed count. A count of the reindeer is also recommended to aid ascertaining their possible impact on the muskox population. Further, because it likely influences muskox survival, the winter snow conditions (e.g. amount, ice, snowmelt/spring onset) should be documented. Since snow distribution may impact the timing of muskox movement e.g. from highland plateaus into lowlands, future counts should document or at least summarize snow conditions, and note exceptional/unusual years.

Catastrophic stochastic events

Cuyler (2019) drew attention to the growing possibility that current climate warming in Greenland could produce catastrophic stochastic weather events, which within a single season have a strong negative influence on animal abundance. Recently, stochastic events involving pathogen outbreak/epidemics among Canadian muskoxen were associated with subsequent abrupt population decline (Tomaselli et al. 2023). For the Ivittuut region, conceivable stochastic event risks would include not just extreme weather but also pathogen outbreak/epidemics. Both are density dependent, so their effect is amplified at high animal density (Hansen et al. 2019).

Weather events

The current warming of the Arctic may have both positive and negative roles regarding future vegetation quality, quantity, and availability. On the positive side, a longer and warmer growing season could create more plant biomass thereby increasing overall carrying-capacity, not just for muskox but for all herbivores. In a warmer climate, arctic tundra plants may grow earlier and faster, and increase in abundance (Elmendorf et al. 2012a, 2012b). Already increased shrub abundance has been observed (Myers-Smith et al. 2011, 2015) as well as greening of the Arctic recorded from satellite-derived vegetation indices (Zhu et al. 2016) in most of the Arctic. Since herbivores reduce vegetation productivity, specifically of shrubs (Gottfried et al. 2012), a higher density of herbivores may somewhat counteract these responses to a changing climate (Post & Pedersen 2008, Post 2013).

On the negative side of a warming Arctic, drought may reduce and damage plant biomass, with severity depending on frequency, duration, intensity, and area affected. Similarly negative, if warmer wetter winters occur then forage availability could be partially or completely obstructed by events depositing excessive snow depths and/or thick layer(s) of ice, which results from thaw/freeze rain-on-snow (ROS). Event severity will be determined as above for drought. Events that limit vegetation/forage quantity and availability, may cause starvation, and ultimately reduce survival and reproduction.

Pathogen events

Arctic warming creates further concerns beyond the forage supply for muskoxen. These include hotter summers amplifying insect harassment resulting in cows unable to attain the fat reserves required for ovulation and reproduction (Adamczewski et al. 1998). Further, hotter summers may facilitate the arrival of new pathogen vectors (e.g. insects, birds) and support immergence of diseases/parasites new to the arctic. Similarly, longer warmer summers may release long dormant pathogens.

Although carcasses are too often extremely difficult to detect, unusual mortalities have been observed in muskox populations in the Canadian Artic (Tomaselli et al 2023). For example, an outbreak of *Erisypelothrix rhusiopathiae* (a bacterium not normally active in the Arctic) has been active on Victoria and Banks Island since 2010 (Kutz et al 2015), and more recently on several High-Arctic Islands. As either the primary or secondary pathogen, it may have played a strong role in the recent precipitous decline of South Victoria (85%) population (Tomaselli et al 2023). Further, there have been increasing disease trends of endemic and (re)emerging diseases in declining muskox populations. Among these, *Brucella suis* biovar 4, Orf virus can have population level impacts (Tomaselli et al 2013, 2014, 2018).

It is common knowledge that high animal density exacerbates the spread of pathogens. Meanwhile, the Ivittuut peninsula now has a history of high muskox density. Allowing high density to persist in a warming Arctic may be counterproductive to a healthy population in the future.

A severe stochastic event, whether by weather or pathogen outbreak, could decimate muskox abundance on the Ivittuut peninsula. If that occurs, then harvest can contribute to further population decline (Cuyler 2020 in supplementary materials). In the future, mitigating management measures to alleviate the negative impact of extreme events may be required. The extent of a severe event will determine whether one or more regions/populations are affected and consequently also require mitigating management.

Calf production

Muskox calves are usually born mid-April through June, with parturition (birth) dates as early as 05 April and as late as 19 June (Lent 1988). This ca. 2½-month period contrasts sharply to caribou, which across the Arctic have highly synchronous breeding within populations (Lent 1966, Bergerud 1975, Skogland 1989, Adams & Dale 1998). As with other ruminants, both the onset of puberty and probability of successful breeding increases with female body mass and therefore varies across the Arctic (Rowell et al. 1997; White et al. 1997). First calf production at age 3-years is common in most habitats (Schmidt et al. 2015; Tessaro et al. 1984; Latour 1987; Reynolds 2001). However, under favorable conditions, cows can produce calves at age 2-years, e.g. in captivity (Rowell 1991), but also in the wild, which can result in rapidly expanding populations (Alendal 1971; Jingfors and Klein 1982; Tessaro et al. 1984; Olesen 1993; Reynolds 1998). The latter has been observed in West Greenland. During the 1980s expansion of the recently translocated Maniitsoq muskox population, juvenile yearling cows attained the body weight necessary to ovulate in their second autumn and at age 2-years, produce a calf, and further to breed every year thereafter (Olesen 1993). By contrast, in north-east

Greenland, muskox cows bred in alternate years (Thing et al. 1987). In the Arctic, poor cow body condition can result in non-annual breeding (White et al. 1997), and in many muskox populations cows calve at intervals of 2-3 years, probably because they did not regain enough body reserves during a single summer season after pregnancy and milk production (Reynolds 2001). Of course, population density, lactational status and forage (quantity, quality, and availability) also affect the likelihood of pregnancy in large herbivores (Pachkowski et al. 2013).

Muskox cows typically produce a single calf and twinning has rarely been documented (Alendal 1971; Wilkinson 1971; Rowell et al. 1997). On the Ivittuut peninsula, however, cows giving birth to twins was possible. Muskox cows, require 22% body fat to have a 50% probability of pregnancy (Adamczewski et al. 1998). For perspective, caribou cows need only ca. 7% body fat for pregnancy (Crête et al. 1993; Pachkowski et al. 2013). This suggests twinning in muskoxen may require > 22% body fat, and we suspect that for a cow to be able to attain that amount of fat would require optimal range conditions and likely also low animal densities. In the past, the Ivittuut peninsula appears to have provided those conditions. This is likely no longer be true. After 2009, the calf production rate slowed down (Figs. 19, 20) and the year 2016 coincided with what appears to be the beginning of a 2-year decline in population size, as per the 2015-2017 counts (Fig. 21). Good cow body condition is required to improve their calf production.

Changing plant communities

Throughout the Arctic, large herbivores are known to influence plant community structure (Bernes et al. 2015, Suominen & Olofsson 2000), and ecosystem processes and functions (Cahoon et al. 2012, Vowles et al. 2018). Specifically, increased herbivore densities in areas that had historically low herbivore densities can rapidly change the vegetation because grazing intolerant plants are quickly eradicated, and grazing tolerant species can colonize the gaps (Olofsson et al. 2013). Further, there is solid evidence that large herbivores reduce the abundance of shrubs, and that higher densities and diversity of herbivores speed up that process (Olofsson & Post 2018).

Since the translocation of muskoxen to Ivittuut in 1987, there has been no monitoring of the habitat. Muskoxen, being a large heavy bodied browser/grazer, can be expected to alter ecosystems they enter, specifically when these are finite like the Ivittuut peninsula. We know that arctic ecosystems respond quickly to changes in the abundance of muskoxen, owing to modified vegetation dynamics and nutrient cycling, e.g. trampling by large numbers of muskoxen can reduce plant biomass (Mosbacher et al. 2018).

While completing the 2015-2017 counts, muskox grazing impact on forage plants was suggested by anecdotal observations (Figs. 31, 32, Appendix 7). We observed that although valley lowlands still possessed extensive areas of willow shrub landscape, entire swaths were stripped of bark and often also trampled. Typically, leaf development was lacking even by early July, although a cold spring may have influenced the latter. In early June 2015, the Ikka fjord grasses/sedges on the north shoreline were grazed to the ground. Simultaneously and nearby on the same north shoreline, seven recently deceased adult muskoxen were observed. Although cause of death was not examined, perhaps in June 2015 muskox density in the Ikka area was higher than could be supported by the habitat.

The heavy bark stripping and trampling of willow shrub landscapes in most valley lowlands suggests the muskoxen are currently in the process of altering the plant community landscape in the Ivittuut region. While heavily grazed grasses and sedges may regenerate annually, the damaged mature (ancient) willow shrub will likely require years or decades to recover, if ever under continued herbivory and trampling. According to pasture scientists in Alaska, the above is not considered overgrazing since changing plant communities is expected and normal when large herbivores enter an ecosystem, and this alteration is not considered overgrazing until soil erosion occurs (J. Rowell pers. comm.). In June 2017, muskox grazing or gouging/rubbing had exposed soil on the vegetated slopes of Blindtarmen, indicating overgrazing had begun. The Ivittuut region warrants examination with well-designed studies to investigate and document ecosystem/plant community change under muskox herbivory.

Elevation use

Overall, most muskox observations during the counts of 2015, 2016 and 2017 were at elevations under 100 m. Two of the counts occurred before mid-June and were before the insect season. The 2016 count, however, occurred at the end of June and into early July. Interestingly, in 2016 groups were at elevations above 200 m, including several groups at elevations from 300 to 600 m. It is possible that the later timing of the 2016 count resulted in higher elevation use by the muskoxen to reduce insect harassment.

Harvest

Control of harvest management has been a patchwork of local and/or central authorities (Appendix 3). Until the 2009 amalgamation of municipalities, the small Ivittuut municipality regulated and allocated the muskox harvest quotas independently of, but in discussion with the Greenland central administration, and the quotas were typically conservative (Figs. 5). Hunting seasons varied widely across years, and could include separate summer, autumn, winter and spring seasons for sport and commercial hunting that differed from the timing of trophy seasons (Appendix 3). Regardless, annual harvests fell short of that needed to prevent population growth.

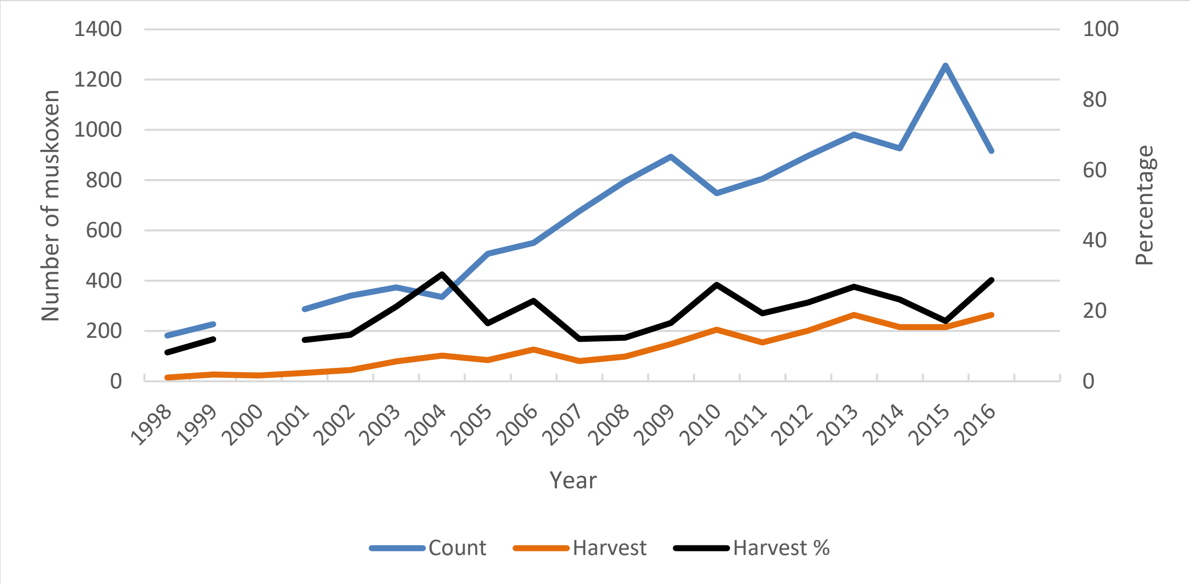

Figure 35. The muskox counts, harvests and percentage of the count taken by harvest in the 1998-2016 period.

By 2010, Ivittuut, along with several other municipalities, was amalgamated into a huge new municipality, Kommuneqarfik Sermersooq, which took over harvest regulation and allocation in collaboration with the Greenland central administration. Regardless, and despite sharply increased harvest quotas post-2009 (Fig. 5), annual harvests still fell short of the numbers necessary to prevent population growth (Fig. 35), which was exacerbated by the continuing too few cows harvested (Figs. 6, 7).

The previous sections suggest there has been, and perhaps still are, a high density of muskoxen inhabiting the Ivittuut peninsula. Ignoring possible negative stochastic events, this alone bodes ill for the future size or health of this muskox population. Considering the nearby Arsuk community, a conceivable goal would be to reduce the population size to facilitate meat security and income (e.g. from commercial sale of meat, and the trophy bull and qiviut industries). A reduction might be achieved through well thought out management and supervision of the harvest. Since past harvests have been predominantly juveniles and bulls (Figs. 6, 7; Tables 9, 10 in Appendix 3), changing just the annual quota will likely be insufficient action taken. Specifically, if a population crash has occurred since 2017, as suggested by the natural mortality observed in 2018 and the low 2020 count (Appendix 9).

Counts – how many muskoxen were missed?

For the Ivittuut peninsula, how well do the minimum counts reflect the true number of muskoxen? Minimum counts record only those animals observed and acknowledges that not all animals are detected. Whether cruising along the shoreline or hiking in the terrain, muskoxen could be hidden from view by terrain (ravines, hills, etc.) and vegetation. On the Ivittuut peninsula willow shrub can grow > 2 m in height and where willow density is tight, these can completely hide even large adult bull muskoxen and specifically small-bodied spring calves. Further, supine calves in pocketed terrain, among tussocks, or behind other muskoxen are often completely hidden from view, until they stand up and move about. Snow can curtail count effort. Owing to difficulties walking through snow, spring and early summer counts seldom include elevations above 200 m. Any muskoxen remaining at high elevations are not counted. The September 2005 count was the first time over 500 muskoxen were counted. This was attributed to all animals being at low elevations where they were easy to detect. In 2007, the September count was 637 muskoxen. None of the known remaining four ear-tagged cows were observed and at least 30 to 50 more animals were suspected in areas not covered by that September count. Later that same autumn, two out of the four ear-tagged cows were observed. Counts lasting several days cover more area and detect more muskoxen than one-day counts. All the above begs the question; How many muskoxen do counts miss? Below are two examples of counts, a multi-day, and a 1-day, for which harvest data was available for the period until the next count. This permitted calculation of an approximate value for missed muskoxen.

- In 2009, between the September and December multi-day counts, hunters harvested 183 muskoxen. The September count was 894, while the December count was 851. Clearly, the September count could have observed at least 1034 muskoxen. However, 13.5% of the September minimum number of muskoxen present on the Ivittuut peninsula went undetected.
- In 2012, a 1-day early April count observed 581 muskoxen. Unable to get into the high elevations owing to snow conditions, an additional 100 animals were suspected. No calves were seen at that time. Subsequently, from the 15th of April until the beginning of October, hunter harvest shot 132 muskoxen. (Note. In 2012, there were further animals shot before and after those dates). The 05 October count observed 897 animals, which included 221 calves. After removing calves but adding harvest, simple arithmetic reveals that the 1-day April count missed 227 animals (age > 1-year), which is 28%. Alternately, if April's suspected 100 missing animals are added to the total count, then only 127 animals were missed (age > 1-year), which is 16%.

Undetected muskoxen were ca. 13% for the multi-day count but ca. 16% - 28% for the rapid 1-day count. As expected, multi-day counts, which cover a greater area, better reflect the true muskox number.

Herbivore range expansion

The muskoxen have expanded their range beyond the borders of the Ivittuut peninsula. Range expansion was observed both north and south of the Ivittuut region. The presence of mixed sex and age, including calves, suggests it likely that muskoxen have already or will establish viable populations beyond the Ivittuut peninsula.

Muskoxen are no longer the only large herbivore on the Ivittuut peninsula. Since the early 2000's, semi-domestic reindeer have wandered northward from the Isortoq Reindeer Herding District, expanding into the Ivittuut region, becoming feral. By 2015, perhaps earlier, these had established a resident population. Thus, for several years now, Ivittuut has been designated the 11th caribou/reindeer harvest management region in Greenland, which includes the feral reindeer in the government regulated annual caribou harvest. In the nearby Arsuk community, some welcomed the advent of feral reindeer and exploited this additional trophy hunting opportunity, while others regarded the feral animals as intruders.

Demographics 2015-2017

Detailed demographics were available for three years, 2015, 2016 and 2017 (Tables 4, 5). Animals of unknown sex and age (i.e. age > 1-year) were a large proportion of any count (Figs. 22, 25), which confounds interpretation of the results. Possible changes from 2015 to 2017 are rendered inconclusive owing to the number of unknowns. Reducing the number of unknowns will require perhaps new methods, or at the least, allocating more time to ascertain sex and age while using high-powered spotting scopes. Binoculars (10x magnification) proved insufficient for the task. Regardless, for the 2015-2017 period mature cows (age ≥ 3-years) and their calves made up approximately half of all observations on any count. Further, the proportion of calves versus all other animals observed remains reliable and can be compared with calf proportions on all pre-2015 counts.

Recommendations for future muskox demographics & minimum counts

Ground counts in Ivittuut are usually accomplished by hiking into the valleys and sailing along the coastline. Like the rest of Greenland, Ivittuut terrain is rugged. Thus, a ground count can only observe a portion of the muskoxen present in the areas viewed and the amount of the Ivittuut area covered is limited to the coasts and the few valleys where hikers walk. Count effort is basically lacking in the highlands above 200 m elevation, which constitute ca. 78% of the Ivittuut peninsula. Hence the name 'minimum' count.

Drones might facilitate accuracy of counts & knowledge of herd structure
The relatively small valleys of the Ivittuut peninsula might lend themselves to the range capacity of some modern unmanned aerial vehicles, i.e. UVAs/drones, albeit expensive ones. Drones might assist and augment the collection of demographics data from groups already detected and counted, but only if the following are true. There is an altitude (determined by field experience) for drone presence overhead that does not make muskoxen aggregate tightly hiding calves beneath the larger animals. The sex and age data are collected from direct observation on an operator screen in real-time, specifically because post-processing of images is time-consuming and double counting individuals may occur.

Count accuracy
Whether sailing the coastline or hiking on land, terrain features and dense vegetation can hide muskoxen from observers. An assisting drone, being overhead, could detect muskoxen that were otherwise hidden from view. This would improve accuracy of minimum counts.

Demographics knowledge
Accurate muskox herd structure data is difficult to obtain. One of the problems is distance. Muskox groups are often too far away from the observer. Although use of 60x telescope can permit counting the number of animals, distance can make determination of sex and age difficult or impossible. Drones might make distance to an observed group irrelevant. Positioning a drone above a group of muskoxen may make it possible to distinguish female from male horns and perhaps even horn morphology to permit ageing. Reducing the number of animals lacking sex and age data would increase the accuracy of bull to cow ratio and the calf recruitment value (i.e. calves per 100 cows). Regarding the latter, another problem is undetected calves. Owing to their small size, calves resting among tussocks and vegetation can be completely obscured from view. Calf percentage and recruitment values become less accurate when calves that are present are hidden and thus undetected. Observers hiking through the terrain may move on before those calves become active and visible. Sending a drone to reconnoitre already observed but too far distant muskox groups would likely improve ability to reliably ascertain sex and age composition and specifically the number of calves present. Strengthening demographic data would assist predictions of population trend.

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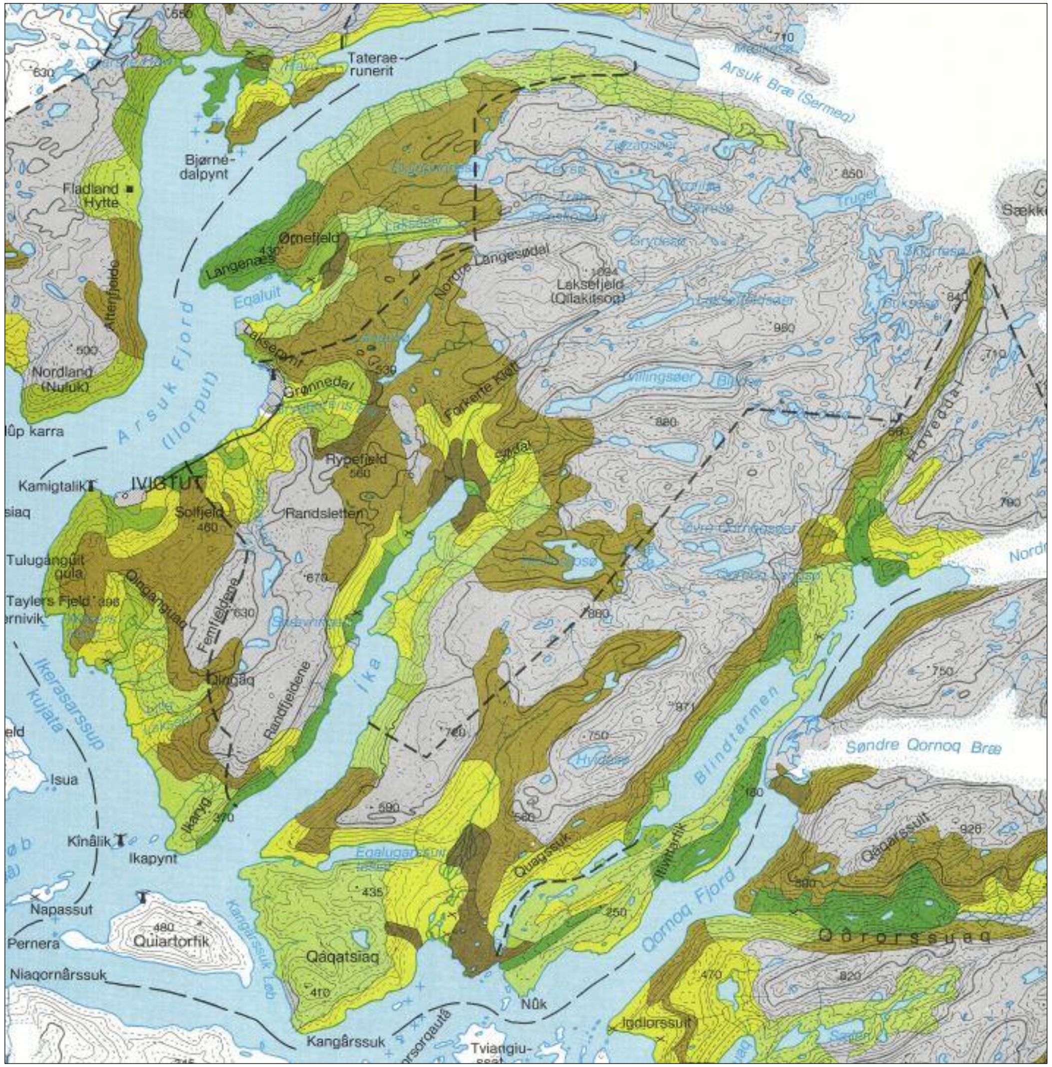
Appendix 1 – Place names (official and unofficial) commonly used in the Ivittuut region.

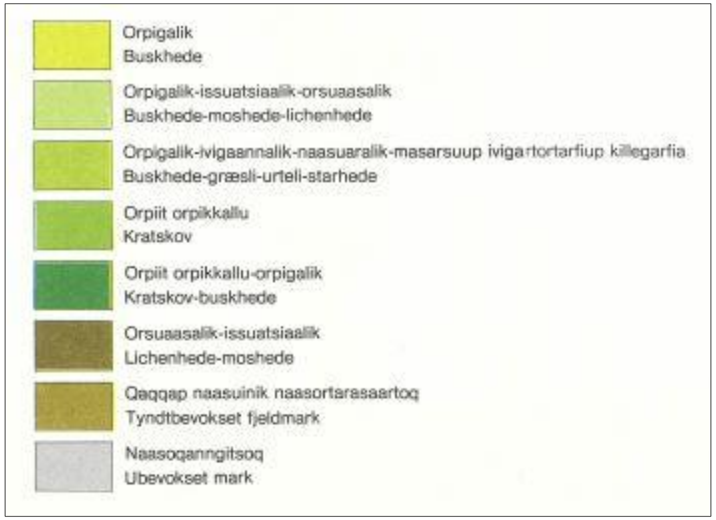
Official place names can be found here: https://www.arcgis.com/apps/View/index.html?appid=c5c7d9d52a264980a24911d7d33914b5

Figure 36. lace names (primarily Danish) for the Ivittuut region, which is inhabited by the Ivittuut muskox population.

Figure 37. Place names (primarily Greenlandic) for the Ivittuut region, which is inhabited by the Ivittuut muskox population.

Appendix 2: Maps of Ivittuut vegetation & elevation





The vegetation classifications are from 1986 and the work of Icelandic Institute for Agricultural Research and Greenland Experimental Station Upernaviarsuk. The Danish Geodetic Mapping Institute provided the underlying map for Greenland 1:250 000. The map was published in 1987 by the Co-operative Sheep Farming Associations in Greenland with the permission (A.395/86) from the Danish Geodetic Mapping Institute. Copyright belongs to Tryk Offsetmyndir sf. See figure 39 for English translation of the above legend for classification of vegetation.

Figure 38. 1987 vegetation map for the Ivittuut region. Copyright: Tryk Offsetmyndir sf.

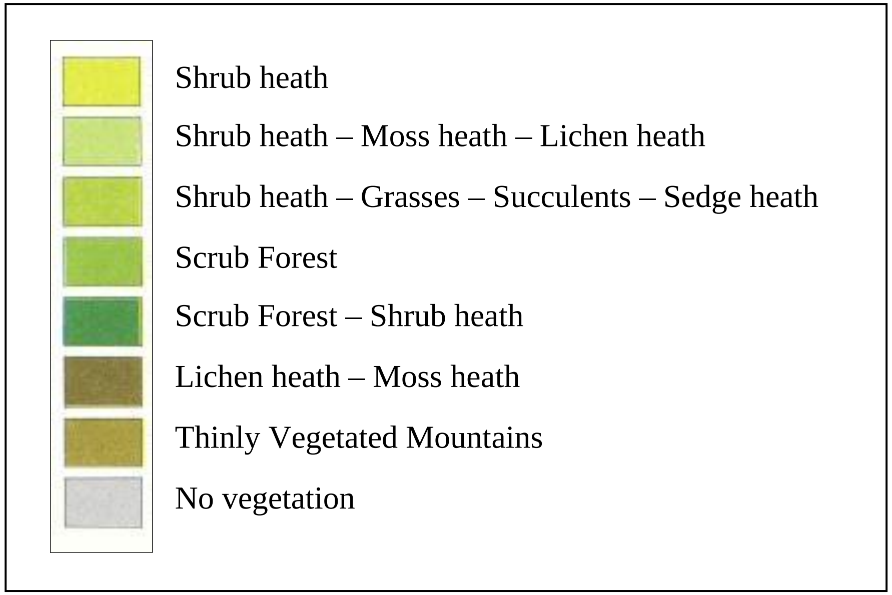


Figure 39. English legend explanation for the 1987 vegetation map of the Ivittuut region Figure 38. Copyright: Tryk Offsetmyndir sf. The category "No vegetation" refers to the barrens, which are currently better understood to have very sparse vegetation cover (Walker et al. 2005), and succulents are understood to be 'forbs'.

Figure 40. The 1987 map of vegetated landcover in the Ivittuut region and two immediately adjacent areas, constructed by Icelandic Institute for Agricultural Research and Greenland Experimental Station Upernaviarsuk. Areas of vegetated landcover that comprise possible range pasture for muskoxen are, North of Ilorput/Arsuk Fjord (pink), Ivittuut region (green) and south of Nordre Qoornoq Bræ (purple). See Table 8 for the area covered by specific vegetation class within each of the three vegetated areas above.

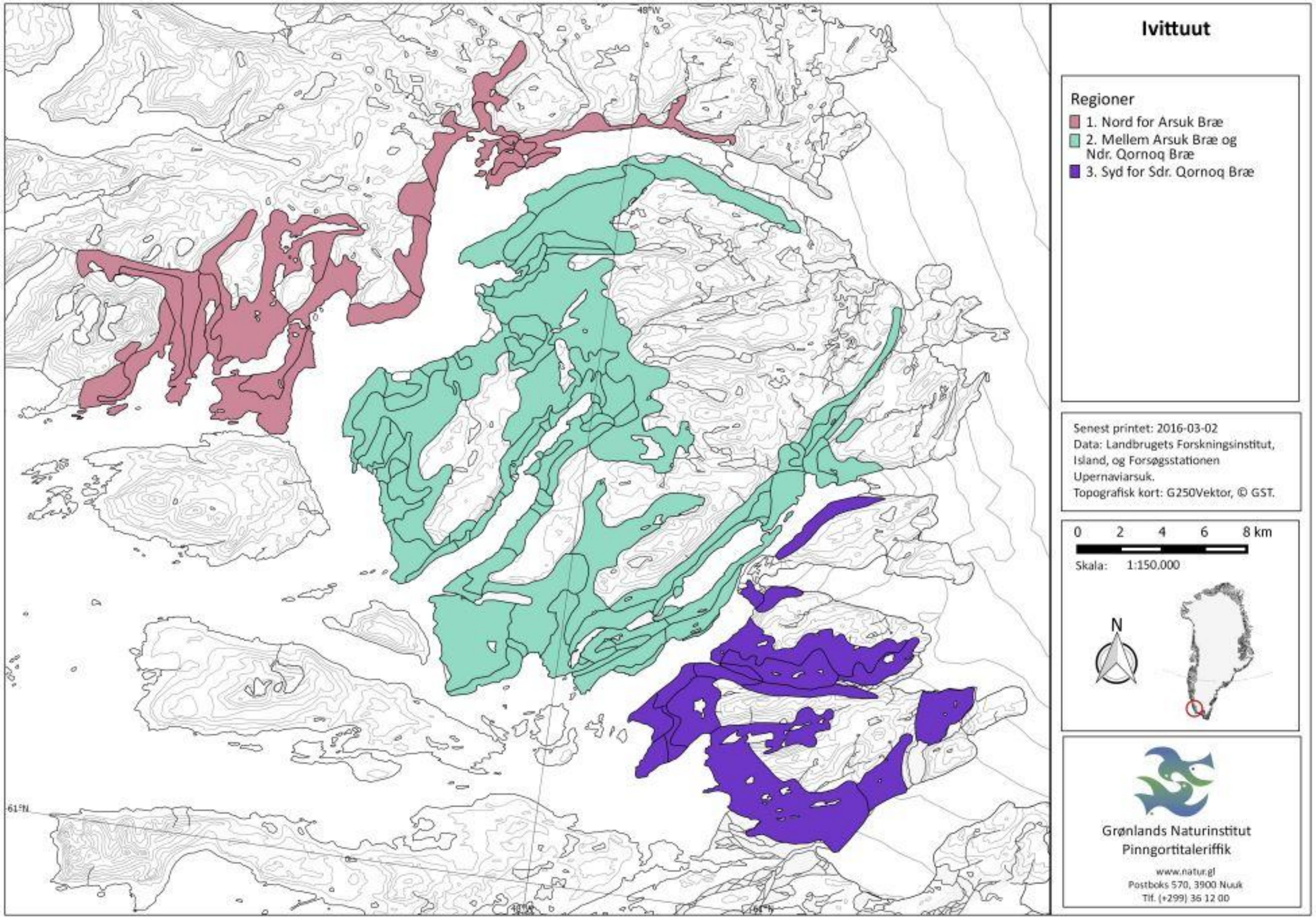


Table 8. Area for each of the 1987 vegetation classes occurring within the three areas of vegetated landcover illustrated in figure 40. Succulents are understood to be 'forbs'.

	Colour on Figure 40			
	Light Green	Dusky Pink	Purplish Blue	
Vegetation Classification	**Ivittuut region (km^2)**	**North of Ilorput/Arsuk Fjord (km^2)**	**South of Ndr. Qoornoq Bræ (km^2)**	**Sum Area (km^2)**
Shrub heath	41.8 (19.3 %)	18.0 (22.4 %)	12.0 (16.9 %)	71.8 (19.5 %)
Shrub heath – Moss heath – Lichen heath	50.6 (23.4 %)	6.1 (7.6 %)	27.0 (38.1 %)	83.7 (22.7 %)
Shrub heath – Grasses – Succulents – Sedge heath	12.2 (5.6 %)	6.6 (8.2 %)	0.7 (1.0 %)	19.5 (5.3 %)
Scrub forest	3.5 (1.6 %)	4.1 (5.1 %)	NA	7.6 (2.1 %)
Scrub forest – Shrub heath	12.8 (5.9 %)	0.9 (1.1 %)	5.3 (7.5 %)	19.0 (5.2 %)
Lichen heath – Moss heath	8.4 (3.9 %)	3.0 (3.7 %)	0.7 (1.0 %)	12.1 (3.3 %)
Thinly vegetated mountains	87.4 (40.3 %)	41.8 (51.9 %)	25.2 (35.5 %)	154.4 (41.9 %)
Sum vegetated area (km^2)	**216.7** (100 %)	**80.5** (100 %)	**70.9** (100 %)	**368.1** (100 %)
Barren (very sparse vegetation)	215.0	NA	NA	NA
Sum area (km^2)	**ca. 432**	NA	NA	NA

Elevation Legend

0-200 m, 95 km²

200-700 m, 270 km²

> 700 m, 66 km²

Lakes cover 19 km²

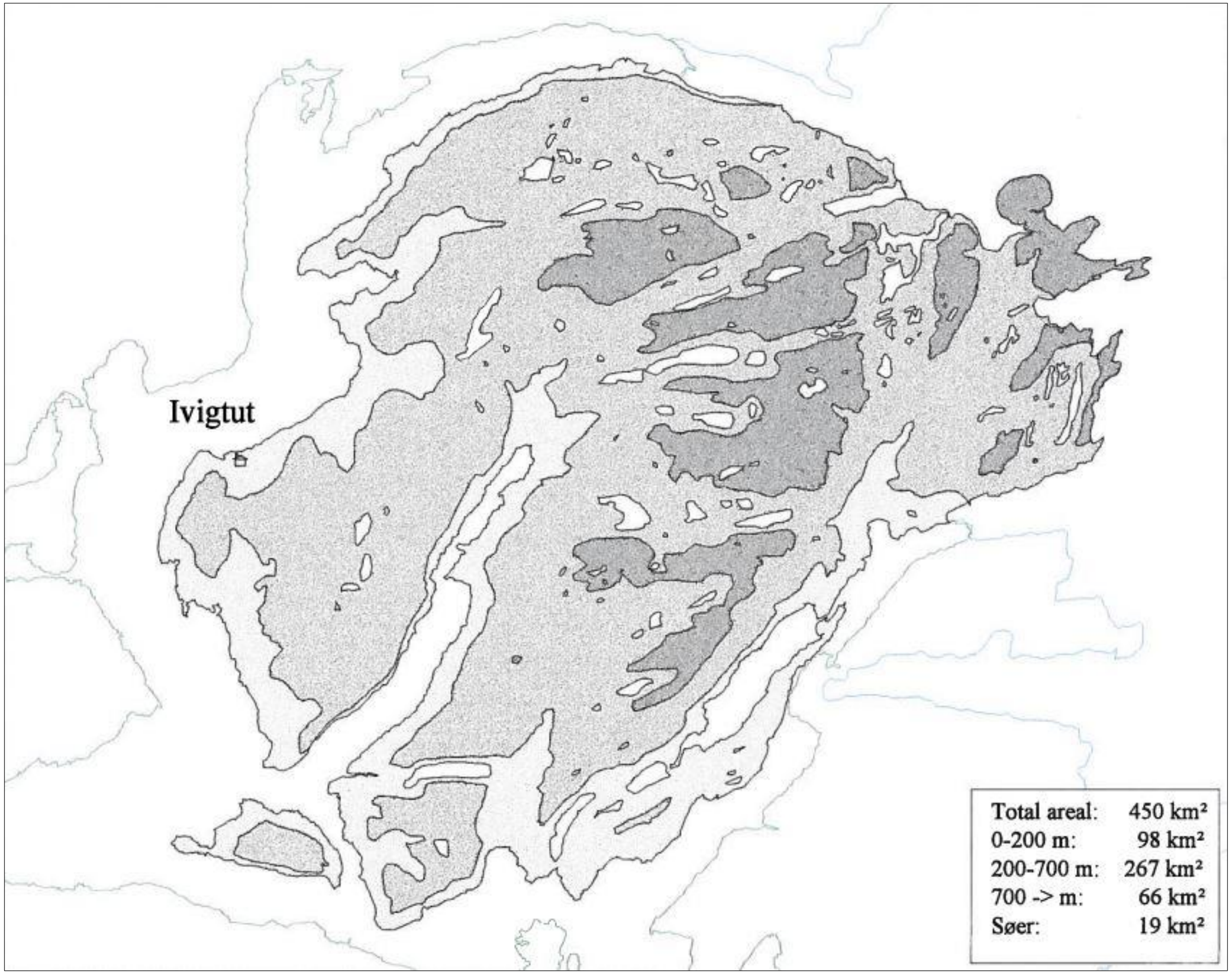


Figure 41. Map of the Ivittuut region, illustrating amount and distribution of three elevation categories. Although island Quiartorfik features on this map, its areas are not included in the areas provided.

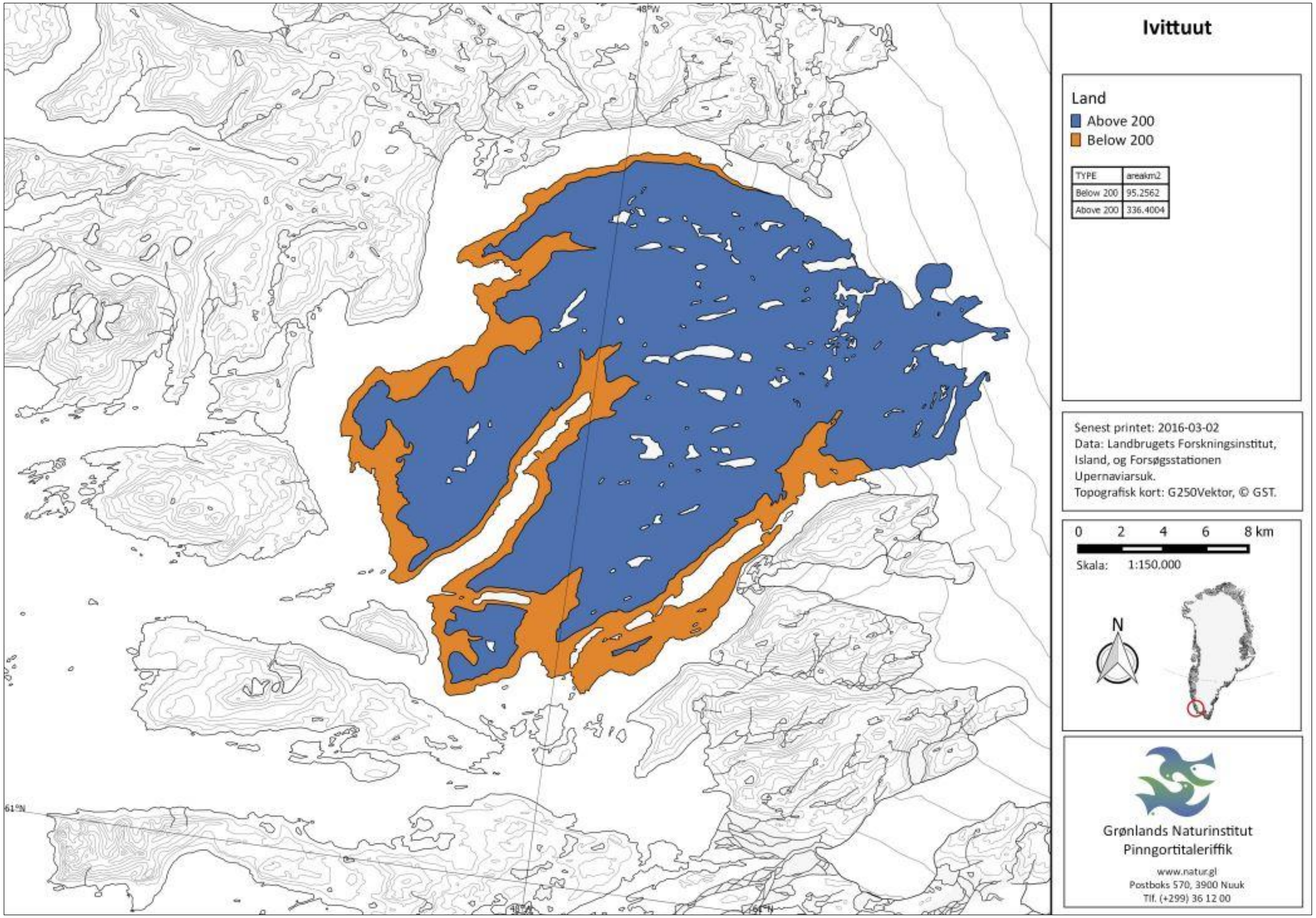


Figure 42. Map illustrating the amount and distribution of two elevation categories: Elevations of 0-200 m cover 95.3 km², and elevations above 200 m cover 336.4 km².

Appendix 3

Harvests & harvest regulation of the muskox population on the Ivittuut peninsula

Table 9. Harvest Ivittuut muskox population: months with hunting seasons and quota allocation for 1987 – 2016 period. Blank cells indicate values unknown.

Year	Commercial / Sport Season[1]	Trophy Bull Season[1]	QUOTA Commercial / Sport	QUOTA Trophy	QUOTA Total
1987-1993	none	none	0	0	**0**
1994	Jul/Sep/Dec	Jul/Sep/Dec	0	0	**5**
1995	Aug/Nov/Dec	Aug/Nov/Dec	18	5	**23**
1996	Aug/Nov/Dec	Aug/Nov/Dec	15	5	**20**
1997	Mar/Jun/Jul/Nov	Mar/Jun/Jul/Nov	25	5	**30**
1998	Jun/Jul	Jun/Jul	15	5	**20**
1999	Mar/Jun/Jul/Nov	Jul			**30**
2000	Mar/Jun/Nov	Mar/Jun	30	5	**35**
2001	Jul/Aug/Nov	Jul/Aug/Nov	30	10	**40**
2002	Mar/Jul/Aug/Nov	Jul/Aug			**45**
2003	Mar/Jul/Aug/Nov	Jul/Aug/Nov	70	15	**85**
2004	Mar/Jul/Aug/Nov/Dec	Jul/Aug	87	18	**105**
2005	Mar/Jul/Aug/Nov/Dec	Mar/Jul			**50**
2006	Mar/Jul/Aug/Nov/Dec	Jul/Aug	140	20	**160**
2007	Mar/Jul/Aug/Nov/Dec	Jul	130	25	**155**
2008	Mar/Jul/Aug/Nov/Dec	Jul/Aug			**160**
2009	Mar/Jul/Aug/Nov/Dec	Jul/Aug	170	30	**200**
2010	Mar/Jul/Aug/Nov/Dec	Jul/Aug/Sep/Oct			**260**
2011	Mar/Aug/Nov/Dec	Jul/Aug/Sep/Oct			**300**
2012	Feb/Mar/Aug/Sep/Oct/Nov	Jul/Aug/Sep			**300****
2013	Feb/Mar/Aug/Sep/Oct/Nov	Jul/Aug/Sep	225	78	**303**
2014	Mar/Aug/Sep/Oct/Nov	Jul/Aug/Sep/Oct	225	78	**303**
2015	Mar/Aug/Sep/Oct/Nov	Feb/Jul/Aug/Sep			
2016	Aug/Sep/Oct/Nov/Dec	Aug/Sep/Oct			

* 1991 Trial hunt by Ivittuut municipality took one adult bull. Further, 1992 trial hunt by Ivittuut municipality took two adult bulls, and a third was shot illegally at Arsuk.
**Assumed, given values in previous and subsequent years.
[1] Harvest may or may not apply to entire month and may have been restricted to specific dates within a given month.
Source: Greenland government Department of Fisheries & Hunting or filled-in report forms.

Table 10. Ivittuut muskox population: harvest numbers, harvest demographics (as per special report forms), and other sources of mortality.

Year	HARVEST: Unknown sex Calf	Unknown sex Juvenile	Cow Calf	Cow Juvenile	Cow Adult	Bull Calf	Bull Juvenile	Bull Adult	TOTAL Shot	OBSERVED MORTALITY: Illegal Shot	Crippling Shot	Natural	TOTAL known deaths
AGE (years)	< 1	> 1 & < 3	< 1	> 1 & < 3	> 3	< 1	> 1 & < 5	≥ 5					
1991	0	0	0	0	0	0	0	1	1	0	0	0	1*
1992	0	0	0	0	0	0	0	2	2	1	0	0	**3****
1993	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994	0	0	0	0	0	0	1	2	3	1	0	0	**4**
1995	0	0	0	4	0	0	8	9	21	0	0	1	**22**
1996	0	0	0	2	0	0	9	6	17	0	0	1	**18**
1997	0	0	0	2	0	0	19	9	30	0	0	0	**30**
1998	0	0	0	3	0	0	6	6	15	0	0	1	**16**
1999	0	0	0	9	0	0	16	2	27	0	0	1	**28**
2000	0	0	0	8	0	0	8	5	23	0	0	0	**23**
2001	0	0	0	4	1	0	12	17	34	0	0	0	**34**
2002	0	0	0	8	5	0	23	7	45	0	0	1	**46**
2003	0	0	0	18	0	0	33	12	79	0	0	1	**80**
2004	0	0	1	37	1	0	47	16	102	0	0	0	**102**
2005	0	0	0	26	4	0	40	14	84	0	0	0	**84**
2006	0	0	0	45	3	0	65	13	126	0	0	0	**126**
2007	0	0	0	22	2	0	35	21	80	0	1	0	**81**
2008	0	5	0	28	0	0	40	26	99	0	0	0	**99**
2009	0	0	17	23	13	13	53	29	148	0	0	4	**152**
2010	0	0	21	23	21	17	55	57	194	2	9	0	**205**
2011	0	0	3	32	16	5	28	70	154	1	0	0	**155**
2012	0	2	0	6	3	3	14	48	200	1	0	0	**201**
2013	1	1	17	38	22	22	107	56	264	0	0	0	**264**
2014	0	0	2	56	7	3	85	62	215	0	0	2	**217**
2015	0	0	0	44	6	0	80	84	214	1	0	6	**221**
2016	0	0	0	50	68	0	69	77	264	0	0	0	**264**
SUM	**1**	**8**	**61**	**488**	**172**	**63**	**853**	**651**	**2441**	**7**	**10**	**18**	**2,476**

* 1991 Trial hunt by Ivittuut municipality took one adult bull.
** 1992 Trial hunt by Ivittuut municipality took two adult bulls, and a third was shot illegally at Arsuk.
Sources: Special report forms (*særmeldingsskemaer*) for each animal shot, notes and observations by Per Nukaaraq Hansen, and observations during muskox counts.

In 2003, the Greenland Institute of Natural Resources (GINR) advised that the muskox density was high relative to the area with vegetation cover and might impact/alter existing vegetation landscapes. To conserve existing forage resources, GINR recommended the Ivittuut population be stabilized and kept at ≤ 300 muskoxen (Cuyler 2003).

In 2008, Ivittuut municipality petitioned the Home-Rule government of Greenland for local ownership of the Ivittuut muskox population (P.N. Hansen pers. comm.). Following a meeting with the government of Greenland's Department for Fisheries, hunting and Agriculture (DFFL), Ivittuut municipality clarified they wanted management control of the Ivittuut muskoxen, whose translocation they had financed in 1987. DFFL supported the idea of a locally managed muskox population in Ivittuut and began investigating possibilities together with the Ivittuut municipality and several other government entities.

Until 2009, the Ivittuut municipality regulated annual muskox harvest quotas independently of, but in discussion with, the Home-Rule government of Greenland's central administration. In 2009, this was then named Department of Fisheries, Hunting and Agriculture (DFFL) and the Department of Environment and Nature (DMU). Later names altered somewhat, and their acronyms became APN and DIM, respectively. Further, the municipality also allocated the harvest quota among sport, commercial and trophy hunting, and all hunting was still overseen by the Ivittuut hunting officer. The December 2009 minimum count observed ca. 900 muskox (P.N. Hansen pers. comm.). Given total Ivittuut land area is 432 sq km, muskox density was ca. 2 per km^2. The GINR advice for the 2010-2011 period in Ivittuut (Cuyler et al 2010) remained unchanged relative to that given in 2003 (Cuyler 2003).

In 2009, Self-Rule was established for Greenland. That same year, Greenland merged its existing 18 municipalities into just five. Ivittuut was amalgamated into the larger Sermersooq Municipality, with control of harvest regulation and allocation transferred to Sermersooq and the Self-Rule government of Greenland. Both are in Greenland's capital city, Nuuk. After harvest, the December 2009 muskox count of ca. 900 was triple that GINR had recommended in 2003 and again in 2010. Further, range deterioration (not specified) was noted in the Nuuk/Nuuk Sø area of the Ivittuut peninsula, which raised concern about potential problems for the muskox population (P.N. Hansen pers. comm.). Further, the number of old bulls (age > 9-years, well past trophy-prime) was deemed too high, because unwanted by trophy hunters.

In summer 2010, Sermersooq opened Ivittuut muskox harvest to any Greenland hunter and without hunting officer supervision for each animal. Violations of hunting regulations became common. These included use of low-caliber weapons (e.g. .222), firing into muskox groups from boats, cows shot despite being accompanied by a calf (age < 1-year), and meat, skins and trophy heads left to rot in the terrain (P.N. Hansen pers. comm.). Multiple crippled animals were observed. Several entire carcasses of muskoxen, dead from bullet wounds, were discovered. Photos were taken of six carcasses found, a trophy bull, a cow, and four subadults. Not surprisingly, foreign trophy hunters to the Ivittuut region in 2010 reacted negatively to this situation, which was bad 'advertising' for the Arsuk trophy industry (P.N. Hansen pers. comm.). During harvest control checks by hunting officer, muskoxen shot by non-Ivittuut hunters often did not match the license specified sex/age permitted owing to hunter inability to differentiate bulls from cows or adults from juveniles, and harvest was bull-biased with many trophy bulls taken (P.N. Hansen pers. comm.). The consensus among Arsuk hunters was the Ivittuut muskox population was being damaged by too many unsupervised outside hunters (P.N. Hansen pers. comm.).

Figure. 43. View northeast at the small coastal town of Arsuk, which is immediately north of the Ivittuut peninsula. Photo C. Cuyler.

Not surprisingly, conflict arose with local hunters from the Arsuk community (Fig. 43), who were concerned about the sustainability of their own subsistence harvests. Specifically endangered was their commercially valuable bull trophy hunting industry, which involved not just payment for a trophy bull, but also for local hunting guides, lodging, transport, and miscellaneous purchases in the settlement of Arsuk. Outside interest in hunting Ivittuut muskoxen continued. In 2012, Sermersooq was petitioned by hunters from both north and south of the Ivittuut region, but specifically Kujalleq (South Greenland municipality), for a larger portion of the annual Ivittuut muskox harvest (K. Lorentzen pers. comm. (Sermersooq borger service)). Meanwhile, development of local Arsuk management for Ivittuut muskoxen was gathering momentum.

Figure 44. The Arsuk Resource Management Council established June 2015: purpose to manage the muskox resource in the Ivittuut region. Front row left to right: Jonathan Rasmussen, Lassinnguaq Mikaelsen, Kaaleeraq Sørensen. Back row left to right: Gerhardt Frederiksen, Peter Albrechtsen, Jørgen Christensen, Frank Feldmann, Knud Mikaelsen, (not present for photo Ejnar Jakobsen). Photo C. Cuyler.

Arsuk Resource Management Council

Since 2000, the Ivittuut muskoxen population has been an important source of meat and income for the small remote Arsuk community, which has few alternative sources of income. By 2008, the well-established guided trophy hunting tours for Ivittuut muskoxen were of central economic importance to the Arsuk community (Cuyler et al. 2020). Meanwhile, the central government and research facilities were financially unable to undertake population assessments. The Greenland government proposed to hand over a share of the responsibility for managing the Ivittuut muskox population to the local users (Cuyler et al. 2020). The result was a collaborative community-government approach to monitoring and management. Thus, in June 2015, several local commercial hunters, trophy agents and interested individuals of the Arsuk community met with members of government administration, wildlife management, GINR and a sociologist in the Arsuk public school meeting room to discuss local monitoring and management of the muskox resource in the Ivittuut region (Cuyler et al. 2020). This resulted in establishment of the Arsuk Resource Management Council (Fig. 44) composed of local trophy agent/guides and commercial hunters/fishermen and environmentally interested locals. In 2015, Council goals for the Ivittuut muskox population included stable abundance, maximal calf production, stable bull trophy and local subsistence harvests. Since 2016, membership included several further Arsuk hunters having a stake in the status and health of the Ivittuut muskox population. Members are local muskox experts and participate in annual muskox counts (Fig. 45).

Figure 45. Ground count by local experts coordinating efforts with hunting officers to obtain minimum number of muskoxen present as well as sex and age structure in the Ivittuut muskox population. Photo C. Cuyler.

Trophy Harvest

Although some foreign trophy hunters may prefer bulls of advanced age, many seek muskox bulls offering maximum horn size, i.e. a trophy. In 2009, P.N. Hansen (pers. comm.) cited concern that old bulls (age > 9-years) were too numerous. The latter was a concern because local trophy guides/agents are aware that trophy hunters generally will not shoot an old bull with worn down, split, or cracked horns. Those characteristics lessen measured horn size, i.e. are not trophies. Severe horn wear is easily recognized by blunt rounded tips, which are the same color as the rest of the horn. No trace of black tips remains. Old bulls have participated in multiple breeding seasons, with dominance displays and fighting among bulls. Horn wear reduces horn size. Mature bulls aged 5-7 years, with undamaged boss and sharp, black-tipped horns present the best chance for maximal measurements of possible trophy size (albeit if pasture conditions provide a high quality, quantity, and availability of vegetation). Thus, the trophy agents among the Arsuk Resource Management council are interested in maintaining a renewable supply of bulls aged 5-7 years. The high densities of muskoxen observed since 2009 are likely incompatible with a renewable annual supply of bulls bearing trophy sized horns or the number of those bulls desired by the local trophy hunting industry in Arsuk, Ivittuut.

Vegetation

Within the Arsuk Resource Management Council, opinion was divided whether the Ivittuut vegetation was impacted by muskox grazing/browsing. While some members thought hard grazing was highly visible, others denied any vegetation change since the 1987 arrival of the muskoxen.

Miscellaneous

Greenland hunting bylaws for muskox include the following for sport and commercial hunters. The minimum legal caliber rifle is a 6.5 x .55. Expanding as well as full metal jacket ammunition are permitted. For foreign trophy hunters the minimum legal caliber is 7.62 mm (e.g. 30-06) and several types of ammunition are permitted.

Appendix 4

Minimum count & Demographics data collection sheet used in 2015 – 2017 period.

Table 11. Data collection sheet for 2015 count and demographics of muskoxen in Ivittuut region. Except for year calf born, data sheets for 2016-17 were the same.

Umimmaat / Moskus IVITTUUT 61°N_Vestgrønland – JUNI 2015 Ikinnerpaamik kisitsineq + katersat sannaq / Minimum Count + Demographics														
Ulloq	*Sumiiffik*	Umimmaat Amerlas-suiat	**Kinaana unknown ?**		**Piaraq** inunngorp **2015**	**Arnaviaq COW** ♀♀			**Angutiviaq BULL** ♂♂					
Date	*Grid* **Cell**	**Total Group size**	**ukiut / year ≥ 3**	**ukiut / year 1-2**	**Born 2015 CALF**	**ukiut / year 1**	**ukiut / year 2**	**ukiut / year ≥ 3**	**ukiut / year 1**	**ukiut / year 2**	**ukiut / year 3**	**ukiut / year 4**	**ukiut / year ≥ 5**	**ukiut / year ≥ 10**

Appendix 5
Muskox Sex & Age Field Guide, by C. Cuyler

MUSKOXEN – JUNE

Cow CALF

Small body size, NO horns.
White fuzz hair on forehead.
Body is covered with short soft dark fuzzy hair.
White patch hair behind shoulders is visible.
Males and females look alike, are indistinguishable.

Cow 1-year old

Body height is ca. ½ adult.
<u>Tiny</u> horns are either invisible or barely visible.
White fuzz hair across forehead is plentiful.

Cow 2-year old

Body height is ca. 2/3 adult
Horns are visible and <u>slender</u>, including at base.
White fuzz hair across forehead remains plentiful.

MUSKOXEN – JUNE

Bull CALF

Small body size, NO horns.
White fuzz hair on forehead.
Body is covered with short soft dark fuzzy hair.
White patch hair behind shoulders is visible.
Males and females look alike, are indistinguishable.

Bull 1-year old

Body height is ca. ½ adult
Small straight horns are highly visible.
Horn base is <u>thick</u>.
Horn tips are black and sharp.
White fuzz hair across forehead.

Bull 2-year old

Body height is ca. 2/3 adult
Horns are long with a definite forward curve.
Horn base is <u>thick</u>.
Horn tips are black with sharp point.
White fuzz hair across forehead.

MUSKOXEN – JUNE

Cow 3-year old

Horns are long and slender.
No forehead horn bases are visible.
Forehead is covered with white fuzz hair.
Horns curl forward and out sideways.

Cow 4-years and older

Cows 4-years and older have adult horn size/shape. Top of forehead has visible horn bases. Forehead will always have white fuzz hair. Adult cow horns are slender and curl in a generally forward direction rather than out sideways. Head and face are narrow.

MUSKOXEN – JUNE

Bull 3-year old

Horns are long and thick.
Horn bases are broad and pushing onto the forehead.
Horn bases are pale whitish colour.
Forehead fuzz hair is "pushed-up" by growing horns.
Horn tips are black with sharp points.

Bull 4-year old

Horn 'BOSS' covers forehead, but 'flat' and pale. Forehead horn 'BOSS' has no dark rugged markings. Fuzz hair still behind and between the two horns. Horn tips are black with sharp points. Head and face are broad.

MUSKOXEN – TROPHY Bulls – JUNE

Bull 5-6 year old

Horns are long, thick and curve out to sides.
Forehead horn BOSS deep with dark rugged markings.
White fuzz hair behind horns is gone.
Horn tips are black with sharp points.
Head and face are broad.

MUSKOXEN – TROPHY Bulls – June

Bull > 6-years old

Horns are long, thick and curve out to sides.
Forehead horn BOSS deep with dark rugged markings.
White fuzz hair behind horns is gone.
Horn tips have begun to wear down. The older the bull, the more rounded and blunted the tips become until no black colour is left.
Head and face are broad.

Muskox Sex & Age Field Guide, as implemented by MOXNET - muskox expert network under terrestrial Circumpolar Biodiversity Monitoring Program (CBMP) for Conservation of Flora & Fauna (CAFF). Available from CAFF website and C. Cuyler, e-mail: chris.cuyler@natur.gl. Available in six other languages: Kalaallisut, Dansk, Français, Inuinnaqtun, Inuktitut, and Русский (respectively; Greenlandic, Danish, French, Inuit Northwest Territories Canada, Inuit Nunavut Canada, and Russian).

Appendix 6: Raw data for 2015, 2016 and 2017 Ivittuut muskox counts

2015 Count

Table 12. Raw data 2015 muskox count (04– 12 June) in Ivittuut region. Zeros are data. Blank cells are lack of data.

2015 Date	Grid Cell	Group Size	Elevation (m)	Unknown sex/age	2015 Calf	Unknown sex	Cow ♀♀	Bull ♂♂			
						Age (years)					
						1 or 2	≥ 3	3	4	≥ 5	≥ 10
4 June	B8	5	<100	0	2	1	2	0	0	0	0
4 June	B8	2	<100	0	0	0	0	0	0	2	0
4 June	B8	4	<100	0	0	2	1	0	0	1	0
4 June	B8	13	<100	5	1	3	2	0	0	2	0
4 June	B8	7	>200	0	1	3	3	0	0	0	0
4 June	B8	2	<100	0	0	0	0	0	1	1	0
4 June	B7	10	<100	0	1	4	3	0	2	0	0
4 June	B7	7	<100	0	0	0	0	2	0	5	0
4 June	B7	4	>200	0	2	0	2	0	0	0	0
4 June	B6	4	<100	0	0	0	0	1	1	2	0
4 June	B6	8	<200	0	3	0	4	0	0	1	0
4 June	B7	3	<100	0	0	0	0	0	1	2	0
4 June	B6	4	<100	0	2	0	2	0	0	0	0
4 June	B6	3	<100	0	0	0	2	0	1	0	0
4 June	B6	3	<100	0	0	0	0	0	2	1	0
4 June	B7	10	<100	7						3	
4 June	B6	3	<100	0	0	0	0	0	2	1	0
4 June	B6	7	<100	0	0	0	0	1	1	5	0
4 June	B6	1	<100	0	0	0	1	0	0	0	0
4 June	A6	8	<100	0	0	2	1	1	2	2	0

4 June	A6	5	<100	0	0	0	1	0	0	4	0
4 June	B5	1	<100	0	0	0	0	0	0	1	0
4 June	C5	7	<100	0	1	0	1	3	1	1	0
6 June	D4	2	<100	0	0	1	0	0	1	0	0
6 June	D4	5	<200	0	1	2	2	0	0	0	0
6 June	D4	12	<100	0	1	1	2	3	1	4	0
6 June	D4	26	>200	0	3	7	10	3	0	3	0
6 June	D4	3	>200	0	1	0	2	0	0	0	0
6 June	D5	4	>200	0	0	0	0	2	0	2	0
6 June	D4	5	>200	0	1	2	2	0	0	0	0
6 June	D4	5	>200	0	0	2	3	0	0	0	0
6 June	D4	5	>200	0	0	1	2	1	1	0	0
6 June	D4	1	>200	0	0	0	0	1	0	0	0
6 June	D3	6	>200	6		0	0				
6 June	D3	2	>200	2		0	0				
6 June	D4	10	>200	0	2	3	3	2	0	0	0
6 June	D4	5	<100	0	1	1	3	0	0	0	0
6 June	D4	2	<100	0	0	0	0	0	0	2	0
6 June	D4	1	<100	0	0	0	0	0	0	1	0
6 June	D4	1	<100	0	0	0	0	0	0	1	0
6 June	D5	1	<100	0	0	0	0	0	0	1	0
6 June	D5	1	<100	0	0	0	0	0	0	1	0
8 June	D3	6	<100	0	2	2	2	0	0	0	0
8 June	D3	4	<100	0	2	0	2	0	0	0	0
8 June	D3	10	<100	0	1	6	3	0	0	0	0
8 June	D3	2	<100	0	0	0	0	2	0	0	0
8 June	E3	5	<100	0	2	0	2	0	0	1	0
8 June	E3	2	<100	0	0	0	0	0	0	2	0
8 June	E3	10	<100	0	2	4	4	0	0	0	0

8 June	E3	5	<100	0	1	2	2	0	0	0	0
8 June	E3	7	<100	0	1	2	4	0	0	0	0
8 June	E3	7	<100	5	1	0	1				
8 June	E3	2	<100	0	1	0	1	0	0	0	0
8 June	E3	3	<100	0	0	2	1	0	0	0	0
8 June	E3	3	<200	0	1	1	1	0	0	0	0
8 June	E3	2	>300	2		0	0				
8 June	E3	4	>300	4		0	0				
8 June	D3	7	<100	0	2	2	3	0	0	0	0
8 June	D3	5	<100	0	1	2	1	1	0	0	0
8 June	D3	2	<100	0	1	0	1	0	0	0	0
8 June	D3	4	<100	0	2	0	2	0	0	0	0
8 June	D3	2	<100	0	1	0	1	0	0	0	0
8 June	D3	5	<100	0	1	2	1	1	0	0	0
8 June	D3	5	<100	0	1	2	2	0	0	0	0
8 June	C3	3	<100	0	0	2	0	1	0	0	0
8 June	C3	8	<100	0	3	2	3	0	0	0	0
8 June	C3	1	<100	0	0	0	1	0	0	0	0
8 June	D2	1	<100	0	0	0	0	0	0	1	0
8 June	E3	8	<200	8		0	0				
9 June	C9	2	<100	0	0	0	0	0	0	2	0
9 June	C9	5	<100	0	0	1	3	0	0	1	0
9 June	D8	4	<100	0	1	2	1	0	0	0	0
9 June	D9	1	<100	0	0	0	0	0	0	1	0
9 June	D8	2	<100	0	1	0	1	0	0	0	0
9 June	D8	2	<100	0	1	0	1	0	0	0	0
9 June	D8	1	<100	0	0	0	0	0	0	1	0
9 June	D8	5	<100	5		0	0				
9 June	D8	4	<100	0	2	0	2	0	0	0	0

9 June	D8	2	<200	0	1	0	1	0	0	0	0
9 June	D9	5	<100	3	1	0	1	0	0	0	0
9 June	D8	1	<100	0	0	0	0	0	0	1	0
9 June	C9	1	<100	0	0	0	0	0	0	1	0
9 June	D9	3	<100	0	0	0	0	0	0	3	0
9 June	D9	6	<100	0	1	3	1	1	0	0	0
9 June	D9	1	<100	0	0	0	0	0	0	1	0
9 June	F10	6	<100	0	1	2	3	0	0	0	0
9 June	F9	1	<200	0	0	0	0	0	0	1	0
9 June	G9	3	<100	0	1	1	1	0	0	0	0
9 June	I7	1	<100	0	0	0	0	0	1	0	0
9 June	I6	4	<200	0	1	1	2	0	0	0	0
9 June	I6	3	<200	0	0	0	0	0	0	3	0
9 June	I6	1	<200	0	0	0	1	0	0	0	0
9 June	I6	5	<200	1	0	2	1	1	0	0	0
9 June	I6	2	<200	0	0	1	1	0	0	0	0
9 June	I6	2	<200	0	1	0	1	0	0	0	0
9 June	I6	10	<200	0	1	3	6	0	0	0	0
9 June	I6	3	<200	0	1	0	1	1	0	0	0
9 June	I6	3	<200	0	1	1	1	0	0	0	0
9 June	I6	4	<200	0	2	0	2	0	0	0	0
9 June	I6	37*	<200	4	7	9	15	1	1	0	0
9 June	I6	11	<100	0	1	1	6	1	1	1	0
9 June	I6	16*	<100	6	2	6	2				
9 June	I6	3	<100	0	1	1	1	0	0	0	0
9 June	I6	3	<100	0	0	2	1	0	0	0	0
9 June	I6	3	>200	0	1	1	1	0	0	0	0
9 June	I6	2	<100	0	0	0	1	1	0	0	0
9 June	I6	3	>200	0	1	1	1	0	0	0	0

9 June	I6	4	>200	0	0	1	0	3	0	0	0
9 June	I6	1	>200	0	0	0	1	0	0	0	0
9 June	I7	2	<100	0	1	0	1	0	0	0	0
9 June	I7	1	<100	0	0	0	0	1	0	0	0
9 June	I7	7	<100	0	2	2	2	1	0	0	0
9 June	I7	2	<100	0	0	0	2	0	0	0	0
9 June	I6	11	<100	0	2	6	3	0	0	0	0
9 June	I6	2	<100	0	0	0	0	0	0	2	0
9 June	I6	7	<100	5	1	0	1				
9 June	I7	10	<100	0	1	4	5	0	0	0	0
9 June	H7	4	<100	0	1	2	1	0	0	0	0
9 June	H7	1	<100	1	0	0	0				
9 June	H7	6	<100	4	1	0	1	0	0	0	0
9 June	I7	2	<100	0	0	0	0	1	0	1	0
9 June	I7	2	<100	0	0	1	1	0	0	0	0
9 June	I7	1	<100	0	0	0	0	0	1	0	0
9 June	I7	1	<100	0	0	0	0	1	0	0	0
9 June	I7	8	<100	0	2	1	5	0	0	0	0
9 June	I7	2	<100	0	0	2	0	0	0	0	0
9 June	I7	2	<100	0	0	0	1	0	0	1	0
9 June	I7	9	<100	0	1	1	1	3	1	2	0
9 June	I7	7	<100	2	1	2	2	0	0	0	0
9 June	I7	5	<100	0	1	2	2	0	0	0	0
9 June	I7	7	<100	0	2	1	2	1	1	0	0
9 June	I7	2	<100	0	1	0	1	0	0	0	0
9 June	I7	2	<100	0	0	0	2	0	0	0	0
9 June	H7	4	<100	0	1	2	1	0	0	0	0
9 June	H7	6	<100	2	0	3	1	0	0	0	0
9 June	H7	2	<200	0	0	1	1	0	0	0	0

9 June	H7	4	<100	0	1	1	1	1	0	0	0
9 June	H7	9	<100	4	2	0	3				
9 June	H7	10	<200	3	1	3	3				
9 June	H7	6	<100	0	1	2	3	0	0	0	0
9 June	H7	1	<100	0	0	0	1	0	0	0	0
9 June	H7	12	<100	2	2	2	5	1			
9 June	H7	20	<100	0	4	5	11	0	0	0	0
9 June	H7	11	<100	0	2	4	5	0	0	0	0
9 June	H7	4	<200	0	1	1	2	0	0	0	0
9 June	H7	1	<200	0	0	0	0	1	0	0	0
9 June	H7	11	<200	11		0	0				
9 June	H8	5	<200	0	1	1	2	1	0	0	0
10 June	E9	17	<100	0	3	4	4	4	0	2	0
10 June	E9	5	<100	0	1	0	1	0	1	2	0
10 June	E8	3	<200	0	0	1	2	0	0	0	0
10 June	E8	7	<200	0	1	2	4	0	0	0	0
10 June	D9	6	<200	0	1	1	1	2	1	0	0
10 June	E9	3	<100	0	1	1	1	0	0	0	0
10 June	E9	7	<100	6		0	0			1	
10 June	E9	8	<100	4	2	0	2				
10 June	E9	2	<100	0	1	0	1	0	0	0	0
10 June	E10	10	<100	0	2	4	4	0	0	0	0
10 June	E10	3	<100	0	0	0	0	0	0	3	0
10 June	C9	2	<100	0	0	0	0	0	1	1	0
10 June	C9	1	<100	0	0	0	0	0	0	1	0
10 June	D8	4	<100	0	1	1	2	0	0	0	0
10 June	D8	3	<100	0	1	1	1	0	0	0	0
10 June	D8	5	<100	0	1	2	2	0	0	0	0
10 June	D7	1	<100	0	0	0	1	0	0	0	0

10 June	D7	1	<100	0	0	0	0	0	0	1	0
10 June	E6	5	<100	0	1	2	2	0	0	0	0
10 June	E6	5	<100	0	0	2	3	0	0	0	0
10 June	F5	1	<100	0	0	0	0	0	0	0	1
10 June	F5	4	<100	0	1	2	1	0	0	0	0
10 June	F5	3	<100	0	1	1	1	0	0	0	0
10 June	F5	3	<100	0	0	0	1	0	1	1	0
10 June	F5	4	<100	0	1	2	1	0	0	0	0
10 June	F5	2	<100	0	1	0	1	0	0	0	0
10 June	F5	7	<100	0	0	2	3	0	0	2	0
10 June	F5	2	<100	0	1	0	1	0	0	0	0
10 June	F5	4	<100	0	0	2	2	0	0	0	0
10 June	F5	1	<100	0	0	0	1	0	0	0	0
10 June	E5	2	<100	0	1	0	1	0	0	0	0
10 June	E5	2	<100	0	0	1	1	0	0	0	0
10 June	E5	14	<100	0	3	6	5	0	0	0	0
10 June	E5	22	<100	0	5	10	6	1	0	0	0
10 June	E5	14	<100	0	2	7	5	0	0	0	0
10 June	E5	27	<100	0	4	11	11	1	0	0	0
10 June	E5	27*	>200	17	4	0	6				
10 June	E5	14*	<100	6	2	0	6				
10 June	E5	1	<100	0	0	0	0	0	0	1	0
10 June	E5	5	<100	0	1	0	4	0	0	0	0
10 June	E6	6	<100	0	2	1	3	0	0	0	0
10 June	E6	9	<100	0	2	3	3	1	0	0	0
10 June	E6	5	<100	0	1	2	2	0	0	0	0
10 June	E6	2	<100	0	0	0	0	2	0	0	0
10 June	E6	10	<100	0	1	4	4	0	1	0	0
10 June	E6	14	<100	0	2	6	4	1	1	0	0

10 June	E6	7	<100	0	1	1	3	0	2	0	0
10 June	E6	6	<100	0	2	2	2	0	0	0	0
10 June	E6	7	<100	2	1	0	2	2	0	0	0
10 June	E6	4	<100	0	2	0	2	0	0	0	0
10 June	E6	6	<100	0	1	3	2	0	0	0	0
10 June	E6	3	<100	0	0	2	1	0	0	0	0
10 June	E6	4	<100	1	1	0	2	0	0	0	0
10 June	E6	8	<100	0	2	3	3	0	0	0	0
10 June	E6	4	<100	0	1	1	2	0	0	0	0
10 June	E6	4	<100	0	1	1	2	0	0	0	0
10 June	E6	3	<100	0	0	1	2	0	0	0	0
10 June	E6	7	<100	0	1	4	2	0	0	0	0
10 June	E6	7	<100	0	3	0	3	0	0	1	0
10 June	D6	2	<100	0	0	0	0	1	1	0	0
10 June	D6	3	<100	0	1	1	1	0	0	0	0
10 June	D6	5	<100	0	2	1	2	0	0	0	0
10 June	D7	5	<100	0	2	1	2	0	0	0	0
10 June	D7	5	<100	0	1	3	1	0	0	0	0
10 June	D7	2	<100	0	1	0	1	0	0	0	0
10 June	D7	2	<100	0	1	0	1	0	0	0	0
10 June	D7	3	<100	0	0	1	2	0	0	0	0
10 June	D7	2	<100	0	1	0	1	0	0	0	0
10 June	D7	1	<100	0	0	0	0	0	1	0	0
10 June	D7	15	<100	0	3	6	5	1	0	0	0
10 June	D7	9	<100	0	1	4	4	0	0	0	0
10 June	D7	9	<100	0	1	5	3	0	0	0	0
10 June	C8	3	<100	0	1	0	2	0	0	0	0
10 June	C8	8	<100	0	2	3	3	0	0	0	0
10 June	C8	4	<100	0	2	0	2	0	0	0	0

10 June	C8	8	<100	0	2	3	3	0	0	0	0
10 June	C8	5	<100	0	2	1	2	0	0	0	0
10 June	C8	2	<100	0	0	1	1	0	0	0	0
12 June	8-9G	64*	<200	13	11	0	38			2	

*NOT all one group. Several groups lumped into one entry.

Table 13. Raw data for one group of five muskoxen observed on north side of Arsuk Fjord, and therefore emigrated out of Ivittuut region, muskox count 04–12 June 2015.

2015 Date	Grid Cell	Group Size	Elevation (m)	Unknown sex/age	2015 Calf	Unknown sex	Cow ♀♀	Bull ♂♂			
						Age (years)					
						1 or 2	≥ 3	3	4	≥ 5	≥ 10
8 June	1G	5	<100	0	0	2	3	0	0	0	0

2016 Count

Table 14. Raw data 2016 muskox count (23 June – 02 July) in Ivittuut region. Zeros are data. Blank cells are lack of data.

2016 Date	Grid Cell	Group Size	Elevation (m)	Unknown sex/age	2016 Calf	Unknown sex			Cow ♀♀			Bull ♂♂					
						Age (years) 1	2	1 or 2	1	2	≥ 3	1	2	3	4	≥ 5	≥ 10
23 June	G2	3	>200	0	0	0	0	0	0	0	1	1	0	1	0	0	0
23 June	G2	5	<200	0	0	0	0	1	0	0	2	1	1	0	0	0	0
23 June	G2	1	<200	0	0	0	0	0	0	0	0	0	0	1	0	0	0
23 June	G2	1	<200	0	0	0	0	0	0	0	0	0	1	0	0	0	0
23 June	D4	5	<200	0	0	0	0	0	1	0	3	0	1	0	0	0	0
23 June	D3	2	<200	0	0	0	0	0	0	0	0	0	0	0	2	0	0
24 June	D3	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	D3	5	<200	0	0	0	0	0	1	0	2	0	2	0	0	0	0
24 June	E3	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	E3	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	E3	6	<200	0	0	0	0	0	1	0	3	0	1	0	1	0	0
24 June	E3	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	E3	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	E3	1	>200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	E3	1	>200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24 June	D3	1	<200	0	0	0	0	0	0	0	1	0	0	0	0	0	0
24 June	E3	6	>200	0	0	0	0	1	0	1	2	0	0	2	0	0	0
24 June	E3	3	>200	0	0	0	0	0	0	0	1	1	1	0	0	0	0
24 June	E3	6	>200	0	0	0	2	0	0	0	2	0	1	1	0	0	0
24 June	D4	2	>200	0	0	0	0	1	0	0	1	0	0	0	0	0	0
24 June	F2	6	>200	0	0	0	0	2	0	0	2	0	1	0	0	1	0
24 June	F4	8	>200	0	0	0	0	2	0	0	6	0	0	0	0	0	0
24 June	D5	4	>200	4	0	0	0										
24 June	E4	10	>200	10	0	0	0										
24 June	E4	8	>200	8	0	0	0										

24 June	E4	14	>200	0	0	0	0	1	1	0	10	0	2	0	0	0	0
24 June	D4	10	>200	0	0	0	0	1	1	0	4	2	2	0	0	0	0
25 June	D4	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
25 June	D4	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
25 June	D5	4	<200	0	0	0	0	0	0	0	0	0	0	0	1	3	0
25 June	D5	2	<200	0	0	0	0	0	0	0	0	0	0	0	0	2	0
25 June	D5	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
25 June	D5	7	>200	0	0	0	0	2	2	0	3	0	0	0	0	0	0
25 June	D5	5	>200	0	0	0	0	0	1	0	3	1	0	0	0	0	0
25 June	D4	3	<200	0	0	0	0	0	0	0	0	0	0	0	0	3	0
25 June	D5	9	<200	0	0	0	0	2	2	0	4	0	0	1	0	0	0
25 June	D5	5	>200	0	0	0	0	0	1	0	2	0	1	0	1	0	0
25 June	D5	12	>200	6	0	0	0	0	1	0	3	1	0	0	0	1	0
26 June	C5	3	>200	0	0	0	0	0	0	0	0	0	1	1	0	1	0
26 June	C5	4	>200	0	1	0	0	0		0	3		0	0	0	0	0
26 June	C5	6	<200	0	0	0	0	1	2	0	2	1	0	0	0	0	0
26 June	C5	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
26 June	C5	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
26 June	B6	3	>200	0	0	0	0	1	0	0	2	0	0	0	0	0	0
26 June	B6	4	>200	0	0	0	0	0	1	0	2	0	1	0	0	0	0
26 June	B6	2	>200	0	0	0	0	0	0	1	1	0	0	0	0	0	0
26 June	B6	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
26 June	B6	14	<200	0	0	0	0	3	2	0	6	0	2	1	0	0	0
26 June	B6	6	>500	0	0	0	0	0	1	0	4	1	0	0	0	0	0
26 June	B6	2	>400	0	0	0	0	0	1	0	1	0	0	0	0	0	0
26 June	B6	3	>400	0	0	0	0	1	0	0	2	0	0	0	0	0	0
26 June	B6	14	>400	0	0	0	0	4	2	0	7	1	0	0	0	0	0
26 June	B6	2	>300	0	0	0	0	0	0	0	1	0	1	0	0	0	0
26 June	B6	18	<200	0	0	0	0	2	4	1	9	0	0	2	0	0	0
26 June	B6	9	>200	0	0	0	0	1	1	1	5	1	0	0	0	0	0
26 June	B6	3	<200	0	0	0	0	0	0	0	0	0	0	0	1	2	0
27 June	B7	12	<200	4	2		1	2			3						

27 June	B7	5	<200	0	0	0	0	0	0	0	0	0	0	1	2	2	0
27 June	B7	8	>400	8													
27 June	B7	3	>200	0	0	0	0	0	0	0	0	0	0	0	0	3	0
27 June	B8	5	>200	3	1						1						
27 June	B8	4	>200	0	0	0	0	0	0	0	0	0	0	0	0	4	0
27 June	B8	6	>200	5			1										
27 June	B8	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	B8	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	C8	6	<50	0	0	0	0	2	0	0	2	0	1	1	0	0	0
27 June	D7	1	<50	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	D7	4	<50	0	0	0	0	1	1	0	2	0	0	0	0	0	0
27 June	D7	3	<50	0	0	0	0	0	0	0	0	0	1	0	2	0	0
27 June	D7	8	<50	2				1	1	0	2	0	0	1	1	0	0
27 June	D6	26	<100	0	0	0	0	4	4	0	13	3	1	1	0	0	0
27 June	D6	4	<100	0	0	0	0	0	1	0	2	1	0	0	0	0	0
27 June	D6	7	<100	0	0	0	0	1	1	1	3	1	0	0	0	0	0
27 June	E6	11	<100	0	0	0	0	3	1	0	5	1	0	1	0	0	0
27 June	E6	3	<10	0	0	0	0	0	0	0	1	1	1	0	0	0	0
27 June	E6	4	<10	0	0	0	0	1	1	0	2	0	0	0	0	0	0
27 June	E5	6	<50	0	0	0	0	0	0	0	1	1	1	0	0	3	0
27 June	E5	1	<3	0	0	0	0	0	0	0	0	0	0	1	0	0	0
27 June	E5	7	<200		2	0	0	1		0	3		0	0	1	0	0
27 June	E5	20	<100		2	2		6	1		8	1		0	0	0	0
27 June	E5	2	<100		1	0		0		0	1		0	0	0	0	0
27 June	E5	1	<100	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27 June	E5	3	<100	0	0	0	0	0	0	0	0	0	0	0	0	3	0
27 June	E5	10	<100		4			0		1	3		2	0	0	0	0
27 June	E5	11	<100	0	0	0	0	3	1	0	5	1	1	0	0	0	0
27 June	E5	3	<100	0	0	0	0	0	0	0	0	0	0	0	0	3	0
27 June	E6	15	<100	1	0	0	0	3	1	1	8	1	0	0	0	0	0
27 June	E6	4	<100	0	0	0	0	0	0	0	2	2	0	0	0	0	0
27 June	E6	1	<100	0	0	0	0	0	0	0	0	0	0	0	0	1	0

27 June	E6	3	<200	0	0	0	0	0	0	0	2	0	0	0	0	1	0
27 June	E6	1	>300	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	E6	3	<100	0	0	0	0	0	0	0	1	0	0	0	1	1	0
27 June	E6	10	<100	0	0	0	0	2	1	1	4	1	0	1	0	0	0
27 June	E6	2	>300	2	0	0	0	0	0	0	0	0	0	0	0	0	0
27 June	E6	1	<100	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	E6	1	<10	0	0	0	0	0	0	0	0	0	0	0	1	0	0
27 June	D6	4	<100	0	0	0	0	1	1	0	2	0	0	0	0	0	0
27 June	D6	2	<50	0	0	0	0	0	0	0	0	0	0	1	0	1	0
27 June	D7	1	<5	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	D7	3	<200		1			0		0	2		0	0	0	0	0
27 June	D7	2	<200	0	0	0	0	0	0	0	0	0	0	0	0	2	0
27 June	D7	2	<200	0	0	0	0	0	0	0	0	0	0	1	0	1	0
27 June	D7	1	<200	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27 June	D7	2	<200		1	0		0		0	1		0	0	0	0	0
27 June	D7	12	<200		2	2		2			6			0	0	0	0
27 June	D7	12	<200				5	0			7			0	0	0	0
27 June	D7	7	<200		4			1		0	2		0	0	0	0	0
27 June	D8	5	<200				2	0			3			0	0	0	0
27 June	C8	2	<200				1	0			1			0	0	0	0
27 June	C8	1	>400	1													
27 June	C9	15	<50	0	0	0	0	2	2	1	7	1	2	0	0	0	0
27 June	C9	5	<50	0	0	0	0	0	2	0	2	0	1	0	0	0	0
27 June	C9	1	<50	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27 June	D9	2	<50		1			0		0	1	0	0	0	0	0	0
27 June	D9	5	<100		2			0			2	1	0	0	0	0	0
27 June	D9	4	>400	0	0	0	0	2	0	0	2	0	0	0	0	0	0
27 June	C9	3	<100	0	0	0	0	0	0	0	0	0	0	0	0	3	0
27 June	C10	1	<100	0	0	0	0	0	0	0	0	0	0	0	0	1	0
29 June	E9	8	<50	1	0	0	0	0	0	1	1	1	0	0	0	4	0
29 June	E9	8	<50	0	0	0	0	0	1	1	1	0	0	1	1	3	0
29 June	E9	2	<50	0	1	0	0	0		0	1		0	0	0	0	0

29 June	D9	4	<100	0	0	0	0	1	1	0	2	0	0	0	0	0	0
29 June	D9	2	<100	0	1	0	0	0		0	1		0	0	0	0	0
29 June	E8	4	>200	0	0	0	0	0	0	0	2	0	0	0	1	0	1
29 June	D9	1	<50	0	0	0	0	0	0	0	1	0	0	0	0	0	0
29 June	E8	5	>200	0	0	0	0	0	0	1	2	0	0	1	0	0	1
29 June	E8	2	>200	2				0									
29 June	E8	5	>200	0	0	0	0	1	0	0	2	1	0	1	0	0	0
29 June	E8	11	>200	0	0	0	0	1	1	0	6	1	0	1	0	1	0
29 June	E8	3	>100	0	0	0	0	0	0	0	3	0	0	0	0	0	0
29 June	E8	3	>300				2	0			1			0	0	0	0
29 June	E8	5	>400	0	0	0	0	1	1	0	2	0	1	0	0	0	0
29 June	E8	16	>200	0	0	0	0	2	2	1	8	1	1	1	0	0	0
29 June	E8	4	>300	0	0	0	0	0	1	0	2	0	0	1	0	0	0
29 June	E8	6	>400	0	0	0	0	1	1	0	2	2	0	0	0	0	0
29 June	E8	5	>300	0	0	0	0	0	0	0	3	0	1	0	0	1	0
29 June	E8	2	>200	0	0	0	0	0	0	0	2	0	0	0	0	0	0
29 June	E8	10	>300	0	0	0	0	0	2	0	5	3	0	0	0	0	0
29 June	E9	9	>200	0	0	0	0	2	4	0	2	1	0	0	0	0	0
29 June	E9	8	>200	0	0	0	0	0	0	2	4	0	1	0	0	1	0
29 June	E9	8	>200	0	0	0	0	2	0	0	5	0	1	0	0	0	0
29 June	E9	7	>200	0	0	0	0	1	0	2	2	0	0	1	1	0	0
29 June	E8	2	>400	0	0	0	0	0	0	1	1	0	0	0	0	0	0
29 June	E9	6	>200	0	0	0	0	1	1	0	3	0	0	1	0	0	0
29 June	E8	12	>300	0	0	0	0	1	1	1	5	1	1	1	0	1	0
29 June	E9	5	>200	0	0	0	0	0	1	0	2	2	0	0	0	0	0
1 July	E9	2	<50	0	0	0	0	0		0	0	0	0	0	0	2	0
1 July	E9	8	<50	0	0	0	0	1	1	0	3	1	1	0	0	1	0
1 July	E9	1	<50	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	E9	3	<50	0	0	0	0	1	0	0	1	0	1	0	0	0	0
1 July	E9	7	<50	0	1	1	0	2			3	0	0	0	0	0	0
1 July	E9	1	<50	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	E10	7	<50	0	0	0	0	1	2	0	3	1	0	0	0	0	0

1 July	E9	5	<50				2	1			2	0	0	0	0	0	0
1 July	E9	3	<100				1	2	0	0	0	0	0	0	0	0	0
1 July	F9	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	G9	2		0	0	0	0	0	1	0	1	0	0	0	0	0	0
1 July	H8	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	F9	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	F9	4		0	0	0	0	2	0	0	2	0	0	0	0	0	0
1 July	F9	8		0	0	0	0	1	1	0	4	1	0	0	0	1	0
1 July	H7	7		0	0	0	0	1	2	0	3	0	1	0	0	0	0
1 July	H7	5		5	0	0	0	0	0	0	0	0	0	0	0	0	0
1 July	H7	15		0	0	0	0	2	0	0	8	0	1	1	0	3	0
1 July	H7	2		0	0	0	0	0	0	0	0	0	1	0	0	1	0
1 July	H7	1		0	0	0	0	0	0	0	1	0	0	0	0	0	0
1 July	H7	4		0	0	0	0	1	0	0	2	0	1	0	0	0	0
1 July	H7	5		0	0	0	0	0	1	0	3	0	0	0	0	1	0
1 July	H7	1		0	0	0	0	0	0	1	0	0	0	0	0	0	0
1 July	H7	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
1 July	I7	2		0	0	0	0	0	1	0	1	0	0	0	0	0	0
1 July	I7	2		0	0	0	0	0	0	1	1	0	0	0	0	0	0
1 July	I7	10		0	0	0	0	0	1	0	2	1	2	0	0	4	0
1 July	I7	7		0	0	0	0	0	0	0	4	0	3	0	0	0	0
1 July	I7	6		0	0	0	0	1	1	0	3	0	0	0	0	1	0
1 July	I6	5		0	0	0	0	0	1	2	1	0	1	0	0	0	0
1 July	I6	2		0	0	0	0	0	0	2	0	0	0	0	0	0	0
1 July	I7	2		0	0	0	0	0	0	0	0	0	0	0	0	2	0
1 July	I7	2		0	0	0	0	1	0	0	1	0	0	0	0	0	0
1 July	I7	5		0	0	0	0	1	1	0	2	1	0	0	0	0	0
1 July	I7	7		0	0	0	0	0	0	0	4	2	1	0	0	0	0
2 July	I7	3		0	0	0	0	0	0	0	1	1	0	0	0	1	0
2 July	I7	2		0	0	0	0	0	0	2	0	0	0	0	0	0	0
2 July	I6	2		0	0	0	0	0	0	0	0	0	0	1	0	1	0
2 July	I6	7		0	0	0	0	0	1	2	2	2	0	0	0	0	0

2 July	I6	7		0	0	0	0	0	0	0	4	1	0	0	0	2	0
2 July	I6	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
2 July	I6	1		0	0	0	0	0	0	0	0	0	0	0	0	1	0
2 July	I6	4		0	0	0	0	0	1	0	3	0	0	0	0	0	0
2 July	I6	4		0	0	0	0	1	0	0	1	2	0	0	0	0	0

2017 Count

Table 15. Raw data 2017 muskox count (08–13 June) in Ivittuut region. Zeros are data. Blank cells are lack of data.

2017 Date	Grid Cell	Group Size	Elevation (m)	Unknown sex/age	2017 Calf	Unknown sex				Cow ♀♀			Bull ♂♂					
						Age (years)												
						1	2	1- 2	≥ 3	1	2	≥ 3	1	2	3	4	≥ 5	≥ 10
8 June	B6	7	< 50		1					2	0	3	0	1	0	0	0	0
8 June	B6	6	< 50		0					0	1	3	0	2	0	0	0	0
8 June	B6	4	< 50		3					0	0	1	0	0	0	0	0	0
8 June	B6	4	< 50		2					0	0	2	0	0	0	0	0	0
8 June	B6	4	< 50		2					0	0	2	0	0	0	0	0	0
8 June	B6	1	< 50		0					0	0	0	0	1	0	0	0	0
8 June	B6	2	< 50		1					0	0	1	0	0	0	0	0	0
8 June	B6	5	< 50		0					0	0	2	0	2	1	0	0	0
8 June	B7	1	< 50		0					0	0	0	0	0	0	0	1	0
9 June	A6	1	3		0					0	0	0	0	0	1	0	0	0
9 June	B6	4	30		2					0	0	2	0	0	0	0	0	0
9 June	B6	2	< 50	2														
9 June	A6	3	3		1					0	0	1	0	0	0	1	0	0
9 June	B5	1	< 50		0					0	0	1	0	0	0	0	0	0
9 June	B5	3	< 50		0					0	0	0	0	0	0	1	2	0
9 June	B5	3	< 50		1					0	0	2	0	0	0	0	0	0
9 June	B5	3	< 50		1					0	1	1	0	0	0	0	0	0
9 June	B5	2	< 50	2														
9 June	B6	2	10		0					0	0	0	0	0	0	1	1	0
9 June	B6	8	10		2					0	0	2	0	2	2	0	0	0
9 June	D4	5	10		0					0	0	3	0	0	0	1	1	0
9 June	D4	3	10		0					0	0	0	0	0	1	2	0	0
9 June	D4	1	20	1														
9 June	D4	3	< 50		0					0	0	0	0	0	1	1	1	0
9 June	D4	6	< 50		2					1	0	3	0	0	0	0	0	0

9 June	D4	4	< 50		1		0	1	1	0	0	0	1	0	0
9 June	D4	4	<100		0		0	0	1	0	0	1	2	0	0
9 June	D4	10	< 50		5		0	0	5	0	0	0	0	0	0
9 June	D4	5	< 50		1		1	0	2	1	0	0	0	0	0
9 June	D4	1	< 50		0		0	0	1	0	0	0	0	0	0
9 June	D4	1	< 50			1									
9 June	D4	3	< 50		1	1	0	0	1	0	0	0	0	0	0
9 June	D4	1	< 50	1											
9 June	D4	4	< 50		1	2	0	0	1	0	0	0	0	0	0
9 June	D4	2	< 50		0		0	0	0	0	0	1	1	0	0
9 June	D4	3	< 50		0		0	2	0	0	1	0	0	0	0
9 June	D4	2	< 50		0		1	0	1	0	0	0	0	0	0
9 June	D4	2	< 50		1		0	0	1	0	0	0	0	0	0
9 June	D4	6	< 50		0		0	0	0	0	0	1	2	3	0
9 June	D4	3	< 50		1		0	0	1	0	0	0	0	1	0
9 June	D4	2	< 50		0		0	0	0	0	0	0	0	2	0
9 June	D4	2	< 50		0		0	0	1	0	0	0	0	1	0
9 June	D4	1	< 50		0		0	0	1	0	0	0	0	0	0
9 June	D4	2	< 50		1		0	0	1	0	0	0	0	0	0
9 June	D4	2	< 50		1		0	0	1	0	0	0	0	0	0
9 June	D4	1	10		0		0	0	0	0	0	1	0	0	0
9 June	D3	6	10		2		0	0	2	0	2	0	0	0	0
9 June	D3	4	< 50		2		0	0	2	0	0	0	0	0	0
9 June	D3	1	< 50		0		0	0	0	0	0	0	0	1	0
9 June	D3	3	< 50		1		1	0	1	0	0	0	0	0	0
9 June	D3	3	< 50		1		0	0	2	0	0	0	0	0	0
9 June	D3	1	< 50		0		0	0	1	0	0	0	0	0	0
9 June	D3	2	< 50	2											
9 June	D3	3	< 50	3											
9 June	D3	2	< 50		1		0	0	1	0	0	0	0	0	0
9 June	D3	4	< 50		1		0	0	2	0	0	1	0	0	0
9 June	D3	2	< 50	2											

9 June	D3	16	< 50	3	6							6			1			
9 June	D3	2	< 50	2														
9 June	D3	6	< 50		2					0	1	2	0	0	1	0	0	0
9 June	E2	4	< 50	4														
9 June	F2	4	< 50	2	1							1						
9 June	D2	3	< 50	3														
11 June	B8	3	< 50		1	1					0	1		0	0	0	0	0
11 June	B8	6	< 50						6									
11 June	B8	2	< 50						2									
11 June	B8	5	< 50		1					1	0	2	0	0	0	1	0	0
11 June	C8	1	< 50		0					0	0	0	0	0	1	0	0	0
11 June	C8	16	< 50		2					4	1	5	1	2	1	0	0	0
11 June	C8	5	< 50		0				1	0	0	1	0	1	0	1	1	0
11 June	C8	1	< 50		0					0	0	0	0	0	1	0	0	0
11 June	C8	2	< 50		1					0	0	1	0	0	0	0	0	0
11 June	C8	3	< 50		0					0	0	1	0	1	1	0	0	0
11 June	C8	10	< 50		2					1	0	4	1	0	2	0	0	0
11 June	C8	5	< 50		0					1	0	1	1	2	0	0	0	0
11 June	C8	1	< 50		0					0	0	0	0	0	1	0	0	0
11 June	C8	3	< 50		0					0	0	2	0	1	0	0	0	0
11 June	C8	2	< 50		0					0	0	0	0	0	0	2	0	0
11 June	C8	1	<100		0					0	0	1	0	0	0	0	0	0
11 June	C8	1	< 50		0					0	0	0	0	0	1	0	0	0
11 June	D7	2	< 50		0					0	0	0	0	0	1	1	0	0
11 June	D7	4	<100		1	1	1					1			0	0	0	0
11 June	D7	17	< 50		4					1	1	8	1	1	1	0	0	0
11 June	D6	2	< 50		0					0	0	0	0	0	1	0	1	0
11 June	D6	3	< 50		0					1	0	1	0	1	0	0	0	0
11 June	D6	7	< 50		3					0	0	3	0	0	1	0	0	0
11 June	D6	2	< 50		0					0	0	1	0	0	0	1	0	0
11 June	E6	13	< 50		2					1	0	5	0	1	0	4	0	0
11 June	E6	6	< 50					1	2			2		1				

11 June	E6	6	< 50				6									
11 June	E6	8	< 50		2			2	1	3	0	0	0	0	0	0
11 June	E6	2	< 50		0			0	0	1	0	1	0	0	0	0
11 June	E5	6	< 50		1			1	0	3	0	1	0	0	0	0
11 June	E5	6	< 50		1			0	0	4	0	1	0	0	0	0
11 June	E5	1	< 50		0			0	0	0	0	0	0	0	1	0
11 June	E5	5	< 50				5									
11 June	E5	6	< 50		1		1	1	0	1	0	0			2	0
11 June	E5	6	< 50		1			2	0	3	0	0	0	0	0	0
11 June	E5	3	< 50		0			0	0	0	0	1	0	1	1	0
11 June	E5	4	< 50		1	2				1			0	0	0	0
11 June	E5	23	< 50	11	6					6						
11 June	E5	22	< 50	20	1					1						
11 June	F5	1	< 50		0		1									
11 June	F5	4	<100		1			1	0	1	0	1	0	0	0	0
11 June	F5	4	< 50		2			0	0	2	0	0	0	0	0	0
11 June	F5	3	< 50		0		3									
11 June	F5	2	< 50		0		2									
11 June	F5	2	< 50		0		2									
11 June	F5	5	< 50	1	2					2						
11 June	E5	3	< 50	1	1					1						
11 June	F6	12	< 50	8	2					2						
11 June	E6	5	< 50		2			0	0	2	1	0	0	0	0	0
11 June	E6	4	< 50		0			0	0	0	0	0	0	0	4	0
11 June	E6	6	< 50	1	1					4						
11 June	D7	12	< 50		2	2	4			2		1	1			
11 June	D8	1	< 50		0			0	0	0	0	0	0	0	1	0
11 June	C9	2	<100				2									
11 June	C9	2	< 50		0			0	0	0	0	0	1	0	1	0
11 June	C9	9	< 50		1			1	0	4	0	1	1	1	0	0
11 June	C9	3	< 50		0			0	0	2	0	1	0	0	0	0
11 June	C9	5	< 50	1	1					2	1					

11 June	C9	5	< 50	5	0											
11 June	D10	3	< 50	3	0											
11 June	D10	1	< 50		0			0	0	0	0	0	0	0	1	0
11 June	E9	6	< 50		2			0	1	2	0	1	0	0	0	0
11 June	E9	6			0			1	0	4	1	0	0	0	0	0
11 June	E9	3			0			0	0	1	0	0	1	0	1	0
11 June	E9	3			0			0	0	2	0	0	0	0	1	0
11 June	E9	12			2			1	1	6	0	1	1	0	0	0
11 June	E9	2			0			0	0	1	0	1	0	0	0	0
11 June	E9	3			0			0	0	1	0	0	2	0	0	0
11 June	E9	6				2	4									
11 June	E9	1			0			0	0	1	0	0	0	0	0	0
11 June	E9	2			0			0	0	1	0	1	0	0	0	0
11 June	E8	2		2												
12 June	E9	6	< 50		3			0	0	3	0	0	0	0	0	0
12 June	E9	1	< 50		0			0	0	0	0	0	0	0	1	0
12 June	E9	6	< 100	6												
12 June	F9	3	< 50		0			0	0	0	0	0	0	0	3	0
12 June	F9	1	< 50		0			0	0	0	0	0	0	0	1	0
12 June	F9	2	< 50		0			0	0	0	0	0	0	1	1	0
12 June	F9	4	< 100		1	2				1						
12 June	F9	1	< 50		0			0	0	0	0	0	0	0	1	0
12 June	H8	5	< 50		1			0	1	3	0	0	0	0	0	0
13 June	I6	4	< 200		0			0	0	2	0	0	2	0	0	0
13 June	I6	2	< 200		0			0	0	1	0	1	0	0	0	0
13 June	I6	2	< 200		0			0	0	1	1	0	0	0	0	0
13 June	I6	4	< 200		2			0	0	2	0	0	0	0	0	0
13 June	I6	6	< 200		2			1	0	2	0	1	0	0	0	0
13 June	I6	1	< 200		0			0	0	0	0	0	1	0	0	0
13 June	I6	1	< 200		0			0	0	0	0	0	0	0	1	0
13 June	I6	1	< 200		0			0	0	1	0	0	0	0	0	0
13 June	I6	9	< 150		4			1	0	4	0	0	0	0	0	0

13 June	I6	2	< 200		0			0	0	0	0	0	0	0	2	0
13 June	I6	1			0			0	0	0	0	0	0	0	1	0
13 June	I6	6	< 150		2			0	2	2	0	0	0	0	0	0
13 June	I6	4	< 50		1			0	0	2	0	1	0	0	0	0
13 June	I6	4			1			0	1	1	0	1	0	0	0	0
13 June	I6	9			2			1	1	4	1	0	0	0	0	0
13 June	I6	2			0			0	0	1	0	1	0	0	0	0
13 June	I6	3	< 50		1			0	0	2	0	0	0	0	0	0
13 June	I6	1	< 50		0			0	0	0	0	0	0	1	0	0
13 June	I6	2	< 50		0			0	0	0	0	0	0	1	1	0
13 June	I6	3	< 50		0			0	1	1	0	1	0	0	0	0
13 June	I6	1	< 50			1										
13 June	I6	3	100 m		1			0	1	1	0	0	0	0	0	0
13 June	I6	1	100 m				1									
13 June	H7	16	< 50		5	4			1	6						
13 June	H7	2	< 50		1			0	0	1	0	0	0	0	0	0
13 June	H7	2	< 50				2									
13 June	H7	7	< 100	5	1					1						
13 June	H7	6	< 50		0			1	2	3	0	0	0	0	0	0
13 June	H7	2	< 200				2									
13 June	H7	10		8	1					1						
13 June	H7	4	< 50		0			0	0	2	0	1	1	0	0	0
13 June	H7	1	< 50	1												
13 June	H7	1	< 200	1												
13 June	H7	2	< 50		0			0	0	0	0	0	0	0	2	0
13 June	H7	2	< 200				2									
13 June	H7	1	< 50				1									
13 June	H7	2	< 50		0			0	0	0	0	0	0	0	2	0
13 June	H7	5	< 50		1			1	1	2	0	0	0	0	0	0
13 June	H7	4	< 50	2	1					1						
13 June	F9	1			0			0	0	0	0	0	0	0	1	0
13 June	F9	3		3												

13 June	F9	4		4														
13 June	F9	3		3														
13 June	F9	1			0					0	0	0	0	0	0	0	1	0
13 June	G9	1			0					0	0	0	0	0	0	0	1	0
13 June	H8	1			0					0	0	0	0	0	0	0	1	0
13 June	I7	51		26	9							9					7	

Table 16. Raw data for one group of seven muskoxen observed in Qoororsuaq valley and therefore emigrated out of Ivittuut region, muskox count 08–13 June 2017.

2017 Date	**Grid Cell**	**Group Size**	**Elevation (m)**	**Unknown sex/age**	**2017 Calf**	**Unknown sex**				**Cow ♀♀**			**Bull ♂♂**					
						Age (years)												
						1	**2**	**1- 2**	**≥ 3**	**1**	**2**	**≥ 3**	**1**	**2**	**3**	**4**	**≥ 5**	**≥ 10**
12 June	H10	7	< 50		1					0	1	3	0	1	0	0	0	1

Appendix 7
Visible effects of muskox grazing / browsing on vegetation landscape

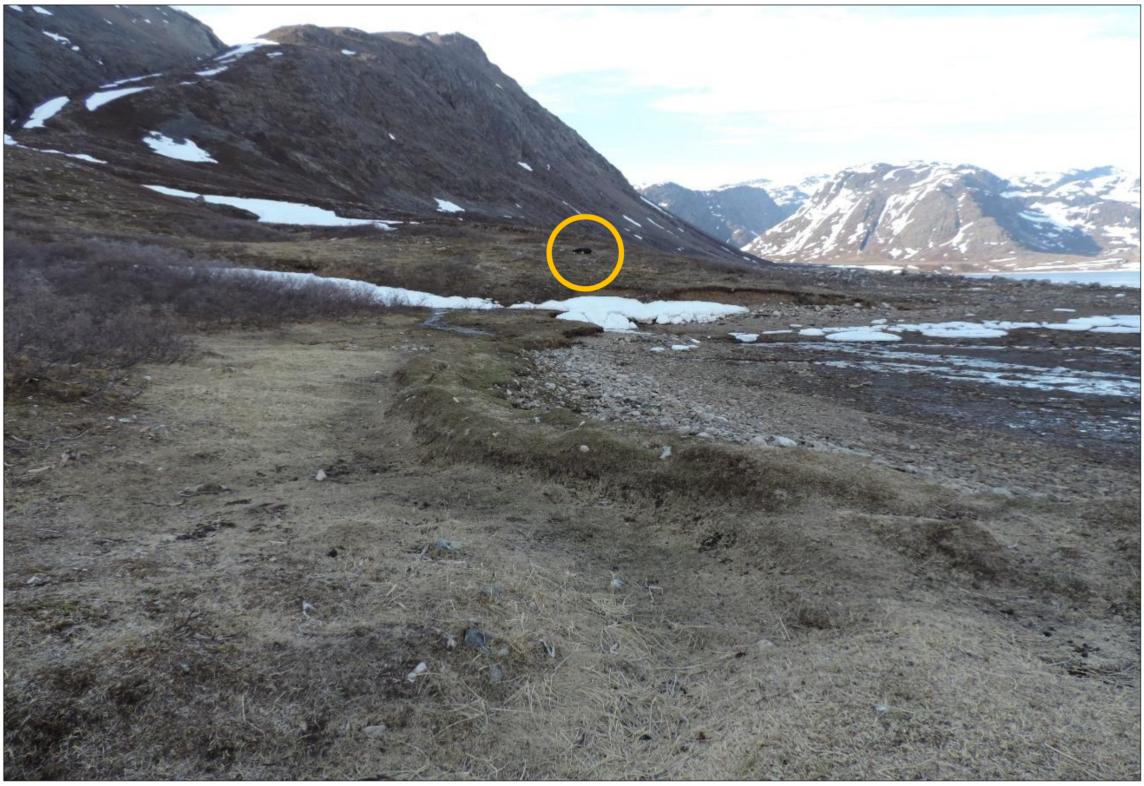


Figure 46. Grasses/sedges grazed to ground level, west shore Ikka Fjord, 10 June 2015. Top: extent of heavy grazing, with dead muskox cow in background and another nearby (not in photo). Bottom: closeup of grazed to ground vegetation at the shoreline. Photos C. Cuyler.

Figure 47. Grassy tussocks in the lowland valley immediately north of Taylershavn, 25 June 2016. Grass/sedge is closely cropped, almost to ground level, by muskoxen. Photo C. Cuyler

Figure 48. Shoreline grass/sedge NOT grazed to ground level, Taylershavn, 06 June 2015. Photo C. Cuyler

Figure 49. Willow shrubs stripped of bark in Laksebund/Lakselv Valley, 08 June 2015. Photo C. Cuyler

Figure 50. Hillside willow shrubs in Laksebund/Lakselv Valley, above 08 June 2015 and below 24 June 2016, similar location. The 2016 photo best illustrates browsing damage. Despite full green-up, there is scant foliage and many 'naked' branches owing to browsing by muskoxen. Photos C. Cuyler.

Figure 51. Trampling and bark stripping of willows in Laksebund/Lakselv Valley, 2016.; above, bark and foliage lacking, below swath of trampled and dead willow shrubs. Photos C. Cuyler.

Figure 52. View on 29 June 2016, north of Heksested cabin in Oksedalen, looking NE up into the 1st valley and towards the 'saddle' pass that separates the 1st valley from the 2nd valley beyond. Despite advanced greening of valley vegetation, the mature willows (foreground) lack leaves and bark stripping is evident. There dark spots center photo in the distance are three muskoxen grazing. Photo C. Cuyler.

Figure 53. Closeup of willow shrubs stripped of bark, Ikkabund, 10 June 2015. Photo C. Cuyler.

Figure 54. River valley north of Heksested cabin in Oksedalen, large extent of willow shrubs lacking leaf green-up although 03 July 2016, while bark stripping and browsing are evident. Photo C. Cuyler.

Appendix 8

Raw data for observations of other species encountered on Ivittuut peninsula during 2015, 2016, & 2017 muskox minimum counts

Table 17. Raw data for other species encountered in Ivittuut region during the 2015, 2016, and 2017 muskox minimum counts. Blank cells are lack of observations.

Date	Grid Cell	Reindeer	Arctic hare	Arctic fox	White-tailed eagle	Falcon	Seal	Harlequin duck	Common Eider	Comment
04-jun-15	8B		2							Among boulders along shoreline
04-jun-15	8B		4							Some amidst the muskoxen
04-jun-15	7B	2								Near shoreline
04-jun-15	7B	1								Bull, large antlers, elevation >300 m
04-jun-15	6B			1	2					Hunting the tidal zone
06-jun-15	4D		2							Among boulders near muskoxen
09-jun-15	9C	8		1	1					Bulls, large antlers in velvet
09-jun-15	9D	1								Elevation > 100 m
09-jun-15	9D	3								Elevation < 200 m
09-jun-15	9D	36								Including 12 calves (age <3 months)
09-jun-15	9D	7								Including 4 calves (age < 3 months)
09-jun-15	9D			1						BLUE phase, near shore cabin
09-jun-15	9G			1						BLUE phase, among shore boulders
09-jun-15	7I						3			Lying relaxed on pans of ice
09-jun-15	6I				3	1				
09-jun-15	7H						1			Qinngeriarsivaq
09-jun-15	7H		2							
09-jun-15	8H							2		Feeding in the 'narrows'
09-jun-15	8H		1							Rocky steep slope near shore
09-jun-15	8H	10								North side of the 'narrows'
10-jun-15	9E			1						
10-jun-15	9E	10								Near the saddle to second valley
10-jun-15	10C	3								Near shoreline
TOTALS 2015		**81**	**11**	**5**	**6**	**1**	**4**	**2**	**0**	

23-jun-16	G2			1	5					
25-jun-16	D5			1						Inner Grønnedal, snow patches
27-jun-16	C8	9								
27-jun-16	C9				1					Flying around overhead, 'barking'
27-jun-16	C9	1								Bull, age ca. 3-year
29-jun-16	D9				1					Flying around overhead, 'barking'
29-jun-16	E8	10								
01-jul-16	E9	6								
01-jul-16	E9	1								
02-jul-16	I7		8							Near Paradise Cabin
TOTALS 2016		**27**	**8**	**2**	**7**	**0**	**0**	**0**	**0**	
07-jun-17	B6			1						White phase, moulting
07-jun-17	B6				1					Circling overhead
08-jun-17	B6			1						White phase, moulting
11-jun-17	B7	6								Bulls all in one group
11-jun-17	E6	8								High mountainside, snow patch
11-jun-17	C9				2					Flying about Kangaarsuk Løb
11-jun-17	D9	3								Juvenile males
12-jun-17	E10	23								Included ≥10 calves, Nuuk point
12-jun-17	E10	8								Included 4 calves, Nuuk point
12-jun-17	F10								many	Could NOT get airborne, fat bellies
12-jun-17	H8	2								Bulls, glacial till front of glacier
12-jun-17	I7						2			Heads popped up, Qinngerlersivaq
13-jun-17	H8	1								Bull, glacial till front of glacier
13-jun-17	I7		2							NE end of Qinngerlersivaq bay.
14-jun-17	B7			2						near Taylershavn summer cabin
TOTALS 2017		**51**	**2**	**4**	**3**	**0**	**2**	**0**	**many**	

Appendix 9

Muskox counts & observations post-2017

The following paragraph is from the count report and P.N. Hansen (pers. comm.).

The April 2018 count observed only 650 muskoxen and 50-60 calves. Methods included hiking or snowmobiling into the terrain, and as usual, cruising the coastline, but areas covered were not specified. Later in June, 16 muskoxen were found dead from natural causes (10 cows, 6 bulls). All carcasses were emaciated. The six bulls were adults, i.e. all had trophy sized horns. Most of the cows were adults. One dead adult cow had a surviving newborn calf nearby (Fig. 55). Efforts were made to feed the calf; however, it died raising the mortality count to 17. It is possible more carcasses were present but went undetected. Most carcasses were found in the Lakselv and Paradiset valleys. These are on opposite sides of the Ivittuut peninsula and suggests mortality was widespread throughout the region. Never had so many deaths by natural causes been detected in one year since muskox translocation to Ivittuut in the summer of 1987. Additionally, 2018 snowmelt was later than normal as was muskoxen shedding their qiviut wool, and adult cows appeared markedly thin with little or no milk for their newborn calves. All the above suggests the possibility of a crash year as might be expected from high density combined with limited winter/spring forage resources.

Figure 55. Ivittuut Hunting Officer, Per Nukaaraq Hansen, with orphaned newborn calf, which later died. Photo P. N. Hansen.

In 2018, the entire Arsuk harvest quota was filled, i.e. 76 muskoxen (36 Trophy bulls, 40 juvenile cows (age 1-2 years)), and nematode round worms were observed. Although the entire trophy quota was filled, it was hard to find bulls with trophy-sized horns. 2018 was the first year, trophy guides used an entire day to find a suitable trophy bull for the foreign hunters to take and guided hunts in September took both trophy muskoxen and reindeer (F. Feldmann pers. comm.). Importantly for 2018, the Arsuk Resource Management Council lost a key member, Ejnar Jakobsen, due to an unfortunate fatal accident. Thus, trophy agent numbers dropped from four to three in the community and the local team conducting annual minimum counts lost an experienced and valued member.

In the first week of May 2020, snow on the mountains brought most of the muskoxen into the lowlands where they were easy to detect. The hunting officer, P.N. Hansen, counted 556 muskoxen (areas covered not specified). The count included 40 trophy bulls, 82 young bulls, 156 adult cows and 278 muskoxen of undetermined sex or age. No newborn calves were observed during the count, which could be expected given the timing of the count.

Figure. 56. Muskox hoof-print in shallow snow. Photo C. Cuyler.

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