SOUTH GREENLAND – REGIONAL ENVIRONMENTAL BASELINE ASSESSMENT FOR MINING ACTIVITIES

Scientific Report from DCE – Danish Centre for Environment and Energy No. 482 2023

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Janne Fritt-Rasmussen[1]
Katrine Raundrup[2]
Anders Mosbech[1]

[1]Aarhus University, Department of Ecoscience
[2]Greenland Institute of Natural Resources

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Data sheet

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Authors: Janne Fritt-Rasmussen[1], Katrine Raundrup[2], Anders Mosbech[1]

Contributing authors: Peter Aastrup[1], David Boertmann[1], Drude Fritzbøger Christensen[1], Janne Fritt-Rasmussen[1], Kim Gustavson[1], Ida Bomholt Dyrholm Jacobsen[2], Kasper Lambert Johansen[1], Christian Juncher Jørgensen[1], Debora Hansen Kleist[2], Christian Koch Madsen[3], Anders Mosbech[1,] Josephine Nymand[2], Simun Dalsenni Olsen[4], Katrine Raundrup[2], Jens Søndergaard[1], Kristine Thrane[4] og Karl Zinglersen[2]

Institutions: [1]Aarhus University, Department of Ecoscience; [2]Greenland Institute of Natural Resources, [3]Nunatta Katersugaasivia Allagaateqarfialu / Greenland National Museum & Archived (NKA), [4]Geological Survey of Denmark and Greenland (GEUS)

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Referees: Josephine Nymand[2] (Chapter 1, 8 and 9), Kim Gustavson[1] (Chapter 3), Aili Labansen[2] (Chapter 4), Daniel Spelling Clausen[1] (Chapter 5 and 7), Ida Bomholt Dyrholm Jacobsen[2] (Appendix 3), Peter Aastrup[1] (Appendix 4)
[1]Aarhus University, Department of Ecoscience; [2]Greenland Institute of Natural Resources

Quality assurance, DCE: Kirsten Bang

Linguistic QA: Anne Mette Poulsen

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Abstract: This regional environmental baseline assessment of mining activities in South Greenland is based on a project idea developed between Environmental Agency for Mineral Resource Activities (EAMRA), Greenland Institute of Natural Resources (GINR) and DCE (AU). The purpose of the project is to provide a basis for supporting environmentally sound planning and regulation of mining activities by summarising existing regional background information supplemented with new studies and making these results operational and easily accessible.

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Contents

Preface

The purpose of a Regional Baseline Assessment (RBA) is to provide a basis for supporting environmentally sound planning and regulation of mining activities by summarising existing regional background information supplemented with new studies and making these results operational and easily accessible.

This RBA for South Greenland compiles existing baseline information on geology, environmental chemistry, biodiversity, human use, and archeology of South Greenland. The existing information has been supplemented with a vegetation mapping study and additional sampling and chemical analysis of environmental samples.

The available information is presented and described on a general level in the report and supported by overview maps. The full data are given in NatureMap.gl and an integrated project-specific webGIS.

The area in South Greenland was selected by the Environmental Agency for Mineral Resource Activities (EAMRA) in dialogue with DCE – Danish Centre for Environment and Energy (at Aarhus University) and Greenland Institute of Natural Resources (GINR) as a pilot region for the project because of the large potential for mining activities, several ongoing mining activities, and lack of overview of environmental and biodiversity conflict zones. Based on the experience from this report, other regions will be selected and analysed.

The report is prepared by DCE and GINR.

The project was funded by EAMRA.

Sammenfatning

Formålet med en regional baggrundsundersøgelse (RBU) er at tilvejebringe oplysninger til støtte for miljømæssig forsvarlig planlægning og regulering af mineaktiviteter. Det gøres ved at sammenfatte eksisterende regionale baggrundsoplysninger suppleret med nye undersøgelser og gøre disse resultater operationelle og let tilgængelige. RBU'en for Sydgrønland samler eksisterende rumlige baggrundsoplysninger om geologi, miljøkemi, biodiversitet, menneskelig brug og kulturarvsværdier i Sydgrønland. De eksisterende oplysninger er suppleret med en vegetationskortlægningsundersøgelse samt yderligere indsamling og kemiske analyser af miljøprøver. Baseret på de nuværende oplysninger er der udarbejdet en integreret rumlig overlay-analyse, der fremhæver zoner med flere interessenter herunder mulige fremtidige minedriftsaktiviteter og områder med relevans af biologisk, menneskelig og kulturarvsmæssig karakter.

De tilgængelige oplysninger præsenteres og beskrives på et overordnet niveau i rapporten og understøttes af oversigtskort. Alle data findes på NatureMap.gl og i en integreret projektspecifik webGIS (rba.eamra.gl). Den videnskabelige rapport "South Greenland – Regional Environmental Baseline Assessment for mining activities" består af 9 kapitler og 4 bilag.

Kapitel 1 Indledning – Regionale baggrundsundersøgelse (RBU) af mineaktiviteter i Sydgrønland

Minedrift (efterforskning, udnyttelse og transport) må nødvendigvis forventes at have en vis indvirkning på natur og miljø. I Grønland, som i andre lande, er det ofte nødvendigt at oprette midlertidige industrizoner i forbindelse med minedrift. Minedrift har en negativ indvirkning på naturen, de oprindelige miljøforhold og lejlighedsvis kulturarven, og kan begrænse andre former for menneskelig brug i området. Miljøbestemmelser og naturplanlægning har til formål at sikre, at den eksisterende natur og det eksisterende miljø ikke ødelægges til skade for nuværende såvel som kommende generationer samtidig med, at der skabes mulighed for at udvikle aktiviteter i forbindelse med minedrift. Tilstrækkelig baggrundsviden om procesteknologi, geokemi, økotoksikologi, biodiversitet og økologiske sammenhænge kan hjælpe med at forudsige konsekvenser af nye mineprojekter. Gennem planlægning, afbødning og regulering kan eventuelle indvirkninger, der rækker ud over det faktiske udnyttelsesområde i vid udstrækning begrænses.

I udvalgte områder af særlig interesse i forhold til landbaserede mineaktiviteter vil RBU tilvejebringe:

- tilgængelig viden om sårbare og biologisk vigtige områders placering gennem undersøgelser af plante- og dyrearters udbredelse samt lokalkendskab til områderne.
- opdateret viden om naturlige baggrundsniveauer for udvalgte grundstoffer.
- forbedret offentlig adgang til opdateret miljørelevant viden og data via bl.a. NatureMap (naturemap.eamra.gl).

Kapitel 2 De geologiske rammer for Sydgrønland set fra et mineperspektiv

Dette kapitel giver et kort overblik over de geologiske rammer i Sydgrønland med fokus på beskrivelser af lokaliteter af økonomisk interesse, herunder specifikationer for berigede grundstoffer. Flere detaljer findes i Bilag 1 ”Report on the geological setting of South Greenland” (kun på engelsk). Disse oplysninger giver en vigtig forståelse af de geologiske baseline-niveauer i interesseområdet (”Area of Interest”, AOI). I Sydgrønland er der flere forekomster af økonomisk interesse. Baseret på miljøgeokemien er nogle af de grundstoffer, der potentielt kan have en indvirkning på miljøet og skal forvaltes, blevet identificeret. En oversigt over disse forekomster findes i tabel 2.1.

Kapitel 3 Sydgrønlands miljømæssige baggrundskemi

Dette kapitel giver et overblik over de tilgængelige miljøkemiske data om Sydgrønland. Dataene stammer fra forskellige projekter og præsenteres her som median-, minimums- og maksimumsværdier. Data kan findes i miljøkemidatabasen ”AMDA”, der vedligeholdes af DCE/GINR Environmental Datacenter.

Sydgrønlands baggrundsmiljøkemi er blevet undersøgt i løbet af de sidste ca. 40 år, hovedsageligt i forhold til mulighederne for mineraludnyttelse, der er nævnt i kapitel 2, og efterforsknings- og udnyttelsesaktiviteter (figur 3.1). Samlet set består de vigtigste typer miljøprøver af blåmuslinger (*Mytilus edulis*), sne-kruslav (*Flavocetraria nivalis*), sediment, ferskvand (filtreret og ufiltreret), korthornet ulk (*Myoxocephalus scorpius*) og tang (*Fucus vesiculosus* og *Ascophyllum nodosum*). Analyser af andre prøvetyper er også tilgængelige og findes i AMDA-databasen.

Baseret på alle tilgængelige baggrundsdata (prøver, der repræsenterer ikke-forurenede forhold) i AMDA-databasen er der beregnet ”grønlandske median” koncentrationsværdier for ca. 70 forskellige grundstoffer i otte forskellige prøvetyper. Baggrunds-medianværdier er også blevet beregnet for otte adskilte større regioner i Grønland. Her er den ”sydgrønlandske median” af primær relevans for det område, der er af interesse for denne vurderingsrapport. Den fuldstændige liste over regionale mediankoncentrationsværdier for de forskellige grundstoffer i de forskellige prøvetyper findes i Bilag 2.

Kapitel 4 Biodiversitet og biologisk vigtige og beskyttede områder

Dette kapitel giver et overblik over det biologiske miljø. Dette inkluderer en præsentation af den almindeligt forekommende fauna samt populationernes betydning på tre forskellige niveauer: på AOI-skala, på grønlandsk skala og på globalt plan. Trusselsstatus i henhold til rødlisten (opsummeret på baggrund af IUCN-trusselskategorierne: LC, mindst bekymring; NT, nær truet; VU, sårbar; EN, truet; og CR, kritisk truet) på både nationalt og globalt plan fremgår af tabel 4.1 (fauna) og tabel 4.2 (flora).

Da offshoreområderne ikke er inkluderet, er det kun havpattedyr og fisk, der forekommer i kystmiljøet, der er omfattet. Af havpattedyrene er den spættede sæl (*Phoca vitulina*) af særlig betydning, da størstedelen af den grønlandske bestand findes i AOI. Der er et enkelt område, hvor denne art stadig opholder sig – ved øgruppen Qeqertat øst for Narsaq Kujalleq (Narsarmijit). De fleste hvaler, der forekommer i Sydvestgrønland, opholder sig i offshore farvande, men vågehval (*Balaenoptera acutorostrata*) og i mindre grad pukkelhval (*Megaptera novaeangliae*) forekommer langs kysten og i de ydre dele af fjordene om sommeren.

En stor del af kapitlet er dedikeret til land- og ferskvandsfugle samt havfugle. Af rovfuglene har især havørnen relativt høje tætheder af yngleområder, og en betydelig del af den grønlandske bestand findes i AOI. Den vestlige AOI er meget vigtig for den grønlandske bestand af strømand (*Histrionicus histrionicus*). Flere fugle, der er forbundet med havmiljøet, yngler og overvintrer i AOI, hvor den vigtigste havfuglegruppe er alkefugle. AOI er især værdifuld for lomvie (*Uria aalgae*) og polarlomvie (*Uria lomvia*). Om vinteren fungerer kysten og farvandet ud for Sydvestgrønland, herunder AOI, som meget vigtige vinterhabitater for havfugle og fugle, der yngler i ferskvand.

Mere end 370 plantearter vides at forekomme i Sydgrønland, og af disse findes 56 inden for AOI og er rødlistede (sårbare og nær truede). Ti af disse arter er unikke for Sydgrønland. Der blev lavet et opdateret vegetationskort (skala 10x10 m) over Sydgrønland med fem vegetationstyper (krat, dværgbuskhede, lavholdig dværgbuskhede, græsland og kær). Detaljeret information om de metoder, der er anvendt til at lave vegetationskortet, findes i Bilag 3.

Inden for AOI er tre steder ”Naturbeskyttelsesområder”: Uunartoq og de to dale Qinngua og Klosterdalen, der er beskyttet efter Naturbeskyttelsesloven. Tre steder er beskyttet af ”Fuglebekendtgørelsen”(med hjemmel i Jagtloven): Kitsissut Avalliit (også AOI'ets eneste Ramsar-område, nr. 388), Indre Kitsissut og øerne Qeqertat øst for Narsaq Kujalleq (Narsarmijit). Desuden blev I 2017 et område kaldet ”Kujataa – et subarktisk landbrugslandskab i Grønland” optaget på UNESCO’s verdensarvsliste. Det UNESCO-beskyttede område består af flere landområder omgivet af en bufferzone og er beskyttet af en forvaltningsplan med hjemmel i flere love.

På grund af manglende specifik viden om distribution og diversitet er svampe, mosser, laver samt og hvirvelløse dyr ikke inkluderet i denne rapport. Desuden er nogle af de resultater, der præsenteres i dette kapitel, baseret på relativt gamle data. Det gælder især fordelingen af plantearter, og flere af fuglekolonierne er ikke blevet undersøgt i de seneste år.

Kapitel 5 Menneskelig brug

Dette kapitel giver et overblik over menneskelig brug, dvs. landbrug/dyrehold (får og rensdyr samt udsættelse af moskusokser), anvendelse af marine ressourcer, plantager samt turisme og større tekniske infrastrukturer. Menneskets udnyttelse af ressourcerne i Sydgrønland er kendetegnet ved tilstedeværelsen af landbrug og dyrehold. Det er den eneste region i Grønland, hvor dette foregår i stor skala. Sydgrønland har ca. 6.500 indbyggere – ca. 5.600 indbyggere i byerne Qaqortoq, Narsaq og Nanortalik og ca. 900 i bygderne inklusive fårefarme.

Landbrug blev først introduceret i området af nordmændene ca. 985 e.Kr. I århundreder holdt nordmændene bl.a. får og kvæg, men fra ca. 1450 e.Kr. og i den følgende 4-500 års periode var der ikke landbrug og dyrehold i

Grønland. Fårehold blev genetableret i 1915, og i dag er der knap 40 aktive farme med ca. 18.000 får og ca. 350 køer i Sydgrønland.

Rensdyrhold foregår to steder – i Isortoq (siden 1973) og i Tuttutooq (siden 1992). De to bestandes samlede udbredelse dækker ca. 1700 km^2 og omfatter ca. 1.200 (Isortoq) og 350 (Tuttutooq) dyr. 18 moskusokser blev udsat i Ippatit-dalen på den nordlige kyst af Nanortalik-halvøen i 2014. I dag er der knap 50 moskusokser i området.

Langs store dele af kysten udnyttes fiskeressourcer til både privat såvel som kommerciel brug. Generelt er erhvervsfiskeriet i Sydgrønland begrænset i forhold til andre grønlandske farvande. I rapporten præsenteres de vigtige områder for fiskeri af fjeldørred (*Salvelinus alpinus*), atlanterhavstorsk (*Gadus morhua*), hellefisk (*Reinhardtius hippoglossoides*), stenbider (*Cyclopterus lumpus*), dybvandsrejer (*Pandalus borealis*) og snekrabbe (*Chionoecetes opilio*).

En væsentlig del af udarbejdelsen af en RBU er at inkludere lokal viden om de biologiske ressourcer i AOI. Da der blev lagt planer for feltarbejdet i 2020, var dette et integreret element, men på grund af Covid-19-restriktioner blev feltarbejdet beskåret til kun at omfatte vegetationsanalyser og indsamling af miljøprøver til kemiske analyser (se kapitel 3). Da møder med lokalbefolkningen, kommunale repræsentanter samt andre interessenter var forbudt, er inddragelse af opdateret lokal viden ikke en del af dette kapitel.

Kapitel 6 Grønlands kulturhistorie – en introduktion

Dette kapitel giver et overblik over kulturhistorien. Kulturarvszonerne i Sydgrønland fremgår af figur 6.2 og 6.3. Figur 6.4 viser endvidere tætheden af registreret kulturarv i Sydgrønland. Tætheden af steder med kulturarv viser først og fremmest omfanget af arkæologiske undersøgelser, men også til en vis grad det faktiske omfang af tidligere bosættelser.

Steder med kulturarv findes næsten overalt i Grønland, men i visse landskabstyper og ved visse landskabstræk er det mere sandsynligt finde at nye, uregistrerede steder - især større lejre eller bosættelser. De landskabstræk, der normalt får øget opmærksomhed under arkæologiske undersøgelser – og bør få det samme under efterforsknings- og udviklingsaktiviteter pga. den øgede sandsynlighed for at frembringe kulturarvssteder/landskabstræk – kan ses i tabel 6.1.

Kapitel 7 Integreret rumlig analyse af overlappende interesser

I kapitel 4-6 præsenteres en række kort, der fremhæver kendte udbredelsesområder for vigtig flora og fauna, menneskelig brug af regionen og områder med kulturarv. Alle disse træk kan betragtes som landskabs-mæssige aktiver eller interesser, der bør tages i betragtning ved planlægning af efterforskning efter mineralressourcer eller udvindingsaktiviteter.

I dette kapitel gives en sammenfattende analyse af, hvor mange af disse landskabsmæssige aktiver der overlapper med hinanden i forskellige dele af interesseområdet (AOI). I alt indgik 51 kortlag i analysen (tabel 7.1). Der blev gennemført tre forskellige analyser – en, der omfattede alle 51 kortlag, der afspejler både flora og fauna, menneskelig brug og kulturarv (figur 7.1 og 7.2), en med 34 kortlag med hovedsagelig biologisk relevante oplysninger (figur

7.3) og en baseret på 29 kortlag med oplysninger, der primært afspejler menneskelig brug og kulturarvsinteresser (figur 7.4).

Når man anvender kortene, skal man huske på, at et stort antal overlap i et område ikke nødvendigvis betyder, at aktiviteter omkring udnyttelse af mineralske ressourcer vil have en stor miljøpåvirkning her. De understreger dog, at der med den nuværende viden er behov for at tilgodese flere forskellige interesser i forbindelse med mineraludvinding.

Kapitel 8 Minedrift og miljøpåvirkninger

I dette kapitel gives en oversigt over de typiske miljøpåvirkninger, der kan forventes fra moderne miner, der drives i henhold til høje internationale miljøstandarder. Eksempler på den geografiske udstrækning og varighed af de virkninger, der kan forventes ved typisk moderne minedrift, gives for forskellige aktiviteter. Man skal dog huske på, at mineralprojekter er forskellige, og det samme gælder de potentielle miljøpåvirkninger.

Det sidste afsnit i dette kapitel beskriver potentielle miljøpåvirkninger fra ulykker.

Kapitel 9 Fremtidsperspektiver og datahuller

Dette kapitel giver et overblik over de fremtidige klimaforandringer, der forventes at ske i Sydgrønland. Det giver endvidere eksempler på huller i data og dermed viden, der er identificeret i rapporten.

Summary

The purpose of a Regional Baseline Assessment (RBA) is to provide information to support environmentally sound planning and regulation of mining activities by summarising existing regional background information supplemented with new studies and making these results operational and easily accessible. The RBA for South Greenland compiles existing spatial baseline information on geology, environmental chemistry, biodiversity, human use, and heritage values of South Greenland. The existing information has been supplemented with a vegetation mapping study and additional sampling and chemical analysis of environmental samples. Based on the current information, an integrated spatial overlay analysis was compiled, which highlights areas with potential conflict zones between possible future mining activities and areas of biological, human and heritage values interest.

The available information is presented and described on a general level in the report and supported by overview maps. The full data are given in NatureMap.gl and an integrated project-specific webGIS (rba.eamra.gl). The scientific report "South Greenland – Regional Environmental Baseline Assessment for mining activities" is comprised of 9 chapters and 4 appendices.

Chapter 1 Introduction – Regional baseline assessments (RBA) of mining activities in South Greenland

Mining activities (exploration, exploitation and transport) are bound to have a certain impact on nature and environment. In Greenland, as in other countries, it is often necessary to set up temporary industrial zones in connection with mining. Mining has a negative impact on nature, the original environmental conditions and occasionally cultural heritage, and it may limit other types of human use in the area. Environmental regulations and nature planning aim to ensure that the existing nature and environment are not destroyed to the detriment of current as well as future generations, while still creating the possibility of developing mining activities. Sufficient background knowledge about process technology, geochemistry, ecotoxicology, biodiversity, and ecological contexts can help predict the impacts of new mining projects and often by planning, mitigation and regulation largely limit any effects beyond the actual area of exploitation.

Regional Baseline Assessments (RBA) of mining activities will, for selected areas of mining interest, provide:

available knowledge of the location of vulnerable and important areas through studies of the distribution of plant and animal species as well as local knowledge of the areas.

updated knowledge of natural background levels for selected elements.

improved public access to updated environmentally relevant knowledge and data via, e.g., NatureMap (naturemap.eamra.gl).

Chapter 2 Geological setting of South Greenland from a mining perspective

This chapter gives a short overview of the geological setting of South Greenland with focus on descriptions of localities of economic interest, including specifications of enriched elements. More details can be found in Appendix 1 "Geology in South Greenland". This information provides an important understanding of the geological baseline levels in the Area of Interest (AOI). In South Greenland, there are several occurrences of economic interest. Based on the environmental geochemistry, some of the elements that may potentially have an impact on the environment and need to be managed have been identified. An overview of these occurrences is given in Table 2.1.

Chapter 3 The environmental baseline chemistry of South Greenland

This chapter gives an overview of the available environmental chemistry data on South Greenland. The data are derived from different projects and presented here as median, minimum, and maximum values. Data can be found in the environmental chemistry database "AMDA", maintained by the DCE/GINR Environmental Datacenter.

The baseline environmental chemistry of South Greenland has been investigated during the past approx. 40 years, mostly in relation to the mineral prospects mentioned in Chapter 2 and exploration and exploitation activities (Figure 3.1). Overall, the major types of environmental samples available are of blue mussels (Mytilus edulis), crinkled snow lichens (Flavocetraria nivalis), sediments, fresh water (filtered and unfiltered), shorthorn sculpin (Myoxocephalus scorpius) and seaweed (Fucus vesiculosus and Ascophyllum nodosum). Analyses of other matrices are also available and found in the AMDA database.

Based on all available baseline data (samples representing unpolluted conditions) in the AMDA database, "Greenland median" concentration values of approx. 70 different elements in eight different sample types have been calculated. Baseline median values have also been calculated for eight separate larger regions of Greenland. Here, the "South Greenland median" is of primary relevance to the area of interest for this assessment report. The full list of regional median concentration values of the different elements in the different sample types are given in Appendix 2.

Chapter 4 Biodiversity and biologically important and protected areas

This chapter gives an overview of the biological environment. This includes presenting the regular occurring fauna as well as the significance of the populations at three different levels: at AOI scale, at Greenland scale and at global scale. The threat status according to the red list (summarised based on the IUCN threat categories: LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; and CR, critically endangered) both at national and global level is presented in Table 4.1 (fauna) and Table 4.2 (flora).

As the offshore areas are not included, only marine mammals and fish occurring in the coastal environment are included. Of the marine mammals the harbour seal (Phoca vitulina) is of particular importance as the major part of the Greenland population is found in the AOI. There is a single area where this species still haul-out – at the archipelago Qeqertat east of Narsaq Kujalleq (Narsarmijit). Most of the whales occurring in Southwest Greenland stay in offshore waters however, minke whale (Balaenoptera acutorostrata) and to a lesser degree humpback whale (Megaptera novaeangliae) occur along the coast and in the outer parts of the fjords in the summertime.

A large section of the chapter is dedicated to terrestrial and freshwater birds as well as seabirds. Of the birds of prey especially white-tailed eagle has relative high densities of nesting territories, and a significant part of the Greenland population is found in the AOI. The western AOI is very important for the Greenland harlequin duck population (Histrionicus histrionicus). Several birds associated with the marine environment breed and winter in the AOI, with the most important seabird group being the alcids. The AOI is especially valuable for common murre (Uria aalgae) and thick-billed murre (Uria lomvia). In winter, the coast and the waters off Southwest Greenland, including the AOI, act as very important winter habitats for seabirds and birds breeding at freshwaters.

More than 370 species of plants are known to occur in South Greenland and of these, 56 are found within the AOI and are red listed (vulnerable and near threatened). Ten of these species are unique to South Greenland. An updated vegetation map (scale 10x10 m) of South Greenland with 5 vegetation types (copse, dwarf shrub heath, lichen-rich shrub heath, grassland, and fen) was made. Thorough information on the methods used for making the vegetation map can be found in Appendix 3.

There are four types of protected areas in the South Greenland AOI. The areas fall within the legislation related to "Nature protection areas", "The bird protection act", "Ramsar sites" and "The UNESCO's World Heritage List". Within the AOI three sites are "Nature protection areas": Uunartoq, and the two valleys Qinngua and Klosterdalen. There are three sites in the "Bird protection act": Kitsissut Avalliit (also the AOI's only Ramsar site, no. 388), Indre Kitsissut and the islands of Qeqertat east of Narsaq Kujalleq (Narsarmijit). In 2017 an area called "Kujataa – a subarctic farming landscape in Greenland" was included in the UNESCO World Heritage List. The UNESCO protected area is composed of several land areas surrounded by a buffer zone.

Due to lack of specific knowledge of distribution and diversity, fungi, bryophytes, and invertebrates are not included in this report. Furthermore, some of the results presented in this chapter is based on relatively old data. This holds particularly true for the distribution of plant species, and several of the bird colonies have not been surveyed in recent years.

Chapter 5 Human use

This chapter gives an overview of the human use i.e., agriculture/farming (sheep and reindeer as well as muskox introductions), use of marine resources, plantations as well as tourism and larger technical infrastructures. Human use of the resources in South Greenland is characterised by the presence of land-based agriculture and farming. It is the only region in Greenland where this takes place at a large scale. South Greenland is home to approximately 6,500 inhabitants – ca. 5,600 people in the towns of Qaqortoq, Narsaq and Nanortalik, and ca. 900 in the settlements including sheep farms.

Agriculture was first introduced in the area by the Norse ca. 985 AD. For centuries the Norse farmed e.g., sheep and cattle, but from ca. 1450 AD and the following 4-500 year period agriculture and farming was absent from Greenland. Sheep farming was re-introduced in 1915 and today there are 37 active farms with ca. 18000 ewes and ca. 350 heads of cattle in South Greenland.

Reindeer herding takes place at two locations – at Isortoq (since 1973) and at Tuttutooq (since 1992). The combined ranges of the two herds amounts to ca. 1700 km2 and holds ca. 1200 (Isortoq) and 350 (Tuttutooq) animals. 18 muskoxen were introduced to the Ippatit valley on the northern coast of the Nanortalik peninsula in 2014. Today there are little less than 50 muskoxen in the area.

Long stretches of the coastline has fishing resources for both private as well as commercial use. In general, the commercial fishing in South Greenland is limited compared to other Greenland waters. In the report, the important areas for fishing Arctic char (Salvelinus alpinus), Atlantic cod (Gadus morhua), Greenland halibut (Reinhardtius hippoglossoides), lumpsucker (Cyclopterus lumpus), northern shrimp (Pandalus borealis) and snow crab (Chionoecetes opilio) are presented.

An essential part of making an RBA is to include local knowledge of the biological resources in the AOI. When plans were made for the field work in 2020, this part was an integral element, but due to Covid-19 restrictions the field work was trimmed to only include vegetation analyses, and collection of environmental samples for chemical analyses (see chapter 3). As meetings with locals, municipality representatives as well as other stakeholders were prohibited, the inclusion of updated local knowledge is not part of this chapter.

Chapter 6 Greenland's cultural history – an introduction

This chapter gives an overview of the cultural history. The heritage zones in South Greenland are presented in Figures 6.2 and 6.2. Furthermore Figure 6.3 shows the density of registered heritage sites within a 5 km hexagon grid in South Greenland. The heritage site density mostly reveals archaeological survey intensity but also to some extent actual past settlement intensity.

While heritage sites in Greenland may be found almost everywhere, particular landscape types and features are predictively more likely than others to produce new, unregistered sites – especially larger camps or settlements. Land-scape features that normally receive heightened attention during archaeological surveys and should do so also during exploration and development activities because of their increased probability for producing heritage sites/features, can be found in Table 6.1.

Chapter 7 Integrated spatial analysis of overlapping interests

In chapters 4-6, a number of maps are presented, highlighting known distribution areas of important flora and fauna, human use of the region and concentrations of cultural heritage sites. All these features may be regarded as landscape assets or interests that should be taken into account when planning mineral resource exploration or extraction activities.

In this chapter, a summary analysis of how many of these landscape assets overlap in different parts of the area of interest (AOI) is provided. In total, 51 map layers were included in the analysis (Table 7.1). Three different analyses were conducted – one including all 51 map layers, reflecting both flora and fauna, human use and cultural heritage (Figure 7.1 and 7.2), one including 34 map layers with mainly biologically relevant information (Figure 7.3) and one based on 29 map layers with information primarily reflecting human use and cultural heritage interests (Figure 7.4).

When using the maps, it should be remembered that a large number of overlaps in an area do not necessarily mean that mineral resource activities will have a high environmental impact here. They do, however, emphasise that, given the present knowledge, several different interests need to be addressed in relation to mineral extraction operations.

Chapter 8 Mining and environmental impacts

In this chapter, an overview of the typical environmental impacts that can be expected from modern mines operated according to high international environmental standards is given. Examples of the geographical extent and duration of the effects that can be expected from a typical modern mining operation is provided for different activities. It should, however, be kept in mind that mineral projects are diverse and so are the potential environmental impacts.

The last section in this chapter describes potential environmental impacts from accidents.

Chapter 9 Future perspectives and data gaps

This chapter gives an overview of the future climatic changes expected to occur in South Greenland. It further provides examples of the data gaps identified throughout the report.

Naalisagaq

Immikkoortumi Killeqarfiup iluani Naliliinermi (RBA) aatsitassarsiornermi avatangiisitigut pilersaarusiorsinnaaneq naliliisinnaanerlu nunami immikkoortumi paasissutissat pioreersut aammalu paasissutissat misissuisimanermit piusut nutaat tunngavigalugit naliliinissaq aammalu paasiuminartunngorlugit tamanillu pissarsiarineqarsinnaasunik suliaqarnissaq suliami siunertarineqarpoq.

RBA Kalaallit Nunaata kujataanut atuuttup suliarisimasap ujarassiornikkut, avatangiisitigut akuutissaqarnikkut, uumasoqatigiit assigiinngisitaarneratigut, inuit nunamik atuineratigut aammalu Kalaallit Nunaata kujataani eriagisassaqarfitsigut inissisimaffik tamakkiinerusumik takussutissaqartippaa. Paasissutissat pioreersut nunap naggorinnerinut tunngasutigut takussutissatigut ilassuteqartinneqarsimapput aammalu avatangiisinit akuutissat misiliutaasimasutut katersat misissorneqarnerannik ilassuteqartinneqarlutik. Paasissutissat maannamut pigineqartut aallaavigalugit tamakkiisumik misissueqqissaarneq ingerlanneqarsimavoq taassumalu misissuisimanerup takutippaa sumiiffiit assigiinngitsut siunissami aatsitassarsiorfigineqassappata soqutigisassat qaleriiffeqassasut uanimi uumasoqatigiit, inuit aammalu kingornussassat isiginiartillugit soqutigisat sumiiffinni qaleriiaaramik.

Paasissutissat pigineqartut saqqummiunneqarput aammalu nalunaarummiittut nalinginnaasumik nassuiaatigineqarlutik tamannalu aamma ataatsimut quppersakkatigut takuneqarsinnaapput. Paasissutissat tamakkiisut NatureMap.gl aqqutigalugu tunniunneqarput aamma immikkut suliaq WebGIS (rba.eamra.gl) erseqqissaassutaalluni. Ilisimatuussutsikkut nalunaarusiaq "Kalaallit Nunaata kujataani - Immikkoortumi killeqarfimmi naliliineq Kalaallit Nunaata kujataanut atuuttoq aatsitassarsiornermut suliaqarnermut sammititaq" suliaavoq eqikkagaq 9-nik kapitalilik ilassuteqartorlu 4-nik.

Kapitali 1 Aallarniut – Immikkoortup killeqarfiata iluani naliliineq Kalaallit Nunaata kujataanut atuuttoq (RBA) aatsitassarsiornermut suliaqarnermut sammititaq

Aatsitassarsiornermik ingerlatsinerit (misissueqqaarnerit, piiaanerit assartuinerillu) avatangiisimut nunamullu arlaatigut sunniuteqartarput. Kalaallit Nunaanni, soorlu nunani allanitulli pisariaqartartutulli, atuukkallartussanik suliffissuaqarnermut killeqarfiliinissaq atuukkallarpoq, taamaaliornissarlu pinngitsoorneqarsinnaanngilaq. Aatsitassarsiorneq nunamut pitsaanngitsumik kinguneqartarpoq, nunap siornatigut iluserisimasaa aammalu ilaatigut eriagisassaqarfiit kulturikkut pingaaruteqartut minnerunngitsumillu inuit atuisimanerat sumiiffimmi ersiuteqartarlunilu ersittarpoq. Avatangiisit pillugit malittarisassat aammalu nunamik atuinermi pilersaarutit qulakkeerinnittussaapput aatsitassarsiornerup periarfissiissutaasa peqqutigisaannik nunap avatangiiserisallu ingerlatsinermit aserorneqannginnissaat maannamut kinguaariinnut siunissamilu kinguaariit atuisinnaanissaannut mattussaanissaat pinngitsoortinniagassaagami. Paasissutissat ilisimasallu naammattut pingaaruteqarput, ingammik teknologimut, ujarassiornikkut akuutissanut, nunami akuutissanut, uumassusillit assigiinngisitaarnerinut aammalu uumasoqatigiit imminnut ataqatigiinnerinut tunngasut pigineqartariaqarput aatsitassarsiornermi ingerlatsiniarnermi aammalu pilersaarusiorniarnermi, nakkutiginninniarnermi malittarisassiornermilu annertuumik piiaanermi sumiiffimmut sunniutigisinnaasai sillimaffigineqarniassammata.

Killeqarfimmi sumiiffiup iluaniittumi naliliineq (RBA) aatsitassarsiornermik ingerlatsiniarnermi soqutigineqartussat makkuupput:

Paasissutissat pigineqartut sumiiffimmut attuumassuteqartut aarlerinartumiittullu ilisimatusarnikkut paasisaqarfigineqarnissaat, aammattaaq naasut uumasullu assigiinngitsut sumiiffimmiittut katersorlugit nalunaarsorneqarnissaat.

Avatangiisinut immikkut aaliangiiffigineqarsimasunut tunngatillugu avatangiisit pillugit paasissutissat ullutsinnut malinnaasut pigilissallugit.

Avatangiisit assigisaallu pillugit paasissutissat ilisimasallu innuttaasunit aaneqarsinnaasut ullutsinnut tulluartuunissaat qulakkiissaallugit soorlu NatureMap (naturemap.eamra.gl) aqqutigalugu.

Kapitali 2 Kalaallit Nunaata kujataa aatsitassarsiornerup tungaanit isigalugu

Kapitalimi uani Kujataani ujarassiornikkut sumiiffiit aningaasarsiornikkut soqutiginaateqartut aatsitassallu akoqannginnerit ilanngullugit naatsumik sammineqassapput. Paasissutissat itisiliinerusut Ilanngussaq 1-imi "Kalaallit Nunaani ujarassiorneq"-mi takuneqarsinnaapput. Paasissutissat aatsitassat killeqarfimmi sumiiffiup iluaniittut inissisimaneri Sumiiffimmi Soqutigisaqarfimmi (AOI) paasissutissiisuupput. Kujataani aningaasarsiornikkut soqutiginaateqarfiit arlariiupput. Avatangiisini ujaqqat akuutissatigut katitigaanerat aallaavigissagaanni, avatangiisinut sunniuteqaateqarsinnaasut aammalu aqulluarneqartariaqartut suussusersineqarput. Taakku tamakkiisumik Takussutissiaq 2.1-mi atuarneqarsinnaapput.

Kapitali 3 Immikkoortumi killeqarfimmi Kalaallit Nunaata kujataani akuutissatigut kemi-p isikkua

Kapitalimi uani avatangiisini akuutissat pillugit paasissutissat Kujataanut attuumassutillit sammineqassapput. Paasissutissat suliniutinit assigiinngitsunik ingerlataqartunit saqqummiunneqassapput immikkut taallugit 'Akunnattumik naleqarlutik naatsorsukkat', 'Naatsorsukkat minnerpaamiitinneri' aammalu naatsorsukkat nalingi annertunerpaamiittut. Avatangiisini akuutissat pillugit paasissutissat "AMDA"-mit, DCE/Pinngortitaleriffimmillu avatangiisit pillugit paasissutissaasivimmit isumagineqarput.

Kujataani killeqarfiup iluani avatangiisit akorisaannik misissuineq ukiuni 4o-it missaanniittuni ingerlanneqartuarsimavoq, amerlanertigut aatsitassarsiorsinnaanissamut attuumassuteqartut periarfissat Kapitali 2-mi taaneqartut aamma misissueqqissaarnissat aatsitassarsiorsinnaanissamullu suliniutit pineqartillugit (Takussutissiaq 3.1). Ataatsimut isigalugu, avatangiisini misissugassat katersorneqarsimasut amerlanersai tassaapput uillut (Mytilus edulis), orsuatsiaat (Flavocetraria nivalis), qaleriissaarnerit, imeq tarajoqanngitsoq (salinnikoq salinneqanngitsorlu), kanajoq (Myoxocephalus scorpius) aamma qeqqussat (Fucus vesiculosus and Ascophyllum nodosum). Kisitsisit allat tunngavigalugit misissueqqissaarnerit allat aamma AMDA-p paasissutissartaanni takuneqarsinnaapput.

Killeqarfimmi paasissutissat pigineqareersut tunngavigalugit (avatangiisinit mingutserneqarsimanngitsunit misissugassat tiguneqarsimasut) AMDA-mi paasissutissartaanniittut, assigiinngitsut 70-it assigiinngitsunut arfineq-pingasuusunut agguarneqarsinnaasut naatsorsorneqarsimapput "Kalaallit Nunaani uuttuinermi akunnattumik inerneqartutut”. Killeqarfiup sumiiffiata iluani naliliinermi uuttuinermi akunnatsumik nalinga sumiiffinni annertuuni amma Kalaallit Nunaani sumiiffinni allani arfineq pingasuusuni naatsorsorneqarsimavoq. Uani "Kalaallit Nunaanni uuttuinermi akunnatsumik inernilik" nalunaarusiami uani sumiiffimmut soqutigisamut annerpaajusumik tulluartinneqarpoq. Sumiiffinni uuttuinermi akunnattumik inerniliussat allattorsimaffiat tamakkiisoq naleqassutsinut assigiinngitsunut misissuinermit takussutissartalik Ilanngussaq 2-mi takuuk.

Kapitali 4 Pinngortitamii assigiingisitaarneq aamma uumassuseqatigiissutsit pingaarutillit sumiiffiilu

Kapitalimi avatangiisinii uumassuseqatigiit tamakkiisumik takussutissaqartinneqarput. Uumasoqassuseq assigiinngitsunut pingasunut aggulullugu saqqummiunneqassaaq: AOI-mut uuttuutigalugu, Kalaallit Nunaani uuttuutit atorlugit aammalu nunarsuarmioqatigiit uuttuutigisaat atorlugu. Aarlerinartorsiortitaasut tamarmik allattorsimaffimmi aappaluttumi nalunaarsorneqarsimasut (naalisarneqartoq IUCN aarlerinartorsiornermut uuttuutigisai atorlugit; LC mianernanngitsumiittoq; NT, aarlerinartumiilernissaminut qanittumiittoq; VU, ernumanartumiittoq; EN, nungutaanissamut aarlerinartorsiortoq; aammalu CT, nungutaalluinnarnissamut ulorianartorsiortoq nunat tamarmiusut tamarmik aammalu nunarsuaq tamakkerlugu uuttuutit atorlugit inissisimaffik saqqummiunneqassaaq Takussutissiaq 4.1 (uumasut) aamma Takussutissaq 4.2 (naasut).

Sinerissap avataa ilanngunneqanngimmat, miluumasut imarmiut aalisakkallu sinerissap qanittuani avatangiisiniittut kisimik ilanngunneqarput. Miluumasunit imarmiunit aataaq (Phoca vitulina) immikkut pingaaruteqarpoq tassami Kalaallit Nunaanni aataaqassutsip annerpaartaa AOI-miimmat. Sumiiffiik ataaseq uninngaarfigineqartartoq - Qeqertani Narsaq Kujalliup (Narsarmijit) kangianiittoq. Arferit amerlanerpaat Kujataata kujammut kippasissuaniittarput sinerissallu avataaniittarlutik, taamaattoq tikaagullik (Balaenoptera acutorostrata) aammalu annikitsumik qipoqqaq (Megaptera novaeangliae) sinerissami takussaasarput pingaartumik aasaanerani kangerluit silarpasissuini.

Kapitalimi annertungaatsiartumik timmissat nunamiittut aammalu imartaniittut timmiarussallu eqqartorneqangaatsiassapput. Timmissanit qaasuttunit nattorallit sumiiffinni amerlasuuni manniliortarput Kalaallit Nunaannilu peqassuseq eqqarsaatigissagaanni amerlanerpaat AOI-mi takussaapput. AOI-p kitaa toornaviarsoqassuseq (Histrionicus histrionicus) eqqarsaatigalugu Kalaallit Nunaanut tamanut sanilliullugu pingaaruteqarluinnartumik inissisimavoq. Timmissat imartani avatangiiseqartut arlalissuit AOI-mi ukiisarput, taakkunanit pingaarnerpaajullutik timmiaaqqat. AOI appa sigguttooq pingaaruteqarluinnarpoq (Uria aalgae) aamma appa (Uria lomvia)-nut pingaaruteqarluinnarpoq. Ukiuunerani, sineriak Kujataatalu imartaa, AOI ilanngullugu, timmiarussanut timmissallu tatsinut qaniittunut manniliortunut ukiivittut pingaaruteqaqaaq.

Kujataani naasut assigiinngitsut ilisimaneqartut 370-it sinneqartut Kujataani naasuupput taakkunanillu 56-it AOI-p iluaniipput allattorsimaffimmilu aappalaartumi nalunaarsorneqarsimapput (navianartorsiortutut aammalu aarlerinartorsiortitaanissamut qanittumiittutut). Taakkunanit naasunit qulit Kujataanut immikkuullarissuupput. Naasut pillugit nalunaarsuut takussutissaq (scale 10x10 m) Kujataani naasut assigiinngitsut 5-it immikkoortitat tassaapput (orpikkat, musaasat, orsuatsiaat, ivikkat aamma uiffaat. Naasut pillugit nalunaarsuutit suliarinerini periuseq pillugu Ilanngussaq 3-mi takuneqarsinnaavoq.

Kujataani AOI-mi sumiiffiit sisamat illersorneqartut sisamat assigiinngitsuupput. Sumiiffiit illersorneqarneri "Nunaminertat illersorneqartut", "Timmissat illersorneqarnerat pillugu inatsit", "Samsar sites" aamma "UNESCO-p nunarsuarmioqatigiinnut kingornussarsiaqarfiata allattorsimaffia"   inatsisinut attuumassuteqarput. AOI-p iluani sumiiffiit pingaasut tassaapput "Nunaminertat illersorneqartut" iluani: Uunartoq aammalu Qinnguani qooroq Klosterdalenimilu qooroq. "Timmissat illersorneqarnerat pillugu inatsit" iluaniittut pingasuupput: Kitsissut Avalliit (aamma AOI-mi Ramsar site nr. 388), Kitsissuit ilua aammalu Qeqertat Narsaq Kujalliup (Narsarmijit) kangia. "Kujataa - Kalaallit Nunaanni issittumi nunalerineq" 2017-mi UNESCO-p nunarsuarmioqatigiit kingornussassaqartut allattorsimaffimmut ilanngunneqarpoq. UNESCO-mi kingornussarsiaqarfik sumiiffiup iluani arlariinnik nunatanik katitigaavoq.

Paasissutissat immikkuullarissut pigineqannginneri peqqutaalluni pupiit, bryophytes aamma inevertebrates pillugit uani nalunaarusiami ilanngunneqanngillat. Ilassutigalugu, inerniliussat ilai uani kapitalimi ilanngunneqartut paasissutissanit qangarnitsaneersuupput. Uani immikkut naasut suussusaalu pillugit aammalu timmiaqarfiit ukiuni kingullertigut misissuiffigineqarsimannginneri pissutaallutik.

Kapitali 5 Inuit atuinerat

Kapitalimi uani inuit atuinerat nalinginnaasumik eqqartorneqassaaq, soorlu nunalerinermi/ uumasuuteqarnermi (savat, tuttut aamma umimmaliinerit), imartat pisuussutaannik atuineq, orpeqarfiit, takornariaqarneq aammalu attaveqaatit teknikkimut sammisut . Kujataani avatangiisimik atuineq annerpaamik nunalerinermit uumasuuteqarnermillu tunngaveqarpoq. Kalaallit Nunaanni taamatut ingerlatsineq Kujataani kisimi pivoq. Kujataa 6,500-it missaanik inoqarpoq - 5,600 missingi illoqarfinni Qaqortoq, narsaq aamma Nanortalimmiillutik, 900-it missingi nunaqarfinni savaateqarfinnilu.

Nunalerineq aatsaat qallunaatsiaanit 985-mi eqqunneqarpoq. Ukiuni untritilikkaani qallunaatsiaat savaateqarneq nersutaateqarnerlu ingerlassimavaat, kisianni ukioq 1450-ip kingorna ukiuni 4-500-ni Kalaallit Nunaani nunalerinermik ingerlatsisoqarsimanngilaq. Kujataani savaateqarneq ukioq 1915-mi eqquteqqinneqarpoq ullumikkullu savaateqarfiit 37-iupput savat piaqqiortut 18000-iupput nersutillu 350-it uumasuutigineqarlutik.

Tuttuuteqarneq sumiiffinni marlunni ingerlanneqarpoq - Isortumi (1973-miilli) aamma Tuttutuumi (1992-miilli). Tuttuuteqarfiit ataatsimut nunami isorartussutsimi 1700 km2 inissisimapput aammalu 1200 -it missaani (Isortoq) aamma 350-it missaani (Tuttutooq) uumasuuteqarput. Ippatit qoorua Nanortallup nuua 2004-mi 18-nik umimmalerneqarpoq. Ullumikkut 50-it ataallugit sumiiffik taanna umimmaqarpoq.

Sinerissat annertunerpaava aalisagarpassuaqarpoq inuinnarnit aammalu inuussutissarsiutigalugu aalisartunit aalisarfigineqartumik. Kalaallit Nunaata sinneranut sanilliullugu Kujataani aalisarneq annikinneruvoq. Nalunaarusiami eqaluit (Salvelinus alpinus), saarullik (Gadus morhua), qaleralik (Reinhardtius hippoglossoides), nipisak (Cyclopterus lumpus), raaja (Pandalus borealis) saattuat (Chionoecetes opilio) saqqummiunneqarput.

RBA-p suliarinerani pingaartut ilagaat nunaqavissut pisuussutit AOI-mi uumassusillit pillugit innuttaasut ilisimasaat ilanngutissallugit. Sumiiffimmi sulinissami pilersaarusiorneq 2020-mi ingerlanneqarlernerani pingaartinneqarluinnarpoq, kisiannili nualluussuup Covid-19 peqqutigalugu killilersuutit atuunnerini tamanna pinngilaq taamaallaallu naasut pillugit misissuinerit, avatangiisinit misissugassanik akuutissanik tigusinerit ingerlanneqarput (Kapitali 3). Nunaqavissut ataatsimeeqatiginissaat, kommunimi sinniisut ataatsimeeqatiginissaat aammalu aaliangiisartut allat ataatsimeeqatigisinnaaneri inerteqqutigineqarmat nunaqavissut isumaat uani kapitalimi ilanngunneqanngillat.

Kapitali 6 Kalaallit Nunaanni kulturikkut oqaluttuassartaq – aallarniut

Kapitalimi kulturikkut oqaluttuassartaq ataatsisimut isiginerusoq saqqummiunneqassaaq. Kujataani eriagisassaqarfiit sumiinneri Takussutissiaq 6.2-mi aamma 6.3-mi takuneqarsinnaapput. Ilanngullugulu Takussutissiaq 6.3-mi Kujataani nukissiuteqarfinnit 5 km iluini eriagisassaqarfiit akulikissusaat ersersinneqassapput. Eriagisassaqarfiit sumiinneri amerlanertigut itsarnisarsiornikkut misissuisimanerit sumiissusersineqartarput kisiannili ilaatigut nunaqarfiit imminnut qanissusai aamma peqqutaasarput taamaattoqarneranut.

Kalaallit Nunaanni eriagisassaqarfiit sumi tamaani nassaassaagaluartut, nunap ilusaasigut isikkuisigullu takuneqarsinnaasarpoq tamanna nassaassaqarfiusoq suli nalunaarsorsimanngitsumik - pingaartumik inoqarfiit imaluunniit nunaqarfiit angisuujusimatillugit. Nunap isikkuatigut qattunersaqarlutik tinunertaqartutut isikkullik itsarnisarsiornikkut misissuinikkut suussusersineqartariaqarput arlaannaatigulluunniit misissueqqissaarniartoqartillugu aammalu ingerlatsisoqarniartillugu sumiiffiit eriagisassaanersut paasineqarnissaat qulakkeerniarlugu, tamakkuusinnaasut Takussutissaq 6.1-imi takuneqarsinnaapput.

Kapitali 7 Soqutigisat qaleriiffianni tamakkiisumik isiginnilluni itisiliineq

Kapitalini 4-6-ni nunap assingi arlariit saqqummiunneqarput, erseqqissaavigalugu sumiiffiit naasunut aamma uumasunut inuillu kulturikkut eriagisassaqarfinni atuinerinut pingaaruteqartut sumiiffiit. Takussutissat taakku imaassinnaavoq nuna nalinginnaasutut isigineqartut kisiannili ilisimagineqassaaq aatsitassarsiorluni misissueqqaarniarnermi piiaaniarnermilu pilersaarusiornermi pingaaruteqartuuneri.

Kapitalimi nunat tamakku soqutiginaateqartut assigiinngitsutigut soqutiginaateqarneri AOI-p iluani qaleriiffeqarsinnaammata. Katillugu, nunap assingi qaleriiffeqartut 51-it misissueqqissaarsimanernik ilallit (Takussutissaq 7.1) ilanngunneqarput. Misissueqqissaarnerit pingasut ingerlanneqarsimapput - ataaseq nunap assingi qaleriiffeqartut 51-sut naasut uumasullu, inuit atuinerat aammalu kulturikkut eriagisassaqarfiit (Takussutissiaq 7.1 aamma 7.2), nunap assingani ataatsimi qaleriiffillit 29-put inuit atuinerat pillugu paasissutissartaqarlutik aammalu kulturikkut eriagisassanut soqutiginaateqartunut attuumassuteqarlutik (Takussutissiaq 7.4).

Nunap assingi atorneqartillugit eqqaamaneqassaaq qaleriiffillit amerlasuut sumiiffimmi ataatsimiippata isumaqartoqassanngimmat aatsitassarsiornermi ingerlatsinermi avatangiisinut annertoorujussuarmik tassanerpiaq sunniuteqassasut. Taamaattoq, maannamut ilisimasanik soqutigisanut arlariinnut aatsitassarsiorniarnermut ingerlatsiniarnermi soqutiginaateqarsinnaammata.

Kapitali 8 Aatsitassarsiorneq aamma avatangiisinut sunniutit

Kapitalimi uani avatangiisinut sunniutit nalinginnaasut ullutsinni aatsitassarsiornermi nutaaliaanerusumi nunarsuarmioqatigiinni piumasaqaataasut naapertorlugit sunniutaasinnaasut sammineqassapput. Nunamut sunniutit aammalu sunniutit qanoq sivisutigisumik piusinnaaneri aammalu aatsitassarsioriaatsit assigiinngisitaartut pineqartillugit avatangiisinut suut sunniutigisinnaaneraat assersuutigineqassapput.

Kapitalimi uani immikkoortoq kingullermi ajutoortoqartillugu avatangiisinut sunniutaasinnaasut pillugit nassuiaateqartoqassaaq.

Kapitali 9 siunissami periarfissat paasissutissanillu amigaateqarnerit

Kapitamili uani siunissami silap allanngoriartornerata Kujataanut sunniutigiumaagassaat qanoq ittut ilimagineqarsinnaanersut sammineqassaaq. Nalunaarusiamittaaq tamarmi assersuutitut paasissutissaasinnaasut suut amigaatigineqarnersut saqqummiunneqartussaapput.

1 Introduction – Regional baseline assessments (RBA) of mining activities in South Greenland

By Anders Mosbech[1], Katrine Raundrup[2] and Janne Fritt-Rasmussen[1]

[1]Department of Ecoscience, Aarhus Universitet, [2]Greenland Institute of Natural Ressources

Mining activities (exploration, exploitation and transport) are bound to have a certain impact on nature and environment. In Greenland, as in other countries, it is often necessary to set up temporary industrial zones in connection with mining. Mining has a negative impact on nature, the original environmental conditions and occasionally cultural heritage, and it may limit other types of human use in the area. Environmental regulations and nature planning aim to ensure that the existing nature and environment are not destroyed to the detriment of current as well as future generations, while still creating the possibility of developing mining activities. Sufficient background knowledge about process technology, geochemistry, ecotoxicology, biodiversity and ecological contexts can help predict the impacts of new mining projects and often by planning, mitigation and regulation largely limit any effects beyond the actual area of exploitation.

Sensible planning and the use of the best available technologies (BAT) and best environmental practise (BEP), in addition to ongoing monitoring of the impact, can substantially limit the effect of mining on nature and environment. Mining projects often have a limited life span of a few decades, and it is important to plan from the very beginning if certain valuable biodiversity areas should be left untouched, and how the mining area is to be restored at the end of the project. Long-term planning can potentially ensure that valuable biotopes are restored in the landscape when a mine is closed, even if such biotopes are to some extent created artificially. In connection with mining projects, it is important to thoroughly analyse and describe the potential environmental impact as early as possible in the planning phase. Deciding whether the activity is desirable and the environmental impact is acceptable – locally as well as regionally and globally – is a democratic process and a political decision.

So far, area regulation of exploration activities in Greenland has been flexible. In practice, each initial investigation has been assessed based on existing knowledge, even when it was obvious that the existing knowledge was subject to significant uncertainty. It has been an important premise for this practice that exploration usually only gives rise to limited impacts on nature and environment. It has generally been possible to place disturbing activities in the least environmentally harmful places and periods so that a disturbing activity has been carried out, e.g., when vulnerable, moulting geese are absent from an area or that driving in connection with seismic surveys has been done when the landscape is snow-covered.

In the late exploration phase and in the exploitation phase, the activities are linked to specific and delimited areas and take place over longer periods (decades). In other words, there is no or little flexibility here as to where and when the activities are to take place. The companies must describe in their Environmental Impact Assessment (EIA) report how they intend to avoid or minimise disturbances as well as all other environmental impacts. It is therefore crucial for the companies that there is sufficient data to prepare adequate and accurate EIA reports. In cases where the available knowledge has been insufficient, it has been a requirement for the companies to carry out background studies to supplement the existing knowledge to fill out the knowledge gaps.

The Government of Greenland has, as an aid to obtain a regional overview of nature and environmental conditions in connection with the tender for oil exploration and exploitation permits on land, prepared regional environmental assessments (Strategic Environmental Impact Assessment - SEIA) for Jameson Land and Disko-Nuussuaq.

According to the same principles, Regional Baseline Assessments (RBA) of mining activities will, for selected areas of mining interest, provide:

- available knowledge of the location of vulnerable and important areas through studies of the distribution of plant and animal species as well as local knowledge of the areas.
- updated knowledge of natural background levels for selected elements.
- improved public access to updated environmentally relevant knowledge and data via, e.g., NatureMap (www.naturemap.eamra.gl).

This RBA of mining activities in South Greenland is the result of a project cooperation between EAMRA, GINR and DCE (Aarhus University). The purpose of the project is to provide a basis for supporting environmentally sound planning and regulation of mining activities by summarising regional background information and conduct sensitivity analyses and making these results operational and easily accessible. The purpose is threefold:

- To make it easier for the authorities to plan and regulate mining activities in relation to nature and the environment.
- To make it easier for locals and other stakeholders to get information on the potential impact of mining activities in the region.
- To make it easier and less costly for companies and their consultants to plan exploration activities considering the environment. The RBA will also be valuable for mining companies and holders of small-scale permits in connection with the preparation of the EIA ("Guidelines for the preparation of the EIA report [Environmental Impact Assessments] for mineral utilization in Greenland" of 2015).

The RBA for South Greenland has compiled existing information on geology (Chapter 2 and Appendix 1, input from GEUS), biodiversity (Chapter 4), human use (Chapter 5), cultural history and archeology (Chapter 6, input from Greenland National Museum and Archives) in the region. This report is based on published information, databases and local knowledge, and the information is supplemented with selected studies including remote sensing analysis of vegetation (Appendix 3) and chemical analyses of environmental background samples (Chapter 3 and Appendix 2). The area of interest (AOI) is shown in Figure 1.1. Based on the regional information compiled, we have conducted an integrated spatial overlay analysis of overlapping interests in the region (Chapter 7). Combined with knowledge of the generic environmental footprint of modern mining activities (Chapter 8), the overlay analysis can inform regional planning of mining activities.

An essential part of making an RBA is to include local knowledge of the biological resources in the AOI. When plans were made for the field work in 2020, this part was an integral element, but due to Covid-19 restrictions the field work was trimmed to only include vegetation analyses, collection of bladderwrack (Fucus vesiculosus) and blue mussel (Mytilus edulis), as well as samples of soil and snow-crust lichen (Flavocetraria nivalis) for chemical analyses (see chapter 3). As meetings with locals, municipality representatives as well as other stakeholders were prohibited, the inclusion of updated local knowledge is not part of this chapter. However, local involvement during the hearing phase of this report is possible.

The chapters in this report are intended for an overview of current knowledge but also include data gaps (Chapter 9). Appendix 4 summarizes relevant reccomendations by DCE/GINR regarding current field rules.

The report does not fulfil the contents of either an Environmental Impact Assessment (EIA) or a Social Impact Assessment of specific mining projects.

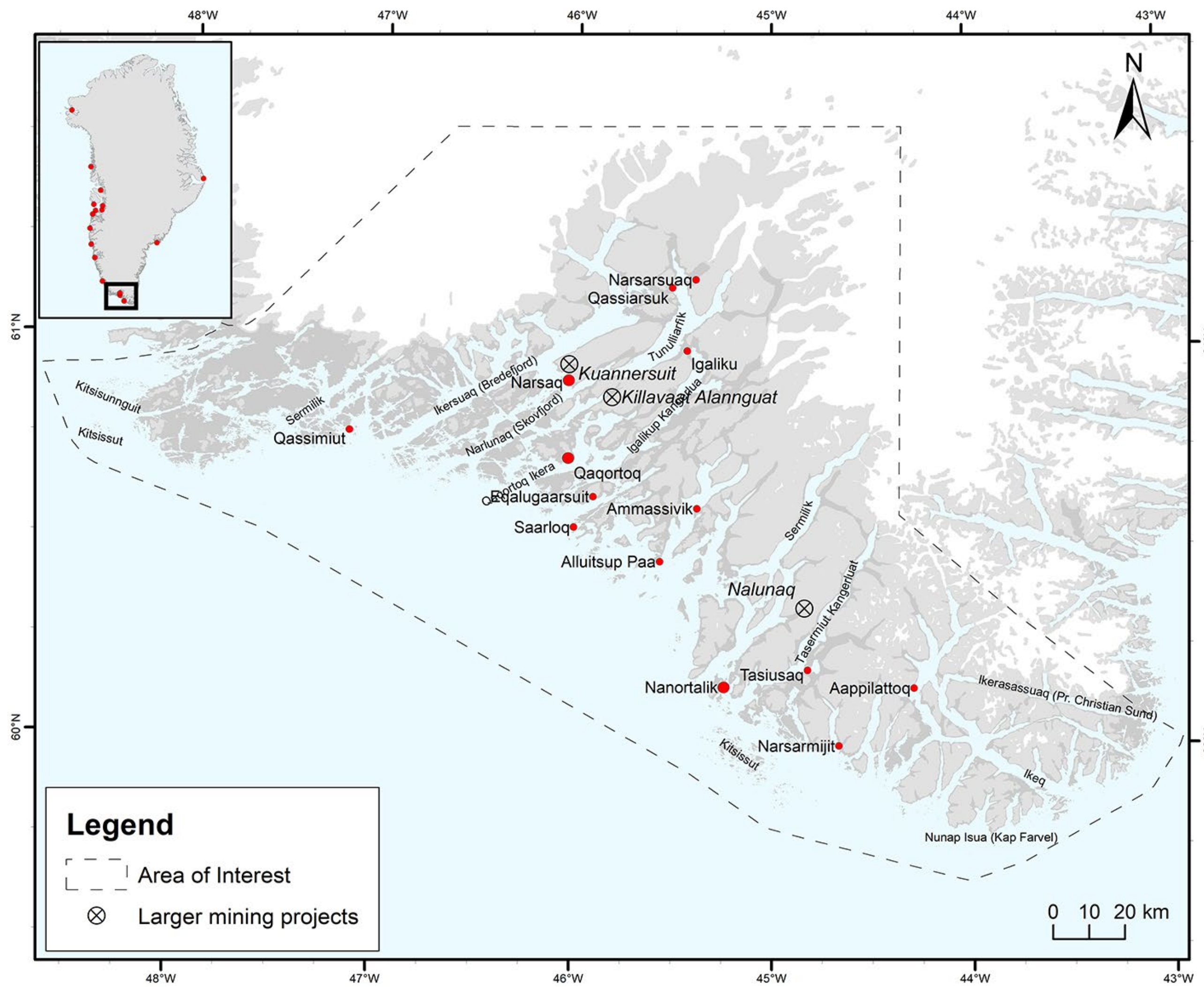


Figure 1.1. Area of interest of the Regional Baseline Assessment of South Greenland.

2 Geological setting of South Greenland from a mining perspective

By Kristine Thrane[1]

[1]*Geological Survey of Denmark and Greeland*

This chapter gives a short overview of the geological setting of South Greenland with focus on descriptions of localities of economic interest, including specifications of enriched elements. More details can be found in Appendix 1 "Geology in South Greenland". This information provides an important understanding of the geological baseline levels in the area of interest.

South Greenland is comprised of Archaean and Palaeoproterozoic rocks (Archaean = 4,000 to 2,500 million years ago; Palaeoproterozoic = 2,500 to 1,600 million years ago). Later, during the Mesoproterozoic (1,600 to 1,000 million years ago), the basement was affected by tectonic activity, and the crust was stretched, which resulted in a so-called rift zone. Sedimentary basins were subsequently deposited in the rift zones. At the same time, magma rose into the crust, forming magma chambers and intrusions in the higher levels. In some places, the magma travelled all the way to the surface and was deposited as large lava flows.

South Greenland has been divided into four geological domains (see Figure 2.1). The Northern, Central and Southern Domains, comprising Archaean and Palaeoproterozoic rocks, occupy geographically confined areas, whereas the Gardar Domain comprises Mesoproterozoic rocks that are distributed over most of South Greenland and deposited on or intruding into the older rocks. The area of interest defined for the South Greenland Regional Baseline Assessment (RBA) of mining activities (Figure 1.1 Introduction) covers a somewhat different area from what is defined by the geology; hence, the Northern domain, some of the Garder intrusions and the east coast are not included in the RBA area.

In South Greenland, there are several occurrences of economic interest. Based on the environmental geochemistry, some of the elements that may potentially have an impact on the environment and need to be managed have been identified. These occurrences are described in the following, and an overview is given in Table 2.1.

In the Northern Domain, two occurrences of gold (Au) have been found and investigated.

The Central Domain hosts copper (Cu) occurrences, including the small historic copper mines, the Josva mine (1851-54; 1905-14) and the Frederik VII mine (1852, 1905, 1912). In addition, gold occurrences as well as many small veins and enclaves with elevated uranium (U) concentrations have been found.

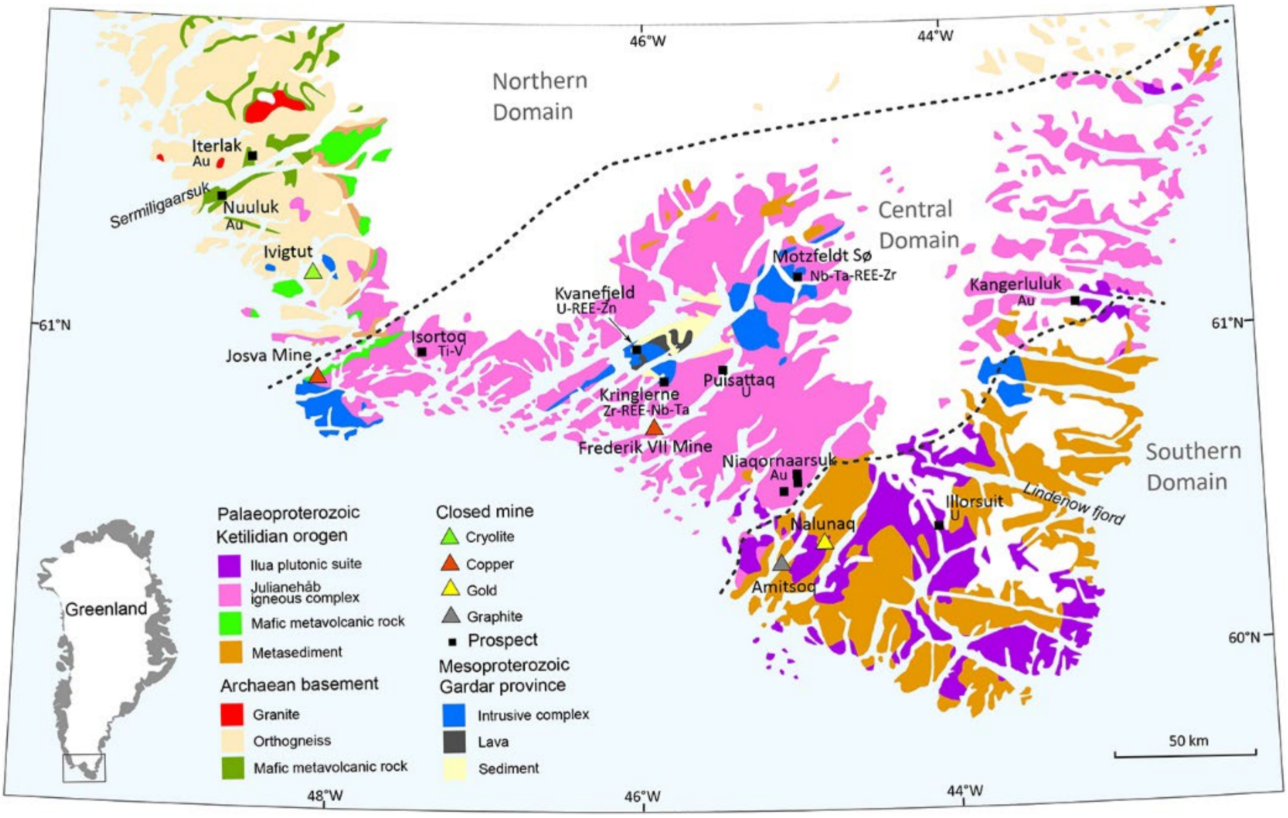


Figure 2.1. Geological division of South Greenland. From Steenfelt et al. (2016).

Table 2.1. Overview of known geological occurrences of economic interest, including specification of main enriched elements for South Greenland. For explanation of element abbreviations, please refer to the text. Ag: Silver, La: Lanthanum.

Domain	Name	Main enriched elements
Northern Domain	Nuuluk + Iterlak	Au, As
Central Domain	Niaqornaarsuk/Vagar	Au, Ag, As, (F)
	Josva Mine – Ilordleq Group	Cu, Ag, Au
	Nunatak – Nordre Sermilik	U, Th
	Puisattaq + Vatnahverfi	U, Th, F
Southern Domain	Illorsuit	U, Th
	Amitsoq + Sissarissoq	Graphite
	Nalunaq + Lake 410 + Ippatit	Au, As
	S-type granites	U, Th
Gardar Domain	Kvanefjeld	REE, U, Th, Zn, F
	Kringlerne	Zr, Nb, Ta, REE, F
	Igaliko - Motzfelt Sø	Nb, Ta, U, Th, Zr, Ce, La, F
	Ivigtut	Cryolite, F, Zn, P
	Grønnedal-Ika	REE, Zn, Fe
	Isortoq	Fe, Ti, V

The Southern Domain also contains closed mines, the Nalunaq gold mine (2003-2013) and the Amitsoq graphite mine (1915-1924). There are several other prospects for gold, graphite and uranium. Geochemical analyses show that the entire Southern Domain is enriched in arsenic (As) and that antimony (Sb), cesium (Ce), copper, and zinc (Zn) are enriched locally.

The Gardar Domain is known for hosting numerous magmatic intrusions of unique geochemical composition. These rocks contain a range of rare elements and minerals, including those at the famous historic cryolite mine (Ivigtut, 1854-1987). Currently, Kvanefjeld and Kringlerne are the main active prospects under development in the area and are especially investigated for their rare earth elements (REE) potential. Furthermore, Gardar intrusions are, in general, enriched in zirconium (Zr), niobium (Nb), uranium, zinc, thorium (Th), fluorine (F), beryllium (Be), lithium (Li), phosphorus (P), yttrium (Y), gallium (Ga) and tantalum (Ta). In addition, enormous dolerite dykes at Isortoq are enriched in iron (Fe), titanium (Ti) and vanadium (V).

More details can be found in Appendix 1 "Geology in South Greenland".

References

Steenfelt, A., Kolb, J. & Thrane, K. 2016. Metallogeny of South Greenland: A review of geological evolution, mineral occurrences and geochemical exploration data.

3 The environmental baseline chemistry of South Greenland

By Janne Fritt-Rasmussen[1], Drude Fritzbøger Christensen[1,2], Kasper Lambert Johansen[1], Jens Søndergaard[1] and Peter Aastrup[1]

[1]Department of Ecoscence, Aarhus University, [2]Current address: Department of Geosciences and Natural Resource Management, University of Copenhagen

This chapter gives an overview of the available environmental chemistry data on South Greenland. The data are derived from different projects and presented here as median, minimum and maximum values. All data can be found in the environmental chemisty database "AMDA", maintained by the DCE/GINR Environmental Datacenter.

3.1 Overview of available environmental samples analysed for South Greenland

The geology of South Greenland is described in detail in Chapter 2. Overall, South Greenland is divided into four domains (North, Central, South and Garder domain) classified by the type of rocks /major tectonic units found in the various parts whose specific geology defines the possibility for mineral exploration and exploitation activities.

The baseline environmental chemistry of South Greenland has been investigated during the past approx. 40 years, mostly in relation to the mineral prospects mentioned in Chapter 2 and exploration and exploitation activities (Figure 3.1). The environmental chemistry includes measurements of elements in, e.g., water, sediment, lichens, mussels, seaweed and fish samples. The work has involved taking baseline samples and, for the active mine sites, also monitoring samples. In addition, designated baseline studies for concentrations of elements in South Greenland have been completed. These include samples collected in 2020 in an east-west transect in the central part of the RBA area for determining the background concentrations of elements and thereby improving the baseline data available for the RBA of South Greenland (see the Section "Baseline environmental chemistry" for more details). An overview of localities, sample types and analysed elements for the area of interest is given in Figure 3.1 and Table 3.1. Apart from the already analysed samples presented in this chapter and available in the AMDA database, DCE, Aarhus University also maintains an environmental sample bank of frozen and dried samples, derived mostly from baseline studies conducted prior to different mine projects but also related to other research projects. The sample bank contains more than 20,000 samples that can be analysed for elements of interest.

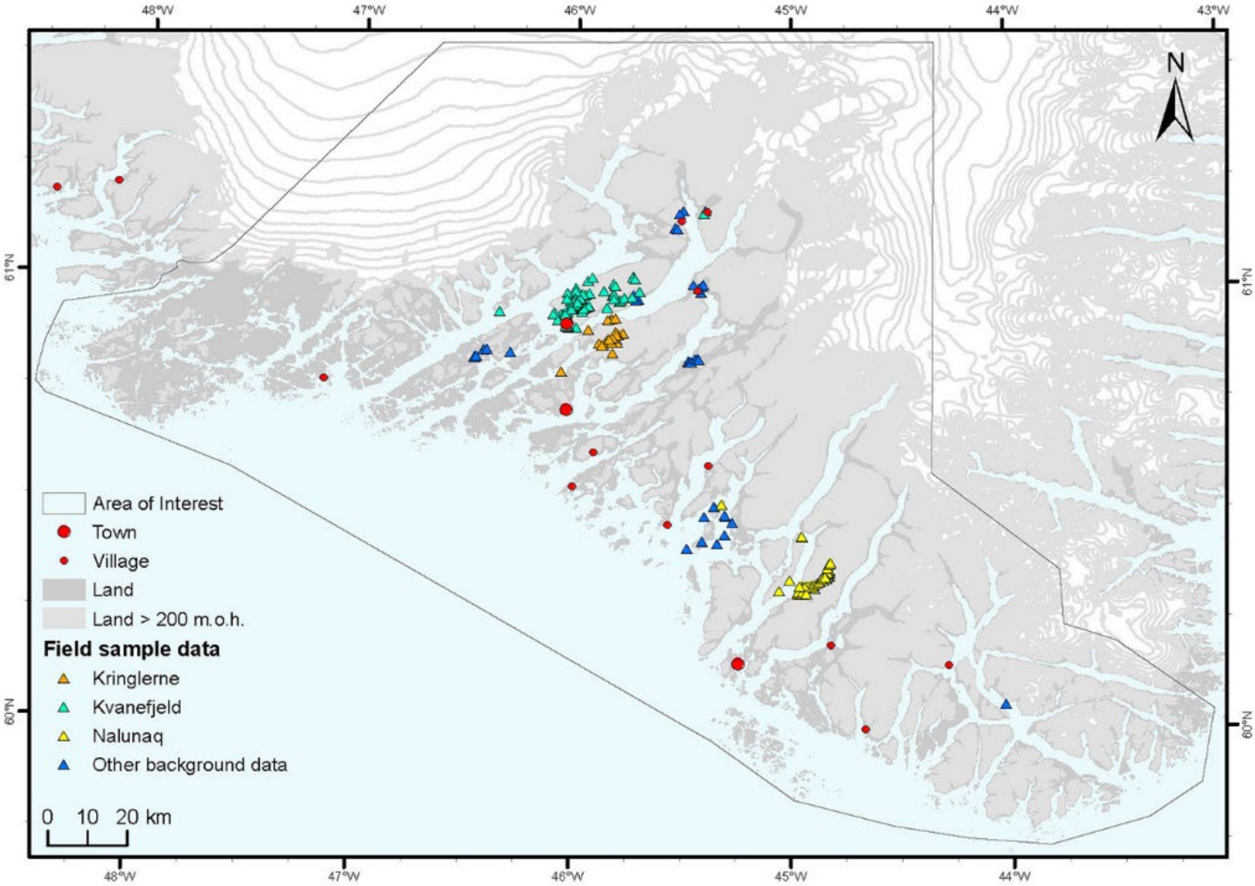


Figure 3.1. Locations of sites previously used for collection of samples for environmental chemistry analyses in South Greenland; the results can be found in the AMDA database. The category "other background data" is a combination of the available baseline studies (the projects 'AMAP', 'Heavy metals' and 'South Greenland RBA').

As the environmental chemistry data consist of data from 1982 and onwards, sampling approaches, chemical analysis measurements and sample types have changed over the years. This must be considered when assessing and using the data. The chemical analyses include AAS (Atomic Absorption Spectroscopy) and, more recently, ICP-MS (Inductively Coupled Plasma Mass Spectrometry) analyses. Overall, the major types of environmental samples available are of blue mussels (*Mytilus edulis*), crinkled snow lichens (*Flavocetraria nivalis*), sediments, fresh water (filtered and unfiltered), shorthorn sculpin (*Myoxocephalus scorpius*) and seaweed (*Fucus vesiculosus* and *Ascophyllum nodosum*). Analyses of other matrices are also available and found in the AMDA database.

Seaweed and blue mussels are sessile and accumulate elements from the surrounding seawater and thus reflect the water quality over longer time spans. However, seaweed tips show the year-to-year contamination (reflecting the element accumulation in the growing season) and blue mussels a period of 10-15 years (Bach 2020). Blue mussels are widely distributed in Greenland, except in the northern parts of East Greenland (Wenne et al. 2020). They are internationally well-established monitoring organisms and have been shown to bioaccumulate elements in their tissue due to filtration of large volumes of water when feeding (suspension feeders, leading to metal accumulation of both dissolved and particle-bound metals) (Rigét et al. 1997; Søndergaard et al. 2011). The element accumulation in seaweed is considered only to reflect the dissolved elements in the seawater (Rainbow 1995).

Table 3.1. Environmental chemistry data on South Greenland in the AMDA database. Sample types, years, total number of samples and analysed elements are available for each project. The category “seaweed” contains two types of brown fucoid macroalgae. Similar sample types collected in different years at one location can be analysed for different elements. Consequently, the number of concentration records for a specific element might be smaller than the reported number of samples in the sample type category. The analyses are conducted by use of ICP-MS or AAS. The locations of the different projects are shown in Figure 3.1. The projects ‘AMAP’, ‘Heavy metals’ and ‘South Greenland RBA’ are compiled in ‘other background data’ in Figure 3.1.

Project name	Sample types	Elements	Dry matter % (d.m.%)	Sampling years	Number of samples
AMAP	Shorthorn sculpin (liver)	Cd, Hg, Pb, Se	d.m.%	1994	45
	Sediment	As, Cd, Cu, Hg, Ni, Pb, Zn		1994	5
	Blue mussel	Cd, Hg, Pb, Se	d.m.%	1994	29
Heavy metals	Sediment	Hg		1985	2
Kringlerne	Blue mussel		d.m.%	1989	18
	Shorthorn sculpin	Cd, Hg, Se	d.m.%	1989	1
	Unfiltered water	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hg, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Pd, Pt, Rb, Rh, S, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr		2007, 2010	25
Kvanefjeld	Blue mussel	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pb-210, Pd, Po-210, Pr, Pt, Ra-226, Ra-228, Rb, Re, Ru, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	d.m.%	2001, 2009, 2014, 2017	22
	Crinkled snow lichen	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pb-210, Pd, Po-210, Pr, Pt, Ra-226, Ra-228, Rb, Re, Ru, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr		2009, 2014, 2017	32
	Seaweed	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pb-210, Pd, Po-210, Pr, Pt, Ra-226, Ra-228, Rb, Re, Ru, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	d.m.%	2001, 2009, 2014, 2017	16
	Sediment	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, F, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pb-210, Pd, Po-210, Pr, Pt, Ra-226, Ra-228, Rb, Re, Ru, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr		2009, 2013, 2014	4
	Shorthorn sculpin	Ag, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Pb-210, Po-210, Ra-226, Ra-228, Sb, Se, Sn, Sr, Th, Ti, Tl, U, V, Zn		2008, 2009, 2014	5
	Soil	Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Ra, Sb, Se, Sn, Sr, Th, Ti, Tl, U, V, Zn		2009, 2014	3

	Filtered water	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, F, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr		2011, 2013, 2014, 2017	107
Nalunaq	Blue mussel	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hg, K, La, Li, Mg, Mn, Mo, Nd, Ni, P, Pb, Pd, Pt, Rb, Rh, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, Y, Zn, Zr	d.m.%	1998, 2000, 2001, 2004-2007, 2009, 2011, 2012, 2014, 2015, 2017	138
	Crinkled snow lichen	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hg, K, La, Li, Mg, Mn, Mo, Nd, Ni, P, Pb, Pd, Pt, Rb, Rh, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, Y, Zn, Zr	d.m.%	1998, 2000, 2001, 2004-2007, 2009, 2011-2015, 2017	228
	Seaweed	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hg, K, La, Li, Mg, Mn, Mo, Nd, Ni, P, Pb, Pd, Pt, Rb, Rh, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, Y, Zn, Zr	d.m.%	1998, 2000, 2001, 2004-2007, 2009, 2011-2015, 2017	137
	Sediment	As, Au, Cd, Co, Cr, Cu, Fe, Hg, Ni, Pb, Se, Zn	d.m.%	2012	7
	Shorthorn sculpin	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hg, K, La, Li, Mg, Mn, Mo, Nd, Ni, P, Pb, Pd, Pt, Rb, Rh, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, Y, Zn, Zr		2000, 2004-2009, 2011-2013, 2017	188
	Filtered water	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Rh, Ru, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, T, Tm, U, V, W, Y, Yb, Zn, Zr		2012-2014, 2019	29
	Unfiltered water	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, Sc, Se, Sm, Sr, Ta, Tb, Te, Th, Ti, Tm, U, V, W, Y, Yb, Zn, Zr		2019	4
South Greenland RBA	Blue mussel	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, Sb, Sc, Se, Sm, Sr, Ta, Tb, Te, Th, Ti, Tm, Tl, U, V, W, Y, Yb, Zn, Zr	d.m.%	2020	24
	Crinkled snow lichen	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, Sb, Sc, Se, Sm, Sr, Ta, Tb, Te, Th, Ti, Tm, Tl, U, V, W, Y, Yb, Zn, Zr		2020	20
	Seaweed	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, Sb, Sc, Se, Sm, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr		2020	11
	Soil	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Hg, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Ru, Sb, Sc, Se, Sm, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr		2020	21

The measured element concentrations for filtered fresh water for dissolved elements are here defined as elements that can pass through a 0.45 µm filter. Hence, unfiltered fresh water also contains some particles in suspension. In addition to water sample elements, pH, temperature, electrical conductivity and redox potential (Eh)/oxygen are typically measured (Bach 2020).

Lichens are generally abundant in the Arctic. The crinkled snow lichen, *Flavocetraria nivalis*, is the preferred species for monitoring in Greenland as it is found in most parts of Greenland (Søndergaard et al. 2020). Lichens are used as a monitoring organism for dust deposition due to their large surface area, lack of roots and long lifespan. Their ability to accumulate dust and air pollutants from mining activities has been reported in several studies (Naeth and Wilkinson 2008; Søndergaard et al. 2011; Søndergaard et al. 2013; Søndergaard et al. 2020). With continuous pollution, the element concentration in lichens is found to increase with exposure time. Therefore, transplantation of lichens is often used for monitoring, typically for one year/short-term exposure to dust deposition.

The shorthorn sculpin (*Myoxocephalus scorpius*) is a highly common species in the fjords of Greenland and is relatively stationary at the seafloor (Muus 1990) and easy to catch. Hence, it has been a key monitoring organism for measuring bioaccumulation in the marine environment near mine sites (Søndergaard et al. 2020). Another fish species, Arctic char, should also be included in monitoring programs if present in the rivers near the mine sites.

Knowledge about the baseline environment, e.g., stream sediment samples, water samples and rock samples is also available from geological surveys (see Chapter 2 Geology).

3.2 Data from areas with former mining activities

Until now, most of the mining activities in South Greenland are related to exploration activities and minor field camps. The only mine that has been in actual operation over a longer period in the area of interest is the Nalunaq Goldmine which was in operation between 2004 and 2013 (Boertmann et al. 2018). Other mining activities during the late 19th and early 20th centuries included the Josva cobber mine near Innatsiaq (2,252 tonnes of ore mined in total), the Frederik VII cobber mine near Qaqortoq (18 tonnes of ore mined in total) and the Amitsoq graphite mine near Nanortalik (6,000 tonnes of ore mined in total) (Secher and Sørensen 2014). At Kvanefjeld, ore has also been mined; see below section about the "Kvanefjeld area".

Nalunaq area

This chapter summarises the activities on Nalunaq and is based on the report "*Environmental monitoring at the Nalunaq gold mine, South Greenland, 2004-2019*" (Bach 2020).

The Nalunaq Mountain is situated in a wide glacial valley reaching into the Saqqaa Fjord approx. 40 km northeast of Nanortalik. It contains a Proterozoic narrow-vein, high-grade gold deposit (Bach 2020). The gold deposit was discovered in 1992 (Secher et al. 2008) and, together with other findings, the area is considered a major gold province (Bach 2020).

The Nalunaq mine opened in 2004 as the first gold mine in Greenland and was closed again in 2013-2014. The Nalunaq mine is located in Kirkespirdalen, a glacial valley with mountain peaks reaching 1,200-1,600 m above sea level, and a river, Kirkespirelven, runs through the valley (Bach 2020). A 12 km long road was constructed from the mine to the fjord where an ore storage area was made. A pier was constructed with a barge at the end and a ship loading facility. The mining included coarse rock crushing on site and stockpiling of ore in the pier area before shipment of the ore (Bach 2020).

DCE completed an environmental baseline study in the period 1998-2001 (Glahder et al. 2005), and DCE/GINR conducted the environmental monitoring from 2004-2019, involving sample collection of selected environmental monitoring components (lichens, Arctic char, blue mussels, seaweed, sculpins and freshwater samples). The monitoring was based on analyses of a long list of elements (e.g., As, Cd, Co, Cr, Cu, Hg and Pb) measured in the samples and compared with the baseline samples. Full descriptions of the monitoring sampling and results from 2004-2013 can be found in Glahder and Asmund (2005, 2006, 2007); Glahder et al. (2008, 2009, 2010, 2011); Bach et al. (2012), Bach & Asmund (2013) and Bach et al. (2014).

After mine closure, the environmental monitoring programme continued in 2014, 2015 and 2017 with modifications (Bach et al. 2015; Bach and Larsen 2016; Bach and Larsen 2018). A final monitoring was conducted in 2019, where only water samples were analysed, and the biota samples are stored at DCE for potential future analyses (Bach and Olsen 2020).

During the environmental monitoring, it has been found that especially As, Co, Cr and Cu are elements of concern in the Nalulanq area. In Table 3.2 values of these elements in environmental baseline and monitoring samples taken in the Nalunaq area over the years (1998-2019) for blue mussels (*Mytilus spp*.), lichens (*Flavocetrari nivalis*), sediments, fresh water (filtered and unfiltered) and seaweed (*Fucus vesiculosus* and *Ascophyllum nodosum*) are given. In Figure 3.2, a detailed map shows the sampling sites for the different available samples. Analyses of other matrices and elements are also available.

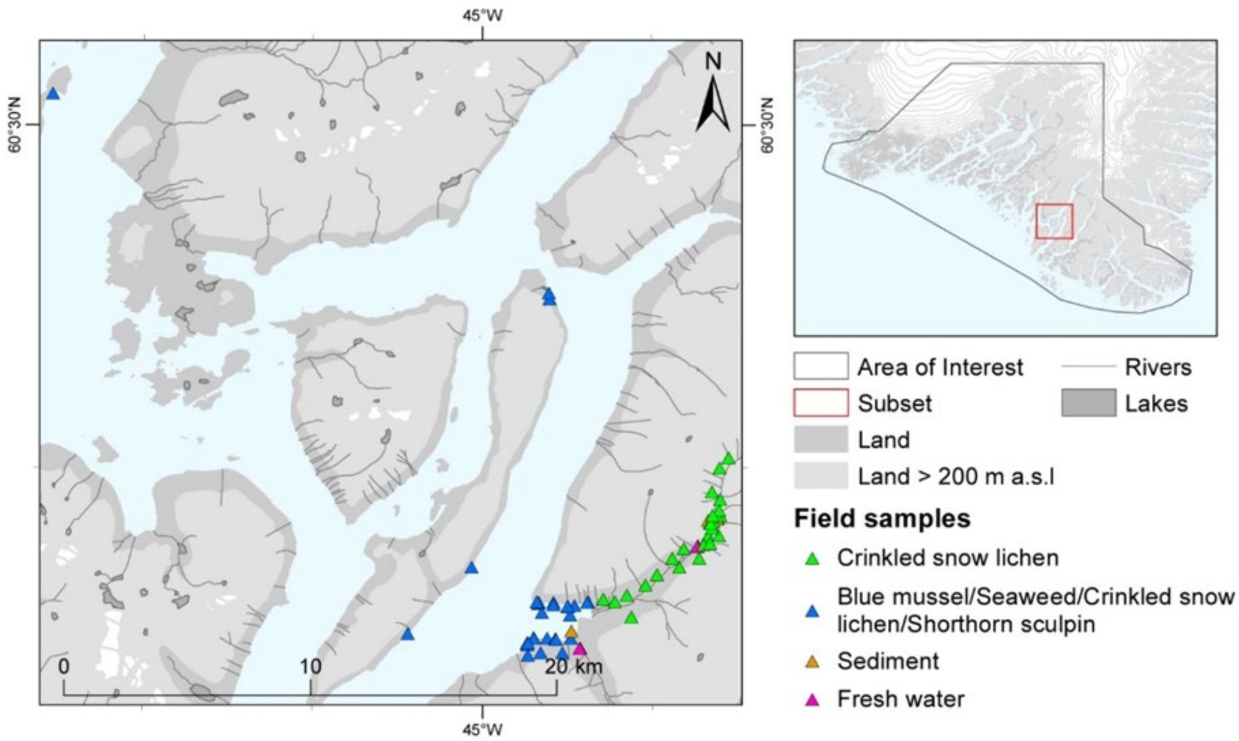


Figure 3.2. The Nalunaq area showing sampling sites for the different available sample types. The blue triangles are sites where several sample types were collected: blue mussel and/or seaweed and/or crinkled snow lichen and/or shorthorn sculpin.

In Table 3.2, also the "Greenland median value" and "South Greenland median value" of unpolluted samples are found for the purpose of comparison as well as, when possible, relevant guideline values. See the section "Baseline environmental chemistry studies" for details on how the Greenland and South Greenland median values are calculated.

Table 3.2. Concentrations of As, Co, Cr and Cu in environmental samples taken in the Nalunaq area over the years (1998-2019) for blue mussels (*Mytilus* spp.), lichens (*Flavocetralis nivalis*), sediments, fresh water (filtered and unfiltered) and seaweed (*Fucus vesiculosus* and *Ascophyllum nodosum*). “Greenland median” and “South Greenland median” values are calculated based on available baseline samples (unpolluted conditions) in the AMDA database. Where available, relevant guideline values are given.

Element	Sample type		Median	Min.	Max.	No. of meas.	No. of samples	Greenland Median	South Greenland Median	Guideline values
As	Blue mussel	mg/kg	11.57	0.01	20.84	154	138	12.66	12.5	
As	Crinkled snow lichen	mg/kg	0.49	0	9.33	256	228	0.04	0.05	
As	Filtered water	µg/l	6.3	0.6	306.11	25	25	0.05	0.11	4 µg/l[a]
As	Seaweed	mg/kg	52.03	11.83	89.54	165	138	40.59	38.92	
As	Sediment	mg/kg	18.09	3.06	338.91	8	7	5.37	5.6	20-52 mg/kg[b]
As	Shorthorn sculpin	mg/kg	2.3	0.78	22.25	216	188	7.08	2	
Co	Blue mussel	mg/kg	0.32	0.0003	0.77	154	138	0.58	0.53	
Co	Crinkled snow lichen	mg/kg	0.21	0.00005	3.22	255	227	0.18	0.11	
Co	Filtered water	µg/l	0.51	<DL	50.85	29	29	0.02	0.01	
Co	Seaweed	mg/kg	0.26	0.08	1.45	162	138	0.58	0.45	
Co	Sediment	mg/kg	7.88	2.19	37.02	8	7	9.11	1.4	
Co	Shorthorn sculpin	mg/kg	0.02	<DL	0.15	216	188	0.05	0.01	
Co	Unfiltered water	µg/l	0.13	0.007	7.35	4	4	0.08	0	
Cr	Blue mussel	mg/kg	0.64	0.0005	2.25	154	138	1.06	0.75	
Cr	Crinkled snow lichen	mg/kg	0.6	0.0002	6.29	258	228	0.33	0.25	
Cr	Filtered water	µg/l	0.07	0.02	0.17	29	29	0.08	<DL	3 µg/l[a]
Cr	Seaweed	mg/kg	0.1	<DL	2.36	166	138	0.29	0.18	
Cr	Sediment	mg/kg	69.24	31.66	198.35	8	7	66.77	1.1	70-560 mg/kg[b]
Cr	Shorthorn sculpin	mg/kg	0.01	<DL	0.57	215	188	0.01	<DL	
Cr	Unfiltered water	µg/l	0.09	0.08	0.12	4	4	0.11	0.02	
Cu	Blue mussel	mg/kg	6.99	0.006	12.23	154	138	7.37	7.12	6 mg/kg
Cu	Crinkled snow lichen	mg/kg	1.05	0.0004	22.23	256	228	0.76	0.66	
Cu	Filtered water	µg/l	1.22	0.04	28.49	29	29	0.61	0.19	2 µg/l[a]
Cu	Seaweed	mg/kg	1.42	0.05	19.35	165	138	1.97	2.12	
Cu	Sediment	mg/kg	17.24	5.44	285.38	8	7	20.44	13	35-51 mg/kg[b]
Cu	Shorthorn sculpin	mg/kg	1.27	0	16.69	216	188	1.6	1.2	
Cu	Unfiltered water	µg/l	0.27	0.09	1.15	4	4	0.68	0.08	

a) Greenland Water Quality Criteria (GWQC) (MRA 2015).

b) Bakke et al. (2010) – Norwegian sediment quality criteria; classification “Good”.

c) OSPAR (2014) - Assessment criteria used in the CEMP data assessment for mussels.

3.3 Other environmental baseline site investigations

Some sites in the area of interest have been investigated as part of the license application and approval process, but active mining has not yet been conducted. These sites are related to Kvanefjeld and Kringlerne, both located in the Gardar domain, and overall descriptions are given below.

Kvanefjeld area

Kvanefjeld mountain is located 8 km NE of Narsaq with a peak of 690 m. Kvanefjeld holds a uranium mineralization in the alkaline Ilimaussaq intrusion (Pilegaard 1990). The area has been investigated since 1955, and in 1962 180 tonnes ore were mined. In 1979, the Kvanefjeld Uranium Project was started, and 4,000 tonnes of ore were mined in 1979-1980 (Pilegaard 1990) and again in 1982 and 1983. Some of this ore was placed in piles below Kvanefjeld and some on the hillside just outside the mine entrance (approx. 10,000 tonnes ore) (Asmund 2001). The possible environmental impacts of these ore deposits were investigated in a monitoring programme in 2001 (Asmund 2001). Environmental samples were collected and analysed for a long list of elements, including Rare Earth Elements (REE). Elevated levels were seen for REE, zirconium, niobium and thorium compared with background levels. However, similar concentrations were measured before the pilot-scale mining activity initiated in 1976 due to the natural impact from Kvanefjeld (Asmund 2001). The main and overall conclusion from this monitoring was that the ore piles and leakage from the mine entrance did not affect the Narsaq river/Narsaq Ilua.

The Narsaq river basin holds a fourth order drainage network (Pilegaard 1990). The freshwater chemistry in the area has been investigated on several occasions (Pilegaard 1990 and references herein). In general, the water quality is typical for waters draining igneous rocks (Pilegaard 1990). However, elevated concentrations of some elements are found, particularly fluoride.

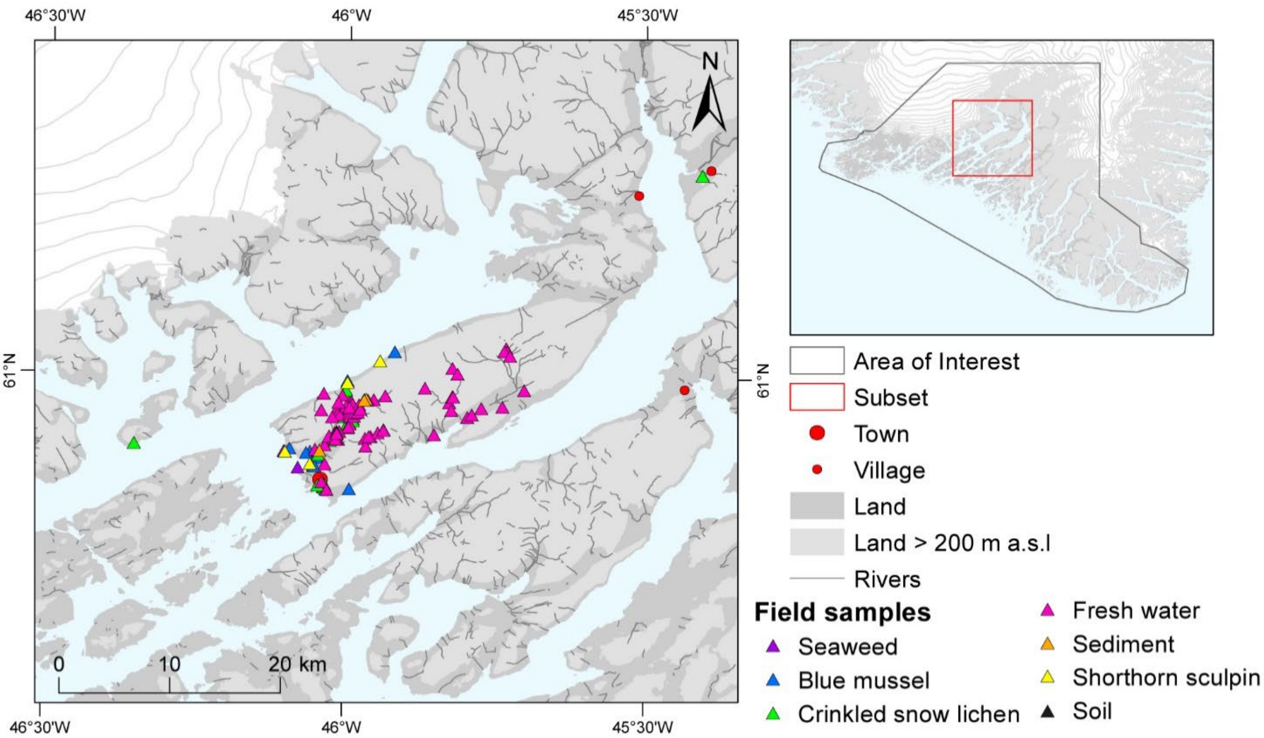


Figure 3.3. The Kvanefjeld area with location of sites where the different available sample types were collected.

Table 3.3. Concentrations of REE (total*), Zn, U, Pb and F in environmental samples taken in the Kvanefjeld area over the years (2001-present) for blue mussels (*Mytilus* spp.), lichens (*Flavocetralis nivalis*), sediments, fresh water (filtered and unfiltered) and seaweed (*Fucus vesiculosus* and *Ascophyllum nodosum*). “Greenland median” and “South Greenland median” values are calculated based on available baseline samples (unpolluted conditions) in the AMDA database. Where available, relevant guideline values are given. For more details about ecotoxicity of fluoride, rare earth elements and naturally occurring radionuclides, please consult Hansen et al. 2022.

Element	Sample type		Median	Min.	Max.	No. of meas.	No. of samples	Greenland Median	South Greenland Median	Guideline values
F	Filtered water	µg/l	1039	<DL	28302	91	91	1039	1039	1500[e]
F	Sediment	mg/kg	3.12	3.12	3.12	2	2	3.12	3.12	
Pb	Blue mussel	mg/kg	3.74	0.16	11.14	27	22	0.69	1.01	1.3 mg/kg[c]
Pb	Crinkled snow lichen	mg/kg	1.00	0.18	11.41	34	32	0.66	0.82	
Pb	Filtered water	µg/l	0.06	<DL	7.06	116	107	0.03	0.06	1 µg/l[a]
Pb	Seaweed	mg/kg	0.23	<DL	0.85	25	16	0.12	0.23	
Pb	Sediment	mg/kg	39	<DL	110	4	4	14.13	18.14	30-83 mg/kg[b]
Pb	Shorthorn sculpin	mg/kg	<DL	<DL	<DL	5	5	0.007	0.007	
Pb	Soil	mg/kg	70	14	87	3	3	12.55	13.28	
U	Blue mussel	mg/kg	0.21	<DL	0.87	38	22	0.26	0.25	
U	Crinkled snow lichen	mg/kg	0.07	<DL	1.6	37	32	0.01	0.06	
U	Filtered water	µg/l	0.08	0.004	2.82	116	107	0.06	0.08	15 µg/l[f]
U	Seaweed	mg/kg	0.76	0.15	1.56	31	16	0.64	0.85	
U	Sediment	mg/kg	30	0.0003	61	6	4	1.95	30	
U	Shorthorn sculpin	mg/kg	<DL	<DL	0.02	10	5	0.002	<DL	
U	Soil	mg/kg	30	22	74	6	3	3.45	3.47	
Zn	Blue mussel	mg/kg	74	16	245	27	22	75.70	74.23	63 mg/kg[c]
Zn	Crinkled snow lichen	mg/kg	21	8	90	34	32	19.25	22.18	
Zn	Filtered water	µg/l	1.42	0.133	14.17	116	107	0.99	1.41	10 µg/l[a]
Zn	Seaweed	mg/kg	35.30	<DL	129.62	25	16	13.98	19.61	
Zn	Sediment	mg/kg	215	0.002	730	4	4	69.11	92.62	150-360 mg/kg[b]
Zn	Shorthorn sculpin	mg/kg	10	8	61	5	5	33.71	10	
Zn	Soil	mg/kg	300	40	380	3	3	64.85	68.54	
∑REE*	Blue mussel	mg/kg	46					7.21	11.42	
∑REE*	Crinkled snow lichen	mg/kg	9					7.06	10.12	
∑REE*	Filtered water	µg/l	0.35					0.34	0.35	2 µg/l[d]
∑REE*	Seaweed	mg/kg	3.96					1.66	3.75	
∑REE*	Sediment	mg/kg	0.0002					109.87	0.0002	

*Sum of the individual median concentrations of all 17 REEs except Pm.

a) MRA (2015) Greenland Water Quality Criteria (GWQC).

b) Bakke et al. (2010) – Norwegian sediment quality criteria; classification “Good”.

c) OSPAR (2014) - Assessment criteria used in the CEMP data assessment for mussels.

d) de Boer et al. (1996), Safety levels for each individual REE for drinking water in the Netherlands, for ∑REE an estimated value would be 32 µg/L.

e) Anon (2008) Greenland quality limits for drinking water, raw water and water.

f) CWQG (2011) Canadian Water Quality Guidelines.

Elevated concentrations of quite a few elements occur at Kvanefjeld. Results of measurements of REE (total), Zn, U, Pb and F in environmental samples taken in the Kvanefjeld area over the years (2001-present, by mining company consultants as well as DCE) in blue mussels (*Mytilus* spp.), lichens (*Flavocetraria nivalis*), sediments, fresh water (filtered and unfiltered) and seaweed (*Fucus vesiculosus* and *Ascophyllum nodosum*) are given in Table 3.3. Analyses of other matrices are also available. In Figure 3.3 a detailed map shows the sampling sites for the different available samples.

Kringlerne area

Killavaat Alannguat or Kringlerne is a group of stratified rocks located at the Kangerluarsuk fjord between Narsaq and Qaqortoq. In those rock formations, the mineral eudialyte is found, which contains high concentrations of many rare elements, among those the REEs.

Background environmental samples were collected in 1988, 1989, 2007, 2008 and 2010 in relation to exploration activities. These samples are stored in the environmental sample bank for analysis in future EIA studies as part of an exploration license application. Hence, only very few chemical analyses are available today. See Figure 3.4 for the location of the sites where the analysed samples were collected and Table 3.4 for measurements of selected elements.

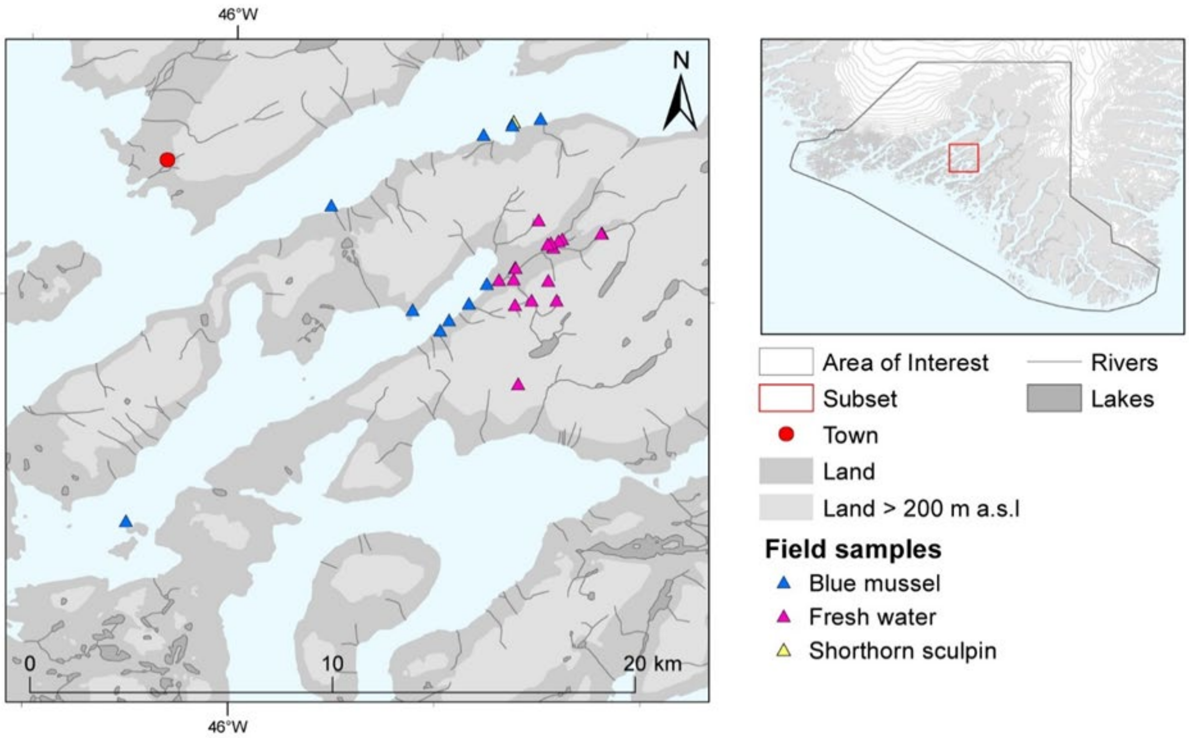


Figure 3.4. The Kringlerne area with location of sites where the different available sample types were collected.

Table 3.4. Concentrations of REE (total*), Zn, U, Pb and F in environmental samples taken in the Kringlerne area over the years (1989 and 2007, 2010) of short-horn sculpin (*Myoxocephalus scorpius*) and fresh water (filtered). "Greenland median" and "South Greenland median" values are calculated based on available baseline samples (unpolluted conditions) in the AMDA database. Where available, relevant guideline values are given.

Element	Sample type		Median	Min.	Max.	No. of meas.	No. of samples	Greenland Median	South Greenland Median	Guideline values
Cd	Shorthorn sculpin	mg/kg	2.85	2.85	2.85	1	1	1.00	0.46	0.026 mg/kg[b]
Cd	Unfiltered water	µg/l	0.01	<DL	0.09	30	25	0.01	0.01	0.1 µg/l[a]
Hg	Shorthorn sculpin	mg/kg	0.04	0.04	0.04	1	1	0.05	0.01	0.035 mg/kg[b]
Hg	Unfiltered water	µg/l	<DL	<DL	0.13	30	25	<DL	<DL	0.05 µg/l[a]
Pb	Unfiltered water	µg/l	0.06	0.001	0.49	30	25	0.10	0.06	1 µg/l[a]
Se	Shorthorn sculpin	mg/kg	0.25	0.25	0.25	1	1	0.86	0.88	
Se	Unfiltered water	µg/l	0.20	<DL	0.43	30	25	0.07	0.20	
U	Unfiltered water	µg/l	0.05	0.01	0.69	30	25	0.12	0.05	15 µg/l[c]
Zn	Unfiltered water	µg/l	2.27	<DL	16.29	30	25	2.56	2.27	10 µg/l[a]

a) Greenland Water Quality Criteria (GWQC) (MRA 2015).

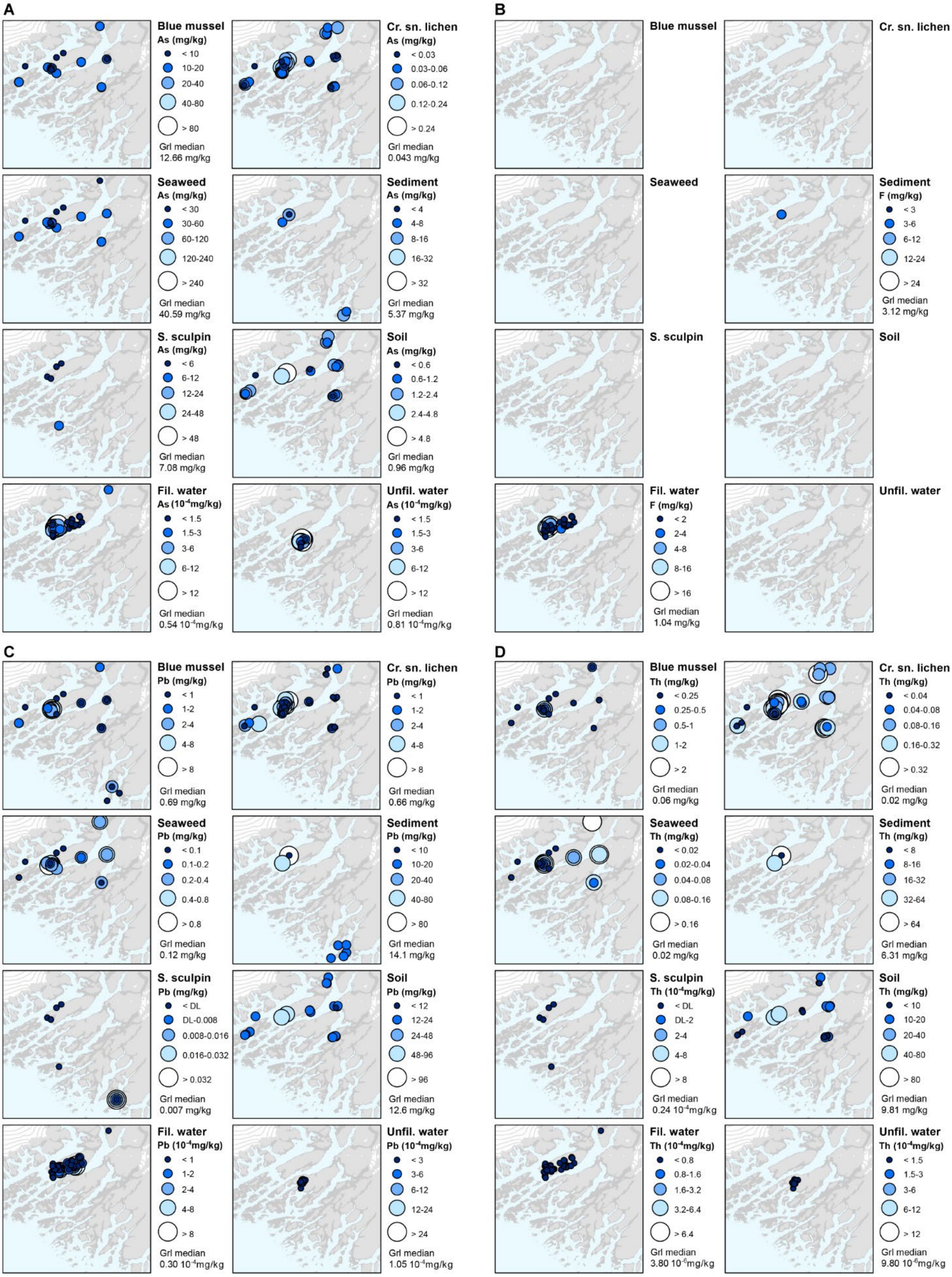
b) OSPAR (2014) - Assessment criteria used in the CEMP data assessment for fish.

c) CWQG (2011) Canadian Water Quality Guidelines.

Baseline environmental chemistry studies

In Figure 3.5 (A-F), concentrations of selected elements (As, F, Pb, Th, U and Zn) in the different sample types are presented for the area of interest. Only baseline samples are included in the maps, i.e., no samples related to active mines or other known anthropogenic pollution are included.

Based on all available baseline data (samples representing unpolluted conditions) in the AMDA database, "Greenland median" concentration values of approx. 70 different elements in eight different sample types have been calculated. The "Greenland median" values are calculated from a total of 2115 samples from all over Greenland (seaweed: 71; crinkled snow lichen: 194; blue mussel: 364; short-horn sculpin: 854; sediment: 123; soil: 43; filtered water: 288, and unfiltered water: 178). Relevant "Greenland median" values are included in Figure 3.5 for indication of levels, and the full list of "Greenland median" values are given in Appendix 2. Note that for some elements and sample types very few data exist. Also note that the "Greenland median" values are not geographically/spatially weighed, but represents unweighted medians of baseline samples, which typically cluster in areas where there has been an interest in mining operations, but also supplemented with other environmental samples.



A
Blue mussel
As (mg/kg)
< 10
10-20
20-40
40-80
> 80
Grl median
12.66 mg/kg
Cr. sn. lichen
As (mg/kg)
< 0.03
0.03-0.06
0.06-0.12
0.12-0.24
> 0.24
Grl median
0.043 mg/kg
Seaweed
As (mg/kg)
< 30
30-60
60-120
120-240
> 240
Grl median
40.59 mg/kg
Sediment
As (mg/kg)
< 4
4-8
8-16
16-32
> 32
Grl median
5.37 mg/kg
S. sculpin
As (mg/kg)
< 6
6-12
12-24
24-48
> 48
Grl median
7.08 mg/kg
Soil
As (mg/kg)
< 0.6
0.6-1.2
1.2-2.4
2.4-4.8
> 4.8
Grl median
0.96 mg/kg
Fil. water
As (10^{-4}mg/kg)
< 1.5
1.5-3
3-6
6-12
> 12
Grl median
0.54 10^{-4}mg/kg
Unfil. water
As (10^{-4}mg/kg)
< 1.5
1.5-3
3-6
6-12
> 12
Grl median
0.81 10^{-4}mg/kg
B
Blue mussel
Cr. sn. lichen
Seaweed
Sediment
F (mg/kg)
< 3
3-6
6-12
12-24
> 24
Grl median
3.12 mg/kg
S. sculpin
Soil
Fil. water
F (mg/kg)
< 2
2-4
4-8
8-16
> 16
Grl median
1.04 mg/kg
Unfil. water
C
Blue mussel
Pb (mg/kg)
< 1
1-2
2-4
4-8
> 8
Grl median
0.69 mg/kg
Cr. sn. lichen
Pb (mg/kg)
< 1
1-2
2-4
4-8
> 8
Grl median
0.66 mg/kg
Seaweed
Pb (mg/kg)
< 0.1
0.1-0.2
0.2-0.4
0.4-0.8
> 0.8
Grl median
0.12 mg/kg
Sediment
Pb (mg/kg)
< 10
10-20
20-40
40-80
> 80
Grl median
14.1 mg/kg
S. sculpin
Pb (mg/kg)
< DL
DL-0.008
0.008-0.016
0.016-0.032
> 0.032
Grl median
0.007 mg/kg
Soil
Pb (mg/kg)
< 12
12-24
24-48
48-96
> 96
Grl median
12.6 mg/kg
Fil. water
Pb (10^{-4}mg/kg)
< 1
1-2
2-4
4-8
> 8
Grl median
0.30 10^{-4}mg/kg
Unfil. water
Pb (10^{-4}mg/kg)
< 3
3-6
6-12
12-24
> 24
Grl median
1.05 10^{-4}mg/kg
D
Blue mussel
Th (mg/kg)
< 0.25
0.25-0.5
0.5-1
1-2
> 2
Grl median
0.06 mg/kg
Cr. sn. lichen
Th (mg/kg)
< 0.04
0.04-0.08
0.08-0.16
0.16-0.32
> 0.32
Grl median
0.02 mg/kg
Seaweed
Th (mg/kg)
< 0.02
0.02-0.04
0.04-0.08
0.08-0.16
> 0.16
Grl median
0.02 mg/kg
Sediment
Th (mg/kg)
< 8
8-16
16-32
32-64
> 64
Grl median
6.31 mg/kg
S. sculpin
Th (10^{-4}mg/kg)
< DL
DL-2
2-4
4-8
> 8
Grl median
0.24 10^{-4}mg/kg
Soil
Th (mg/kg)
< 10
10-20
20-40
40-80
> 80
Grl median
9.81 mg/kg
Fil. water
Th (10^{-4}mg/kg)
< 0.8
0.8-1.6
1.6-3.2
3.2-6.4
> 6.4
Grl median
3.80 10^{-6}mg/kg
Unfil. water
Th (10^{-4}mg/kg)
< 1.5
1.5-3
3-6
6-12
> 12
Grl median
9.80 10^{-6}mg/kg

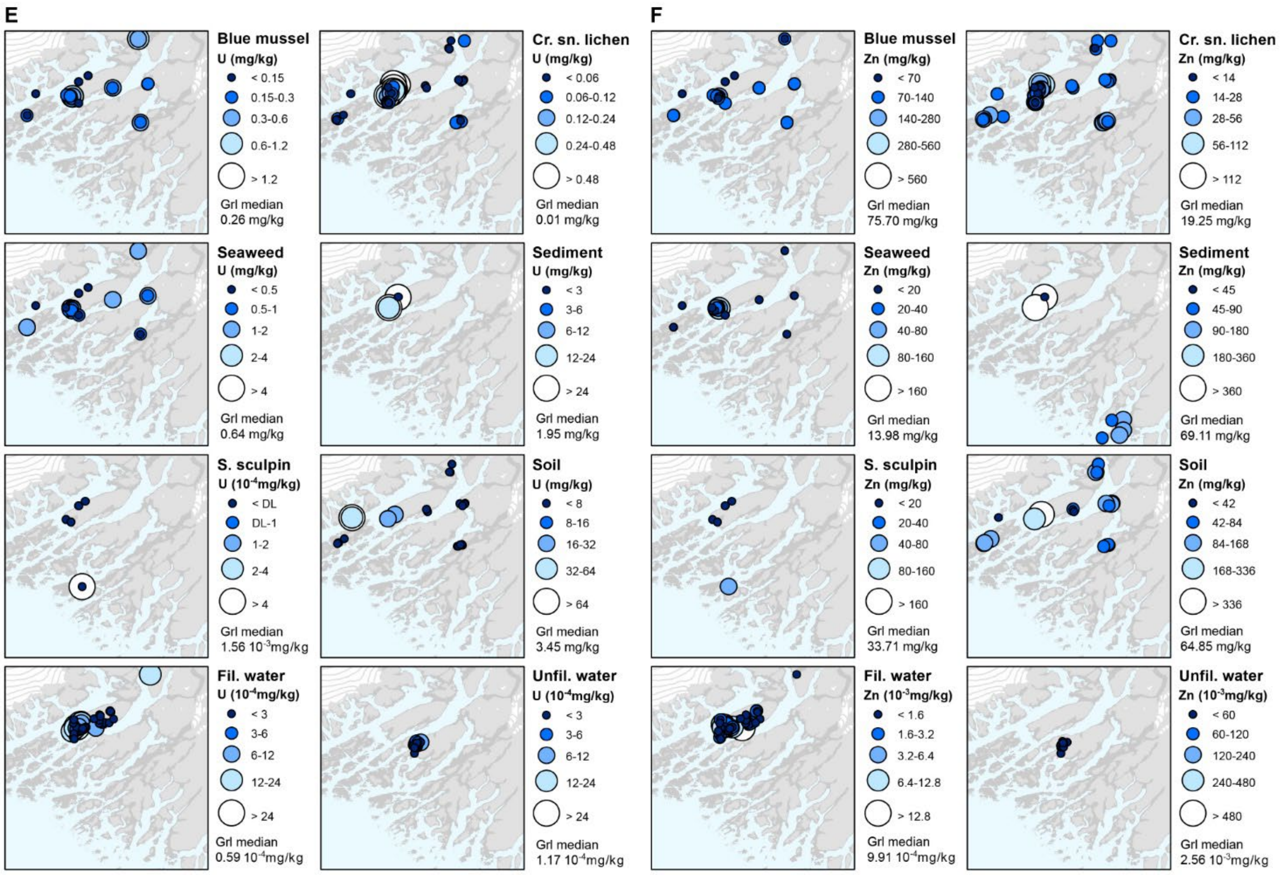


Figure 3.5. Concentrations of the elements arsenic, As (a), fluor, F (b), lead, Pb (c), thorium, Th (d), uranium, U (e) and zinc, Zn (f) in the different sample types for baseline samples (unpolluted conditions) given in the AMDA database for the area of interest. A "Greenland median" value calculated from all available baseline data in the AMDA database is also included for indications of levels. Maps with no levels are due to "no data available".

Baseline median values have also been calculated for eight separate larger regions of Greenland. Here, the "South Greenland median" is of primary relevance to the area of interest for this assessment report. The full list of regional median concentration values of the different elements in the different sample types are given in Appendix 2, including a map that shows the regional subdivision of Greenland and the relative sampling density within the different regions.

Baseline data on South Greenland – field work 2020

Environmental samples (lichens, soil, mussels and seaweed) were collected to establish baseline levels in a selected and central part of the South Greenland RBA area of interest. The five sampling sites (Site 1-5) can be seen in Figure 3.6. Based on relevant elements for other parts of the assessment area, levels of As, Zn, Pb, U, Th and REE are presented in Figure 3.7 for the collected sample types (lichen, soil, seaweed and mussels). In the figure, "Greenland median" values are also given for comparison. There is variation between the results from the five sites, and no clear indication of whether the element concentrations in the collected samples are above or below the Greenland median values is obtained. Thus, the sampes do not clearly reflect the mineralisation in the area and the related elements but highlight variations in the baseline levels. These results underline the importance of a thorough and well-planned baseline study to identify the specific baseline levels of environmental samples for a new mining site.

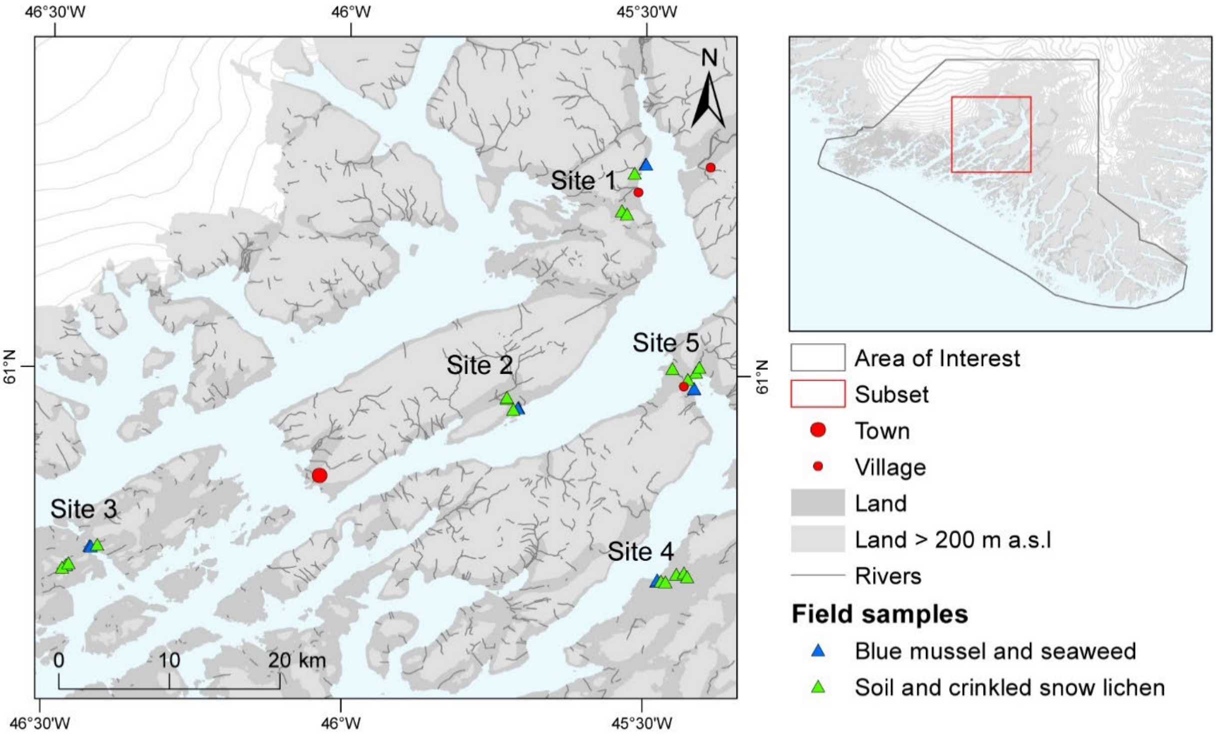


Figure 3.6. Sites for environmental sample collection during the field work in summer 2020.

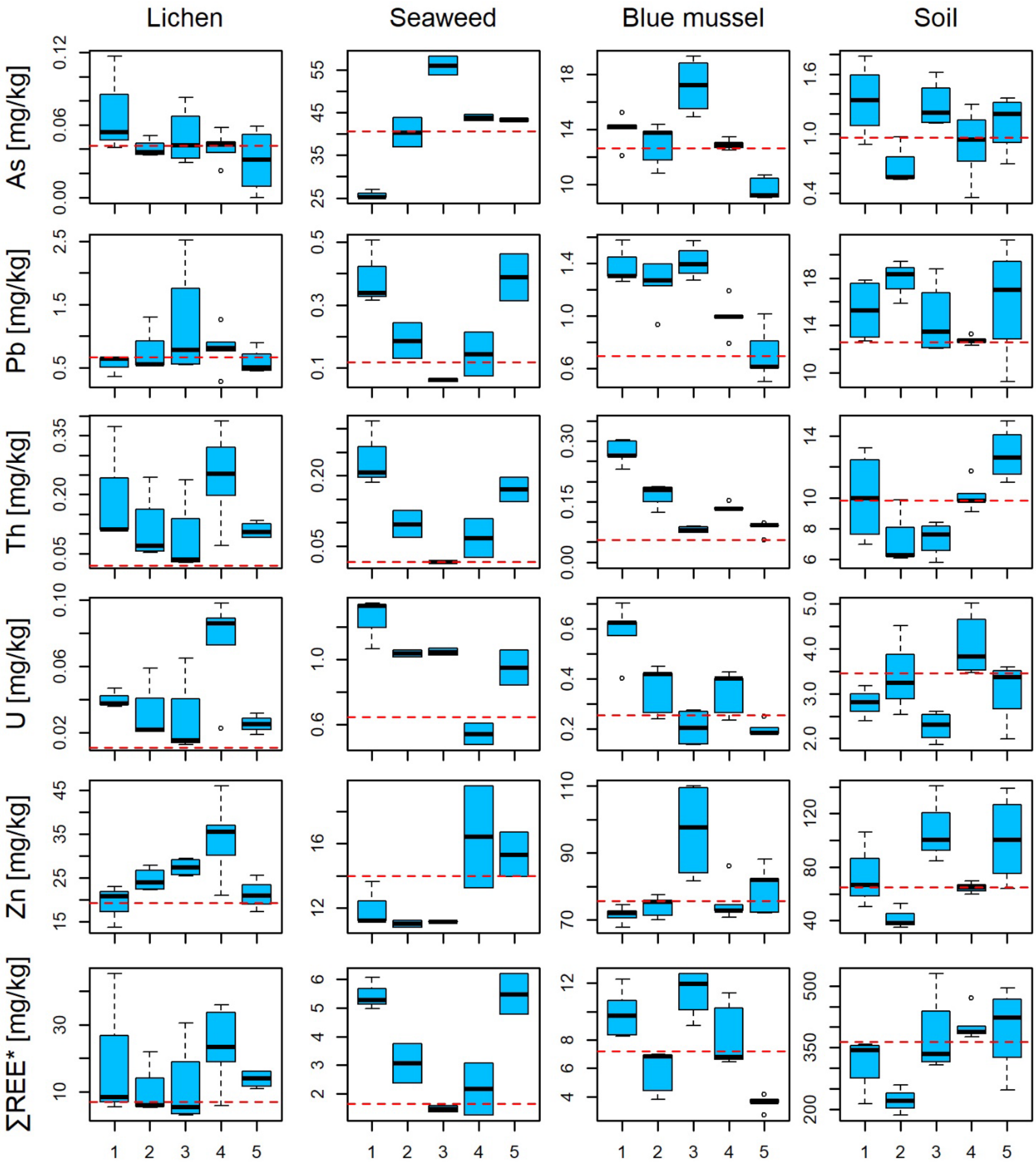


Figure 3.7. Boxplots of concentrations of As, Zn, Pb, U, Th and REE in different different sample types (lichen, soil, seaweed and mussels) collected as baseline data during fieldwork in the summer 2020 (South Greenland RBA baseline samples). The numbers on the x-axis refer to the site numbers in Figure 3.6. Dashed red line: "Greenland-median" value.
*Sum of the individual median concentrations of 17 REEs except Pm.

3.4 Geological and environmental chemistry

For this report, GEUS has prepared a summary description of the geology of Southern Greenland (see Chapter 2 and Appendix 1), and further details can be found in Steenfeldt et al. (2000 and 2016).

As part of the summary, GIS data are available, presenting the content of different elements based on geochemical stream sediment analyses from the GEUS database and collected during different geological surveys. Stream sediment samples are available for Zn, Pb, U, Th and As (GIS data). The stream sediments were sampled throughout South Greenland as evenly as possible from second or third order streams, preferably with catchment areas less than 10 km² (Thrane and Olsen 2020, Appendix 1). Water samples and rock samples are available for fluorine. The rock data include data from two separate but comparable databases (GEOROC and the GEUS database); hence, these data are compiled and presented together (GIS data). For further details see Appendix 1.

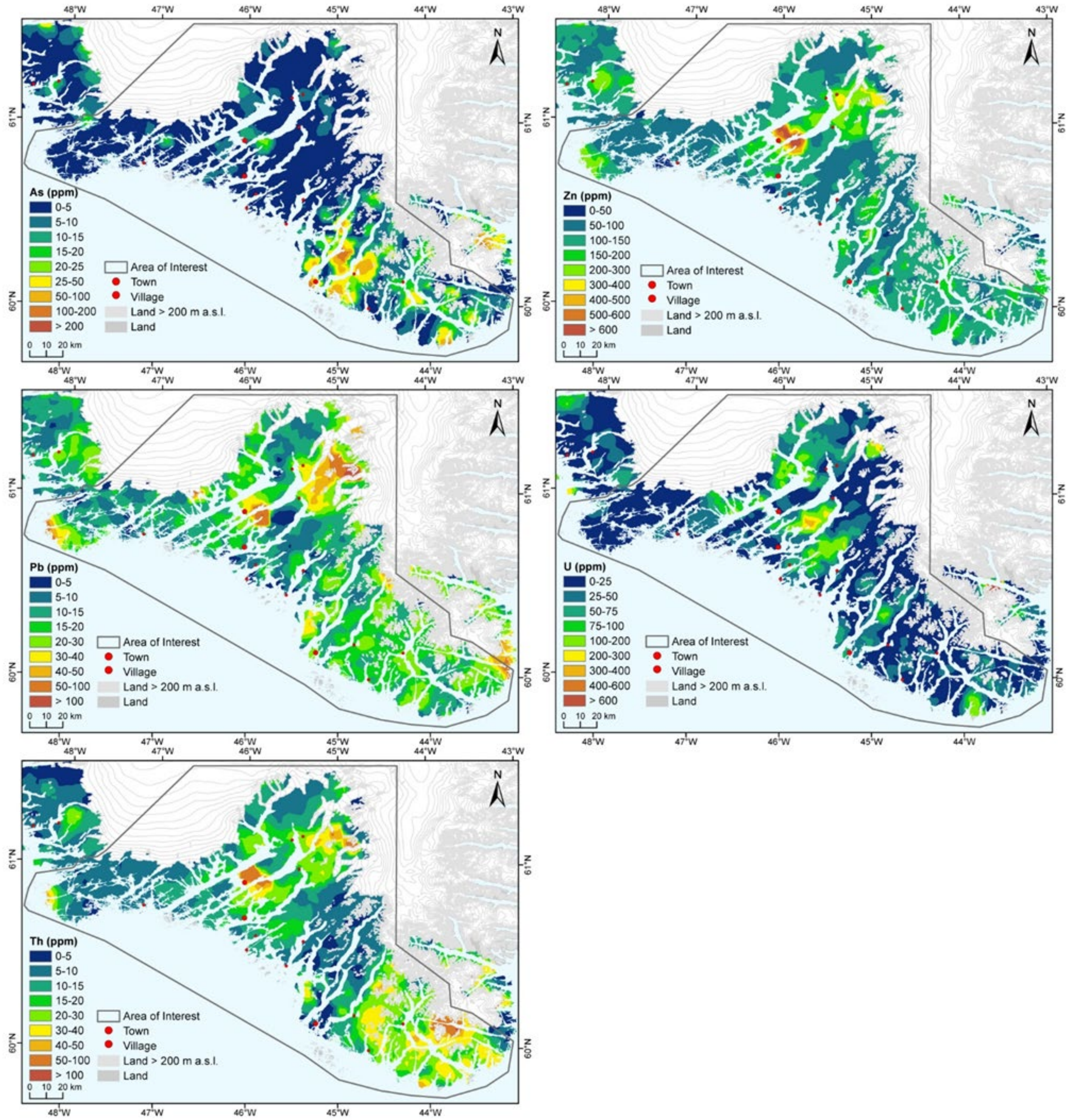


Figure 3.8. Geochemical colour-contoured grid maps of concentrations of arsenic, As, zink, Zn, lead, Pb, uranium, U, and thorium, Th based on analyses of stream sediments. Data from the GEUS-database (GIS data).

The geochemical data from the stream sediment samples are interpreted to represent the surrounding catchment area and are therefore a good exploration tool. The data have been interpolated into a grid with a cell size of 2,500 m using kriging. A spherical model was used, and the model parameters (nugget, range and partial sill) were determined for each element from their semi-variograms. The maps are shown in Figure 3.8 (a, b, c, d, e). For the fluorine samples, the maps are presented in Figure 3.9.

Based on the stream sediments, South Greenland has previously been shown to be chemically distinct from the rest of Greenland, and particular uranium and arsenic are enriched here. Gold has also been recorded with the highest density and magnitude of stream sediment within Greenland (Steenfelt 1990; Steenfelt 1996).

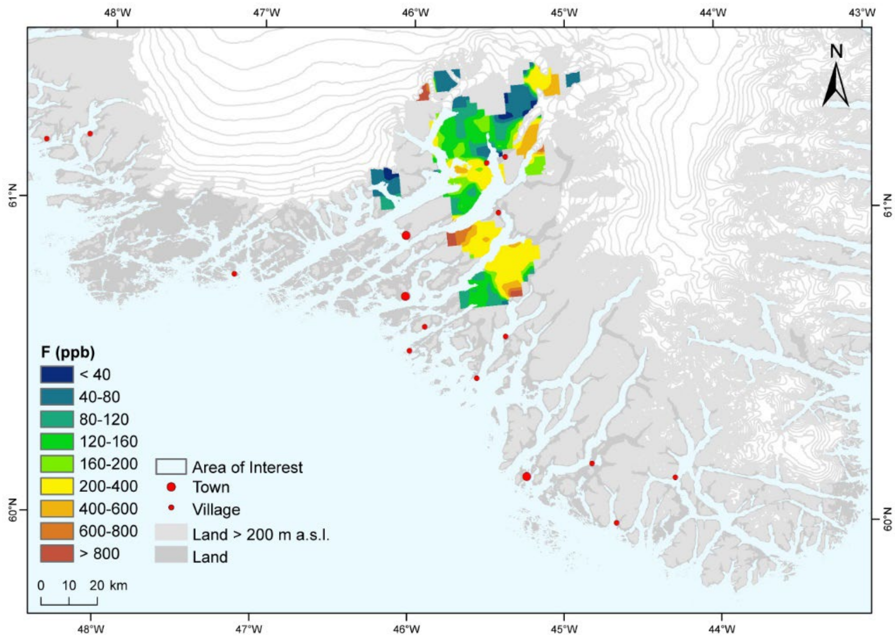


Figure 3.9. Geochemical colour-contoured grid maps of concentrations of fluorine (F) based on analyses of water samples. Data from the GEUS-database (GIS data).

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4 Biodiversity and biologically important and protected areas

By Katrine Raundrup[1,] Karl Zinglersen[1] and David Boertmann[2]

[1]*Greenland Institute of Natural Resources,* [2]*Department of Ecoscience, Aarhus University*

4.1 Introduction

South Greenland has the mildest climate in Greenland, and the interior parts of the area of interest (AOI) are climatically identified as sub-Arctic because the July average temperature is higher than 10 °C. This means that the vegetation in protected areas can be very lush, and that agriculture is possible. The biodiversity among vascular plants is high, while it is low among terrestrial birds and mammals.

This chapter gives an overview of the biological environment of the AOI. This includes presenting the regular occurring fauna as well as the significance of the populations at three different levels: at AOI scale, at Greenland scale and at global scale. Furthermore, the threat status according to the red list (summarised based on the IUCN threat categories: LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; and CR, critically endangered) both at national and global level is presented. Table 4.1 summarises this information for the fauna and Table 4.2 for the flora.

As the offshore areas are not included, only marine mammals and fish occurring in the coastal environment are included. Information on protected areas, in-depth description of vegetation mapping as well as biologically important areas is presented. Due to lack of specific knowledge of distribution and diversity, fungi, bryophytes, and invertebrates are not included in this report.

South Greenland is known as the agricultural region in Greenland. Aspects related to this subject is presented in chapter 5 Human use.

Table 4.1. Birds and mammals in the AOI including their habitat (F, Freshwater; M, Marine; T, Terrestrial), and national as well as global red list status (IUCN threat categories: LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; DD, data deficient; NE, not evaluated). Furthermore, the occurrence in the AOI (B, breeder; W, winter visitor; S, summer visitor), the importance of the AOI to the population in summer and winter (L, low; M; medium; H, high; 0, do not occur; ?, unknown), and the importance of the AOI for the international population. *Endemic subspecies. Data based on Boertmann & Bay (2018). The current red list classification according to IUCN can be found at www.iucn.redlist.org.

			Population red list status			Importance of AOI to population		Importance of AOI to global population
Species	**Scientific name**	**Habitat**	**National**	**Global**	**Occurrence**	**Summer**	**Winter**	
Birds								
Long-tailed duck	*Clangula hyemalis*	F, M	LC	VU	B, W	L	H	M
King eider	*Somateria spectabilis*	M	LC	LC	W	0	L	L
Common eider	*Somateria mollissima*	M	LC	NT	B, W	L	H	M
Red-breasted merganser	*Mergus serrator*	F, M	LC	LC	B, W	L	M	L
Harlequin duck	*Histrionicus histrionicus*	F, M	LC	LC	B, S, W	M	M	M
Mallard	*Anas plathyrhynchos*	F, M	LC	LC	B, W	L	H	H*
Rock ptarmigan	*Lagopus mutus*	T	LC	LC	B, W	L	L	L
Red-throated diver	*Gavia stellata*	F, M	LC	LC	B	L	0	L
Great northern diver	*Gavia immer*	F, M	NT	LC	B	M	0	M
Northern fulmar	*Fulmarus glacialis*	M	LC	LC	B, W	L	L	L
Great shearwater	*Ardenna gravis*	M	LC	LC	S	L	0	L
Great cormorant	*Phalacrocorax carbo*	M	LC	LC	W	0	L	L
Ringed plover	*Charadrius hiaticula*	T	LC	LC	S	L	0	L
Purple sandpiper	*Calidris maritima*	T	LC	LC	B, W	L	L	L
Red-necked phalarope	*Phalaropus lobatus*	F, M	LC	LC	B	L	0	L
Atlantic puffin	*Fratercula arctica*	M	VU	VU	B	L	L	L
Black guillemot	*Cepphus grylle*	M	LC	LC	B, W	M	M	L
Razorbill	*Alca torda*	M	LC	NT	B	H	0	L
Little auk	*Alle alle*	M	LC	LC	W	0	M	L
Thick-billed murre	*Uria lomvia*	M	VU	LC	B, W	H	H	M
Common murre	*Uria aalge*	M	EN	LC	B, W	H	H	L
Arctic skua	*Stercorarius parasiticus*	M	LC	LC	B	L	0	L
Black-legged kittiwake	*Rissa tridactyla*	M	VU	VU	B, W	L	L	L
Black-headed gull	*Chroicocephalus ridibundus*	F, M	VU	LC	B	H	0	L
Lesser black-backed gull	*Larus fuscus*	M	LC	LC	B	M	0	L

Iceland gull	*Larus glaucoides*	M	LC	LC	B, W	L	M	M*
Glaucous gull	*Larus hyperboreus*	M	LC	LC	B, W	L	M	L
Great black-backed gull	*Larus marinus*	M	LC	LC	B, W	L	M	L
Arctic tern	*Sterna paradisaea*	M	NT	LC	B	L	0	L
White-tailed eagle	*Haliaeetus albicilla*	T, M	VU	LC	B, W	H	H	M
Gyrfalcon	*Falco rusticolus*	T	NT	LC	B, W	L	L	L
Peregrine falcon	*Falco peregrinus*	T	LC	LC	B	M	0	L
Northern wheatear	*Oenanthe oenanthe*	T	LC	LC	B	L	0	L
Redwing	*Turdus iliacus*	T	DD	LC	B	H	?	L
Raven	*Corvus corax*	T	LC	LC	B, W	L	L	L
Common redpoll	*Acanthis flammea*	T	LC	LC	B	L	0	L
Arctic redpoll	*Acanthis hornemanni*	T	LC	NE	W	0	L	L
Lapland bunting	*Calcarius lapponicus*	T	LC	LC	B	L	0	L
Snow bunting	*Plectrophenax nivalis*	T	LC	LC	B	L	0	L
Mammals								
Ringed seal	*Phoca hispida*	M	LC	LC	S, W	L	L	L
Harbour seal	*Phoca velutina*	M	CR	LC	S, W	H	H	L
Harp seal	*Pagophilus groenlandicus*	M	LC	LC	S, W	L	L	L
Hooded seal	*Cystophora cristata*	M	VU	VU	S	M	L	M
Bearded seal	*Erignathus barbatus*	M	LC	LC	W	L	L	L
Minke whale	*Balaenoptera acutorostrata*	M	LC	LC	S	L	L	L
Humpback whale	*Megaptera novaeanglia*	M	LC	LC	S	L	L	L
Harbour porpoise	*Phocoena phocoena*	M	LC	LC	S	L	L	L
White-beaked dolphin	*Lagenorhynchus albirostratus*	M	LC	LC	S	L	L	L
White-sided dolphin	*Lagenorhynchus acutus*	M	DD	LC	S	L	L	L
Long-finned pilot whale	*Globicephala melas*	M	LC	LC	S	L	L	L
Polar bear	*Ursus maritimus*	M/T	VU	VU	S, W	L	L	L
Arctic fox	*Vulpes lagopus*	T	LC	LC	B, W	L	L	L
Arctic hare	*Lepus arcticus*	T	LC	LC	B, W	L	L	L

4.2 Mammals

Terrestrial mammals

There are seven naturally occurring land mammals in Greenland of which only two are found in South Greenland: Arctic fox (*Vulpes lagopus*), and Arctic hare (*Lepus arcticus*).

The fox and hare are found throughout the area, but their numbers are unknown. The hare is a valued game animal, while the fox is hunted mainly as it is a vector for rabies (see Chapter 5 "Human use") with open-quota hunting from mid-September to mid-May (Arctic fox) and from August to April (Arctic hare). Both have a favourable conservation status and are assessed as of "least concern" (LC) on the Greenland red list (Boertmann and Bay 2018).

Muskoxen (*Ovibos moschatus*) were introduced to the valley Ippatit on the Nanortalik peninsula in 2014 (see Chapter 5.3 and Figure 5.2) and are thus not naturally occurring in the area. The most recent survey (in 2020) estimated 46 animals, and they are still protected from hunting.

Domestic reindeer (*Rangifer tarandus tarandus*) were introduced to Isortoq in 1973 and to Tuttutooq in 1992 (see Chapter 5.2.3 and Figure 5.2), and they are still herded at those two locations (Cuyler 1999). At both locations, the reindeer are gathered once a year for slaughter (see Chapter 5 "Human use").

Marine mammals

Several marine mammals occur regularly in the waters in South Greenland. Of the seal species, harbour seal (*Phoca vitulina*) is of particular importance as the major part of the Greenland population is found in the AOI (Figure 4.1). The species is otherwise found throughout the temperate zone and the southern parts of the arctic zone. Today, it is very rare in Greenland and considered critically endangered (Boertmann and Bay 2018) with only few of the former haul-out sites still used for breeding and moulting (Rosing-Asvid 2010). Within the AOI, there is a single area where harbour seals still haul out – at the archipelago Qeqertat east of Narsaq Kujalleq (Narsarmijit) (Figure 4.1). The area is likely in use during the breeding season (late May to early July) and during the moulting period (mid-August to mid-September), though both breeding and moulting may occur outside these periods (Rosing-Asvid 2010). As the Greenland population has shown a considerable decrease and presently is estimated to approximately 100 individuals, of which half occur in the AOI, it is listed as "critically endangered" (CR) on the Greenland red list (Table 4.1 and Boertmann and Bay 2018). Harbour seal has been protected from hunting since 2010 (Anon. 2010), and regulations of mineral resources activities in relation to harbour seal haul-outs may be implemented in the future (see Appendix 3).

Four other seal species occur regulary in the AOI (Frederiksen et al. 2012), and all are common in Greenlandic waters. Ringed seal (*Phoca hispida*) is common and widespread in ice-covered waters (such as fjords with glacier ice) throughout the year. Harp seal (*Pagophilus groenlandica*) is numerous along the coasts in the summertime but occur also in winter; whelping has recently been recorded on the offshore ice in Julianehåb Bight (Rosing-Asvid 2008). Hooded seal (*Cystophora cristata*) occurs mainly in offshore areas, and its global population is decreasing. It is thus assessed as "vulnerable" (VU) on the Greenland and international red lists (Boertmann and Bay 2018) due to a decrease of the entire population. The fourth seal species is bearded seal (*Erignathus barbatus*), which occurs in small numbers when ice is present.

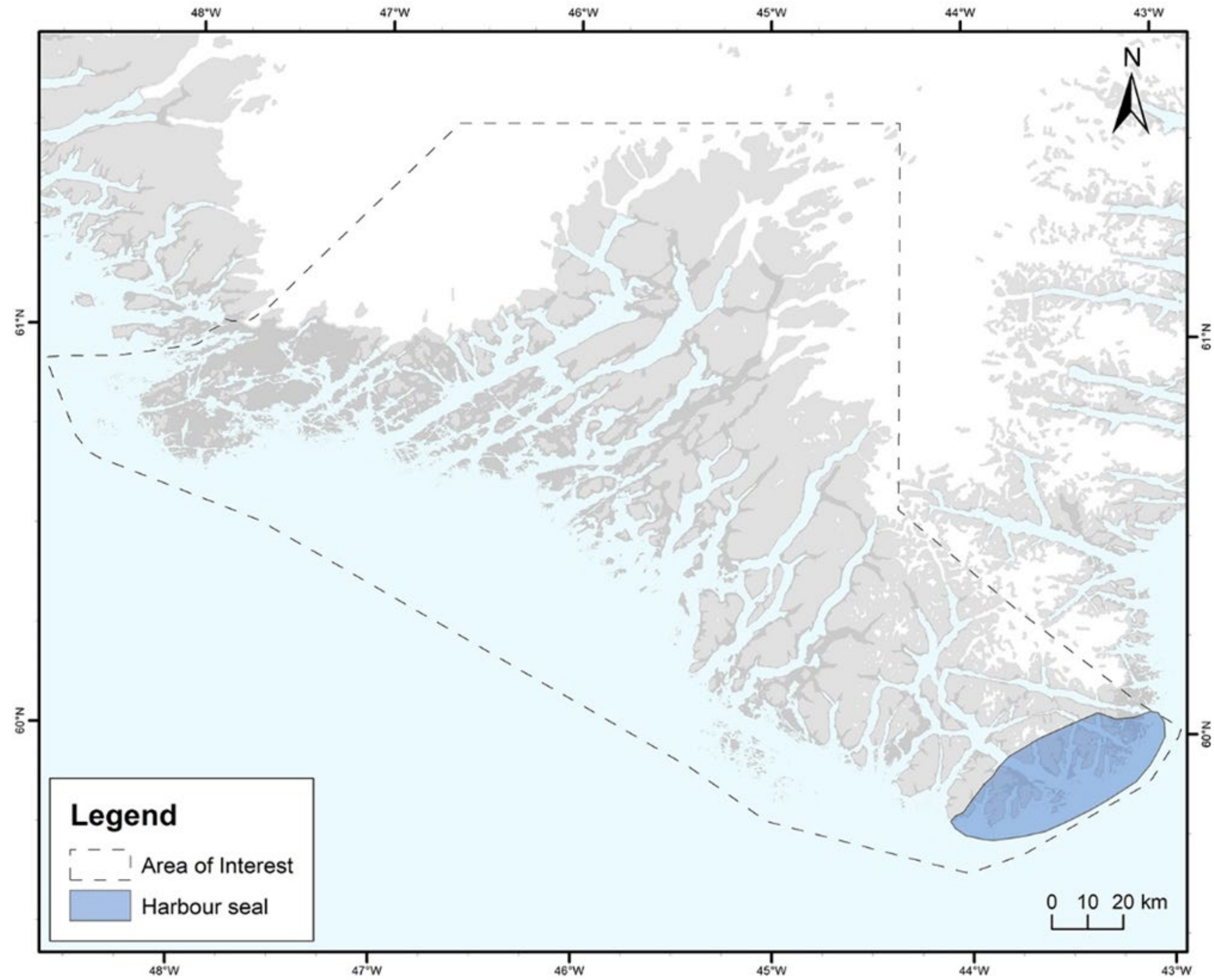

Figure 4.1. Area within which harbour seals are found in the AOI. During breeding and moulting, one or more specific haul-out sites within the marked are used (Rosing-Asvid et al. 2020).

Most of the whales occurring in Southwest Greenland stay in offshore waters and are not relevant for this report. However, among baleen whales, minke whale (*Balaenoptera acutorostrata*) and to a lesser degree humpback whale (*Megaptera novaeangliae*) also occur along the coast and in the outer parts of the fjords in the summertime. Both species are numerous in Greenland waters. Among the toothed whales, only harbour porpoise (*Phocoena phocoena*) is common in the AOI, while species such as white-beaked dolphin (*Lagenorhynchus albirostris*), white-sided dolphin (*Lagenorhynchus acutus*) and long-finned pilot whale (*Globicephala melas)* occasionally occur in coastal waters.

Polar bears (*Ursus maritimus*) occasionally occur in the AOI where they arrive with the drift ice from East Greenland.

4.3 Birds

Terrestrial and freshwater birds

The most abundant birds in the terrestrial environment of the AOI are the passerines: snow bunting (*Plectrophenax nivalis*), Lapland bunting (*Calcarius lapponicus*), northern wheatear (*Oenanthe oenanthe*), common redpoll (*Carduelis flammea*) and raven (*Corvus corax*) are common breeders. They are all widespread in Greenland and have a favourable conservation status, and seen from a conservational point of view, the region is of low importance for the populations. In recent years, redwing (*Turdus iliacus*) has immigrated to the region and is found in the plantations. Its population status is unknown, but redwing is common in, e.g., Narsarsuaq. Most of the passerines, except ravens and a few snow buntings, leave Greenland for the winter.

A single passerine species – the Arctic redpoll (*Acanthis hornemanni*) – does not breed within the AOI but occurs as a winter visitor from the northern part of Greenland.

Rock ptarmigan (*Lagopus mutus*) also occurs in the terrestrial environment of the AOI, generally in low numbers but in some years, it is more common than in others. Ptarmigans stay throughout the winter where the population in South Greenland is supplemented with migrants from the north. Ptarmigan is a valued game bird (see Chapter 5 "Human use") with open season hunting from August to April.

Two shorebirds breed in terrestrial habitats in the AOI: purple sandpiper (*Calidris maritima*) and common ringed plover (*Charadrius hiaticula*). Neither of the two are common here but are widespread in Greenland, and seen from a conservational point of view, the AOI is of low importance to the population in Greenland.

Three birds of prey with very different life strategies breed in the AOI: peregrine falcon (*Falco peregrinus*), white-tailed eagle (*Haliaeetus albicilla*) and gyrfalcon (*Falco rusticolus*). The peregrine falcon is rather common in the area and is also widespread in most of Greenland. The population is thriving and has a favourable conservation status. Peregrines are migratory birds that leave Greenland for the winter. Breeding peregrines use the same nesting cliff from year to year, and here they are sensitive to disturbance (Christensen et al. 2016).

Gyrfalcon breeds in low numbers in the AOI. Gyrfalcons are stationary, and the winter population is supplemented with birds from the northern parts of Greenland and arctic Canada. The Greenland population is assessed as "near threatened" (NT) on the Greenland red list due to its very small population size (Christensen et al. 2016). Seen from a conservational point of view, the AOI is of no particular significance for the population. Breeding gyrfalcons often use the same nest year after year and are very sensitive to disturbance at their nesting area.

White-tailed eagle (*Haliaeetus albicilla*) is found in both terrestrial and marine coastal habitats. It occurs along the coasts in most of the AOI. Relatively high densities of nesting territories, up to 6 per 10 km^2 (Figure 4.2), are found in some areas, and a significant part of the Greenland population is found here. The AOI is therefore of high importance for the population during both winter and summer. White-tailed eagle is listed as "vulnerable" (VU) on the Greenland red list due to its small population size (Boertmann and Bay 2018).

The breeding eagles are usually stationary, while young non-breeders are known to move between different regions in Greenland (Lyngs 2003). White-tailed eagles switch between a number of nests situated within their territories between years and are very sensitive to disturbance here, especially when brooding and when the chicks are up to two weeks old.

Several birds are associated with freshwater habitats during the breeding time. The great norther diver (common loon, *Gavia immer*) is found in large lakes, and due to a small population in Greenland it is assessed as "near threatened" (NT) on the Greenland red list. Red-throated diver (*Gavia stallata*) breeds by small lakes and ponds near the coast and is rather common. Both divers leave Greenland for the winter.

Mallards (*Anas plathyrhynchos*), long-tailed ducks (*Clangula hyemalis*), harlequin ducks (*Histrionicus histrionicus*) and red-necked phalaropes (*Phalaropus lobatus*) all breed at freshwater sites in the AOI – harlequin ducks at turbulent rivers, the other at lakes and ponds. The phalaropes leave Greenland for the winter, while the other three species spend the winter in coastal waters of the AOI. Mallards are common and widespread; long-tailed ducks breed here and there in low numbers and occur in large flocks in winter. Very few harlequin ducks breed in the AOI, while many males from other parts of Greenland and Canada assemble in coastal waters in late summer to moult (Figure 4.3) and subsequently also to spend the winter there (Boertmann and Mosbech 2002). While the AOI is of low importance for mallards, long-tailed ducks, and phalaropes, the western AOI is very important for the Greenland harlequin duck population (Figure 4.3). The long-tailed duck is assessed as "vulnerable" on the global red list (BirdLife International 2018b).

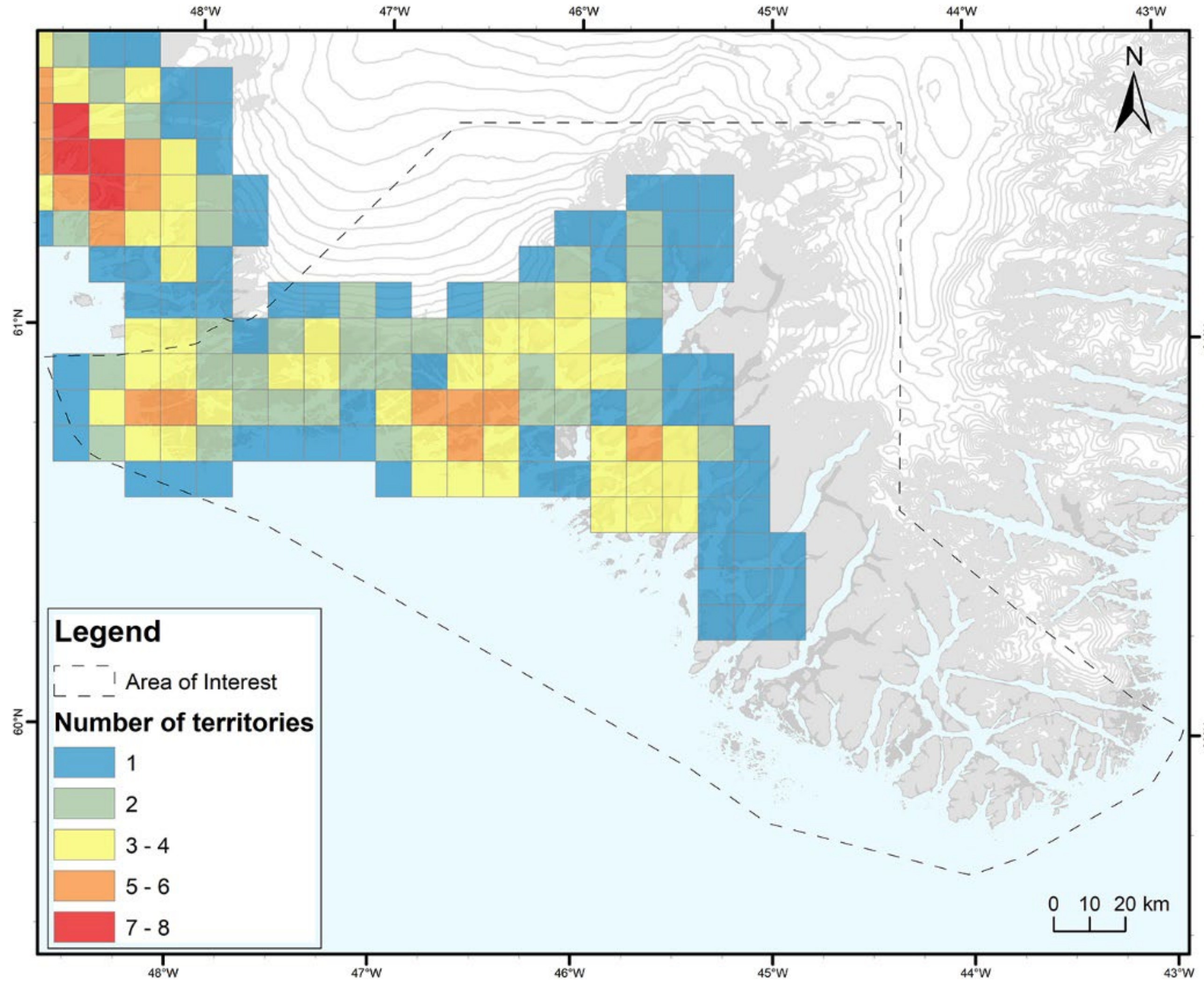

Figure 4.2. Number of white-tailed eagle territories in the central and northern part of the AOI. The species also breeds in the southern part, but the numbers are unknown. The squares are 10x10 km, absence of squares represents “no data available”. Based on data from before 2000.

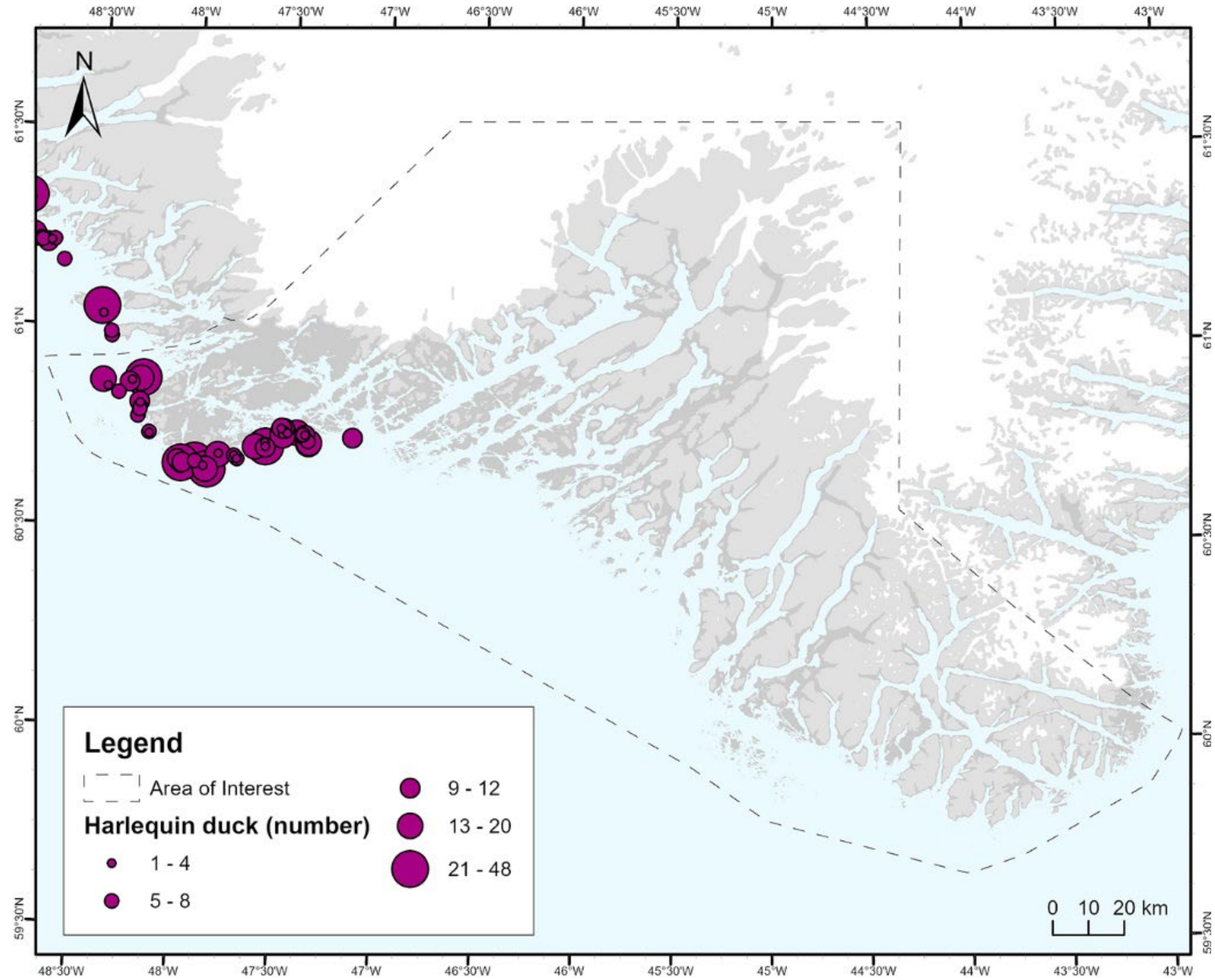

Figure 4.3. Moulting harlequin ducks observed during a survey in summer 1999.

Seabirds

Several birds associated with the marine environment breed and winter in the AOI.

Most of the seabirds breed in colonies varying in size from a few pairs to several thousands. The colonies of the AOI were surveyed in 2003 (Boertmann 2004), and the important colonies on Kisissut Avalliit are regularly monitored and studied (e.g. (Linnebjerg et al. 2013). Survey data from the colonies including historical information are kept in a database maintained by DCE and GINR (Boertmann et al. 2010), and the data presented in the figures in this subchapter are derived from this database. Seabird colonies are sensitive to disturbance and guidelines to minimise the effects of mineral exploration activities are available.

The most widespread colonial seabirds are gulls. Four large species: glaucous (*Larus hyperboreus*), Iceland (*Larus glaucoides*), great black-backed (*Larus marinus*) and lesser black-backed gull (*Larus fuscus*) are common within the AOI. The smaller black-legged kittiwake (*Rissa tridactyla*) has a much more restricted breeding distribution with colonies on Kitsissut Avalliit and in a few fjords where glaciers calve (Figure 4.4). Black-headed gull (*Chroicocephalus ridibundus*) breeds in a few colonies, of which some are found at inland lakes. Both kittiwake and black-headed gull are red-listed, both as “vulnerable”

(VU) – the kittiwake because of population decline and the black-headed gull because of a very small population.

Lesser black-backed gull and black-headed gull leave Greenland for the winter. Kittiwakes move to offshore waters and are rarely observed near the coast in winter. The remaining gulls stay in the coastal waters of the AOI during winter where large flocks can be found, e.g., near harbours where food is available. The AOI is probably very important to these populations of gulls in winter.

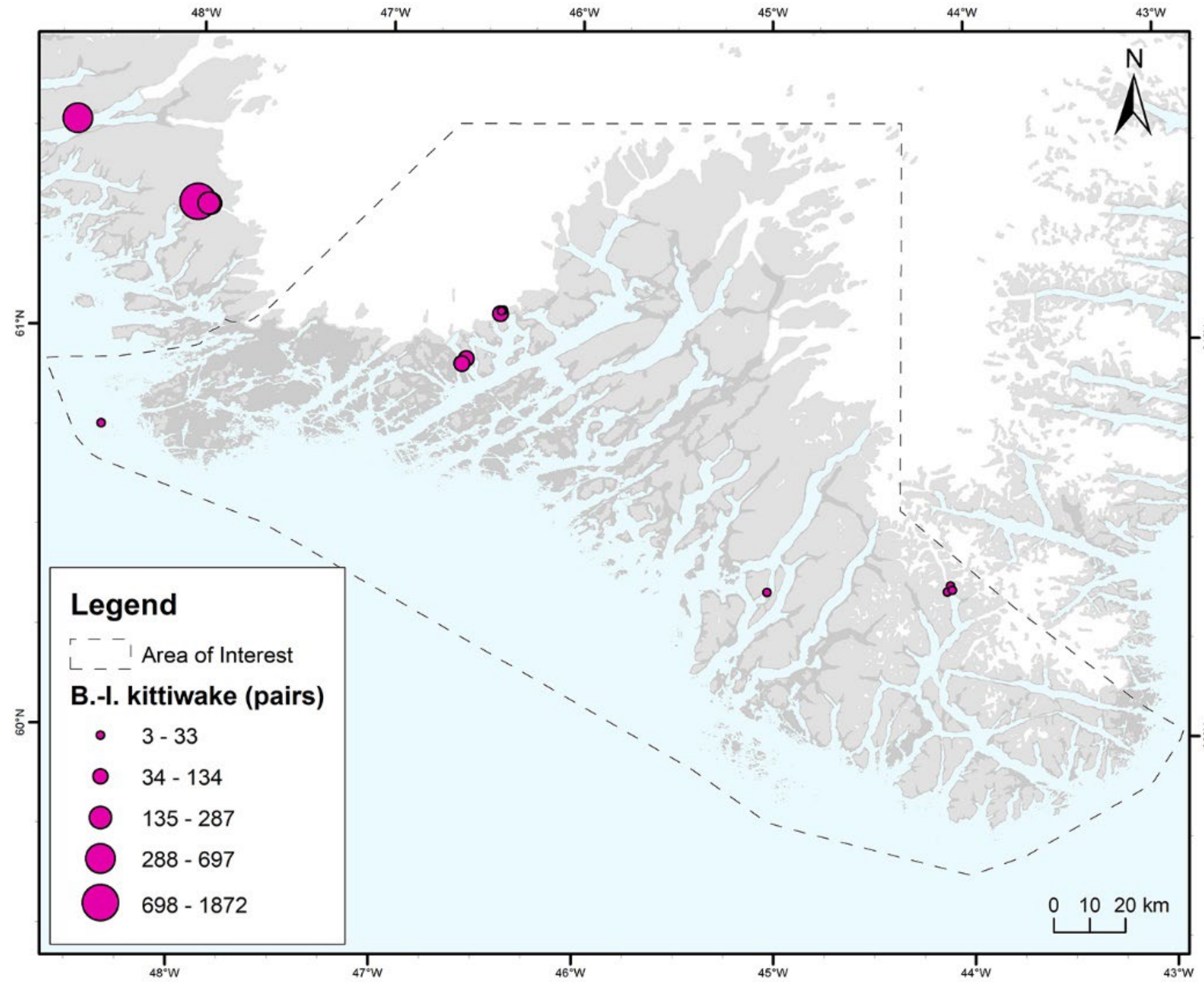

Figure 4.4. Black-legged kittiwake colony locations and size as number of breeding pairs. Data from Greenland Seabird Colony Register.

Only a few colonies of Arctic tern (*Sterna paradisaea*) are found in the AOI, mainly along the outer coast (Figure 4.5). Arctic tern is much more numerous further North, and the population in the AOI must be considered as marginal. The species is assessed as "near threatened" (NT) on the Greenland red list (Table 4.1, Boertmann and Bay 2018) due to a population decline in West Greenland.

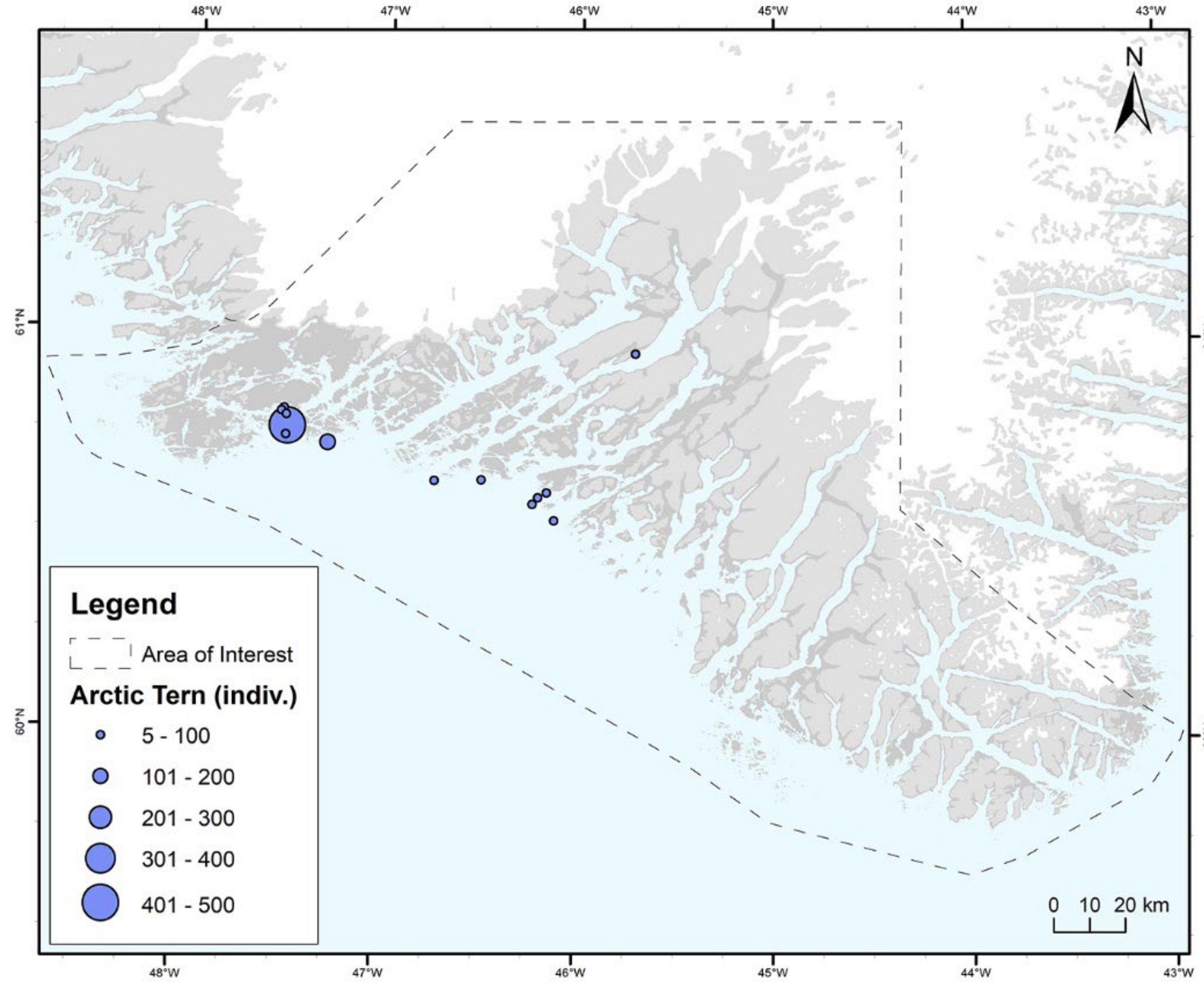

Figure 4.5. Arctic tern colony locations and size as number of individuals. Data from Greenland Seabird Colony Register.

Arctic skuas (*Stercorarius parasiticus*) breed in low numbers at a few sites in the AOI and are often solitary. They leave for the winter.

The other important group of seabirds within the AOI is the alcids. Widespread in the AOI and in Greenland is black guillemot (*Cepphus grylle*) that breeds in small colonies mainly along the outer coast. Razorbill (*Alca torda*) is found in small numbers on Kitsissut Avalliit and on small islands and coastal cliffs along the outer coast, e.g., off Nunap Isua (Kap Farvel) and in Indre Kitsissut (Figure 4.6). Razorbill is of international concern as is assessed as "near threatened" (NT) on the global red list (BirdLife International 2018a). Thick-billed murre (*Uria lomvia*) is a numerous alcid in the Arctic, and ca. 5-7% of the global population breeds in Greenland. Within the AOI, only one colony (at Kitsissut Avalliit) is known, but individuals have been observed at a seabird-breeding cliff in summer near Nanortalik (the small dot in Figure 4.7). Kitsissut Avalliit is the southernmost breeding site for the species in Greenland, with the nearest other colony located in Arsuk Fjord, just north of the AOI (Figure 4.7). The closely related common murre (*Uria aalge*) occurs in low numbers among the thick-billed murre on Kitsissut Avalliit. Both murre species are assessed as threatened on the Greenland red list, common murre as "endangered" (EN) and thick-billed murre as "vulnerable" (VU), and the AOI is important for the Greenland populations of both species. Finally, Atlantic puffin (*Fratercula arctica*) breeds in a few colonies (Figure 4.8). This species is more numerous further north, but the conservation status of the population is unfavourable as declines have been noted in some of the key areas, and it is thus assessed as "vulnerable" (VU) on the national red list.

Despite being very numerous in the offshore waters of the AOI, northern fulmar (*Fulmarus glacialis*) breeds only on the Kitsissut Avalliit archipelago and on a cliff near Nunap Isua (Kap Farvel) (Figure 4.9).

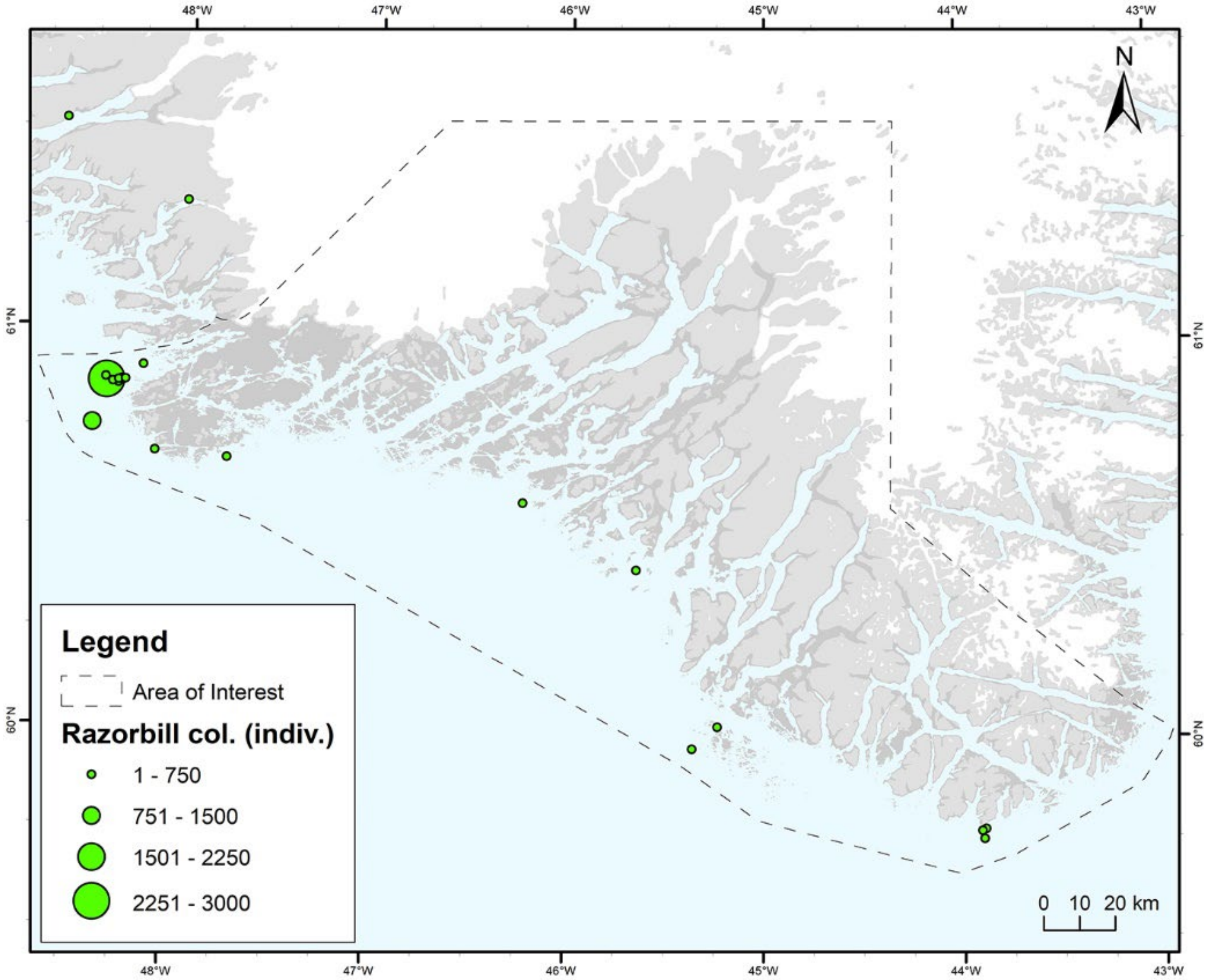

Figure 4.6. Razorbill colony locations and size as number of individuals. Data from Greenland Seabird Colony Register.

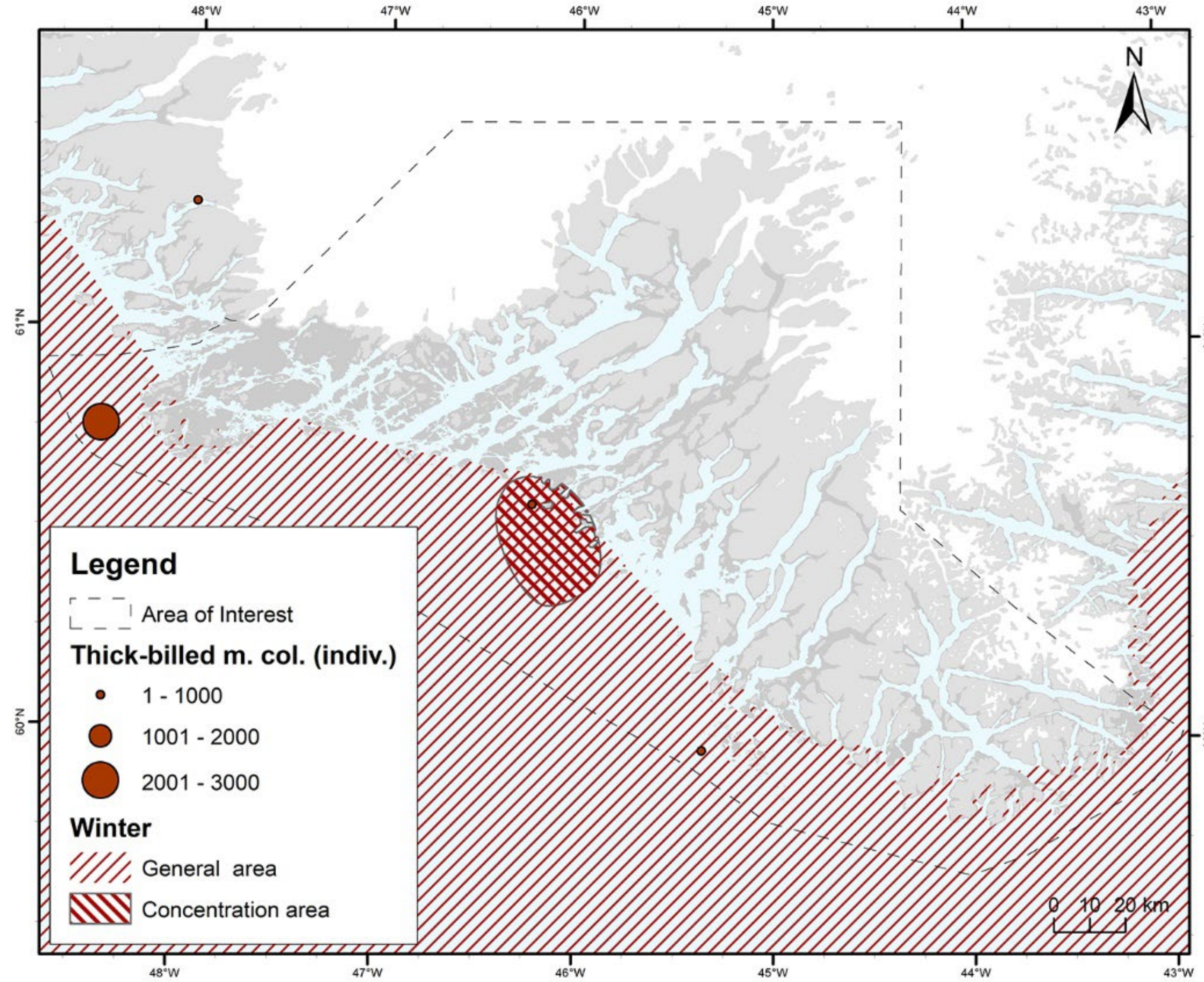

Figure 4.7. Thick-billed murre colony locations as well as distribution areas in summer (thin lines) and winter concentration area (thicker lines). Data from Greenland Seabird Colony Register.

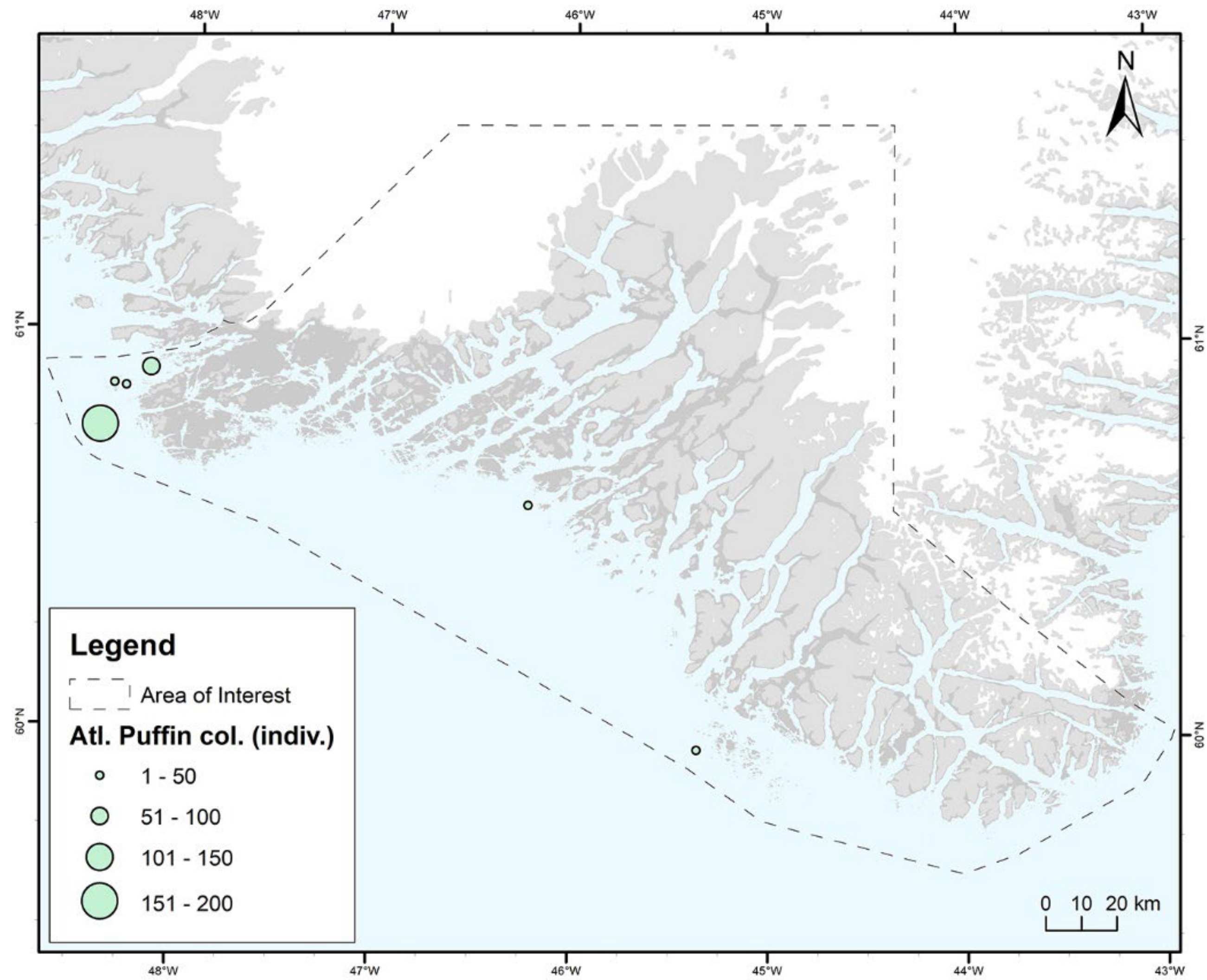

Figure 4.8. Atlantic puffin colony locations and size as number of individuals. Data from Greenland Seabird Colony Register.

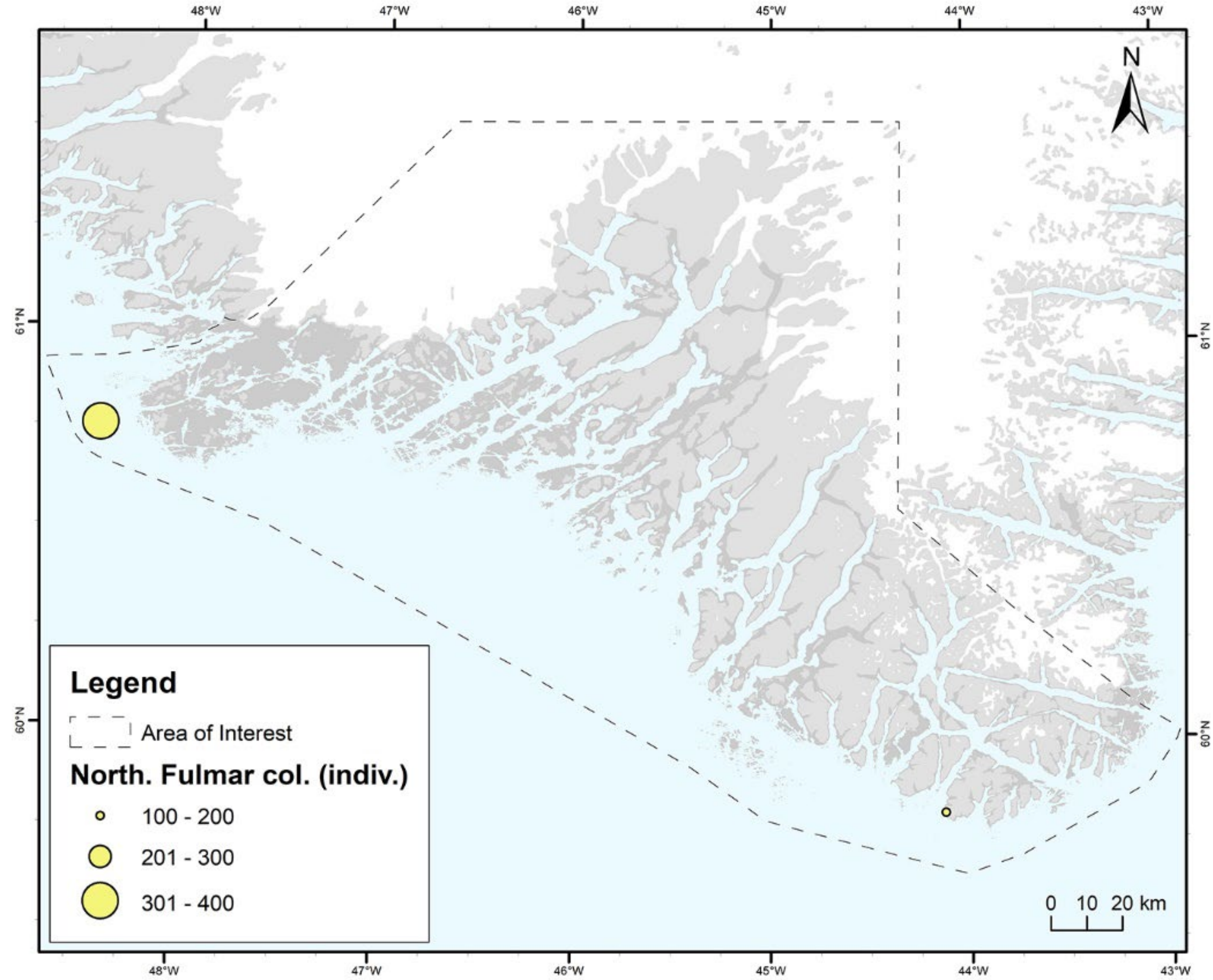

Figure 4.9. Northern fulmar colony locations and size in number of individuals. Data from Greenland Seabird Colony Register.

Among the ducks, only common eider (*Somateria mollissima*) is strictly marine, breeding in a few colonies on small islands along the outer coast (Figure 4.10). Red-breasted merganser (*Mergus serrator*) breeds solitarily at both lakes and marine coasts, and males and non-breeding females assemble in sheltered bays and fjord to moult.

In winter, the coast and the waters off Southwest Greenland, including the AOI, act as very important winter habitats for seabirds and birds breeding at freshwaters (Boertmann et al. 2006; Merkel et al. 2019). Millions of seabirds from arctic Canada, even Alaska, Greenland, Svalbard, Norway and Russia, arrive in the autumn and spend the winter along the coasts and in offshore waters. Figures 4.10. and 4.7 show where the highest occurrences of common eiders and thick-billed murres were found in the 2017 surveys. Both species are valued game birds, and thousands are bagged each year in the AOI during winter (www.stat.gl).

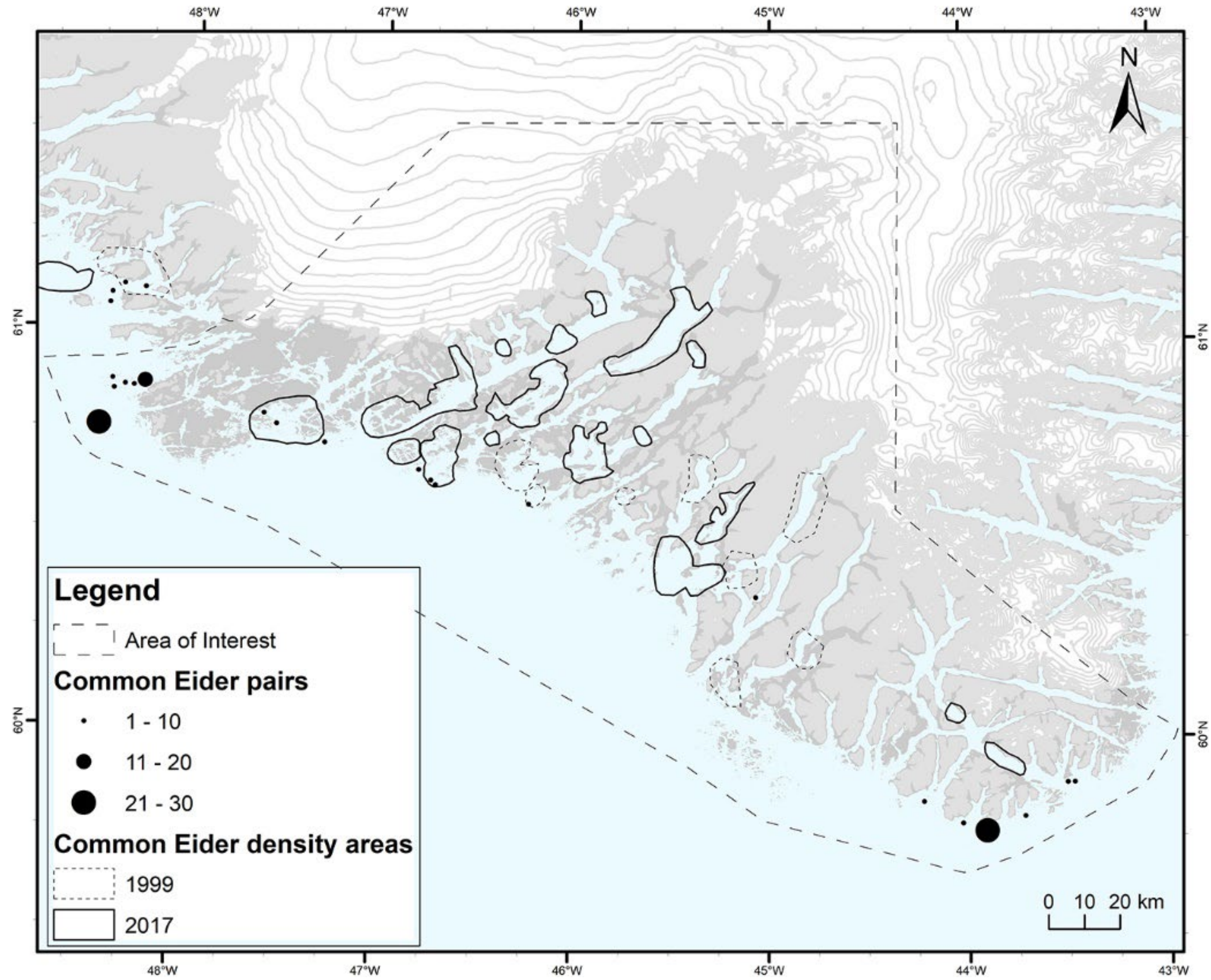

Figure 4.10. Common eider colonies and high-density wintering areas observed during surveys in 1999 (dashed lines) and 2017 (full lines). Data from Merkel et al. (2019). Many of the smallest dots represent breeding colonies with an unknown number of birds.

Other numerous species in winter are black-legged kittiwake, northern fulmar, little auk (*Alle alle*) – all mainly found offshore, the large gull species (see above) and great cormorant (*Phalacrocorax carbo*). Even land and freshwater birds winter along the coasts of the AOI, including purple sandpipers, mallards, king eiders and long-tailed ducks. In March 2017, both mallard and long-tailed ducks were found in high densities in the AOI (Merkel et al. 2019).

4.4 Fish and shellfish

West Greenland waters are rich in fish and shellfish, although the South Greenland waters are generally perceived as being less rich in fish than other Greenland waters. Within the AOI several species relevant for commercial fishery are present: Atlantic cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*), lumpsucker (*Cyclopterus lumpus*), northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*). Moreover, Arctic char (*Salvelinus alpinus*) is an important species for subsistence and sport fishery. A review of the species including maps of catches is found in Chapter 5 "Human Use".

4.5 Vegetation

Red listed plant species

More than 370 species of plants are known to occur in South Greenland (Feilberg 1984). Among these 56 are found within the AOI and are red listed (vulnerable and near threatened) on the Greenland Red List 2018 (Table 4.2, Boertmann and Bay 2018). Ten of these species are unique to South Greenland.

The distribution of the historically known observations of red listed plants is shown in Figure 4.11. The figure is based on digitisations of maps reporting and analysing herbarium specimens (Feilberg 1984) collected primarily between 1962 and 1996 in the Greenland Botanical Survey as well as data from supplementary publications on the distribution of specific species (e.g. Bay 1993). Both dots (the observations) and a buffer zone around each observation point are shown on the distribution map as the geographical precision of the scanned markings is low.

Possible areas for red listed plant species are shown in Figure 4.11. These areas are produced by applying a buffer zone with a radius of 3.5 km around historic point observations of red listed plants (also shown as dots in figure 4.11), excluding areas above 800 m altitude and areas covered by sea or glaciers. A buffer radius of 3.5 km was chosen to account for inaccuracies in the digitization of the historic data and the fact that data was produced only as presence data, not absence data. Thus, absence of a dot does not necessarily mean absence of red listed plants, and red listed plants may likely be present in other locations than those marked by a dot. Marine areas, areas above 800 m altitude and permanent glaciers were erased from the buffer zone to exclude areas without any vegetation. As such, the dots and 'possible area for red listed plants' do not visualize nor represent actual estimates of distribution but rather broader potential areas. Potential areas for red listed plants are areas in which it would be relevant to search for the specific species before activities that may affect vegetation are initiated. Actual estimates of distribution should consider e.g., the vegetation type the species are associated with. The vegetation mapping described in the subsequent section was not done with the specific purpose of mapping red listed species and hence cannot be used for this.

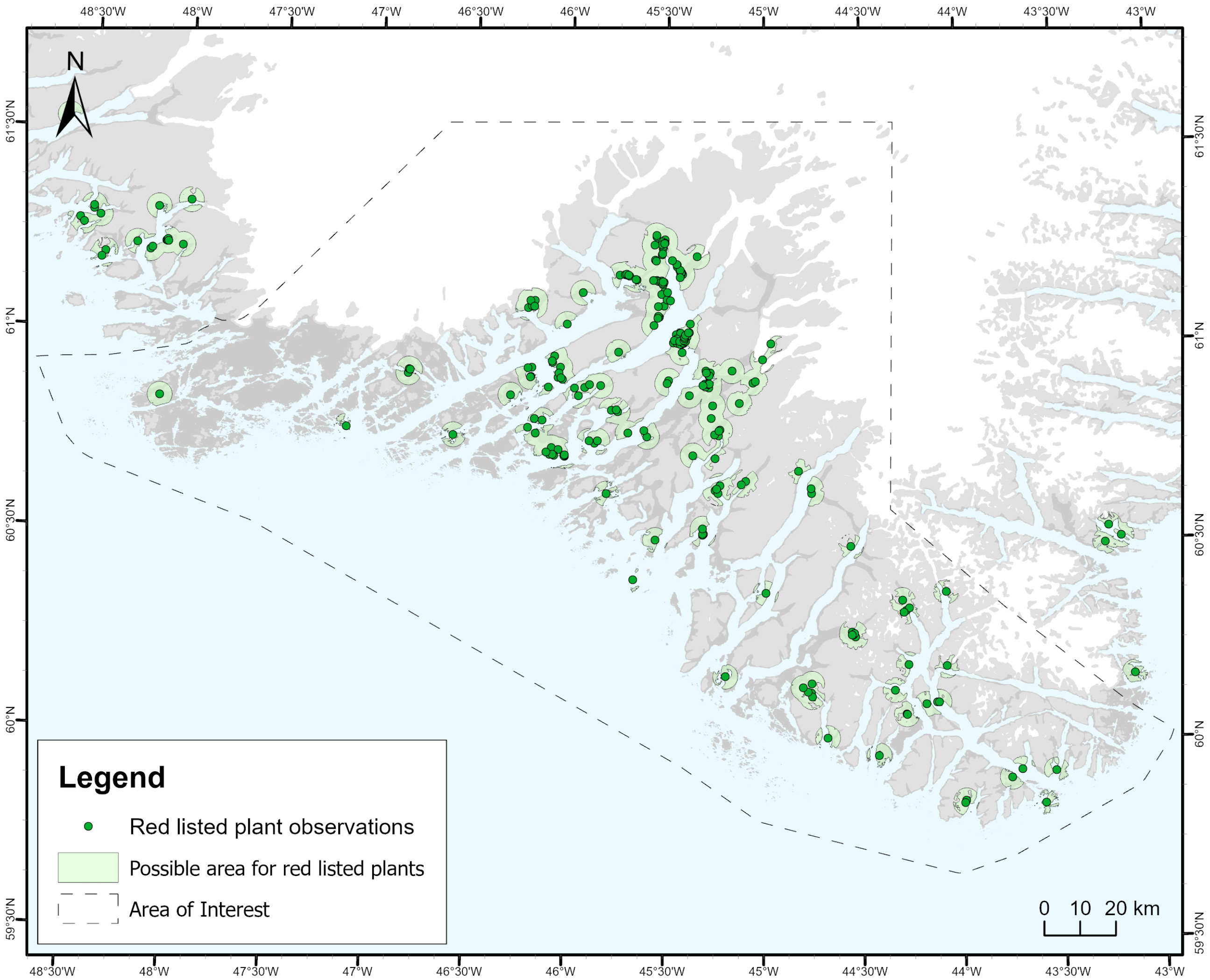

Figure 4.11. Distribution map of observations of red listed (vulnerable and near threatened) plants in the AOI. The geographical precision of the individual observations is fairly low, thus a buffer zone (of 3.5 km radius, cut off by coastline and 800 m altitude line) of each observation is included in the map (the possible area for the red listed plants).

Table 4.2. Threatened (red listed; near threatened and vulnerable) vascular plants in the AOI. The IUCN threat categories: LC (least concern), NT (near threatened) and VU (vulnerable), as well as the vegetation type in which they are known to occur are shown (Boertmann and Bay 2018).

Species	Author	Red list status	Vegetation type
*Agrostis gigantea**	Roth	VU	Copse
Agrostis stolonifera	L.	NT	Fen
Alchemilla vestita	(Bus.) Raunk.	NT	-
Alchemilla wichúrae	(Bus.) Stefanss.	NT	Herb slope
Amerorchis rotundifolia	(Banks ex Pursh) Hult.	VU	Copse
Andromeda polifolia	L.	VU	Fen
*Athyrium filix-femina**	(L.) Roth.	VU	Herb slope
Atriplex longipes ssp. praecox	Drej.	VU	-
Botrychium multifidum	(Gmel.) Rupr.	VU	Herb slope
Botrychium simplex	Hitchc.	VU	Grassland
Botrychium tenebrosum	A.A. Eaton	VU	Grassland
Cakile edentula ssp. edentula	(Bigelow) Hook.	VU	-
Calamagrostis hyperborea	Lge.	NT	Copse

Calamagrostis poluninii	T. Sør.	NT	Fell field
Carex abdita	Wbg.	VU	Steppe
*Carex buxbaumii**	Wbg.	VU	Lake
Carex chordorrhiza	L.	VU	Fen
Carex disperma	Dew.	VU	Copse
Carex lyngbyei	Horn.	VU	Saltmarsh
Carex mackenziei	Krecz.	VU	Saltmarsh
Carex magellanica ssp. irrigua	Lam.	NT	Fen
Carex panicea	L.	NT	Fen
Carex salina	Wbg.	VU	Saltmarsh
Carex trisperma	Dew.	VU	Fen
*Carex viridula**	Michx.	VU	Fen
Catabrosa aquatica	(L.) Beauv.	VU	Stream
Cornus canadensis	L.	NT	Dwarf-shrub heath
Cystopteris montana	(Lam.) Desv.	VU	Copse
*Danthonia spicata**	(L.) Beauv.	VU	Copse
Drosera rotundifolia	L.	NT	Fen
Dryopteris abbreviata	(DC.) Newman	NT	Copse
*Eleocharis palustris**	(L.) Roemer & Schultes	VU	Fen
Eleocharis quinqueflora	(F. Hartmann) O. Schwartz	NT	Saline lakes, fen
*Eleocharis uniglumis**	(Link) Schultes	VU	Fen
*Galium boreale**	L.	VU	Copse
Gentiana amarella	(L.) Boerner	VU	-
Gentianella detonsa	(Rottb.) Don	NT	Saline lakes
Geum rivale	L.	VU	Homothermic spring
*Hierochloë odorata**	(L.) Beauv.	VU	Fen
*Isoëtes lacustris ssp. lacustris**	L.	VU	Lake
*Juncus gerardii**	Lois.	VU	Saltmarsh
Juncus ranarius	Perr. & Song.	NT	-
Myriophyllum spicatum ssp. exalbescens	L.	NT	Lake
Parnassia kotzebuei	Cham & Schlechht.	NT	Riverbed
Polypodium virginianum	L.	VU	Rock
*Potamogeton natans**	L.	VU	Lake
Potentilla anserina (*)	L.	NT	Saltmarsh
Primula egaliksensis	Wormsk.	NT	Homothermic spring, riverbed
Rorippa islandica	(Oed.) Borb.	VU	Lake
Rubus chamaemorus	L.	NT	Dwarf-shrub heath
Rubus saxatilis	L.	VU	Herb slope
*Sagina nodosa **	(L.) Fenzl	NT	-
*Selaginella rupestris**	(L.) Spring	VU	Rock
*Trientalis europaea**	L.	VU	Dwarf-shrub heath
Utricularia intermedia	Hayne	NT	Lake
Vaccinium myrtillus	L.	VU	Dwarf-shrub heath

* In Greenland only known from the AOI.

Vegetation mapping

A large part of the fieldwork done in 2020 was related to sampling of ground truthing points to validate an updated satellite-based vegetation map (Figure 4.12). The full background report on methodologies and an in-depth description of techniques used to elaborate the vegetation map can be found in Appendix 3.

When referring to vegetation mapping, it is important to note that mapping of vegetation types/classes will not reveal the distribution or occurrences of red listed or any other specific species. A number of the red listed species occur in vegetation types not identified by the method used here and due to the scale of the mapping (10 m x 10 m), e.g., the vegetation types “snow patch” and “herb slope” are not included. These types often have a very limited distribution and at the scale of this vegetation mapping, they are not distinguishable.

Vegetation analyses were undertaken to classify the vegetation types. The types were classified based on species composition, but the classification also included information on, e.g., height of vegetation, slope, and soil moisture. Five broad vegetation types were classified: dwarf shrub heath, lichen-rich dwarf shrub heath, fen, grassland, and copse (Table 4.3).

Table 4.3. Field observations of the dominant species of the different vegetation types in south Greenland.

Vegetation type	Dominant species
Dwarf shrub heath	*Salix glauca*, *Salix arctophila*, *Vaccinium ulignosum*, *Betula glandulosa*, *Deschampsia flexuosa*
Lichen-rich dwarf shrub heath	*Salix glauca*, *Salix arctophila*, *Vaccinium ulignosum*, *Betula glandulosa*
Fen	*Carex bigelowii*, *Carex rostrata*, *Carex rariflora*, *Carex microglochin*, *Scirpus caespitosus*
Grassland	*Deschampsia flexuosa, Carex bigelowii*, *Poa pratensis*, *Agrostis* sp., *Agrostis hyperborea*, *Kobresia myosuroides*, *Calamagrostis langsdorfii*
Copse	*Salix glauca*, *Betula pubescens*

The vegetation map (Figure 4.12) shows some general tendencies in the spatial distribution of the different vegetation types. Dwarf shrub heath and copse are the dominant vegetation types and account for more than 50% of the vegetated area. They are most widespread in low-lying areas (elevations < approx. 200 m) in the inland/inner parts of the fjords. In the outer parts close to the open ocean, lichen-rich dwarf shrub heath is more pronounced. Moreover, fen is widespread in these areas as it grows in proximity to water, and lakes are vast in these areas. However, fen vegetation is observed throughout South Greenland within ca. 30-40 m of most lakes. Grassland is the least common vegetation type, accounting for about 12% of the vegetated area, but it is found throughout the area. The largest continuous areas of grassland exist near Igaliku, Qassiarsuk and in an area between Kangerluarsorujuk and Nuugaarsuk. Agricultural fields make up a very small area (ca. 1,200 ha, see Chapter 5 “Human use”), and they are mostly present in the regions of Qassiarsuk and Igaliku.

In addition to the mapped vegetation types, woodland also occurs in southern Greenland. Its extent is, however, limited and therefore not included in the vegetation analysis. According to Meilby et al. (2019), there are several larger plantations, mainly consisting of spruce, in the inner fjords in South

Greenland (Figure 5.1). In addition to woodland, tall copse vegetation with tree heights of more than 3 m is also found in the AOI. These areas provide favourable conditions for the occurrence of high-diversity forest floors, including a large number of epiphytic lichen and basidia mushrooms (Christensen et al. 2016). In the future, areas suitable for woodland are expected to increase due to a changing climate. However, natural expansion will likely be slow and local due to dispersal constraints (Normand et al. 2013).

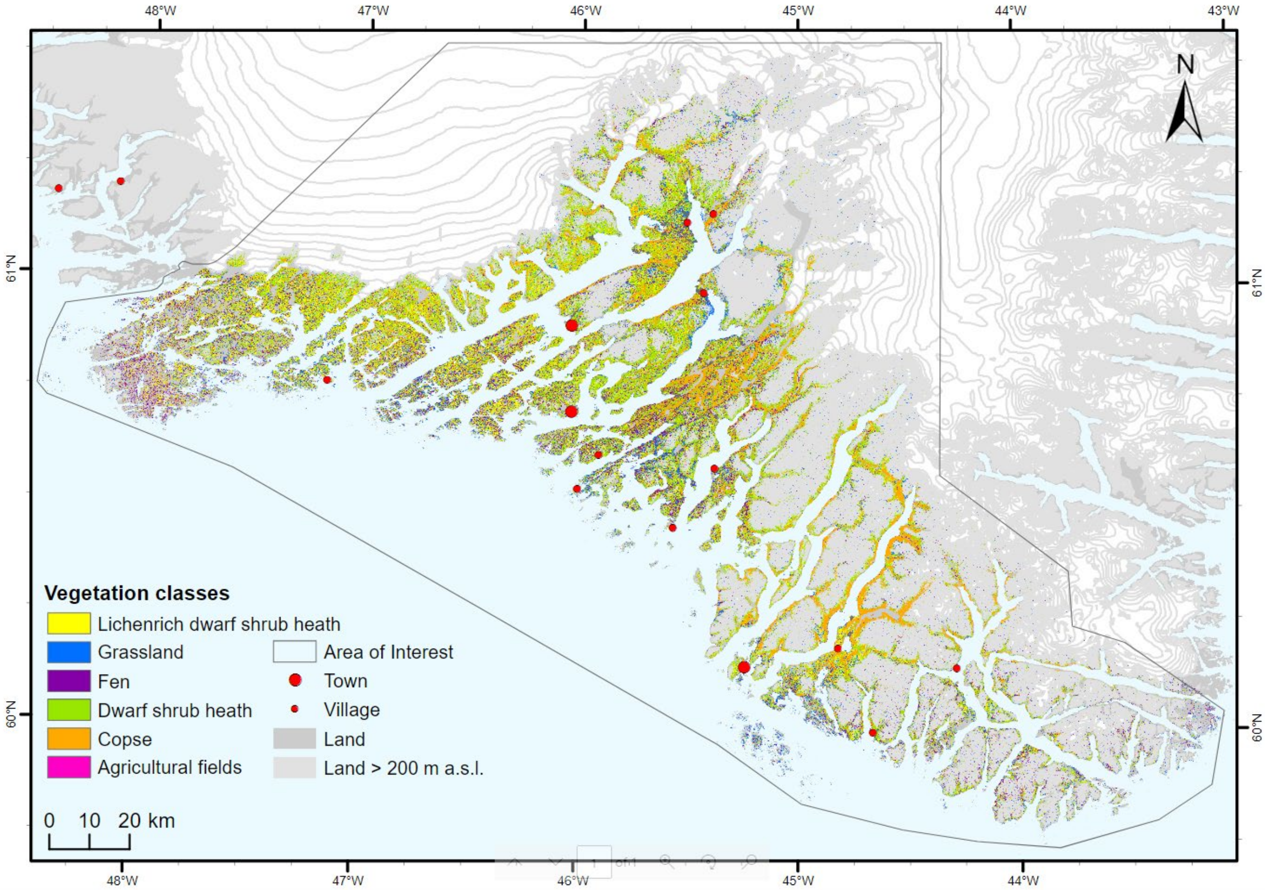

Figure 4.12. Vegetation map of South Greenland. The location and size of agricultural fields are based on data from the Agency for Data Supply and Efficiency (SDFE 2017).

4.6 List of protected areas

There are several types of protected areas in the South Greenland AOI (Figure 4.13). The areas fall within the legislation related to:

- The nature protection areas
- The bird protection act
- Ramsar sites
- UNESCO's World Heritage List.

Nature protection areas (Nature Conservation Act) include the island of Uunartoq where a homeothermic spring is located (Anon. 2005a). The Uunartoq spring is the only hot spring within the AOI, and almost all other homeothermic springs are located on Disko Island, West Greenland or around Ittoqqortoormiit, East Greenland. The water of Uunartoq has a temperature of 42 °C (Hjartarson and Armannsson 2010), and it is an important recreational site both for locals and tourists.

The two valleys Qinngua (Anon. 2005b) and Klosterdalen (Landsrådsvedtægt af 30. juni 1970) on the east side of Tasermiut Fjord are both nature protection areas due to their unique vegetation. There are extensive areas covered with woodlands consisting primarily of birch (*Betula pubescens*) and to a lesser degree willow (*Salix glauca*) (Feilberg 1984).

The Bird Protection Act (Anon. 2019) identifies a number of "bird protection areas". Within the AOI, three such areas are found, all of which are archipelagos with high numbers of breeding seabirds: Kitsissut Avalliit, Indre Kitsissut and the islands of Qeqertat east of Narsaq Kujalleq (Narsarmijit) (Figure 4.13). The protection measures are primarily aimed on issues related to traffic and disturbance of wildlife in the birds' breeding periods.

The Bird Protection Act (Anon. 2019) also includes general protection of seabird breeding colonies from traffic and disturbing activities. Seabird colonies in the AOI are shown in Figure 4.13 as small green and yellow dots.

Aside from the Greenlandic legislation related to the Bird Protection Act, Greenland has also adopted the Ramsar Convention on Wetlands (https://www.ramsar.org/). Within the AOI, there is one Ramsar site located at the archipelago of Kitsissut Avalliit (https://rsis.ramsar.org/ris/388; Figure 4.13). Ramsar sites are designated according to the international convention of wetlands, and they are included in Greenlandic legislation (Anon. 2016a).

In relation to exploration of minerals and hydrocarbons, a number of "areas important to wildlife" have been identified (Anon. 2000). In those areas, activities related to exploration for minerals are regulated to minimise disturbance of wildlife. Within the AOI, these include bird cliffs and bird islands. Please refer to NatureMap on NunaGis for further information (layer: "Bird Important Areas"). See Chapter 8 on recommendations related to protected areas and mineral resources activities.

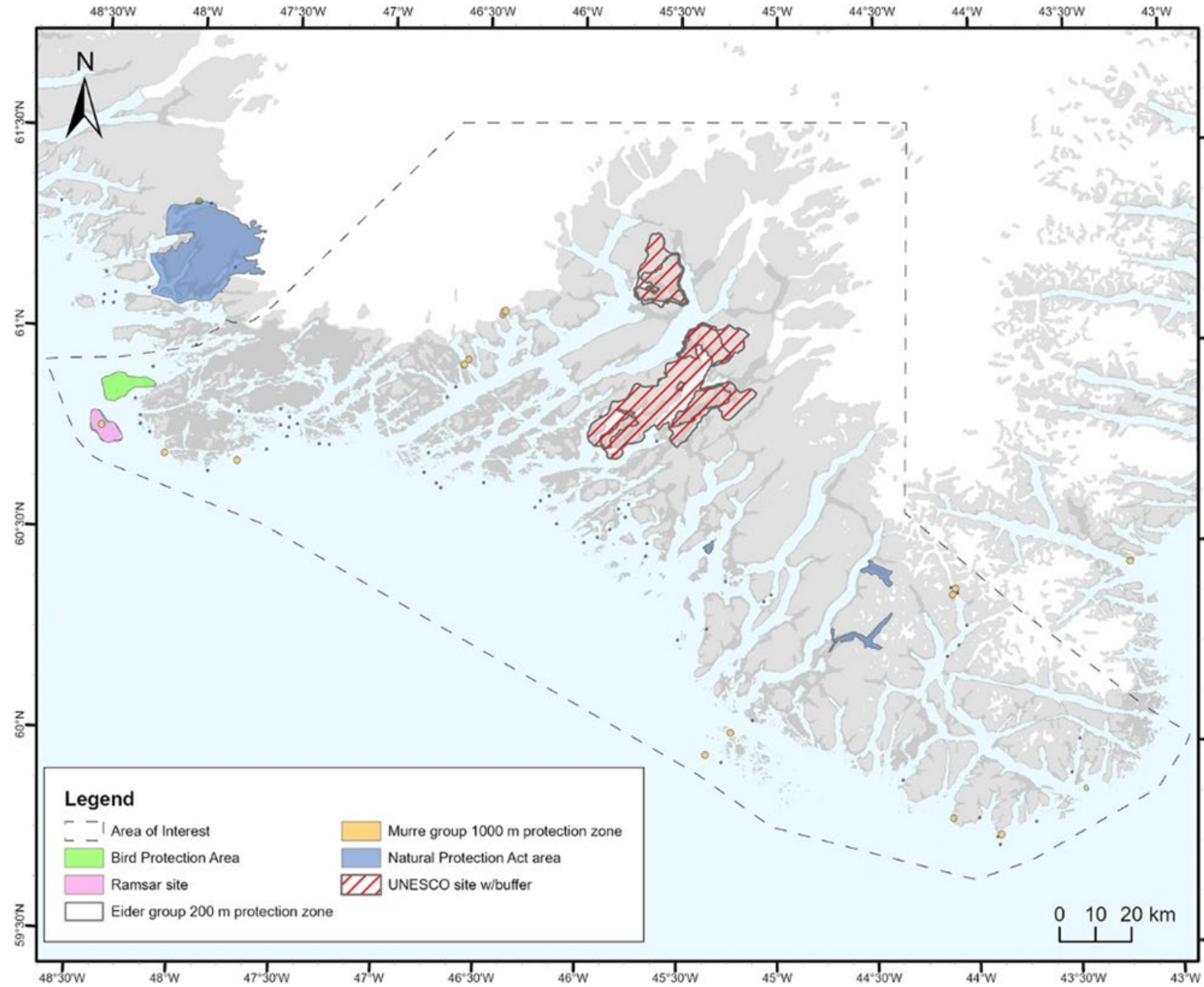

Figure 4.13. Nature protection areas according to the Greenland Nature Protection Act, Ramsar sites, Bird protection areas, UNESCO World Heritage List sites as well as relevant protection zones for eider and murre groups (seen on this figure as circles; please refer to the WebGIS for better visualisation of the colony locations).

Finally, in 2017 an area called "Kujataa – a subarctic farming landscape in Greenland" was included in the UNESCO World Heritage List. The area was designated according to cultural heritage without protection of biological interests (Anon. 2016b). The protected area is composed of several land areas surrounded by a buffer zone (https://naalakkersuisut.gl/da/Naalakkersuisut/Moeder-for-Naalakkersuisut/M%C3%B8dereferater/2018/11/22_11_18) (Figure 4.13). The UNESCO site is the third of its kind in Greenland and covers the agricultural history in the area from the introduction by the Norse to modern-day farming (Vésteinsson et al. 2016).

4.7 Biologically important areas

In 2016, a report on ecological and biological important areas in West and Southeast Greenland was published (Christensen et al. 2016). The report provides an overview of important areas for ecosystems and species, and identifies three types of important areas:

- *Species-specific core areas*. These are hot spots critical for specific species. They may be areas containing relatively large numbers of individuals, migration corridors or other types of important areas.

- *Important habitats, nature types or other ecosystem components*. These include areas with high biological productivity, areas that are biologically unique and/or possess high biodiversity etc.
- *Ecological and biological valuable areas*. These are defined as areas where the species-specific core areas and important habitats, nature types or ecosystem components are particularly close.

The report identifies 23 *Ecological and biological valuable areas* of which three are found either partly or entirely within the AOI. In the Christensen et al. (2016) report, the three areas are referred to as "Area 17, 18 and 19" (Figure 4.14).

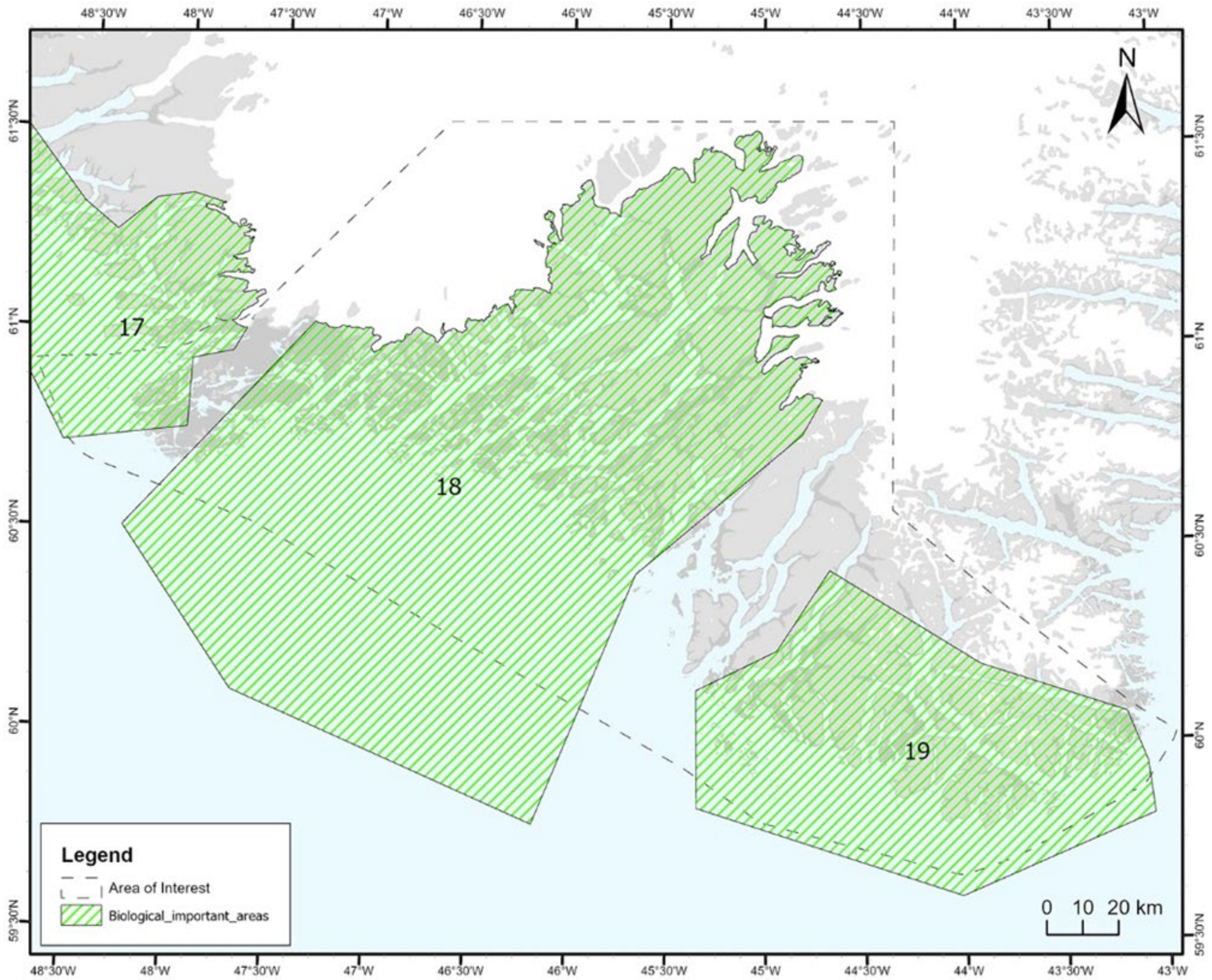

Figure 4.14. The three ecological and biological important areas located in the AOI marked as 17, 18 and 19 in the report by Christensen et al. (2016). For location names mentioned in the text, please refer to Figure 1.1 and the species-specific figures in this chapter.

The report concludes that these 23 ecological and biological valuable areas can be regarded as a network, which, if protected against actual threats, could safeguard a representative part of important habitats, ecosystems, and species in West and Southeast Greenland. However, the report recommends that while further strategic work related to nature protection should focus on these 23 areas, there may also be a need for protection of certain species-specific core areas outside of the 23 ecological and biological valuable areas. For location names mentioned in the text, please refer to Figure 1.1 and the species-specific figures in this chapter.

Only the southern part of area 17 is included in the AOI. This area includes the very important seabird breeding colonies at the archipelagos Indre Kitsissut and Kitssisut Avalliit, holding a very high (in a Greenland context) diversity of seabird species, including thick-billed murre, common murre, razorbill, Atlantic puffin, and white-tailed eagle. Several of these species are assessed as threatened in Greenland and/or globally (Table 4.1, Boertmann and Bay 2018). Along the coasts, high numbers of harlequin ducks (Figure 4.3) moult in late summer and the offshore areas are important winter habitats for many seabirds, including thick-billed murres and common eiders (Figures 4.7 and 4.10). The offshore areas also include important areas for baleen whales.

The interior parts of area 18 (Figure 4.14) include most of the subarctic climate zone of Greenland. The vegetation is rich in lush birch (Betula sp.) and alder (Alnus crispa) shrubs, and many sites have a high diversity of vascular plants, including species that are rare and threatened in Greenland (Figure 4.11, Table 4.2). There are sites with low coasts and river outlets with Arctic char stocks (Figure 5.4), and the white-tailed eagle is relatively common (Figure 4.2). Area 18 is also the centre for agriculture in Greenland, including sheep farming and growing of potatoes (see Chapter 5 "Human use"). There is also a rich cultural heritage with many Norse remains (see Chapter 6 for archaeological descriptions). The offshore parts are important winter habitats for seabirds (e.g., common eiders, thick-billed murres) and important summer habitats for baleen whales.

Area 19 includes subarctic habitats in the western part, including the most extensive birch woodlands (see section 4.7). White-tailed eagle is also frequent in this area, and at Nunap Isua and further east there are important seabird breeding colonies, including common eiders and razorbills. The archipelago Qeqertat is one of very few sites where harbour seals occur regularly today (Figure 4.1). This is also a bird protection area. The offshore waters are important for migrating as well as wintering seabirds (e.g., common eider and thick-billed murre), to hooded seals (Cystophoa cristata) in spring and to baleen whales in summer, and polar bears (Ursus maritimus) occur frequently when drift ice is present.

There are, as mentioned above, also valuable ecological and biological areas outside the three areas 17, 18 and 19. These include two bird cliffs with breeding kittiwakes and other gulls in the strait east of the island Ammalortoq, bird cliffs in the head of the fjord Kangersuneq Qingorleq (see also Figure 4.4) and the coasts off area 18 and 19, which are important winter habitats for common eiders.

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5 Human use

By Katrine Raundrup[1], Josephine Nymand[1], Peter Aastrup[2] and Karl Zinglersen[1]

[1]Greenland Institute of Natural Resources, [2]Department of Ecoscience, Aarhus University

5.1 Introduction

South Greenland is home to approximately 6,500 inhabitants – ca. 5,600 people in the towns of Qaqortoq, Narsaq and Nanortalik, and ca. 900 in the settlements including sheep farms (numbers as per 1 January 2021, www.stat.gl). The area of interest, AOI (Figure 5.1) of this report is located in Kommune Kujalleq, the southernmost municipality in Greenland.

In this chapter, the human use in the AOI is described.

The municipality plan for the entire area can be found at www.kujalleq.cowi-plan.dk/dk (in Danish and Greenlandic only). It includes maps of, e.g., recreational areas, area allotments, farming areas and technical infrastructure, all of which are summarised in Figure 5.1. The municipality plan is implemented through the Law on Planning and Land Use with the aim to protect nature, allocate areas between human use and nature, advance development and involve the inhabitants. The municipality has the obligation to establish a complete plan and assessment of land use, natural and economic resources in the region as well as goals for the development of businesses and population. The plan, valid for a specific period, must include (and not disagree with) the national sector plans and interests such as conservation zones, infrastructure for energy and transport and other vital societal interests. The authorities and organsations at the national level are obliged to inform the municipality of their plans and interests affecting the municipality level. The municipality plan provides the basis for the municipality to regulate and administer requests from organisations and citizens for area allotments and activities involving land use in inhabited and uninhabited places (Anon. 2010).

Land use and activities related to mineral activities are regulated through the Mineral Resources Act by the Mineral Licence and Safety Authority concerning permits to and inspection of facilities etc. on the basis of other relevant acts and regulations and through hearings with relevant authorities (Mineral Resources Act, §3, govmin.gl).

Human use of the resources in South Greenland is characterised by the presence of land-based agriculture and farming. It is the only region where this takes place at a large scale. Naturally, there is also a large component related to the resources found at sea and coastal areas. In this chapter, agriculture/farming, use of marine resources, plantations as well as tourism and larger technical infrastructures are presented.

South Greenland has a long history of agriculture as farming was first introduced by the Norse ca. 985 AD. The Norse brought a variety of animals with them, including sheep, cattle, goats, pigs, horses, and chickens (Madsen 2015). The Norse were present in Greenland until ca. 1450 AD, and during the

4–500-year period there were up to 200 farms in the area. The reasoning for leaving remains unclear, but unsustainable land use (Arneborg et al. 2012) as well as climate change (Grove 2001) are likely the main causes.

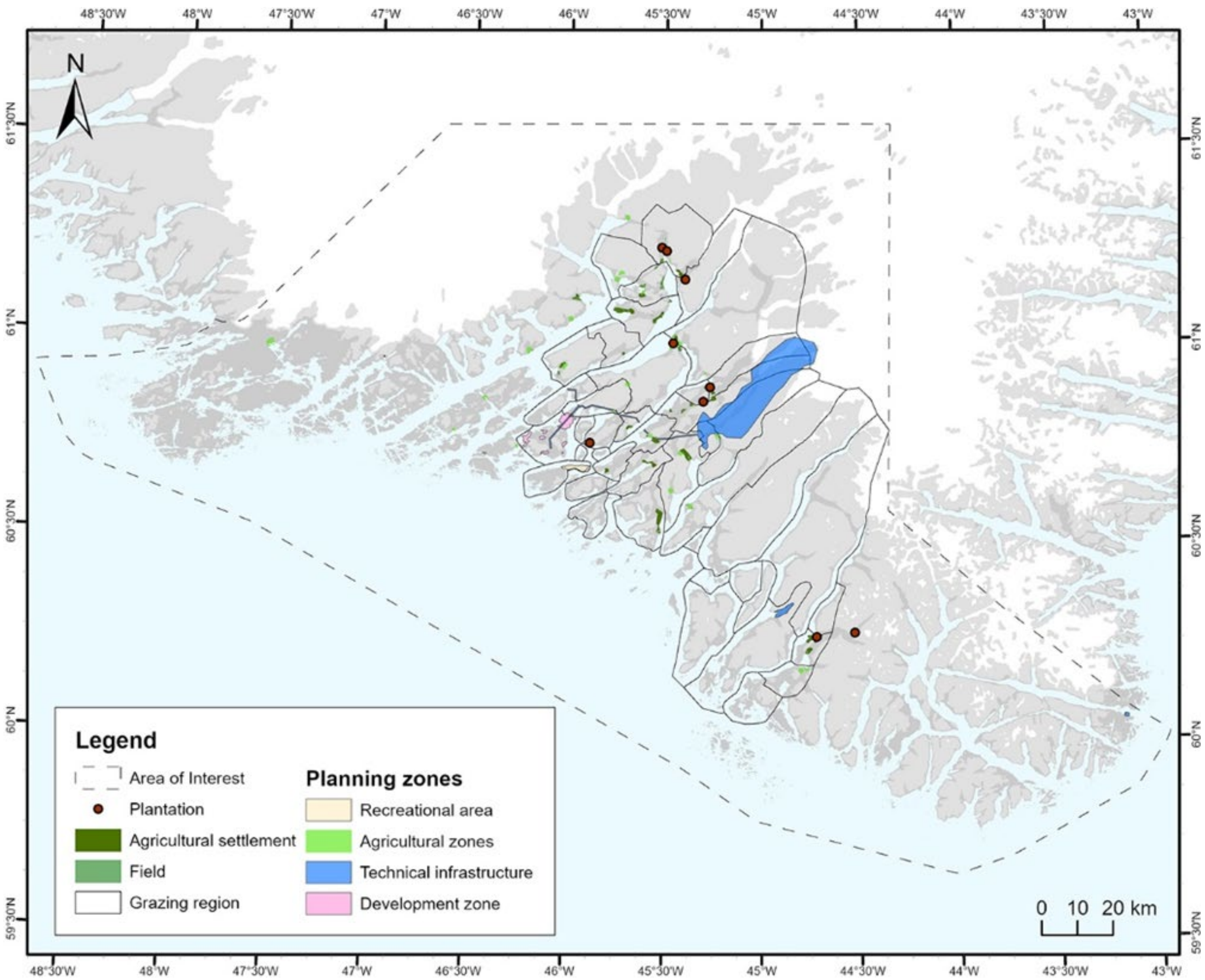

Figure 5.1. Municipality plan for Kujalleq with recreational and agricultural zones, fields, grazing regions, reindeer herding areas, plantations as well as technical infrastructure. Reference: www.kujalleq.cowiplan.dk/dk.

In the following several centuries, farming did not occur in Greenland until sheep farming was reintroduced in 1915 (Nymand 2018). Until the 1970'ies, the sheep were managed based on extensive all-year round grazing with some stabling during winter (Austrheim et al. 2008). Following a winter with heavy snow and strong frost in 1966/1967 resulting in the death of more than 50% of the ewes and another catastrophic winter in 1971/1972, the management regime was changed into what is more or less similar to modern-day farming with winter stables (see subchapter 5.2).

Before the catastrophic winters in the late 1960'ies and early 1970'ies, the number of ewes had increased from ca. 250 introduced from Iceland in 1915 to ca. 45,000 in 1966. After the massive die-offs, the number of ewes ended up around 20,000.

5.2 Modern-day agriculture

The number of farms has gradually decreased from 52 in 2005 to 37 in 2019 (www.stat.gl). The majority of the farms rely on sheep, but a few have, e.g., only cattle or only grow crops or potatoes.

Sheep farming

In 1982, a management plan for sheep farming was implemented, stipulating outdoor grazing for six months of the year (1 May – 31 October) and stable feeding for the remaining six months (1 November – 30 April; Austrheim et al. 2008). This management regime still prevails today, although the dates may vary with the weather conditions.

To supply their sheep with forage during winter, the farmers rely on a combination of home-grown crops (mainly different grasses for hay and ensilage) and imported feed. Thus, fields with forage crops are scattered in the landscape around all active farms (Figure 5.1). The area of fields has increased from 900 ha in 2005 to ca. 1,200 ha in 2019 (www.stat.gl).

During the same period, the number of ewes decreased from ca. 21,000 in 2005 to ca. 18,000 in 2019 (www.stat.gl). The number of lambs produced for slaughter each year is fairly stable – around 20,000. The lambs are taken to the local butchery, Neqi A/S (www.kni.gl/en/vores-virksomheder/om-neqi/k) in Narsaq in autumn for slaughter.

In a recently published "Strategy for Agriculture 2021-2030" (APNN 2020), a future goal of 28,000 lambs for slaughter per year is suggested. Furthermore, there is a goal of 80% of the winter feed to be home-grown (currently ca. 50% is imported). To be able to reach those goals, more areas in the open land will have to be turned into fields (Westergaard-Nielsen et al. 2015), and more effective management of the sheep in general is needed to be able to produce more lambs per ewe.

Parts of the grazing regions in South Greenland have been showing signs of over-grazing for decades, while others have areas with more or less active erosion due to removal of vegetation (Fredskild 1992, Massa et al. 2012).

In recent years, some farmers have moved away from sheep farming and started producing potatoes and other crops, including turnips. In the recently published "Strategy for Agriculture 2021-2030", increased production of vegetables is one of the aims (APNN 2020).

Cattle farming

In recent years, some farmers have introduced cattle at their farms, and today there are ca. 300 heads (www.stat.gl). The majority of the cattle are kept for meat production, while only a handful are kept for milk for the local household. As with the sheep, the cattle graze in the mountains during the summer months and stay in stables during winter.

Cattle up for slaughter are handled at the local butchery Neqi in Narsaq.

Reindeer herding

The native caribou (*Rangifer tarandus groenlandicus*) is found in most of the ice-free areas of West Greenland aside from the most southern parts of the country. In 1952, semi-domestic reindeer (*Rangifer tarandus tarandus*) were brought from Norway to Itinnera (the inner parts of Nuup Kangerlua/Godthåbsfjord at 64°N, i.e., further north than the AOI of this report). Ca. 260 animals were released in the area. Up until the late 1990'ies, there was reindeer herding in the area (Cuyler 1999).

From the Itinnera-herd, 98 reindeer were introduced as the Isortoq herd (Figure 5.2) in 1973 and 1974. These reindeer have a range of ca. 1,500 km² in the mountains where they live all year round. They are gathered for slaughter once a year. The most recent estimate is ca. 1,200 animals.

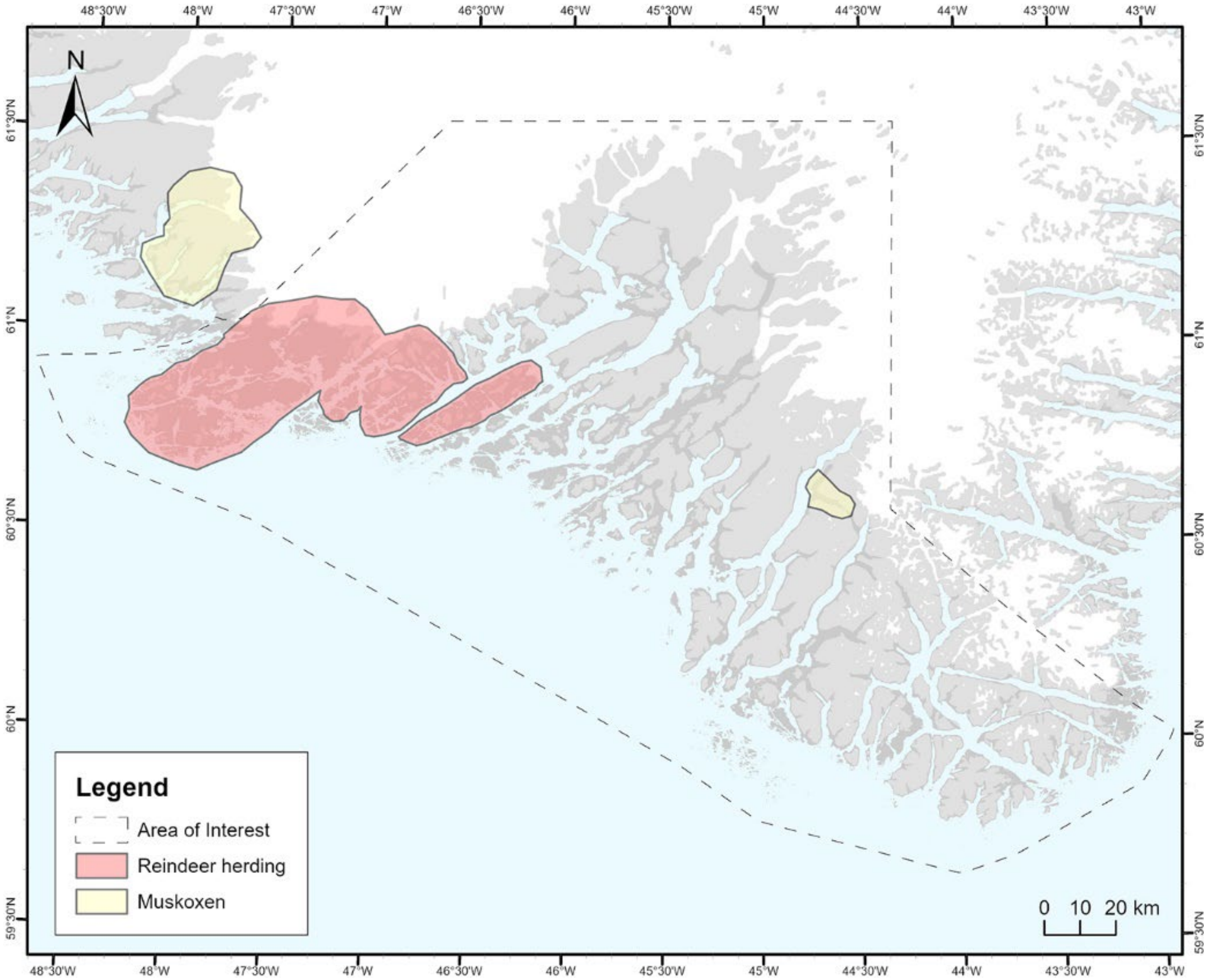

Figure 5.2. Reindeer herding areas (marked in purple). The westernmost area is "Isortoq" and the easternmost "Tuttutooq". The muskox introduction area at Nanortalik is marked in yellow. Northwest of the AOI, the Ivittuut muskox population is found (also marked in yellow).

An additional herd was established at Tuttutooq (Figure 5.2) in 1992 (Cuyler 1999). The animals there have a range of ca. 220 km², and the most recent estimate is ca. 350 animals.

5.3 Muskox introduction

Muskoxen (*Ovibos moschatus)* do not occur naturally in West Greenland, but calves from East Greenland were introduced to the inland area of Kangerlussuaq (ca. 66°N) in the middle of the 1960'ies. From the fast-growing Kangerlussuaq population, additional translocations to several areas were carried out along the west coast, including Ivittuut, in 1987 (Boertmann et al. 1992).

In 2014, 18 muskoxen (12 females and 6 males) were set out in a valley at Ippatit on the northern coast of the Nanortalik peninsula (yellow marking in Figure 5.2). The muskoxen originated from the introduced population at Ivittuut (larger yellow marking in Figure 5.2 just northwest of the AOI). Prior to the introduction, a report on, e.g., available suitable muskox habitat with sufficient grazing quality was produced, and this area was estimated to ca. 150 km^2 (Feilberg and Bürger 2013).

A minimum count in 2020 estimated a population size of 46 animals (pers. comm. N.M. Lund, APNN). The population size is still too small for hunting to take place.

5.4 Plantations

Natural woodlands are very rare in Greenland and only occur within the subarctic region in the inner parts of the fjord systems in South Greenland (Böcher 1979 and Chapter 5). The arrival of Hans Egede in Greenland in 1721 marked the beginning of the colonial period in Greenland. With the arrival of Norwegians and Danes to the budding number of colonies along the coasts, the need for wood for, e.g., burning increased (Meilby et al. 2019). The naturally occurring birch forests were depleted to a large degree to provide material for indoor heating.

As a result of the diminishing areas with trees usable for heating, plantations of mainly foreign species started in the 1840'ies. Several plantations were initiated, but at many of the locations the seedlings or young trees did not survive. Most of the plantations were, and still are, based on coniferous species such as Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), white spruce (*Picea glauca*) and Siberian larch (*Larix sibirica*) (Ødum 1979).

Figure 5.3. The edge of the Qanasiassat plantation in the Tunulliarifk Fjord. Photo: K. Raundrup.

Today, there are still eight plantations scattered in South Greenland (Figure 5.1 and Figure 5.3). The largest is the arboretum in Narsarsuaq, which covers more than 100 ha with more than 100,000 plantings of more than 100 species (Christensen et al. 2016; Ræbild et al. 2019). The most recent plantation was initiated in 2004 at Itilleq close to Igaliku. More than 20,000 seedlings of Siberian larch and spruce species were planted in a 7 ha area (Meilby et al. 2019).

5.5 Hunting

Hunting in Greenland is managed by the Government of Greenland. There are two types of hunters: recreational hunters and subsistence hunters. In South Greenland, the three relevant land animals hunted are ptarmigan (*Lagopus mutus*), Arctic hare (*Lepus arcticus*), and Arctic fox (*Alopex lagopus*). All three species are found throughout in the area and in ample numbers.

The number of hunted animals varies greatly between years. Especially the number of hunted ptarmigans has decreased tremendously from 2006 to 2019. This corresponds to a significant decrease in the number of both recreational and subsistence hunters in South Greenland. In 2006, 714 people were registered at either recreational or subsistence hunters (524 and 190, respectively), while in 2019 the corresponding numbers had decreased to 269 and 127, totaling 369 hunters (www.stat.gl).

Arctic foxes may be infected by rabies and are thus often culled when observed close to sheep farms. Outbreaks of rabies in South Greenland have been found to occur at 5-6 year intervals (Raundrup et al. 2015), and in years with outbreaks more foxes are likely killed as a precaution.

No areas of special importance for the hunters have been identified.

5.6 Coastal fishing

Long stretches of the coastline has fishing resources for both private as well as commercial use. In general, the commercial fishing in South Greenland is limited compared to other Greenland waters. In the following, the important areas for fishing Arctic char (*Salvelinus alpinus*), Atlantic cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*), lumpsucker (*Cyclopterus lumpus*), northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*) are presented.

Arctic char

Arctic char is common in the entire AOI, and most larger rivers hold a spawning population. Arctic char spawn in freshwater, and the young fish stay in freshwater for some years before they migrate to the marine environment. Some lakes and rivers have non-migrating char. All Arctic char winter in freshwater, and this period is thus crucial for their survival (Christensen et al. 2016). Arctic chars are found in many rivers (Figure 5.4), and fishing is likely to take place in many of them.

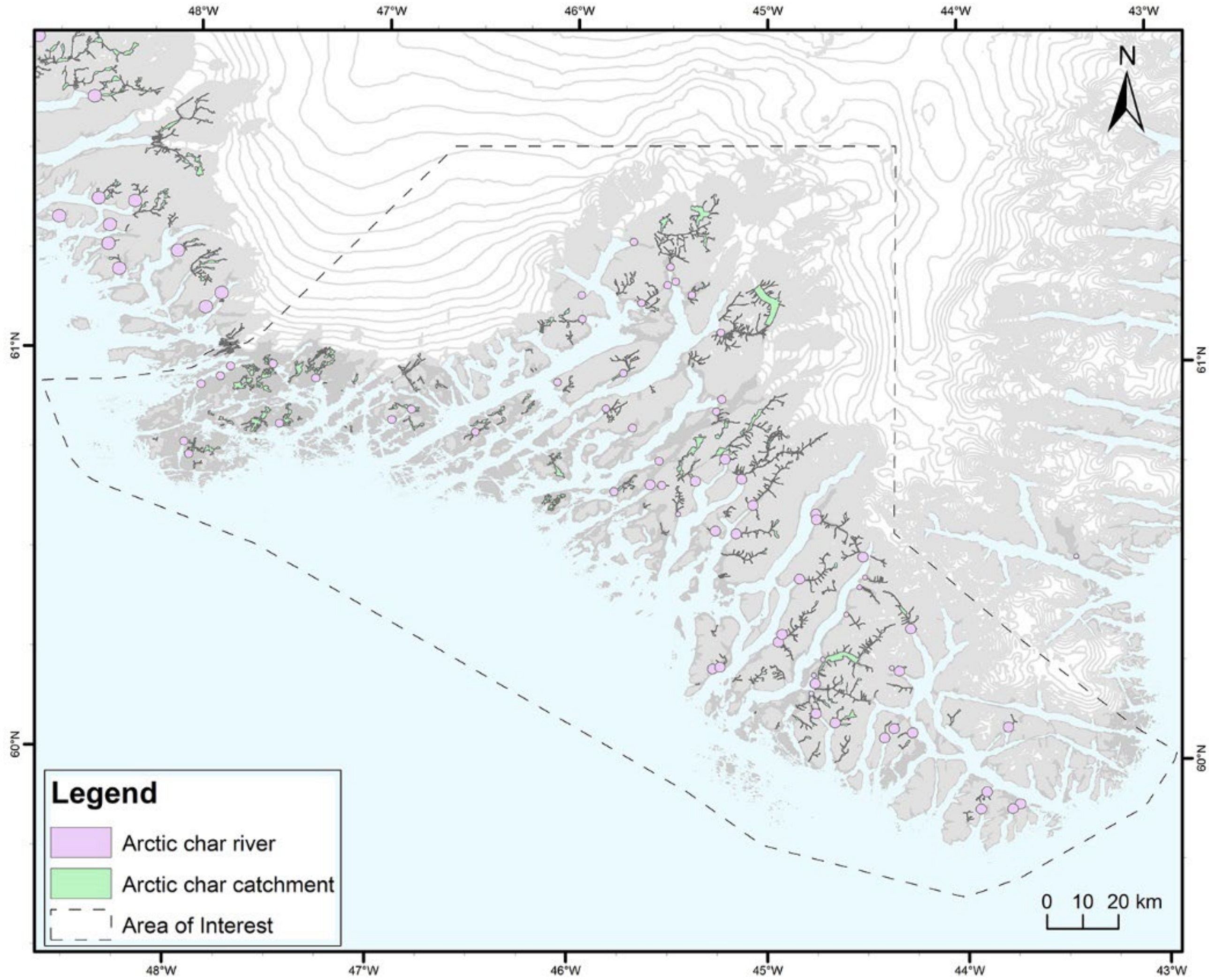

Figure 5.4. Arctic char rivers as well as relevant catchment rivers and lakes.

Atlantic cod

The Atlantic cod is found both offshore and in the fjords, and in South Greenland the West Greenland and East Greenland stocks mix. There is considerable fishing of this resource, though most catches are taken outside the AOI (Figure 5.5). Some fishing does, however, take place within the fjords (Christensen et al. 2016).

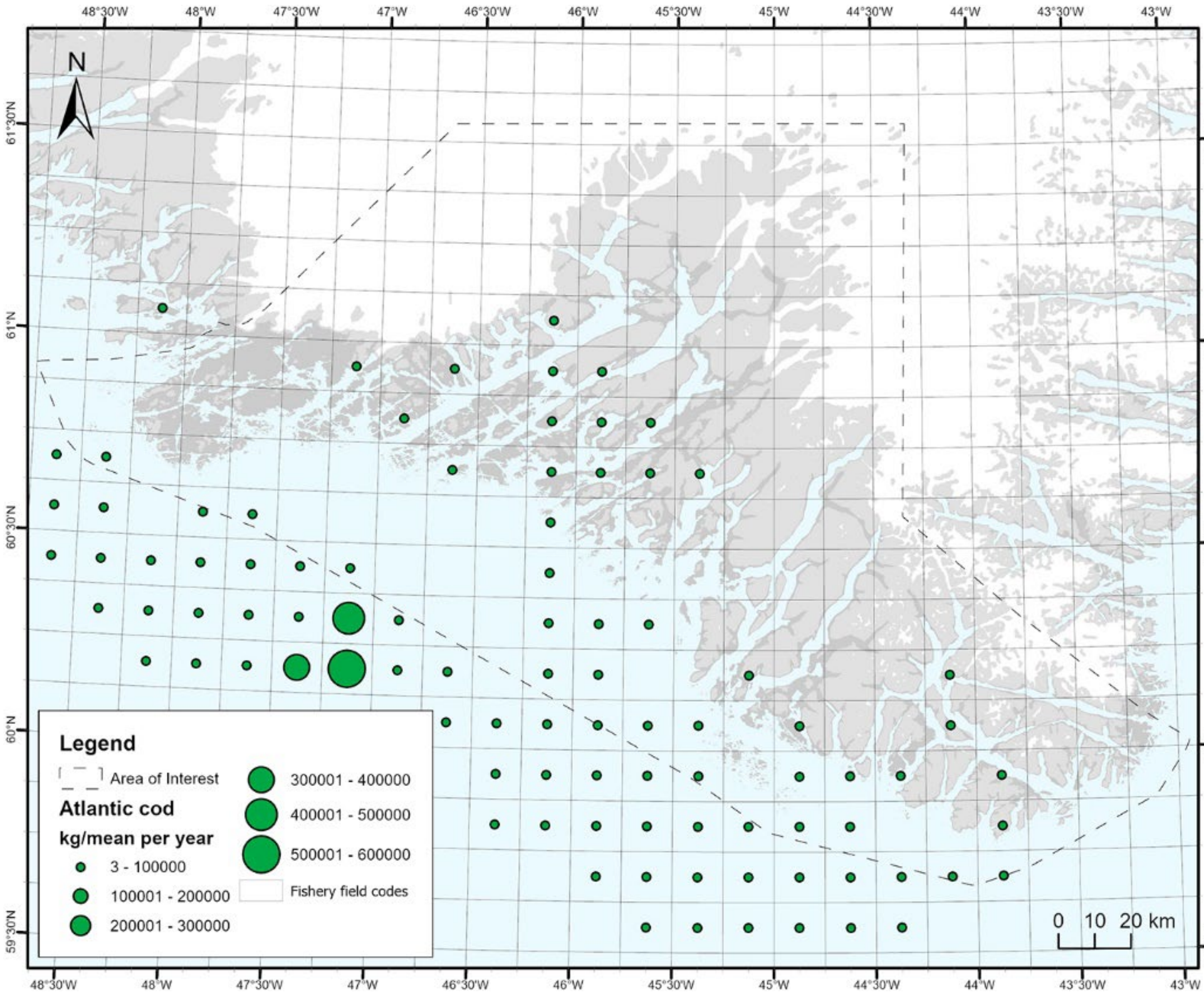

Figure 5.5. Average catches of Atlantic cod in kilos per year (2014-2019). The squares refer to the individual fishery field codes (statistical catch squares). The individual dots are centered in each of the relevant squares and thus do not necessarily refer to the specific catch position within the field code area.

Greenland halibut

Within the AOI, Greenland halibut is mainly found in the fjord systems (Figure 5.6). The annual catches per year in the area are relatively low aside from one location in the inner parts of the fjord system in Southeast Greenland. One of the important spawning areas is found offshore west of the southernmost part of Greenland (Christensen et al. 2016).

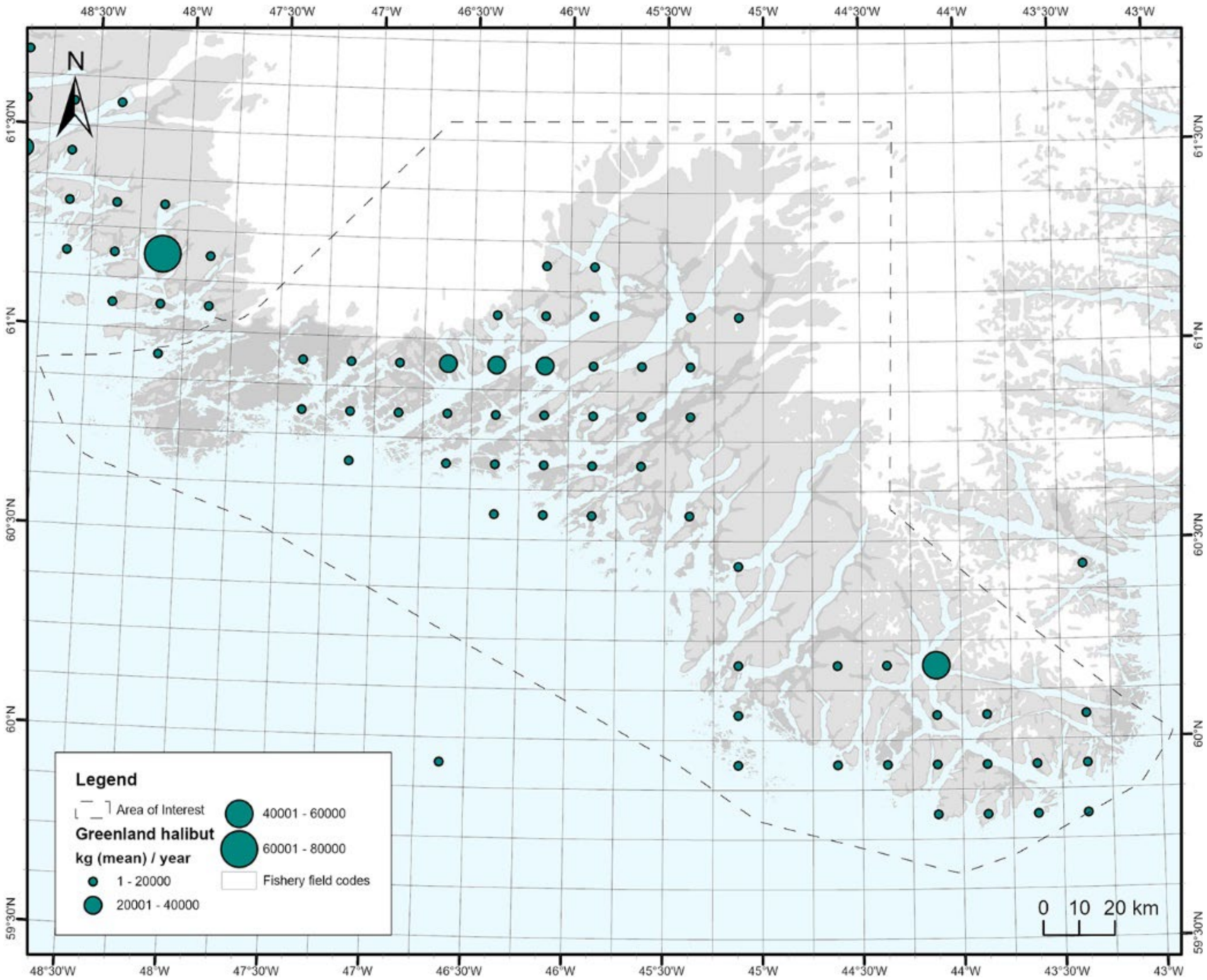

Figure 5.6. Average catches of Greenland halibut in kilos per year (2014-2019). The squares refer to the individual fishery field codes (statistical catch squares). The individual dots are centered in each of the relevant squares and thus do not necessarily refer to the specific catch position within the field code area.

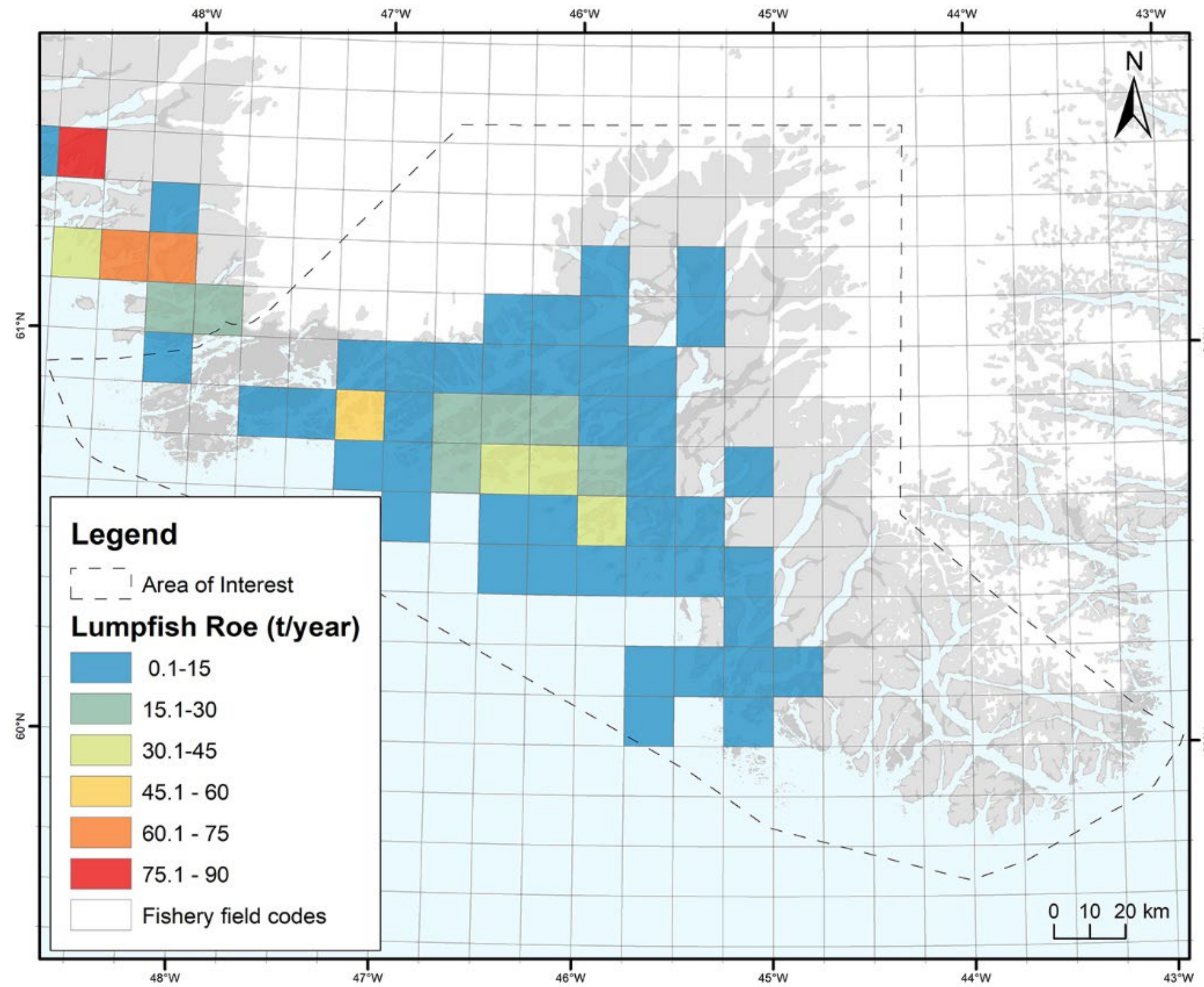

Figure 5.7. Average catches of lumpfish roe in tons per year (2014-2018). The squares refer to the individual fishery field codes (statistical catch squares). The colour coding refers to the average catch in each of the squares.

Lumpsucker

Lumpsuckers spawn along most of the coast within the AOI, though in fairly low numbers. They spawn in spring (March through June), and during that period fishing for the species is extensive. The fishing is primarily for female lumpsuckers as they have a valuable roe for export abroad. A smaller part of the total catch is sold at local meat markets (Figure 5.7, Christensen et al. 2016).

Northern shrimp

Northern shrimp is mainly a deep-sea species and is often found at depths down to 600 m. It is thus not common in the more shallow coastal areas within the AOI (Figure 5.8). The distribution used to be more uniform along the entire west coast of Greenland, but in recent years the northern shrimps have moved northwards and thus away from the AOI (Christensen et al. 2016).

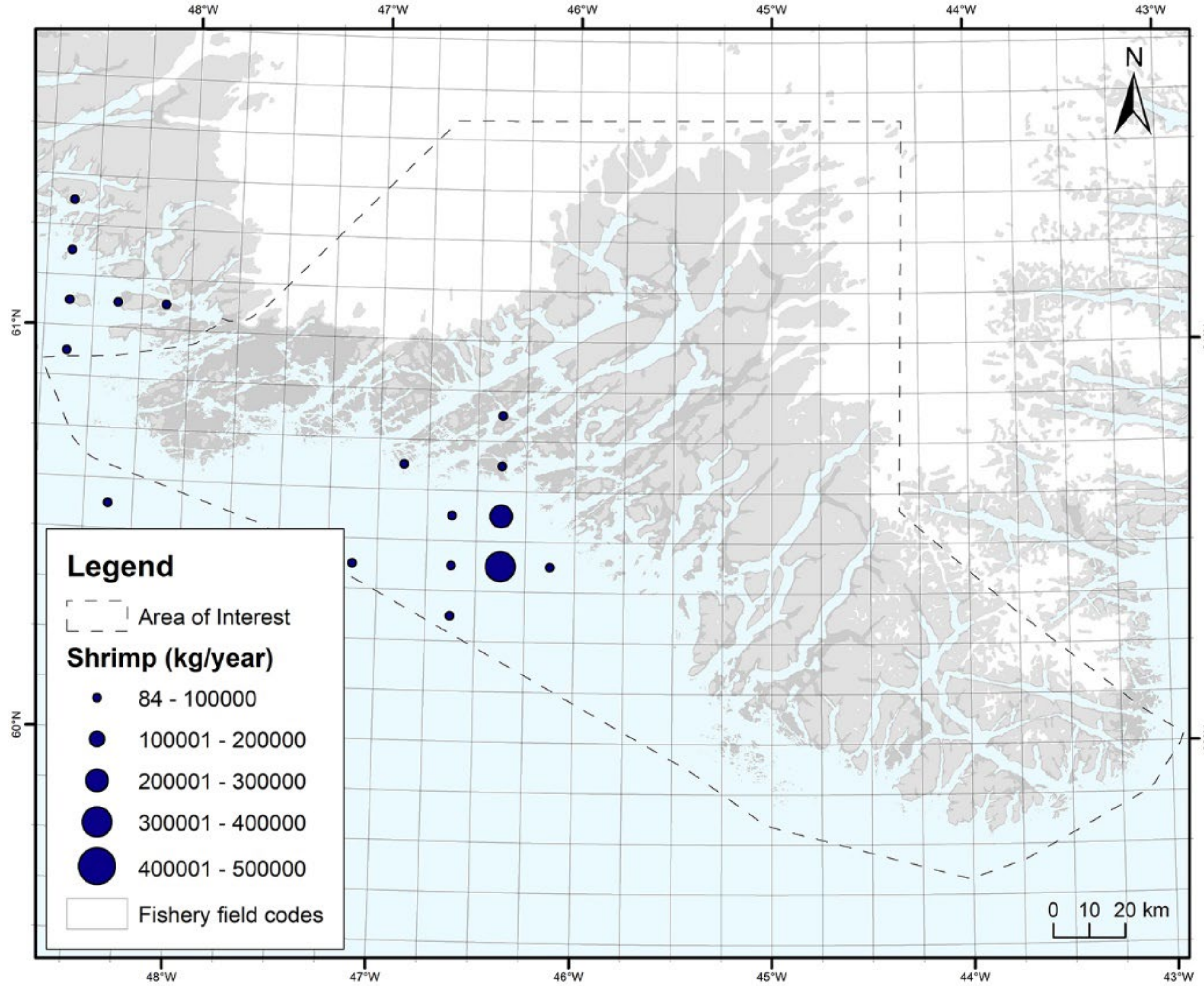

Figure 5.8. Average catches of northern shrimp in kilos per year (2014-2018). The squares refer to the individual fishery field codes (statistical catch squares). The individual dots are centered in each of the relevant squares and thus do not necessarily refer to the specific catch position within the field code area.

Crab

Snow crab is found both offshore as well as in the fjords. Most crabs change their shell during the period between March and August, making them especially vulnerable. During the shell shift, the crabs are referred to as soft-shell crabs and are of no commercial interest. The catch of snow crabs per year in the AOI is relatively modest (Figure 5.9, Christensen et al. 2016).

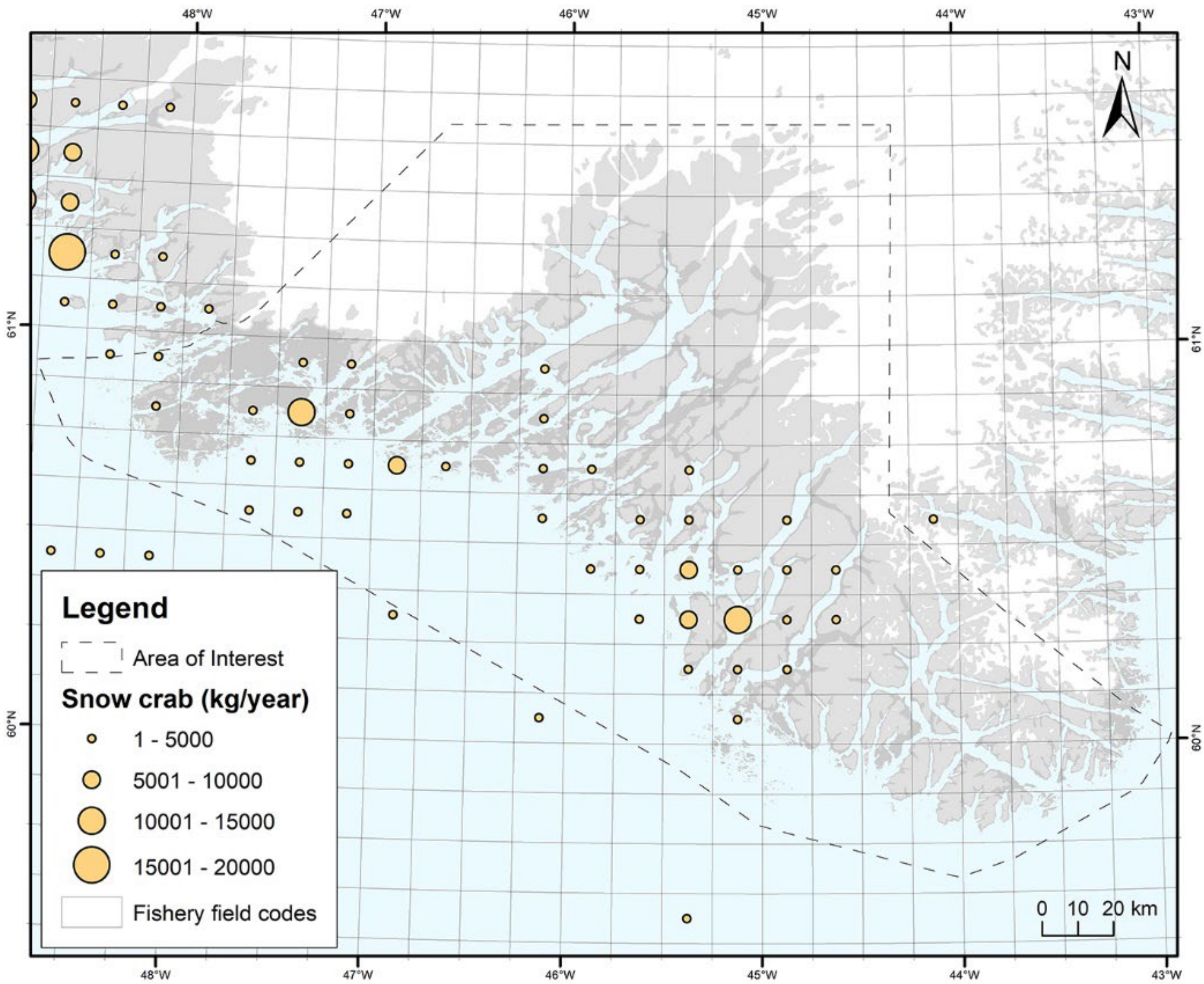

Figure 5.9. Average catches of snow crab in kilos per year during the period 2014-2019. The squares refer to the individual fishery field codes (statistical catch squares). The individual dots are centered in each of the relevant squares and do thus not necessarily refer to the specific catch position within the field code area.

5.7 Tourism

Tourism is an increasing industry in the Arctic, including Greenland. In South Greenland, the tourist activities can, to a large degree be split in two: cruise ship tourism and hiking tourism.

The cruise ship tourism is at a fairly high scale with more than 175,000 passengers visiting the region between 2015 and 2019 (Figure 5.10; www.stat.gl). The main season is August with almost 29,000 tourists visiting in 2019. Tourists from cruise ships rarely walk far from the location where the ship calls at, i.e., they often stay within a few kilometres of the site, town, or settlement they are visiting.

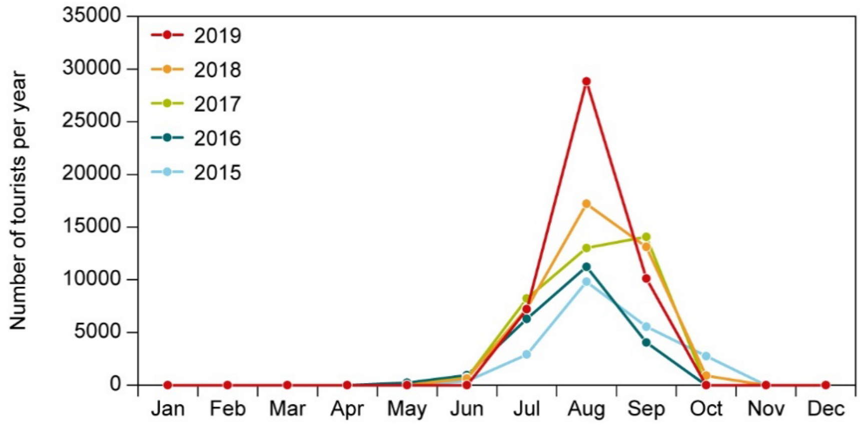

Figure 5.10. Number of cruise ship passengers visiting Nanortalik, Qaqortoq, Narsaq, Narsarsuaq and Qassiarsuk.

There are no official statistics on the number of hiking tourists, but they are increasing. This corresponds to the increasing number of sheep farmers who offer "bed & breakfast" as a way of increasing their revenue. There are several hiking trails, many of which follow parts of the established dirt roads in the landscape (Figure 5.11). The most prominent routes are the treks between Narsaq and Qassiarsuk and between Qaqortoq and Igaliku.

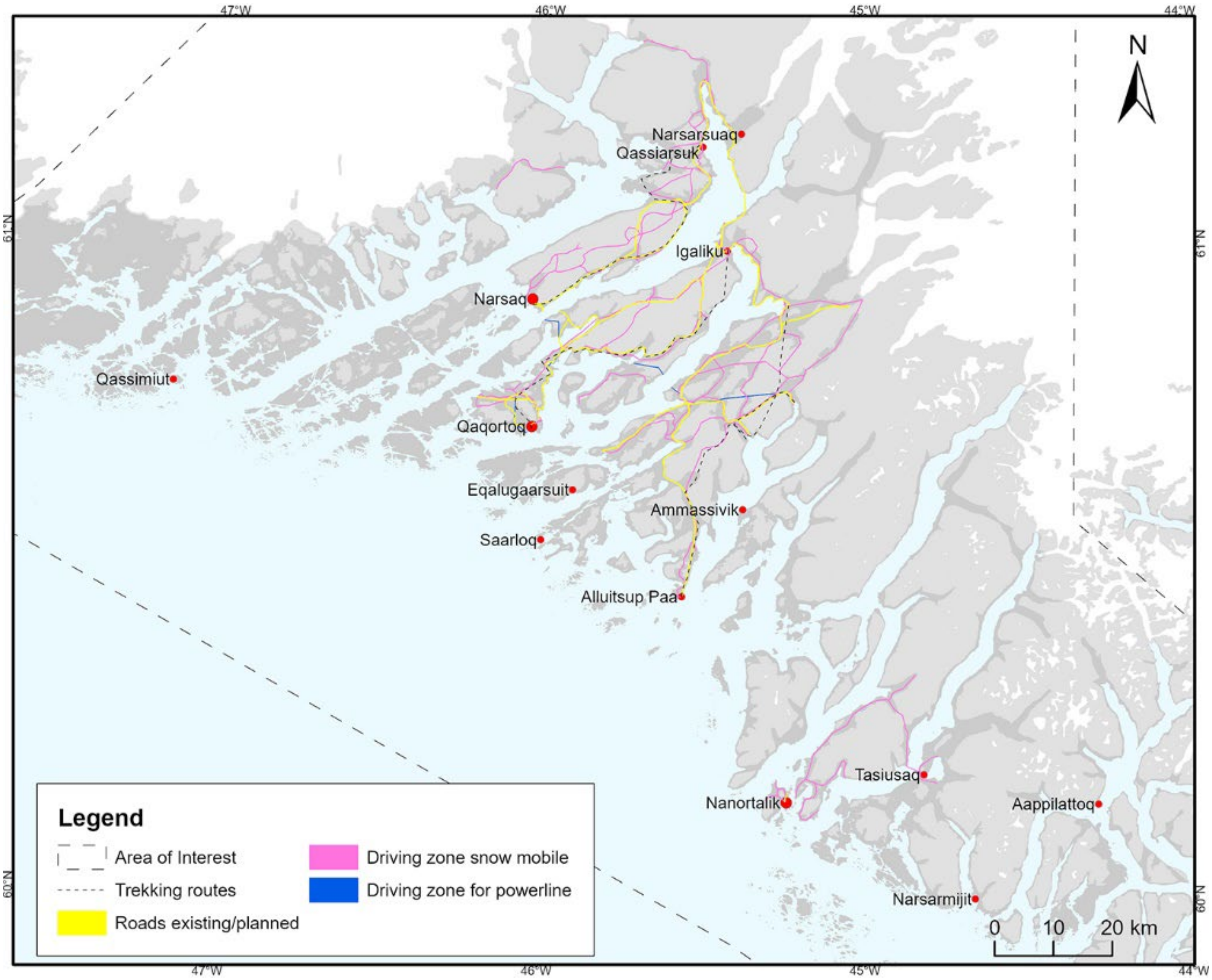

Figure 5.11. Hiking trails, existing and planned roads as well as driving zones within the area of interest. Data from the Municipality Plan (www.kujalleq.cowiplan.dk/dk).

5.8 Technical infrastructures

In the municipality plan summarised in Figure 5.1, two technical infrastructure areas are mentioned. The largest is the hydropower plant at Qorlortorsuaq including its catchment rivers and lakes. The construction of the plant was finished in 2008. It has the capacity of 7.6 MW and generates power for Narsaq and Qaqortoq (www.nukissiorfiit.gl/da/Produkter/Vedvarende-energi/Vandkraft).

The smaller infrastructure area is the upland area to the currently inactive goldmine Nalunaq, located ca. 35 km northwest of Nanortalik, whose activities were terminated in 2013.

Within the AOI, a fairly developed network of roads connecting sheep farms and settlements exits (Figure 5.1). The map in Figure 5.11 also highlights the network of hiking routes connecting, e.g., Qassiarsuk with Narsaq, Igaliku with Qaqortoq and long stretches within the Vatnarhverfi area.

5.9 Oil spill sensitivity

An extract of the data from the Oil Spill Sensitive Atlas published in 2004 (Mosbech et al. 2004) is shown in Figure 5.12. The classification of sensitivity is based on a variety of parameters primarily related to the biological resources of the area as well as human use of the resources. Accordingly, areas that are sensitive to oil spill are areas with, e.g., specific coastal types, archaeological remains, a high density and/or diversity of biological resources as well as areas important for fishing and hunting. The oil spill sensitivity atlas published in 2004 included community consultations, thus incorporating information of local use of the area.

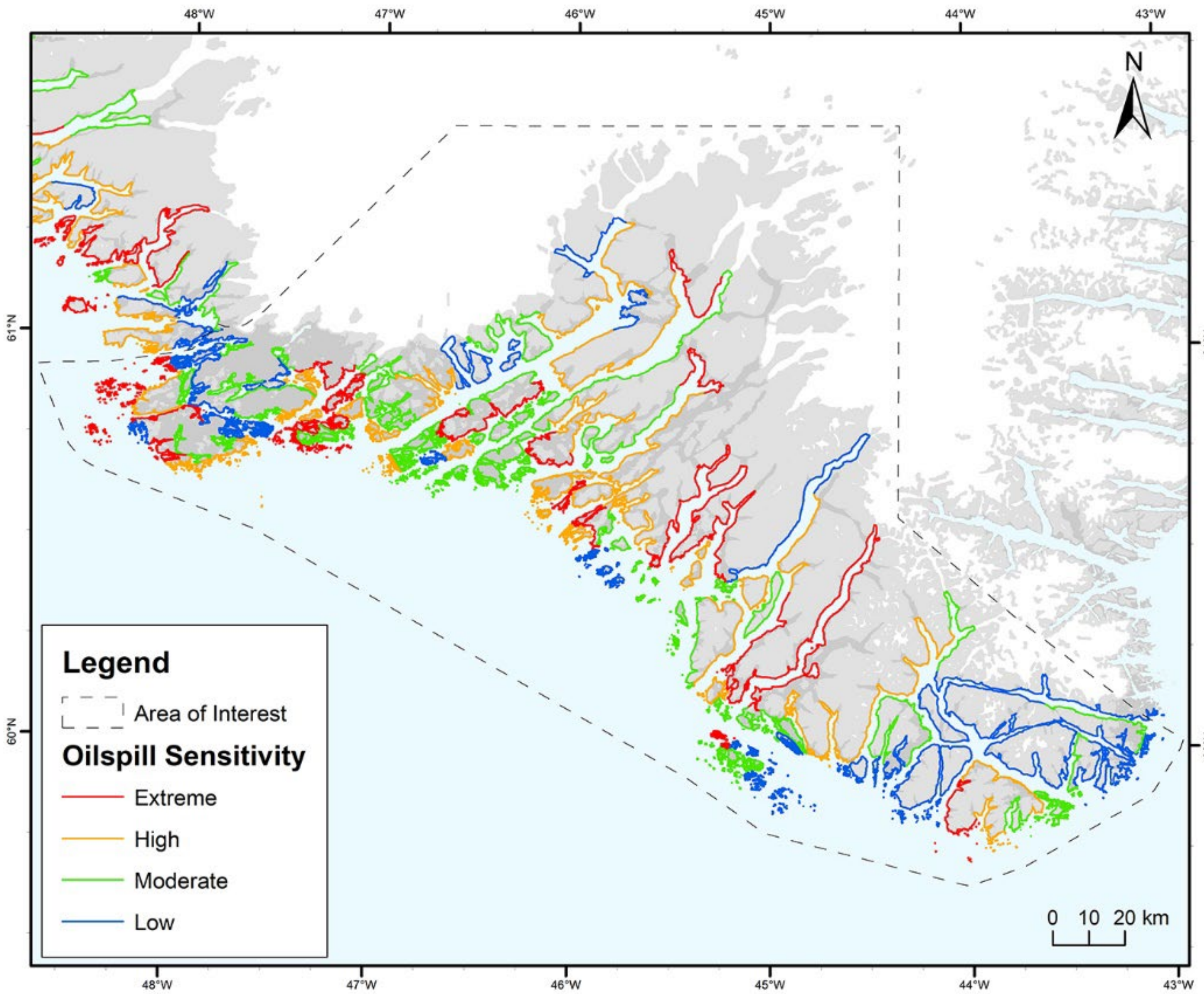

Figure 5.12. Oil spill sensitivity along the coast in South Greenland (from Mosbech et al. (2004)).

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6 Greenland's culural history – an introduction

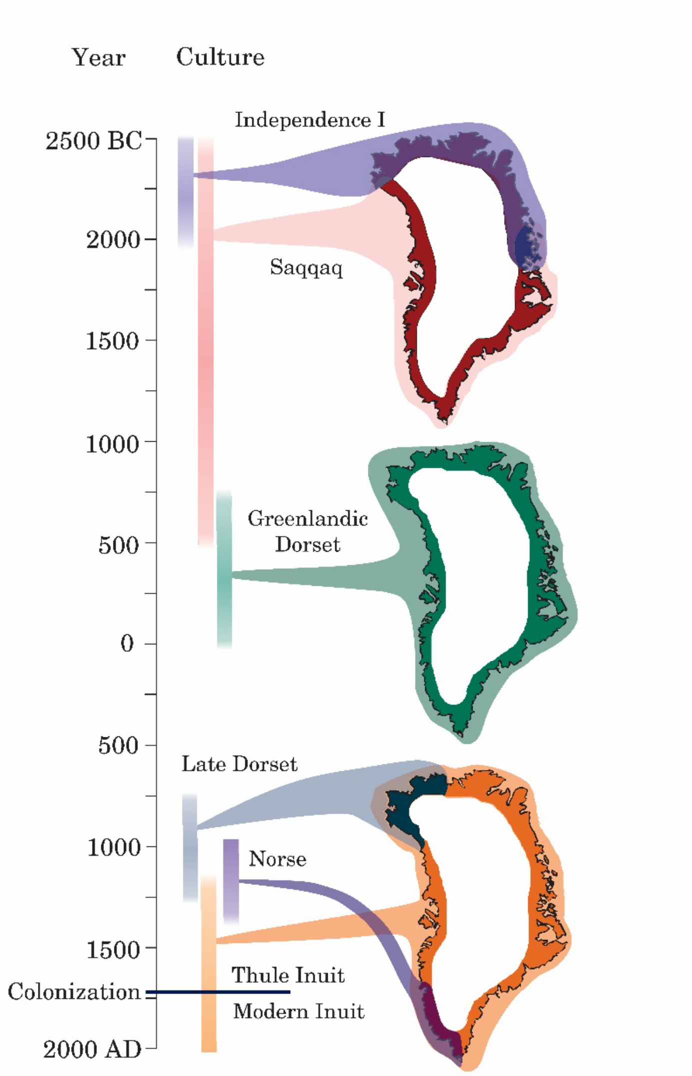
By Christian Koch Madsen[1]

[1]*Nunatta Katersugaasivia Allagaateqarfialu/Greenland National Museum & Archives (NKA)*

Greenland's cultural history spans ca. 4,500 years (Figure 6.1). The first people to migrate into Greenland from the North American Arctic were the Saqqaq and Independence I cultures. Between approx. 2,500-500 BCE, they spread to all of Greenland. Minor changes in technology and material culture identified around 800 BCE are interpreted as the advent of a new culture, possibly a new influx of people from the North American Arctic, the Greenlandic Dorset. This culture disappeared from Greenland around year 0, leaving the country totally unpopulated for some 800 years. The Late Dorset culture only inhabited the northwestern tip of Greenland between approx. 800-1,300 CE and was the final impulse of Paleo-Inuit peoples to migrate into Greenland. All these peoples shared similar cultural traits across the North American Arctic. They were small groups of hyper-mobile, marine-oriented hunter-gatherers with "lightweight settlements" and a specialised hunting toolset, where stone was the main raw material for piercing and cutting implements. The various Paleo-Inuit cultures are therefore also in unison referred to as the Arctic Small Tool tradition (ATSt).

In the decades before the year 1,000 CE, a small in-migration of Icelandic Vikings settled in Southwest Greenland. They established two Catholic communities of dispersed settlements based on farming, hunting and trade with Europe for the following approx. 450 years. These medieval Greenlandic Norsemen came into increasing contact with the Thule culture Inuit that migrated into Greenland from Canada around 1,200 CE and spread over the whole country over a couple of centuries. The Thule culture Inuit are the direct ancestors of Greenland's present Inuit population. The Thule culture Inuit brought with them new developments in hunting and transport technology, more substantial settlements and trade networks. However, the Thule culture trade networks became increasingly inseparable from goods supplied from a growing fleet of European whalers appearing in Greenland waters already from the 17th century CE. While whaling camps were set up on various points along the west coast, European presence only became permanent with the Danish-Norwegian colonies established from 1721 CE onwards. The colonisation of Greenland led to a wide-ranging change in settlement patterns and resource use that is reflected in the culture and geography of Greenland's society today.

Figure 6.1. Timeline and ge-opgrahical dispersion of the main cultural epochs in Greenland's history.



6.1 National heritage authorities and sites in Greenland

Nunatta Katersugaasivia Allagaateqarfialu/Greenland National Museum & Archives (NKA) is an administratively decentral, public institution of Naalakkersuisut (the Government of Greenland), currently functioning under authority of the Ministry of Education, Culture, Sports and Church (https://naalakkersuisut.gl/en/Naalakkersuisut/Departments/IKTIN). NKA is the central and sole authority and administration for overseeing and managing Greenland's heritage sites within the legal frameworks laid down by the Government of Greenland in heritage acts and executive orders (see below). NKA also reviews and approves mineral exploration, exploitation and other development activities with potential impacts on heritage sites and protected cultural landscapes. Additional information on the visions, missions and responsibilities of the NKA can be found on the museum's website: http://www.nka.gl.

The National Greenlandic Heritage Act (Anon. 2019a) defines heritage sites as: "ancient physical remains or traces of human activity in the past, and the context in which they are situated" (§ 2, stk. 2). It is a broad definition meant to ensure the protection of heritage sites that can be anything from a thin cultural layer or small scatter of lithic debris to extensive, multi-component sites with tens of features and ruins preserved, in rare instances almost to original height. Heritage sites from the various cultures to Greenland are found all over the country, from the coastal archipelagos to the edge of the Ice Cap. Some 5,686 heritage sites are presently registered in the Greenland National Museum and Archives' online heritage site inventory: nunniffiit.natmus.gl.

This heritage site inventory has been built up over more than 200 years and, as a consequence, site information and data quality vary greatly. Some heritage sites are described in detail and mapped with precision (less than 20%), while others may only be registered with a place name. Also, the accuracy of heritage site positions varies greatly as most were recorded prior to the development of accurate maps or GPS-technology. Only heritage sites marked with a GPS-symbol in nunniffiit.natmus.gl are considered geographically fixed. Different numbering systems for heritage sites in Greenland have existed over the years. Today, all heritage sites are officially designated 'NKAH' (Nunatta Katersugaasivia Allagaateqarfialu Heritage) and added a unique ID number from 0001 to infinity.

The heritage sites registered in nunniffiit.natmus.gl only represent part of the sites actually found in the landscape. Large parts of Greenland have only been archaeologically surveyed to a small extent, or not at all. Thus, the 5,686 heritage sites presently registered may constitute as little as 1/10 of the heritage sites really found in the landscape. However, all heritage sites and features—whether currently registered or not, and irrespective of their documentation level—are protected under the national Greenlandic heritage legislation.

6.2 National Greenlandic heritage legislation summarised

A unique aspect of the Greenlandic heritage sites is that they are often still preserved and visible on the surface, while cool and dry environmental conditions have ensured the preservation of rare organic artifacts such as, e.g., feather, fur, wood, hair, including mummified human and animal remains. While this heritage preservation is beneficial to the population, archaeologists, scientists, tourists etc., the unique preservation also makes most Greenlandic heritage sites, and their surrounding Arctic vegetation, extremely sensitive to disturbance.

The National Greenlandic Heritage Act (Anon. 2019a) serves to automatically protect all built environments and physical remains from the past, while the National Greenlandic Museum Act (Anon. 2019b) stipulates that cultural artifacts and ecofacts ('kulturlevn' in the National Museum Act) must not be disturbed or removed (§ 28, stk. 2). Any find of such artifacts or ecofacts should instead be reported to the NKA or nearest local museum. Natural heritage objects ('naturlevn' in the National Museum Act) —such as fossil and subfossil botanical or zoological remains, including the layers in which they are found, and meteorites—are also protected under the National Museum Act (Inatsisartutlov nr. 4 af 12. juni 2019) as well as under the National Nature Act (Anon. 2003).

Special heritage legislation exits for several protected areas in Greenland. Generally, there are two types of heritage area protection: protected heritage areas and other heritage protection ('fredning' and 'anden kulturarvsbeskyttelse', respectively, in the National Greenlandic Heritage

Act). Protected heritage areas are the most regulated and, generally, no activities other than providing access to heritage features are allowed. In areas under other heritage protection, certain activities can be allowed if they comply with the stipulations of specified heritage legislation (executive orders, Anon. 2016, 2018).

Specified regulations for the National Park in Northeast Greenland are written directly into the National Greenlandic Heritage Act, while heritage regulations for other protected areas are defined in a series of executive orders (Anon. 1937, 1950, 1954, 1971, 1989, 2005, 2007, 2008, 2010, 2016, 2018). Several areas in Greenland are protected to safeguard combined natural and cultural heritage values. Specific regulations for such protected areas are laid down in individual executive orders.

The main protective regulations laid down in the National Greenlandic Heritage Act can be summarised as follows:

- All physical, ancient remains ('fortidsminder' in the National Greenlandic Heritage Act)—e.g., ruins, settlements, graves, cairns, traps, cultural layers etc.—predating 1900 CE are automatically protected, including all associated artifacts and ecofacts. All graves, regardless of age, are protected. In the National Park in Northeast Greenland, all cairns are protected regardless of their age, and no man-made objects, regardless of their age, can be disturbed or removed from the park without prior approval by the NKA. The same applies to man-made objects of Greenlandic origin and predating 1945 in the rest of the country.
- All singular physical, ancient remains and heritage features are protected by two buffer zones: within 2 m of individual, ancient remains/features no activity can take place; within 20 m of individual ancient remains/features only public access to or information about the site/feature may be established (signposts, paths, site/feature demarcation etc.). In the National Park in Northeast Greenland, the buffer zones are 2 m and 100 m, respectively.
- Any type of exploration and development activity—whether public or private—in the open land must be informed and reviewed by the NKA through established, formal hearing processes. Depending on the heritage values and development plans, the NKA can require, or the developer can ask for, a prior archaeological survey ('arkæologisk besigtigelse' in the National Greenlandic Heritage Act § 11) to establish what heritage values and concerns exist within an area. Subsequently, the NKA can require, or the developer can ask for, an archaeological investigation ('arkæologisk undersøgelse' in the National Greenlandic Heritage Act § 12) of heritage sites/features in the area impacted by development, after which any bands on activities may be lifted.
- All activities planned for areas under any type of special, existing heritage protection must priorly be reviewed by the NKA in accordance with executive order nr. 38 of 1 October 2020 (Anon. 2020). Depending on NKA's preliminary assessment of the impact of a planned activity on the specific and defined heritage attributes, any developer may subsequently be required to carry out a complete heritage impact assessment ('kulturarvsvurdering' in the executive order nr. 38 of 1 October 2020). All expenses incurred on the NKA and Government of Greenland in connection with upholding the heritage management laid down by national heritage acts and executive orders must be paid by a developer or contractor after a pre-agreed budget (National Greenlandic Heritage Act § 14).

Based on long experience with both public and private developers, early and direct dialogue with the NKA regarding development or exploration activities and projects can significantly minimise the chance of running into any heritage issues and decrease any related economic expenses.

6.3 Heritage zones

This section provides a map-based overview of heritage sites and values defined in three zones and site density maps in South Greenland. These maps provide a desk-based tool for assessing heritage values and potential management concerns in and around license and activity areas. The character and uncertainties of the existing available heritage site information and data (see above) present a great challenge in terms of geographically fixing and delineating areas with and without heritage values. The zoning and visualisation of heritage values adopted here are designed to be:

Robust: i.e., reflect the actual heritage evidence currently registered in [NUNNIFFIIT (nunagis.gl)](nunagis.gl)

Applicable: i.e., presented and visualised in a way that corresponds to how the NKA practicably is likely to approach development and exploration activities in the various heritage zones in terms of existing heritage legislation.

Reproducible: i.e., can be extended to all parts of Greenland regardless of varying data quality and without compromising heritage management concerns.

Zone 1: Protected Heritage Areas

Definition: *Geographically defined heritage areas with legal protection laid down and specified in existing national heritage acts or executive orders.*

Expected heritage management action: No exploration, exploitation or development activity will be allowed in protected heritage areas (zone 1, Figure 6.2), and any planned activity must be assessed and permitted through a rigorous hearing process involving the executive order no.. 38 of 1 October 2020 (Anon. 2020) and approval by both the NKA and the National Heritage Committee ('Kulturarvsrådet' in the National Greenlandic Heritage Act).

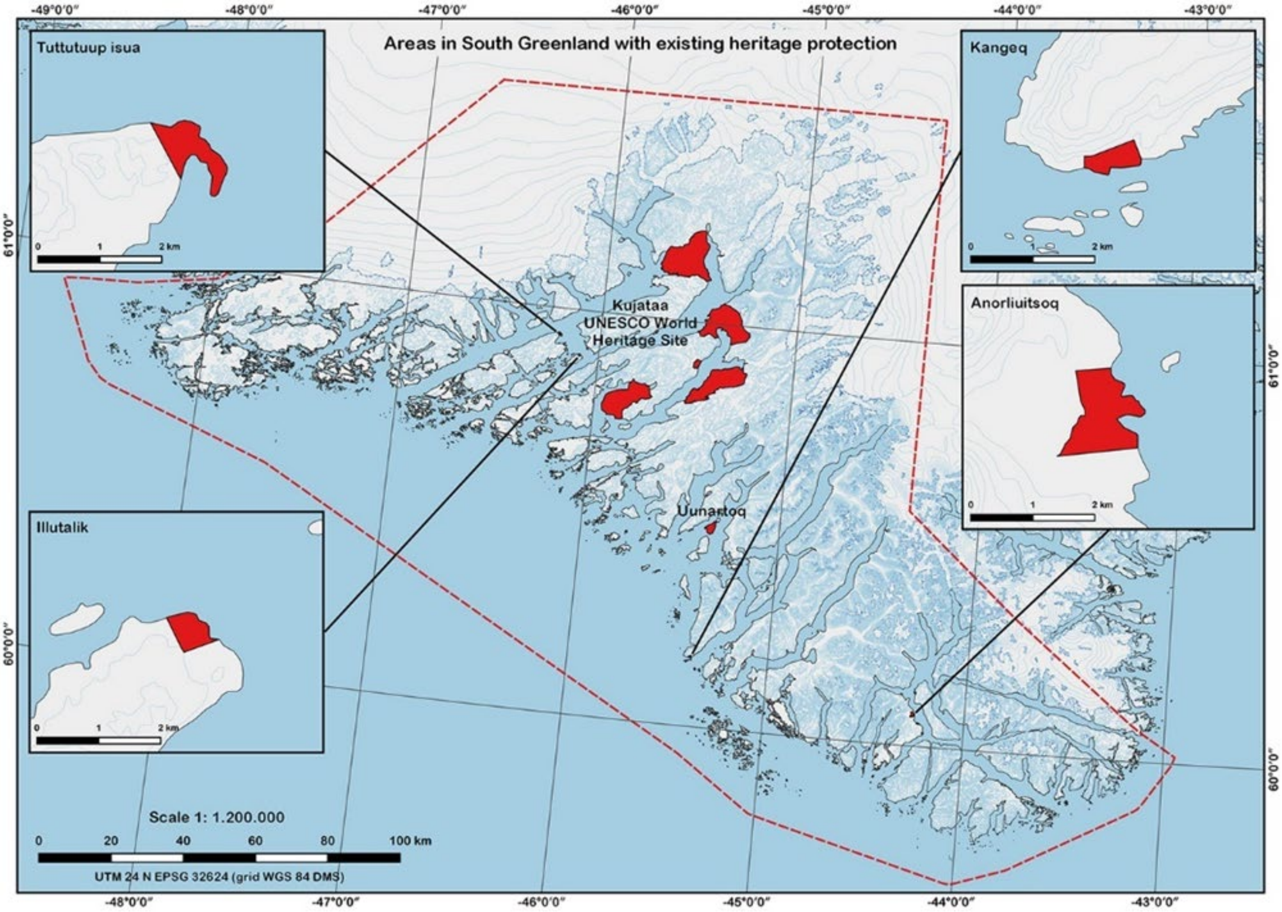


Figure 6.2. Map showing the currently most protected heritage areas in South Greenland (zone 1 protection).

Zone 2: Sensitive heritage areas

Definition: *Heritage areas that include rare, sensitive and/or nationally important heritage site(s), including areas that are scheduled for future heritage protection.*

Expected heritage management action: While exploration, exploitation or development activities are not de facto excluded in sensitive heritage areas (zone 2, Figure 6.3), the NKA will normally advise developers against disturbing such areas. Especially in those scheduled for future heritage protection or define no-go zones to either be totally avoided or completely archaeologically investigated, prior to the onset of any exploration or development activity.

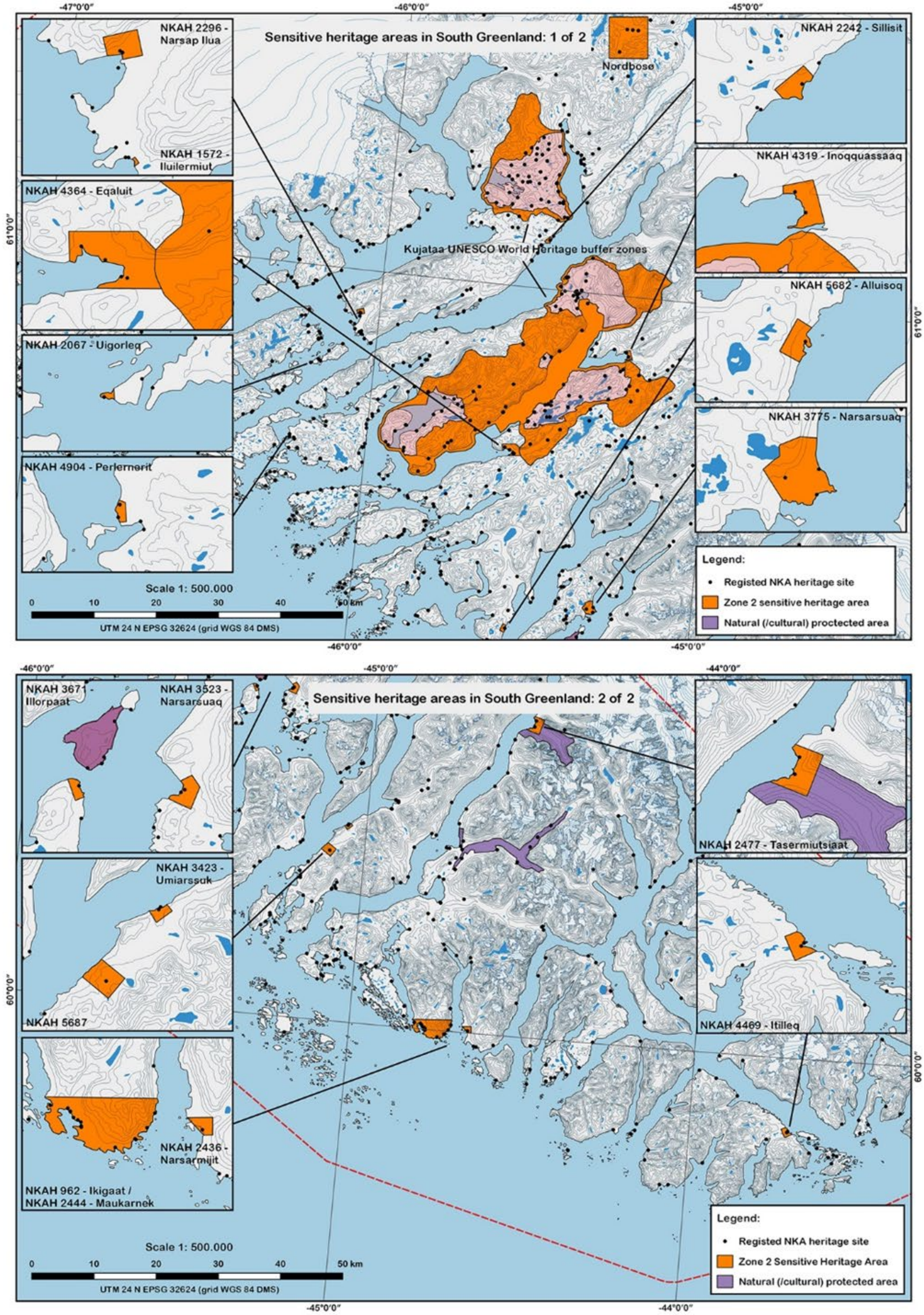


Figure 6.3. Map showing currently defined sensitive heritage areas in South Greenland (zone 3).

Zone 3: Heritage site buffer zones

Definition: *A buffer zone of 500 m diameter—250 m radius from each central heritage site point in nunniffiit.natmus.gl—inside which ca. > 80% of the site's heritage features are expectedly located.*

Expected heritage management action: In the current version of nunniffiit.natmus.gl, all heritage sites are mapped as point data due to the varying documentation quality (see above). However, most sites consist of several (up to tens of) separate heritage features ('fortidsminder' in the National Greenlandic Heritage Act), each protected by the 2 m and 20 m (100 m in the Northeast Greenland National Park) buffer zones described above. Thus, heritage sites effectively consist of several protected zones, often with interlaying unprotected corridors. Clearly, it is extremely difficult and risky to carry out exploration, exploitation and development activities that navigate through these corridors without transgressing the legislated protective zones. NKA therefore considers a polygon of 500 m diameter—250 m radius from each heritage point in nunniffiit.natmus.gl—a heritage site buffer zone (zone 3), within which exploration, exploitation and development activities are not advised or, at a minimum, can only be carried out once heritage features have been accurately mapped.

6.4 Heritage site density maps

Figure 6.3 shows the density of registered heritage sites within a 5 km hexagon grid in South Greenland. The heritage site density mostly reveals archaeological survey intensity but also to some extent actual past settlement intensity. Thus, the heritage site density map provides some indication of what heritage management action is required by the NKA prior to carrying out activities in zones of varying site density:

- < 4 heritage sites: The area is most likely little investigated or not at all, and the existing heritage inventory is based on older interview information and random reporting of sites. The NKA will likely require a full archaeological survey ('a*rkæologisk besigtigelse*' in the National Greenlandic Heritage Act) prior to exploration or development activities. Identified sites may require subsequent complete or partial archaeological investigation ('*arkæologisk undersøgelse*' in the National Greenlandic Heritage Act).
- 5-8 heritage sites: The area is most likely moderately investigated, and the existing heritage inventory is based on a combination of both older and recent, systematic heritage site registrations. Depending on the exact situation and the available heritage information, the archaeological surveys required by the NKA in these areas may be more targeted or, in some instances, mainly aimed at producing more accurate, digital site inventories and maps. Heritage sites may require subsequent complete or partial archaeological investigation ('a*rkæologisk undersøgelse*' in the National Greenlandic Heritage Act).
- > 9 heritage sites: The area is most likely well investigated, and the existing heritage inventory is a fairly detailed combination of both older and recent, systematic heritage site registrations. The area was also densely populated and used in the past. The need for archaeological surveys required by the NKA in these areas will be more limited and mainly be aimed at producing accurate, digital site inventories and maps, if they do not already exist. Heritage sites may require subsequent complete or partial archaeological

investigation ('a*rkæologisk undersøgelse*' in the National Greenlandic Heritage Act).

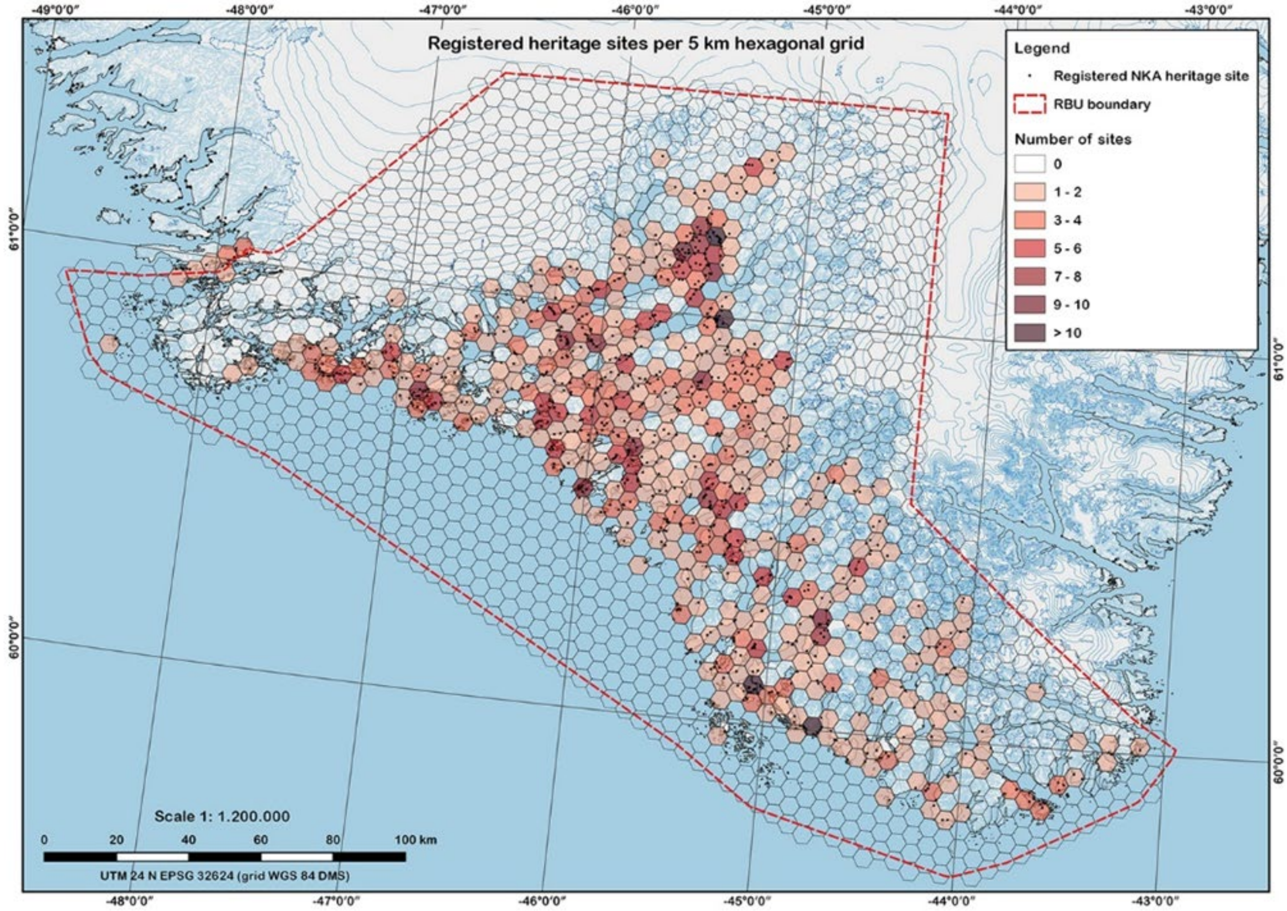


Figure 6.4. Map showing the density of currently recorded heritage sites within 5 km diameter hexagons.

6.5 Heritage site location predictive landscape features

Some 90% of the heritage sites are located right on the coast to a fjord or open ocean, a clear result and evidence of the continued dependence of marine resources and routeways among all the cultures to inhabit Greenland in the past. While heritage sites in Greenland may be found almost everywhere, particular landscape types and features are predictively more likely than others to produce new, unregistered sites—especially larger camps or settlements. Landscape features that normally receive heightened attention during archaeological surveys, and should do so also during exploration and development activities because of their increased probability for producing heritage sites/features, can be found in Table 6.1.

Table 6.1. List of landscape features that normally receive heightened attention during archaeological surveys. Note that this list of landscape features is not exhaustive or prioritised.

Landscape feature
Coast/fjord near sheltered bays and inlets
Landscape bottlenecks (isthmuses, gorges etc.)
River mouths
River fords/crossings
Southern facing, grassy slopes
Promontories/headlands
Distinctive landmarks (hills, peaks etc.)
Gravelly beach terraces
Expedient landscape routes
Mountain passes
Vantage points
Valley floors with freshwater access
Geological resource concentration (steatite, calcedony, schist, sandstone etc.)
Natural resource concentration (nesting cliff, grazing areas, migratory bottlenecks etc.)

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Anon. 2019a. Inatsisartutlov nr. 5 af 12. juni 2019 om ændring af Inatsisartutlov om fredning og anden kulturarvsbeskyttelse af kulturminder (Skærpede beskyttelsesregler for Nationalparken i Nord- og Østgrønland, præcisering af regler om vedligeholdelse og restaurering af bygninger og vurdering af aktiviteters virkning på kulturarven i kulturhistoriske områder): http://lovgivning.gl/da-DK/Lov?rid={1D78601F-9F4D-4C33-9550-0C393BF397CE}.

Anon. 2019b. Inatsisartutlov nr. 4 af 12. juni 2019 om ændring af Inatsisartutlov om museumsvæsen (Skærpede udførselsregler for Nationalparken i Nord- og Østgrønland samt bestemmelser om Museumsnævnets sammensætning, funktionsperiode og vederlæggelse): http://lovgivning.gl/da-DK/Lov?rid={44AAE914-29CD-4856-9AC6-696B5796630E}.

Anon. 2020. Selvstyrets bekendtgørelse nr. 38 af 1. oktober 2020 om vurdering af aktiviteters virkning på kulturarven i kulturhistoriske områder: http://lovgivning.gl/lov?rid={37F8DA99-95FE-44FA-B801-EAEAAE670E6B}.

7 Integrated spatial analysis of overlapping interests

By Kasper Lambert Johansen[1], Karl Zinglersen[2], Katrine Raundrup[2] and Anders Mosbech[1]

[1]Department of Ecoscience, Aarhus University, [2]Greenland Institute of Natural Resources

7.1 Introduction

In chapters 4-6, a number of maps have been presented, highlighting known distribution areas of important flora and fauna, human use of the region and concentrations of cultural heritage sites. All these features – be it a seabird colony, a tourist trekking route or an archaeological site – may be regarded as landscape assets or interests that should be taken into account when planning mineral resource exploration or extraction activities.

In this chapter, we provide a summary analysis of how many of these landscape assets overlap in different parts of the area of interest (AOI). It is important to stress that the analysis involves no extrapolation or prediction of occurrences. It simply summarises what is presently known and presented in the report. This means that areas with few overlaps may be the result of lack of knowledge rather than lack of presence (see Chapter 9). It is also important to stress that the different landscape assets included in the analysis may be affected very differently by, e.g., mining activities (see Chapter 8).

The summary analysis was performed as a so-called GIS overlay analysis using custom-made Python scripts in ArcGIS Pro 2.8.0. In principle, the different map layers presented in chapters 4-6 were simply stacked on top of each other, and for each 250x250 m cell in a grid system covering the entire AOI, the number of map layers with features present in the cell were counted. Thus, a resulting cell value of, e.g., 3 indicates that one or more features were present at the centre of the cell in three different map layers.

In total, 51 map layers were included in the analysis (Table 7.1). As features need to cover an area to overlap and count in the overlay calculation, point and polyline features were buffered, effectively turning them into polygons with an area (see “Geometry” in Table 7.1). The buffer radii used were in many cases determined by legislative regulation, e.g., protection zones around seabird colonies, in other cases by the degree of spatial uncertainty associated with data or real-world sizes of features (see “Buffer radius (m)” in Table 7.1). Some features were also buffered in accordance with a perceived zone of influence: when conducting activities within this distance, the feature needs to be considered (see Chapter 8). Especially when buffering features, it becomes relevant to make sure that they are constrained to their right element. e.g., that red-listed plant observations do not count in cells at sea, although these cells fall within the buffer zone of an observation. Thus, each input layer was constrained to count only in cells of the type specified in the column “Habitat” in Table 7.1.

Table 7.1. Map layers included in the overlay analysis in Figure 7.1. The contents of the columns are explained in Section 7.2. Besides the analysis including all 51 layers listed, two sub-analyses were run, one including mainly biologically relevant layers (see column "Biology" and Figure 7.2) and one including layers mainly reflecting human use/cultural heritage (see column "Human use" and Figure 7.3). The habitat type "Ice free land" refers to terrestrial areas not covered by inland ice.

Name	Geometry	Buffer radius (m)	Habitat	Sub-analysis	
				Biology	Human use
Aesop prawn fishery areas	Polygons	0	Sea	1	1
Agricultural settlements	Polygons	0	Ice free land		1
Arctic char freshwater catchments	Polygons	400	Ice free land	1	
Arctic char river mouths	Points	1000	Sea	1	1
Arctic tern colonies	Points	500	Land and sea	1	
Atlantic cod fishery areas	Polygons	0	Sea	1	1
Atlantic puffin colonies	Points	500	Land and sea	1	
Bird protection areas	Polygons	0	Land and sea	1	
Black-legged kittiwake colonies	Points	1000	Land and sea	1	
Capelin subsistence fishery	Polylines	500	Sea	1	1
Common eider colonies	Points	500	Land and sea	1	
Common eider wintering areas	Polygons	0	Sea	1	
Common murre colonies	Points	1000	Land and sea	1	
Cultural herritage sites	Points	500	Land		1
Development zones	Polygons	0	Land		1
Drinking water barrier zones	Polygons	0	Land		1
Driving zones for powerlines	Polygons	177	Land		1
Fertile vegetation (NDVI>=0.5)	Polygons	0	Ice free land	1	
Fields	Polygons	0	Ice free land		1
Grazing regions	Polygons	0	Ice free land		1
Greenland halibut fishery areas	Polygons	0	Sea	1	1
Harbour seal concentration area	Polygons	0	Sea	1	
Harbour seal haul-out site	Polygons	0	Land	1	
Harlequin duck sightings	Points	1000	Sea	1	
Homothermic springs 100 m zone	Polygons	400	Land and sea	1	
Lumpsucker roe fishery	Polygons	0	Sea	1	1
Lumpsucker subsistence fishery	Polylines	500	Sea	1	1
Muskox herding areas	Polygons	0	Ice free land		1
Nature protection areas	Polygons	0	Land	1	
Northern fulmar colonies	Points	1000	Land and sea	1	
Northern shrimp fishery areas	Polygons	0	Sea	1	1
Oil spill sensitive shorelines	Polylines	500	Land and sea	1	1
Planning zones	Polygons	0	Land		1
Plantations	Points	1000	Ice free land		1
Populated areas	Polygons	0	Ice free land		1
Ramsar areas	Polygons	0	Land and sea	1	
Razorbill colonies	Points	1000	Land and sea	1	
Redfish fishery areas	Polygons	0	Sea	1	1
Red-listed plants, possible area	Polygons	0	Land	1	
Reindeer herding areas	Polygons	0	Ice free land		1
Roads (existing/planned)	Polygons	177	Land		1
Salt or saline lakes 100 m zone	Polygons	400	Land and sea	1	
Snow crab fishery areas	Polygons	0	Sea	1	1
Snow mobile driving zones	Polygons	177	Land		1
Sub-Arctic climate zone	Polygons	0	Ice free land	1	
Thick-billed murre colonies	Points	3000	Land and sea	1	
Tourism areas	Polygons	0	Land and sea		1
Trekking routes	Polylines	500	Land		1
UNESCO areas	Polygons	0	Land		1
White-tailed eagle nesting sites	Points	1000	Land and sea	1	
Wolffish fishery areas	Polygons	0	Sea	1	1

7.2 Results of the integrated spatial analyses

Three different analyses were conducted – one including all 51 map layers, reflecting both flora and fauna, human use and cultural heritage (Figure 7.1 and 7.2), one including 34 map layers with mainly biologically relevant information (Figure 7.3) and one based on 29 map layers with information primarily reflecting human use and cultural heritage interests (Figure 7.4).

The areas in the inner parts of Tunulliarfik (north of Narsarsuaq towards Qinngua and on the opposite side of the fjord at Qassiarsuk), areas around Igaliku and to some extent Igaliku Kujalleq are all areas with multiple overlapping layers of biological, cultural heritage as well as human use features (Figures 7.1 - 7.4). On land, these are areas with multiple human uses, including towns (Narsaq and Qaqortoq and, to a lesser degree, the areas around Nanortalik), settlements and grazing areas for sheep farms as well as cultural heritage hotspots. Along the coasts, they represent overlapping fishing grounds as well as seabird colonies.

The group of islands at Ydre Kitsissut is an important nesting area for different seabird species and is thus highlighted through overlap of many biological layers in Figure 7.3.

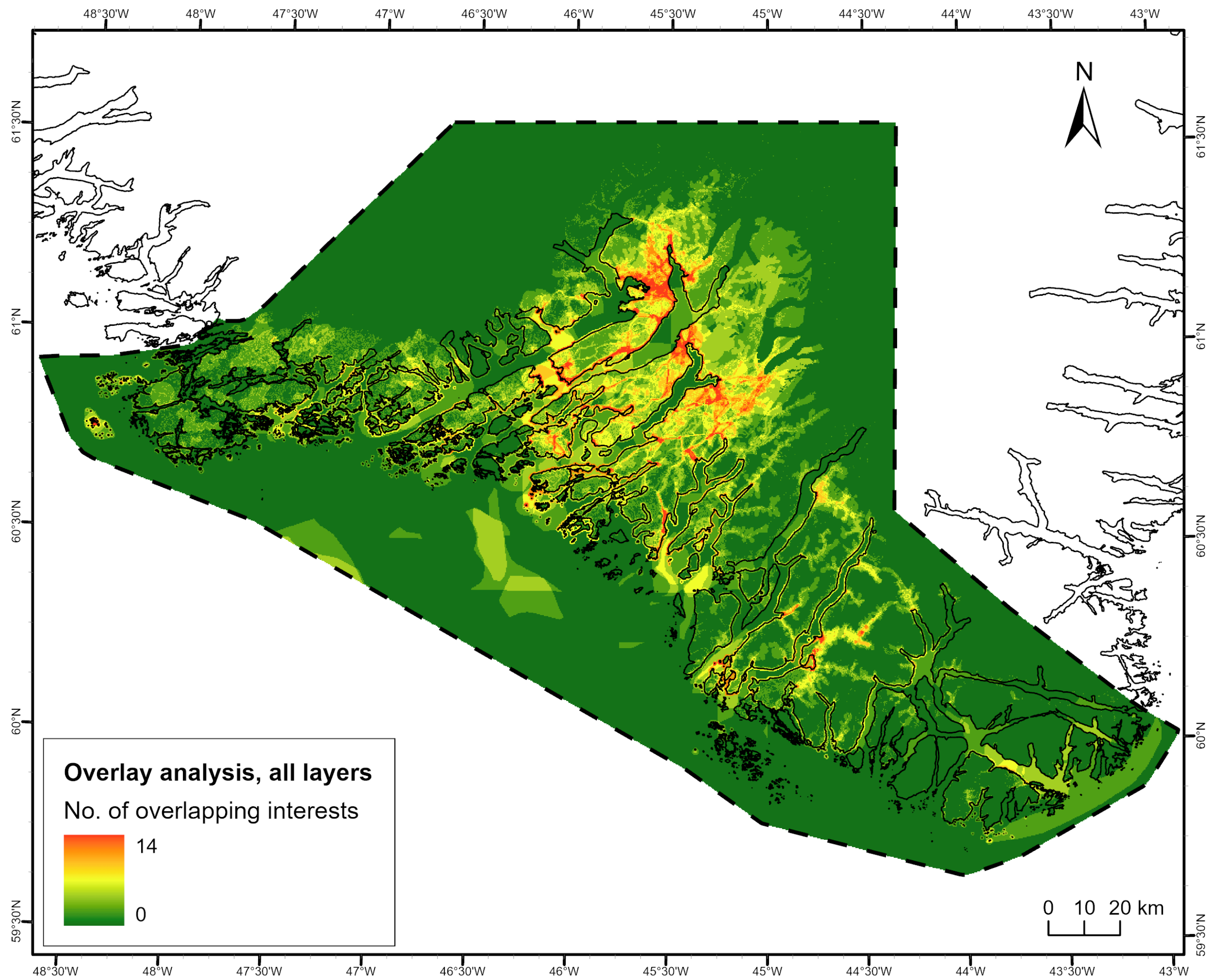

Figure 7.1. Result of overlay analysis of all 51 map layers listed in Table 7.1, spanning flora and fauna, human use and cultural heritage interests. The maximum cell values are 14, reflecting that in these cells features from 14 different map layers overlap.

A large number of overlaps in an area do not necessarily mean that mineral resource activities will have a high environmental impact here. They do, however, emphasise that, given our present knowledge, several different interests need to be addressed in relation to mineral extraction operations. In the following section, the potential pollution and generic impacts on the biodiversity of mineral exploration and exploitation are summarised.

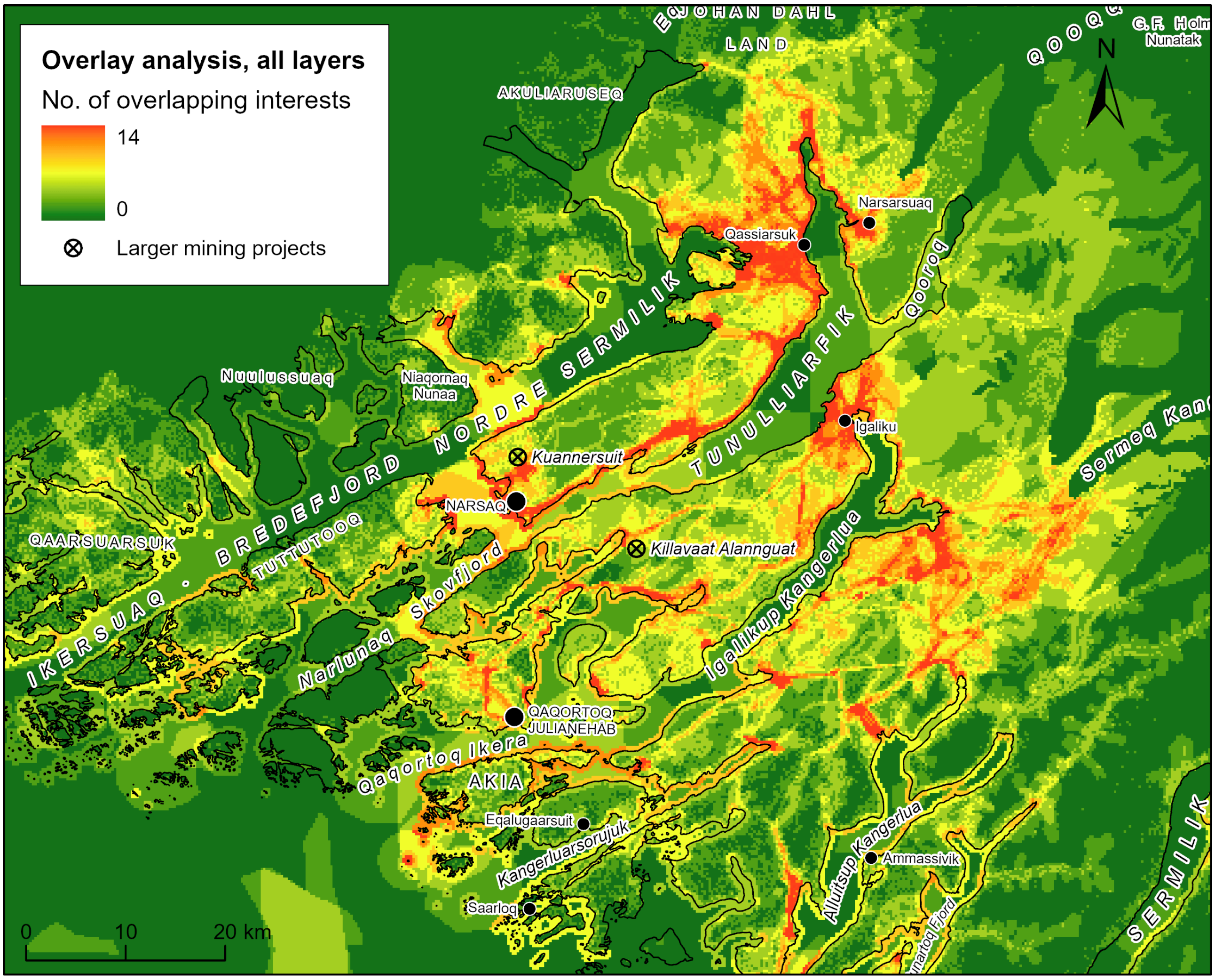

Figure 7.2. Same overlay analysis result as in Figure 7.1, only this time zoomed in on the area where most landscape interests overlap. Towns and villages are indicated with black dots, and sites of larger mining projects are also shown.

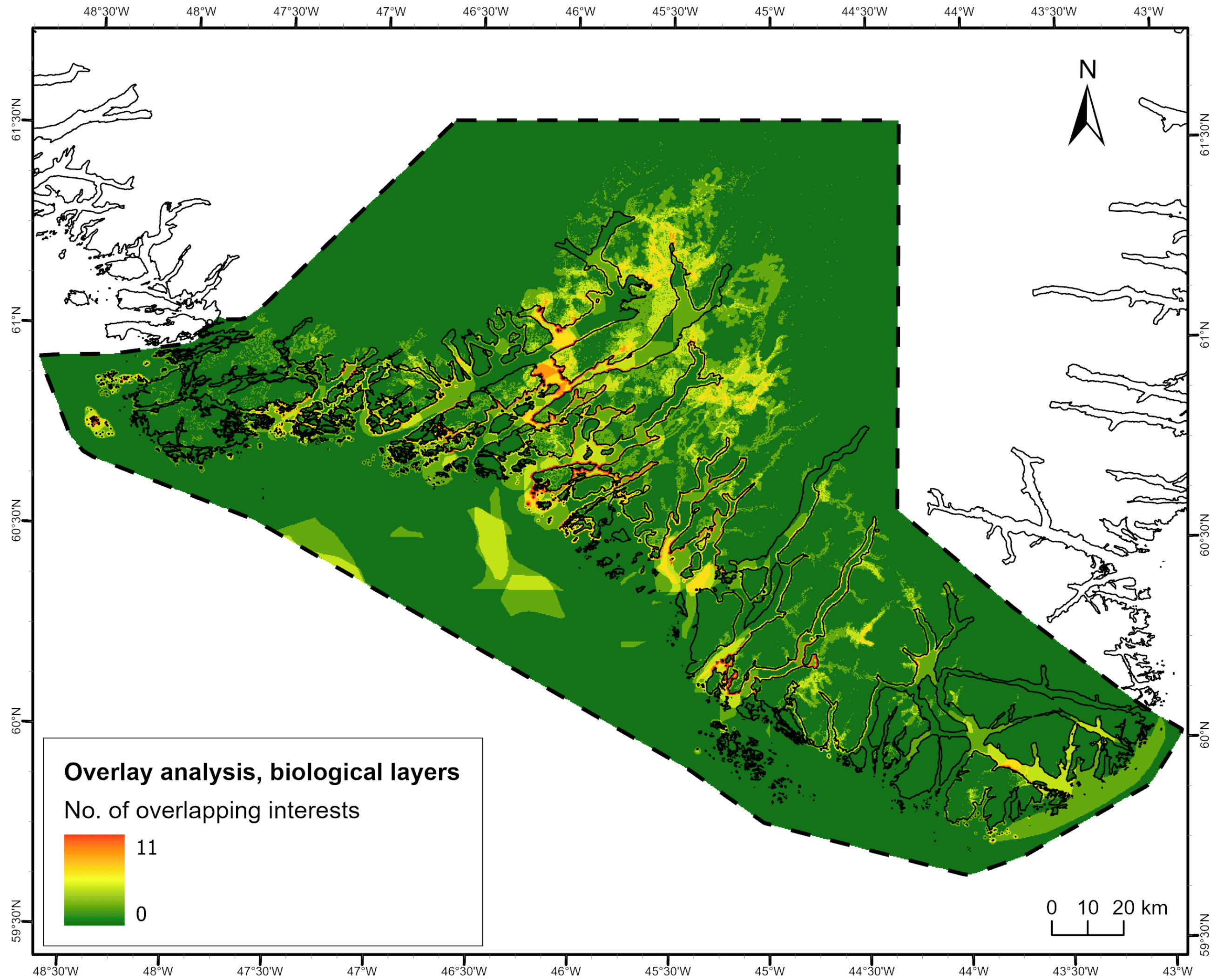

Figure 7.3. Result of overlay analysis of 34 map layers with mainly biologically relevant information (see column "Sub-analysis, biology" in Table 7.1 for included map layers).

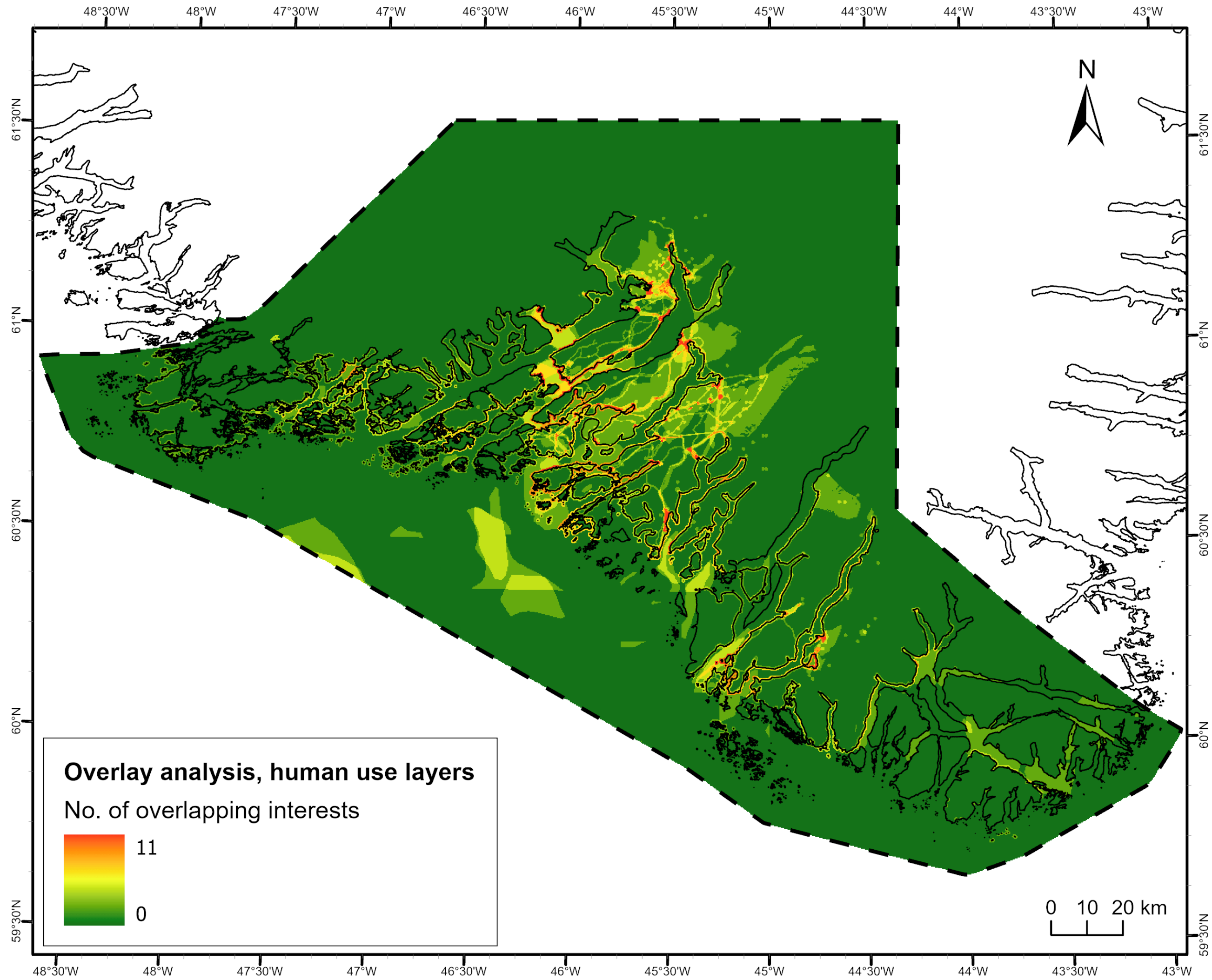

Figure 7.4. Result of overlay analysis of 29 map layers with mainly human use and cultural heritage relevant information (see column "Sub-analysis, human use" in Table 7.1 for included map layers).

8 Mining and environmental impacts

By Anders Mosbech[1], David Boertmann[1], Kim Gustavson[1], Christian Juncher Jørgensen[1] and Janne Fritt-Rasmussen[1]

[1]Department of Ecoscience, Aarhus University

8.1 Environmental impacts from mining activities

In this chapter, we give an overview of the typical environmental impacts that can be expected from modern mines operated according to high international environmental standards. It should, however, be kept in mind that mineral projects are diverse and so are the potential environmental impacts.

The last section in this chapter describes potential environmental impacts from accidents.

Exploration is the first phase of the mining activities and includes search for exploitable minerals by various methods. Typically, small teams of geologists, transported by helicopters, boats, ATV's etc., search the terrain using different geophysical methods and take samples by hand or handheld equipment. These activities are regulated by the "field rules" (see Appendix 3 for more details). The main environmental impacts of such activities are often limited to local disturbances of wildlife with expected short-term effects and damage to the vegetation when using ATV's and other vehicles. There may also be risks of minor spills of drilling additives and fuel.

Later in the exploration phase, the activities focus on delimitation of the ore and on assessing the concentration of commercial minerals at a potential mine site. Establishment of infrastructure, buildings, roads, airstrips etc. may follow. The environmental focus should be on minimising the potential long-term impacts from such activities. Environmental impacts from the later exploration stage may include disturbance of wildlife, habitat loss because of infrastructure and emissions to the surroundings, including generated dust and waste/wastewater from the camp facilities and the exploration activities. If a mine is established, the largest environmental challenge to handle in a safe manner is the deposition of mining waste and tailings, from which harmful substances otherwise may leach into the environment. If the mine is constructed as an open pit mine, land areas will be excavated with impacts on the physical environment (see Figure 8.1). Such impacts will be more restricted for underground mines. The infrastructure will be enlarged, with facilities for ore processing and harbour facilities for overseas shipment of concentrate. To avoid pollution, the concentration processes should be carefully handled, especially if chemical processes are applied. The energy consumption will typically be large and based on oil unless hydropower is established.

Finally, when the mine closes, the mine site will be rehabilitated to a state that with time should resemble pre-mining conditions.
In the following, the different potential impacts and environmental effects of mining activities are reviewed, and we provide examples of the geographical extent and duration of the effects that can be expected from a typical modern mining operation.

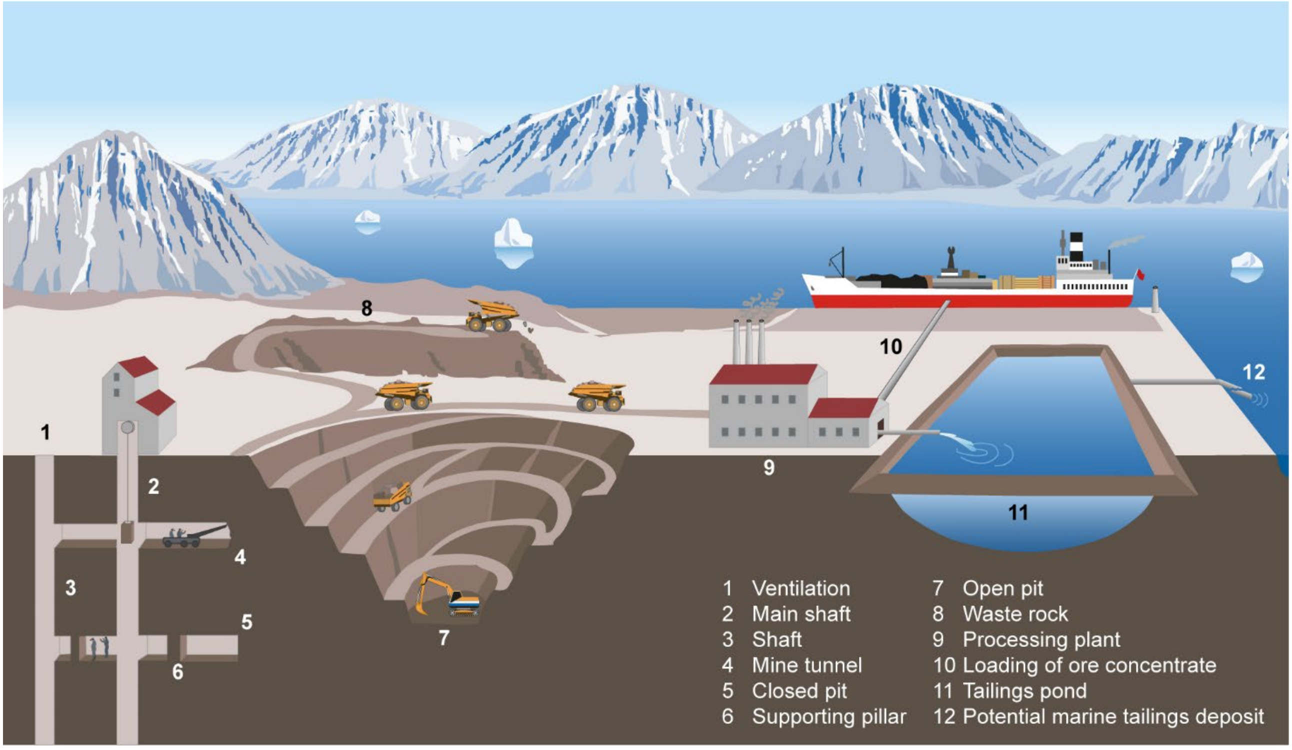

Figure 8.1. Overview of impacts from a mine site.

Definitions of terms used in the impact overview

The geographical extent of impacts can vary. Three overall levels are defined for the impact review:

- Local: Refers to the actual industrial project area and to the near surroundings up to a few kilometres.
- Regional: Refers to the region in which the mining-related activities take place, up to a few tenth of kilometres.
- Global: Refers to the entire world and is only relevant for the release of greenhouse gasses.

The duration of impacts and effects includes three levels:

- Short-term: Refers to a period of up to a few years.
- Long-term but temporary: Refers to a period longer than a few years and often decades, e.g., the lifetime of a mine, but effects are still potentially reversible.
- Permanent: Refers to a period where the effects are irreversible or expected to last more than 100 years.

The effects on habitats caused by impacts from the activities is defined in three levels:

- No significant reduction of habitat quality or ecological damage: An insignificant number of individuals of a population of animals or plants may be affected by reduced habitat quality or habitat loss. The level of pollutants is below the guideline values for good environmental quality but may be above background concentrations.
- Reduced habitat quality: The quality of a habitat is reduced by a given activity, e.g., dust, wastewater discharge or disturbance. The density of

specific animals or plants can be reduced. The level of pollutants can be above guideline values for good environmental quality or background concentrations, and biological effects may occur.
- Habitat loss: This is the process by which a natural habitat becomes incapable of supporting its native species so that the plants and animals previously inhabiting the site become displaced or die. This typically happens in the mining area itself due to excavations and construction of waste facilities, implying that the area typically needs to be rehabilitated when the mining activity ceases.

8.2 Disturbance of wildlife – noisy activities and presence of people and infrastructure

Noisy activities at a mine site include, e.g., blasting, mechanical processing of ore and all the machinery used at the site besides the presence of people and infrastructure. All these activities have the potential to disturb wildlife, i.e., birds and mammals, by displacement from their natural habitats and should be regulated carefully to reduce the impact. Disturbance of wildlife is usually a local impact, but in case of pipelines, roads and helicopter flying etc. the disturbance can be more widespread. If short-term and/or if alternative habitats are available, the effects will be reversible or insignificant, but long-term impacts could cause loss of feeding possibilities, calving grounds, moulting grounds etc. Some animals such as caribou will also avoid infrastructure at a certain distance, contributing to reducing their available habitat. A few species such as polar foxes, polar bears and ravens may be attracted to a mine site because of easily available food in form of garbage, and this may increase their predation pressure on prey species near a mine site.

Disturbance of wildlife is reduced by concentrating infrastructure near the mine facilities, by careful planning the construction of roads to avoid habitats critical to specific populations and by directing helicopter flying to defined traffic lanes and sufficiently high altitudes in order to minimise the affected areas. Moreover, off-road activities, including people on foot, should be restricted and only allowed along predefined tracks. Some animals, e.g., geese, may habituate to disturbance if the disturbing activities are carried out in a predictable way.

Wildlife may recognise people as predators (hunters) and try to avoid them at long distances. Therefore, animals belonging to populations exposed to human hunting pressure are more shy and scared than animals from populations that are not hunted. This also apply to infrastructures that the animals relate to the presence of human beings.

In Table 8.1 the disturbance by noise is described for different noise types. More details about disturbances can be found in Frederiksen et al. (2017).

Table 8.1. Sources of disturbance by noise.

Type/stressor	Duration of impact	Geographical extent	Effect and effect level
Helicopters	Short-/long-term	Local/Few km along route	Reduced habitat quality for wildlife if disturbance is frequent
Helicopters are important means of transport during most of the phases of the development of a mine. Helicopters are very noisy and have the potential to scare wildlife such as moulting geese many km away, both locally and along the flight routes (regional). The effects can be mitigated, although not avoided, by establishing well-defined flight routes and flight altitudes.			
Fixed winged aircrafts	Short-/long-term	Local/Few km from airstrip	Reduced habitat quality for wildlife if disturbance is frequent
Fixed winged aircrafts will be used if airstrips are established at a mine site and occasionally also during exploration. They are noisy during take-off and landing, but their cruising altitude is usually too high to disturb wildlife. As fixed winged aircraft behaviour is predictable, some animals living near the airstrip may habituate to the noise.			
Blasting	Short-/long-term	Local/Few km	Reduced habitat quality for wildlife if disturbance is frequent
Blasting generates noise and, if frequent, possible loss of habitats. However, a few blastings might have short-term and local impacts.			
Other noisy processes	Short-/long-term	Local/Up to a few km	Reduced habitat quality for wildlife if disturbance is frequent
These activities take place at and near the mine site and will have local effects.			

8.3 Loss of habitats from constructions and buildings

Habitat losses occur when activities or infrastructure affect habitats physically so that the plants and animals living there can no longer use the habitat. The loss can be extremely localised, e.g., a building, or more extensive, e.g., the area where the mining pit is excavated. In addition, deposition sites for mining waste and tailings may occupy large areas, and in the case of tailings, lakes may be included as deposits. A dam across a river can obstruct the passage of Arctic char, and the flooding behind a dam may impact large terrestrial areas.

The hydrology of an area may be impacted by road construction, causing water logging or the opposite – drainage of wetland areas. Moreover, there is permafrost in many parts of Greenland, which may be impacted and destroyed (human-induced thermokarst) by establishment of different infrastructures.

In general, habitat loss from mining activities is local. However, if, e.g., a rare red-listed plant has its only occurrence at a mine site, the effect of the habitat loss is of national concern (National Responsibility species). While the habitat loss following mine establishment typically is local, the effects are often of long-term duration. Remediation after termination of the activities is therefore required to prevent permanent habitat loss. Full remediation of old mining areas to the pre-mining state is often difficult, but new habitats can be created.

The effects of mining constructions are best mitigated by including high quality background knowledge in the planning of all constructions and activities in the affected area to avoid the most valuable habitats. Such knowledge should be gained by background studies of the local ecology and natural history before initiating any activities.

Table 8.2 gives an overview of the most typical types of mining constructions related to mineral exploration and exploitation activities. Specific plans and regulations will be established as part of the prospecting licence and exploration licence and will include under which terms the constructions can take place. These regulations will follow the principles of the Best Available Technology (BAT) and Best Environmental Practice (BEP) to avoid unnecessary environmental impact on the surroundings.

Table 8.2. The impact of key mining infrastructure.

Type/stressor	Duration of impact	Geographical extent	Effect and effect level
Roads	Long-term	Local/regional	Habitat loss
Helipads and airstrips	Long-term	Local	Habitat loss
Harbour	Long-term	Local	Habitat loss
These examples of habitat loss caused by the building of new infrastructure are local and generally restricted to the area of the infrastructure itself. The ecological effects will mainly be at individual level, but habitat loss may be significant for the biodiversity of rare plants and vegetation types. Where new infrastructure changes currents or water runoff, some habitat change in a larger area may occur. Careful planning based on in-depth background knowledge can mitigate the effects.			
Buildings and other facilities	Long-term	Local	Individual
Buildings and other stationary facilities differ in size and number, but overall the impacts are local. Effects on especially rare plant species can be mitigated by careful planning of the construction to avoid habitats critical for specific populations.			
Mine pit	Permanent	Local	Habitat loss
Waste rock and tailings storage facilities	Permanent	Local	Habitat loss
Dams across streams and rivers	Long-term	Local/regional	Habitat loss/Reduced habitat quality
A mine pit, waste rock and tailings deposits are permanent and will result in destruction of habitats in the area that they cover. After mine closure, the area may be rehabilitated; however, in general not to the state of the original habitat. A dam can be removed, but if the population of Arctic char is gone, immediate recovery is not likely. Restocking may be a possibility.			

8.4 Pollution from mining activities

There are multiple possible sources of pollution from mining activities, which should be carefully regulated and mitigated to avoid unacceptable impacts on the environment. Potential sources of pollution include deposition of mining waste and tailings, the processes used for concentration of the ore, dust generation, sewage from camps (grey and black wastewater) etc. The recipients are the atmosphere (airborne emissions), the waterbodies near the mining site (sewage, leaching from tailings and waste rock, discharges from mining processes) and the terrestrial environment (dust, waste rock, tailings). The pollution and its effects should be reduced to acceptable levels by regulation and monitoring.

Discharges to water bodies – water pollution

Discharges to waters bodies include, e.g., effluents from mining waste and tailings, tailings depositions, wastewater from processing activities and wastewater (sewage) from camp facilities etc.

Treatment of wastewater from mine sites is typically needed to achieve sufficiently low levels of contaminants before the wastewater can be discharged to the environment. Several techniques exist to treat the different kinds of wastewater from mining activities and may include biological filtration and/or chemical precipitation of pollutants.

Discharges of water from processing activities can also be a source of pollution, and the water should be properly treated to avoid release of heavy metals, other non-degradable contaminants and toxic substances as well as chemicals used in the concentration processes to the environment. Radionuclides may also be a concern if such occur in the ore.

Wastewater from the mining processes may also contain slurry and other fine particles that may accumulate on the seabed or the lake bottom near the discharge site and possibly lead to habitat loss where local benthic fauna can be covered by the accumulating sediments. There is also risk of resuspension of fine particles and hence further spreading.

Sewage from camps may cause local eutrophication and be the source of different toxic as well as pharmaceutical contaminants. Sewage can be treated and discharged with acceptable concentrations of polluting substances.

In Table 8.3 and 8.4, examples of the sources to water pollution are given.

Table 8.3. Discharges of particulate matter and sediment from mining activities to water bodies.

Type/stressor	Duration of impact	Geographical extent	Effects and effect level
Discharge to lakes	Lifespan of mine	Local*, < 1 km according to guideline value restrictions	Reduced habitat quality
Discharge to rivers	Lifespan of mine	Regional downstream	Reduced habitat quality
Discharge to the sea	Lifespan of mine	Local*, < 1 km according to guideline value restrictions	Reduced habitat quality

Discharges from a mine include, e.g., effluents from mining waste and tailings, tailings deposition etc. Long-term impacts exceeding the lifetime of a mine are found if discharged sediments accumulate and contaminants in the sediments are not adequately removed, elements of concern constituting a particular risk, e.g., process chemicals, metals, radionuclides and nutrients. There is also a risk of resuspension and subsequent downstream spreading of particles. If discharge concentrations are below the guideline values, the effects are of short-term duration when the discharge stops. Guideline value restrictions on discharges ensure that there will be no significant effect outside a buffer/mixing zone of typically less than 1 km.

*) However, if runoff from lakes occurs, the extent might be regional downstream of the recipient. Further, the geographical extent depends on the particle size of the discharged particulate matter/sediment, wind, waves etc. Reduced habitat quality is expected as increased turbidity, reduced algae growth and increased sedimentation cause physical/chemical stress to pelagic and benthic organisms. Potentially, bioaccumulation and toxic effects of chemicals and metals on algae, crustaceans, fish, birds etc. may occur if discharges are not properly regulated and monitored. Note that special focus should be directed at the possible generation of acid mine drainage if the material contains reactive sulphides.

Table 8.4. Discharges of wastewater from mining activities to water bodies

Type/stressor	Duration of impact	Geographical extend	Effects and effect level
Discharge to lakes	Lifespan of mine	Local*, < 1 km according to guideline value restrictions	Reduced habitat quality
Discharge to rivers	Lifespan of mine	Local*, < 1 km according to guideline value restrictions	Reduced habitat quality
Discharges to the sea	Lifespan of mine	Local*, < 1 km according to guideline value restrictions	Reduced habitat quality
Wastewater discharge from a mine includes, e.g., effluents from mining waste and tailings, wastewater from processing activities etc. Long-term impacts are seen if dilution is insufficient or the wastewater contains critical levels of elements of concern, e.g., process chemicals, metals, radionuclides and nutrients. If discharge concentrations are below the guideline values, effects are of short-term duration when the discharge stops. Guideline value restrictions ensure that there will be no significant effect outside a buffer/mixing zone of typically less than 1 km. *) However, if runoff from lakes occurs, the effect might extend downstream of the recipient. Further, the geographical extent depends on the mixing/dilution capacity of the recipient. Reduced habitat quality is expected. This includes bioaccumulation and toxic effects of chemicals and metals on algae, crustaceans, fish, birds etc. if discharges are not properly regulated and monitored. Note that special focus should be directed at the possible generation of acid mine drainage if the material contains reactive sulphides.			
Sewage (domestic wastewater) discharge to fresh and marine recipients	Lifespan of mine	Local, < 1 km according to guideline value restrictions	Reduced habitat quality
Discharge of sewage from camps may have long-term local impacts, but cleaning is possible and should be applied already when exploration takes place to avoid negative effects. Long-term or short-term effects of nutrient and pathogens depend on the mixing capacity of the recipient as well as on the discharge composition. If the discharge is below the guideline values only short-term effects are expected when the discharge stops. Discharge restrictions can ensure that there will be no significant effect outside a buffer/mixing zone of typically less than 1 km. The size of the geographical extent depends on the mixing capacity at the point of discharge and the recipient (water depth, wave height, wind strength, current etc.). Reduced habitat quality is expected, which may include eutrophication and spreading of pathogens.			

Air pollution – combustion

Combustion of fuel oil for energy generation (unless renewable energy is established as an energy source) and for vehicles, ships, aircrafts and other machinery consumes significant amounts of fuel. The combustion activities may emit considerable amounts of greenhouse gasses, black carbon (BC) and, especially if heavy fuel oil is used, also SO_x and NO_X that contribute to formation of Arctic haze and acidification of soil and freshwater bodies. The processing of the ore may also release pollutants to the air.

The emissions from energy generation can be reduced by applying the most energy efficient processes by including smoke cleaning and avoiding heavy fuel oils and are best mitigated by establishing renewable energy plants in connection with the mine. This will, however, increase other impacts such as habitat loss and disturbance of wildlife. Other emissions to the atmosphere, including incineration of domestic waste, can be reduced by different cleaning processes and by applying BET and BAP.

In Table 8.5 examples of the sources to air pollution is described.

Table 8.5. Air emissions – combustion.

Type/stressor	Duration of impact	Geographical extend	Effects and effect level
Fuel oil as energy supply	Short-term (air quality) / Long-term (climate change)	Global/Regional/Local	Local/Global NO_X, SO_x,
Air emissions from a mine using fuel oil as energy supply release greenhouse gasses, NO_x, SO_x, particulate matter and black carbon (soot), which may impact the local air quality. Greenhouse gas emissions also contribute to the global climate change. Can be reduced by applying the most energy efficient processes and smoke cleaning as well as by avoiding heavy fuel oil and, ultimately, use of renewable energy.			
Waste incineration	Lifespan of mine	Local, < 1 km according to guideline value restrictions	Reduced habitat quality
Waste incineration takes place during the entire lifetime of a mine. If emissions are below guideline values, only short-term effects are expected when the emission stops. Can be reduced by applying the most efficient processes and smoke cleaning, thereby ensuring that there will be no significant effects outside a buffer/mixing zone of typically less than 1 km. Air emission from waste incineration may include, e.g., acid gases, dioxins/furans, heavy metals and NO_x.			

Air pollution – dust

Many of the mechanical processes at a mine site such as blasting, crushing of ore, transport of ore, driving on dirt roads etc. will create mineral dust. When dispersed and deposited in the environment, mineral dust may cause habitat loss through smothering of the surrounding vegetation and introduce contaminants from the ore, tailings, and waste rock into the soil ecosystems. Mineral dust on snow surfaces may decrease the albedo of the snow surface, leading to increased melt rates. Environmental impacts from mining-related emissions of mineral dust are mainly a local to regional phenomenon, but finer dust particles may enter the global atmospheric circulation and affect cloud formation and the radiative balance. Presence of fine mineral dust in the work environment of mine sites is often also an occupational health issue.

There are many ways to mitigate dust emission from raw mineral extraction processes, but it cannot be eliminated completely. It is particularly important to reduce dust emission from mines with radionuclide-containing ore due to health issues.

In Table 8.6 examples of the sources to dust pollution is described.

Table 8.6. Air emission – dust.

Origin	Duration of impact	Geographical extend	Effect and impact
Mine activities (Excavating, blasting, sorting, processing)	Lifespan of mine	Local, < 1 km according to guideline value restrictions	Reduced habitat quality/worst case habitat loss
Transport	Lifespan of mine	Local, < 1 km according to guideline value restrictions	Reduced habitat quality/worst case habitat loss
Waste rock and tailings facilities	Lifespan of mine	Local, < 1 km according to guideline value restrictions	Reduced habitat quality/worst case habitat loss

Dust from the mechanical processes, traffic and transport at a mine site may cover and impact the surrounding vegetation and affect habitat quality and, in the worst case, cause habitat loss. The dust may contain contaminants from the ore and waste rock. Only short-term effects are expected when the activity stops if it is well regulated. However, long-term effects may occur if the dust contains critical levels of elements of concern, e.g., process chemicals, heavy metals, and radionuclides. Dust-reducing measures should be included to limit the impact and dust management, and emission restrictions can ensure that there will be no significant effects outside a buffer zone of typically less than 1 km.

8.5 Accidents

Tailings facilities represent a risk, especially if they are wet, and polluted water and waste can spread to the environment following dam failure. The most catastrophic accidents related to mining are breakdown of tailings deposits in old, badly constructed, poorly managed and uncontrolled sites. Accidents are prevented by careful planning and by applying BEP and BAT, and have rigorous internal management as well as public monitoring and control systems in place.

Other accidents are related to storage and transport of fuel oil. On land, spilled oil can be contained, but if it is not contained and oil is released to rivers or the sea, large areas can be impacted. Especially, a large oil spill from a tanker supplying the mine with fuel may potentially affect the marine and coastal environments, with long-lasting, regional scale effects at ecosystem level.

Oil spills on land contaminate the soil, and in the Arctic oil is extremely slowly degraded and still found in the soil many decades after the spill. However, oil spills on land are usually local with localised impacts.

In Table 8.7 examples of major accidents are given.

Table 8.7. Accidents.

Type	Duration of impact	Geographical extend	Ecological level
Oil spills in rivers and sea	Potentially long-term	Potentially regional	Potentially ecosystem
Oil spills from fuel storage facilities or tankers/vessels. Long-term if not remediated in due time. The impact is likely local but could increase in space to a regional extend and result in reduced habitat quality at the ecosystem level if the oil spill is very large and in the sea.			
Oil spills on land	Potentially long-term	Local	Individual
Oil spills from fuel storage facilities. Long-term if not remediated. The impact is most likely local but could spread and cover nearby water bodies.			
Tailings deposit failure	Potentially long-term	Local/regional	Reduced habitat quality and habitat loss
Tailings dam failure may have long-term local and potentially regional impacts through waterways. If large amounts of toxic tailings and mining waste are released, reduced habitat quality at ecosystem level might occur.			

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9 Future perspectives and data gaps

By Katrine Raundrup[1], Janne Fritt-Rasmussen[2] and Anders Mosbech[2]

Greenland Institute of Natural Resources[1], Department of Ecoscience, Aarhus University[2]

9.1 Future perspectives

The climate is changing, and even the moderate IPCC climate models predict global temperature increases of ca. 2 °C by the end of the century (IPCC 2014). Especially the Arctic regions are experiencing changes at a faster rate than elsewhere (Cohen et al. 2014). At regional scale, DMI has developed climate models covering Greenland. The South Greenland regional baseline assessment area is part of the climate modelling for South Greenland (Christensen et al. 2015). For this region, the predicted climate-related changes include, e.g., annual temperature increases of 3-4 °C and an increased annual precipitation of 100-200 mm by the end of this century. Further, the number of days with extreme weather conditions is expected to increase. This includes, e.g., days with extreme precipitation (corresponding to days with more than 25 mm precipitation), which are expected to increase by 5-7 days. Currently, the assessment area has 10-25 days with this type of extreme weather. The longest period with draught (corresponding to consecutive days with less than 1 mm precipitation) is furthermore expected to increase by 4-6 days from the currently 10-15 days.

The climate changes expected to occur during this century will have tremendous effect on the growing season of the vegetation. The beginning of the growing season (period of consecutive days with temperatures above 5°C) is expected to advance by approx. 30 days. The growing season at the end of the century is thus expected to start in April/May compared to May/June today. The length of the growing season is also expected to increase by up to 60 days.

The temperature increase will result in glacial retreat making new areas available for mineral exploitation but also for agricultural use (Lehmann et al. 2016). Further, the combined effects of increased temperature, precipitation etc. will change the living conditions for both vegetation, animals, and the local communities within the assessment area. The changes will likely favour some species while others may decline. Ultimately, both the communities and the vegetation as well as animals will have to adapt to the new conditions in a warmer future.

In a rapidly changing Arctic, the present biodiversity is challenged. The areas that today are biologically important may lose their importance, and new areas of significance may be identified based on changes in species distribution and abundance. Changes in the human use of biodiversity will trail the ecological changes, and the agricultural sector will have potential for development. The rapid changes also present a challenge for environmental management of mineral extraction as exploration and exploitation operations are multi-decadal and waste storage facilities for tailings should last for thousands of years. Careful planning, monitoring at several levels, and adaptive management are recommended to avoid unforeseen impacts of the operations.

9.2 Data gaps

Due to the rapid climate change, there is a general need for more intense monitoring of biodiversity and ecological systems to enable adaptation of the planning and regulation of human activities. Ideally, the monitoring of mining operations should be integrated with a regional monitoring programme on climate, biodiversity, ecosystem and human activities to inform adaptive management.

While the development of such a regional ecological monitoring programme could improve the management and regulation of mineral operations, in this baseline assessment a number of data gaps regarding the biological environment described in the report have been identified that are relevant to highlight.

No data on insects, fungi, or lichens are presented primarily due to lack of studies on their distribution, abundance, and coverage in the area.

There are also areas with no or limited data. In the overlay analysis presented in Chapter 7, lack of data will result in areas with zero or only very few overlapping layers. Areas with low values are thus not necessarily areas with little relevant use, biological relevant features, or the like but may represent areas that are "under-studied".

Some results included in this report are based on relatively old data. This holds particularly true for the distribution of plant species (Table 4.2, Figure 4.11), and several of the bird colonies have not been surveyed in recent years.

Environmental background samples are only available for limited parts of South Greenland and mostly related to existing mine sites, e.g., Nalunaq, Kringlerne and Kvanefjeld. A range of environmental background samples were collected in an area around the central part of the Garder Domain during the field campaign in 2020. These background samples had low concentrations of all elements despite the relative proximity of a mineralisation. The large variation in the geology of the area thus highlights the importance of the availability of a sufficient set of relevant environmental background samples.

Outreach and local involvement were initially an integrated part of the RBA project. However, primarily due to Covid-19 restrictions we have not been able to update data on the local use of the biological resources and general use of the area.

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Appendix 1 Report on the geological setting of South Greenland

By Kristine Thrane and Simun Dalsenni Olsen[1]

[1]*Geological survey of Denmark and Greenland*

This appendix gives a short overview of the geological setting of South Greenland and descriptions of localities of economic and environmental relevance. GIS maps have been produced to show the distribution of selected elements of interest. The locations described and the distribution of geochemical data are restricted to the areas defined as South Greenland by GEUS. This report is based on a review of the geological, mineral occurrences and geochemical exploration data of South Greenland by Steenfelt et al. (2016) – this report can be accessed for further details and references.

Overview of geological setting of South Greenland

South Greenland comprises three main tectono-stratigraphic components: (1) Archaean basement, (2) Palaeoproterozoic Ketilidian orogen and (3) Mesoproterozoic Gardar alkaline igneous province (Fig. 1). Phanerozoic rocks are volumetrically insignificant and comprise Mesozoic dolerite as well as kimberlite sills and dykes. Quaternary glaciers covered the region with the possible exception of the highest peaks. The ice cap, the Inland Ice, remains over most of South Greenland with glaciers extending towards the coast through valleys and fjords.

South Greenland has been divided into four domains. The Northern Domain, Central and Southern Domains, covering Archaean and Palaeoproterozoic rocks, occupy geographically confined areas, while the Gardar Domain comprises Mesoproterozoic rocks distributed over most of South Greenland superposed on or intruding into the older rocks (Steenfelt et al., 2016).

The Northern Domain is composed of Meso- to Neoarchaean orthogneiss with enclaves of supracrustal units (Kalsbeek et al., 1990; Garde et al. 2002). The domain also includes Palaeoproterozoic supracrustal cover rocks, and it has been intruded by Palaeoproterozoic granites and of Mesoproterozoic Gardar alkaline complexes, as well as dyke swarms in Palaeoproterozoic, Mesoproterozoic and Mesozoic times. Two gold prospects (Nuuluk and Iterlak) are hosted by Mesoarchaean greenstones.

The Central Domain encompasses Palaeoproterozoic plutonic rocks of the c. 1850 to c. 1780 Ma Julianehåb igneous complex, comprising a variety of granitoids mainly granodiorites (Kalsbeek et al., 1990; Garde et al. 2002). Two age groups are discerned, an early igneous complex strongly deformed and a late igneous complex that is little deformed. The Central Domain has also been the site of most of the tectonism and magmatism related to the Gardar province. The most important mineral occurrences are located at the edges of the domain and include a small, closed copper mine (Josva Mine) and a number of shear zone hosted gold occurrences at Niaqornaarsuk. A small copper mineralisation was exploited at Frederik VII mine. Many small vein-type uraninite occurrences, with Puisattaq as the best known, are hosted in fracture zones in the late Julianehåb igneous complex.

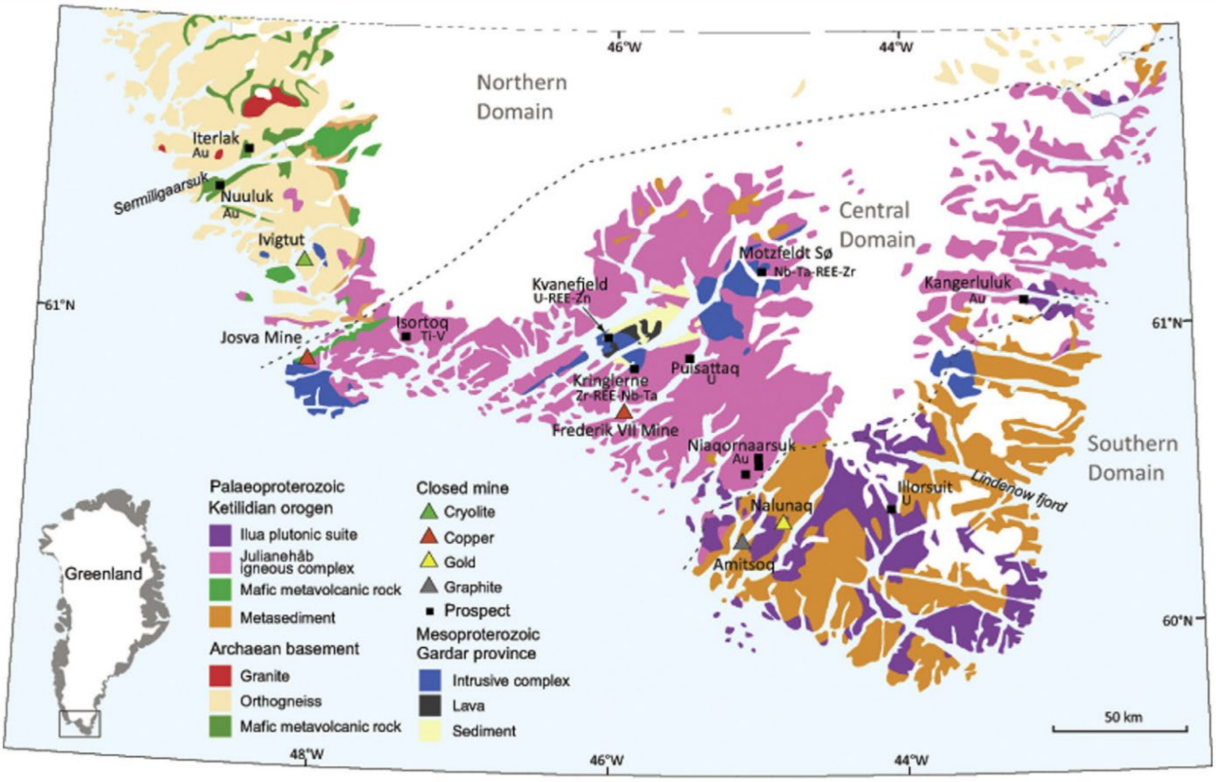

Figure A1.1. Major tectonic units of South Greenland with main mineral occurrences and domains. After Steenfelt et al., 2016.

The Southern Domain comprises large volumes of supracrustal rocks and the c. 1755-1723 Ma Ilua plutonic suite of granitoids to noritic rocks (Allaart, 1976; Chadwick et al., 2000; Garde et al. 2002). Metasedimentary rocks predominate, but the supracrustal sequences also include mafic metavolcanic lavas and volcanoclastic rocks. The lower parts of the supracrustal sequences have a high proportion of metapelites that are strongly deformed; they are metamorphosed at high grade and partially melted. The upper parts of the supracrustal sequence, mainly metaarkose, have a low metamorphic grade overprint and they are less deformed. The peak of metamorphism and anatectic melting of the entire metasedimentary succession occurred around 1790 to 1770 Ma. The Southern Domain hosts two closed mines, the Nalunaq gold mine and the Amitsoq graphite mine, several prospects for gold, graphite and uranium, fx the stratabound uraninite occurrence at Illorsuit. Stream sediment data show the entire Southern Domain is enriched in As, and that Sb and Cs are enriched in certain areas associated with occurrences of metaarkose at low metamorphic grade. Enrichment of Cu and Zn also occur in the Southern Domain.

The Gardar Domain (also known as the Gardar province) encompasses Mesoproterozoic sedimentary and magmatic rocks emplaced during several episodes of continental rifting in the time interval 1300-1140 Ma (Emeleus and Upton, 1976; Upton et al., 2003). Sediments and lavas are preserved in the Eriksfjord Formation, along with large volumes of alkaline magma in the form of dyke swarms and central intrusive complexes. The Gardar intrusive complexes are formed of very unusual rock compositions and host mineral deposits with a range of rare elements such as Be, Li, F, P, Y, Ga, Zr, Nb, REE, Hf, Ta, Th, U. The most famous was the cryolite mine at Ivittuut. Currently, Kvanefjeld, Kringlerne and Motzfeldt Sø are the main prospects for Zr, Nb, Ta, REE, U and Zn, and a dolerite at Isortoq hosts a Fe-Ti-V prospect.

Geological locations of economic and environmental significance in South Greenland

Northern Domain

1. Gold prospects in Tartoq Group: Nuuluk and Iterlak

The Mesoarchaean Tartoq Group (Szilas et al., 2013) occurs as six isolated remnants of a multiply deformed supracrustal belt tectonically squeezed in with orthogneiss in an over 40 km long and up to 5 km wide zone on both sides of Sermiligaarsuk. The Tartoq group is clearly outlined as anomalous in Au and As by stream sediment fine fraction and samples with elevated Sb occur locally (Steenfelt, 2000). Gold mineralisation was recognised in the Tartoq supracrustal rocks during the 1970s and several exploration campaigns (Renzy Mines Ltd. 1991, Greenex A/S, Nunaoil A/S, Nordic Mining ASA, and presently Nanoq Resources Ltd.) has since been conducted including dense sampling, electro-magnetic surveying and drilling on the best targets. As a result, high gold grades (up to 50 ppm Au) have been recorded in well-defined mineralised zones. At Nuuluk, gold is hosted in two distinct NNE-SSW trending, 50-100 m wide and 5 km long thrust zones. The western carbonate zone comprises a distal hydrothermal alteration assemblage with carbonate (calcite, dolomite or ankerite depending on host rock composition), chlorite, pyrite and tourmaline in veins. The proximal alteration zone comprises ankerite, muscovite (fuchsite), chlorite, quartz, pyrite, arsenopyrite, pyrrhotite, chalcopyrite, tennantite and gold. The highest gold concentrations (up to 41 ppm Au) are in samples from the eastern carbonate zone. A halo of elevated As and Cu occurs in the gold zone, which suggests that the auriferous fluids were also enriched in these elements (Kolb, 2011). The gold is hosted in either graphite and magnetite schists, or more competent greenschists in the form of quartz veins.

At Iterlak, gold is hosted in two NNE-SSW trending, approximately 100 m wide and 200-400 m long zones, namely the Western Valley zone and the Eastern Valley zone. Higher gold values are also recorded from carbonate-sericite alteration zones in the belt. The Western Valley zone comprises hydrothermally altered greenschist and banded iron formation. Gold mineralisation occurs in the proximal alteration zones and altered banded iron formation, mainly in quartz-rich samples, i.e. quartz-ankerite veins (Evans and King, 1993). In the carbonate-sericite alteration zone up to 25% volume increase is associated with higher K, Ba, Cs, Rb and loss on ignition (LOI), and lower Mg, Ca and Na; locally, Fe, Al and Ti are slightly enriched. Gold enrichment is associated with high base metal contents and LOI, indicating hydrothermal alteration, but is also located in Fe-rich samples. The recorded gold concentrations are up to 12 ppm in the Iterlak occurrence (Kolb et al., 2013).

The Eastern Valley zone is characterised by hydrothermally altered greenstone, talc schist and banded iron formation. The proximal alteration zone is confined to talc schist, forming a talc-ankerite-sericite-chlorite-pyrite assemblage. The banded iron formation shows a pyrite and minor chalcopyrite alteration. The hydrothermal alteration was not complete leaving magnetite as a primary or a metamorphic mineral in the banded iron formation and talc schist behind. Gold enrichment is most pronounced in magnetite rich talc schist, where magnetite is replaced by up to 7 mm, euhedral pyrite. The proximal hydrothermal alteration caused a slight mass increase together with Ca, Cu, LOI and minor K enrichment and depletion in Mg (Steenfelt et al., 2016).

Central Domain

1. Gold prospect on Niaqornaarsuk peninsula – Vagar prospect

Gold mineralisation on the Niaqornnarsuk peninsula was identified *in-situ* during follow-up of stream sediment Au anomalies (Olsen and Pedersen, 1991). Continued work by NunaOil A/S-NunaMinerals A/S and GEUS included surface mapping, stream sediment and rock sampling, drilling and assaying. Regional chip and grab samples in the structural lineament zones gave a wide range of gold values (up to 1000 ppb Au) and 14 samples in excess of 100 ppb (Chadwick et al., 1994). Gold at Niaqornaarsuk peninsula occurs preferably in quartz veins, which are 0.5-5m wide. The hydrothermal alteration assemblage consists of quartz, K-feldspar, muscovite, chlorite, biotite, epidote, calcite, monazite, pyrite, pyrrhotite, bismuth tellurides, sulphosalt minerals, fluorite and gold. Elements enriched during the hydrothermal alteration are Bi, Au, Ag, Ga, W, As, Te and Ba, whereas base metals are only slightly enriched (Schlatter et al., 2013).

2. Ilordleq Group and the Josva Mine

The Ilordleq Group is situated in the Kobberminebugt shear zone (McCaffrey et al., 2004). It consists of metavolcanic and metasedimentary rocks forming up to some hundred meters wide bands (Kalsbeek et al., 1990). The Group hosts Au-Cu-Ag mineralisation, and up to 5 vol.% sulphides.

The Josva mine at the south coast of Kobberminebugt was mined by Grønlands Minedrift Aktieselskab in two periods between 1853-1855 and 1905-1914. It is estimated that 90 tons of copper plus small amounts of gold (0.5 kg) and silver (50 kg) was extracted from 2200 tons of ore that were smelted at the site. The ore contained 4.1 % Cu with 0.8 ppm Au and 11 ppm Ag (Ball, 1923). The size of the remaining ore body at Josva Mine is estimated to be 2000-3000 tons of ore containing 30-40 tons of copper (Nielsen, 1976).

3. Nunatak - Nordre Sermilik uranium occurrences

North and northwest of Narsarsuaq, the basement complex contains several uranium-mineralised enclaves of fine-grained and porphyritic quartz-feldspar rich metamorphic rocks interpreted to be of volcanic origin (Allaart, 1976). Both aeroradiometric and stream sediment data showed that the area around Nordre Sermilik is generally enriched in uranium (Armour-Brown et al., 1983; Schjøth et al., 2000). During ground follow-up of one of the radiometric anomalies, uranium mineralisations were discovered at Nunatak north of the head of Nordre Sermilik (Nyegaard and Armour-Brown, 1986).

Many rafts have 10-40 times higher background radioactivity than the surrounding granite owing to uranium and thorium mineralisation. The richest occurrence is within a 0.5 to 1 m thick gneissic raft. Uraninite and secondary U-minerals are concentrated in two small zones with concentrations of up to 1.3% U and 1131 ppm Th. In addition, vein-hosted pitchblende mineralisations were located in late fractures in the granodiorite. Two samples of vein material with uranium pitchblende returned 1.1 and 1.6 % U, respectively.

4. Uranium mineralisations in fracture zones: Puisattaq prospect and Vatnahverfi showings

The Central Domain is strongly fractured and clearly outlined by an abundance of stream sediment and stream water uranium anomalies and over 200 occurrences with more than 100 ppm U or Th were discovered (Armour-Brown et al., 1983). Uranium occurrences are commonly small lenses, but they occur along fractures traceable for distances of up to 10 km. Comprehensive descriptions are found in Nyegaard and Armour-Brown (1986). The radioactive occurrences comprise four types: (i) Pitchblende associated with faults, fractures and related joints. (ii) Brannerite, also associated with fractures and disseminated in altered granite along them. (iii) Thorium dominated fenitised veins. (iv) Allanite in pegmatites. Pitchblende or brannerite may be accompanied by secondary uranium minerals, galena, pyrite, chalcopyrite, while gangue minerals commonly comprise calcite, quartz and fluorite.

The densest population of known pitchblende veins occurs at Puisattaq (Armour-Brown et al., 1984). Four pitchblende veins lie in the northern part of a 150 - 200 m wide, EW-trending fault zone within 1 km of each other between 100 to 200 m above sea level. The veins are not exposed, and were found by tracing radioactive boulders back to their source. The veins are up to 11 m long and 5 cm wide. Vein samples contain from 0.75% to 6.3% U and very little Th. One vein is found in a 5 m wide red felsic dyke and is more like a joint filling a few metres long, but also with many radioactive spots located for 50 m along its strike in fractures in the dyke. Cracks in the pitchblende frequently contain small grains of galena which is probably radiogenic in origin. It is associated with specular hematite and minor pyrite and chalcopyrite. The pyrite is cataclastic and partly altered to limonite and may be replaced by hematite.

The frequency of faults and fractures in the Central Domain appears to increase towards the Vatnahverfi area to the south of Puisattaq. Veinlets or irregular bodies with pitchblende or more commonly brannerite have been observed in many of the faults together with fluorite, calcite and hematite (Armour-Brown et al., 1984). Individual occurrences are rarely more than one metre in length, but they are aligned along the faults. Samples from the richest locality returned up to 3.6 wt.% U. Armour-Brown et al. (1984) provides results of analyses of rocks and minerals. The landscape at Vatnahverfi is low-lying, has much vegetation and lakes, i.e. poor rock exposure, so that more and perhaps richer uranium occurrences are expected to exist in this area.

Southern Domain

1. Illorsuit uranium prospect

The Illorsuit prospect is the largest and richest of the occurrences recorded by the airborne radiometric survey (Armour-Brown, 1986; Steenfelt and Armour-Brown, 1988). More than 35 uranium mineral occurrences have been found scattered in the supracrustal rocks. Disseminated fine-grained uraninite is concentrated along layering in the metavolcanic rocks, or more commonly in small strata-bound fractures related to specific members of meta-arkose and metaandesite. The highest grade uranium mineralisation is about 50 m long and up to 5 m wide with grades up to 7 % U. It is estimated that the Illorsuit prospect contains 17,000 tons of uranium ore with a grade of 0.31 % U corresponding to 50 tons of uranium metal (Armour-Brown, 1986).

2. Graphite occurrences

The graphite occurrences in the Southern Domain comprise the closed mine site at Amitsoq and the prospect Sissarissoq (Kalsbeek et al. 1990; Bondam, 1992a and references therein). At Amitsoq, three parallel graphite-bearing horizons have been identified in the gneiss, the main horizon reaches 13.2 m width and approximately 600 m along strike, pinching to 3.5 m width in the northeast. The two minor horizons are 4 m wide and have a strike extent of approx. 100 m (Bondam, 1992b). The ore consists of finely disseminated crystalline graphite flakes in a quartz-rich groundmass, accompanied by minor pyrite and biotite. The graphite flakes are up to 15 mm in size and the graphite content varies between 20-24 vol.% (Ball, 1923; Bondam, 1992b). Only one geochemical analysis of an average ore grade was published as 21.0 wt.% C, 6.0 wt.% S and 0.2 wt. % H_2O (Høeg, 1915). Production in the Amitsoq mine was initiated 1914, when about 130 tons of graphite ore were excavated, followed by 2000 tons in 1915. After a break during World War I, mining was resumed, but only 571 tons of graphite concentrate were produced during 1918-1921 and exploitation ended in 1922 (Ball, 1923). The ore reserves were calculated at 250,000 t, but only 6,000 t graphite ore was produced.

At Sissarissoq, south of Amitsoq, a number of shallow north-dipping lens-shaped bodies of graphite occur in pelitic to semipelitic paragneisses. The occurrence was trenched and sampled, indicating 4,000 tons of graphite ore. A single analysed sample contains 24 % graphite and c. 7 % sulphur (Bondam, 1992b).

3. Gold deposits: Nalunaq, Lake 410 and Ippatit

These gold occurrences are located in quartz vein systems related to shear zones, and they have high contents of arsenopyrite, the Au-As association of Stendal and Frei (2000). High anomalies for Sb and Cs in stream sediment characterise all three areas.

The closed Nalunaq mine is situated in a main valley in the Nanortalik peninsula, where an epigenetic gold mineralisation associated with a narrow quartz vein system in amphibolite was exploited. The main vein is generally 0.8-2m in width and has a lateral extent of 1300 m vertically and 800 m horizontally. A comprehensive geochemical database of analyses of almost 16,000 samples and geochemical whole rock analyses of >4700 rock samples from the mine or from areas near Nalunaq shows that the hydrothermal alteration zone is enriched in Si, K, Au, Sb, Ag, Sb, Bi and W (Schlatter and Olsen, 2011)

The Nalunaq mine was opened 2004 and closed 2014. The mine was initially owned by Nalunaq Gold Mine A/S, a subsidiary of Crew Gold Corporation, together with NunaMinerals A/S, and in the first years of operation, the ore was shipped abroad for processing. In 2009 Angel Mining (Gold) A/S took over the mine along with facilities and infrastructure. An underground processing plant was constructed and the first doré was produced on site in

May 2011 (Sørensen, 2013). Approximately 714,000 t of ore at an average grade of approx. 15 g/t Au were produced from a 1700 m long and 0.1-2.0 m wide auriferous quartz vein, yielding 10.7 t gold metal.

At Lake 410, south of Nalunaq, two parallel, ≤ 2 m wide, locally laminated, gold-bearing quartz veins are hosted in amphibolite with hydrothermal graphite-arsenopyrite-chalcopyrite-pyrite alteration (Olsen and Petersen, 1995; Porrit, 2004). Auriferous amphibolite also shows quartz-carbonate-mica alteration and an early calc-silicate alteration. The quartz veins contain as much as 2.22 ppm Au over 2 m in drill core intersections (Porrit, 2004), and altered amphibolite contains up to 4.8 ppm Au over 2 m in chip samples (Olsen and Petersen, 1995).

At Ippatit, north of Nalunaq, a gold mineralisation with up to 832 ppb Au, is hosted in up to 2 m wide quartz veins in biotite schist associated with graphite-quartz-biotite-sulphide alteration (Olsen and Petersen, 1995). Similar quartz veins occur in amphibolite and meta-volcanoclastic rocks, which are separated from the biotite schist by a S-dipping shear zone displaying quartz-graphite-pyrrhotite alteration. Samples of silicified schist with disseminated arsenopyrite have As in the order of 2000 ppm, confirming the Au-As association.

4. S-type granites

The high temperature-low pressure conditions imposed upon the sedimentary succession resulted in metamorphism and partial melting. As a result, granitic melts are present as ubiquitous veins and pegmatites in the sedimentary packages, but they also accumulated into large coherent bodies (Chadwick et al., 2000). The largest is a regionally sub-horizontal granite sheet, more than 1000 m thick and covering over 2000 km^2 in the southernmost islands. The granitic melts were able to concentrate incompatible elements during magma differentiation and bring them upwards through the crust. Elevated to high U values in stream sediment is spatially associated with S-type granite, and pitchblende mineralisation was found in migmatitic neosome within metaarkose north of Nalunaq (Armour-Brown et al., 1983). Recorded uranium concentrations in the neosome are between 1000 and 8000 ppm. So far only U has been of interest although the granitic melts have the potential to form complex pegmatites enriched in Li, Sn, W as well as tourmaline and beryl (Steenfelt et al., 2007). High Th concentrations in stream sediment are spatially associated with the S-type granites.

Gardar Domain

1. Kvanefjeld (Kuannersuit) depostit

The Ilímaussaq intrusive complex is world famous for its unique rock types and wealth of rare minerals (Sørensen, 1967; Petersen, 2001). The intermediate sequence of the intrusion is represented by the most evolved rocks, lujavrites, and host the Kvanefjeld deposit, and the related Zone Sørensen and Zone 3. The lujavrite is a fine grained, commonly laminated, syenite. Highly evolved phases have the highest concentrations of the presently targeted ore elements U, REE, Zn and F. The mineralogy and petrology of the lujavrites are discussed in Rose-Hansen and Sørensen (2002), Sørensen et al. (2006).

The first investigations at Kvanefjeld were undertaken by collaboration between GGU, the University of Copenhagen and Risø National Laboratory and comprised geological and radiometric mapping, drilling, drill hole logging, drill core analyses, driving of adits, ore processing tests, feasibility studies, and environmental impact studies. The principal uranium ore mineral was found to be steenstrupine, but other U bearing minerals and substances are known, and the Th/U ratio of the ore is 2.5. Summaries of the investigations are given by Sørensen (2001).

Commercial exploration at Kvanefjeld was initiated in 1986 (drilling by Rimbal Pty Ltd.), and Greenland Minerals and Energy Ltd. (GMEL) took over in 2007 and conducted intensive drilling, chemical, mineralogical and metallurgical investigations with the objective of evaluating the lujavrite as a rare earth element resource. Steenstrupine was found to be the dominant host of rare earth elements (besides uranium), and it was realised that the lujavrite's content of sphalerite opened the possibility for extraction of Zn, thereby adding to the value of the ore. The total identified conventional mineral resource inventory for Kvanefjeld is 102,820 tonnes U. The company list ore grades as: U_3O_8 273 ppm, LREO 9524 ppm, HREO 392 ppm, Y_2O_3 882 ppm, Zn 2351 ppm.

2. Kringlerne Zr-Nb-Ta- REE deposite

The Ilímaussaq intrusive complex is world famous for its unique rock types and wealth of rare minerals (Sørensen, 1967; Petersen, 2001). The floor series of the intrusion, the kakortokites, crops out in the southern part of the Ilímaussaq complex, known as Kringlerne in a spectacular rhythmically layered series of black-red-white units (Bohse et al., 1971). The layered cumulates are formed by relative enrichment of the minerals arfvedsonite (black), eudialyte (red) and feldspar-nepheline (white). The kakortokite also contains aegirine, aenigmatite, sodalite, fluorite, analcime, rinkite and minor sulphides (sphalerite, galena, löllingite). Eudialyte (Na-Ca-(Fe, Mn)-Zr-silicate) is the main host of niobium, tantalum and rare earth elements, and the niobium and rare earth element bearing rinkite is a supplementary host. A particularly eudialyte-rich layer has been evaluated as raw material for production of zirconia (Bohse et al., 1971), whereas later exploration concerned niobium-tantalum and rare earth elements. The present licensee, Rimbal Pty Ltd, plans to treat the kakortokite as a bulk ore, from which a eudialyte concentrate can be made by magnetic mineral separation (www.tanbreez.com). Estimates are given as follows for the size and grades of this large (over 4 billion tons) low-grade deposit (1.8 % ZrO_2, 0.2 % Nb_2O_5, 0.5 % LREE, 0.15 % HREE).

3. The Igaliko complex - Motzfelt Sø prospect

The Igaliko complex is the largest igneous mass within the Gardar province. It comprises four intrusive centres, Motzfeldt, North Qôroq, South Qôroq and Igdlerfigssalik (Emeleus and Harry, 1970). The Motzfeldt centre covers an area of approximately 150 km^2 and consists of concentric units of peralkaline undersaturated syenites emplaced at the boundary between Julianehåb granitoids and Eriksfjord Formation. The outermost units, the Motzfeldt Sø Formation, underwent extreme magmatic differentiation thereby producing a residual liquid rich in volatiles and incompatible elements, which intruded the margin of the complex and formed a number of peralkaline microsyenite sheets and pegmatites. In addition, extensive hydrothermal alteration of the Motzfeldt

Sø syenite occurred along the margins and especially at the roof. The associated pyrochlore mineralisation probably formed where the incompatible element/volatile enriched magmatic residuum received an influx of silica and meteoric water. The resulting increase in oxygen fugacity, acidity and hydrothermal activity facilitated migration with subsequent deposition of the pyrochlore together with zircon, thorite and abundant fluorite (Tukiainen, 1988). Mineralisation occurrences with Nb-Ta-U-Th-Zr-Ce-La are hosted in altered syenite and peralkaline microsyenite of the Motzfeldt Sø Formation. The metals occur mainly in pyrochlore (Nb, Ta, U, REE), thorite (Th), zircon (Zr) bastnaesite (REE, Th) and monazite (REE). Average concentrations of 50-80 ppm U and 80-120 ppm Th were recorded, with local peaks of 500-700 ppm U and 2000 ppm Th (Thomassen 1988, 1989). A minor sulphide mineralisation is associated with some fault zones and Thomassen (1988) mentions additional potential for Be (up to 797 ppm), Li (up to 1810 ppm) and Mo (up to 202 ppm). Commercial investigations by Angus and Ross Plc. (Armour-Brown, 2001) followed by RAM Resources concerned the Nb-Ta mineralisation at first and later included the REE resources. Typically the total rare earth oxide (TREO) comprises 82.5 % light rare earth oxides (La, Ce, Pr, Nd, Sm), 6.5 % heavy rare earth oxide (Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and 10.6 % Y_2O_3.

The North Qoroq centre of the large composite Igaliko complex consists of five concentric intrusions of nepheline syenite (Emeleus and Harry, 1970). The rocks include eudialyte bearing lujavrite and like in the nearby Motzfeldt centre, it shows areas of metasomatic alteration (Coulson and Chambers, 1996). Therefore, the complex could have a certain unrecognised/uninvestigated potential for REE mineralisation.

4. Ivigtut granite and cryolite deposite

The Ivigtut granite complex occupies a 270 m wide cylindrical stock that was intruded into Archaean gneiss and is surrounded by a 60 m wide intrusion breccia. Mineralised faults and crush zones (sulphides, carbonates, fluorite), often with high levels of radioactivity, Sr, Ba and REE, dissect the surrounding region (Bailey, 1980). The Ivigtut cryolite deposit (Bailey, 1980; Pauly and Bailey, 1999) was located within the roof zone of a 270 m wide cylindrical stock of alkali granite. The deposit of Ivigtut is unique and sustained mining for over 100 years with cryolite as the main product and galena and sphalerite as bi-products. The rich cryolite ore body is now exhausted, but minor amounts of low grade cryolite ore remains in addition to fluorite, siderite, galena, sphalerite and quartz (Pauly and Bailey, 1999). The cryolite body and its hydrothermally altered host-granite contain a long range of rare minerals (see references in Pauly and Bailey, 1999).

5. Grønnedal-Ika complex

This complex consists of two layered series of nepheline syenite that has been intruded by a small carbonatite plug. Stream sediment REE anomalies cluster in and around the Grønnedal-Íka complex, and also the Zn concentrations are high, with a mean of 309 ppm and maxium value at 540 ppm. A magnetite-siderite occurrence with minor sphalerite is located where a dolerite dyke cut the carbonatite. Exploration by Kryolitselskabet A/S comprised ground magnetic mapping followed by trenching and drilling. The occurrence was estimated to contain at least 0.8 million t magnetite grading 25-30% iron (Bondam, 1992a). A potential for Nb-Ta in pyrochlore, phosphorus in apatite and REE related to the carbonatite has been suggested (Sørensen and Kalvig, 2011).

A system of E-W or NE-SW striking fractures in the larger area around Ivittuut and Grønnedal-Ika was found to contain Th mineralisation associated with zones of cataclasis and with radioactive carbonatite veins also containing pyrite, chalcopyrite, sphalerite, galena, magnetite, apatite, barite, fluorite (Armour-Brown et al., 1982). The Th mineral is assumed to be thorite or thorogummite. Minor pyrochlore mineralisation (up to 1000 ppm U and 1 % Nb) within and next to a major N-S fault was reported by Armour-Brown et al. (1982). The carbonatite veins are considered possible hosts of REE mineralisation.

6. Giant dykes at Isortoq

Giant dykes differ from the majority of younger dykes by their impressive widths of 150 to 800 m and their textural and structural features more akin to those of the intrusive complexes (Emeleus and Upton, 1976; Upton and Fitton, 1985). The giant dykes at Isortoq hosts Fe-Ti-V mineralisation. The Isortoq area was initially examined by Hunter Minerals Pty Ltd. for magmatic Cu-Ni-PGE mineralisation similar to the Voisey's Bay deposits of Labrador, Canada, based on geological similarities. To date, no Cu-Ni-PGE mineralisation has been identified, but two areas of magnetite-rich olivine-gabbro (troctolite) were identified during helicopter-borne magnetic and electromagnetic survey (Turner and Nichols, 2013). Subsequent drilling intersected several zones up to 145 metres in true width and up to 231 metres vertically of magnetite-bearing troctolite. The Isortoq dykes show apparent widths of up to 200 m, and the mineralised troctolite can now be traced over a strike length of 16.3 kilometres using geophysical data and surficial structural features combined with current and historic core drilling confirmations. The mineralisation is made up of troctolite rich in titaniferous magnetite, where Ti and V occur in exsolved phases within the magnetite. West Melville Metals Inc. announced a NI 43-101 compliant inferred resource of 70.3 mill. t at 29.6 % Fe, 10.9 % TiO_2 and 0.144 % V_2O_5 (15 % Fe cutoff; Turner and Nichols, 2013).

7. The Qassiarsuk carbonatite complex

The Qassiarsuk carbonatite complex comprises lavas, pyroclastic rocks and subvolcanic intrusions of alkaline silicate rocks and carbonatites. The volcanic rocks are interlayered with sandstones and basalts belonging to the lower part of the Eriksfjord Formation. The carbonatites range in composition from calcite carbonatite to iron-poor dolomite carbonatite and ankerite ferrocarbonatite (Andersen, 2008). Sandstones, volcanic rocks and basement are penetrated by diatremes with (silico)carbonatitic, alkaline ultramafic and phonolitic matrix compositions interpreted as feeders to the pyroclastic rocks (Upton et al., 2003). The carbonatitic rocks have been investigated for their contents of apatite (Knudsen, 1986). Samples of carbonatite have up to c. 3.5 % P_2O_5, while the highest contents (up to 35 % P_2O_5), were found in fenite adjacent to carbonatite and lamprophyre intrusions. The fenite zones rarely exceed a few metres in width. Local LREE mineralisation is a possibility that have not been documented. Several uranium anomalies in stream water and stream sediment are spatially associated with faults within an area near Qassiarsuk complex. Many small occurrences of pitchblende, coffinite and brannerite have been located in fractures and joints in the surrounding rocks (Nyegaard and Armour-Brown, 1986).

Summary

The main elements of economic and environmental interest at the various geological locations described in the section above are listed in Table A1.

Table A1. Summary of the geological locations of economic and environmental interest in South Greenland, including the main enriched elements.

Domain	Name	Main enriched elements
Northern Domain		
	Nuuluk + Iterlak	Au, As
Central Domain		
	Niaqornaarsuk/Vagar	Au, Ag, As, (F)
	Josva Mine – Ilordleq Group	Cu, Ag, Au
	Nunatak – Nordre Sermilik	U, Th
	Puisattaq + Vatnahverfi	U, Th, F
Southern Domain		
	Illorsuit	U, Th
	Amitsoq + Sissarissoq	Graphite
	Nalunaq + Lake 410 + Ippatit	Au, As
	S-type granites	U, Th
Gardar Domain		
	Kvanefjeld	REE, U, Th, Zn, F
	Kringlerne	Zr, Nb, Ta, REE, F
	Igaliko - Motzfelt Sø	Nb, Ta, U, Th, Zr, Ce, La, F
	Ivigtut	Cryolite, F, Zn, P
	Grønnedal-Ika	REE, Zn, Fe
	Isortoq	Fe, Ti, V

GIS maps

The GIS maps presenting the content of different metals is based on geochemical stream sediment analyses from the GEUS database. The fluorine content was not analysed from the stream sediments, instead the fluorine content was measured from water samples (Steenfelt, 2001; Steenfelt, 2004) and rock samples from selected areas (Larsen, 1979; Kihler et al., 20009; Pearce and Leng, 1996; Schjøth et al., 2000; Upton and Thomas, 1980). As only a limited number of fluorine analyses are measured in the study area, conductivity of the streams have been included in the dataset; these are not a direct link, but correlated well to the fluorine content of stream water (see Steenfelt and Dam, 1982).

Stream sediment samples

The stream sediment samples were collected by GEUS during several individual field campaigns. They are sampled throughout South Greenland as evenly as possible from second or third order streams preferably with catchment areas less than 10 Km^2. The high-density of sampling document local variations. At each sampling site c. 500 g of composite stream sediment was collected. The dry samples were sieved at GEUS and the <0.1 mm faction was analysed for major and trace elements (for further details see Steenfelt, 1999; Steenfelt et al., 2016). The geochemical data from the stream sediment samples are interpreted to represent the surrounding catchment area, and is therefore a good exploration tool. All the geochemical stream sediment analyses are stored in GEUS database.

Fluorine

Water samples: In the study area 448 water samples are analysed for fluorine, the results have laid the background for a drinking water survey reports (Steenfelt, 2000, 2004). The conductivity of stream water have been measured for 3268 samples and are reported by Armour-Brown et al. (1982).

Rock samples GEUS: Rock samples collected for mapping-, classification-, petrogenetic- and economic purposes. 170 samples in the GEUS database were analysed for fluorine (Schjøth et al., 2000).

Rock samples from GEOROC: Precompiled files of geographic and geological provinces are available at the GEOROC database (URL: http://georoc.mpch-mainz.gwdg.de/georoc/). In South Greenland, only samples from the Gardar Province were analysed for fluorine, a total of 105 fluorine analyses are presented.

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Appendix 2 Environmental chemistry baseline values

By Janne Fritt-Rasmussen1 and Kasper Lambert Johansen 1

[1]*Department of Ecoscence, Aarhus University*

Regional environmental baseline element values

Based on baseline data (samples representing unpolluted conditions) in the AMDA database, regional median concentration values and ranges of approx. 70 different elements in eight different sample types (seaweed, crinkled snow lichen, blue mussel, short-horn sculpin, sediment, soil, filtered water and unfiltered water) have been calculated. In total 1480 samples with geographical coordinates were included. Figure A 2.1 shows the distribution of samples across Greenland, and the sub-division of the dataset into seven different regions. In the tables that follow, the naming of the regions from Figure A 2.1 is used. Most of the columns in the tables should be self-explicatory, but a few need mentioning: q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. As some samples were sub-divided prior to measurement (e.g. a sculpin spilt in liver, bone, muscle etc), the number of measurements may be greater than the number of individual samples. Among the values, "<DL" means that the concentration is below the detection limit of the instrument.

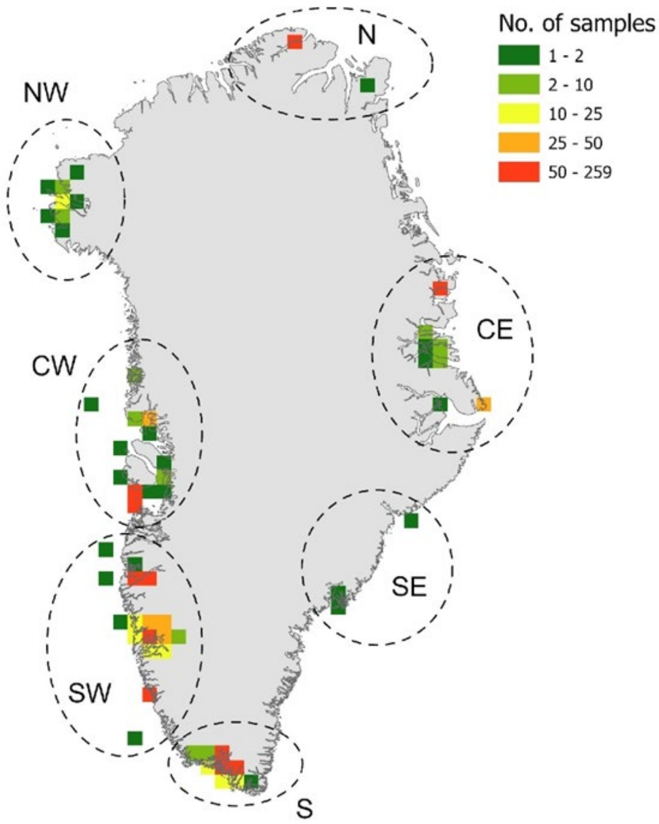

Figure A2.1. Distribution of baseline samples (unpolluted conditions) with geographical co-ordinates in the AMDA database (n=1480), and the sub-division of Greenland used for calculating the regional baseline element concentration values

Table A2.1 Regional environmental baseline element concentration values for the region "South Greenland" (S). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRL region	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
S	Blue mussel	Ag	mg/kg	<DL	0.022	0.055	0.062	0.096	41	37
S	Blue mussel	Al	mg/kg	108.322	242.565	383.012	466.11575	11550.883	30	26
S	Blue mussel	As	mg/kg	1.836	4.573	12.5	14.36	19.316	61	42
S	Blue mussel	Au	mg/kg	<DL	<DL	<DL	<DL	<DL	30	26
S	Blue mussel	B	mg/Kg	2.9	3.200	4.7	11.4	20	11	11
S	Blue mussel	Ba	mg/kg	<DL	1.656	3.404	5.337	24.899	41	37
S	Blue mussel	Be	mg/Kg	<DL	0.011	0.018	0.154	24.681	51	42
S	Blue mussel	Bi	mg/kg	<DL	<DL	0.005	0.006	0.013	41	37
S	Blue mussel	Ca	mg/kg	260	1467.755	2567.941	3708.607	7500	41	37
S	Blue mussel	Cd	mg/kg	0.3	1.895	2.4395	2.869	5.78	68	57
S	Blue mussel	Ce	mg/Kg	0.804	2.208	3.6265	7.101475	43.542	40	31
S	Blue mussel	Co	mg/Kg	0.076	0.394	0.529	0.754	0.882	51	42
S	Blue mussel	Cr	mg/Kg	<DL	0.436	0.753	1.022	4.581	51	42
S	Blue mussel	Cs	mg/kg	0.018	0.026	0.037	0.051	3.223	30	26
S	Blue mussel	Cu	mg/kg	1.3	6.239	7.122	7.714	8.981	41	37
S	Blue mussel	d.m.%	%	9.62	13.510	14.7	16.8	22.9	71	57
S	Blue mussel	Dy	mg/Kg	0.039	0.090	0.133	0.436	1.580	40	31
S	Blue mussel	Er	mg/Kg	0.02	0.045	0.0715	0.334	0.890	40	31
S	Blue mussel	Eu	mg/Kg	0.014	0.033	0.042	0.111	0.247	40	31
S	Blue mussel	Fe	mg/kg	23	210	303.724	500.216	672.248	41	37
S	Blue mussel	Ga	mg/kg	0.061	0.161	0.2155	0.266	7.205	30	26
S	Blue mussel	Gd	mg/Kg	0.093	0.221	0.3465	1.789	4.295	40	31
S	Blue mussel	Hf	mg/kg	0.004	0.007	0.0085	0.014	0.089	30	26
S	Blue mussel	Hg	mg/kg	0.059	0.077	0.089	0.098	0.121	57	46
S	Blue mussel	Ho	mg/Kg	0.008	0.017	0.027	0.085	0.325	40	31
S	Blue mussel	K	mg/kg	2100	9795.595	11000	12278.343	14407.694	41	37
S	Blue mussel	La	mg/Kg	0.815	1.958	3.7345	11.635	48.733	40	31
S	Blue mussel	Li	mg/kg	0.091	0.221	0.2625	0.413	1.173	30	26
S	Blue mussel	Lu	mg/Kg	0.002	0.005	0.0095	0.021	0.082	40	31
S	Blue mussel	Mg	mg/kg	440	1700.881	2563.073	2865.142	3304.842	41	37
S	Blue mussel	Mn	mg/Kg	1.2	9.540	11.677	15.969	24.948	51	42
S	Blue mussel	Mo	mg/Kg	<DL	0.065	0.454	0.569	1.748	51	42
S	Blue mussel	Na	mg/kg	2300	7488.873	14418.954	19000	24771.202	41	37
S	Blue mussel	Nb	mg/Kg	0.077	0.137	0.21237	0.596	3.515	40	31
S	Blue mussel	Nd	mg/Kg	0.41	1.072	1.694	5.695	23.023	40	31
S	Blue mussel	Ni	mg/Kg	0.14	0.758	1.1217	1.2935	2.598	51	42
S	Blue mussel	P	mg/kg	1800	9200	10000	11159.657	12911.895	41	37
S	Blue mussel	Pb	mg/kg	0.16	0.701	1.011	2.220	11.139	68	57
S	Blue mussel	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	8	8
S	Blue mussel	Pd	mg/kg	0.009	0.022	0.042	0.049	0.091	30	26
S	Blue mussel	Po-210	Bq/kg	10	13	22	51.96	72	13	13
S	Blue mussel	Pr	mg/Kg	0.112	0.302	0.4955	1.815	6.840	40	31
S	Blue mussel	Pt	mg/kg	<DL	<DL	<DL	<DL	<DL	28	24

S	Blue mussel	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	25	11	11
S	Blue mussel	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	8	8
S	Blue mussel	Rb	mg/Kg	4.658	5.699	6.1895	6.872	180.37	40	31
S	Blue mussel	Re	mg/kg	<DL	<DL	<DL	<DL	3.36E-04	30	26
S	Blue mussel	Ru	mg/Kg	<DL	<DL	<DL	<DL	0.001	30	26
S	Blue mussel	Sb	mg/kg	<DL	<DL	0.012	0.014	0.026	41	37
S	Blue mussel	Sc	mg/kg	0.05	0.089	0.102	0.156	0.228	30	26
S	Blue mussel	Se	mg/kg	0.7	3.750	4.393	4.892	6.383	68	57
S	Blue mussel	Sm	mg/Kg	0.066	0.166	0.238	0.702	2.861	40	31
S	Blue mussel	Sn	mg/Kg	<DL	<DL	<DL	0.019	0.036	21	16
S	Blue mussel	Sr	mg/kg	3.2	15	31.539	35.49	65	41	37
S	Blue mussel	Ta	mg/kg	0.002	0.003	0.003	0.004	0.052	30	26
S	Blue mussel	Tb	mg/Kg	0.009	0.021	0.0305	0.168	0.357	40	31
S	Blue mussel	Te	mg/kg	<DL	<DL	0.002	0.004	0.007	30	26
S	Blue mussel	Th	mg/Kg	<DL	0.080	0.132	0.256	1.575	51	42
S	Blue mussel	Ti	mg/kg	2.3	9.600	11.533	24.217	35.703	41	37
S	Blue mussel	Tl	mg/kg	<DL	<DL	<DL	<DL	0.131	41	37
S	Blue mussel	Tm	mg/Kg	0.003	0.006	0.01	0.028	0.112	40	31
S	Blue mussel	U	mg/Kg	<DL	0.040	0.247	0.404	0.867	62	42
S	Blue mussel	V	mg/Kg	0.09	0.577	0.83	1.034	2.179	51	42
S	Blue mussel	W	mg/kg	0.013	0.018	0.0255	0.038	0.054	30	26
S	Blue mussel	Y	mg/Kg	0.24	0.506	0.8045	4.710	14.588	40	31
S	Blue mussel	Yb	mg/Kg	0.017	0.033	0.059	0.151	0.591	40	31
S	Blue mussel	Zn	mg/Kg	16	68.965	74.227	81.804	244.548	51	42
S	Blue mussel	Zr	mg/Kg	0.143	0.271	0.402	1.398	5.001	40	31
S	Crinkled snow lichen	Ag	mg/kg	<DL	0.001	0.002	0.008	0.1	53	50
S	Crinkled snow lichen	Al	mg/kg	79.327	156.795	289.393	410.621	802.194	50	47
S	Crinkled snow lichen	As	mg/kg	<DL	0.040	0.051	0.076	0.237	54	51
S	Crinkled snow lichen	Au	mg/kg	<DL	<DL	<DL	<DL	<DL	51	48
S	Crinkled snow lichen	B	mg/Kg	<DL	<DL	<DL	0.35	0.7	3	3
S	Crinkled snow lichen	Ba	mg/kg	4.031	7.442	9.843	17.846	108.629	53	50
S	Crinkled snow lichen	Be	mg/kg	<DL	0.027	0.042	0.130	2.2	53	50
S	Crinkled snow lichen	Bi	mg/kg	<DL	0.002	0.003	0.004	0.011	53	50
S	Crinkled snow lichen	Ca	mg/kg	579.614	1030.952	2312.046	3673.034	11728.483	53	50
S	Crinkled snow lichen	Cd	mg/kg	0.017	0.041	0.074	0.111	0.230	60	56
S	Crinkled snow lichen	Ce	mg/kg	1.113	2.443	4.043	13.629	115.518	50	47
S	Crinkled snow lichen	Co	mg/kg	0.041	0.067	0.110	0.194	1.011	54	51
S	Crinkled snow lichen	Cr	mg/kg	<DL	0.136	0.251	0.518	3.936	53	50
S	Crinkled snow lichen	Cs	mg/kg	0.014	0.032	0.059	0.119	1.787	50	47
S	Crinkled snow lichen	Cu	mg/kg	0.268	0.478	0.659	0.935	4	54	51
S	Crinkled snow lichen	Dy	mg/kg	0.041	0.090	0.139	0.417	5.032	50	47
S	Crinkled snow lichen	Er	mg/kg	0.020	0.044	0.066	0.189	2.482	50	47
S	Crinkled snow lichen	Eu	mg/kg	0.011	0.028	0.051	0.102	0.751	50	47
S	Crinkled snow lichen	Fe	mg/kg	54.584	144.046	226.611	421.102	1144.165	54	51
S	Crinkled snow lichen	Ga	mg/kg	0.067	0.144	0.233	0.547	3.240	50	47
S	Crinkled snow lichen	Gd	mg/kg	0.062	0.151	0.274	0.797	7.583	50	47
S	Crinkled snow lichen	Hf	mg/kg	0.003	0.011	0.020	0.037	0.223	50	47

S	Crinkled snow lichen	Hg	mg/kg	0.020	0.028	0.032	0.038	0.062	56	52
S	Crinkled snow lichen	Ho	mg/kg	0.008	0.016	0.025	0.074	0.957	50	47
S	Crinkled snow lichen	K	mg/kg	924.725	1343.928	1641.467	1891.197	2313.793	53	50
S	Crinkled snow lichen	La	mg/kg	0.598	1.298	2.215	8.119	119.516	50	47
S	Crinkled snow lichen	Li	mg/kg	<DL	0.055	0.125	0.213	1.041	50	47
S	Crinkled snow lichen	Lu	mg/kg	0.002	0.004	0.007	0.016	0.191	50	47
S	Crinkled snow lichen	Mg	mg/kg	352.553	597.200	721.598	981.806	1206.669	53	50
S	Crinkled snow lichen	Mn	mg/kg	16.830	32.186	51.414	73.633	135.183	53	50
S	Crinkled snow lichen	Mo	mg/kg	<DL	0.032	0.041	0.056	0.19	53	50
S	Crinkled snow lichen	Na	mg/kg	140.363	420.938	600	724.394	1242.014	53	50
S	Crinkled snow lichen	Nb	mg/kg	0.138	0.370	0.618	1.117	5.045	50	47
S	Crinkled snow lichen	Nd	mg/kg	0.466	0.997	1.616	5.058	60.595	50	47
S	Crinkled snow lichen	Ni	mg/kg	<DL	0.118	0.169	0.374	4.941	54	51
S	Crinkled snow lichen	P	mg/kg	262.105	486.725	606.965	787.435	1298.859	53	50
S	Crinkled snow lichen	Pb	mg/kg	0.176	0.549	0.818	1.729	11.408	55	52
S	Crinkled snow lichen	Pb-210	Bq/kg	260	260	260	260	260	1	1
S	Crinkled snow lichen	Pd	mg/kg	6.29E-04	0.002	0.013	0.044	0.156	50	47
S	Crinkled snow lichen	Po-210	Bq/kg	114.9	235.075	299.15	456.6	680.1	22	22
S	Crinkled snow lichen	Pr	mg/kg	0.131	0.278	0.449	1.458	18.622	50	47
S	Crinkled snow lichen	Pt	mg/kg	<DL	<DL	<DL	<DL	0.003	50	47
S	Crinkled snow lichen	Ra-226	Bq/kg	<DL	14.500	29	58.5	88	3	3
S	Crinkled snow lichen	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	1	1
S	Crinkled snow lichen	Rb	mg/kg	0.929	2.144	3.256	4.259	10.097	50	47
S	Crinkled snow lichen	Re	mg/kg	<DL	<DL	<DL	6.83E-05	0.001	50	47
S	Crinkled snow lichen	Ru	mg/Kg	<DL	<DL	<DL	<DL	0.001	50	47
S	Crinkled snow lichen	Sb	mg/kg	<DL	0.003	0.005	0.008	0.059	53	50
S	Crinkled snow lichen	Sc	mg/kg	0.026	0.070	0.096	0.13	1.321	50	47
S	Crinkled snow lichen	Se	mg/kg	<DL	0.047	0.060	0.076	0.2	59	55
S	Crinkled snow lichen	Sm	mg/kg	0.074	0.162	0.267	0.809	8.687	50	47
S	Crinkled snow lichen	Sn	mg/kg	<DL	<DL	<DL	0.35	0.7	3	3
S	Crinkled snow lichen	Sr	mg/kg	5.354	11.832	20.081	29.636	104.551	53	50
S	Crinkled snow lichen	Ta	mg/kg	0.002	0.004	0.011	0.020	0.061	50	47
S	Crinkled snow lichen	Tb	mg/kg	0.008	0.018	0.027	0.093	0.968	50	47
S	Crinkled snow lichen	Te	mg/kg	<DL	<DL	<DL	6.55E-04	0.004	50	47
S	Crinkled snow lichen	Th	mg/Kg	<DL	0.080	0.128	0.389	4.7	53	50
S	Crinkled snow lichen	Ti	mg/kg	5.9	17.181	32	53.869	94.508	53	50
S	Crinkled snow lichen	Tl	mg/kg	<DL	<DL	<DL	0.006	0.047	53	50
S	Crinkled snow lichen	Tm	mg/kg	0.003	0.006	0.008	0.023	0.298	50	47
S	Crinkled snow lichen	U	mg/Kg	<DL	0.031	0.062	0.206	1.6	56	50
S	Crinkled snow lichen	V	mg/kg	0.114	0.217	0.417	0.646	3.156	53	50
S	Crinkled snow lichen	W	mg/kg	<DL	0.008	0.016	0.020	0.110	50	47
S	Crinkled snow lichen	Y	mg/kg	0.267	0.502	0.782	2.673	47.257	50	47
S	Crinkled snow lichen	Yb	mg/kg	0.015	0.032	0.049	0.127	1.530	50	47
S	Crinkled snow lichen	Zn	mg/kg	8.397	16.503	22.183	28.413	90	55	52
S	Crinkled snow lichen	Zr	mg/kg	0.131	0.433	0.871	1.798	12.639	50	47
S	Filtered water	Ag	µg/l	<DL	<DL	0.004	0.009	0.051	119	110
S	Filtered water	Al	µg/l	2.8	15.065	25.2	31.7	233.15	119	110

S	Filtered water	As	µg/l	<DL	<DL	0.105	0.506	4.827	119	110
S	Filtered water	Au	µg/l	<DL	<DL	0.003	0.007	0.022	119	110
S	Filtered water	B	µg/l	0.224	0.649	0.815	1.121	2.829	19	19
S	Filtered water	Ba	µg/l	0.217	0.525	2	5.421	46.597	119	110
S	Filtered water	Be	µg/l	0.002	0.023	0.051	0.122	0.771	119	110
S	Filtered water	Bi	µg/l	<DL	<DL	<DL	2.50E-04	0.008	119	110
S	Filtered water	Ca	µg/l	275	1632.5	2060	3207.5	7677	119	110
S	Filtered water	Cd	µg/l	<DL	0.002	0.004	0.010	0.039	119	110
S	Filtered water	Ce	µg/l	0.001	0.020	0.042	0.094	0.493	119	110
S	Filtered water	Cl	µg/l	3209	4965	6824	10640.5	19655	83	83
S	Filtered water	Co	µg/l	<DL	0.002	0.005	0.008	0.086	119	110
S	Filtered water	Cr	µg/l	<DL	<DL	<DL	0.025	0.14	119	110
S	Filtered water	Cs	µg/l	0.001	0.006	0.01	0.014	0.181	119	110
S	Filtered water	Cu	µg/l	<DL	0.108	0.186	0.284	3.802	119	110
S	Filtered water	Dy	µg/l	3.00E-04	0.007	0.010	0.022	0.484	118	110
S	Filtered water	Er	µg/l	3.10E-04	0.004	0.006	0.0102	0.278	118	110
S	Filtered water	Eu	µg/l	<DL	0.001	0.002	0.007	0.051	118	110
S	Filtered water	F	µg/l	<DL	153.000	1039	1914	28302	91	91
S	Filtered water	Fe	µg/l	<DL	2.546	7.37	40.203	257.1	118	110
S	Filtered water	Ga	µg/l	<DL	0.008	0.027	0.093	0.968	119	110
S	Filtered water	Gd	µg/l	5.00E-04	0.011	0.016	0.036	0.622	118	110
S	Filtered water	Ge	µg/l	0.018	0.023	0.028	0.0327	0.038	2	2
S	Filtered water	Hf	µg/l	<DL	0.004	0.009	0.019	0.471	118	110
S	Filtered water	Hg	µg/l	<DL	<DL	<DL	<DL	0.013	119	110
S	Filtered water	Ho	µg/l	5.00E-05	0.001	0.002	0.004	0.098	118	110
S	Filtered water	K	µg/l	45	272	333	437.5	972	119	110
S	Filtered water	La	µg/l	0.007	0.046	0.08	0.222	0.604	119	110
S	Filtered water	Li	µg/l	<DL	0.175	0.39	3.482	5.87	119	110
S	Filtered water	Lu	µg/l	<DL	1.85E-04	5.00E-04	0.001	0.004	43	43
S	Filtered water	Mg	µg/l	59.2	283.800	425	700	1585	119	110
S	Filtered water	Mn	µg/l	<DL	0.380	3.165	3.82	53.61	94	86
S	Filtered water	Mo	µg/l	<DL	0.371	1.565	2.590	29.018	119	110
S	Filtered water	Na	µg/l	670.8	5387.5	7970	10168	62174	119	110
S	Filtered water	Nb	µg/l	<DL	0.004	0.008	0.014	1.608	118	110
S	Filtered water	Nd	µg/l	0.005	0.036	0.07	0.171	0.579	119	110
S	Filtered water	Ni	µg/l	<DL	<DL	0.026	0.054	0.289	119	110
S	Filtered water	P	µg/l	<DL	<DL	1.15	2.13	98.5	119	110
S	Filtered water	Pb	µg/l	<DL	<DL	0.059	0.102	7.064	119	110
S	Filtered water	Pd	µg/l	<DL	<DL	0.001	0.002	0.005	119	110
S	Filtered water	Pr	µg/l	0.001	0.019	0.027	0.066	0.916	118	110
S	Filtered water	Pt	µg/l	<DL	<DL	<DL	<DL	0.003	119	110
S	Filtered water	Rb	µg/l	0.227	0.694	0.982	1.825	7.34	119	110
S	Filtered water	Re	µg/l	<DL	<DL	1.00E-04	2.00E-04	0.005	118	110
S	Filtered water	Rh	µg/l	0.001	0.001	0.001	0.001	0.002	2	2
S	Filtered water	Ru	µg/l	<DL	<DL	<DL	<DL	0.001	119	110
S	Filtered water	S	µg/l	228	423.250	457	506	1851	86	86
S	Filtered water	Sb	µg/l	<DL	<DL	0.035	0.087	1.408	119	110

S	Filtered water	Sc	µg/l	<DL	0.010	0.02	0.021	0.156	119	110
S	Filtered water	Se	µg/l	<DL	0.029	0.064	0.116	0.39	119	110
S	Filtered water	Si	µg/l	4.89	20.660	26.42	41.35	73.8	19	19
S	Filtered water	Sm	µg/l	0.001	0.012	0.018	0.044	0.545	118	110
S	Filtered water	Sn	µg/l	<DL	<DL	0.002	0.02	0.179	95	86
S	Filtered water	Sr	µg/l	1.98	8.585	9.54	18.43	41	119	110
S	Filtered water	Ta	µg/l	<DL	<DL	2.50E-04	0.007	0.054	118	110
S	Filtered water	Tb	µg/l	1.50E-04	0.001	0.002	0.004	0.082	118	110
S	Filtered water	Te	µg/l	<DL	<DL	<DL	0.002	0.014	119	110
S	Filtered water	Th	µg/l	<DL	0.002	0.003	0.005	0.031	119	110
S	Filtered water	Ti	µg/l	<DL	0.030	0.05	0.1	0.335	119	110
S	Filtered water	Tl	µg/l	<DL	<DL	0.002	0.009	0.125	119	110
S	Filtered water	Tm	µg/l	<DL	5.00E-04	8.15E-04	0.001	0.037	118	110
S	Filtered water	U	µg/l	0.004	0.024	0.081	0.175	2.823	119	110
S	Filtered water	V	µg/l	<DL	0.020	0.05	0.06	0.431	119	110
S	Filtered water	W	µg/l	<DL	0.004	0.015	0.030	0.882	119	110
S	Filtered water	Y	µg/l	0.007	0.027	0.051	0.094	0.619	119	110
S	Filtered water	Yb	µg/l	4.80E-04	0.003	0.005	0.008	0.227	118	110
S	Filtered water	Zn	µg/l	0.133	0.790	1.413	2.005	14.167	119	110
S	Filtered water	Zr	µg/l	<DL	0.019	0.055	0.113	0.637	119	110
S	Seaweed	Ag	mg/kg	<DL	0.062	0.087	0.100	0.15	20	19
S	Seaweed	Al	mg/kg	27.612	55.386	315.724	536.015	821.404	14	13
S	Seaweed	As	mg/kg	1.06	32.200	38.92	43.934	58.24	39	28
S	Seaweed	Au	mg/kg	<DL	<DL	<DL	<DL	0.031	17	15
S	Seaweed	B	mg/Kg	15	16	64.5	117.5	120	6	6
S	Seaweed	Ba	mg/Kg	1.1	12.374	15.487	30.537	168.194	36	26
S	Seaweed	Be	mg/Kg	<DL	0.004	0.024	0.068	0.227	36	26
S	Seaweed	Bi	mg/kg	<DL	<DL	0.001	0.002	0.006	20	19
S	Seaweed	Ca	mg/kg	970	9250	12834.617	16388.848	19552.58	20	19
S	Seaweed	Cd	mg/Kg	0.164	0.485	0.773	1.133	1.632	39	28
S	Seaweed	Ce	mg/Kg	<DL	0.442	0.836	1.477	2.046	30	20
S	Seaweed	Co	mg/Kg	0.089	0.319	0.448	0.684	1.176	39	28
S	Seaweed	Cr	mg/Kg	<DL	0.093	0.183	0.306	1.1	39	28
S	Seaweed	Cs	mg/kg	0.029	0.040	0.058	0.076	0.104	14	13
S	Seaweed	Cu	mg/kg	<DL	1.766	2.116	2.588	4.175	23	21
S	Seaweed	d.m.%	%	11.7	11.970	15.58	17.61	20.48	23	7
S	Seaweed	Dy	mg/Kg	0.020	0.059	0.077	0.101	0.205	30	20
S	Seaweed	Er	mg/Kg	0.011	0.030	0.050	0.076	0.130	30	20
S	Seaweed	Eu	mg/Kg	0.014	0.028	0.044	0.066	0.184	30	20
S	Seaweed	Fe	mg/Kg	9	36.561	66.147	191.742	639.101	39	28
S	Seaweed	Ga	mg/kg	0.027	0.052	0.142	0.212	0.308	14	13
S	Seaweed	Gd	mg/Kg	0.032	0.116	0.160	0.241	0.370	30	20
S	Seaweed	Hf	mg/kg	<DL	0.005	0.009	0.012	0.017	14	13
S	Seaweed	Hg	mg/kg	<DL	0.002	0.005	0.007	0.02	33	22
S	Seaweed	Ho	mg/Kg	0.003	0.011	0.014	0.021	0.044	30	20
S	Seaweed	K	mg/kg	3100	19321.078	24240.486	26925.848	32126.829	20	19
S	Seaweed	La	mg/Kg	<DL	0.345	0.845	1.165	2.691	30	20

S	Seaweed	Li	mg/kg	0.212	0.416	0.569	0.685	1.045	14	13
S	Seaweed	Lu	mg/Kg	0.001	0.004	0.006	0.007	0.013	30	20
S	Seaweed	Mg	mg/kg	1000	8060.584	8415.778	8721.788	9607.26	20	19
S	Seaweed	Mn	mg/Kg	2.4	21.866	31.427	46.162	121.042	36	26
S	Seaweed	Mo	mg/Kg	<DL	<DL	<DL	0.107	0.142	36	26
S	Seaweed	Na	mg/kg	1600	12096.082	19002.002	23948.742	39000	20	19
S	Seaweed	Nb	mg/Kg	0.029	0.086	0.150	0.269	0.597	30	20
S	Seaweed	Nd	mg/Kg	0.154	0.566	0.808	1.256	2.061	30	20
S	Seaweed	Ni	mg/Kg	<DL	0.551	0.83	1.324	2.294	39	28
S	Seaweed	P	mg/kg	200	960.858	1121.279	1326.842	1882.325	20	19
S	Seaweed	Pb	mg/Kg	<DL	0.091	0.231	0.340	0.85	39	28
S	Seaweed	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	3	3
S	Seaweed	Pd	mg/kg	0.021	0.957	1.223	1.548	1.698	14	13
S	Seaweed	Po-210	Bq/kg	<DL	<DL	<DL	11.66	19.6	9	9
S	Seaweed	Pr	mg/Kg	0.034	0.132	0.213	0.311	0.561	30	20
S	Seaweed	Pt	mg/kg	<DL	<DL	<DL	<DL	<DL	13	12
S	Seaweed	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	11	6	6
S	Seaweed	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	3	3
S	Seaweed	Rb	mg/Kg	8.129	11.616	15.033	19.112	26.217	30	20
S	Seaweed	Re	mg/kg	0.009	0.015	0.023	0.056	0.087	14	13
S	Seaweed	Ru	mg/Kg	<DL	0.006	0.008	0.010	0.011	14	13
S	Seaweed	Sb	mg/Kg	<DL	0.008	0.012	0.015	0.022	36	26
S	Seaweed	Sc	mg/kg	0.017	0.062	0.143	0.222	0.317	14	13
S	Seaweed	Se	mg/kg	<DL	0.012	0.021	0.030	0.04	47	28
S	Seaweed	Sm	mg/Kg	0.022	0.092	0.137	0.202	0.313	30	20
S	Seaweed	Sn	mg/kg	<DL	<DL	<DL	<DL	<DL	6	6
S	Seaweed	Sr	mg/kg	68	672.768	785.360	912.644	1148.521	20	19
S	Seaweed	Ta	mg/kg	<DL	0.001	0.002	0.004	0.007	14	13
S	Seaweed	Tb	mg/Kg	0.004	0.013	0.018	0.033	0.052	30	20
S	Seaweed	Te	mg/kg	<DL	0.001	0.002	0.003	0.004	14	13
S	Seaweed	Th	mg/Kg	<DL	0.018	0.044	0.129	0.316	36	26
S	Seaweed	Ti	mg/kg	0.6	2.099	4.561	28.548	52.207	20	19
S	Seaweed	Tl	mg/kg	<DL	<DL	<DL	0.006	0.016	20	19
S	Seaweed	Tm	mg/Kg	0.001	0.004	0.005	0.007	0.016	30	20
S	Seaweed	U	mg/Kg	0.15	0.552	0.854	1.149	1.560	42	26
S	Seaweed	V	mg/Kg	0.06	0.148	0.307	0.465	1.111	36	26
S	Seaweed	W	mg/kg	<DL	0.003	0.007	0.015	0.027	14	13
S	Seaweed	Y	mg/Kg	<DL	0.238	0.357	0.478	1.711	30	20
S	Seaweed	Yb	mg/Kg	0.009	0.026	0.037	0.051	0.089	30	20
S	Seaweed	Zn	mg/Kg	<DL	11.144	19.614	36.226	129.617	39	28
S	Seaweed	Zr	mg/Kg	0.138	0.388	0.560	0.866	2.4	30	20
S	Sediment	Ag	mg/kg	<DL	<DL	<DL	0.065	0.26	4	4
S	Sediment	Al	mg/kg	0.045	35000	63439	65940	68618	9	9
S	Sediment	As	mg/kg	3.72E-04	2.600	5.6	7.485	11	7	6
S	Sediment	Au	mg/kg	1.40E-06	1.98E-06	2.55E-06	3.13E-06	3.70E-06	2	2
S	Sediment	B	mg/Kg	0.001	0.001	3.201	9.3	18	4	4
S	Sediment	Ba	mg/kg	8.86E-04	8.94E-04	22.000	50.75	71	4	4

S	Sediment	Be	mg/kg	8.90E-05	1.04E-04	15.000	42.75	81	4	4
S	Sediment	Bi	mg/kg	<DL	<DL	<DL	1.25E-07	5.00E-07	4	4
S	Sediment	Ca	mg/kg	2.72E+00	2.784	4051.404	9075	12000	4	4
S	Sediment	Cd	mg/kg	4.30E-06	0.168	0.2	0.215	0.42	9	9
S	Sediment	Ce	mg/kg	7.00E-06	8.00E-06	9.00E-06	1.00E-05	1.10E-05	2	2
S	Sediment	Cl	mg/Kg	6.24E+00	6.250	6.261	6.271	6.281	2	2
S	Sediment	Co	mg/kg	1.00E-06	2.50E-06	1.400	3.225	4.5	4	4
S	Sediment	Cr	mg/kg	<DL	5.25E-06	1.100	2.9	5	4	4
S	Sediment	Cs	mg/kg	1.70E-05	1.78E-05	1.85E-05	1.93E-05	2.00E-05	2	2
S	Sediment	Cu	mg/kg	<DL	4.900	13	22.623	29.906	9	9
S	Sediment	Dy	mg/Kg	2.99E-06	3.01E-06	3.03E-06	3.04E-06	3.06E-06	2	2
S	Sediment	Er	mg/Kg	1.64E-06	1.90E-06	2.16E-06	2.41E-06	2.67E-06	2	2
S	Sediment	Eu	mg/Kg	2.00E-07	2.50E-07	3.00E-07	3.50E-07	4.00E-07	2	2
S	Sediment	F	mg/Kg	3.12E+00	3.119	3.1205	3.122	3.124	2	2
S	Sediment	Fe	mg/kg	<DL	<DL	11500	24000	27000	4	4
S	Sediment	Ga	mg/kg	3.97E-04	4.03E-04	4.08E-04	4.14E-04	4.19E-04	2	2
S	Sediment	Gd	mg/Kg	3.60E-06	3.65E-06	3.70E-06	3.75E-06	3.80E-06	2	2
S	Sediment	Hf	mg/Kg	9.80E-06	1.17E-05	1.37E-05	1.56E-05	1.75E-05	2	2
S	Sediment	Hg	mg/kg	<DL	0.031	0.04615	0.076	0.128	32	10
S	Sediment	Ho	mg/Kg	7.00E-07	7.30E-07	7.60E-07	7.90E-07	8.20E-07	2	2
S	Sediment	K	mg/kg	4.66E-01	0.480	600.242	1275	1500	4	4
S	Sediment	La	mg/kg	2.00E-05	2.10E-05	2.20E-05	2.30E-05	2.40E-05	2	2
S	Sediment	Li	mg/kg	0.002	5.439	19.652	26.88	29.035	7	7
S	Sediment	Lu	mg/Kg	1.10E-07	1.48E-07	1.85E-07	2.23E-07	2.60E-07	2	2
S	Sediment	Mg	mg/kg	4.31E-01	0.444	1350.224	2900	3500	4	4
S	Sediment	Mn	mg/kg	0.00001	0.00001	600	1400	2000	4	4
S	Sediment	Mo	mg/kg	0.004	0.004	1.102	2.275	2.5	4	4
S	Sediment	Na	mg/kg	13.688	13.990	10507.045	21500	23000	4	4
S	Sediment	Nb	mg/Kg	1.00E-07	6.00E-07	1.10E-06	1.60E-06	2.10E-06	2	2
S	Sediment	Nd	mg/kg	2.20E-05	2.28E-05	2.35E-05	2.43E-05	2.50E-05	2	2
S	Sediment	Ni	mg/kg	<DL	2.300	5	9.138	10.278	9	9
S	Sediment	P	mg/kg	<DL	<DL	400	817.5	870	4	4
S	Sediment	Pb	mg/kg	<DL	13.650	18.14	19.33	110	9	9
S	Sediment	Pb-210	Bq/kg	240	240	240	240	240	1	1
S	Sediment	Pd	mg/kg	<DL	<DL	<DL	<DL	<DL	2	2
S	Sediment	Po-210	Bq/kg	230	230	230	230	230	1	1
S	Sediment	Pr	mg/Kg	4.90E-06	5.38E-06	5.85E-06	6.33E-06	6.80E-06	2	2
S	Sediment	Pt	mg/kg	<DL	2.50E-08	5.00E-08	7.50E-08	1.00E-07	2	2
S	Sediment	Ra-226	Bq/kg	340	407.5	475	542.5	610	2	2
S	Sediment	Ra-228	Bq/kg	230	230	230	230	230	1	1
S	Sediment	Rb	mg/kg	0.003	0.003	0.003	0.003	0.003	2	2
S	Sediment	Re	mg/Kg	2.00E-07	2.25E-07	2.50E-07	2.75E-07	3.00E-07	2	2
S	Sediment	Ru	mg/Kg	<DL	<DL	<DL	<DL	<DL	2	2
S	Sediment	S	mg/kg	5.63E-01	0.578	0.593	0.608	0.623	2	2
S	Sediment	Sb	mg/kg	1.93E-04	1.98E-04	0.210	0.445	0.52	4	4
S	Sediment	Sc	mg/kg	8.90E-05	8.93E-05	8.95E-05	8.98E-05	9.00E-05	2	2
S	Sediment	Se	mg/kg	7.60E-05	7.98E-05	0.850	1.825	2.2	4	4

S	Sediment	Si	mg/Kg	4.26E-02	0.043	0.044	0.044	0.045	2	2
S	Sediment	Sm	mg/kg	3.00E-06	3.55E-06	4.10E-06	4.65E-06	5.20E-06	2	2
S	Sediment	Sn	mg/kg	<DL	<DL	8	18.75	27	4	4
S	Sediment	Sr	mg/kg	1.30E-02	0.013	36.007	89	140	4	4
S	Sediment	Ta	mg/Kg	<DL	2.50E-07	5.00E-07	7.50E-07	1.00E-06	2	2
S	Sediment	Tb	mg/Kg	3.50E-07	4.20E-07	4.90E-07	5.60E-07	6.30E-07	2	2
S	Sediment	Te	mg/kg	9.00E-06	1.03E-05	1.15E-05	1.28E-05	1.40E-05	2	2
S	Sediment	Th	mg/Kg	1.20E-06	1.80E-06	30.5	93.25	190	4	4
S	Sediment	Ti	mg/kg	2.04E-04	2.07E-04	350	715	760	4	4
S	Sediment	Tl	mg/kg	1.20E-05	2.18E-05	0.445	0.918	1	4	4
S	Sediment	Tm	mg/Kg	2.40E-07	2.75E-07	3.10E-07	3.45E-07	3.80E-07	2	2
S	Sediment	U	mg/Kg	3.27E-04	5.750	30	46.75	61	6	4
S	Sediment	V	mg/kg	4.80E-05	5.85E-05	4.750	11.125	16	4	4
S	Sediment	W	mg/kg	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04	2	2
S	Sediment	Y	mg/kg	2.70E-05	2.80E-05	2.90E-05	3.00E-05	3.10E-05	2	2
S	Sediment	Yb	mg/Kg	1.77E-06	1.79E-06	1.82E-06	1.84E-06	1.86E-06	2	2
S	Sediment	Zn	mg/kg	0.002	56.690	92.62	104.93	730	9	9
S	Sediment	Zr	mg/kg	3.70E-05	4.93E-05	6.15E-05	7.38E-05	8.60E-05	2	2
S	Shorthorn sculpin	Ag	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	As	mg/kg	1.3	1.300	2	4.4	10	5	5
S	Shorthorn sculpin	B	mg/Kg	<DL	<DL	0.5	0.6	1.8	5	5
S	Shorthorn sculpin	Ba	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Be	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Bi	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Ca	mg/kg	68	160	220	710	1400	5	5
S	Shorthorn sculpin	Cd	mg/kg	<DL	0.330	0.465	0.657	2.853	32	31
S	Shorthorn sculpin	Co	mg/kg	0.006	0.006	0.013	0.023	0.028	5	5
S	Shorthorn sculpin	Cr	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Cu	mg/kg	0.9	1.100	1.2	1.6	1.9	5	5
S	Shorthorn sculpin	d.m.%	%	22.64	31.165	34.695	38.075	53	46	46
S	Shorthorn sculpin	Fe	mg/kg	4	4	5	11	33	5	5
S	Shorthorn sculpin	Hg	mg/kg	0.005	0.007	0.009	0.014	0.036	27	26
S	Shorthorn sculpin	K	mg/kg	2500	2800	3400	3600	3600	5	5
S	Shorthorn sculpin	Mg	mg/kg	200	210	240	240	250	5	5
S	Shorthorn sculpin	Mn	mg/kg	<DL	<DL	0.4	0.6	1.1	5	5
S	Shorthorn sculpin	Mo	mg/kg	<DL	<DL	<DL	<DL	0.09	5	5
S	Shorthorn sculpin	Na	mg/kg	980	1300	1400	1400	2400	5	5
S	Shorthorn sculpin	Ni	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	P	mg/kg	1500	1500	1800	2600	3400	5	5
S	Shorthorn sculpin	Pb	mg/kg	<DL	4.40E-04	0.007	0.015	0.058	31	30
S	Shorthorn sculpin	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	2	2
S	Shorthorn sculpin	Po-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	4	4
S	Shorthorn sculpin	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	2	2
S	Shorthorn sculpin	Sb	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Se	mg/kg	0.2	0.755	0.880	0.958	1.425	32	31
S	Shorthorn sculpin	Sn	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5

S	Shorthorn sculpin	Sr	mg/kg	0.6	0.700	1.5	5.3	8.1	5	5
S	Shorthorn sculpin	Th	mg/Kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	Ti	mg/kg	1	1.200	1.3	1.7	2	5	5
S	Shorthorn sculpin	Tl	mg/kg	<DL	<DL	<DL	<DL	<DL	5	5
S	Shorthorn sculpin	U	mg/Kg	<DL	<DL	<DL	<DL	0.02	10	5
S	Shorthorn sculpin	V	mg/Kg	<DL	<DL	0.06	0.06	0.07	5	5
S	Shorthorn sculpin	Zn	mg/kg	8	9	10	18	61	5	5
S	Soil	Ag	mg/Kg	<DL	0.107	0.1285	0.196	0.266	24	22
S	Soil	Al	mg/kg	8788.775	11128.991	15700.517	31594.816	75039	30	27
S	Soil	As	mg/Kg	<DL	0.906	1.133	1.392	7.1	30	27
S	Soil	Au	mg/Kg	<DL	<DL	<DL	<DL	<DL	21	19
S	Soil	B	mg/Kg	<DL	<DL	<DL	<DL	<DL	3	3
S	Soil	Ba	mg/Kg	49.683	62.347	72.334	108.198	694.597	24	22
S	Soil	Be	mg/Kg	1.1	2.253	2.668	3.686	24	24	22
S	Soil	Bi	mg/Kg	<DL	0.051	0.062	0.087	0.194	24	22
S	Soil	Ca	mg/Kg	3200	4321.276	7436.674	8681.887	11018.383	24	22
S	Soil	Cd	mg/kg	<DL	0.195	0.366	0.479	0.854	30	27
S	Soil	Ce	mg/Kg	76.532	121.082	155.643	164.796	205.363	21	19
S	Soil	Co	mg/Kg	1.8	3.712	4.939	5.579	39.949	24	22
S	Soil	Cr	mg/kg	6.639	16.327	26.595	39.413	196.44	30	27
S	Soil	Cs	mg/Kg	0.691	0.811	1.333	1.523	2.144	21	19
S	Soil	Cu	mg/kg	2.46	4.864	6.539	13.026	83.779	30	27
S	Soil	Dy	mg/kg	3.154	4.022	5.754	6.444	10.114	21	19
S	Soil	Er	mg/kg	1.517	2.012	2.916	3.326	5.136	21	19
S	Soil	Eu	mg/kg	0.811	1.347	1.534	1.676	2.875	21	19
S	Soil	Fe	mg/kg	17216.379	28129.934	31431.712	50645.686	70756	30	27
S	Soil	Ga	mg/Kg	8.473	10.845	11.657	14.544	18.073	21	19
S	Soil	Gd	mg/kg	6.738	11.663	13.25	14.037	20.666	21	19
S	Soil	Hf	mg/kg	0.768	1.601	1.798	2.092	2.754	21	19
S	Soil	Hg	mg/kg	0.018	0.031	0.038	0.055	0.09	29	27
S	Soil	Ho	mg/kg	0.588	0.767	1.091	1.235	1.943	21	19
S	Soil	K	mg/Kg	400	2516.432	2673.33	3319.457	11665.205	24	22
S	Soil	La	mg/Kg	37.652	57.846	75.338	86.79	107.626	21	19
S	Soil	Li	mg/Kg	6.864	7.646	9.076	15.835	25.622	21	19
S	Soil	Lu	mg/kg	0.192	0.216	0.313	0.432	0.652	21	19
S	Soil	Mg	mg/Kg	1620.447	2838.243	3377.623	4318.213	12167.14	24	22
S	Soil	Mn	mg/Kg	220	523.374	608.795	773.855	1254.968	24	22
S	Soil	Mo	mg/Kg	0.204	0.599	0.772	1.243	7.9	24	22
S	Soil	Na	mg/Kg	210	1095.712	1220.503	2206.164	6099.437	24	22
S	Soil	Nb	mg/kg	0.075	0.261	0.734	2.093	5.475	21	19
S	Soil	Nd	mg/Kg	26.199	46.500	54.345	57.639	85.349	21	19
S	Soil	Ni	mg/kg	2.643	4.323	7.080	16.250	201.869	30	27
S	Soil	P	mg/Kg	722.46	983.815	1052.042	1513.253	2668.727	24	22
S	Soil	Pb	mg/kg	5.07	12.198	13.284	17.551	87	30	27
S	Soil	Pd	mg/Kg	0.119	0.141	0.189	0.203	0.296	21	19
S	Soil	Pr	mg/kg	7.537	12.734	15.135	16.503	22.891	21	19
S	Soil	Pt	mg/Kg	0.019	0.030	0.036	0.041	0.05	21	19

S	Soil	Ra	mg/Kg	0.125	0.263	0.4	0.435	0.47	3	3
S	Soil	Rb	mg/Kg	19.234	26.225	31.549	41.589	61.864	21	19
S	Soil	Re	mg/kg	0.003	0.004	0.006	0.008	0.012	21	19
S	Soil	Ru	mg/kg	<DL	<DL	<DL	<DL	0.002	21	19
S	Soil	Sb	mg/Kg	<DL	<DL	<DL	<DL	0.46	24	22
S	Soil	Sc	mg/Kg	2.336	4.089	5.762	6.341	11.98	21	19
S	Soil	Se	mg/kg	<DL	0.100	0.1785	0.266	1.4	30	27
S	Soil	Sm	mg/kg	4.555	7.941	9.49	9.959	15.268	21	19
S	Soil	Sn	mg/Kg	<DL	4.750	9.5	10.75	12	3	3
S	Soil	Sr	mg/Kg	27	40.163	59.902	87.048	159.454	24	22
S	Soil	Ta	mg/Kg	0.01	0.020	0.028	0.04	0.056	21	19
S	Soil	Tb	mg/kg	0.668	0.928	1.283	1.363	2.125	21	19
S	Soil	Te	mg/Kg	<DL	<DL	<DL	<DL	0.04	21	19
S	Soil	Th	mg/Kg	5.835	8.171	9.826	11.811	79	24	22
S	Soil	Ti	mg/Kg	254.886	347.494	401.030	439.367	1200	24	22
S	Soil	Tl	mg/Kg	<DL	0.100	0.1125	0.161	0.86	24	22
S	Soil	Tm	mg/kg	0.212	0.267	0.397	0.475	0.721	21	19
S	Soil	U	mg/Kg	1.866	2.710	3.472	4.834	74	27	22
S	Soil	V	mg/kg	8.611	22.231	37.145	47.503	234.965	30	27
S	Soil	W	mg/Kg	<DL	0.016	0.02	0.047	0.101	21	19
S	Soil	Y	mg/Kg	13.433	17.166	24.223	28.594	45.05	21	19
S	Soil	Yb	mg/kg	1.309	1.534	2.309	2.999	4.377	21	19
S	Soil	Zn	mg/kg	35.16	60.557	68.538	100.651	380	30	27
S	Soil	Zr	mg/Kg	36.16	78.836	85.347	123.98	174.49	21	19
S	Unfiltered water	Ag	µg/l	<DL	<DL	<DL	<DL	0.287	30	25
S	Unfiltered water	Al	µg/l	<DL	1.262	14	27.475	65.1	30	25
S	Unfiltered water	As	µg/l	<DL	0.118	0.735	1.818	2.83	30	25
S	Unfiltered water	Au	µg/l	<DL	0.004	0.007	0.012	0.021	30	25
S	Unfiltered water	Ba	µg/l	0.098	0.323	1.142	2.573	6.93	30	25
S	Unfiltered water	Be	µg/l	0.001	0.010	0.021	0.043	0.142	30	25
S	Unfiltered water	Bi	µg/l	<DL	2.25E-04	0.001	0.002	0.005	30	25
S	Unfiltered water	Ca	µg/l	1361	1750	2076.65	2849.75	3505	30	25
S	Unfiltered water	Cd	µg/l	<DL	0.004	0.01	0.023	0.091	30	25
S	Unfiltered water	Ce	µg/l	<DL	0.004	0.032	0.080	0.115	30	25
S	Unfiltered water	Co	µg/l	<DL	<DL	0.003	0.009	0.019	30	25
S	Unfiltered water	Cr	µg/l	<DL	0.016	0.024	0.038	0.151	30	25
S	Unfiltered water	Cs	µg/l	<DL	0.005	0.013	0.0198	0.063	30	25
S	Unfiltered water	Cu	µg/l	0.005	0.049	0.078	0.315	11.58	30	25
S	Unfiltered water	Fe	µg/l	<DL	0.577	2.638	4.717	24.35	30	25
S	Unfiltered water	Ga	µg/l	0.009	0.034	0.089	0.153	0.213	30	25
S	Unfiltered water	Hg	µg/l	<DL	<DL	<DL	<DL	0.127	30	25
S	Unfiltered water	K	µg/l	167	327.703	347.71	370.75	651	30	25
S	Unfiltered water	La	µg/l	0.014	0.027	0.121	0.210	0.301	30	25
S	Unfiltered water	Li	µg/l	0.22	0.556	0.818	0.888	1.59	30	25
S	Unfiltered water	Mg	µg/l	342	412.500	478.8	518.8	644	30	25
S	Unfiltered water	Mn	µg/l	<DL	0.003	0.055	0.208	0.41	30	25
S	Unfiltered water	Mo	µg/l	0.432	2.324	4.484	5.374	6.218	30	25

S	Unfiltered water	Na	µg/l	3937	5530.750	7726	9512.225	11857	30	25
S	Unfiltered water	Nd	µg/l	0.018	0.033	0.116	0.265	0.479	30	25
S	Unfiltered water	Ni	µg/l	<DL	<DL	0.032	0.099	0.374	30	25
S	Unfiltered water	P	µg/l	<DL	<DL	<DL	0.724	5.3	30	25
S	Unfiltered water	Pb	µg/l	0.001	0.021	0.055	0.167	0.487	30	25
S	Unfiltered water	Pd	µg/l	<DL	<DL	0.002	0.004	0.011	30	25
S	Unfiltered water	Pt	µg/l	<DL	<DL	<DL	<DL	<DL	18	13
S	Unfiltered water	Rb	µg/l	0.579	1.721	2.14	2.474	4.85	30	25
S	Unfiltered water	Rh	µg/l	<DL	<DL	<DL	0.002	0.004	12	12
S	Unfiltered water	S	µg/l	73.951	503.128	904.915	1186.75	1540	30	25
S	Unfiltered water	Sb	µg/l	<DL	0.027	0.037	0.064	0.124	30	25
S	Unfiltered water	Sc	µg/l	0.097	0.168	0.231	0.311	0.883	30	25
S	Unfiltered water	Se	µg/l	<DL	0.010	0.199	0.284	0.433	30	25
S	Unfiltered water	Si	µg/l	44.403	71.947	89.887	110.008	114.02	12	12
S	Unfiltered water	Sn	µg/l	<DL	0.018	0.048	0.093	1.187	30	25
S	Unfiltered water	Sr	µg/l	6.23	8.990	11.552	14.505	20.97	30	25
S	Unfiltered water	Ta	µg/l	<DL	<DL	0.015	0.020	0.052	30	25
S	Unfiltered water	Te	µg/l	<DL	<DL	0.002	0.005	0.015	30	25
S	Unfiltered water	Th	µg/l	0.0009	0.005	0.007	0.013	0.032	30	25
S	Unfiltered water	Ti	µg/l	<DL	0.197	0.282	0.525	1.195	30	25
S	Unfiltered water	Tl	µg/l	<DL	<DL	<DL	0.004	0.087	30	25
S	Unfiltered water	U	µg/l	0.0088	0.035	0.054	0.286	0.695	30	25
S	Unfiltered water	V	µg/l	<DL	0.010	0.031	0.046	0.12	30	25
S	Unfiltered water	W	µg/l	0.013	0.032	0.091	0.149	0.299	30	25
S	Unfiltered water	Y	µg/l	0.032	0.078	0.109	0.311	0.622	30	25
S	Unfiltered water	Zn	µg/l	<DL	0.079	2.27	3.214	16.29	30	25
S	Unfiltered water	Zr	µg/l	0.029	0.057	0.101	0.154	0.284	30	25

Table A2.2 Regional environmental baseline element concentration values for the region “Southwest Greenland” (SW). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRL region	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
SW	Blue mussel	Ag	mg/kg	<DL	<DL	0.069	0.079	0.112	39	36
SW	Blue mussel	Al	mg/kg	0.141	102.88	188.94	428.474	1500	69	63
SW	Blue mussel	As	mg/kg	<DL	10.320	11.75	14.912	20.094	69	63
SW	Blue mussel	Au	mg/kg	<DL	<DL	0.008	0.014	0.034	39	36
SW	Blue mussel	Ba	mg/kg	<DL	0.820	1.871	7.088	15	39	36
SW	Blue mussel	Be	mg/Kg	9.00E-04	0.002	0.003	0.005	0.008	27	24
SW	Blue mussel	Bi	mg/kg	<DL	<DL	0.001	0.003	0.011	39	36
SW	Blue mussel	Ca	mg/kg	3	2740.5	3294	4015.5	10000	27	26
SW	Blue mussel	Cd	mg/kg	0.107	2.661	3.205	4.307	8.643	69	63
SW	Blue mussel	Ce	mg/Kg	<DL	0.262	0.419	1.052	15	39	36
SW	Blue mussel	Co	mg/Kg	0.01	0.42	0.6	1.28	3.3	39	36
SW	Blue mussel	Cr	mg/Kg	0.04	0.948	1.268	1.94	6.2	69	63
SW	Blue mussel	Cs	mg/kg	0.006	0.018	0.022	0.026	0.03	27	24
SW	Blue mussel	Cu	mg/kg	0.13	5.8	7.14	8.18	25	69	63
SW	Blue mussel	d.m.%	%	11.66	16.72	18.63	20.965	24.84	128	125
SW	Blue mussel	Dy	mg/Kg	0.013	0.016	0.020	0.025	0.029	12	10
SW	Blue mussel	Er	mg/Kg	0.006	0.008	0.010	0.011	0.012	12	10
SW	Blue mussel	Eu	mg/Kg	0.006	0.007	0.007	0.010	0.023	12	10
SW	Blue mussel	Fe	mg/kg	<DL	160.672	210.9	351.334	1500	69	63
SW	Blue mussel	Ga	mg/kg	0.035	0.068	0.094	0.115	0.4	27	24
SW	Blue mussel	Gd	mg/Kg	0.052	0.067	0.077	0.096	0.127	12	10
SW	Blue mussel	Ge	mg/kg	0.03	0.040	0.0435	0.0485	0.062	12	10
SW	Blue mussel	Hf	mg/kg	<DL	<DL	<DL	<DL	0.021	12	10
SW	Blue mussel	Hg	mg/kg	0.029	0.099	0.118	0.145	0.816	69	63
SW	Blue mussel	Ho	mg/Kg	0.003	0.003	0.004	0.005	0.005	12	10
SW	Blue mussel	K	mg/kg	38	14000	18053	23496.5	39686	27	26
SW	Blue mussel	La	mg/Kg	<DL	0.336	0.514	0.699	19	35	32
SW	Blue mussel	Li	mg/kg	0.005	0.578	0.879	1.106	1.482	27	24
SW	Blue mussel	Lu	mg/Kg	7.26E-04	8.73E-04	0.001	0.001	0.002	12	10
SW	Blue mussel	Mg	mg/kg	0.2	3312.044	3825	4902.573	9936	57	53
SW	Blue mussel	Mn	mg/Kg	0.03	5.431	6.399	8.07	39	69	63
SW	Blue mussel	Mo	mg/Kg	0.063	0.543	0.637	0.761	1.095	69	63
SW	Blue mussel	Na	mg/kg	95	16500	33804	57030.5	94661	27	26
SW	Blue mussel	Nb	mg/Kg	<DL	0.01	0.012	0.0145	0.024	12	10
SW	Blue mussel	Nd	mg/Kg	<DL	0.210	0.286	0.463	5.7	39	36
SW	Blue mussel	Ni	mg/Kg	<DL	1.450	2.039	3.41	19.009	69	63
SW	Blue mussel	P	mg/kg	33	9561.5	10496	11000	16344	39	36
SW	Blue mussel	Pb	mg/kg	0.005	0.395	0.479	0.655	6.6	69	63
SW	Blue mussel	Pd	mg/kg	<DL	0.002	0.005	0.007	0.020	15	14
SW	Blue mussel	Pr	mg/Kg	0.045	0.067	0.069	0.095	0.108	12	10
SW	Blue mussel	Pt	mg/kg	0.001	0.001	0.001	0.002	0.002	12	10

SW	Blue mussel	Rb	mg/Kg	0.021	6.205	6.641	8.776	10.47	27	24
SW	Blue mussel	Re	mg/kg	1.81E-04	3.08E-04	3.55E-04	3.96E-04	8.04E-04	12	10
SW	Blue mussel	Rh	mg/kg	9.00E-04	0.002	0.002	0.002	0.003	27	24
SW	Blue mussel	S	mg/kg	1574	23159	24072	26212	33721	15	14
SW	Blue mussel	Sb	mg/kg	<DL	<DL	0.007	0.013	0.026	39	36
SW	Blue mussel	Sc	mg/kg	<DL	<DL	0.562	1.215	4.148	39	36
SW	Blue mussel	Se	mg/kg	0.03	2.985	3.48	5.6	9.8	39	36
SW	Blue mussel	Si	mg/kg	8.232	242.29	386.28	467.935	814.02	27	24
SW	Blue mussel	Sm	mg/Kg	<DL	<DL	0.014	0.040	0.063	24	22
SW	Blue mussel	Sn	mg/Kg	<DL	<DL	<DL	<DL	0.031	39	36
SW	Blue mussel	Sr	mg/kg	<DL	30.55	43.5	51.95	76.3	39	36
SW	Blue mussel	Ta	mg/kg	<DL	<DL	<DL	3.00E-04	0.009	27	24
SW	Blue mussel	Tb	mg/Kg	0.003	0.004	0.004	0.005	0.006	12	10
SW	Blue mussel	Te	mg/kg	<DL	0.003	0.003	0.004	0.006	12	10
SW	Blue mussel	Th	mg/Kg	<DL	<DL	0.010	0.019	0.070	39	36
SW	Blue mussel	Ti	mg/kg	0.177	29.215	43.408	110.275	173.45	47	43
SW	Blue mussel	Tl	mg/kg	<DL	<DL	0.004	0.01	0.019	39	36
SW	Blue mussel	Tm	mg/Kg	7.76E-04	8.85E-04	0.001	0.001	0.002	12	10
SW	Blue mussel	U	mg/Kg	2.00E-04	0.161	0.23	0.3	0.43	39	36
SW	Blue mussel	V	mg/Kg	0.522	0.756	1.029	1.543	4.5	54	49
SW	Blue mussel	W	mg/kg	<DL	<DL	0.003	0.017	0.113	24	22
SW	Blue mussel	Y	mg/Kg	<DL	<DL	0.079	0.124	0.185	39	36
SW	Blue mussel	Yb	mg/Kg	0.004	0.005	0.007	0.008	0.009	12	10
SW	Blue mussel	Zn	mg/Kg	0.17	66.031	80.485	98	135.48	69	63
SW	Blue mussel	Zr	mg/Kg	0.002	0.034	0.047	0.067	0.155	35	31
SW	Crinkled snow lichen	Ag	mg/kg	<DL	<DL	<DL	0.005	0.038	64	61
SW	Crinkled snow lichen	Al	mg/kg	24	142.67	231.458	390	2200	103	97
SW	Crinkled snow lichen	As	mg/kg	<DL	<DL	0.03	0.051	0.76	103	97
SW	Crinkled snow lichen	Au	mg/kg	<DL	<DL	<DL	<DL	0.015	64	61
SW	Crinkled snow lichen	Ba	mg/kg	1.144	7.726	28.5	42.25	140	64	61
SW	Crinkled snow lichen	Be	mg/kg	6.00E-04	0.002	0.002	0.003	0.007	25	22
SW	Crinkled snow lichen	Bi	mg/kg	<DL	<DL	<DL	0.001	0.008	64	61
SW	Crinkled snow lichen	Ca	mg/kg	500	5167.5	9700	13000	27000	52	51
SW	Crinkled snow lichen	Cd	mg/kg	0.015	0.060	0.095	0.138	0.525	108	99
SW	Crinkled snow lichen	Ce	mg/kg	<DL	0.307	1.002	5.075	11	64	61
SW	Crinkled snow lichen	Co	mg/kg	<DL	0.11	0.43	0.908	4.6	64	61
SW	Crinkled snow lichen	Cr	mg/kg	<DL	0.204	0.416	1.25	3.3	103	97
SW	Crinkled snow lichen	Cs	mg/kg	0.006	0.017	0.03	0.057	0.087	25	22
SW	Crinkled snow lichen	Cu	mg/kg	<DL	0.561	0.883	2.2	13	103	97
SW	Crinkled snow lichen	d.m.%	%	100	100	100	100	100	13	12
SW	Crinkled snow lichen	Dy	mg/kg	0.009	0.012	0.015	0.017	0.019	12	10
SW	Crinkled snow lichen	Er	mg/kg	0.004	0.006	0.007	0.008	0.009	12	10
SW	Crinkled snow lichen	Eu	mg/kg	0.004	0.005	0.006	0.007	0.008	12	10
SW	Crinkled snow lichen	Fe	mg/kg	27	78.701	129.2	475	1500	103	97
SW	Crinkled snow lichen	Ga	mg/kg	0.017	0.033	0.06	0.285	0.551	25	22

SW	Crinkled snow lichen	Gd	mg/kg	0.033	0.042	0.051	0.066	0.081	12	10
SW	Crinkled snow lichen	Ge	mg/kg	0.012	0.016	0.018	0.025	0.03	12	10
SW	Crinkled snow lichen	Hf	mg/kg	<DL	<DL	<DL	<DL	<DL	12	10
SW	Crinkled snow lichen	Hg	mg/kg	<DL	0.026	0.034	0.094	0.31	107	98
SW	Crinkled snow lichen	Ho	mg/kg	0.002	0.002	0.003	0.003	0.003	12	10
SW	Crinkled snow lichen	K	mg/kg	86	2164.5	2400.000	2600	3200	52	51
SW	Crinkled snow lichen	La	mg/kg	0.090	0.181	1.7	2.8	6.5	59	56
SW	Crinkled snow lichen	Li	mg/kg	0.012	0.026	0.037	0.049	0.100	25	22
SW	Crinkled snow lichen	Lu	mg/kg	4.70E-04	7.31E-04	8.61E-04	9.72E-04	0.001	12	10
SW	Crinkled snow lichen	Mg	mg/kg	88	857.6	1300	1800	3532	91	87
SW	Crinkled snow lichen	Mn	mg/kg	1.7	26.405	41.34	62.338	122.319	103	97
SW	Crinkled snow lichen	Mo	mg/kg	<DL	<DL	0.013	0.025	0.23	103	97
SW	Crinkled snow lichen	Na	mg/kg	<DL	677.5	810	1300	4262	52	51
SW	Crinkled snow lichen	Nb	mg/kg	0.009	0.016	0.018	0.026	0.031	12	10
SW	Crinkled snow lichen	Nd	mg/kg	<DL	0.064	0.184	1.525	5.3	64	61
SW	Crinkled snow lichen	Ni	mg/kg	<DL	0.285	0.696	2.15	6.5	103	97
SW	Crinkled snow lichen	P	mg/kg	<DL	525	654	740	1300	64	61
SW	Crinkled snow lichen	Pb	mg/kg	<DL	0.428	0.532	0.718	6.3	104	98
SW	Crinkled snow lichen	Pd	mg/kg	<DL	<DL	<DL	9.00E-04	0.004	13	12
SW	Crinkled snow lichen	Pr	mg/kg	0.027	0.034	0.040	0.053	0.056	12	10
SW	Crinkled snow lichen	Pt	mg/kg	<DL	<DL	<DL	<DL	<DL	12	10
SW	Crinkled snow lichen	Rb	mg/kg	0.513	1.015	1.835	3.437	6.582	25	22
SW	Crinkled snow lichen	Re	mg/kg	<DL	<DL	<DL	1.07E-05	6.92E-05	12	10
SW	Crinkled snow lichen	Rh	mg/kg	<DL	3.00E-04	5.00E-04	9.00E-04	0.002	25	22
SW	Crinkled snow lichen	S	mg/kg	167	310	427	599	945	13	12
SW	Crinkled snow lichen	Sb	mg/kg	<DL	<DL	<DL	6.00E-04	0.2	64	61
SW	Crinkled snow lichen	Sc	mg/kg	<DL	<DL	<DL	0.235	1.11	64	61
SW	Crinkled snow lichen	Se	mg/kg	<DL	0.049	0.325	1.125	3.3	68	62
SW	Crinkled snow lichen	Si	mg/kg	64.916	105.97	140.39	163.8	255.65	25	22
SW	Crinkled snow lichen	Sm	mg/kg	<DL	<DL	<DL	<DL	0.033	51	49
SW	Crinkled snow lichen	Sn	mg/kg	<DL	<DL	<DL	3.00E-04	0.032	64	61
SW	Crinkled snow lichen	Sr	mg/kg	<DL	19.125	36.65	54.75	100	64	61
SW	Crinkled snow lichen	Ta	mg/kg	<DL	<DL	<DL	1.00E-04	0.003	25	22
SW	Crinkled snow lichen	Tb	mg/kg	0.002	0.002	0.003	0.003	0.004	12	10
SW	Crinkled snow lichen	Te	mg/kg	<DL	<DL	<DL	<DL	<DL	12	10
SW	Crinkled snow lichen	Th	mg/Kg	<DL	<DL	<DL	0.011	0.032	64	61
SW	Crinkled snow lichen	Ti	mg/kg	1.4	15.123	27.873	47.75	110	74	71
SW	Crinkled snow lichen	Tl	mg/kg	<DL	<DL	<DL	<DL	0.033	64	61
SW	Crinkled snow lichen	Tm	mg/kg	5.30E-04	7.51E-04	9.46E-04	0.001	0.001	12	10
SW	Crinkled snow lichen	U	mg/Kg	<DL	<DL	<DL	0.007	0.024	64	61
SW	Crinkled snow lichen	V	mg/kg	<DL	0.181	0.320	1.475	4.3	90	85
SW	Crinkled snow lichen	W	mg/kg	<DL	<DL	<DL	<DL	6.3	51	49
SW	Crinkled snow lichen	Y	mg/kg	<DL	<DL	<DL	0.054	1	64	61
SW	Crinkled snow lichen	Yb	mg/kg	0.004	0.005	0.006	0.007	0.008	12	10
SW	Crinkled snow lichen	Zn	mg/kg	<DL	14.929	18.495	23.278	39.79	104	98

SW	Crinkled snow lichen	Zr	mg/kg	0.053	0.089	0.113	0.155	0.222	35	32
SW	Filtered water	Ag	µg/l	<DL	<DL	0.003	0.010	0.195	67	47
SW	Filtered water	Al	µg/l	2	10.86	18.8	25	206.2	77	57
SW	Filtered water	As	µg/l	<DL	<DL	0.025	0.059	0.177	66	47
SW	Filtered water	Au	µg/l	<DL	<DL	0.003	0.007	0.065	67	47
SW	Filtered water	B	µg/l	0.196	0.2645	0.316	0.458	2.297	27	27
SW	Filtered water	Ba	µg/l	<DL	4.434	21.894	38.146	263.79	67	47
SW	Filtered water	Be	µg/l	<DL	<DL	0.004	0.009	0.024	37	37
SW	Filtered water	Bi	µg/l	<DL	3.00E-04	6.00E-04	8.50E-04	0.008	51	39
SW	Filtered water	Ca	µg/l	949	1900.65	8058.4	16072.5	24362	67	47
SW	Filtered water	Cd	µg/l	<DL	<DL	0.005	0.013	0.106	66	47
SW	Filtered water	Ce	µg/l	<DL	0.121	0.246	0.39	1.03	67	47
SW	Filtered water	Co	µg/l	0.002	0.02	0.051	0.104	0.372	67	47
SW	Filtered water	Cr	µg/l	<DL	0.116	0.194	0.293	0.57	77	57
SW	Filtered water	Cs	µg/l	<DL	<DL	<DL	0.006	0.015	37	37
SW	Filtered water	Cu	µg/l	0.058	0.5	3.304	5	8.45	77	57
SW	Filtered water	Dy	µg/l	4.00E-04	0.006	0.010	0.014	0.028	35	35
SW	Filtered water	Er	µg/l	2.10E-04	0.003	0.004	0.007	0.012	35	35
SW	Filtered water	Eu	µg/l	2.00E-04	0.003	0.008	0.012	0.037	35	35
SW	Filtered water	Fe	µg/l	<DL	6	23.1	51.47	239.4	77	57
SW	Filtered water	Ga	µg/l	<DL	0.006	0.013	0.021	0.054	37	37
SW	Filtered water	Gd	µg/l	9.00E-04	0.011	0.023	0.031	0.086	35	35
SW	Filtered water	Ge	µg/l	0.0064	0.017	0.022	0.027	0.057	17	17
SW	Filtered water	Hf	µg/l	1.00E-04	0.002	0.004	0.005	0.008	35	35
SW	Filtered water	Hg	µg/l	<DL	<DL	0.004	0.009	0.021	66	47
SW	Filtered water	Ho	µg/l	<DL	8.65E-04	0.002	0.003	0.005	35	35
SW	Filtered water	K	µg/l	203	826.6	1725	3014	4989	67	47
SW	Filtered water	La	µg/l	<DL	0.176	0.323	0.41	0.736	67	47
SW	Filtered water	Li	µg/l	<DL	0.151	0.330	0.416	1.537	48	47
SW	Filtered water	Lu	µg/l	1.00E-05	3.75E-04	6.80E-04	0.001	0.002	35	35
SW	Filtered water	Mg	µg/l	107.98	420	2754	4911	18390	77	57
SW	Filtered water	Mn	µg/l	0.06	0.236	1.46	3.76	99.368	77	57
SW	Filtered water	Mo	µg/l	0.008	0.104	0.223	0.299	3.13	66	47
SW	Filtered water	Na	µg/l	351	1214.500	2397	4596.5	127430	67	47
SW	Filtered water	Nb	µg/l	<DL	0.001	0.004	0.007	0.021	35	35
SW	Filtered water	Nd	µg/l	<DL	0.129	0.242	0.324	0.878	67	47
SW	Filtered water	Ni	µg/l	<DL	0.58	1.533	2.741	7.488	77	57
SW	Filtered water	P	µg/l	1.7	3.2	5.1	7.855	27.4	67	47
SW	Filtered water	Pb	µg/l	<DL	0.011	0.025	0.059	0.548	77	57
SW	Filtered water	Pd	µg/l	<DL	<DL	3.00E-04	0.004	0.018	37	37
SW	Filtered water	Pr	µg/l	0.0045	0.028	0.058	0.077	0.207	35	35
SW	Filtered water	Pt	µg/l	<DL	9.00E-04	0.001	0.002	0.007	48	47
SW	Filtered water	Rb	µg/l	<DL	1.076	1.545	2.075	3.23	48	47
SW	Filtered water	Re	µg/l	<DL	3.50E-04	0.001	0.002	0.020	35	35
SW	Filtered water	Rh	µg/l	5.00E-04	0.001	0.0011	0.001	0.002	17	17

SW	Filtered water	Ru	µg/l	<DL	<DL	3.00E-04	0.001	0.002	35	35
SW	Filtered water	S	µg/l	445	866	1398.2	2806.6	21048	48	47
SW	Filtered water	Sb	µg/l	0.012	0.024	0.037	0.05	0.342	56	37
SW	Filtered water	Sc	µg/l	0.011	0.034	0.053	0.074	0.131	67	47
SW	Filtered water	Se	µg/l	<DL	0.038	0.102	0.156	0.407	56	37
SW	Filtered water	Si	µg/l	4.95	8.12	13.76	16.755	53.31	35	35
SW	Filtered water	Sm	µg/l	0.002	0.024	0.034	0.046	0.12	54	35
SW	Filtered water	Sn	µg/l	<DL	<DL	0.008	0.02	0.165	67	47
SW	Filtered water	Sr	µg/l	3.63	8.032	47.263	115.02	210.75	67	47
SW	Filtered water	Ta	µg/l	<DL	3.25E-04	0.002	0.004	0.011	48	47
SW	Filtered water	Tb	µg/l	9.00E-05	0.001	0.002	0.003	0.008	35	35
SW	Filtered water	Te	µg/l	<DL	<DL	0.001	0.004	0.019	29	29
SW	Filtered water	Th	µg/l	<DL	0.009	0.016	0.025	0.121	67	47
SW	Filtered water	Ti	µg/l	0.007	0.135	0.237	0.378	6.39	77	57
SW	Filtered water	Tl	µg/l	<DL	0.002	0.007	0.016	0.049	56	37
SW	Filtered water	Tm	µg/l	1.00E-05	3.40E-04	6.80E-04	0.001	0.003	35	35
SW	Filtered water	U	µg/l	<DL	0.021	0.035	0.075	0.175	56	37
SW	Filtered water	V	µg/l	<DL	0.048	0.167	0.215	0.848	77	57
SW	Filtered water	W	µg/l	0.001	0.005	0.010	0.024	0.161	56	37
SW	Filtered water	Y	µg/l	0.004	0.035	0.053	0.073	0.138	67	47
SW	Filtered water	Yb	µg/l	3.40E-04	0.002	0.004	0.005	0.009	35	35
SW	Filtered water	Zn	µg/l	0.048	0.49	1.19	1.845	60.42	77	57
SW	Filtered water	Zr	µg/l	<DL	0.010	0.053	0.109	0.223	58	57
SW	Seaweed	Ag	mg/kg	<DL	0.099	0.119	0.168	0.215	30	25
SW	Seaweed	Al	mg/kg	3.527	19.63	47.859	83.998	382.735	49	43
SW	Seaweed	As	mg/kg	15.417	30.94	42.089	46.72	91	49	43
SW	Seaweed	Au	mg/kg	<DL	0.005	0.009	0.011	0.035	30	25
SW	Seaweed	Ba	mg/Kg	3.674	7.922	10.136	12.453	67	30	25
SW	Seaweed	Be	mg/Kg	<DL	4.50E-04	0.001	0.003	0.005	27	22
SW	Seaweed	Bi	mg/kg	<DL	0.001	0.001	0.002	0.006	30	25
SW	Seaweed	Ca	mg/kg	4722	6272	6673	7751	22879	17	16
SW	Seaweed	Cd	mg/Kg	0.860	1.393	1.847	2.407	3.466	49	43
SW	Seaweed	Ce	mg/Kg	<DL	0.077	0.134	0.190	0.364	30	25
SW	Seaweed	Co	mg/Kg	0.42	0.55	0.69	0.935	3.5	30	25
SW	Seaweed	Cr	mg/Kg	0.095	0.26	0.45	0.621	5.9	49	43
SW	Seaweed	Cs	mg/kg	0.019	0.022	0.025	0.033	0.047	27	22
SW	Seaweed	Cu	mg/kg	1.18	1.512	1.968	2.613	12	49	43
SW	Seaweed	d.m.%	%	100	100	100	100	100	14	13
SW	Seaweed	Dy	mg/Kg	0.006	0.010	0.014	0.015	0.022	13	10
SW	Seaweed	Er	mg/Kg	0.003	0.006	0.008	0.009	0.012	13	10
SW	Seaweed	Eu	mg/Kg	0.002	0.004	0.005	0.008	0.009	13	10
SW	Seaweed	Fe	mg/Kg	15.7	46.407	75.3	120	386	49	43
SW	Seaweed	Ga	mg/kg	0.024	0.033	0.045	0.382	0.78	27	22
SW	Seaweed	Gd	mg/Kg	0.023	0.043	0.049	0.082	0.105	13	10
SW	Seaweed	Ge	mg/kg	0.013	0.022	0.025	0.033	0.067	13	10

SW	Seaweed	Hf	mg/kg	<DL	<DL	<DL	<DL	<DL	13	10
SW	Seaweed	Hg	mg/kg	<DL	<DL	0.007	0.018	0.15	49	43
SW	Seaweed	Ho	mg/Kg	0.001	0.002	0.003	0.003	0.005	13	10
SW	Seaweed	K	mg/kg	28966	30032	34171	37000	44000	17	16
SW	Seaweed	La	mg/Kg	0.037	0.113	0.161	0.208	0.567	27	22
SW	Seaweed	Li	mg/kg	0.283	0.358	0.433	0.660	1.188	27	22
SW	Seaweed	Lu	mg/Kg	5.55E-04	9.62E-04	0.001	0.001	0.002	13	10
SW	Seaweed	Mg	mg/kg	4776.9	7006.912	7742	8031.25	12000	36	34
SW	Seaweed	Mn	mg/Kg	8.4	13.35	18.52	24.372	59.42	49	43
SW	Seaweed	Mo	mg/Kg	<DL	0.112	0.167	0.224	0.416	49	43
SW	Seaweed	Na	mg/kg	22037	30785	32778	38155	51000	17	16
SW	Seaweed	Nb	mg/Kg	0.003	0.006	0.008	0.011	0.024	13	10
SW	Seaweed	Nd	mg/Kg	<DL	0.085	0.134	0.155	0.300	30	25
SW	Seaweed	Ni	mg/Kg	0.587	1.786	2.3	3.56	8.696	49	43
SW	Seaweed	P	mg/kg	1951	2576.25	2908.5	3131.25	6198	30	25
SW	Seaweed	Pb	mg/Kg	<DL	0.05	0.078	0.131	0.314	49	43
SW	Seaweed	Pd	mg/kg	0.022	0.027	0.032	0.038	0.046	14	13
SW	Seaweed	Pr	mg/Kg	0.013	0.034	0.038	0.056	0.084	13	10
SW	Seaweed	Pt	mg/kg	0.002	0.002	0.002	0.003	0.005	13	10
SW	Seaweed	Rb	mg/Kg	5.518	6.794	8.348	11.912	16.951	27	22
SW	Seaweed	Re	mg/kg	0.052	0.057	0.070	0.077	0.090	13	10
SW	Seaweed	Rh	mg/kg	0.015	0.022	0.024	0.028	0.042	27	22
SW	Seaweed	S	mg/kg	28734	31408.75	34243	35306.75	39674	14	13
SW	Seaweed	Sb	mg/Kg	<DL	0.026	0.034	0.040	0.056	30	25
SW	Seaweed	Sc	mg/kg	<DL	0.083	0.336	0.683	2.821	30	25
SW	Seaweed	Se	mg/kg	0.12	0.203	0.255	0.288	1.8	30	25
SW	Seaweed	Si	mg/kg	15.897	32.609	65.658	189.61	495.29	27	22
SW	Seaweed	Sm	mg/Kg	<DL	0.016	0.022	0.026	0.041	16	13
SW	Seaweed	Sn	mg/kg	<DL	<DL	0.005	0.008	0.029	30	25
SW	Seaweed	Sr	mg/kg	342.2	623.4	704.4	888.75	1256.1	30	25
SW	Seaweed	Ta	mg/kg	<DL	<DL	<DL	9.50E-04	0.003	27	22
SW	Seaweed	Tb	mg/Kg	9.71E-04	0.002	0.002	0.003	0.005	13	10
SW	Seaweed	Te	mg/kg	0.005	0.008	0.008	0.011	0.013	13	10
SW	Seaweed	Th	mg/Kg	<DL	0.007	0.009	0.014	0.022	30	25
SW	Seaweed	Ti	mg/kg	1.459	9.287	20.002	35.539	46.482	34	28
SW	Seaweed	Tl	mg/kg	<DL	0.002	0.006	0.008	0.037	30	25
SW	Seaweed	Tm	mg/Kg	4.10E-04	8.13E-04	0.001	0.001	0.002	13	10
SW	Seaweed	U	mg/Kg	0.24	0.440	0.569	0.657	0.762	30	25
SW	Seaweed	V	mg/Kg	<DL	0.203	0.447	0.789	1.733	35	31
SW	Seaweed	W	mg/kg	<DL	0.003	0.006	0.007	0.011	16	13
SW	Seaweed	Y	mg/Kg	<DL	0.048	0.069	0.093	0.182	30	25
SW	Seaweed	Yb	mg/Kg	0.004	0.005	0.007	0.009	0.011	13	10
SW	Seaweed	Zn	mg/Kg	7.616	10.620	13.17	16	26.881	49	43
SW	Seaweed	Zr	mg/Kg	0.108	0.18	0.217	0.253	0.441	31	25
SW	Sediment	Al	mg/kg	34471.601	39524.713	41602.015	52153.927	57910.718	10	8

SW	Sediment	As	mg/kg	0.859	1.094	3.017	4.978	19.074	16	12
SW	Sediment	Cd	mg/kg	0.071	0.099	0.161	0.221	0.531	12	9
SW	Sediment	Cr	mg/kg	66.689	74.170	91.695	98.147	116.609	10	8
SW	Sediment	Cu	mg/kg	18.480	28.971	40.496	57.433	72.643	12	9
SW	Sediment	Fe	mg/kg	21052.969	22720.893	25292.210	30382.457	51452.921	10	8
SW	Sediment	Hg	mg/kg	<DL	0.035	0.05	0.072	0.2861	61	12
SW	Sediment	LoI%	mg/kg	0.47	0.47	0.47	0.47	0.47	1	1
SW	Sediment	Mg	mg/kg	4915.908	6153.760	8732.886	13322.570	15827.554	10	8
SW	Sediment	Mn	mg/kg	249.819	281.118	321.591	1585.937	2104.600	10	8
SW	Sediment	Mo	mg/kg	0.599	2.407	10.477	13.434	30.346	10	8
SW	Sediment	Ni	mg/kg	28.010	35.349	40.540	47.306	63.141	12	9
SW	Sediment	Pb	mg/kg	9.363	10.171	11.86	13.561	23.410	12	9
SW	Sediment	Se	mg/kg	1.115	1.121	1.127	1.133	1.139	2	1
SW	Sediment	V	mg/kg	38.653	43.752	46.253	48.363	52.549	10	8
SW	Sediment	Water%	mg/kg	16.8	18.125	19.45	20.775	22.1	2	2
SW	Sediment	Zn	mg/kg	44.493	53.142	61.283	68.773	84.96	12	9
SW	Shorthorn sculpin	Ag	mg/kg	0.130	0.246	0.409	0.482	0.699	23	20
SW	Shorthorn sculpin	Al	mg/kg	0.284	0.732	0.948	1.382	2.641	23	20
SW	Shorthorn sculpin	As	mg/kg	1.92	2.72	3.97	7.415	64.51	23	20
SW	Shorthorn sculpin	Au	mg/kg	0.001	0.002	0.003	0.004	0.006	23	20
SW	Shorthorn sculpin	Ba	mg/kg	0.004	0.005	0.006	0.010	0.016	23	20
SW	Shorthorn sculpin	Be	mg/kg	4.00E-04	5.50E-04	7.00E-04	8.50E-04	0.004	23	20
SW	Shorthorn sculpin	Bi	mg/kg	0.001	0.002	0.003	0.004	0.007	23	20
SW	Shorthorn sculpin	Ca	mg/kg	32	57	73	88	128	23	20
SW	Shorthorn sculpin	Cd	mg/kg	0.353	0.707	0.894	1.575	8.224	23	20
SW	Shorthorn sculpin	Ce	mg/kg	0.001	0.001	0.003	0.006	0.039	23	20
SW	Shorthorn sculpin	Co	mg/kg	0.04	0.05	0.07	0.11	0.24	23	20
SW	Shorthorn sculpin	Cr	mg/kg	0.04	0.05	0.06	0.06	0.44	23	20
SW	Shorthorn sculpin	Cs	mg/kg	0.011	0.019	0.02	0.024	0.031	23	20
SW	Shorthorn sculpin	Cu	mg/kg	1.25	2.155	3.65	6.63	11.15	23	20
SW	Shorthorn sculpin	d.m.%	%	15.57	19.52	22.5	23.593	33.58	22	19
SW	Shorthorn sculpin	Fe	mg/kg	58.7	123.5	179.2	285.5	858.7	23	20
SW	Shorthorn sculpin	Ga	mg/kg	0.026	0.03	0.032	0.035	0.039	23	20
SW	Shorthorn sculpin	Hg	mg/kg	0.046	0.080	0.156	0.198	0.274	23	20
SW	Shorthorn sculpin	K	mg/kg	2400	3640	3963	4296	4848	23	20
SW	Shorthorn sculpin	La	mg/kg	0.002	0.003	0.004	0.006	0.043	23	20
SW	Shorthorn sculpin	Li	mg/kg	0.008	0.022	0.027	0.037	0.066	23	20
SW	Shorthorn sculpin	Mg	mg/kg	118.3	199.75	219.4	251.05	316	23	20
SW	Shorthorn sculpin	Mn	mg/kg	0.32	0.495	0.58	0.73	1.04	23	20
SW	Shorthorn sculpin	Mo	mg/kg	0.061	0.094	0.116	0.126	0.176	23	20
SW	Shorthorn sculpin	Na	mg/kg	1064	2475.5	3118	3880	5987	23	20
SW	Shorthorn sculpin	Nd	mg/kg	0.002	0.003	0.004	0.005	0.015	23	20
SW	Shorthorn sculpin	Ni	mg/kg	<DL	<DL	<DL	0.012	0.102	23	20
SW	Shorthorn sculpin	P	mg/kg	2383	2806	3088	3316.5	3808	23	20
SW	Shorthorn sculpin	Pb	mg/kg	0.007	0.008	0.011	0.016	0.021	23	20

SW	Shorthorn sculpin	Pd	mg/kg	0.002	0.002	0.003	0.003	0.005	23	20
SW	Shorthorn sculpin	Rb	mg/kg	0.277	0.442	0.531	0.605	0.769	23	20
SW	Shorthorn sculpin	Rh	mg/kg	3.00E-04	4.00E-04	4.00E-04	5.00E-04	6.00E-04	23	20
SW	Shorthorn sculpin	S	mg/kg	2790	3708	4005	4410.5	4827	23	20
SW	Shorthorn sculpin	Sb	mg/kg	0.003	0.004	0.004	0.005	0.007	23	20
SW	Shorthorn sculpin	Sc	mg/kg	0.093	0.101	0.11	0.120	0.149	23	20
SW	Shorthorn sculpin	Se	mg/kg	0.94	1.07	1.33	1.525	5.13	23	20
SW	Shorthorn sculpin	Si	mg/kg	6.954	8.277	9.587	11.143	16.672	23	20
SW	Shorthorn sculpin	Sn	mg/kg	0.005	0.007	0.008	0.009	0.012	23	20
SW	Shorthorn sculpin	Sr	mg/kg	0.3	0.5	0.7	0.9	1.8	23	20
SW	Shorthorn sculpin	Ta	mg/kg	0.001	0.001	0.002	0.002	0.003	23	20
SW	Shorthorn sculpin	Th	mg/Kg	4.00E-04	6.00E-04	7.00E-04	9.00E-04	0.001	23	20
SW	Shorthorn sculpin	Ti	mg/kg	24.197	27.633	30.048	33.05	38.491	23	20
SW	Shorthorn sculpin	Tl	mg/kg	0.002	0.003	0.003	0.005	0.023	23	20
SW	Shorthorn sculpin	U	mg/Kg	3.00E-04	8.00E-04	0.002	0.003	0.007	23	20
SW	Shorthorn sculpin	Y	mg/kg	<DL	0.001	0.001	0.002	0.006	23	20
SW	Shorthorn sculpin	Zn	mg/kg	38.7	44.275	53.57	62.16	99.44	23	20
SW	Shorthorn sculpin	Zr	mg/kg	0.002	0.004	0.004	0.006	0.011	23	20
SW	Soil	Ag	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Al	mg/kg	0.035	58086.5	67587	71102	72590	7	5
SW	Soil	As	mg/Kg	<DL	0.009	0.019	0.139	0.533	7	5
SW	Soil	Au	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Ba	mg/Kg	0.009	0.009	0.009	0.009	0.009	1	1
SW	Soil	Be	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Bi	mg/Kg	1.30E-06	1.30E-06	1.30E-06	1.30E-06	1.30E-06	1	1
SW	Soil	Ca	mg/Kg	3.445	3.445	3.445	3.445	3.445	1	1
SW	Soil	Cd	mg/kg	<DL	0.033	0.039	0.044	0.049	7	5
SW	Soil	Ce	mg/Kg	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1	1
SW	Soil	Co	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Cr	mg/kg	1.10E-04	40.855	42.118	46.318	84.376	7	5
SW	Soil	Cs	mg/Kg	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1	1
SW	Soil	Cu	mg/kg	4.42E-04	2.288	3.116	6.138	15.81	7	5
SW	Soil	Fe	mg/kg	0.003	11804.5	12866	14229	15570	7	5
SW	Soil	Ga	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Hg	mg/kg	<DL	0.006	0.019	0.03	0.041	6	5
SW	Soil	K	mg/Kg	0.467	0.467	0.467	0.467	0.467	1	1
SW	Soil	La	mg/Kg	2.57E-04	2.57E-04	2.57E-04	2.57E-04	2.57E-04	1	1
SW	Soil	Li	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Mg	mg/Kg	0.423	0.423	0.423	0.423	0.423	1	1
SW	Soil	Mn	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Mo	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Na	mg/Kg	2.535	2.535	2.535	2.535	2.535	1	1
SW	Soil	Nd	mg/Kg	2.32E-04	2.32E-04	2.32E-04	2.32E-04	2.32E-04	1	1
SW	Soil	Ni	mg/kg	1.08E-04	16.732	18.193	24.647	28.357	7	5
SW	Soil	P	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1

SW	Soil	Pb	mg/kg	1.53E-05	10.42	12.73	13.91	15.22	7	5
SW	Soil	Pd	mg/Kg	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1	1
SW	Soil	Pt	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Rb	mg/Kg	6.14E-04	6.14E-04	6.14E-04	6.14E-04	6.14E-04	1	1
SW	Soil	Rh	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	S	mg/Kg	1.911	1.911	1.911	1.911	1.911	1	1
SW	Soil	Sb	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Sc	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Se	mg/kg	<DL	0.065	0.117	0.137	0.333	7	5
SW	Soil	Sn	mg/Kg	9.70E-06	9.70E-06	9.70E-06	9.70E-06	9.70E-06	1	1
SW	Soil	Sr	mg/Kg	0.015	0.015	0.015	0.015	0.015	1	1
SW	Soil	Ta	mg/Kg	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.00E-06	1	1
SW	Soil	Te	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Th	mg/Kg	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1	1
SW	Soil	Ti	mg/Kg	8.37E-05	8.37E-05	8.37E-05	8.37E-05	8.37E-05	1	1
SW	Soil	Tl	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	U	mg/Kg	6.54E-05	6.54E-05	6.54E-05	6.54E-05	6.54E-05	1	1
SW	Soil	V	mg/kg	1.36E-04	29.455	33.349	36.060	38.705	7	5
SW	Soil	W	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
SW	Soil	Y	mg/Kg	3.90E-05	3.90E-05	3.90E-05	3.90E-05	3.90E-05	1	1
SW	Soil	Zn	mg/kg	1.25E-04	14.47	18.74	20.895	25.83	7	5
SW	Soil	Zr	mg/Kg	4.20E-06	4.20E-06	4.20E-06	4.20E-06	4.20E-06	1	1
SW	Unfiltered water	Ag	µg/l	<DL	<DL	<DL	0.004	0.015	78	63
SW	Unfiltered water	Al	µg/l	1.8	21.375	42.913	477.923	2816	88	73
SW	Unfiltered water	As	µg/l	<DL	<DL	0.034	0.1	0.34	88	73
SW	Unfiltered water	Au	µg/l	<DL	<DL	0.003	0.012	0.287	78	63
SW	Unfiltered water	B	µg/l	0.213	0.262	0.273	0.304	0.618	18	18
SW	Unfiltered water	Ba	µg/l	0.58	14.316	23.096	35.031	267.27	78	63
SW	Unfiltered water	Be	µg/l	<DL	0.003	0.011	0.022	0.086	65	63
SW	Unfiltered water	Bi	µg/l	<DL	9.33E-04	0.002	0.004	0.009	62	55
SW	Unfiltered water	Ca	µg/l	492	1954.25	4021	10410.2	22428	78	63
SW	Unfiltered water	Cd	µg/l	<DL	<DL	0.005	0.014	0.134	88	73
SW	Unfiltered water	Ce	µg/l	0.021	0.226	0.526	4.346	17.319	78	63
SW	Unfiltered water	Co	µg/l	<DL	0.048	0.087	0.425	3.036	78	63
SW	Unfiltered water	Cr	µg/l	0.006	0.161	0.313	1.34	12.858	88	73
SW	Unfiltered water	Cs	µg/l	<DL	<DL	0.009	0.153	0.41	65	63
SW	Unfiltered water	Cu	µg/l	0.199	1.139	4.315	6.703	21.99	88	73
SW	Unfiltered water	Dy	µg/l	0.004	0.011	0.015	0.019	0.469	26	26
SW	Unfiltered water	Er	µg/l	0.002	0.006	0.007	0.010	0.196	26	26
SW	Unfiltered water	Eu	µg/l	0.004	0.008	0.010	0.014	0.182	26	26
SW	Unfiltered water	Fe	µg/l	<DL	11.56	100.145	459.075	3481	88	73
SW	Unfiltered water	Ga	µg/l	<DL	0.005	0.026	0.267	0.998	65	63
SW	Unfiltered water	Gd	µg/l	0.011	0.025	0.033	0.042	0.925	26	26
SW	Unfiltered water	Ge	µg/l	0.004	0.019	0.028	0.041	0.417	18	18
SW	Unfiltered water	Hf	µg/l	0.003	0.005	0.006	0.007	0.009	26	26

SW	Unfiltered water	Hg	µg/l	<DL	<DL	0.004	0.009	0.068	88	73
SW	Unfiltered water	Ho	µg/l	6.40E-04	0.002	0.003	0.004	0.078	26	26
SW	Unfiltered water	K	µg/l	126	825.6	1166	2738	4135	78	63
SW	Unfiltered water	La	µg/l	0.022	0.334	0.551	2.212	9.743	78	63
SW	Unfiltered water	Li	µg/l	0.06	0.3	0.53	1.46	4.06	65	63
SW	Unfiltered water	Lu	µg/l	1.80E-04	8.00E-04	0.001	0.002	0.021	26	26
SW	Unfiltered water	Mg	µg/l	56	342.04	1107	3986	9821	79	64
SW	Unfiltered water	Mn	µg/l	0.01	0.52	4.192	23.172	109.17	88	73
SW	Unfiltered water	Mo	µg/l	0.008	0.078	0.154	0.271	3.38	88	73
SW	Unfiltered water	Na	µg/l	215	646.25	1495.4	2809	20195	78	63
SW	Unfiltered water	Nb	µg/l	0.001	0.004	0.006	0.011	0.107	26	26
SW	Unfiltered water	Nd	µg/l	0.02	0.260	0.403	2.033	6.452	78	63
SW	Unfiltered water	Ne	µg/l	1208	1231	1332	1358	2213	9	9
SW	Unfiltered water	Ni	µg/l	0.018	0.924	2.325	3.396	12.351	88	73
SW	Unfiltered water	P	µg/l	<DL	2.825	7.35	26.825	710.5	78	63
SW	Unfiltered water	Pb	µg/l	0.004	0.040	0.091	0.640	2.399	88	73
SW	Unfiltered water	Pd	µg/l	<DL	<DL	0.001	0.003	0.02	65	63
SW	Unfiltered water	Pr	µg/l	0.026	0.070	0.086	0.116	1.756	26	26
SW	Unfiltered water	Pt	µg/l	<DL	<DL	<DL	0.002	0.019	65	63
SW	Unfiltered water	Rb	µg/l	0.324	1.327	1.897	4.889	15.293	65	63
SW	Unfiltered water	Re	µg/l	<DL	<DL	0.003	0.006	0.017	26	26
SW	Unfiltered water	Rh	µg/l	2.00E-04	9.00E-04	0.001	0.002	0.003	18	18
SW	Unfiltered water	Ru	µg/l	<DL	1.25E-04	6.00E-04	0.001	0.003	26	26
SW	Unfiltered water	S	µg/l	<DL	293	1210.6	1766	8705	65	63
SW	Unfiltered water	Sb	µg/l	<DL	0.003	0.011	0.025	0.099	78	63
SW	Unfiltered water	Sc	µg/l	<DL	0.04	0.067	0.093	0.907	78	63
SW	Unfiltered water	Se	µg/l	<DL	0.01	0.051	0.13	0.26	78	63
SW	Unfiltered water	Si	µg/l	4.94	10.453	14.17	16.018	31.51	26	26
SW	Unfiltered water	Sm	µg/l	0.015	0.035	0.044	0.061	0.999	39	26
SW	Unfiltered water	Sn	µg/l	<DL	<DL	0.017	0.074	0.378	78	63
SW	Unfiltered water	Sr	µg/l	1.02	4.896	14.509	63.303	176.95	78	63
SW	Unfiltered water	Ta	µg/l	<DL	4.00E-04	0.004	0.018	0.064	65	63
SW	Unfiltered water	Tb	µg/l	8.20E-04	0.003	0.003	0.004	0.093	26	26
SW	Unfiltered water	Te	µg/l	<DL	<DL	0.0027	0.006	0.043	57	55
SW	Unfiltered water	Th	µg/l	0.001	0.013	0.027	0.194	1.114	78	63
SW	Unfiltered water	Ti	µg/l	<DL	0.201	0.419	11.55	129.09	88	73
SW	Unfiltered water	Tl	µg/l	<DL	<DL	0.009	0.017	0.042	78	63
SW	Unfiltered water	Tm	µg/l	1.20E-04	9.80E-04	0.001	0.002	0.025	26	26
SW	Unfiltered water	U	µg/l	<DL	0.023	0.062	0.346	1.395	78	63
SW	Unfiltered water	V	µg/l	<DL	0.103	0.250	0.86	6.812	88	73
SW	Unfiltered water	W	µg/l	<DL	0.005	0.01	0.021	0.064	78	63
SW	Unfiltered water	Y	µg/l	0.004	0.056	0.097	0.435	2.124	78	63
SW	Unfiltered water	Yb	µg/l	0.001	0.004	0.007	0.008	0.146	26	26
SW	Unfiltered water	Zn	µg/l	<DL	1.229	2.132	4.228	14.01	88	73
SW	Unfiltered water	Zr	µg/l	<DL	0.018	0.095	0.154	0.878	75	73

Table A2.3 Regional environmental baseline element concentration values for the region "Southeast Greenland" (SE). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRLregion	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
SE	Sediment	As	mg/kg	1.260	1.605	2.050	2.435	2.508	6	4
SE	Sediment	Cd	mg/kg	0.155	0.156	0.157	0.158	0.159	2	1
SE	Sediment	Cu	mg/kg	53.115	54.380	55.645	56.910	58.175	2	1
SE	Sediment	Hg	mg/kg	0.006	0.009	0.012	0.036	0.044	52	6
SE	Sediment	Ni	mg/kg	86.378	87.099	87.820	88.541	89.261	2	1
SE	Sediment	Pb	mg/kg	12.550	12.665	12.780	12.895	13.010	2	1
SE	Sediment	Se	mg/kg	0.002	0.011	0.021	0.030	0.039	2	1
SE	Sediment	Zn	mg/kg	169.060	170.093	171.125	172.158	173.190	2	1

Table A2.4 Regional environmental baseline element concentration values for the region "Central West Greenland" (CW). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRLregion	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
CW	Blue mussel	Cd	mg/kg	0.399	1.283	2.85	4.58	9.03	53	45
CW	Blue mussel	d.m.%	%	13	15.64	17.19	18.068	22.1	48	43
CW	Blue mussel	Hg	mg/kg	0.008	0.015	0.078	0.094	0.121	53	45
CW	Blue mussel	Pb	mg/kg	0.316	0.552	0.693	0.765	1.144	35	30
CW	Blue mussel	Se	mg/kg	0.360	0.508	4.401	6.092	7.319	53	45
CW	Crinkled snow lichen	Cd	mg/kg	0.07	0.075	0.08	0.1	0.12	3	3
CW	Crinkled snow lichen	Pb	mg/kg	1.1	1.4	1.7	3.05	4.4	3	3
CW	Crinkled snow lichen	Zn	mg/kg	14	17.5	21	21.5	22	3	3
CW	Sediment	Al	mg/kg	54858	59205	62829	65510	67818	5	5
CW	Sediment	As	mg/kg	1.523	3.463	5.986	9.603	19.83	40	24
CW	Sediment	Cd	mg/kg	0.088	0.090	0.146	0.176	0.249	5	5
CW	Sediment	Cu	mg/kg	17.919	19.918	22.926	34.314	43.844	5	5
CW	Sediment	Hg	mg/kg	0.004	0.010	0.025	0.042	0.178	236	24
CW	Sediment	Li	mg/kg	5.812	12.111	16.133	17.144	18.403	5	5
CW	Sediment	LoI%	mg/kg	6.34	6.4	6.46	7.57	8.68	3	3
CW	Sediment	Pb	mg/kg	10.69	10.87	11.56	12.27	13.91	5	5
CW	Sediment	Water%	mg/kg	56.1	56.1	56.1	56.1	56.1	1	1
CW	Sediment	Zn	mg/kg	33.78	47.23	48.78	52.5	61.97	5	5
CW	Shorthorn sculpin	Cd	mg/kg	0.203	0.662	0.848	1.401	6.484	112	101
CW	Shorthorn sculpin	d.m.%	%	18.45	27.5525	31.46	34.56	45.79	174	122
CW	Shorthorn sculpin	Hg	mg/kg	0.005	0.011	0.016	0.027	0.064	112	101
CW	Shorthorn sculpin	Pb	mg/kg	<DL	0.005	0.0105	0.019	0.05	72	45
CW	Shorthorn sculpin	Se	mg/kg	0.529	0.810	0.915	1.066	1.560	112	101

Table A2.5 Regional environmental baseline element concentration values for the region “Central East Greenland” (CE).

GRL region	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
CE	Crinkled snow lichen	As	mg/kg	0.171	0.1715	0.172	0.2035	0.235	3	3
CE	Crinkled snow lichen	Cd	mg/kg	0.014	0.024	0.047	0.2	0.27	5	5
CE	Crinkled snow lichen	Cr	mg/kg	0.315	0.3405	0.366	0.4325	0.499	3	3
CE	Crinkled snow lichen	Cu	mg/kg	0.832	0.8835	0.935	0.9385	0.942	3	3
CE	Crinkled snow lichen	Fe	mg/kg	183	193.5	204	223.5	243	3	3
CE	Crinkled snow lichen	Hg	mg/kg	0.03	0.03075	0.032	0.0355	0.043	4	3
CE	Crinkled snow lichen	Ni	mg/kg	0.606	0.65325	0.7065	0.7625	0.818	4	3
CE	Crinkled snow lichen	Pb	mg/kg	0.909	1.025	1.38	2.005	3.7	6	5
CE	Crinkled snow lichen	Se	mg/kg	0.037	0.037	0.037	0.0405	0.044	3	3
CE	Crinkled snow lichen	V	mg/kg	0.418	0.4445	0.471	0.4805	0.49	3	3
CE	Crinkled snow lichen	Zn	mg/kg	7	8.31	10.095	13.35	16	6	5
CE	Filtered water	Ag	µg/l	0.154	0.2085	0.238	0.274	0.524	99	92
CE	Filtered water	Al	µg/l	1.9	6	8.6	11.65	87.4	99	92
CE	Filtered water	Au	µg/l	0.0008	0.0038	0.0058	0.0082	0.0381	99	92
CE	Filtered water	Ba	µg/l	0.22	0.455	0.88	1.675	5.24	99	92
CE	Filtered water	Bi	µg/l	0.0002	0.0008	0.0012	0.0019	0.0058	99	92
CE	Filtered water	Ca	µg/l	2622	4617	6086	11685.5	106500	99	92
CE	Filtered water	Cd	µg/l	0.02	0.03	0.04	0.05	0.11	9	9
CE	Filtered water	Ce	µg/l	0.001	0.014	0.021	0.0455	0.278	99	92
CE	Filtered water	Co	µg/l	0.01	0.02	0.03	0.05	0.76	99	92
CE	Filtered water	Cr	µg/l	0.07	0.09	0.11	0.14	0.63	99	92
CE	Filtered water	Cu	µg/l	0.49	0.76	0.92	1.14	3.24	99	92
CE	Filtered water	Fe	µg/l	3	7	9	12	79	99	92
CE	Filtered water	K	µg/l	540	688	767	1048	2167	99	92
CE	Filtered water	La	µg/l	0.001	0.009	0.014	0.02	0.17	99	92
CE	Filtered water	Li	µg/l	0.47	0.68	0.79	0.955	21.78	99	92
CE	Filtered water	Mg	µg/l	431	860.5	1106	1709.5	19540	99	92
CE	Filtered water	Mn	µg/l	0.18	1.115	2.13	5.045	41.4	99	92
CE	Filtered water	Na	µg/l	211	292.5	328	516	1490	99	92
CE	Filtered water	Nd	µg/l	0.002	0.009	0.014	0.0215	0.149	99	92
CE	Filtered water	Ni	µg/l	0.06	0.2	0.28	0.35	3.29	99	92
CE	Filtered water	P	µg/l	3.8	4.25	4.8	5.35	11.3	99	92
CE	Filtered water	Pb	µg/l	0.01	0.02	0.03	0.05325	1.5	108	101
CE	Filtered water	Pt	µg/l	0.0011	0.0016	0.0019	0.0023	0.0043	99	92
CE	Filtered water	Rb	µg/l	0.67	0.915	1.06	1.235	2.16	99	92
CE	Filtered water	S	µg/l	963	1962.5	2431	4561	62450	99	92
CE	Filtered water	Sc	µg/l	0.24	0.445	0.56	0.715	1.51	99	92
CE	Filtered water	Sn	µg/l	0.02	0.03	0.04	0.06	0.78	99	92
CE	Filtered water	Sr	µg/l	7.42	13.05	15.75	23.815	163.48	99	92
CE	Filtered water	Ta	µg/l	0.0016	0.0032	0.0039	0.00585	0.0335	99	92

CE	Filtered water	Th	µg/l	0.0005	0.00235	0.0036	0.00455	0.0227	99	92
CE	Filtered water	Ti	µg/l	0.26498	0.56368	0.72255	1.10935	4.9225	99	92
CE	Filtered water	V	µg/l	0.12	0.195	0.23	0.265	0.48	99	92
CE	Filtered water	Y	µg/l	0.001	0.003	0.004	0.006	0.062	99	92
CE	Filtered water	Zn	µg/l	0.05	0.335	0.595	1.315	158.23	108	101
CE	Filtered water	Zr	µg/l	0.009	0.0255	0.036	0.0545	0.13	99	92
CE	Sediment	As	mg/kg	9.02	10.07	11.12	11.83	12.54	3	2
CE	Sediment	Hg	mg/kg	0.017	0.02025	0.0325	0.05875	0.089	54	4
CE	Shorthorn sculpin	Cd	mg/kg	0.234	0.498	0.687	0.925	2.081	55	47
CE	Shorthorn sculpin	d.m.%	%	17.18	24.6025	28.095	33.5775	44.44	52	47
CE	Shorthorn sculpin	Hg	mg/kg	0.0236	0.0399	0.054	0.079	0.2243	55	47
CE	Shorthorn sculpin	Pb	mg/kg	<DL	<DL	<DL	<DL	0.19	9	3
CE	Shorthorn sculpin	Se	mg/kg	0.491	0.759	0.878	0.994	1.531	43	38

Table A2.6. Regional environmental baseline element concentration values for the region “Northwest Greenland” (NW). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRL region	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
NW	Crinkled snow lichen	As	mg/kg	0.104	0.123	0.142	0.148	0.153	3	3
NW	Crinkled snow lichen	Cd	mg/kg	0.088	0.096	0.114	0.138	0.16	4	4
NW	Crinkled snow lichen	Cr	mg/kg	0.315	0.55	0.785	0.993	1.2	3	3
NW	Crinkled snow lichen	Cu	mg/kg	0.908	0.935	0.961	1.006	1.05	3	3
NW	Crinkled snow lichen	Fe	mg/kg	142	164	186	236.5	287	3	3
NW	Crinkled snow lichen	Hg	mg/kg	0.059	0.061	0.065	0.074	0.089	4	3
NW	Crinkled snow lichen	Ni	mg/kg	0.705	0.920	0.995	1.007	1.03	4	3
NW	Crinkled snow lichen	Pb	mg/kg	1.1	1.1	1.1	1.1	1.1	1	1
NW	Crinkled snow lichen	Se	mg/kg	0.036	0.038	0.04	0.045	0.05	3	3
NW	Crinkled snow lichen	V	mg/kg	0.375	0.462	0.548	0.752	0.956	3	3
NW	Crinkled snow lichen	Zn	mg/kg	11	11	11	11	11	1	1
NW	Sediment	Al	mg/kg	42444	56691.5	60532	64391	65902	7	5
NW	Sediment	As	mg/kg	2.01	4.235	6.56	16.065	24.6	11	8
NW	Sediment	Cd	mg/kg	0.0639	0.133	0.1468	0.276	0.301	7	5
NW	Sediment	Cu	mg/kg	12.471	18.226	25.938	29.266	34.81	7	5
NW	Sediment	Hg	mg/kg	0.004	0.013	0.025	0.040	0.194	58	13
NW	Sediment	Li	mg/kg	16.12	18.682	34.849	42.014	46.196	7	5
NW	Sediment	Ni	mg/kg	1.218	3.905	4.921	6.817	7.884	7	5
NW	Sediment	Pb	mg/kg	5.26	9.1	14.37	17.29	17.9	7	5
NW	Sediment	Zn	mg/kg	25.78	44.53	46.94	73.24	104.76	7	5
NW	Shorthorn sculpin	Cd	mg/kg	0.631	1.233	1.745	2.424	3.381	21	20
NW	Shorthorn sculpin	d.m.%	%	16.99	21.68	24.79	27.34	31.54	21	20
NW	Shorthorn sculpin	Hg	mg/kg	0.038	0.051	0.082	0.1	0.225	21	20
NW	Shorthorn sculpin	Se	mg/kg	0.591	0.746	0.872	0.986	1.066	21	20

Table A2.7 Regional environmental baseline element concentration values for the region “North Greenland” (N). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

GRLregion	Category	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
N	Crinkled snow lichen	Cd	mg/kg	0.07	0.07	0.07	0.07	0.07	1	1
N	Crinkled snow lichen	Pb	mg/kg	2	2	2	2	2	1	1
N	Crinkled snow lichen	Zn	mg/kg	14	14	14	14	14	1	1
N	Sediment	Ag	mg/kg	0.01	0.04	0.07	0.11	0.27	53	43
N	Sediment	Al	mg/kg	27297	35837	41828	54898	76900	53	43
N	Sediment	As	mg/kg	3.54	4.76	5.65	7.72	11.59	53	43
N	Sediment	Au	mg/kg	<DL	<DL	0.008	0.02	0.105	53	43
N	Sediment	Ba	mg/kg	176.15	226.4	291.81	347.74	470.54	53	43
N	Sediment	Be	mg/kg	0.68	1.14	1.39	1.73	2.35	53	43
N	Sediment	Bi	mg/kg	0.08	0.14	0.18	0.22	0.3	53	43
N	Sediment	Ca	mg/kg	32017	44450	54985	84664	152030	53	43
N	Sediment	Cd	mg/kg	0.063	0.12	0.144	0.187	1.395	53	43
N	Sediment	Ce	mg/kg	26.77	36.76	41.58	48.07	66.49	53	43
N	Sediment	Co	mg/kg	6.02	8.19	9.33	11.86	17.72	53	43
N	Sediment	Cr	mg/kg	35.26	50.44	61.85	76.25	111.97	53	43
N	Sediment	Cs	mg/kg	1.72	2.21	2.69	3.92	6.08	53	43
N	Sediment	Cu	mg/kg	10.36	14.04	17.26	22.11	91.03	53	43
N	Sediment	d.m.%	%	100	100	100	100	100	53	43
N	Sediment	Fe	mg/kg	20470	23570	28540	34430	49320	53	43
N	Sediment	Ga	mg/kg	6.97	9.71	11.32	14.66	21.43	53	43
N	Sediment	Hg	mg/kg	<DL	0.025	0.047	0.065	0.195	53	43
N	Sediment	K	mg/kg	7850.8	10918	12260	15393	20708	53	43
N	Sediment	La	mg/kg	12.81	17.03	19.94	23.1	32.34	53	43
N	Sediment	Li	mg/kg	17.66	25.65	30.25	37.51	51.97	53	43
N	Sediment	Mg	mg/kg	9498	11410	14250	17270	26430	53	43
N	Sediment	Mn	mg/kg	227.64	269.17	308.46	353.2	705.32	53	43
N	Sediment	Mo	mg/kg	0.13	0.33	0.58	0.81	1.65	53	43
N	Sediment	N	mg/kg	110	220	325	685	1700	40	40
N	Sediment	Na	mg/kg	3559.9	5003.4	5605.8	11355	13169	53	43
N	Sediment	Nd	mg/kg	13.33	16.99	19.02	21.39	30.26	53	43
N	Sediment	Ni	mg/kg	20.94	24.69	36.59	45.29	62.83	53	43
N	Sediment	P	mg/kg	373.06	449.5	539.74	656.77	1058.7	53	43
N	Sediment	Pb	mg/kg	10.97	13.37	16.68	23.09	124.6	53	43
N	Sediment	Pd	mg/kg	<DL	<DL	0.01	0.03	0.09	53	43
N	Sediment	Pt	mg/kg	<DL	0.001	0.005	0.011	0.027	53	43
N	Sediment	Rb	mg/kg	52.13	63.95	75.78	94.44	133.85	53	43
N	Sediment	S	mg/kg	<DL	245.38	453.93	814.66	2608.3	53	43
N	Sediment	Sb	mg/kg	0.27	0.44	0.66	0.83	2.55	53	43
N	Sediment	Sc	mg/kg	6.26	7.46	8.88	11.37	16.69	53	43

N	Sediment	Se	mg/kg	<DL	0.02	0.44	0.75	3.93	53	43
N	Sediment	Sm	mg/kg	2.92	3.5	3.91	4.3	6.34	53	43
N	Sediment	Sn	mg/kg	0.87	1.46	1.69	2.11	3.08	53	43
N	Sediment	Sr	mg/kg	65.52	87	100.81	129.59	244.34	53	43
N	Sediment	Te	mg/kg	<DL	<DL	0.02	0.07	0.21	53	43
N	Sediment	Th	mg/Kg	3.74	5.18	6.27	7.63	9.53	53	43
N	Sediment	Ti	mg/kg	1652.5	2171.1	2526.5	2954	4512.1	53	43
N	Sediment	Tl	mg/kg	0.21	0.39	0.47	0.62	2.98	53	43
N	Sediment	U	mg/Kg	1.33	1.62	1.89	2.11	3.22	53	43
N	Sediment	V	mg/kg	38.3	49.99	67.33	84.16	118.77	53	43
N	Sediment	W	mg/kg	0.67	1.05	1.32	1.64	3.3	53	43
N	Sediment	Y	mg/kg	14.29	15.79	17.03	19.6	31.26	53	43
N	Sediment	Zn	mg/kg	43.51	57.13	74	88	638.15	53	43
N	Sediment	Zr	mg/kg	60.76	91.11	108.19	126.96	224.31	53	43
N	Unfiltered water	Ag	µg/l	<DL	<DL	<DL	<DL	0.01	19	18
N	Unfiltered water	Al	µg/l	1.2	7.4	13.6	102.8	389.8	19	18
N	Unfiltered water	As	µg/l	<DL	0.06	0.1	0.14	0.33	19	18
N	Unfiltered water	Au	µg/l	<DL	<DL	<DL	<DL	0.018	19	18
N	Unfiltered water	Ba	µg/l	1.49	2.43	3.76	5.92	22.16	19	18
N	Unfiltered water	Be	µg/l	<DL	0.003	0.009	0.012	0.043	19	18
N	Unfiltered water	Bi	µg/l	<DL	0.0003	0.0005	0.001	0.003	19	18
N	Unfiltered water	Ca	µg/l	14547	19326	25422	35403.5	101830	19	18
N	Unfiltered water	Cd	µg/l	<DL	0.002	0.006	0.025	1.785	19	18
N	Unfiltered water	Ce	µg/l	0.006	0.017	0.081	0.102	0.504	19	18
N	Unfiltered water	Co	µg/l	0.01	0.021	0.049	0.084	0.389	19	18
N	Unfiltered water	Cr	µg/l	0.048	0.058	0.073	0.165	0.8	19	18
N	Unfiltered water	Cs	µg/l	0.001	0.004	0.005	0.018	0.07	19	18
N	Unfiltered water	Cu	µg/l	0.03	0.19	0.43	0.555	3.92	19	18
N	Unfiltered water	Fe	µg/l	1.2	3.7	15.7	55.465	458	19	18
N	Unfiltered water	Ga	µg/l	0.0007	0.005	0.008	0.035	0.108	19	18
N	Unfiltered water	Hg	µg/l	<DL	<DL	<DL	<DL	0.099	19	18
N	Unfiltered water	K	µg/l	103	164	251	304	1271	19	18
N	Unfiltered water	La	µg/l	0.005	0.009	0.031	0.0465	0.24	19	18
N	Unfiltered water	Li	µg/l	0.13	0.315	0.45	0.9	4.39	19	18
N	Unfiltered water	Mg	µg/l	1201	2559	3841	8675	82230	19	18
N	Unfiltered water	Mn	µg/l	0.17	1.06	1.98	7.14	40.14	19	18
N	Unfiltered water	Mo	µg/l	0.02	0.040	0.05	0.087	0.215	19	18
N	Unfiltered water	Na	µg/l	148	390.5	1181	1968.5	7574	19	18
N	Unfiltered water	Nd	µg/l	0.007	0.019	0.086	0.106	0.539	19	18
N	Unfiltered water	Ni	µg/l	0.032	0.083	0.139	0.322	1.424	19	18
N	Unfiltered water	P	µg/l	0.5	1.25	3.2	5.7	57.3	19	18
N	Unfiltered water	Pb	µg/l	0.03	0.051	0.116	0.364	5.219	19	18
N	Unfiltered water	Pd	µg/l	0.004	0.006	0.007	0.011	0.034	19	18

N	Unfiltered water	Pt	µg/l	<DL	<DL	<DL	<DL	<DL	19	18
N	Unfiltered water	Rb	µg/l	0.015	0.05	0.104	0.253	0.816	19	18
N	Unfiltered water	S	µg/l	825	3144.5	8036	14250	231360	19	18
N	Unfiltered water	Sb	µg/l	<DL	0.008	0.019	0.037	0.164	19	18
N	Unfiltered water	Sc	µg/l	0.021	0.031	0.043	0.079	0.129	19	18
N	Unfiltered water	Se	µg/l	<DL	0.07	0.14	0.19	1.18	19	18
N	Unfiltered water	Sn	µg/l	<DL	0.008	0.012	0.019	0.06	19	18
N	Unfiltered water	Sr	µg/l	20.24	30.445	40.04	54.185	217.74	19	18
N	Unfiltered water	Ta	µg/l	<DL	<DL	<DL	0.012	0.017	19	18
N	Unfiltered water	Te	µg/l	<DL	<DL	0.001	0.004	0.009	19	18
N	Unfiltered water	Th	µg/l	0.0002	0.0009	0.004	0.009	0.021	19	18
N	Unfiltered water	Ti	µg/l	0.003	0.031	0.124	0.411	3.499	19	18
N	Unfiltered water	Tl	µg/l	<DL	<DL	<DL	<DL	<DL	19	18
N	Unfiltered water	U	µg/l	0.0656	0.137	0.205	0.276	2.502	19	18
N	Unfiltered water	V	µg/l	<DL	0.009	0.026	0.095	0.753	19	18
N	Unfiltered water	W	µg/l	<DL	<DL	<DL	<DL	0.038	19	18
N	Unfiltered water	Y	µg/l	0.023	0.031	0.075	0.106	0.441	19	18
N	Unfiltered water	Zn	µg/l	0.2	0.44	1.05	10.875	838.4	19	18
N	Unfiltered water	Zr	µg/l	<DL	0.012	0.026	0.056	0.204	19	18

Greenland environmental baseline element concentration alues

Based on all available baseline data (samples representing unpolluted conditions) in the AMDA database, "Greenland median" concentration values of approx. 70 different elements in eight different sample types have been calculated. The "Greenland median" values are calculated from a total of 2115 samples from all over Greenland (seaweed: 71; crinkled snow lichen: 194; blue mussel: 364; short-horn sculpin: 854; sediment: 123; soil: 43; filtered water: 288, and unfiltered water: 178). Note that for some elements and sample types very few data exist. Also note that the "Greenland median" values are not geographically/spatially weighed, but represent unweighted medians of baseline samples, which typically cluster in areas where there has been an interest in mining operations, but also supplemented with other environmental samples.

Most of the columns in the tables that follow should be self-explanatory, but a few need mentioning: q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concen-tration measurements of the particular element in the particular sample type. As some samples were sub-divided prior to measurement (e.g. a sculpin spilt in liver, bone, muscle etc), the number of measurements may be greater than the number of individual samples. Among the values, "<DL" means that the concentration is below the detection limit of the instrument.

The results for each sample type are found in Table A2.8-A2.15.

Table A2.8 Greenland environmental baseline element concentration values for blue mussels. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Blue mussel	Ag	mg/kg	<DL	0.021	0.06	0.071	3.004	90	81
Blue mussel	Al	mg/kg	0.141	131.718	259.178	495.119	15767	106	96
Blue mussel	As	mg/kg	<DL	10.065	12.656	15	32.19	148	118
Blue mussel	Au	mg/kg	<DL	<DL	<DL	0.015	0.047	84	74
Blue mussel	B	mg/Kg	2.9	3.2	4.7	11.4	20	11	11
Blue mussel	Ba	mg/kg	<DL	1.1	3.217	6.675	73.6	87	80
Blue mussel	Be	mg/Kg	<DL	0.003	0.011	0.115	24.681	85	73
Blue mussel	Bi	mg/kg	<DL	<DL	0.003	0.005	0.169	87	80
Blue mussel	Ca	mg/kg	3	2246.33	3073.376	4582	68138	75	70
Blue mussel	Cd	mg/kg	0.107	1.956	2.736	4.087	9.03	221	190
Blue mussel	Ce	mg/Kg	<DL	0.499	2.4475	8.013	51.396	86	74
Blue mussel	CH3Hg	mg/kg	<DL	0.009	0.011	0.015	0.019	6	6
Blue mussel	Co	mg/Kg	0.01	0.42	0.582	0.849	6.419	108	91
Blue mussel	Cr	mg/Kg	<DL	0.701	1.058	1.514	18.46	138	118
Blue mussel	Cs	mg/kg	0.006	0.022	0.028	0.049	3.223	64	57
Blue mussel	Cu	mg/kg	0.13	6.134	7.366	8.167	40.73	128	113
Blue mussel	d.m.%	%	9.62	14.925	17.06	19	25.344	299	274
Blue mussel	Dy	mg/Kg	0.013	0.049	0.096	0.313	1.580	52	41
Blue mussel	Er	mg/Kg	0.006	0.025	0.050	0.225	0.890	52	41
Blue mussel	Eu	mg/Kg	0.006	0.02	0.036	0.067	0.247	52	41
Blue mussel	Fe	mg/kg	<DL	163.946	247.617	436.903	12999.3	128	113
Blue mussel	Ga	mg/kg	0.035	0.097	0.162	0.271	7.233	64	57
Blue mussel	Gd	mg/Kg	0.052	0.125	0.252	1.129	4.295	52	41
Blue mussel	Ge	mg/kg	0.03	0.040	0.044	0.049	0.062	12	10
Blue mussel	Hf	mg/kg	<DL	0.001	0.008	0.013	0.089	42	36
Blue mussel	Hg	mg/kg	0.005	0.068	0.09	0.111	0.816	223	191
Blue mussel	Ho	mg/Kg	0.003	0.010	0.019	0.066	0.325	52	41
Blue mussel	K	mg/kg	38	10450.745	12405.711	14703.847	39686	75	70
Blue mussel	La	mg/Kg	<DL	0.537	2.046	6.997	48.733	82	70
Blue mussel	Li	mg/kg	0.005	0.264	0.609	1.099	17.078	64	57
Blue mussel	Lu	mg/Kg	0.001	0.003	0.006	0.018	0.082	52	41
Blue mussel	Mg	mg/kg	0.2	2601.762	3262.55	4532.198	9936	105	97
Blue mussel	Mn	mg/Kg	0.03	5.71	9.205	14.266	358.75	127	112
Blue mussel	Mo	mg/Kg	<DL	0.468	0.594	0.729	2.29	127	112
Blue mussel	Na	mg/kg	95	12000	17223.798	24771.202	94661	73	68
Blue mussel	Nb	mg/Kg	<DL	0.084	0.166	0.425	3.515	52	41
Blue mussel	Nd	mg/Kg	<DL	0.320	1.179	3.730	23.274	86	74
Blue mussel	Ni	mg/Kg	<DL	1.007	1.475	2.608	19.009	138	118
Blue mussel	P	mg/kg	33	9301	10217	11000	16344	87	80

Blue mussel	Pb	mg/kg	0.005	0.479	0.694	1.218	15.63	190	163
Blue mussel	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	8	8
Blue mussel	Pd	mg/kg	<DL	0.007	0.022	0.046	0.091	45	40
Blue mussel	Po-210	Bq/kg	10	13	22	51.96	72	13	13
Blue mussel	Pr	mg/Kg	0.045	0.138	0.362	1.057	6.840	52	41
Blue mussel	Pt	mg/kg	<DL	<DL	<DL	0.001	0.05	47	41
Blue mussel	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	25	11	11
Blue mussel	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	8	8
Blue mussel	Rb	mg/Kg	0.021	6.041	6.563	8.207	180.37	74	62
Blue mussel	Re	mg/kg	<DL	<DL	<DL	0.000	0.001	42	36
Blue mussel	Rh	mg/kg	<DL	0.001	0.002	0.002	0.007	34	31
Blue mussel	Ru	mg/Kg	<DL	<DL	<DL	<DL	0.001	30	26
Blue mussel	S	mg/kg	1574	23159	24072	26212	33721	15	14
Blue mussel	Sb	mg/kg	<DL	<DL	0.009	0.014	0.04	87	80
Blue mussel	Sc	mg/kg	<DL	0.089	0.194	0.951	10.36	76	69
Blue mussel	Se	mg/kg	0.03	2.968	4.085	5.304	12.08	191	163
Blue mussel	Si	mg/kg	8.232	137.005	287.56	444.593	814.02	34	31
Blue mussel	Sm	mg/Kg	<DL	0.039	0.154	0.285	2.861	64	53
Blue mussel	Sn	mg/Kg	<DL	<DL	<DL	0.011	1.16	67	59
Blue mussel	Sr	mg/kg	<DL	28	35.200	51.5	408.9	87	80
Blue mussel	Ta	mg/kg	<DL	<DL	0.002	0.003	0.052	64	57
Blue mussel	Tb	mg/Kg	0.003	0.011	0.0225	0.093	0.357	52	41
Blue mussel	Te	mg/kg	<DL	<DL	0.0028	0.004	0.059	49	43
Blue mussel	Th	mg/Kg	<DL	0.006	0.055	0.187	8.62	97	85
Blue mussel	Ti	mg/kg	0.177	11.388	29.693	79.552	932.75	95	87
Blue mussel	Tl	mg/kg	<DL	<DL	<DL	0.008	0.19	87	80
Blue mussel	Tm	mg/Kg	0.0008	0.003	0.007	0.022	0.112	52	41
Blue mussel	U	mg/Kg	<DL	0.15	0.256	0.369	1.376	108	85
Blue mussel	V	mg/Kg	0.09	0.688	0.928	1.234	30.04	112	98
Blue mussel	W	mg/kg	<DL	<DL	0.017	0.031	0.113	61	55
Blue mussel	Y	mg/Kg	<DL	0.085	0.302	1.274	14.588	86	74
Blue mussel	Yb	mg/Kg	0.004	0.02	0.04	0.120	0.591	52	41
Blue mussel	Zn	mg/Kg	0.17	66.486	75.699	94.696	244.548	138	118
Blue mussel	Zr	mg/Kg	0.002	0.0553	0.243	0.928	6.11	82	69

Table A2.9 Greenland environmental baseline element concentration values for crinkled snow lichen. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Crinkled snow lichen	Ag	mg/kg	<DL	<DL	0.00	0.01	0.10	122	116
Crinkled snow lichen	Al	mg/kg	0.08	150.97	242.75	410.62	2.200.00	158	149
Crinkled snow lichen	As	mg/kg	<DL	0.02	0.04	0.10	0.76	187	176
Crinkled snow lichen	Au	mg/kg	<DL	<DL	<DL	<DL	0.02	118	112
Crinkled snow lichen	B	mg/Kg	<DL	<DL	<DL	0.35	0.70	3	3
Crinkled snow lichen	Ba	mg/kg	0.00	7.40	12.23	33.75	140.00	122	116
Crinkled snow lichen	Be	mg/kg	<DL	0.00	0.03	0.07	2.20	79	73
Crinkled snow lichen	Bi	mg/kg	<DL	<DL	0.00	0.00	0.01	120	114
Crinkled snow lichen	Ca	mg/kg	1.37	1.649.00	3.985.34	9.925.00	27.000.00	110	106
Crinkled snow lichen	Cd	mg/kg	0.00	0.06	0.09	0.13	0.52	213	194
Crinkled snow lichen	Ce	mg/kg	<DL	0.51	3.20	6.80	115.52	117	111
Crinkled snow lichen	Co	mg/kg	<DL	0.09	0.18	0.58	4.60	122	116
Crinkled snow lichen	Cr	mg/kg	<DL	0.19	0.33	0.83	3.94	186	175
Crinkled snow lichen	Cs	mg/kg	0.01	0.03	0.05	0.09	1.79	76	70
Crinkled snow lichen	Cu	mg/kg	<DL	0.558	0.762	1.385	13	188	176
Crinkled snow lichen	d.m.%	%	100	100	100	100	100	13	12
Crinkled snow lichen	Dy	mg/kg	0.009	0.060	0.109	0.349	5.032	63	58
Crinkled snow lichen	Er	mg/kg	0.004	0.029	0.052	0.153	2.482	63	58
Crinkled snow lichen	Eu	mg/kg	0.004	0.020	0.030	0.092	0.751	63	58
Crinkled snow lichen	Fe	mg/kg	0.056	92.876	158.433	411.377	1500	188	176
Crinkled snow lichen	Ga	mg/kg	0.017	0.109	0.207	0.433	3.240	76	70
Crinkled snow lichen	Gd	mg/kg	0.033	0.102	0.190	0.667	7.583	63	58
Crinkled snow lichen	Ge	mg/kg	0.012	0.016	0.018	0.025	0.03	12	10
Crinkled snow lichen	Hf	mg/kg	<DL	0.007	0.017	0.032	0.223	63	58
Crinkled snow lichen	Hg	mg/kg	<DL	0.029	0.034	0.049	0.31	201	182
Crinkled snow lichen	Ho	mg/kg	0.002	0.011	0.020	0.062	0.957	63	58
Crinkled snow lichen	K	mg/kg	86	1584.077	2024.346	2400	3200	108	104
Crinkled snow lichen	La	mg/kg	0.090	0.702	1.875	4.192	119.516	112	106
Crinkled snow lichen	Li	mg/kg	<DL	0.030	0.073	0.157	1.041	76	70
Crinkled snow lichen	Lu	mg/kg	4.70E-04	0.003	0.005	0.014	0.191	63	58
Crinkled snow lichen	Mg	mg/kg	0.771	729.565	940.486	1600	3532	149	142
Crinkled snow lichen	Mn	mg/kg	0.017	27.064	47	66.110	135.183	160	151
Crinkled snow lichen	Mo	mg/kg	<DL	<DL	0.021	0.039	0.23	159	150
Crinkled snow lichen	Na	mg/kg	<DL	565.691	704.883	900.810	4262	108	104
Crinkled snow lichen	Nb	mg/kg	0.009	0.222	0.528	0.904	5.045	63	58
Crinkled snow lichen	Nd	mg/kg	<DL	0.144	1.005	2.1	60.595	117	111
Crinkled snow lichen	Ni	mg/kg	<DL	0.188	0.441	1.205	6.5	188	176
Crinkled snow lichen	P	mg/kg	<DL	510	634.5	757.214	1300	120	114
Crinkled snow lichen	Pb	mg/kg	<DL	0.483	0.665	1.08	11.408	193	182
Crinkled snow lichen	Pb-210	Bq/kg	260	260	260	260	260	1	1
Crinkled snow lichen	Pd	mg/kg	<DL	0.001	0.004	0.035	0.156	64	60

Crinkled snow lichen	Po-210	Bq/kg	114.9	237.85	297.3	454.4	680.1	23	23
Crinkled snow lichen	Pr	mg/kg	0.027	0.187	0.315	1.210	18.622	63	58
Crinkled snow lichen	Pt	mg/kg	<DL	<DL	<DL	<DL	0.003	63	58
Crinkled snow lichen	Ra-226	Bq/kg	<DL	14.5	29	58.5	88	3	3
Crinkled snow lichen	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	1	1
Crinkled snow lichen	Rb	mg/kg	0.513	1.864	2.749	3.933	10.097	76	70
Crinkled snow lichen	Re	mg/kg	<DL	<DL	<DL	5.77E-05	0.001	63	58
Crinkled snow lichen	Rh	mg/kg	<DL	3.00E-04	5.00E-04	9.00E-04	0.002	25	22
Crinkled snow lichen	Ru	mg/Kg	<DL	<DL	<DL	<DL	0.001	51	48
Crinkled snow lichen	S	mg/kg	167	310	427	599	945	13	12
Crinkled snow lichen	Sb	mg/kg	<DL	<DL	5.00E-04	0.005	0.2	120	114
Crinkled snow lichen	Sc	mg/kg	<DL	<DL	0.077	0.148	1.321	117	111
Crinkled snow lichen	Se	mg/kg	<DL	0.046	0.061	0.103	3.3	165	149
Crinkled snow lichen	Si	mg/kg	64.916	105.97	140.39	163.8	255.65	25	22
Crinkled snow lichen	Sm	mg/kg	<DL	<DL	0.033	0.247	8.687	104	99
Crinkled snow lichen	Sn	mg/kg	<DL	<DL	<DL	1.00E-04	0.7	69	66
Crinkled snow lichen	Sr	mg/kg	<DL	13.520	25.847	48.239	104.551	120	114
Crinkled snow lichen	Ta	mg/kg	<DL	5.50E-04	0.004	0.013	0.061	76	70
Crinkled snow lichen	Tb	mg/kg	0.002	0.013	0.022	0.077	0.968	63	58
Crinkled snow lichen	Te	mg/kg	<DL	<DL	<DL	6.43E-04	0.004	63	58
Crinkled snow lichen	Th	mg/Kg	<DL	<DL	0.02	0.119	4.7	120	114
Crinkled snow lichen	Ti	mg/kg	1.4	16.162	30.729	49.857	110	130	124
Crinkled snow lichen	Tl	mg/kg	<DL	<DL	<DL	0.002	0.047	120	114
Crinkled snow lichen	Tm	mg/kg	5.30E-04	0.004	0.007	0.0195	0.298	63	58
Crinkled snow lichen	U	mg/Kg	<DL	<DL	0.011	0.056	1.6	123	114
Crinkled snow lichen	V	mg/kg	<DL	0.203	0.356	0.956	4.3	173	162
Crinkled snow lichen	W	mg/kg	<DL	<DL	0.004	0.015	6.3	104	99
Crinkled snow lichen	Y	mg/kg	<DL	<DL	0.083	0.711	47.257	117	111
Crinkled snow lichen	Yb	mg/kg	0.004	0.022	0.038	0.1035	1.530	63	58
Crinkled snow lichen	Zn	mg/kg	<DL	14.589	19.247	24.3	90	193	182
Crinkled snow lichen	Zr	mg/kg	0.053	0.136	0.315	1.050	12.639	86	80

Table A2.10 Greenland environmental baseline element concentration values for filtered water. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Filtered water	Ag	µg/l	<DL	<DL	0.008	0.208	0.524	305	269
Filtered water	Al	µg/l	<DL	8.35	16.5	28.25	233.15	315	279
Filtered water	As	µg/l	<DL	0.001	0.054	0.319	4.827	205	177
Filtered water	Au	µg/l	<DL	<DL	0.004	0.007	0.065	305	269
Filtered water	B	µg/l	0.196	0.283	0.459	0.72	2.829	50	50
Filtered water	Ba	µg/l	<DL	0.58	2.18	5.688	263.79	305	269
Filtered water	Be	µg/l	<DL	0.005	0.024	0.095	0.771	176	167
Filtered water	Bi	µg/l	<DL	<DL	5.00E-04	0.001	0.008	289	261
Filtered water	Ca	µg/l	275	1661	3790	7330	106500	305	269
Filtered water	Cd	µg/l	<DL	<DL	0.004	0.010	0.11	214	186
Filtered water	Ce	µg/l	<DL	0.019	0.045	0.14	1.03	305	269
Filtered water	Cl	µg/l	3209	4965	6824	10640.5	19655	83	83
Filtered water	Co	µg/l	<DL	0.005	0.02	0.046	0.76	305	269
Filtered water	Cr	µg/l	<DL	0.01	0.08	0.14	0.63	315	279
Filtered water	Cs	µg/l	<DL	0.003	0.008	0.013	0.186	176	167
Filtered water	Cu	µg/l	<DL	0.186	0.61	1.185	8.45	315	279
Filtered water	Dy	µg/l	<DL	0.004	0.009	0.017	0.484	173	165
Filtered water	Er	µg/l	<DL	0.002	0.005	0.009	0.278	173	165
Filtered water	Eu	µg/l	<DL	0.001	0.002	0.008	0.051	173	165
Filtered water	F	µg/l	<DL	153	1039	1914	28302	91	91
Filtered water	Fe	µg/l	<DL	5.174	9.7	33.52	257.1	314	279
Filtered water	Ga	µg/l	<DL	0.007	0.015	0.084	0.968	176	167
Filtered water	Gd	µg/l	<DL	0.006	0.014	0.033	0.622	173	165
Filtered water	Ge	µg/l	0.0064	0.017	0.022	0.028	0.057	19	19
Filtered water	Hf	µg/l	<DL	0.003	0.006	0.012	0.471	173	165
Filtered water	Hg	µg/l	<DL	<DL	<DL	0.003	0.021	205	177
Filtered water	Ho	µg/l	<DL	7.40E-04	0.002	0.003	0.098	173	165
Filtered water	K	µg/l	45	360	687	972	4989	305	269
Filtered water	La	µg/l	<DL	0.016	0.065	0.218	0.736	305	269
Filtered water	Li	µg/l	<DL	0.22	0.61	0.988	21.78	286	269
Filtered water	Lu	µg/l	<DL	1.03E-04	4.35E-04	8.08E-04	0.004	98	98
Filtered water	Mg	µg/l	59.2	319	721.4	1576.5	19540	315	279
Filtered water	Mn	µg/l	<DL	0.532	2.16	3.848	99.368	290	255
Filtered water	Mo	µg/l	<DL	0.164	0.364	2.197	29.018	205	177
Filtered water	Na	µg/l	211	470	2258	6875	127430	305	269
Filtered water	Nb	µg/l	<DL	0.002	0.006	0.009	1.608	173	165
Filtered water	Nd	µg/l	<DL	0.017	0.057	0.173	0.878	305	269
Filtered water	Ni	µg/l	<DL	0.034	0.18	0.43	7.488	315	279
Filtered water	P	µg/l	<DL	1.16	3.9	5.1	98.5	305	269
Filtered water	Pb	µg/l	<DL	0.019	0.03	0.079	7.064	324	288
Filtered water	Pd	µg/l	<DL	<DL	0.001	0.002	0.018	176	167

Filtered water	Pr	µg/l	0.0009	0.014	0.027	0.066	0.916	173	165
Filtered water	Pt	µg/l	<DL	<DL	9.35E-04	0.002	0.007	286	269
Filtered water	Rb	µg/l	<DL	0.793	1.165	1.758	7.34	286	269
Filtered water	Re	µg/l	<DL	<DL	1.00E-04	3.00E-04	0.020	157	149
Filtered water	Rh	µg/l	<DL	<DL	5.00E-04	0.001	0.002	35	35
Filtered water	Ru	µg/l	<DL	<DL	<DL	<DL	0.002	174	165
Filtered water	S	µg/l	206	458	1044	2414	62450	253	245
Filtered water	Sb	µg/l	<DL	0.009	0.033	0.056	1.408	195	167
Filtered water	Sc	µg/l	<DL	0.02	0.055	0.45	1.51	289	253
Filtered water	Se	µg/l	<DL	0.027	0.064	0.128	0.407	195	167
Filtered water	Si	µg/l	4.89	8.778	15.68	27.095	73.8	58	58
Filtered water	Sm	µg/l	0.0004	0.010	0.023	0.043	0.545	192	165
Filtered water	Sn	µg/l	<DL	<DL	0.02	0.03	0.78	281	245
Filtered water	Sr	µg/l	1.755	8.65	13.9	24.14	210.75	305	269
Filtered water	Ta	µg/l	<DL	<DL	0.003	0.005	0.054	285	269
Filtered water	Tb	µg/l	<DL	0.001	0.002	0.004	0.082	173	165
Filtered water	Te	µg/l	<DL	<DL	<DL	0.003	0.019	168	159
Filtered water	Th	µg/l	<DL	0.002	0.004	0.007	0.121	305	269
Filtered water	Ti	µg/l	<DL	0.060	0.183	0.594	6.39	315	279
Filtered water	Tl	µg/l	<DL	<DL	0.004	0.013	0.125	195	167
Filtered water	Tm	µg/l	<DL	2.40E-04	7.00E-04	0.001	0.037	173	165
Filtered water	U	µg/l	<DL	0.019	0.059	0.114	2.823	195	167
Filtered water	V	µg/l	<DL	0.048	0.14	0.228	0.98	315	279
Filtered water	W	µg/l	<DL	0.005	0.015	0.029	0.882	195	167
Filtered water	Y	µg/l	0.001	0.006	0.033	0.064	0.619	305	269
Filtered water	Yb	µg/l	<DL	0.001	0.004	0.007	0.227	173	165
Filtered water	Zn	µg/l	<DL	0.437	0.991	1.839	158.23	324	288
Filtered water	Zr	µg/l	<DL	0.018	0.038	0.083	0.637	296	279

Table A2.11 Greenland environmental baseline element concentration values for seaweed (the “seaweed” category contains two types of brown fucoid macroalgae). q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Seaweed	Ag	mg/kg	<DL	0.086	0.103	0.130	0.215	50	44
Seaweed	Al	mg/kg	3.527	25.555	55.752	101.628	821.404	63	56
Seaweed	As	mg/kg	1.06	31.285	40.591	45.2	91	88	71
Seaweed	Au	mg/kg	<DL	<DL	0.006	0.011	0.035	47	40
Seaweed	B	mg/Kg	15	16	64.5	117.5	120	6	6
Seaweed	Ba	mg/Kg	1.1	8.411	12.990	19.553	168.194	66	51
Seaweed	Be	mg/Kg	<DL	0.0007	0.004	0.032	0.227	63	48
Seaweed	Bi	mg/kg	<DL	1.12E-04	0.001	0.002	0.006	50	44
Seaweed	Ca	mg/kg	970	6375	8200	14144.733	22879	37	35
Seaweed	Cd	mg/Kg	0.164	0.811	1.340	1.967	3.466	88	71
Seaweed	Ce	mg/Kg	<DL	0.121	0.288	0.806	2.046	60	45
Seaweed	Co	mg/Kg	0.089	0.439	0.58	0.778	3.5	69	53
Seaweed	Cr	mg/Kg	<DL	0.165	0.293	0.546	5.9	88	71
Seaweed	Cs	mg/kg	0.019	0.024	0.032	0.045	0.104	41	35
Seaweed	Cu	mg/kg	<DL	1.635	1.97	2.635	12	72	64
Seaweed	d.m.%	%	11.7	14.81	18.05	100	100	37	20
Seaweed	Dy	mg/Kg	0.006	0.018	0.061	0.094	0.205	43	30
Seaweed	Er	mg/Kg	0.003	0.010	0.033	0.060	0.130	43	30
Seaweed	Eu	mg/Kg	0.002	0.008	0.028	0.059	0.184	43	30
Seaweed	Fe	mg/Kg	9	41.438	74.75	134.175	639.101	88	71
Seaweed	Ga	mg/kg	0.024	0.035	0.118	0.301	0.78	41	35
Seaweed	Gd	mg/Kg	0.023	0.055	0.123	0.196	0.370	43	30
Seaweed	Ge	mg/kg	0.013	0.022	0.025	0.033	0.067	13	10
Seaweed	Hf	mg/kg	<DL	<DL	<DL	0.009	0.017	27	23
Seaweed	Hg	mg/kg	<DL	0.002	0.006	0.011	0.15	82	65
Seaweed	Ho	mg/Kg	0.001	0.003	0.012	0.019	0.044	43	30
Seaweed	K	mg/kg	3100	23810.532	29267	33780	44000	37	35
Seaweed	La	mg/Kg	<DL	0.1527	0.284	0.847	2.691	57	42
Seaweed	Li	mg/kg	0.212	0.364	0.459	0.674	1.188	41	35
Seaweed	Lu	mg/Kg	5.55E-04	0.001	0.004	0.006	0.013	43	30
Seaweed	Mg	mg/kg	1000	7215.367	8000.100	8465.171	12000	56	53
Seaweed	Mn	mg/Kg	2.4	14.038	21.7	35	121.042	85	69
Seaweed	Mo	mg/Kg	<DL	0.079	0.112	0.188	0.416	85	69
Seaweed	Na	mg/kg	1600	18380.471	25729.785	32778	51000	37	35
Seaweed	Nb	mg/kg	0.003	0.018	0.093	0.176	0.59662	43	30
Seaweed	Nd	mg/Kg	<DL	0.135	0.221	0.806	2.061	60	45
Seaweed	Ni	mg/Kg	<DL	0.869	1.635	2.784	8.696	88	71
Seaweed	P	mg/kg	200	1300	2415.5	3010.25	6198	50	44
Seaweed	Pb	mg/Kg	<DL	0.063	0.120	0.231	0.85	88	71
Seaweed	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	3	3

Seaweed	Pd	mg/kg	0.021	0.028	0.040	1.22	1.698	28	26
Seaweed	Po-210	Bq/kg	<DL	<DL	<DL	11.66	19.6	9	9
Seaweed	Pr	mg/kg	0.013	0.049	0.139	0.258	0.561	43	30
Seaweed	Pt	mg/kg	<DL	<DL	0.001	0.002	0.005	26	22
Seaweed	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	11	6	6
Seaweed	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	3	3
Seaweed	Rb	mg/kg	5.518	8.348	11.826	16.714	26.217	57	42
Seaweed	Re	mg/kg	0.009	0.023	0.057	0.071	0.090	27	23
Seaweed	Rh	mg/kg	0.0148	0.022	0.024	0.028	0.042	27	22
Seaweed	Ru	mg/kg	<DL	0.006	0.008	0.010	0.011	14	13
Seaweed	S	mg/kg	28734	31408.75	34243	35306.750	39674	14	13
Seaweed	Sb	mg/Kg	<DL	0.010	0.016	0.033	0.056	66	51
Seaweed	Sc	mg/kg	<DL	0.066	0.2215	0.535	2.821	44	38
Seaweed	Se	mg/kg	<DL	0.017	0.032	0.22	1.8	77	53
Seaweed	Si	mg/kg	15.897	32.609	65.658	189.61	495.29	27	22
Seaweed	Sm	mg/Kg	<DL	0.023	0.086	0.159	0.313	46	33
Seaweed	Sn	mg/kg	<DL	<DL	0.002	0.007	0.029	36	31
Seaweed	Sr	mg/kg	68	631.978	726.428	899.075	1256.1	50	44
Seaweed	Ta	mg/kg	<DL	<DL	0.001	0.002	0.007	41	35
Seaweed	Tb	mg/Kg	0.001	0.004	0.014	0.022	0.052	43	30
Seaweed	Te	mg/kg	<DL	0.002	0.004	0.008	0.013	27	23
Seaweed	Th	mg/Kg	<DL	0.008	0.016	0.046	0.316	66	51
Seaweed	Ti	mg/kg	0.6	5.107	13.314	34.086	52.207	54	47
Seaweed	Tl	mg/kg	<DL	<DL	0.003	0.008	0.037	50	44
Seaweed	Tm	mg/Kg	0.000	0.001	0.004	0.006	0.016	43	30
Seaweed	U	mg/Kg	0.15	0.492	0.645	1.020	1.560	72	51
Seaweed	V	mg/Kg	<DL	0.181	0.347	0.683	1.733	71	57
Seaweed	W	mg/kg	<DL	0.003	0.006	0.010	0.027	30	26
Seaweed	Y	mg/Kg	<DL	0.059	0.108	0.355	1.711	60	45
Seaweed	Yb	mg/Kg	0.004	0.009	0.030	0.0458	0.089	43	30
Seaweed	Zn	mg/Kg	<DL	10.98	13.978	24.1353	129.617	88	71
Seaweed	Zr	mg/Kg	0.108	0.217	0.347	0.551	2.4	61	45

Table A2.12 Greenland environmental baseline element concentration values for sediment. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Sediment	Ag	mg/kg	<DL	0.04	0.065	0.108	0.27	58	48
Sediment	Al	mg/kg	0.045	38076.5	48751	63464.25	85920	92	77
Sediment	As	mg/kg	3.72E-04	3.551	5.37	8.825	24.6	146	106
Sediment	Au	mg/kg	<DL	<DL	0.006	0.019	0.105	56	46
Sediment	B	mg/Kg	0.001	0.001	3.201	9.3	18	4	4
Sediment	Ba	mg/kg	8.86E-04	221.493	280.875	344.108	470.54	58	48
Sediment	Be	mg/kg	8.90E-05	1.105	1.38	1.753	81	58	48
Sediment	Bi	mg/kg	<DL	0.133	0.18	0.21	0.3	58	48
Sediment	Ca	mg/kg	2.716	43410	51561	83675.25	152030	58	48
Sediment	Cd	mg/kg	4.30E-06	0.104	0.146	0.191	1.395	100	81
Sediment	Ce	mg/kg	7.00E-06	36.273	41.3	47.275	66.49	56	46
Sediment	Cl	mg/Kg	6.24	6.250	6.261	6.271	6.281	2	2
Sediment	Co	mg/kg	1.00E-06	7.93	9.105	11.623	17.72	58	48
Sediment	Cr	mg/kg	<DL	50.123	66.775	77.976	116.609	68	56
Sediment	Cs	mg/kg	1.70E-05	2.168	2.66	3.883	6.08	56	46
Sediment	Cu	mg/kg	<DL	14.708	20.44	29.023	99.812	100	81
Sediment	d.m.%	%	100	100	100	100	100	55	45
Sediment	Dy	mg/Kg	2.99E-06	3.01E-06	3.03E-06	3.04E-06	3.06E-06	2	2
Sediment	Er	mg/Kg	1.64E-06	1.90E-06	2.16E-06	2.41E-06	2.67E-06	2	2
Sediment	Eu	mg/Kg	2.00E-07	2.50E-07	3.00E-07	3.50E-07	4.00E-07	2	2
Sediment	F	mg/Kg	3.117	3.119	3.121	3.122	3.124	2	2
Sediment	Fe	mg/kg	<DL	23240	27190	32730	51452.921	68	56
Sediment	Ga	mg/kg	3.97E-04	9.463	11.205	14.465	21.43	56	46
Sediment	Gd	mg/Kg	3.60E-06	3.65E-06	3.70E-06	3.75E-06	3.80E-06	2	2
Sediment	Hf	mg/Kg	9.80E-06	1.17E-05	1.37E-05	1.56E-05	1.75E-05	2	2
Sediment	Hg	mg/kg	<DL	0.015	0.029	0.049	0.286	565	121
Sediment	Ho	mg/Kg	7.00E-07	7.30E-07	7.60E-07	7.90E-07	8.20E-07	2	2
Sediment	K	mg/kg	0.466	10769.25	12153	14918.75	20708	58	48
Sediment	La	mg/kg	2.00E-05	16.9475	19.93	22.583	32.34	56	46
Sediment	Li	mg/kg	0.002	21.18	29.128	35.53	51.97	80	67
Sediment	LoI%	mg/kg	0.47	4.873	6.4	7.015	8.68	4	4
Sediment	Lu	mg/Kg	1.10E-07	1.48E-07	1.85E-07	2.23E-07	2.60E-07	2	2
Sediment	Mg	mg/kg	0.431	10747.5	13405	16797.5	26430	68	56
Sediment	Mn	mg/kg	1.00E-05	268.815	308.96	376.468	2104.600	68	56
Sediment	Mo	mg/kg	0.004	0.338	0.625	1.01	30.346	68	56
Sediment	N	mg/kg	110	227.5	330	677.5	1700	42	42
Sediment	Na	mg/kg	13.688	5003.1	5607.65	11366.25	23000	58	48
Sediment	Nb	mg/Kg	1.00E-07	6.00E-07	1.10E-06	1.60E-06	2.10E-06	2	2
Sediment	Nd	mg/kg	2.20E-05	16.778	18.925	21.375	30.26	56	46
Sediment	Ni	mg/kg	<DL	22.87	34.24	45.04	89.261	89	71
Sediment	P	mg/kg	<DL	448.375	546.01	661.833	1058.7	58	48

Sediment	Pb	mg/kg	<DL	12.355	14.125	21.775	124.6	100	81
Sediment	Pb-210	Bq/kg	240	240	240	240	240	1	1
Sediment	Pd	mg/kg	<DL	<DL	0.01	0.03	0.09	56	46
Sediment	Po-210	Bq/kg	230	230	230	230	230	1	1
Sediment	Pr	mg/Kg	4.90E-06	5.38E-06	5.85E-06	6.33E-06	6.80E-06	2	2
Sediment	Pt	mg/kg	<DL	7.50E-04	0.005	0.010	0.027	56	46
Sediment	Ra-226	Bq/kg	340	407.5	475	542.5	610	2	2
Sediment	Ra-228	Bq/kg	230	230	230	230	230	1	1
Sediment	Rb	mg/kg	0.003	63.39	74.835	93.555	133.85	56	46
Sediment	Re	mg/Kg	2.00E-07	2.25E-07	2.50E-07	2.75E-07	3.00E-07	2	2
Sediment	Ru	mg/Kg	<DL	<DL	<DL	<DL	<DL	2	2
Sediment	S	mg/kg	<DL	229.065	444.56	821.353	2608.3	56	46
Sediment	Sb	mg/kg	1.93E-04	0.44	0.635	0.825	2.55	58	48
Sediment	Sc	mg/kg	8.90E-05	7.31	8.815	11.213	16.69	56	46
Sediment	Se	mg/kg	<DL	0.023	0.435	0.8	3.93	66	52
Sediment	Si	mg/Kg	0.043	0.043	0.044	0.044	0.045	2	2
Sediment	Sm	mg/kg	3.00E-06	3.408	3.88	4.263	6.34	56	46
Sediment	Sn	mg/kg	<DL	1.453	1.685	2.125	27	58	48
Sediment	Sr	mg/kg	0.013	83.645	99.945	130.565	244.34	58	48
Sediment	Ta	mg/Kg	<DL	2.50E-07	5.00E-07	7.50E-07	1.00E-06	2	2
Sediment	Tb	mg/Kg	3.50E-07	4.20E-07	4.90E-07	5.60E-07	6.30E-07	2	2
Sediment	Te	mg/kg	<DL	<DL	0.02	0.063	0.21	56	46
Sediment	Th	mg/Kg	1.20E-06	5.173	6.305	7.758	190	58	48
Sediment	Ti	mg/kg	2.04E-04	2058.1	2422.6	2951.15	4512.1	58	48
Sediment	Tl	mg/kg	1.20E-05	0.39	0.465	0.65	2.98	58	48
Sediment	Tm	mg/Kg	2.40E-07	2.75E-07	3.10E-07	3.45E-07	3.80E-07	2	2
Sediment	U	mg/Kg	3.27E-04	1.618	1.945	2.14	61	60	48
Sediment	V	mg/kg	4.80E-05	45.995	61.355	78.29	118.77	68	56
Sediment	W	mg/kg	1.06E-04	0.975	1.285	1.588	3.3	56	46
Sediment	Water%	mg/kg	16.8	19.45	22.1	39.1	56.1	3	3
Sediment	Y	mg/kg	2.70E-05	15.553	17.015	19.128	31.26	56	46
Sediment	Yb	mg/Kg	1.77E-06	1.79E-06	1.82E-06	1.84E-06	1.86E-06	2	2
Sediment	Zn	mg/kg	0.002	52.926	69.105	86.42	730	100	81
Sediment	Zr	mg/kg	3.70E-05	89.033	106.89	126.03	224.31	56	46

Table A2.13 Greenland environmental baseline element concentration values for shorthorn sculpin. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Shorthorn sculpin	Ag	mg/kg	<DL	0.038	0.072	0.171	0.699	94	85
Shorthorn sculpin	Al	mg/kg	<DL	0.15	0.4	0.934	7.88	89	80
Shorthorn sculpin	As	mg/kg	1.099	3.303	7.08	12.163	64.51	102	93
Shorthorn sculpin	Au	mg/kg	<DL	<DL	9.50E-05	0.002	0.006	62	55
Shorthorn sculpin	B	mg/Kg	<DL	<DL	0.5	0.6	1.8	5	5
Shorthorn sculpin	Ba	mg/kg	<DL	<DL	0.004	0.008	0.046	88	80
Shorthorn sculpin	Be	mg/kg	<DL	<DL	3.00E-04	5.00E-04	0.004	76	70
Shorthorn sculpin	Bi	mg/kg	<DL	<DL	3.00E-04	0.001	0.007	94	85
Shorthorn sculpin	Ca	mg/kg	32	70.5	95	156.175	1400	94	85
Shorthorn sculpin	Cd	mg/kg	<DL	0.65	0.996	1.68	10.521	801	737
Shorthorn sculpin	Ce	mg/kg	2.00E-04	5.00E-04	0.001	0.003	0.039	89	80
Shorthorn sculpin	CH3Hg	mg/kg	0.136	0.230	0.401	0.708	1.68	22	20
Shorthorn sculpin	Co	mg/kg	0.006	0.03	0.046	0.068	0.24	102	93
Shorthorn sculpin	Cr	mg/kg	<DL	<DL	0.008	0.04	0.44	101	92
Shorthorn sculpin	Cs	mg/kg	0.01	0.016	0.02	0.02	0.031	89	80
Shorthorn sculpin	Cu	mg/kg	0.45	1.053	1.595	2.87	11.15	102	93
Shorthorn sculpin	d.m.%	%	13.84	24.775	29.55	34.385	53.714	868	765
Shorthorn sculpin	Dy	mg/Kg	<DL	1.25E-05	4.00E-05	1.10E-04	4.80E-04	66	60
Shorthorn sculpin	Er	mg/Kg	<DL	<DL	3.00E-05	1.00E-04	3.20E-04	53	48
Shorthorn sculpin	Eu	mg/Kg	<DL	<DL	1.00E-05	4.00E-05	1.28E-04	50	45
Shorthorn sculpin	Fe	mg/kg	4	25.025	44.04	103.675	858.7	102	93
Shorthorn sculpin	Ga	mg/kg	<DL	<DL	5.00E-04	0.029	0.039	72	65
Shorthorn sculpin	Gd	mg/Kg	<DL	3.00E-05	8.00E-05	1.64E-04	6.87E-04	63	58
Shorthorn sculpin	Hf	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	Hg	mg/kg	<DL	0.024	0.047	0.078	1.776	812	736
Shorthorn sculpin	Ho	mg/Kg	<DL	<DL	1.40E-05	4.75E-05	1.10E-04	42	38
Shorthorn sculpin	K	mg/kg	1229	2020	2411.5	3352.25	4848	94	85
Shorthorn sculpin	La	mg/kg	1.00E-04	7.00E-04	0.002	0.003	0.043	89	80
Shorthorn sculpin	Li	mg/kg	0.008	0.024	0.029	0.047	1.784	89	80
Shorthorn sculpin	Lu	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	Mg	mg/kg	94	160.5	191.45	229.825	374	94	85
Shorthorn sculpin	Mn	mg/kg	<DL	0.375	0.495	0.628	1.49	94	85
Shorthorn sculpin	Mo	mg/kg	<DL	0.039	0.055	0.09	0.176	94	85
Shorthorn sculpin	Na	mg/kg	980	1763.75	2278.5	3086.25	5987	94	85
Shorthorn sculpin	Nb	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	Nd	mg/kg	1.30E-04	3.80E-04	9.40E-04	0.003	0.015	89	80
Shorthorn sculpin	Ni	mg/kg	<DL	<DL	0.004	0.022	0.102	97	89
Shorthorn sculpin	P	mg/kg	1110	1774.5	2198	2854	3808	94	85
Shorthorn sculpin	Pb	mg/kg	<DL	0.001	0.007	0.015	0.19	264	215
Shorthorn sculpin	Pb-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	2	2
Shorthorn sculpin	Pd	mg/kg	<DL	<DL	1.00E-04	0.002	0.005	79	72

Shorthorn sculpin	Po-210	Bq/kg	<DL	<DL	<DL	<DL	<DL	4	4
Shorthorn sculpin	Pr	mg/Kg	5.00E-05	1.00E-04	1.60E-04	0.0003	0.001	58	54
Shorthorn sculpin	Pt	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	Ra-226	Bq/kg	<DL	<DL	<DL	<DL	<DL	5	5
Shorthorn sculpin	Ra-228	Bq/kg	<DL	<DL	<DL	<DL	<DL	2	2
Shorthorn sculpin	Rb	mg/kg	0.26	0.39	0.44	0.53	0.79	89	80
Shorthorn sculpin	Re	mg/Kg	<DL	7.00E-05	1.20E-04	4.28E-04	0.009	66	60
Shorthorn sculpin	Rh	mg/kg	3.00E-04	4.00E-04	4.00E-04	5.00E-04	6.00E-04	23	20
Shorthorn sculpin	Ru	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	S	mg/kg	1896.165	2573.923	3479.094	4005	4827	45	40
Shorthorn sculpin	Sb	mg/kg	<DL	<DL	0.001	0.004	0.007	77	69
Shorthorn sculpin	Sc	mg/kg	<DL	<DL	0.093	0.11	0.149	45	40
Shorthorn sculpin	Se	mg/kg	0.2	0.72	0.857	1.030	5.13	752	691
Shorthorn sculpin	Si	mg/kg	6.954	8.277	9.587	11.143	16.672	23	20
Shorthorn sculpin	Sm	mg/Kg	<DL	3.00E-05	9.95E-05	1.83E-04	7.22E-04	66	60
Shorthorn sculpin	Sn	mg/kg	<DL	<DL	0.007	0.013	0.052	82	75
Shorthorn sculpin	Sr	mg/kg	0.3	0.803	1.2	1.7	8.1	94	85
Shorthorn sculpin	Ta	mg/kg	<DL	<DL	6.00E-05	0.001	0.003	67	60
Shorthorn sculpin	Tb	mg/Kg	<DL	<DL	5.00E-06	2.75E-05	9.00E-05	42	37
Shorthorn sculpin	Te	mg/Kg	<DL	<DL	1.00E-04	3.00E-04	7.00E-04	53	49
Shorthorn sculpin	Th	mg/Kg	<DL	<DL	2.40E-05	5.00E-04	1.20E-03	78	71
Shorthorn sculpin	Ti	mg/kg	<DL	<DL	1.5	29.901	38.491	50	45
Shorthorn sculpin	Tl	mg/kg	<DL	<DL	0.001	0.003	0.023	76	69
Shorthorn sculpin	Tm	mg/Kg	<DL	<DL	<DL	1.70E-05	6.00E-05	32	29
Shorthorn sculpin	U	mg/Kg	<DL	7.00E-04	0.002	0.002	0.021	93	79
Shorthorn sculpin	V	mg/Kg	<DL	0.01	0.027	0.072	0.55	70	64
Shorthorn sculpin	W	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Shorthorn sculpin	Y	mg/kg	<DL	2.00E-04	5.70E-04	0.001	0.006	89	80
Shorthorn sculpin	Yb	mg/Kg	<DL	<DL	1.00E-05	4.50E-05	2.20E-04	55	50
Shorthorn sculpin	Zn	mg/kg	8	26.358	33.705	44.185	99.44	102	93
Shorthorn sculpin	Zr	mg/kg	<DL	8.00E-04	0.002	0.004	0.014	89	80

Table A2.14 Greenland environmental baseline element concentration values for soil. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). "No of meas." refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Soil	Ag	mg/Kg	<DL	0.103	0.124	0.192	0.266	25	23
Soil	Al	mg/kg	0.035	11752.746	30100	58640	93597	49	42
Soil	As	mg/Kg	<DL	0.147	0.963	1.302	7.1	49	42
Soil	Au	mg/Kg	<DL	<DL	<DL	<DL	<DL	22	20
Soil	B	mg/Kg	<DL	<DL	<DL	<DL	<DL	3	3
Soil	Ba	mg/Kg	0.009	61.965	70.667	107.001	694.597	25	23
Soil	Be	mg/Kg	<DL	2.14	2.667	3.642	24	25	23
Soil	Bi	mg/Kg	<DL	0.05	0.062	0.086	0.194	25	23
Soil	Ca	mg/Kg	3.445	4261.771	7162.601	8672.452	11018.383	25	23
Soil	Cd	mg/kg	<DL	0.042	0.1066	0.39	0.854	49	42
Soil	Ce	mg/Kg	1.87E-04	111.045	155.485	164.614	205.363	22	20
Soil	Co	mg/Kg	<DL	3.7	4.908	5.544	39.949	25	23
Soil	Cr	mg/kg	1.10E-04	18	27.739	47.849	368.9	49	42
Soil	Cs	mg/Kg	1.40E-06	0.808	1.313	1.520	2.144	22	20
Soil	Cu	mg/kg	4.42E-04	4.855	7.668	15.645	83.779	49	42
Soil	Dy	mg/kg	3.154	4.022	5.754	6.444	10.114	21	19
Soil	Er	mg/kg	1.517	2.012	2.916	3.326	5.136	21	19
Soil	Eu	mg/kg	0.811	1.347	1.534	1.676	2.875	21	19
Soil	Fe	mg/kg	0.003	15570	29177.644	47357	80108	49	42
Soil	Ga	mg/Kg	<DL	10.8	11.381	14.416	18.073	22	20
Soil	Gd	mg/kg	6.738	11.663	13.25	14.037	20.666	21	19
Soil	Hf	mg/kg	0.768	1.601	1.798	2.092	2.754	21	19
Soil	Hg	mg/kg	<DL	0.015	0.031	0.044	0.09	46	42
Soil	Ho	mg/kg	0.588	0.767	1.091	1.235	1.943	21	19
Soil	K	mg/Kg	0.467	2513.356	2639.8	3296.394	11665.205	25	23
Soil	La	mg/Kg	2.57E-04	57.285	71.979	85.879	107.626	22	20
Soil	Li	mg/Kg	<DL	7.5275	9.004	15.831	25.622	22	20
Soil	Lu	mg/kg	0.192	0.216	0.313	0.432	0.652	21	19
Soil	Mg	mg/Kg	0.423	2796.958	3133.773	4292.613	12167.14	25	23
Soil	Mn	mg/Kg	<DL	472.403	606.963	766.646	1254.968	25	23
Soil	Mo	mg/Kg	<DL	0.567	0.76	1.091	7.9	25	23
Soil	Na	mg/Kg	2.535	1049.873	1200.122	2200	6099.437	25	23
Soil	Nb	mg/kg	0.075	0.261	0.734	2.093	5.475	21	19
Soil	Nd	mg/Kg	2.32E-04	38.72925	54.0625	57.367	85.349	22	20
Soil	Ni	mg/kg	1.08E-04	7.003	11.325	28.357	201.869	49	42
Soil	P	mg/Kg	<DL	983.744	1036.598	1500.773	2668.727	25	23
Soil	Pb	mg/kg	1.53E-05	9.235	12.551	14.776	87	49	42
Soil	Pd	mg/Kg	1.20E-06	0.140	0.176	0.203	0.296	22	20
Soil	Pr	mg/kg	7.537	12.734	15.135	16.503	22.891	21	19
Soil	Pt	mg/Kg	<DL	0.026	0.0355	0.0405	0.05	22	20
Soil	Ra	mg/Kg	0.125	0.263	0.4	0.435	0.47	3	3

Soil	Rb	mg/Kg	6.14E-04	25.920	31.292	41.531	61.864	22	20
Soil	Re	mg/kg	0.003	0.004	0.006	0.008	0.012	21	19
Soil	Rh	mg/Kg	<DL	<DL	<DL	<DL	<DL	1	1
Soil	Ru	mg/kg	<DL	<DL	<DL	<DL	0.002	21	19
Soil	S	mg/Kg	1.911	1.911	1.911	1.911	1.911	1	1
Soil	Sb	mg/Kg	<DL	<DL	<DL	<DL	0.46	25	23
Soil	Sc	mg/Kg	<DL	3.830	5.158	6.320	11.98	22	20
Soil	Se	mg/kg	<DL	0.068	0.132	0.328	1.4	49	42
Soil	Sm	mg/kg	4.555	7.941	9.49	9.959	15.268	21	19
Soil	Sn	mg/Kg	<DL	7.28E-06	4.750	10.125	12	4	4
Soil	Sr	mg/Kg	0.015	36	58.713	86.964	159.454	25	23
Soil	Ta	mg/Kg	2.00E-06	0.018	0.028	0.040	0.056	22	20
Soil	Tb	mg/kg	0.668	0.928	1.283	1.363	2.125	21	19
Soil	Te	mg/Kg	<DL	<DL	<DL	<DL	0.04	22	20
Soil	Th	mg/Kg	1.00E-05	7.937	9.81	11.716	79	25	23
Soil	Ti	mg/Kg	8.37E-05	315.163	395.039	432.265	1200	25	23
Soil	Tl	mg/Kg	<DL	0.099	0.112	0.155	0.86	25	23
Soil	Tm	mg/kg	0.212	0.267	0.397	0.475	0.721	21	19
Soil	U	mg/Kg	6.54E-05	2.588	3.450	4.744	74	28	23
Soil	V	mg/kg	1.36E-04	24.831	36.463	116.595	234.965	49	42
Soil	W	mg/Kg	<DL	0.016	0.020	0.043	0.101	22	20
Soil	Y	mg/Kg	3.90E-05	15.277	24.162	28.314	45.05	22	20
Soil	Yb	mg/kg	1.309	1.534	2.309	2.999	4.377	21	19
Soil	Zn	mg/kg	1.25E-04	25.83	64.852	100.725	380	49	42
Soil	Zr	mg/Kg	4.20E-06	73.07	84.439	122.388	174.49	22	20

Table A2.15 Greenland environmental baseline element concentration values for unfiltered water. q25 refers to the 25% percentile (1st quatile) and q75 to the 75% percentile (3rd quatile). “No of meas.” refers to the number of concentration measurements of the particular element, in the particular sample type, for the particular region. DL refers to detection limit.

Sample Type	Element	Unit	Min	q25	Median	q75	Max	No. of meas.	No. of samples
Unfiltered water	Ag	µg/l	<DL	<DL	<DL	0.004	0.287	194	168
Unfiltered water	Al	µg/l	<DL	13.675	32.146	112.375	2816	204	178
Unfiltered water	As	µg/l	<DL	0.03	0.081	0.16	2.83	204	178
Unfiltered water	Au	µg/l	<DL	<DL	<DL	0.007	0.287	194	168
Unfiltered water	B	µg/l	0.213	0.262	0.273	0.304	0.618	18	18
Unfiltered water	Ba	µg/l	0.098	2.603	5.58	21.418	267.27	194	168
Unfiltered water	Be	µg/l	<DL	0.005	0.012	0.023	0.142	179	166
Unfiltered water	Bi	µg/l	<DL	4.33E-04	0.001	0.002	0.009	178	160
Unfiltered water	Ca	µg/l	492	2153.075	13963.5	21518	113650	194	168
Unfiltered water	Cd	µg/l	<DL	0.003	0.011	0.024	10.86	204	178
Unfiltered water	Ce	µg/l	<DL	0.081	0.192	0.578	17.319	194	168
Unfiltered water	Co	µg/l	<DL	0.018	0.075	0.298	4.131	194	168
Unfiltered water	Cr	µg/l	<DL	0.056	0.108	0.340	12.858	204	178
Unfiltered water	Cs	µg/l	<DL	0.004	0.009	0.026	0.41	181	168
Unfiltered water	Cu	µg/l	0.005	0.26	0.68	4.06	21.99	204	178
Unfiltered water	Dy	µg/l	0.004	0.011	0.015	0.022	0.469	28	28
Unfiltered water	Er	µg/l	0.002	0.006	0.007	0.012	0.196	28	28
Unfiltered water	Eu	µg/l	0.004	0.008	0.010	0.015	0.182	28	28
Unfiltered water	Fe	µg/l	<DL	7.755	35.755	145.95	4025	204	178
Unfiltered water	Ga	µg/l	<DL	0.008	0.026	0.106	0.998	181	168
Unfiltered water	Gd	µg/l	0.011	0.026	0.034	0.049	0.925	28	28
Unfiltered water	Ge	µg/l	0.004	0.019	0.028	0.041	0.417	18	18
Unfiltered water	Hf	µg/l	7.00E-04	0.004	0.005	0.007	0.009	28	28
Unfiltered water	Hg	µg/l	<DL	<DL	<DL	<DL	0.127	204	178
Unfiltered water	Ho	µg/l	6.40E-04	0.002	0.003	0.005	0.078	28	28
Unfiltered water	K	µg/l	97	246.25	397.5	973.575	4135	194	168
Unfiltered water	La	µg/l	0.005	0.056	0.192	0.443	9.743	194	168
Unfiltered water	Li	µg/l	0.06	0.31	0.53	1.07	4.94	181	168
Unfiltered water	Lu	µg/l	1.80E-04	8.40E-04	0.001	0.002	0.021	28	28
Unfiltered water	Mg	µg/l	56	537.5	2123	3998.5	82230	195	169
Unfiltered water	Mn	µg/l	<DL	0.403	3.956	17.86	377.23	204	178
Unfiltered water	Mo	µg/l	0.006	0.04	0.08	0.272	6.218	204	178
Unfiltered water	Na	µg/l	137	406.25	1164.45	3385.5	20195	194	168
Unfiltered water	Nb	µg/l	<DL	0.004	0.006	0.011	0.107	28	28
Unfiltered water	Nd	µg/l	0.007	0.095	0.251	0.479	6.452	194	168
Unfiltered water	Ne	µg/l	1208	1231	1332	1358	2213	9	9
Unfiltered water	Ni	µg/l	<DL	0.102	0.362	2.442	12.351	204	178
Unfiltered water	P	µg/l	<DL	1.4	5.05	13.7	710.5	194	168
Unfiltered water	Pb	µg/l	0.001	0.054	0.105	0.329	21.38	204	178
Unfiltered water	Pd	µg/l	<DL	0.001	0.005	0.008	0.034	181	168
Unfiltered water	Pr	µg/l	0.026	0.070	0.086	0.112	1.756	28	28

Unfiltered water	Pt	µg/l	<DL	<DL	<DL	<DL	0.019	169	156
Unfiltered water	Rb	µg/l	0.015	0.15	1.104	2.057	15.293	181	168
Unfiltered water	Re	µg/l	<DL	<DL	0.002	0.005	0.017	28	28
Unfiltered water	Rh	µg/l	<DL	5.00E-05	0.001	0.002	0.004	30	30
Unfiltered water	Ru	µg/l	<DL	1.00E-04	0.001	0.001	0.003	28	28
Unfiltered water	S	µg/l	<DL	828	1541.3	3815.5	231360	179	166
Unfiltered water	Sb	µg/l	<DL	0.005	0.022	0.040	0.164	194	168
Unfiltered water	Sc	µg/l	<DL	0.038	0.065	0.144	0.907	194	168
Unfiltered water	Se	µg/l	<DL	0.013	0.07	0.15	1.18	194	168
Unfiltered water	Si	µg/l	4.94	11.55	15.945	64.766	114.02	38	38
Unfiltered water	Sm	µg/l	0.0152	0.035	0.045	0.068	0.999	41	28
Unfiltered water	Sn	µg/l	<DL	0.01	0.019	0.051	1.187	192	166
Unfiltered water	Sr	µg/l	1.02	11.202	29.9	45.510	217.74	194	168
Unfiltered water	Ta	µg/l	<DL	<DL	0.009	0.017	0.064	181	168
Unfiltered water	Tb	µg/l	8.20E-04	0.003	0.004	0.005	0.093	28	28
Unfiltered water	Te	µg/l	<DL	<DL	0.002	0.005	0.043	173	160
Unfiltered water	Th	µg/l	2.00E-04	0.004	0.010	0.027	1.114	194	168
Unfiltered water	Ti	µg/l	<DL	0.131	0.345	1.106	129.09	204	178
Unfiltered water	Tl	µg/l	<DL	<DL	<DL	0.008	0.087	194	168
Unfiltered water	Tm	µg/l	1.20E-04	0.001	0.001	0.002	0.025	28	28
Unfiltered water	U	µg/l	<DL	0.042	0.117	0.211	2.502	194	168
Unfiltered water	V	µg/l	<DL	0.028	0.095	0.284	6.812	204	178
Unfiltered water	W	µg/l	<DL	<DL	0.006	0.02	0.299	194	168
Unfiltered water	Y	µg/l	0.004	0.066	0.122	0.363	2.124	194	168
Unfiltered water	Yb	µg/l	0.0015	0.005	0.007	0.009	0.146	28	28
Unfiltered water	Zn	µg/l	<DL	1.190	2.561	5.763	3657.3	204	178
Unfiltered water	Zr	µg/l	<DL	0.028	0.058	0.130	0.878	191	178

Appendix 3 Vegetation map of South Greenland

By Drude Fritzbøger Christensen[1,2]

[1]*Department of Ecoscience, Aarhus University,* [2]*Current address: Department of Geosciences and Natural Resource Management, University of Copenhagen*

The extension and density of vegetation

The vegetation cover in South Greenland can vary in type and abundance within a few metres to kilometres due to changes in e.g., terrain. snow cover. soil type, temperature, and precipitation. The extension, degree of coverage and health of the vegetation are often approximated by use of the "Normalized Difference Vegetation Index" (NDVI).

$$\text{NDVI} = \frac{\text{Near infrared light} - \text{Visible red light}}{\text{Near infra light} + \text{Visible red light}}$$

NDVI is an indicator of photosynthetically active biomass by comparison of the amount of reflected visible red and near-infrared light by the vegetation.

The chlorophyll pigments of healthy vegetation absorb the visible red light for the purpose of photosynthesis, while near-infrared light is mostly reflected to prevent the plant from overheating. Unhealthy (with less chlorophyll pigments) or sparse vegetation (more exposed soil), on the other hand, will absorb less visible red light and at the same time absorb more of the near-infrared light (due to deterioration of the leaf's spongy layer that reflects near-infrared light). This means that dense, healthy vegetation has NDVI values close to one, while sparse (i.e., bare soil) or unhealthy vegetation has NDVI values close to zero. Negative values correspond to other land cover types such as snow and water bodies, but certain types of gravel may also give this signal.

NDVI is thus useful for the monitoring of temporal and spatial variations in vegetation growth and cover. However, in areas or during periods with dense vegetation cover, NDVI can saturate, resulting in lack of correlation between vegetation abundance and NDVI. Moreover, the index is highly sensitive to background variations (e.g., visible soil), with high NDVI values for dark backgrounds (Jensen 2007).

Figure A3.1 shows NDVI values in South Greenland calculated using Sentinel-2 band 4 and 8. The map is a composite image of satellite measurements from 3 and 4 July 2019. The spatial resolution of the image is 10 m. Gradients in NDVI can be seen from the outer parts of the fjords, close to the cold open ocean and towards the inner, protected parts, and from low-lying areas (< 200 m a.s.l.) to higher massifs. NDVI values are largest in sheltered, low-lying areas with values of up to 0.9, indicating high density of green leaves.

Several other studies (see "Studies on NDVI and relation to biomass") have estimated NDVI in South Greenland based on satellite measurements. These studies show a general increase in NDVI over the last decades (Epstein et al. 2012), with the highest NDVI occurring in low-lying (< 200 m a.s.l.), coastal areas in the inner parts of the fjords (Westergaard-Nielsen et al. 2015; Lehmann et al. 2020) in accordance with the results presented in Figure A3.1. The temperature dependence of the vegetation also results in higher NDVI (i.e., more dense vegetation) on south-facing slopes (Westergaard-Nielsen et al. 2015). NDVI values in South Greenland are typically within the range 0.1-0.7, indicating that the land cover spans from very sparse vegetation with dominance of rock/bare soil to dense vegetation cover.

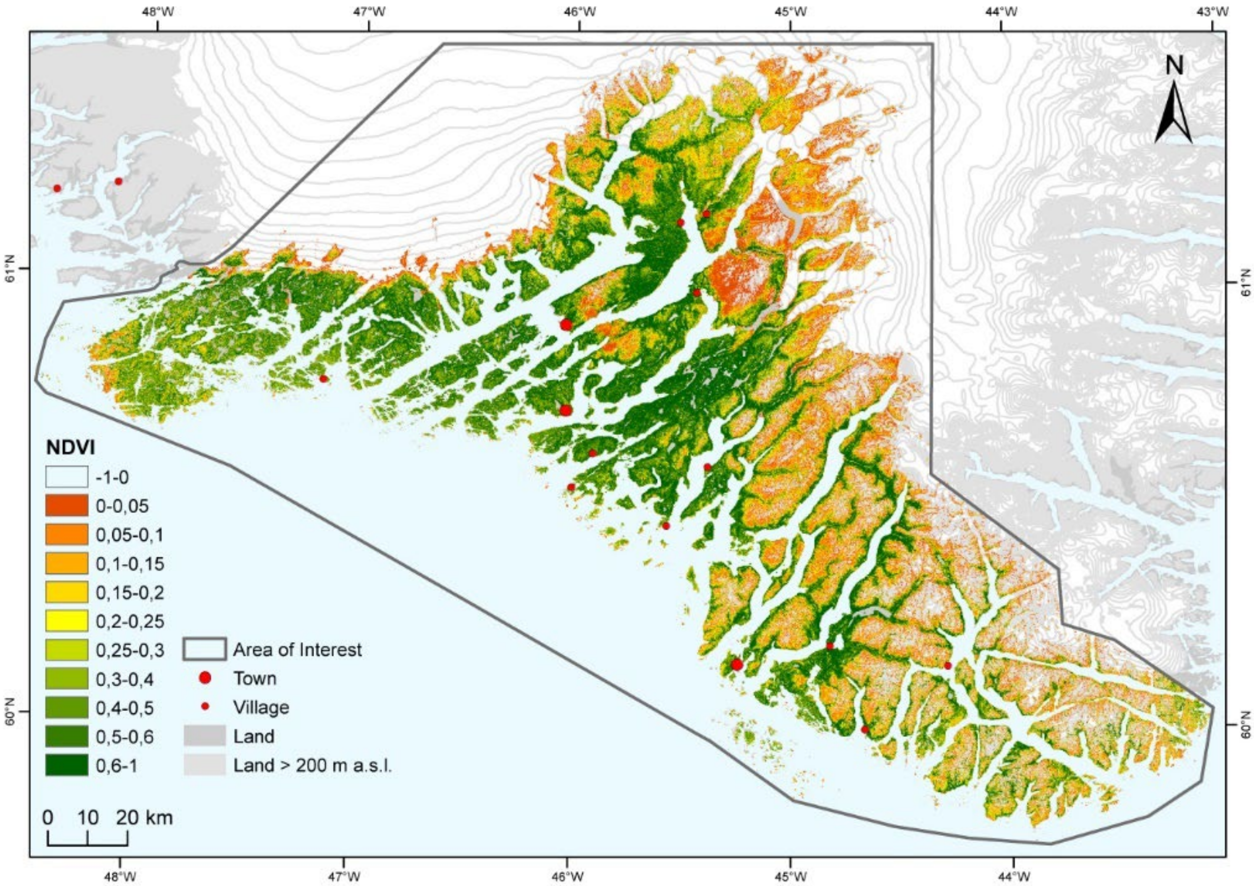

Figure A3.1. NDVI values for South Greenland calculated using Sentinel-2 data from 3 and 4 July 2019.

Studies on NDVI and relation to biomass

Epstein et al. (2012) studied the biomass dynamics in the Arctic over a 29-year period (1982-2010) by developing a regression model between NDVI and above-ground tundra biomass. Above-ground biomass was sampled in the field between 2002-2010 at 13 locations covering different Arctic bioclimate subzones (following the Circumpolar Arctic Vegetation Map by Walker et al. 2005). from zones in the north dominated by bare ground, mosses and lichens to zones in the south characterised by dense vegetation cover and abundance of dwarf shrubs. NDVI was calculated based on data from the Advanced Very-High-Resolution Radiometer instrument (AVHRR) with a spatial resolution of 12.5 km, and maximum annual NDVI was extracted for each biomass sampling location. A strong, positive correlation between NDVI and biomass enabled an estimation of the trend in biomass during the period 1982-2010. In South Greenland, an increase in mean biomass from 230.8 g/m² to 241.7 g/m² was observed, corresponding to an average yearly increase of 0.6 g/m². In comparison, the above-ground biomass in dense, intact tropical forests is observed to range between ca. 30.000 g/m^2 and 50.000 g/m^2 (Cummings et al. 2002).

Westergaard-Nielsen et al. (2015) also studied changes in biomass using the relation between NDVI and biomass found by Jia et al. (2006) in Southwest Greenland during 2000-2012. In addition, they predicted the future above-ground biomass (2090-2099) based on a relation between NDVI and a satellite-based summer warmth index. The summer warmth index was estimated for the period 2090-2099 based on a climate projection model. The purpose of the study was to assess the current state and future potential for sheep farming through examination of the spatial heterogeneity of vegetation greenness and above-ground biomass. For calculation of NDVI, MODIS satellite data with a spatial resolution of 250 m were used. The results showed a spatial distribution of above-ground biomass (NDVI), with the highest biomass occurring in low-lying coastal areas. The predictions for the future indicated a general increase in the relative above-ground biomass of up to 489 g/m^2 (increase per year = 5.7 g/m^2), with the largest increase taking place in areas of current high biomass (2000-2012).

Lehmann et al. (2020) also studied NDVI in relation to farming in South Greenland. Their aim was to investigate a possible relation between lamb carcass weight/quality and feed availability. MODIS satellite data with a spatial resolution of 1 km for the period 2010-2017 were used to calculate NDVI. The results showed a distribution of average annual NDVI in South Greenland (from approximately Narsaq in the north to Nanortalik in the south) with the highest NDVI in the low-lying coastal areas between Narsaq and Alluitsup Paa. The relations between NDVI and carcass weight were shown to be spatially varying with a positive correlation between NDVI and carcass weight for 18 out of 22 grazing areas.

The vegetation types

Vegetation mapping

Based on previous field observations (e.g., Tamstorf 2001; Aastrup et al. 2004; Karami et al. 2018), the vegetation cover of South Greenland can generally be assigned to the following main types: agricultural fields, shrub heaths, grasslands, copse, and fen. Snow-patch, seashore, herb-slope, and woodland (incl. plantations) vegetations are also present in South Greenland (Feilberg 1984) but not relevant for the spatial vegetation mapping in the present analysis. To map the spatial distribution of the vegetation types in the area, multispectral satellite images with a (sampled) spatial resolution of 10 m were used. Seven, almost cloud-free, satellite images obtained by the Sentinel-2 satellite on 3 and 4 July 2019 were used to cover South Greenland. The downloaded satellite images were level 2a products, meaning that data are geometrically and atmospherically corrected. The multispectral data thus consist of bottom-of-atmosphere surface reflection measured at 13 different wavelengths in the visible, infrared, and short-wave infrared spectrum (Table A3.1). Due to different properties of the dominant vegetation classes (e.g., differences in leaf pigments, number of leaf layers and moisture content), the reflection of the different wavelengths will vary between the vegetation types.

Table A3.1. Sentinel-2 band wavelengths and spatial resolution. NIR: near infrared; SWIR: short wave infrared.

Sentinel-2 Bands	Central wavelength (nm)	Resolution (m)
Band 1 – Coastal aerosol	433	60
Band 2 – Blue	490	10
Band 3 – Green	560	10
Band 4 – Red	665	10
Band 5 – Vegetation red edge	705	20
Band 6 – Vegetation red edge	740	20
Band 7 – Vegetation red edge	783	20
Band 8 – NIR	842	10
Band 8a – Vegetation red edge	865	20
Band 9 – Water vapor	945	60
Band 10 – SWIR. cirrus	1375	60
Band 11 – SWIR	1610	20
Band 12 – SWIR	2190	20

Figure A3.2 shows examples of reflection curves for fen, grassland, and copse, respectively. It appears that these vegetation types are best separated in the near infrared part of the spectrum. By comparing the reflectance values of the image pixels to defined spectral signatures (i.e., the reflectance as a function of wavelength) of the vegetation types, a satellite image can be converted to a vegetation map. Field observations are, however, necessary to produce the statistically representative spectral signatures of the vegetation types (e.g., Figure A3.2).

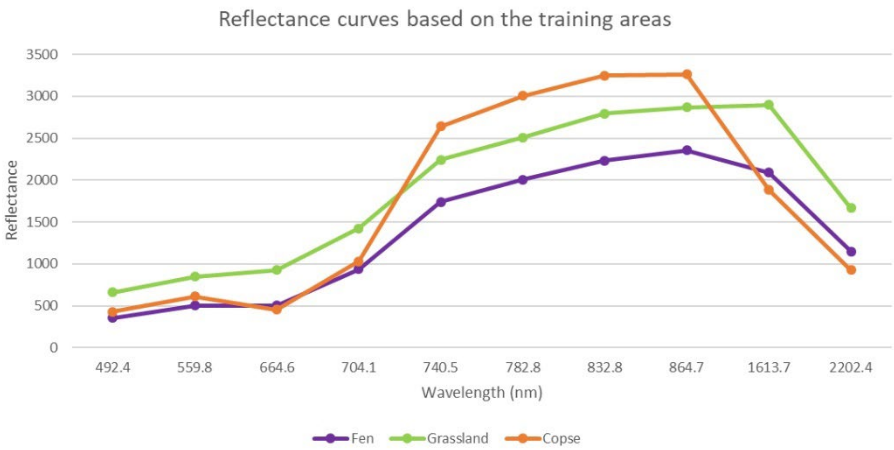

Figure A3.2. Mean reflectance as a function of wavelengths for fen, grassland and copse based on Sentinel-2 surface reflectance values in areas with field observations.

In the present analysis, the supervised classification method 'Maximum Likelihood Classification' was applied. In this method, prior knowledge (obtained in the field) of the vegetation cover at specific locations is used to make training classes, from which spectral statistics (mean, standard deviation etc.) are calculated. Subsequently, every pixel in the image is assigned to a vegetation class based on the statistical likelihood that the pixel belongs to the specific class (Lillesand et al. 2007). The accuracy of the classification is highly dependent on the training classes and thus the field observations.

Field data were collected between 21 July and 3 August 2020 and consisted of vegetation analyses (identification of the vegetation types and the dominant species) with associated GPS positions. The field sites were chosen to achieve a broad sample of the present vegetation types and to cover the spatial variations in vegetation types caused by climate gradients. Hence, field observations were made both near the open ocean and in the inner parts of the fjords (Figure A3.3).

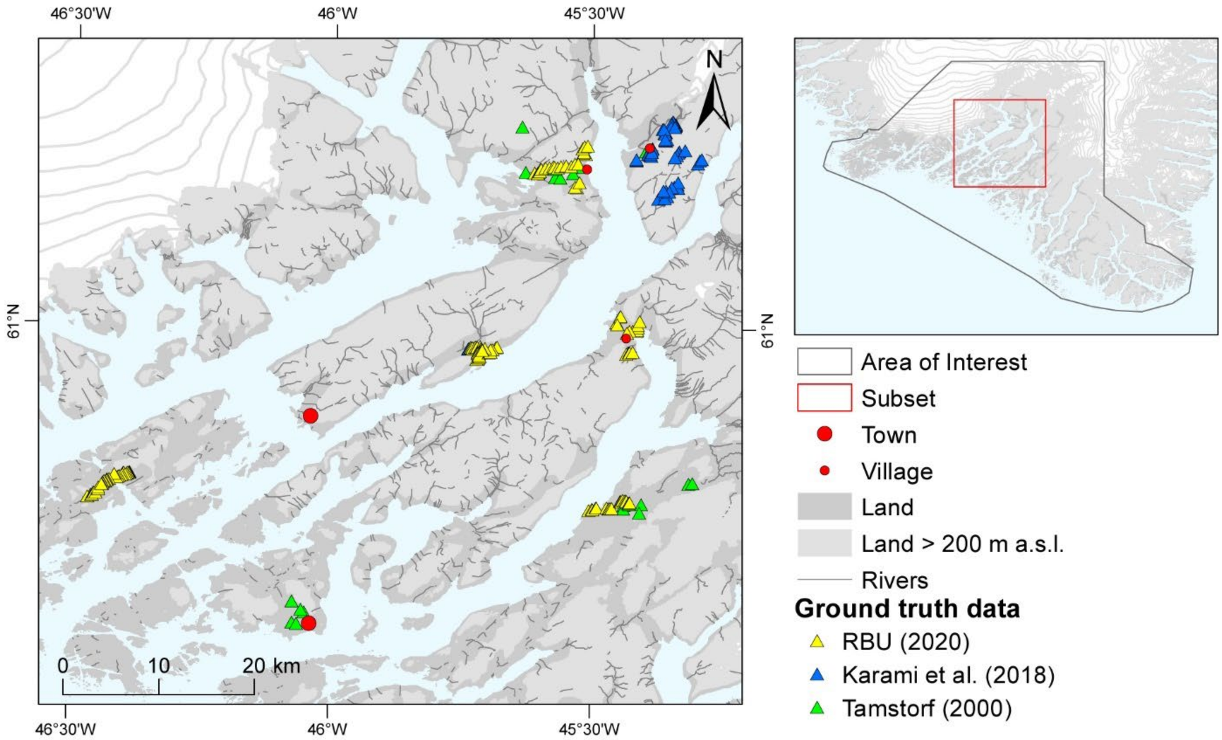

Figure A3.3. Overview map of South Greenland and a zoom in on the area where field observations were carried out (RBA: 138 plots, Karami et al.: 71 plots, Tamstorf: 17 plots, see Table A3.3).

The ground cover was classified into seven different vegetation types based on the classes used by Tamstorf (2001, Table A3.2). Due to time constraints, non-vegetated areas (fell-field) were not classified in the field, instead the observations by Karami et al. (2018) were used in the maximum likelihood classification. In addition to the vegetation classes, lakes and riverbeds/deltas were classified based on visual interpretation of the satellite image to mask out these areas in the final vegetation map.

The number of observations per ground cover class are shown in Table A3.3. Field data obtained by Karami et al. (2018) and Tamstorf (2001) were included in the analysis to increase the total number of observations and thereby gain more robust reflectance statistics. In addition, due to the limited number of observations of agricultural fields, vector data on the location of agricultural fields in South Greenland created by Agency for Data Supply and Efficiency (SDFE) were used instead of the field observations (SDFE 2017). However, as the crop types are mostly unidentified, the data could not be used as ground truth data in the maximum likelihood classification. Instead, the agricultural fields were masked during the classification and added to the final vegetation map afterwards.

Table A3.2. Description of the ground cover classes forming the basis for the maximum likelihood classification.

Ground cover class	Description
Dwarf shrub heath	Mostly on gently sloping (5°) terrain with moist soil conditions. Dominated by *Salix* and *Vaccinium ulignosum*.
Lichen-rich dwarf shrub heath	Mostly in weakly sloping (5˚). well-drained areas. Dominated by *Salix* and *Betula* with widespread lichen (> 25%) and moss (> 40%) cover.
Agricultural fields*	Mostly in low-lying areas (< 200 m a.s.l.) in the inner parts of the fjords. Crops are typically grasses but can also be vegetables or potatoes (Lehmann et al. 2016).
Fen	Horizontal terrain along rivers and lakes and in local wet depressions. Dominated by *Carex* and with widespread moss cover (> 50%).
Grassland	Mostly in weakly sloping (5˚). moist areas. Dominated by *Deschampsia flexuosa*.
Copse	Mostly on sloping (up to 45˚) terrain with moist soil conditions. Dominated by *Betula* and *Salix* with heights of > 0.5 m
Riverbed/delta	Sandy sediments of subaerial delta plains and riverbanks.
Lakes	Water areas of varying depth and turbidity.
Non-vegetated	Mostly rocks or wind-blown surfaces in high elevations (after Karami et al. 2018)

* Agricultural fields are not included in the maximum likelihood classification due to limited field observations and lack of information on crop types in vector data from SDFE (Styrelsen for Dataforsyning og Effektivisering/Agency for Data Supply and Efficiency).

Table A3.3. Number of ground truth observations in each ground cover class. Column 5 is not based on field observations but on a visual interpretation of the satellite data.

Vegetation class	RBA 2020	Karami et al. (2018)	Tamstorf (2000)	Visual interpretation
Dwarf shrub heath	32	3	4	-
Lichen-rich dwarf shrub heath	16	-	-	-
Agricultural fields*	3	-	-	-
Fen	27	2	2	-
Grassland	31	-	5	-
Copse	29	45	6	-
Riverbed/delta	-	-	-	18
Lakes	-	-	-	106
Non-vegetated	-	21	-	-

* Fields with timothe *(Phleum pratense)* and *Poa glauca*

Figure A3.4 shows the data processing steps for drawing up a vegetation map for South Greenland. Step a-c) are preprocessing steps. First, the wavelength bands with a resolution of 10 m and 20 m, respectively, were stacked and resampled to a "new" image with a spatial resolution of 10 m using the nearest neighbor resampling method (Step a). Then, the ocean, snow and ice were masked (Step b) to facilitate the subsequent vegetation classification. To mask these classes, the Normalized Difference Snow Index was calculated:

$$\mathrm{NDSI} = \frac{\text{Visible green light} - \text{Short wave infrared}}{\text{Visible green light} + \text{Short wave infrared}}$$

Snow cover is highly reflective in the visible part of the spectrum, while snow reflectance drops towards zero in the short-wave infrared part. Likewise, clear water has the highest reflectance in the visible part of the spectrum and then drops towards zero in the infrared part (Jensen 2007). Based on a visual inspection of NDSI values and the satellite images, an NDSI threshold of > 0.1 was found useful for separating snow-free land from ice, ocean and land covered by snow. A raster mask was built based on this threshold, and the stacked satellite images were clipped by this mask. In addition, the agricultural fields were masked based on the vector dataset Croplanda from SDFE (SDFE 2017). Subsequently, the masked satellite images were mosaicked (Step c) into one image covering the entire snow-free land surface of South Greenland.

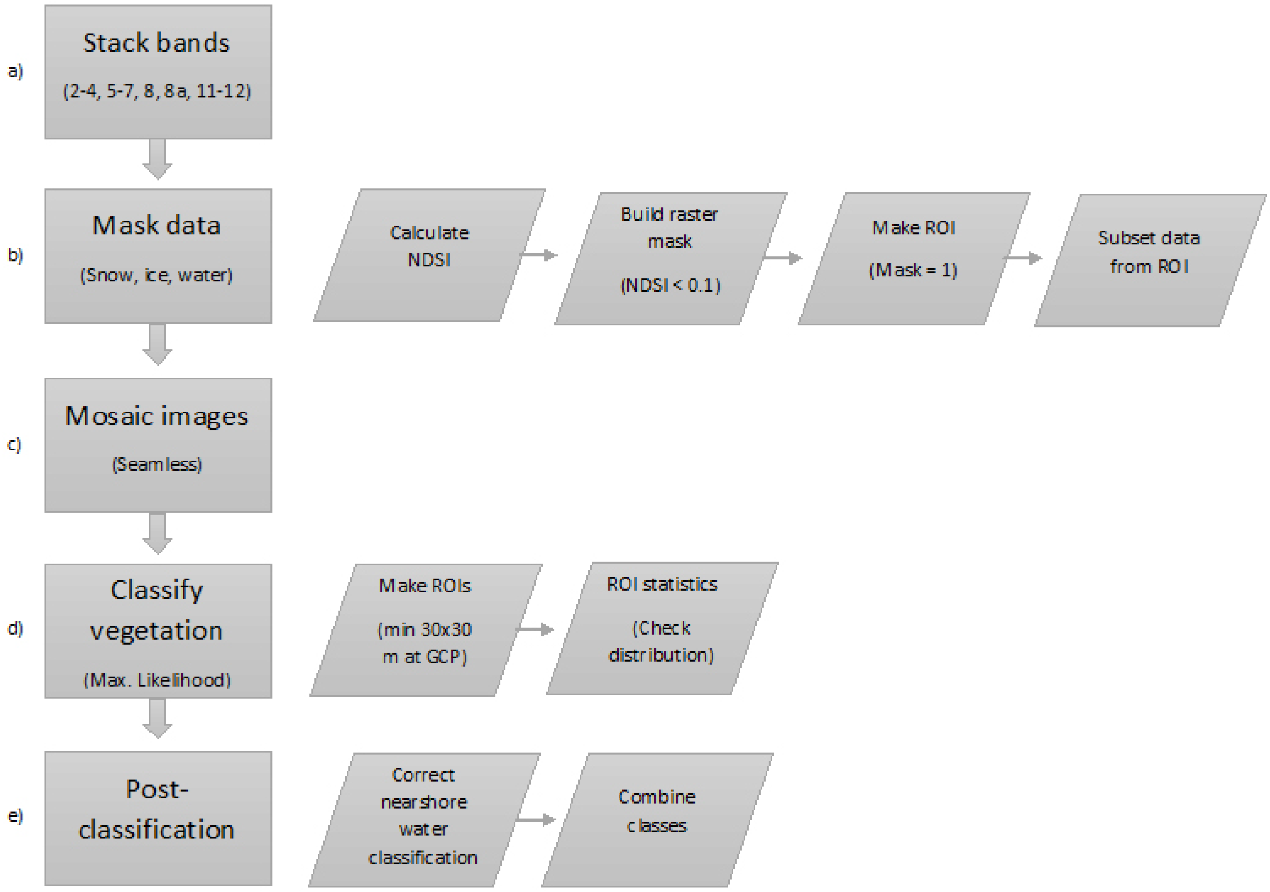

Figure A3.4. Diagram showing the processing steps of transforming Sentinel-2 satellite images into a vegetation map.

In Step d, the snow-free land cover image of South Greenland was classified by use of the maximum likelihood method. Training classes were defined as homogenous areas of at least 30x30 m around the ground observations. Statistics were calculated for each vegetation class based on these training areas, and the distribution of the reflection values in each band for each class was examined to ensure that the data were normally distributed. This is a prerequisite for the maximum likelihood classification. If data have a bi- or trimodal distribution, it is most likely because more classes are included in the same training class, and data should therefore be re-grouped (Jensen 1996). The riverbed/delta class showed a bimodal distribution, and the class was therefore split into three classes of sand with different degrees of vegetation cover.

In the last step (e), the vegetation map was post-processed. The output vegetation map showed a misclassification of pixels at the water/land boundary. Nearshore waters (ca. one pixel from the shore) were classified as copse vegetation. To correct this misclassification, a decision tree was applied to the vegetation map by which copse pixels located less than 10 m from water were changed into water pixels. For this reclassification, a distance-to-water map was calculated. Finally, the different riverbed/delta classes were combined into one class.

Figure A3.5 shows the final vegetation map.

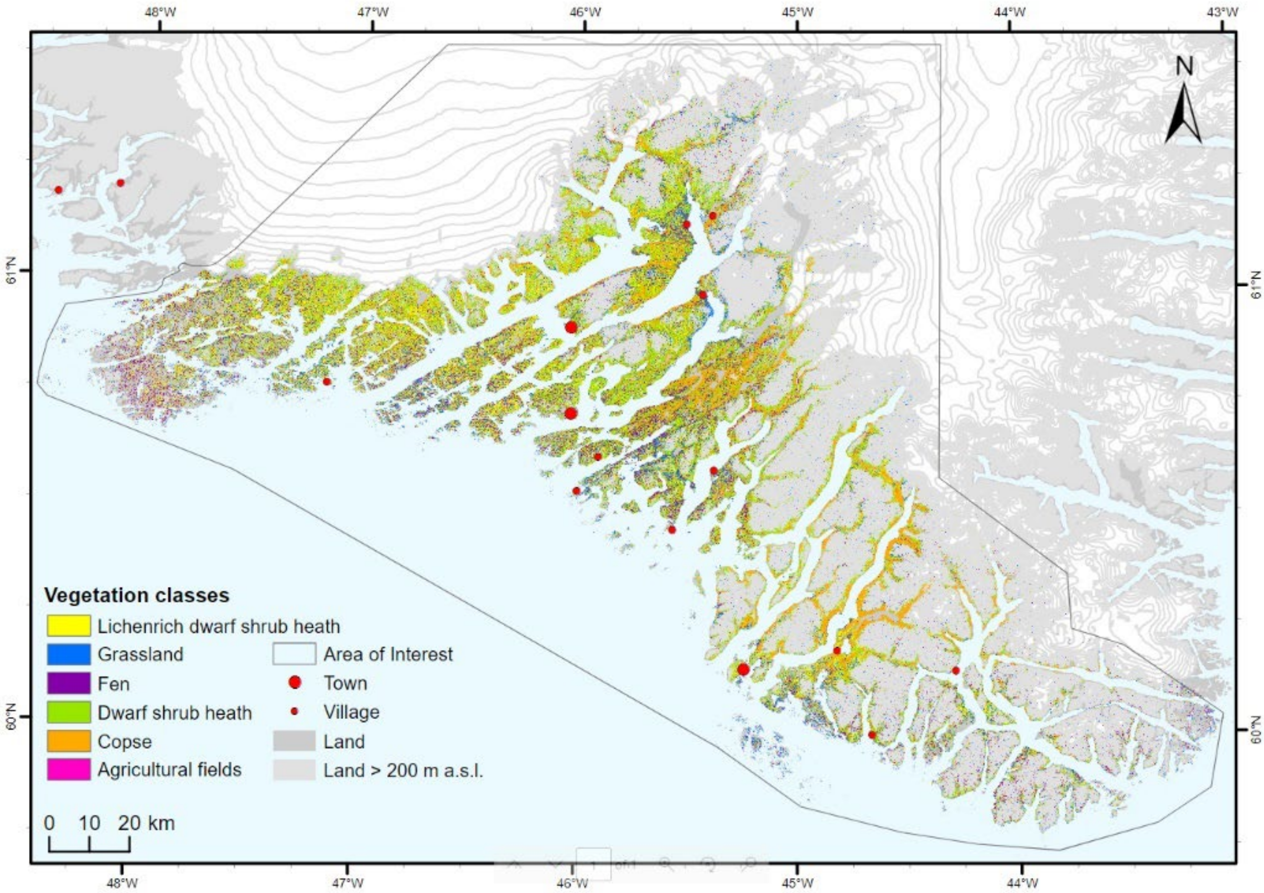

Figure A3.5. Vegetation map of South Greenland.

Spatial variations in vegetation types and their dominant species

The vegetation map (Figure A3.5) shows some general tendencies in the spatial distribution of the different vegetation types. Dwarf shrub heath and copse are the dominant vegetation types, accounting for more than 50% of the vegetated area. They are most widespread in low-lying areas (elevations < approx. 200 m) in the inland/inner parts of the fjords. In the outer parts, close to the open ocean, lichen-rich dwarf shrub heath is more pronounced. Moreover, fen is widespread in these areas as it occurs in proximity to water, and lakes are abundant in the outer areas. Fen vegetation is observed throughout South Greenland within ca. 30-40 m of most lakes. Grassland is the least common vegetation type, accounting for about 12% of the vegetated area, but it occurs all over the area. The largest continuous areas of grassland are found near Igaliku, Qassiarsuk and in an area between Kangerluarsorujuk and Nuugaarsuk. Agricultural fields make up a very small area (ca. 1.200 ha. see Chapter 5 "Human use") and are also mostly present in the regions of Qassiarsuk and Igaliku.

The vegetation analyses performed in this study not only included determining the dominant vegetation type at specific locations in South Greenland but also a determination of the dominant species at the field locations. The dominant species that make up the vegetation classes are summarised in Table A3.4.

Table A3.4. Field observations of the dominant species of the different vegetation types in South Greenland.

Vegetation type	Dominant species
Dwarf shrub heath	*Salix glauca, Salix arctophila, Vaccinium ulignosum, Betula glandulosa, Deschampsia flexuosa*
Lichen-rich dwarf shrub heath	*Salix glauca, Salix arctophila, Vaccinium ulignosum, Betula glandulosa*
Fen	*Carex bigelowii, Carex rostrata, Carex rariflora, Carex microglochin, Scirpus caespitosus*
Grassland	*Deschampsia flexuosa, Carex bigelowii, Poa pratensis, Agrostis sp., Agrostis hyp., Kobresia simplicius-cula, Kobresia myosuroides, Calamagrostis langsdorfii*
Copse	*Salix glauca, Betula pubescens*

The mapped spatial variations in vegetation types are generally in accordance with previous observations (Tamstorf 2001; Aastrup et al. 2004; Karami et al. 2018). Copse and dwarf shrub heath vegetation were thus also previous observed to be most prevalent in low-lying areas in the inner parts of the fjords, while fen vegetation dominated near rivers, lakes and in local depressions. However, grasslands were found to be less widespread in this study compared to the findings of Tamstorf (2001), who found that grassland accounted for twice the area of the present results (Table A3.5). Some of this difference may be attributed to a difference in the delimitation of the AOI in South Greenland, but a decrease in the number of sheep in the area is a more likely cause (see Chapter 5 "Human use"). The latter could result in a smaller grazing pressure and hence an increase in dwarf shrub vegetation to the exclusion of grassland. Moreover, the proportion of lichen-rich dwarf shrub heath to dwarf shrub heath is significantly higher in this study, and fen was also found to be more widespread (Table A3.5). However, in a long-term perspective, a changing climate with increasing temperatures and precipitation (Christensen et al. 2015) will expectedly result in a reduction of lichen cover in favour of denser shrub vegetation (Normand et al. 2013).

Table A3.5. The proportion of the different vegetation types in South Greenland.

	Coverage in % of all the vegetation classes	
	RBA 2020	**Tamstorf (2000)**
Dwarf shrub heath	34.7	52.2
Lichen-rich dwarf shrub heath	17.3	1.5
Fen	15.1	4.6
Grassland	11.9	23.9
Copse	21.0	17.8

In addition to the mapped and mentioned vegetation types, also woodland is found in South Greenland but to a limited extent, and it is therefore not included in the vegetation analysis. According to Meilby et al. (2019), there are several larger, mainly spruce, plantations in the inner fjords in South Greenland (Figure 5.3 in the main report) as well as tall copse vegetation with tree heights of more than 3 m. These areas provide favourable conditions for the existence of high-diversity forest floors, including a large number of epiphytic lichen and basidia mushrooms (Christensen et al. 2016). In the future, areas suitable for woodland are expected to increase due to the changing climate. However, natural expansion will likely be slow and local due to dispersal constraints (Normand et al. 2013).

Previous studies on vegetation types

Feilberg and Folving (1990) carried out two individual projects of, respectively, vegetation mapping and monitoring of potential pastures in Qinngua Valley based on field work during the summers of 1984 and 1985.

The area is a sub-Arctic oasis with woodland and shrub heath. The latter was characterised by Labrador tea (*Ledum groenlandicum*), bog bilberry (*Vaccinium ulignosum*), glandular birch (*Betula glandulosa*) and common juniper (*Juniperus communis*). Woodland existed up to an altitude of ca. 200 m and was dominated by downy birch (*Betula Pubescens*) with an average height of 6 m. Greenland mountain-ash (*Sorbus groenlandica*) was also frequently observed in the valley. Grasslands were found to be less frequent than in other parts of South Greenland and were only observed at sites where the snow persisted for long periods. The grasslands were dominated by mat-grass (*Nardus stricta*).

Feilberg (1984) also published a major phytogeographical study of South Greenland based on more than 30.000 herbarium specimens and field studies in 1974, 1975 and 1976. His study focused on the distribution of the individual species of vascular plants but included delimitation of vegetation zones and vegetation types.

Møller-Lund et al. (1996) studied food sources for the reindeer herd at Isortoq and mapped the vegetation cover in the area. The vegetation mapping was conducted by interpretation of Landsat satellite images with a spatial resolution of 30 m. In the coastal areas, the soil was poor and thin, and vegetation was therefore sparse and mainly made up of crowberry (*Empetrum nigrum*). In the more sheltered areas, grasslands and shrub were prevalent with dominance of stiff sedge (*Carex bigelowii*) and grey-leaf willow (*Salix glauca*), respectively.

Tamstorf (2001) also mapped Greenland vegetation as part of a project on the food sources for caribou and reindeer (Aastrup et al. 2004). The land cover was mapped in the areas of Kangerlussuaq, Nuuk and South Greenland based on Landsat satellite images (spatial resolution: 25 m) and field observations in the summers of 1997, 1998 and 1999. In South Greenland, shrub and fell-field constituted up to 70% of the vegetation cover, while grassland and copse accounted for about 25%. The vegetation was most widespread near the coast, while bare soil/rocks dominated in the inland at higher elevations where wind and lack of precipitation resulted in poor growing conditions.

Orbicon A/S prepared the background report “Kvanefjeld multi-element project – the natural environment of the study area” for the Environmental Impact Assessment for the mining project at Kvanefjeld (Orbicon 2018). The report included a description of the existing environment and, accordingly, a description of the vegetation in the Narsaq Valley. The description was based on field work carried out in August 2013 and September 2014. The lowland (0 – ca. 200 m a.s.l.) was found to be dominated by dwarf-shrub heath consisting mainly of bog bilberry, crowberry, glandular birch, and willow species but with patches of mosses, grasses, and sedges. Close to the Narsaq river mouth some rare species such as autumn gentian (*Gentiana amarella*), golden gentian (*Gentiana aurea*) and common butterwort (*Pinguicula vulgaris*) were found. At higher altitudes (ca. 200 – 680 m m.a.s.l.), dwarf-shrub heath was still prevalent, but larger areas with mosses and lichens and open rocky terrain, snow beds and smaller fens became more widespread. On the Kvanefjeld plateau, the rare species bog rosemary (*Andromeda polifolia*) was found. At the upper northern slopes (ca. 350 – 650 m a.s.l.), vegetation was sparse, and the ground was mostly covered by loose stones and rocks. The limited plant cover consisted mostly of three-leaved rush (*Juncus trifidus*), moss campion (*Silene* *acaulis*), trailing azalea (*Loiseleuria procumbens*), purple saxifrage (*Saxifraga oppositifolia*) and stiff sedge (*Carex bigelowii*).

Karami et al. (2018) developed a large-scale classification approach for classifying Arctic tundra based on multi-temporal Landsat satellite images with a spatial resolution of 30 m. The resultant vegetation map of Greenland was validated with *in situ* field data. The overall aim was to add to the foundation for ecosystem monitoring, upscaling, and simulation of the ecosystems' response to climate changes. In South Greenland, the classification showed in consistence with other studies in that vegetation was most widespread near the coast in the inner part of the fjords with dominance of heath, grasslands, copse, and shrubs. Along streams and lakes, fen was dominant.

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Appendix 4 Rules for fieldwork applied in South Greenland – updates on biodiversity and human use areas

By Ida Bomholt Dyrholm Jacobsen[1] and Anders Mosbech[2]

[1]*Greenland Institute of Natural Resources,* [2]*Department of Ecoscience, Aarhus University*

The main report describes what we know about the occurrence of biodiversity and human use areas that may be impacted by fieldwork related to mineral resources. In this Appendix 4, we assess to which extent the current regulation provides sufficient protection and mitigation within these areas, and we give specific advice to EAMRA on updates on areas not currently regulated by the field rules for mineral exploration.

Thus, in this Appendix specific recommendations are found for updates to the regulation of mineral resource field work activities in South Greenland according to the *Rules for field work and reporting regarding mineral resources (excluding hydrocarbons) in Greenland* hereafter '*the field rules*' (Anon. 2000). The recommendations relate to important biological occurrences and areas that GINR and DCE recommend should be protected but which are not currently covered by *the field rules*. Areas and occurrences already mentioned in *the field rules* in South Greenland need to be updated and revised, but this is not included in these recommendations. In spring 2020, GINR and DCE provided EAMRA with recommendations for a major revision of *the field rules*, reworking these to be included in two executive orders. This Appendix should be seen as an addendum to those recommendations (referred to as the Executive Order Project. These recommendations are being processed by EAMRA and thus, not yet published).

Rules for fieldwork applied in South Greenland

The field rules issued by Government of Greenland regulate all fieldwork related to non-hydrocarbon mineral resources activities in Greenland. *The field rules* comprise 7 chapters dealing with different topics and the present recommendations relate to chapter 2) Areas Important to Wildlife and chapter 3) The National Park in North and East Greenland and other protected areas.

Protected areas in South Greenland

As mentioned in Chapter 4, there are three protected areas (according to the Nature Conservation order) in South Greenland:

- Uunartoq (Anon. 2005a)
- Klosterdalen (Anon. 1970)
- Qinnguadalen (Anon. 2005b).

The areas are included on NatureMap (http://naturemap.eamra.gl. 2021) and referenced and included in advice that GINR and DCE give. However, they are not yet included in the field rules. GINR and DCE recommend that these protected areas are included in the field rules as separate sections with regulations identical to those stated in the orders of each protected area (Anon. 2005a; Anon. 1970; Anon. 2005b).

Ramsar areas

Similar to protected areas, GINR and DCE recommend that Ramsar areas are included in *the field rules* or future executive orders. In South Greenland, the Ramsar Area 388 Ydre Kitsissut is not included in *the field rules*. This area is included in NatureMap, and GINR and DCE recommend including Ydre Kitsissut in the field rules and in future executive orders with requirements for regulations of activities corresponding to those stated in *Selvstyrets bekendtgørelse nr. 12 af 1. juni 2016 om beskyttelse af Grønlands internationalt udpegede vådområder og beskyttelse af visse vandfuglearter* (Anon. 2016).

New biologically important areas

The current field rules regulate the so-called "Areas important to wildlife" that include larger terrestrial mammals and birds. We recommend that the chapter is renamed to "Biologically important areas" to support inclusion of e.g., other animal species, habitats, and plants. The following includes new areas and their sections to be included.

Red-listed vascular plants

The current field rules do not mention species of plants or regulation of any specific areas related to the occurrence of plants besides vegetation in general ("surface and vegetation shall not unnecessarily be damaged"). With the Greenland Red List from 2018, an assessment of the vascular plants in Greenland now exists (Boertmann and Bay 2018). The previous red list from 2007 only contained five species of orchids. With the Greenland Red List assessment now available for vascular plants, GINR and DCE recommend that (areas with) vascular plants be included in *the field rules* and NatureMap. Christensen et al. (2016) delimitate areas with high plant production, important specific vegetation types and endemic and rare species. With the availability of the Greenland Red List, this should be included in any delimitation of areas regulated with regard to plants and vegetation.

The historically known occurrences of red-listed plant species in South Greenland are based on data with low accuracy (digitisation of reports). However, these data remain important in identifying areas where particular attention should be paid when fieldwork is conducted that may affect vegetation by e.g., covering larger areas, disturb or destroy vegetation, alter water flow, emit dust etc.

GINR and DCE recommend that regulations are included in *the field rules* to make it possible to require surveys and investigations to map occurrences of red-listed plant species with exact positions when fieldwork may affect vegetation.

Harbour seals

Harbour seals are sensitive to disturbance while giving birth (mid-May to mid-July), for 3-4 weeks when nursing their pups, and subsequent moulting (moulting finishing in mid-September) (Rosing-Asvid et al. 2020; Teilmann & Dietz. 1994).

GINR and DCE recommend regulating mineral resource activities disturbing harbour seals during this period (15 May – 15 September):

Areas with breeding and moulting harbour seals: During the period 15 May – 15 September the activities indicated in section 2.02.01 in the field rules are subject to approval.

Rivers with Arctic char (and salmon)

GINR and DCE recommend regulating mineral resource activities in and near these rivers and rivers found to host Arctic char (and salmon, but this is only relevant further north in West Greenland) corresponding to the regulation found in *Landstingslov nr. 29 af 18. december 2003 om naturbeskyttelse* (Anon. 2003).

GINR and DCE recommend that it is not permitted to place buildings, do planting, farming or drainage or any other form of changes in the terrain within 100 m from rivers known to host char or salmon.

Saline lakes

Information on saline lakes is included on NatureMap, but it is not exhaustive. Further research and field investigations are needed to obtain data of higher quality on saline lakes in Greenland.

GINR and DCE recommend regulating mineral resource activities in and near saline lakes corresponding to the regulation found in *Landstingslov nr. 29 af 18. december 2003 om naturbeskyttelse* (Anon. 2003).

GINR and DCE recommend that *the field rules* make it possible to require that occurrences of saline lakes in field work areas are identified. Furthermore, it is recommended that it is not permitted to place buildings, do drainage, changes in the terrain, or conduct any other harmful activities within 100 m from saline lakes.

Homeothermic spring

Many more homeothermic springs are thought to exist, and current data may be inaccurate. Further research and investigations are needed to obtain data of higher quality.

GINR and DCE recommend regulating mineral resource activities in and near homothermic springs corresponding to the regulation found in *Landstingslov nr. 29 af 18. december 2003 om naturbeskyttelse* (Anon. 2003).

GINR and DCE recommend that *the field rules* make it possible to require that occurrences of homeothermic springs in field work areas are identified with exact positions. Furthermore, it is recommended that it is not permitted to place buildings, do drainage, changes in the terrain, or conduct any other harmful activities within 100 m from homeothermic springs.

Wintering areas for eiders

Large flocks of eiders occur in the fjords during winter (see Chapter 4). It is not known to which extent the eiders show site fidelity during recurrent disturbance and to what extent they could be affected by recurrent disturbance. Research is needed on eiders use of areas in South Greenland in winter. Should research reveal that eiders show site fidelity to specific areas in South Greenland and could be significantly impacted by recurrent disturbances, GINR and DCE would make recommendations to apply a general regulation of these areas in the field rules or future executive orders.

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SOUTH GREENLAND – REGIONAL ENVIRONMENTAL BASELINE ASSESSMENT FOR MINING ACTIVITIES

This regional environmental baseline assessment of mining activities in South Greenland is based on a project idea developed between Environmental Agency for Mineral Resource Activities (EAMRA), Greenland Institute of Natural Resources (GINR) and DCE (AU). The purpose of the project is to provide a basis for supporting environmentally sound planning and regulation of mining activities by summarising existing regional background information supplemented with new studies and making these results operational and easily accessible.

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