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Nalunaq environmental baseline study 1998-2001

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Data sheet

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Abstract:	An environmental baseline study was performed during 1998-2001 around the Nalunaq gold mine site, Nanortalik district, South Greenland. Official mine start was August 2004. The purposes were to determine background levels of contaminants, accumulation rates and structure of marine sediments, diversity and biomass of the benthic macrofauna and population abundance and composition of snow crabs. Compared to a local reference area only few contaminants had elevated concentrations. Mean sediment accumulation rate was 1089 g/m^2 year. The benthic fauna composition was typical for high latitude boreal fjords and biodiversity in Saqqaa Fjord was not markedly different from biodiversity in Uunartoq Fjord. Studies on snow crab determined catch per effort, carapace width and hardness.
Keywords:	Baseline study, gold mine, Nalunaq, Greenland, contaminants, shorthorn sculpin, Arctic char, blue mussel, brown seaweed, *Cetraria nivalis*, snow crab, sea urchin, benthic macrofauna, marine sediments, accumulation rate, diversity.
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Preface

An environmental baseline study was performed in the Nalunaq area during 1998-2001 by NERI and the Greenland Institute of Natural Resources. The study was financed by Nalunaq I/S. Nalunaq I/S is owned by Crew Development Corporation and NunaMinerals. The purpose of the study was to determine the background level of contaminants, the accumulation rates and structure of marine sediments, the diversity and biomass of the benthic macrofauna and the population abundance and composition of snow crabs. Furthermore, the purpose was to describe the local use of the area around the mining site before mine start. After mine start, monitoring studies are conducted and the results are and will be compared to the baseline data in order to assess possible contamination of the environment.

We wish to thank Nalunaq I/S, and especially Tanja Nielsen, environmental co-ordinator, for support and participation in the baseline studies. The crew on the research vessel Adolf Jensen is thanked for their flexibility, patience and good humour. During the cruises the following persons have participated: Sigga Joensen and Lene Bruun, NERI laboratory technicians, Randi Skytte and Bianca Pedersen, students from Danish Technical University (DTU), Mogens Wium, environmental technician ASIAQ, Adrian Flynn, technician, NSR Consult, and Poul Greisman, URS Corporation.

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Summary

Purposes of the baseline study

The environmental baseline study was performed by NERI during 1998-2001 around the Nalunaq gold mine site, Nanortalik district, South Greenland. The purposes of the study were to determine the background level of contaminants, the accumulation rates and structure of marine sediments, the diversity and biomass of the benthic macrofauna and the abundance and composition of local snow crab populations.

Contaminants in organisms

A total of 872 samples were collected of shorthorn sculpin, Arctic char, blue mussel, brown seaweed, the lichen *Cetraria nivalis*, snow crab, sea urchin and marine sediments. 140 samples of organisms were analysed for content of arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn). Samples were collected prior to the official mine start in 2004. Therefore, highly elevated concentrations was not expected in the Saqqaa and Kirkespir area compared to reference areas in the local Uunartoq Fjord or elsewhere in Greenland. Yet, mining activities took place during the sampling period which could increase concentrations in e.g. the Kirkespir Valley.

Metal concentrations in organisms from the Saqqaa area were, compared to those from the local reference area, elevated only in shorthorn sculpin liver (2-3 times of Cd, Hg and Pb) and in *Cetraria nivalis* (4-5 times of As, Co and Cr). Slightly elevated levels of Pb and Cr were seen in snow crab muscle and blue mussel.

Marine sediments

Sediment accumulation rates were measured at 10 stations in Saqqaa Fjord using the lead-210 dating technique. The mean accumulation rate was 1089 g/m^2 year.

The Saqqaa Fjord could, from the physical and chemical composition of the sediments, be divided in three areas defined by a) the proximity to the Kirkespir river (large amount of sand), b) the deep middle part of the fjord (mainly fine-grained material), and c) the proximity to the Amitsoq island (large amount of coarse material).

Benthic macrofauna

During 2001 the benthic macrofauna was studied in the Saqqaa and Uunartoq fjords. The faunal composition of major taxonomic groups was typical for high latitude boreal fjords and most abundant by biomass were polycaete worms, molluscs and sea urchins. Biodiversity values did not differ markedly between stations, although there was a tendency towards higher diversity in Saqqaa Fjord compared to Uunartoq Fjord.

The sensitivity of the present fauna to an increase in sedimentation rate due to tailings disposal, is not known. If sedimentation rates exceed about 10 cm per year (c. 100 kg/m^2 year), burial and extinction of the fauna is a possibility, whereas lower sedimentation rates can either change species composition or even increase number of species and individuals.

Snow crabs

During spring and autumn 2001 snow crabs were caught in Saqqaa and Uunartoq fjords. The populations in these two fjords should be approximately in the middle of their 8-10 years cycle according to Canadian studies of carapace hardness of adult males. The average carapace width during spring was not different from that found in West Greenland populations. During autumn the average carapace width of Saqqaa crabs was reduced by more than 10% compared to the width during spring. The catch per effort (CPUE) during autumn was low compared to CPUE found at the research fishery in the area autumn 1998; during spring 2001 CPUE was comparable to the autumn 1998 catch. The experimental commercial crab fishery in 2001 (96 tonnes) in the Saqqaa and Uunartoq fjords could have an effect on both CPUE and carapace width found autumn 2001. Yet, in West Greenland areas with more than 10 years of commercial fishery such a reduction seems not to have been taken place. A seasonal crab migration could also be a possible explanation.

Sammenfatning

Formål med baggrundsundersøgelserne

I forbindelse med de fremskredne planer om åbning af en guldmine ved Nalunaq i Nanortalik kommune, Sydgrønland, udførte DMU i perioden 1998-2001 en række miljømæssige baggrundsundersøgelser i området. Undersøgelserne havde til formål at fastlægge baggrundsniveauer for forskellige grundstoffer, bestemme akkumuleringsraten og strukturen af marine sedimenter, undersøge biodiversiteten og biomassen af bunddyrene og angive populationstæthed og kønssammensætning af stor grønlandske krabbe.

Grundstoffer i planter og dyr

Der blev i alt indsamlet 872 prøver af følgende planter og dyr: Almindelig ulk, fjeldørred, blåmusling, blæretang, laven *Cetraria nivalis*, stor grønlandsk krabbe og søpindsvin; desuden blev der indsamlet marine sedimenter. Af disse prøver blev 140 analyseret for deres indhold af arsen (As), cadmium (Cd), kobolt (Co), krom (Cr), kobber (Cu), kviksølv (Hg), bly (Pb) og zink (Zn). Prøverne blev indsamlet inden minens officielle åbning i august 2004. Der forventedes derfor ikke stærkt forhøjede koncentrationer af grundstofferne i Saqqaa og Kirkespir området i forhold til niveauet i referenceområderne lokalt i Uunartoq Fjord eller fra det øvrige Grønland. I indsamlingsperioden blev der dog udført en del mineralefterforskning som f.eks. tunnelboring hvilket kunne betyde forhøjede niveauer lokalt i Kirkespirdalen.

Koncentrationerne af grundstofferne i planter og dyr fra Saqqaa området var i forhold til referenceområdet kun forhøjet i lever fra almindelig ulk (2-3 gange for cadmium, kviksølv og bly) og i *Cetraria nivalis* (4-5 gange for arsen, kobolt og krom). Bly og krom var kun svagt forhøjet i stor grønlandsk krabbe og i blåmusling.

Marine sedimenter

Sedimentationsraten blev målt på 10 stationer i Saqqaa Fjord ved hjælp af bly-210 dateringsmetoden. Middelakkumulationsraten var på 1089 g/m^2 år.

Ud fra den fysisk-kemiske sammensætning af sedimenterne i Saqqaa Fjord, kunne bunden opdeles i følgende tre områder: a) området ud for Kirkespirelvens udløb karakteriseret ved store mængder sand, b) midten af fjorden med hovedsagelig finkornet materiale og c) området tæt på Amitsoq Ø med store mængder af groft materiale.

Bunddyrene

I løbet af efteråret 2001 undersøgtes biodiversitet og biomasse af bunddyrene i fjordene Saqqaa og Uunartoq. Sammensætningen af de største taksonomiske dyregrupper var typisk for nordlige boreale fjorde og vurderet ud fra biomassen udgjorde børsteorme, bløddyr og søpindsvin de talrigeste grupper. Biodiversiteten, målt ud fra forskellige indeks, adskilte sig ikke markant stationerne imellem, men der var dog en tendens til højere biodiversitet i Saqqaa Fjord i forhold til Uunartoq Fjord.

Det er uvist, hvor følsom bundfaunaen vil være over for en øget sedimentationsrate som følge af deponering af tailings i fjorden. Hvis sedimentationsraten overstiger ca. 10 cm per år (omtrent 100 kg/m^2 år) er det muligt, at bundfaunaen vil blive begravet og udslettet, mens lavere sedimentationsrater enten kan føre til en ændret artssammensætning eller ligefrem et øget antal af arter og individer.

Stor grønlandsk krabbe

Den store grønlandske krabbe blev både forår og efterår 2001 fanget i fjordene Saqqaa og Uunartoq. Krabbepopulationerne i de to fjorde synes at være omtrent midt i deres cyklus på 8 til 10 år. Denne vurdering er baseret på canadiske undersøgelser af skjoldets hårdhed hos gamle hankrabber. Den gennemsnitlige skjoldbredde målt om foråret adskilte sig ikke fra skjoldbredden i krabbepopulationer fra Vestgrønland. Skjoldbredden af krabber fra Saqqaa Fjord var om efteråret reduceret med mere end 10 % af forårsskjoldbredden. Krabbefangsten per indsats var i efteråret 2001 lav i forhold til forsøgsfiskeriet i efteråret 1998, mens forårsfangsten 2001 var på niveau med fangsten i efteråret 1998. I 2001 blev der i Saqqaa og Uunartoq fjorde udført et erhvervsmæssigt forsøgsfiskeri med en indhandling af 96 tons krabber. Denne fangst kunne have en betydning for de mindre fangster og skjoldbredder der blev fundet i efteråret 2001. Da sådanne effekter ikke er set i de vestgrønlandske krabbepopulationer, hvor der har været erhvervsfangst i mindst 10 år, kunne en forklaring måske findes i sæsonmæssige trækbevægelser.

Eqikkaaneq

Tunuliaqutaasunik misissuinerit siunertaat

Kujataani, Nanortallup eqqaani, Nalunami guulteqarfiup ammarneqangajalerneranut atatillugu DMU 1998-2001-imi tamaani avatangiisinut tunngatillugu tunuliaqutaasunik misissuisarsimavoq. Misissuinerit pinngoqqaatit assigiinngitsut tunuliaqutaasut aalajangersornissaat, qanoq akuutiginerisa aammalu kinnerit immameersut ilusaasa aalajangersornissaat, uumasut assigiinngisitaartut uumasullu natermiut annertussusiata qanorlu amerlatiginerisa aammalu kalaallit saattuarsuata arnavissanut angutivissanullu agguataarsimanerata misissornissaat siunertaraat.

Pinngoqqaatit naasuni uumasunilu ittut

Naasut uumasullu misissugassat katillugit 872-it katersorneqarput: Kanajoq nalinginnaasoq, eqaluk, uiloq, equutit, orsuaasaq *Cetraria nivalis*, kalaallit saattuaat eqqusarlu; taakkua saniatigut aamma kinnerit immameersut misissugassat katersorneqarput. Misissugassanit taakkunannga 140-t arsen-imik (As), cadmium-imik (Cd), kobolt-imik (Co), krom-imik (Cr), kanngussammik (Cu), kviksølv-imik (Hg), aqerlumik (Pb), zink-imillu (Zn) akoqarnerat misissorneqarpoq. Misissugassat guulltisiorfiup augustusimi 2004 ammarnissaa sioqqullugu katersorneqarput. Taamaattumik pinngoqqaatit Saqqaani Kirkespir-imilu sanilliussuussiviusumut Uunartup Kangerluanut Kalaallit Nunaanilu allanut sanilliullugu annertuserujussuarsimanissaat ilimagineqanngilaq. Misissugassanilli katersuinerup nalaani aatsitassanik ujarlernermik ingerlatsineqarpoq, soorlu sulluorsualiorluni Kirkespirdalen-imi annertusisimanernik kinguneqarluarsinnaasunik.

Saqqaani pinngoqqaatit naasuniittut uumasuniittullu annertussusiat sanilliussuussivimmut naleqqiullugu taamaallaat kanassup nalinginnaasup tinguani annertuseriarsimavoq (cadmium, kviksølv aqerlorlu 2-3-riaammik annertussuseqarlutik) aamma *Cetraria nivalis*-imi (arsen, kobolt krom-ilu 4-5-eriaammik). Aqerloq krom-ilu annikitsuinnarmik kalaallit saattuaanni uillumilu annertuseriarsimapput.

Kinnerit immameersut

Kinninngoriartortarneq Kangerlummi Saqqaani assigiinngitsuni 10-ni uuttortarneqarpoq aqerloq-210 atorlugu pisoqaassusilersueriaaseq atorlugu. Akuliukkiartortarneq agguaqatigiissitsilluni ukiumut 1.089 g/m² annertussuseqarpoq.

Kangerlummi Saqqaani kinnerit fysisk-kemiskimik katitigaanerat aamma imatut pingasunut agguataarneqarsinnaavoq: a) Kirkespirip kuuata akua siorarpassuaqartoq, b) kangerluup qeqqa aseqqorilluinnartuusoq aamma c) Qeqertap Amitsup qanittuani anertoorsuarnik aseqqorluttunik pilik.

Naqqata uumasui

2001-imi ukiaanerani kangerlunni Saqqaani Uunartumilu uumasut assigiinngiiaarnerat qanorlu uumassusillit annertutiginerat misissorneqarpoq. Uumasoqatigiit immikkoortiterinikkut ameerlanerpaasut tassaaneruppput kangerlunni avannarpasinnerusuniittut uumasoqassutsimullu naleqqiullugit tassaanerullutik qullugissat børsteorme-t, uumasut qimerloqanngitsut eqqusallu allanit tamanit amerlanerpaasut. Uumasoqassuseq periaatsit assigiinngitsut atorlugit uuttortarneqartoq misissugassanik tigusiffinnit allanit malunnaatilimmik allaanerussuteqanngilaq, kisiannili kangerlummi Saqqaani Uunartup kangerluanut sanilliullugu annertuneroqqajaanerulluni.

Naqqani uumasut igitassanik kangerlummut inissiineq pissutigalugu kinnerit sukkanerusumik annertusiartornerannut qanoq misikkaritsigiumaarnersut ilisimaneqanngilaq. Imaassinnaavoq kinnerit ukiumut 10 cm missaa sinnerpassuk (ukiumut 100 kg/m² miss.) naqqani uumasut matuneqarsinnaasut nungutinneqarlutillu, annikinnerusumillu kinneqaleriartorneq kinguneqarsinnaalluni uumasut suunerisa allanngornerannik imaluunniit imaassinnaalluni uumasoqalersoq assigiinngisitaarnerusunik amerlanerusunillu.

Kalaallit saattuaat angisooq

Kalaallit saattuaat angisooq 2001-imi upernaakkut ukiakkullu kangerlunni Saqqaani Uunartumilu pisarineqartarpoq. Saattuaqarnera peqartarnerata ukiunik 8-10-nik sivisussuseqartartup qeqqaniikannersorinarpoq. Tanna canadamiut saattuat angutivissat utoqqaat qaleruaasa mattussusiannik misissuinerat tunngavigalugu naliliineruvoq. Qaleruaasa silissusiannik upernaakkut uuttortaanermi agguaqatigiissitsinikkut pissarsiat Kitaani allani saattuaqarfinnit allaanerunngillat. Kangerlummi Saqqaani ukiakkut saattuat qaleruaat upernaakkut saattuat qaleruaannit 10% sinnerlugu aminnerusarpoq. 2001-imi ukiakkut saattuarniarnermi pisat 1998-imi ukiakkut misileraalluni saattuarniarnermit annikinnerupput , kisianni 2001-imi upernaakkut pisat 1998-imi ukiakkut pisatut amerlatigalutik. Kangerlunni Saqqaani Uunartumilu 2001-imi inuussutissarsiutigalugu misileraalluni aalisarnermi saattuat 96 tons tunineqarput. Aalisarneq taanna 2001-imi ukiakkut pisat ikinnerullutillu qaleruaasa minnerunerannut sunniuteqarsimasinnaavoq. Sunniutit taamaattut Kitaani saattuaqarfinni maannamut inuussutissarsitigalugu minnerpaamik ukiuni 10-ni aalisarfiusimasuni takuneqarsimanngimmata immaqa ukiup qanoq ilinera najoqqutaralugu saattuat illikartarnerannik nassuiaatissaqarsinnaavoq.

1 Introduction

The Nalunaq gold project in summary

The gold deposit is situated 8 km from the coast in the Kirkespir Valley, which lies 40 km northeast of Nanortalik. The deposit was discovered in 1992 and since then extensive geological investigations have been carried out. In 1998 a 299 m long tunnel was driven along the gold ore and during 1998 to 2002 a total of 4,600 m of adits and raises have been developed. No underground investigations were carried out in 2003. In 2000 approximately 40,000 tonnes of crushed ore with an average gold concentration of 20 g per ton were deposited at the mine site. Since 1998 15 km of diamond drilling has been performed. In mid 2002 a feasibility study and an Environmental Impact Assessment were presented to the authorities. The mining company originally had planned to process the ore on site at Nalunaq. The waste, i.e. tailings, produced should be deposited either on land or in the Saqqaa Fjord. The company decided not at first to build a processing plant but instead to ship the ore to a plant outside of the mining site. Early 2004 c. 31,000 tonnes was shipped to Spain for gold extraction. Nalunaq Gold Mine A/S commenced mining during spring 2004 based on ore shipping the first years. The description above is based on information from Bureau of Minerals and Petroleum (2002, 2004) and Råstofdirektoratet (2003). The mine was officially opened on 26 August 2004.

Environmental studies during the Nalunaq exploration

The exploration period at Nalunaq of about 12 years can be categorized in an early phase when the infrastructure was developed, an intensive phase when the mine was designed and the pre-exploitation phase when the plans for exploitation was outlined. During the early phase when the site was developed, a road was constructed and the drilling camp was settled, environmental studies and regulation focused on disturbance of wildlife, protection of areas important to wildlife (no such areas are found near the Nalunaq area), lush vegetation and the Arctic char population in the river, prevention of oil spills and contamination from human waste and waste water (NERI unpubl. data). During the intensive phase environmental studies concentrated on contaminants from ore and waste and their dispersal in the terrestrial, fresh water and marine environments. Finally, environmental studies in the pre-exploitation phase focused on baseline studies that should be able to describe the environment prior to mine start. The baseline study was designed to describe chemical and physical impacts on marine organisms because marine tailings disposal was one of the options. Also, the population of Arctic char in the Kirkespir River was a part of the baseline study, because the Arctic char, fished by locals and tourists, could be contaminated or reduced in numbers by contaminants from the mine, the processing plant or tailings deposited on land. Finally, lichens were sampled and analysed in order to describe a possible contamination of the terrestrial environment from the processing plant, stockpiles, tailings landfills and roads built partly by waste rocks.

Purposes of the Nalunaq environmental baseline studies

One of the purposes of the Nalunaq environmental baseline study was to determine the natural background level of contaminants in the environment. The baseline level ideally should be based on samples from at least three years to obtain information on year to year variations. Samples should consist of mainly sedentary organisms sampled during a relatively fixed period of the year. After the mine has started its activities, the results from monitoring can be compared to the baseline data in order to assess possible contamination of the environment. Also, a baseline study may reveal high metal concentrations which can be ascribed to natural processes and not to the mining activities (Glahder et al. 1996). Included in this baseline study was also an investigation of biodiversity and biomass of the benthic macrofauna in Saqqaa and Uunartoq fjords. The purpose was to describe the benthic fauna prior to a possible sub-sea tailings disposal in Saqqaa Fjord where Uunartoq Fjord served as reference area. If sub-sea tailings disposal was applied then possible effects on the bottom fauna could be assessed. Also, the baseline study included a study on population abundance and composition of snow crab. The purpose was to describe the snow crab fishing stocks prior to tailings disposal in order to evaluate possible effects of the tailings on a potential commercial crab fishery in the area.

NERI baseline studies described in the report

The first baseline study during 21-25 May 1998 was initiated because the gold exploration activities at that time went into a more extensive phase with e.g. tunnel driving. The 1998 baseline study comprised a reduced sampling program with sampling stations only in the Kirkespir Valley and the Kirkespir Bay. Due to exploration progress and a wish from the mining company to start a mine within few years, more comprehensive baseline studies were performed during the three periods: 22 September-3 October 2000, 28 March-4 April 2001, and 26 September-10 October 2001. Samples of mussel, seaweed, fish, crabs, benthos, sediment and lichens were collected in Saqqaa Fjord, Kirkespir Bay and Valley, and at reference stations at Uunartoq about 30 km northwest of the Kirkespir Bay (Fig. 1).

Other NERI baseline studies

Other baseline studies, not described in this report, were performed during the period 2000-2001. During spring 2001 an interview study on fishing, hunting and tourism was carried out in the Nanortalik district (Glahder 2001). In connection to mineral exploration in the Kirkespir area in 1988 by Nanimas & Greenex A/S, a semi-quantitative study on the Arctic char population in the Kirkespir River was performed (Boje 1989).

Other baseline studies

During the period February 1998 to August 1999 Nalunaq I/S collected freshwater samples from the Kirkespir River. The samples were analysed by Lakefield Research Ltd. for content of metals and general parameters (Lakefield 1998a, b, 1999a-d). A thorough bathymetric study in Saqqaa Fjord was performed by The Royal Danish Administration of Navigation and Hydrography in 1999 (The Royal Danish Administration of Navigation and Hydrography, *in litt*). During August-October 2000 URS Corporation performed an oceanographic study in the Saqqaa Fjord, and in that fjord as well as in Uunartoq Fjord benthic fauna was sampled and analysed (Greisman 2000). Further oceanographic studies in Saqqaa Fjord and measurements of the water flow of the Kirkespir River, carried out in 2001 and 2002 by Hayco Consultants, has been reported in an Environmental Impact Assessment (SRK Consulting 2002).

Content of the report

This report describes all samples collected in the four baseline studies carried out during 1998-2001 (chapter 3), heavy metal concentrations in selected organisms in the Nalunaq area and in a reference area (chapter 4), a description of sediments in the Saqqaa Fjord from a lead-210 dating study and from a study characterising the sediment structure (chapter 5), a study on the benthic macrofauna in soft sediments of Saqqaa and Uunartoq fjords (chapter 6), and a study of snow crabs in the Saqqaa Fjord (chapter 7). All data are compiled in Appendices 1-5.

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2 Study area

Kirkespir Valley and the Nalunaq site

The Nalunaq gold deposit and mine is situated in South Greenland in the Nanortalik municipality (Fig. 1). It lies 40 km Northeast of Nanortalik and eight km from the coast of Saqqaa Fjord in the Kirkespir Valley. The valley floor is relatively lush with a delta area containing grassland, fens and marshes, and shrubs of more than one meter high northern willow. From about year 1000 to 1500 Norsemen lived here in a large farmstead of at least 22 ruins (Grønlands Landsmuseum, 1988). Also Eskimo ruins are discovered in the area (Hans Kapel, pers. comm.). Further six kilometres up the river fens and willow shrubs are found scattered along the river. Above the waterfall six km from the coast, the valley floor is mainly covered by marshes and grassland areas. The valley is lined with mountains of 1,000 m or more and the slopes contain sparse fell-field vegetation. The river holds an Arctic char population of about 5,000 migrating chars and an unknown number of resident chars (Boje 1989).

The Nanortalik district and population

Nanortalik municipality is situated in South Greenland around 60°N and 45°W (Fig. 1). It covers a total area of 15,000 km^2, of which 8,000 km^2 are ice-free land (Bertelsen et al. 1990). The total population is c. 2,600 persons, with c. 1,500 living in Nanortalik and the remainder in settlements and sheep farms (Anon. 1999). The total labour force of Nanortalik municipality, i.e. persons between 15 and 62 years of age, was 1,620 persons in February 2001 (E. Hammeken 2001, *in litt.*). The distribution in towns and settlements was the following: Nanortalik 977 persons, Tasiusaq 66, Alluitsup Paa 333, Ammassivik 68, Narsaq Kujalleq 69 and Aappilattoq 107.

Climate

The climate in the region is so called sub-arctic, which means that the warmest mean monthly temperature is below 10°C, but the climate is mild enough to allow trees to grow (Salomonsen 1990). In Nanortalik May–November have positive mean temperatures between 1 and 5 °C, while December–April have negative mean temperatures between -1 and -5°C. The average annual precipitation is 858 mm at Qaqortoq (60°43'N; 46°03'W), the weather station closest to Nanortalik with normal precipitation data (Asiaq 2001).

Polar ice

In normal years the Polar ice occurs in South Greenland from January to July but there can be considerable variation from this norm (Bertelsen et al. 1990). The Polar ice is carried from East Greenland by the East Greenland Current.

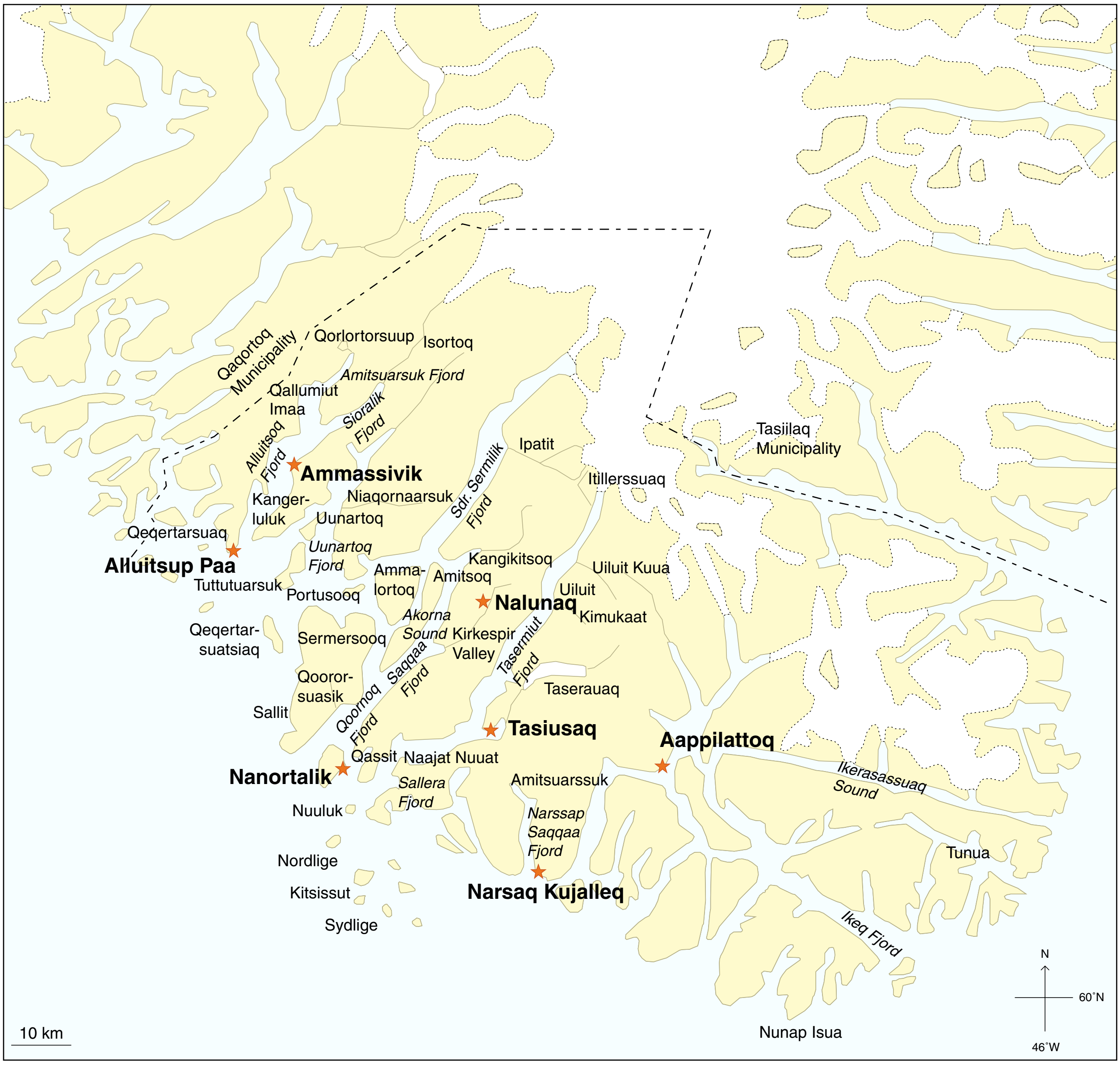

Figure 1. The Nanortalik municipality in South Greenland with the gold deposit Nalunaq, Nanortalik town and the settlements marked with a red asterisk.

3 Samples collected

In this chapter all samples collected during 1998-2001 are presented. Exact positions of the sampling sites, called stations, are found in Appendix 1. The samples are divided in fish, crabs, mussels, seaweed, sea urchins, lichens and sediments. The specific data on each sample is found in Appendix 2. A total of 872 samples were collected, with 36 in 1998, 468 in 2000, 88 in spring 2001 and 280 in autumn 2001. In Table 1, the number of samples of different organisms and sediments in the different periods can be seen.

Table 1. Number of samples collected in the Nalunaq area during 1998-2001. The samples are separated in sample categories and year (periods). Nalunaq I/S collected the samples during August and October 2001 in the Kirkespir Valley.

Sample type	Total	May 1998	Sept. 2000	March 2001	Aug. 2001	Sept. 2001	Oct. 2001
Shorthorn sculpin	75		71	2		2	
Sculpins (12 pooled)	1					1	
Atlantic salmon	9		9				
Arctic char	19		7		12		
Atlantic cod	43		43				
Greenland cod	145		52	41		52	
Spotted wolffish	15		4	3		8	
Arctic eelpout	17		3	3		11	
Sculpin sp. (e.g., Atlantic poacher)	1		1				
Lumpfish	1		1				
Lipris/Careproctus sp	2		1			1	
Skate	3		2	1			
Snow crab	96		34	34		28	
Sand crab	2		2				
Deep sea prawn (?)	13		8	4		1	
Crangonidae	20		7			13	
Blue mussel	122	4	60			58	
Clam	6		2			4	
Sea urchin	19		10			9	
Brown seaweed	88	8	40			40	
Laminaria sp	2					2	
Cetraria nivalis	72	18	26		3	20	5
Cetraria cucullata	3						3
Cladonia rangiferina	7						7
Sediment, marine	83		83				
Sediment, river	6	6					
Harp seal	1		1				
Bearded seal	1		1				
Total	872	36	468	88	15	250	15

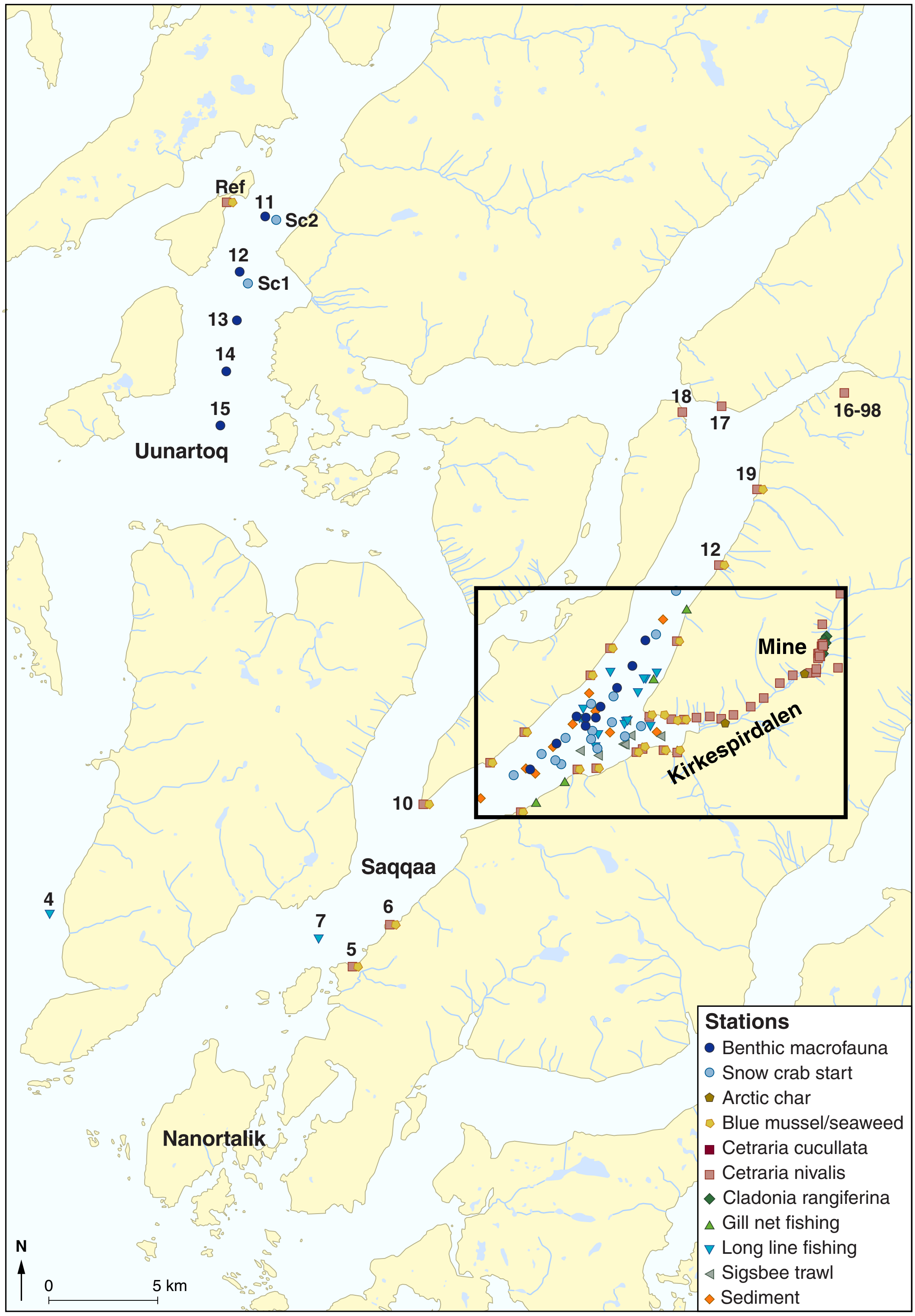

Figure 2. Sampling stations around the Nalunaq gold mine site in South Greenland. Frame includes Fig. 3. Numbers refer to App.1, Tables 25-34.
Letters and numbers are omitted if not necessary for understanding.

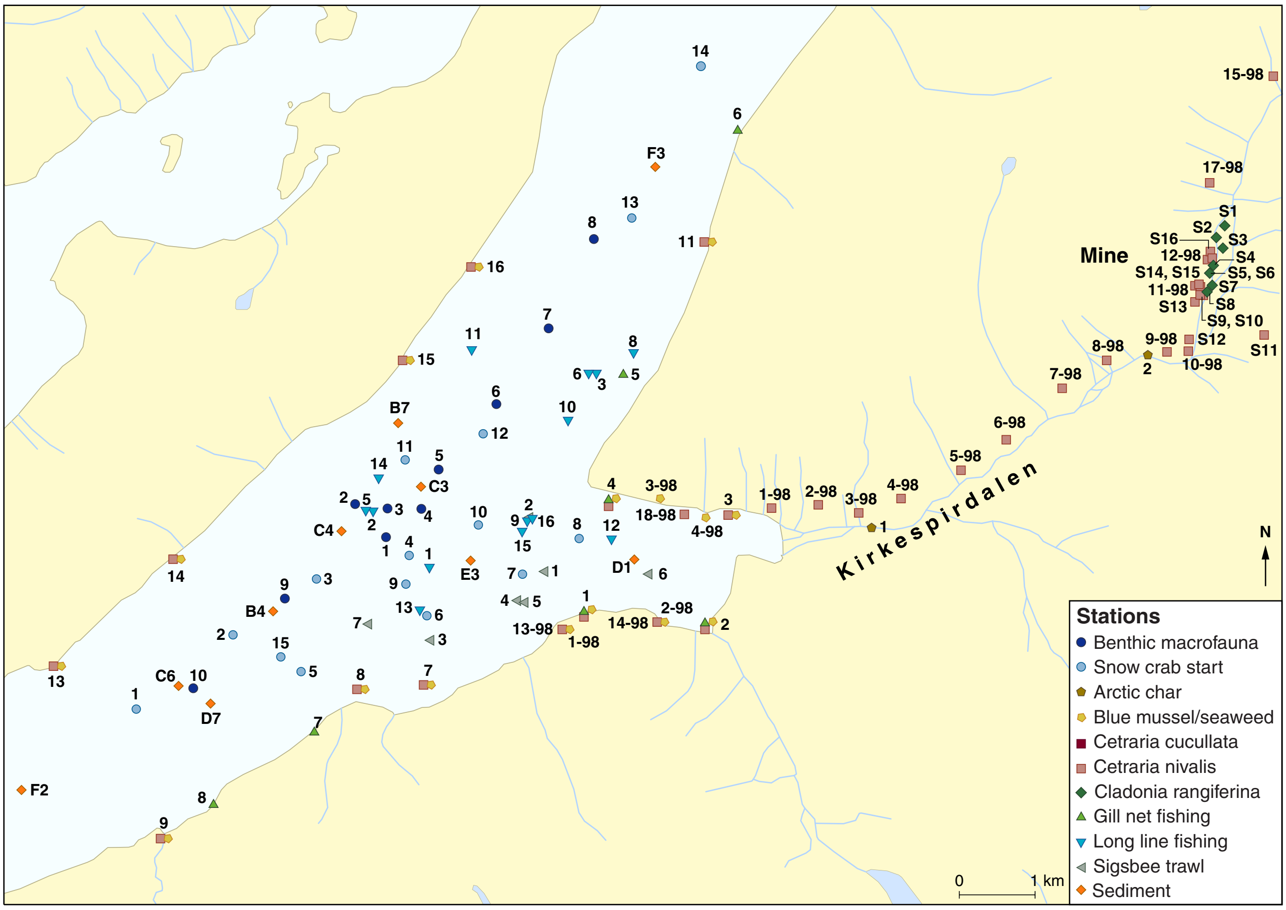

Figure 3. Sampling stations around the Nalunaq gold mine site in South Greenland. Numbers refer to Appendix 1, Tables 25-34. Letters and numbers are omitted if not necessary for understanding.

3.1 Fish

Gill net catches

Gill nets were applied at eight stations on the three surveys in September 2000, March-April 2001, and September-October 2001 (Table 2). On the first survey there was a good catch of shorthorn sculpins *Myoxocephalus scorpius*, Greenland cod *Gadus ogac* and Atlantic cod *Gadus morhua*, but surprisingly few fish were caught in the gill nets during the last two surveys. Six large Atlantic salmons *Salmo salar* were caught at station net-3 at the first survey and many small Atlantic cod were caught as well. At the last two surveys Greenland cod were nearly the only species caught. Greenland cod has a low commercial value compared to Atlantic cod and Atlantic salmon. Shorthorn sculpins have no commercial value, but they are appreciated by Greenlanders for fish soup. Shorthorn sculpins are important for baseline and monitoring purposes because they are relatively sedentary compared to the species more valuable for consumption. Also, shorthorn sculpin is widely distributed in Greenland being absent only in North Greenland (Salomonsen 1990).

Nets were set and tended every day at three different stations until a reasonable sample size was reached. The total catch at each station may therefore consist of catches from several days. The nets were tied on land and placed perpendicular to the coast about 50 metres from the shore.

We have no explanation of the complete absence of Atlantic cod at the last two surveys and the exceptional low catch of shorthorn sculpin in 2000 (4 specimens). The low catch of shorthorn sculpin is unexpected because the species has been used in other environmental surveys in Greenland where it has been easy to catch in sufficient numbers. Yet, at monitoring studies in August 2004 and 2005 adequate numbers, 37 and 16, were caught, respectively (Glahder & Asmund 2005, Andersen, J. B., Nalunaq Gold Mine 2005, *in litt.*).

Samples of muscle, liver, and row or milt were taken from all fish species. In total, meat, liver and row or milt from 246 fish are stored in the tissue bank at NERI.

Long line catches

Long lines for the catch of bottom fish were set in Saqqaa Fjord in September 2000, in March/April 2001 and in September/October 2001. The long-lines, each with 500 hooks, were baited with squid. Greenland halibut *Reinhardtius hippoglossoides* was not caught during the cruise in September 2000. From Nanortalik fishermen we were told that Saqqaa Fjord holds a population of Greenland halibut, and that they can be caught during December-April, both months included (Glahder 2001). It was therefore decided to make a special effort to catch Greenland halibut at a cruise late March 2001. Yet, no Greenland halibut were caught at this survey. The long line fishing in September/October 2001 was similar to that the previous year.

In total only 57 fish were caught on approximately 12,000 long line hooks. Moreover, nine skates and one Greenland cod were caught in the crab traps. This poor catch compared to the effort indicates a low density of bottom dwelling fish.

Samples of muscle and liver were taken from all Greenland cod, spotted wolffish *Anarhichas minor* and most of the Arctic eelpout *Lycodes reticuæatus*. Samples of row and milt were taken from fish where these organs were well developed. Whole samples were taken of skates and some of the Arctic eelpouts. The samples are kept frozen or dried at NERI.

Table 2. Number of fish caught at gill net stations in the Nalunaq area during 2000-2001.

Station	Atlantic salmon	Greenland cod			Shorthorn sculpin			Atlantic cod		
	Sept.-Oct. 2000	Sept.-Oct. 2000	March 2001	Sept.-Oct. 2001	Sept.-Oct. 2000	March 2001	Sept.-Oct. 2001	Sept.-Oct. 2000	March 2001	Sept.-Oct. 2001
net-1	0	2	5	8	4	0	0	0	0	0
net-2	0	8	1	4	9	0	0	0	0	0
net-3	6	6	14	2	10	0	0	41	0	0
net-4	0	8	2	3	3	0	0	106	0	0
net-5	0	10	3	2	0	0	0	1	0	0
net-6	0	4	6	11	7	1	1	0	0	0
net-7	0	4	1	2	8	0	1	4	0	0
net-8	0	10	1	3	53	1	0	2	0	0
Total	**6**	**52**	**33**	**35**	**94**	**2**	**2**	**154**	**0**	**0**

Arctic char fished in Kirkespir River

In the semi-quantitative study on the Arctic char population in the Kirkespir River performed in 1988 a total of 70 char were collected (Boje 1989). Of these 14 specimens were resident, the remainder were migratory. In 2000 a total of seven Arctic char were caught in the Kirkespir River, and in 2001, 12 char were caught in the river. All samples comprise whole fish and they are stored at NERI.

Sigsbee trawl catches

Biological samples from water depths between 10 and 120 m were obtained by the use of a Sigsbee trawl. This trawl is a 1.5 m wide bottom trawl originally designed for mussels, clams and sea urchins. Trawling with this trawl at six stations in and near the Kirkespir Bay gave samples of sea urchins, clams, several species of small fish, and various shrimp species, mainly *Crangon* species. The catches on the stations 1, 3, 5 and 6 contained the highest diversity. Most of the species collected have not yet been identified.

The samples are stored at NERI. Note that there is a good collection of sea urchin row from several positions and dates. Also, there is a good collection of shrimps.

3.2 Snow crab

During the cruise in September 2000 it was realised that Saqqaa fjord was poor in bottom fish, but rich in crabs. Several sand crabs and many big snow crabs were caught. After this observation it was decided to perform quantitative investigations of the abundance of snow crabs in the fjord. Crab traps or pots were applied at 15 stations in Saqqaa Fjord and at two stations at the reference locality in Uunartoq Fjord. At each station 12 traps were applied in one string, with 40 metres between traps. Trap no. 3 and 10 had a mesh width of 21 mm intended to catch females. The other traps had a mesh width of 140 mm intended for catching of males only. Adult males are significantly larger than adult females. Each trap was supplied with two fresh squids as bait. Each crab was weighed, and several standard crab measures were made. The stations were placed on four different bottom types: Mud with few stones (6 stations), stony with mud (5 stations), sandy (4 stations), and muddy with stones (the 2 reference stations). The different bottom types were determined in a study performed in September 2000 (Pedersen & Pedersen 2001).

Table 3. Number and weight of male and female snow crab caught during two periods in 2001

	March-April	Sept.- Oct.
Number of stations	17	17
Number of traps per station	12	12
Number of male snow crabs	623	400
Number of female snow crabs	1	341
Minimum number of crabs per station	7	3
Maximum number of crabs per station	67	172
Total weight of male snow crabs (kg)	548	270

More male crabs were caught in March-April 2001 than in September-October 2001, and measured in catch per effort the figures were 2.69 and 1.32 kg male per pot, respectively.

Crab samples

From each station five big and five small male crabs were selected. From each of the groups a pooled sample of meat from the walking legs and a pooled sample of hepatopancreas were taken. Hepatopancreas is a liver-like organ. In few cases less than five crabs were sampled.

3.3 Blue mussel and brown seaweed

The blue mussel *Mytilus edulis* and the brown seaweed *Fucus vesiculosus* are widely used as indicator organisms for marine pollution of surface water. These organisms have been collected during three periods in the Nalunaq area. During May 1998 mussels and seaweed were sampled at four stations in the Kirkespir Bay, and during September-October in both 2000 and 2001, the same 20 sampling stations were used both years.

The blue mussels were sorted in size groups. From stations with many mussels of varying sizes, four size groups were used. At some stations less than four groups were sampled. The soft parts of up to 20 individuals were cut out of the shells, left for drainage and then transferred to a plastic bag and frozen.

Brown seaweed was always collected in duplicate at each station. Only the new growth tips were used and washed three times with ion exchanged water in order to remove salt and epifauna. The seaweed was then frozen in plastic bags.

3.4 Sea urchin

NERI has not collected sea urchin prior to this baseline study. Because this study is also a background investigation for a possible marine deposition of tailings, it is important to collect background samples from several regimes of water depth in the Saqqaa Fjord. Sea urchins are numerous at depths between the tidal zone and the seafloor of the Saqqaa Fjord. The eggs of the sea urchin were therefore sampled as an easily recognisable organ and indicator for the intermediate marine water depths. The size of the sea urchins is given as largest body diameter.

3.5 Lichens

The lichen *Cetraria nivalis* often grows directly on dead organic material. It has no root system like herbs, so water and nutritive salts are absorbed only from the atmosphere, e.g. from rain, snow and dust. Therefore, the collection and analyses of lichens can be used to monitor the contamination of the environment by e.g. metals tied to dust particles. This has been used in Greenland with success at the three mines in Maarmorilik, Ivittuut and Mestersvig. In many cases it will be possible to obtain a semi-quantitative correlation between the concentration of an element in the lichen and the fall down of that element. *Cetraria nivalis* has been collected in 1998, 2000 and 2001 in the Nalunaq area. Samples were collected both at the blue mussel and brown seaweed stations and in the Kirkespir Valley up to 10 km from the Saqqaa fjord. Future monitoring of air pollution in the area can compare newly sampled lichens with these baseline samples. Lichens were sampled in paper bags, left indoor until dry, packed and shipped to NERI.

The list does also include 15 lichen samples collected by the Nalunaq crew during summer 2001 in the Kirkespir Valley. These samples were then handed over to NERI. Species collected were *Cladonia rangiferina, Cetraria nivalis* and *Cetraria cucullata*.

3.6 Sediments

Marine sediments from Saqqaa Fjord in 2000

In areas where sedimentation takes place, like in the deepest parts of the Saqqaa Fjord, concentration gradients of pollutants can be calculated. Also, sediment cores can be dated (see chapter 5.1) and contamination over past decades can be calculated. During September 2000 a total of 83 sediment core samples were collected in the Saqqaa Fjord with a HAPS sediment gravity core sampler. The diameter of the core is 0.014 m^2. The samples were cut into 1 cm slices, freeze dried and stored at NERI.

River sediments from the Kirkespir River in 1998

Like marine sediments, fine grained river sediments can be used to calculate concentration gradients of pollutants. During 1998 river sediments were sampled at six stations of which two stations were situated upstream the mine camp.

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4 Heavy metals in selected organisms

Eight species were analysed for eight metals in order to estimate the baseline level of metals in the area. The metals found relevant, based on the knowledge of ore composition and on concentrations in the Kirkespir River (Lakefield 1998a, b, 1999a-d), were: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn). The organisms analysed were Arctic char, shorthorn sculpin and spotted wolffish (livers from these three species), snow crab (meat and hepatopancreas), sea urchin (eggs), blue mussel, brown seaweed, and the lichen *Cetraria nivalis.* A total of 140 samples were analysed (Appendix 2).

4.1 Analytical methods

All samples were analysed by an atomic absorption method after dissolution in nitric acid. Approximately one g fresh, or 300 mg dried sample and four ml concentrated Merck Suprapur nitric acid, were added to Teflon bombs with stainless steel caps, and then heated for 12 hours at 150°C. After cooling, the dissolved samples were left uncovered until the majority of the nitrous oxides had evaporated. If nitrous oxides remain in the solutions then it is necessary to add more potassium permanganate solution in order to obtain the permanent pink colour necessary for reliable mercury results. The samples were then diluted with milli Q water to approximately 25 g in polyethylene bottles.

Determination of Zn and high concentrations of Cu and Cd

Zinc was determined by conventional flame atomic absorption spectroscopy with a Perkin Elmer model 3030 spectrophotometer using an acetylene and air flame. The apparatus was calibrated using single element commercial standards (Titrisol) in diluted nitric acid of the same strength as the samples. High concentrations of Cu (>100 µg/l) and Cd (>25 µg/l) were determined in the same way.

Determination of Hg

Mercury was determined following reduction with sodium borohydride in a flow injection system. A dedicated instrument Perkin Elmer FIMS was used. Before analysing for Hg, potassium permanganate solution was added to all samples until a permanent pink colour was obtained in order to maintain an oxidising environment and prevent loss of Hg.

Determination of Pb, Cr, Co, As, and low concentrations of Cu and Cd

A Perkin Elmer Zeemann graphite tube AAS was used in the analysis of these elements. The recommended matrix modifiers and analytical details were those generally recommended by the manufacturer (Perkin Elmer 1991). Arsenic was analysed with nickel nitrate as matrix modifier.

Accreditation

The NERI laboratory is accredited by Danak according to the EN 17025 with the accreditation no. 435. The quality control is described by Asmund and Cleeman (2000).

4.2 Fish results

Sample size and fish species

The samples analysed consisted of liver samples from five Arctic char caught in the Kirkespir River in September 2000 and October 2001, five shorthorn sculpin caught in Saqqaa Fjord in September 2000, and five Spotted wolffish caught in Saqqaa Fjord in April, September and October 2001. Where possible, reference data are given, either from Uunartoq Fjord in the area (Fig. 1) or from elsewhere in Greenland with locality given where possible. Refer to Tables 4-6.

Table 4. Metal concentrations (mg/kg wet weight (w.w.)) in Arctic char liver from Saqqaa, and from a reference area at Nuuk.

The samples from Nuuk were collected in 1999 and analysed by NERI for the project "Screening of contaminants in human Diet". D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number.

	D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**32.14**	**0.45**	**0.077**	**0.041**	**0.026**	**8.7**	**0.024**	**0.0057**	**34.9**
Std.dev.		0.13	0.027	0.013	0.022	10.2	0.009	0.0023	6.1
n	1	6	6	6	6	6	6	6	6
Nuuk									
average			**0.097**				**0.019**		
Std. dev.			0.032				0.004		
n			5				5		

Table 5. Metal concentrations (mg/kg w.w.) in shorthorn sculpin liver from Saqqaa, and from reference areas at Uunartoq (Aarkrog 1997), in Greenland (Aarkrog 1997; NERI, AM Database) and in the Thule area (Glahder et al. 2003).
D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number. * = Include many numbers below detection limit.

	D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**31.54**	**3.23**	**1.04**	**0.021**	**0.017**	**1.80**	**0.028**	**0.0045**	**32.14**
Std.dev.	4.09	2.07	0.40	0.017	0.019	0.66	0.013	0.0037	1.64
n	6	6	6	6	6	6	6	6	6
Uunartoq									
Average			**0.504**				**0.011**	**0.014**	
Std. dev.			0.203				0.005	0.019	
n			19				19	19	
Greenland									
Average			**1.37**				**0.044**	**0.017**	
Std. dev.			1.25				0.036	0.024	
n			230				230	106	
Thule									
Average		**10.7**	**1.02**		**0.001***	**1.56**	**0.048***	**0.059**	**29.7**
Std. dev.		10.9	0.62		0.020	1.24	0.035	0.071	5.13
n		30	30		30	30	30	30	30

Table 6. Metal concentrations (mg/kg w.w.) in spotted wolffish liver and muscle from Saqqaa, and from a reference area at Uummannaq (Qeqertanguit 2002).
D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number.

Sample		D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Se	Zn
Liver	**Average**	**32.93**	**2.15**	**0.49**	**0.035**	**0.038**	**7.07**	**0.056**	**0.015**	**2.38**	**25.24**
	Std.dev.	6.23	0.75	0.36	0.057	0.070	3.13	0.021	0.009	0.63	3.40
	n	16	6	6	6	6	6	16	6	10	6
Muscle	**Average**	**35.88**						**0.082**		**0.34**	
	Std.dev.	51.37						0.028		0.10	
	n	11						11		11	
Uum-mannaq Liver	**Average**								**0.0251**		
	Std. dev.								0.0027		
	n								6		
Muscle	**Average**								**0.018**		
	Std. dev.								0.009		
	n								7		

4.3 Snow crab results

Sample size and organs analysed

A total of 36 pooled samples (in most cases comprising 5-6 crabs) of either meat or hepatopancreas were analysed (Tables 7 and 8). The 28 samples comprised 14 relatively small carapace lengths and 14 relatively large carapace lengths from seven stations in Saqqaa Fjord. The remainder 8 samples comprised four small and four large carapace lengths from a reference station in Uunartoq Fjord. The crabs were caught during September-October 2000, March-April 2001, and September-October 2001.

Table 7. Metal concentrations (mg/kg w.w.) in snow crab hepatopancreas from Saqqaa, and from reference areas at Uunartoq and in Greenland.
Samples from Greenland reference areas were collected and analysed for the NERI project ”Screening of contaminants in human diet”. D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number.

	D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**41.38**	**36.6**	**3.11**	**0.15**	**0.16**	**4.47**	**0.034**	**0.098**	**24.4**
Std.dev.	4.00	4.7	1.54	0.03	0.019	1.24	0.0075	0.027	3.40
n	8	21	21	19	21	21	21	21	´21
Uunartoq Average		**31.8**	**3.46**	**0.10**	**0.24**	**8.86**	**0.027**	**0.062**	**24.0**
Std.dev.		12.4	2.67	0.037	0.18	12.38	0.009	0.019	8.1
n		5	5	6	8	5	7	5	5
Greenland Average			**4.92**				**0.072**		
Std.dev.			1.57				0.021		
n			6				6		

Table 8. Metal concentrations (mg/kg w.w.) in snow crab muscle from Saqqaa, and from reference areas at Uunartoq and in Greenland.
Samples from Greenland reference areas were collected and analysed for the NERI project "Screening of contaminants in human diet". D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number.

	D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**18.77**	**22.1**	**0.012**	**0.037**	**0.051**	**5.47**	**0.018**	**0.091**	**23.0**
Std.dev.	2.69	4.3	0.005	0.008	0.056	1.05	0.009	0.009	3.3
n	11	21	21	19	19	21	21	21	21
Uunartoq									
Average		**20.6**	**0.019**	**0.027**	**0.026**	**5.98**	**0.045**	**0.039**	**28.0**
Std.dev.		6.3	0.011	0.003	0.009	0.70	0.009	0.009	4.2
n		7	7	7	7	7	7	7	7
Greenland									
Average			**0.03**				**0.092**		
Std.dev.			0.03				0.006		
n			11				11		

4.4 Sea urchin results

Sample size and organ analysed

A total of five composite eggs samples (comprising eggs from nine to 12 individuals), collected on one station in Saqqaa Fjord were analysed for metals (Table 9). Three of the samples were collected in September 2000 and two samples in October 2001.

Table 9. Metal concentrations (mg/kg w.w.) in sea urchin eggs from Saqqaa, and from reference areas in the Thule area (Glahder et al. 2003).
D.m.% = Percent dry matter. Std. dev. = Standard deviation. n = sample number.

	D.m.%	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**17.2**	**3.1**	**0.06**	**0.033**	**0.099**	**0.41**	**0.006**	**0.014**	**29.0**
Std.dev.	2.3	1.1	0.03	0.007	0.029	0.03	0.001	0.005	12.1
n	6	6	6	6	6	6	6	6	6
Thule									
Average	**17.8**	**2.5**	**0.23**		**0.35**	**0.39**	**0.009**	**0.031**	**31.3**
Std. dev.	1.7	0.5	0.08		0.11	0.08	0.004	0.009	3.8
n	10	10	10		10	10	10	10	10

4.5 Blue mussel results

Sample size

In total 32 blue mussel samples were analysed (Table 10). Of these four samples were sampled from four stations in 1998, 14 samples from seven stations (among these one reference station) were sampled in September and October 2000, and 14 samples from seven stations (one reference station) were sampled in September and October 2001.

Table 10. Metal concentrations (mg/kg w.w.) in blue mussels from Saqqaa, and from reference areas at Uunartoq and in Greenland (NERI, AM Database).
Std. dev. = Standard deviation. n = sample number.

	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**1.79**	**0.83**	**0.036**	**0.114**	**1.13**	**0.020**	**0.187**	**13.2**
Std.dev.	0.24	0.30	0.008	0.043	0.17	0.003	0.053	2.6
n	32	32	32	32	32	32	32	32
Uunartoq								
Average	**1.59**	**0.74**	**0.037**	**0.080**	**1.15**	**0.017**	**0.127**	**12.6**
Std.dev.	0.12	0.27	0.002	0.008	0.13	0.006	0.035	1.1
n	5	5	5	5	5	5	5	5
Greenland								
Average		**0.83**				**0.015**	**0.124**	
Std. dev.		0.39				0.003	0.043	
n		70				70	52	

4.6 Brown seaweed results

Sample size

36 samples of brown seaweed were analysed for metal concentrations in new growth tips (Table 11). Of these, eight samples were sampled in May 1998 from four stations, 14 samples from seven stations were sampled in September and October 2000, and 14 samples from seven stations were sampled in September and October 2001.

Table 11. Metal concentrations (mg/kg dry weight (d.w.)) in brown seaweed from Saqqaa, and from reference areas at Uunartoq and Nuuk, Godthåbsfjord (Riget et al. 1997).
Std. dev. = Standard deviation. n = sample number.

	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**47.0**	**1.83**	**0.21**	**0.113**	**1.06**	**0.012**	**0.106**	**7.74**
Std.dev.	8.4	0.52	0.04	0.123	0.25	0.008	0.040	2.43
n	42	42	39	43	42	42	42	42
Uunartoq								
Average	**51.4**	**1.38**	**0.18**	**0.059**	**0.93**	**0.0073**	**0.102**	**6.35**
Std.dev.	8.5	0.25	0.05	0.031	0.097	0.0039	0.014	1.72
n	6	6	6	6	6	6	6	6
Nuuk Range	**25.1-30.7**	**0.5-2.1**	**0.5-0.8**	**0.6**	**2.1-5.3**		**0.4**	**7.2-10.2**

4.7 Lichen *Cetraria nivalis* results

Sample size

A total of 16 samples from the same number of stations were analysed for metal concentrations (Table 12). Of these, five were sampled May 1998, six during September 2000, and another six during August, September and October 2001.

Average concentrations from Saqqaa (Table 12) represent all stations sampled in the Kirkespir Valley and at the Kirkespir Bay shoreline. Uunartoq represents two samples collected on the Uunartoq Island.

Table 12. Metal concentrations (mg/kg d.w.) in *Cetraria nivalis* from Saqqaa, and from reference areas at Uunartoq and in Greenland (Aarkrog 1997; NERI, AM Database).
.Std. dev. = Standard deviation. n = sample number.

	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
Average	**0.265**	**0.079**	**0.170**	**0.736**	**1.012**	**0.032**	**1.123**	**21.8**
Std.dev.	0.274	0.029	0.161	1.266	0.795	0.005	0.355	7.4
n	18	18	17	20	18	20	18	18
Uunartoq								
Average	**0.05**	**0.10**	**0.04**	**0.17**	**0.56**	**0.04**	**0.65**	**19.5**
Std.dev.	0.02	0.04	0.01	0.17	0.08	0.01	0.42	7.4
n	2	2	2	2	2	2	2	2
Greenland								
Average	**0.120**	**0.083**		**0.421**	**0.815**	**0.045**	**1.534**	**16.5**
Std.dev.	0.048	0.031		0.269	0.186	0.013	0.656	8.0
n	25	31		25	26	31	22	22

4.8 Discussion and conclusion

All samples were collected prior to mine start. Therefore, highly elevated concentrations were not expected in the Saqqaa and Kirkespir area compared to reference areas in Uunartoq Fjord or elsewhere in Greenland. Yet, some mining activities were performed in the sampling period; among these were the construction of about 4½ km of adits during 1998-2002 and c. 40,000 ton of ore crushed and deposited. This could increase concentrations in samples from especially the Kirkespir River and Valley. According to the Nalunaq I/S Environmental Baseline Study (Lakefield 1998a, b, 1999a-d) elevated concentrations could be expected of Co, Cu and Hg, and slightly elevated concentrations of As, Cd, Pb and Zn.

Metals in fish liver

The baseline concentrations of the eight metals in livers of Arctic char and spotted wolffish from Saqqaa could be compared only to reference concentrations of Cd and Hg, and Pb, respectively. No elevations in these metals were found in the two species. In shorthorn sculpin livers from Saqqaa, Cd, Hg and Pb were elevated 2-3 times compared to sculpins from Uunartoq, while no elevations were seen when Saqqaa sculpins were compared to sculpins from Thule and Greenland. The remainder metals were not elevated in sculpin livers from Saqqaa when compared to sculpins from Thule. Average Cd concentrations in shorthorn sculpin livers from Saqqaa exceeded the EU threshold value for consumption of 0.5 mg/kg w.w. Average Cd concentrations in shorthorn sculpin from Uunartoq and Cd concentrations in spotted wolffish from Saqqaa were identical to this EU threshold value. Such high Cd concentrations in fish livers are found everywhere in Greenland (Johansen et al. 2004) and is not a specific problem related to the Nalunaq area.

Metals in snow crab

Both hepatopancreas and muscle from snow crab were analysed for metal concentrations. Compared to concentrations in crabs from Uunartoq only Pb and Cr in muscle were slightly elevated. Cd and Hg concentrations were lower in Saqqaa and Uunartoq compared to Greenland reference areas.

Metals in sea urchin

Prior to this baseline study sea urchin had not been part of baseline sampling programs in Greenland. Metal concentrations in sea urchin were analysed in connection to the Thule Air Base environmental study (Glahder et al. 2003) and concentrations from reference areas in Thule were compared to those from Saqqaa. In general concentrations in sea urchin from Saqqaa were below or equal to concentrations from Thule sea urchin.

Metals in blue mussel

Metal concentrations in blue mussels from Saqqaa did not differ from concentrations in blue mussels from Uunartoq; Cr and Pb were probably in the high end. Concentrations of Cd, Hg and Pb are comparable to those from other parts of Greenland.

Metals in brown seaweed

Concentrations in brown seaweed from Saqqaa were in general at the same level as concentrations in seaweed from Uunartoq. Compared to concentrations in the Nuuk area the level in the Nalunaq area was in general low; only As was at a higher level.

Metals in lichens

Average concentrations in *Cetraria nivalis* from the Saqqaa area were comparable to the Uunartoq area except for As, Co and Cr where concentrations in lichens from Saqqaa were 4-5 times higher. Compared to average concentrations in lichens from Greenland, levels of As and Cr were still about twice as high in the Saqqaa area.

Conclusions

Metal concentrations in organisms from the Saqqaa area were, compared to those from the reference area around Uunartoq, elevated only in shorthorn sculpin liver (2-3 times of Cd, Hg and Pb) and in *Cetraria nivalis* (4-5 times of As, Co and Cr). Slightly elevated levels were seen for Pb and Cr in snow crab muscle and blue mussel.

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5 Marine sediments

During 20 September–4 October 2000 marine sediments were collected in the Saqqaa Fjord by the use of a HAPS gravity core sampler. Sediment samples were collected both to establish accumulation rates and to determine different sediment structures. Also, sediments were collected for baseline purposes as described in chapter 3.

5.1 Lead-210 dating

A selection of the sediment cores has been dated at the Gamma Dating Centre, University of Copenhagen. The main results are given in Table 13 (Kunzendorf 2001).

Table 13. Sediment accumulation rates in Saqqaa Fjord.

Station	Accumulation rate 0-5 cm (g/m^{2}year)	Depth (m)
C3B	957	247
C4A	644	247
C6	751	202
D1B	1579	83
D7	1185	267
E3B	1075	170
F2	2324	265
F3	492	305
B7B	839	142
B4B	1046	267
Mean	**1089**	

5.2 Sediment samples and structure

Description of marine sediments from Saqqaa Fjord

Of the HAPS core samples, 32 were cut into 1 cm slices and 17 were preserved in PVC tubes for measurements of oxygen consumption rates. 34 samples were analysed for trace element and grain size analyses. All cores were described by standard procedures, including grain size, colour, smell, occurrence of stones, texture etc. Sampling, analyses and results are described in Danish in Pedersen & Pedersen (2001). An English abstract of the results is referred to below.

The Pedersen & Pedersen (2001) study

All samples were taken from the survey vessel Adolf Jensen. On approximately 40 stations in Saqqaa Fjord, sediment cores were sampled and described. Almost all the cores contained fine-grained material (clay and silt) deep in the core and coarser material in the top of the sediment. The clay and silt fraction was black/greenish, often with a foul smell of hydrogen sulphide.

After returning to Denmark some of the cores were examined at DTU. Properties like the amount of water and organic material in the sediment, grain size distribution, X-ray diffraction, cation exchange capacity (CEC), pore water and micro-organisms were studied.

The micro-organisms registered were similar to the organisms in ordinary Greenland sediments and so is the content of organic material. The content of clay minerals is considerable, but the observed types of minerals show no surprises. The CEC indicates that the reactivity of the sediment is considerable, and there is no elevation of nutrients compared to standard values. The samples of pore water were oxidised following the sampling, which implied that neither sulphate, nor nitrate could be measured. The concentration of chloride was slightly lower than standard values for seawater, which was expected since the fjord contains both fresh water and seawater. The sediment was aerobic on the very top of the core, yet only few millimetres down the core the sediment became anaerobic.

It is possible to divide the fjord in three areas. In one area close to the Kirkespir Valley all the cores contained a considerable amount of sand, which originates from the rivers close by. In the middle of the fjord containing the deepest parts, another area could be characterised by mainly fine-grained material and few coarse elements in the upper part of the core. The coarse material probably originates from icebergs. The third area could be located close to the coastline of Amitsoq, and there was a considerable amount of coarse material in the top of the core. The coarse material comes mainly from the steep slopes of Amitsoq.

The distribution of coarse material in the upper part of the cores could indicate a climatic change, which occurred 30-40 years ago. Since 1960 Greenland has become cooler, which might have caused more icebergs and more erosion, and this again might lead to an increase in deposition of coarse material.

Saqqaa is a fjord with a depth not different from many Greenland fjords with almost no currents at the bottom. Clay and silt is therefore deposited in the deepest parts. The sediment is getting coarser closer to the surface and the contents of clay minerals and organic matter make the reactivity of the sediment considerable.

6 Benthic macrofauna

Introduction

Benthic macrofauna is commonly used as an environmental indicator, and a great knowledge exists of how this fauna reacts to changes in sedimentation rates of organic as well as inorganic fine-grained material (e.g. Pearson & Rosenberg 1978). Examples are e.g., investigations of titanium mining in the northern Skagerrak (Olsgaard & Hasle 1993), the effects of oil drilling operations in the North Sea (e.g., Gray et al. 1990; Olsgaard & Gray 1995), and effects of tailings from the fixed link over the Øresund (Josefson & Petersen 2001). These studies have shown changed species composition and/or diversity as a result of the tailing impacts.

This report describes the findings of the September/October 2001 survey of macrozoobenthic fauna and sediment in the Saqqaa and Uunartoq fjords, southern Greenland, carried out by NERI, Departments of Arctic Environment and Marine Ecology, with Bio/consult as and GEUS as subcontractors. The investigation was made on behalf of the Nalunaq I/S to provide a basis for the environmental impact assessment in connection with the Nalunaq Gold Mine Project. If sub-sea tailing from the mining is chosen, this study can provide a baseline for future impact assessments. This was the second environmental survey of macrozoobenthos undertaken in this area before disposal of tailings from the mine, and the present report describes species composition, diversity, abundance and biomass of the benthic invertebrate communities and some sediment variables at 15 different stations. The first benthic fauna study was performed during autumn 2000 (Greisman 2000).

If sub-sea tailings deposition (Marine Tailings Placement (MTP)) is chosen, tailings from the mine is planned to be discharged below the stratified brackish water layer at c. 150 m with the ultimate deposition on the seafloor at about 250 m in Saqqaa Fjord just outside Kirkespirdalen. Five benthic stations were established in the deepest part of the fjord that is in the area of anticipated direct impact from the disposals. Additional five stations were established as primary control stations in the Saqqaa Fjord further away from the disposal area at similar depth as the impact stations. Another five stations were established as secondary control stations in another fjord, Uunartoq, but at similar depth and sediments as in Saqqaa. The present report contains a description of the macrobenthic communities in the basins of the two fjords. Species composition, biodiversity and biomass are compared both between the fjords and within Saqqaa Fjord. Further, the communities in the fjords are compared to knowledge available from corresponding communities in other high-boreal fjords as well as open marine areas. One central question asked was whether the biodiversity value in the Saqqaa Fjord motivated change of disposal strategy.

Expected effects in Saqqaa will depend on the magnitude of the tailings and the size composition of the material deposited.

6.1 Methods

Based on previous knowledge of where the tailings are likely to deposit and in order to ensure proper controls, benthic fauna stations were placed in the following way. In the Saqqaa Fjord five stations were placed west of the tailings discharge outlet in the deepest part of the fjord (Fig. 4) and distributed in what is anticipated to become the impact area. Southwest and northeast of the ”impact area” additional five stations were placed at similar water depths as the impact stations and spaced 1000-1500 metres apart. In the case of restricted spreading of the tailings these stations are anticipated to act as control sites. In the case of more extensive spreading of tailings in Saqqaa Fjord, five control stations were established in a different fjord (Uunartoq) at similar depths as in Saqqaa and spaced 1000-1500 metres apart (Fig. 4). Thus, the station net ensures controls for two different scenarios with regard to dispersal of the tailings. Moreover, we anticipate the natural variability to be kept at a minimum by choosing similar water depth and sediments.

At each station five replicate samples were taken with a ”HAPS” sampler for benthic macrofauna. The internal diameter of the HAPS-corer was 13.5 cm, thus covering a bottom area of 0.0143 m^2. Only sediment cores with depth >10 cm was accepted. In addition, at each station one HAPS-sample was taken for sediment variables. A sample of the top 2-cm of the sediment core was put into a plastic bag and later deep-frozen at c. -20°C. Fauna sediment samples were suspended with some seawater and sieved through a 1-mm mesh. Sieve residue was put into a plastic container with ca. 5 % formalin buffered with natriumtetraborate. Sediment analyses were made by GEUS (The Geological Survey of Denmark and Greenland, Copenhagen) and comprised water content (or the inverse dry matter content), loss on ignition (reflecting amount of organic matter) following standard methods (DS 405.11 and DS 204), and grain size analysis. Grain size analysis was made using dry sieving of the fraction >63 µm and sedigraph analysis of the fraction <63 µm following Danish standard methods (DS). Fauna analysis was made by Bio/consult as, Århus, Denmark, and comprised species determination to lowest possible taxon, determination of number of individuals, wet weight (WW), dry weight (DW) and ash-free dry weight (AFDW) of each taxon. Of these three weight measures only AFDW is used in the analysis in this status report. AFDW is the most relevant biomass measure with respect to energy flow as it does not include shell structures or gut contents (such as sediment grains) of the animals. DW is a necessary step to determine AFDW.

Multivariate analysis of similarity and computation of diversity indices were made using the PRIMER package V.5 for Windows and details on algorithms are found in Clarke and Warwick (1994) and Clarke and Gorley (2001).

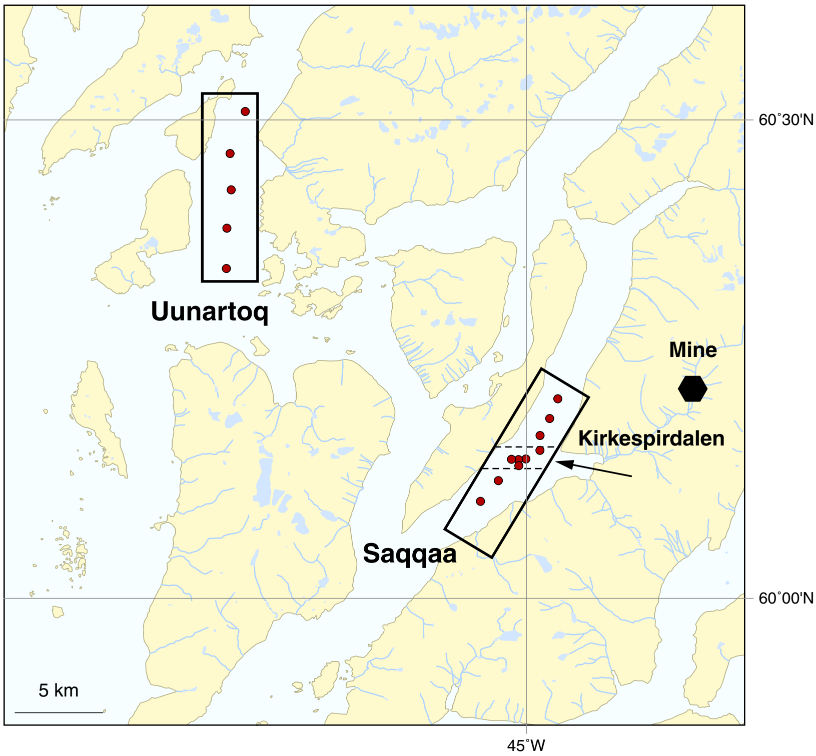

Figure 4. Map shoving the investigation area with positions of sampling stations for macrobenthic fauna and sediment. The Saqqaa Fjord area includes both impact stations (dots within broken lines) and primary reference stations (dots outside broken lines). The Uunartoq area includes only reference stations. For exact positions, see Table 34, Appendix 1. Mine indicated by pentagon. Arrow indicates approximate position of proposed Marine Tailings Placement (MTP).

6.2 Results

Acceptable samples were obtained at all stations, although several trials were needed at the stations with stones. Sediments at most stations were composed of very soft mud and larger (>2 cm diameter) stones. The latter were probably deposited from ice-mountains. The fauna communities looked rather similar being dominated by protobranch bivalves and polychaetes.

Sediment composition

The surface (top 2 cm) sediments at the sampled stations were in general characterised by very soft mud. The sediment compositions were highly similar, the sediment between stones (2-8 cm in diameter) had a high content of fine material, where the <63µm fraction accounted for 60-98% of the dry weight (with one exception) (Table 34, App. 1). Stones/gravel occurred in particular at the Saqqaa stations. The loss on ignition, a measure of organic material, varied mostly between 5 and 7% of sediment dry weight (DW). Water content varied mostly between 50 and 70% of sediment wet weight (WW). Statistical testing for differences between fjords and between impact and control stations in Saqqaa did not show any significant differences between areas for any of the sediment variables.

Table 14. Results of statistical comparison with Students t-test on water depth and sediment variables.

Variable	Saqqaa-Uunartoq		Saqqaa impact-control	
	t (n = 10,5)	p	t (n = 5,5)	p
Water depth	0.723	0.489	-1.577	0.155
Water content	-2.122	0.060	-0.839	0.438
Loss on ignition	0.004	0.997	0.291	0.779
Percent fines	-1.421	0.189	-0.552	0.617

Macrozoobenthos

Complete tables of taxa and their average abundance and average biomass at each station are presented in Appendices 3 and 4.

Totals and major taxonomic groups

The total abundance varied between 490 and 2517 individuals per m^2 and there was significantly higher (Students t-test, t = 6.72, P<0.001) abundance at the Saqqaa stations (average of 1804 ind./m^2) compared to the stations in Uunartoq (average 764 ind./m^2). The difference between the two fjords was nearly threefold. There was no significant difference in abundance between impact and control stations within Saqqaa (Students t-test, t = 0.241, P>0.05). On average more than 80% of the individuals belonged to the taxonomic group Polychaeta. The second most important group in terms of numbers was Mollusca which on average accounted for ~10 % of the total. There was no major difference in terms of taxonomic group composition neither within Saqqaa Fjord, nor between the Saqqaa and Uunartoq (Fig. 5).

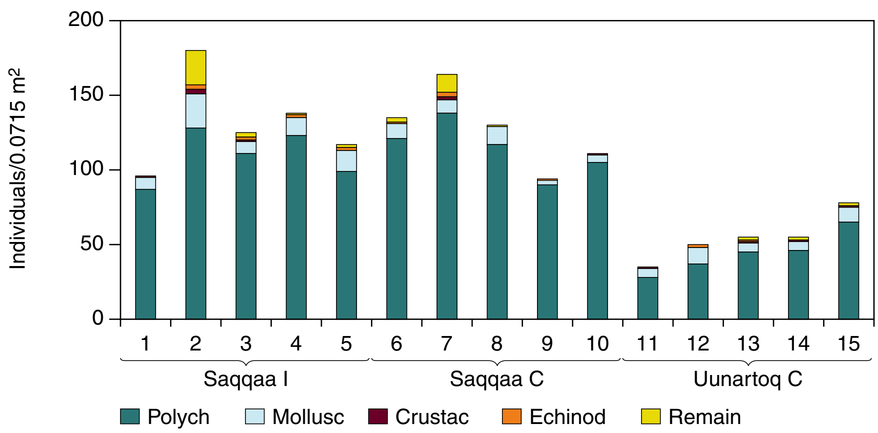

Figure 5. Composite bar plot showing composition of total number of individuals in terms of major taxonomic fauna groups at the 15 stations in Saqqaa and Uunartoq (I = Impact, C = Control). The groups are bristle worms (Polych), molluscs i.e. mussels and snails (Mollusc), crustaceans i.e. mostly amphipods and cumaceans (Crustac) and echinoderms, here mainly a sea star (Echinod). The rest group (Remain) contains taxa like sipunculids, nemerteans etc. Note the lower values at stations 11 to 15 in the Uunartoq Fjord.

The total biomass, in the following only referring to ash-free dry weight, varied between 2.05 and 15.84 g AFDW/m^2, on average 10.88 g/m^2, and there was no significant difference between Saqqaa and Uunartoq (Students t-test, t = -0.398, P>0.05), nor between impact and control in Saqqaa (Students t-test, t = -0.374, P>0.05). Compared to abundance, biomass was much less dominated by Polychaeta, and

Mollusca accounted for an equal or greater part, of the biomass than Polychaeta. At some stations also the group Echinodermata accounted for a significant part of the biomass (Fig. 6). As for abundance there was no consistent difference in terms of taxonomic groups between Saqqaa and Uunartoq (Fig. 6).

Species composition

Patterns in species composition was analysed using non-metric multidimensional scaling (MDS) and hierarchical clustering of stations using Bray-Curtis similarities based on species abundance and biomass (AFDW). Analyses were performed both on untransformed values and fourth root transformed values, where the former emphasises the most dominating species and the latter putting less weight to dominants. Composition of abundance was different in Saqqaa compared to Uunartoq (Fig. 7). The most clear separation between the 2 fjords was obtained on untransformed values where similar results were obtained with both MDS and clustering analysis (Fig. 7, top panels).

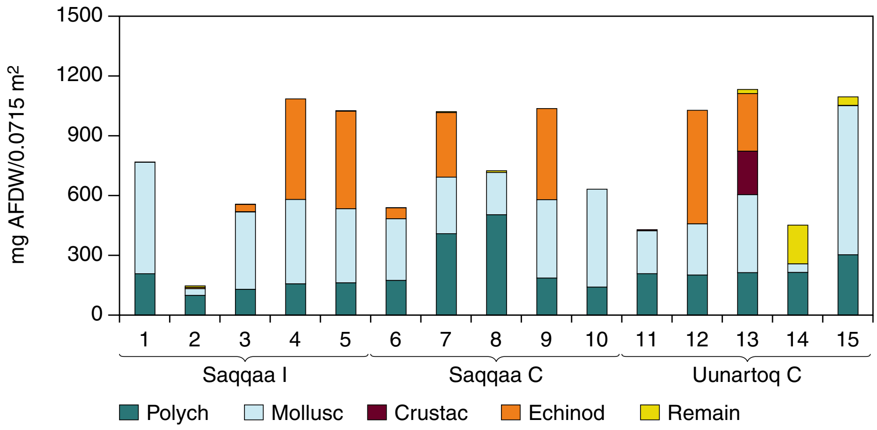

Figure 6. Composite bar plot showing composition of total biomass (AFDW) in terms of major taxonomic fauna groups at the 15 stations in Saqqaa and Uunartoq. For further explanation see Fig. 5.

Testing for non-random patterns with the ANOSIM test, showed that Uunartoq had a significantly different species composition ($P<0.01$) compared to Saqqaa, both for untransformed and fourth root transformed data (Table 15). Comparison of species composition between impact (Station nos. 1-5) and controls (Station nos. 6-10) within Saqqaa did not show any difference (Fig. 7, Table 15: pair-wise A B).

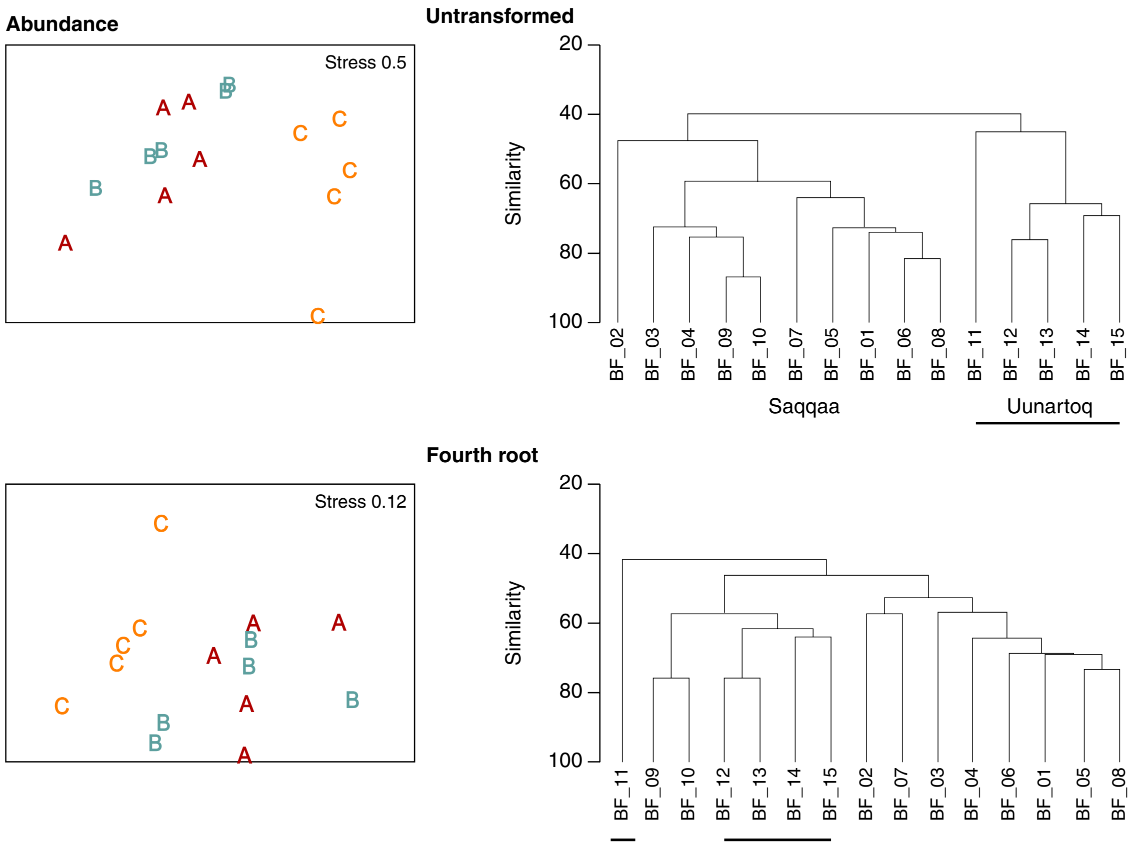

Figure 7. Results of multivariate analyses of species abundances from the 15 stations in Saqqaa and Uunartoq. Impact and reference stations in Saqqaa are indicated by A and B respectively. Stations in Uunartoq are indicated by C. Left panels show results from multidimensional scaling (MDS) of Bray-Curtis similarity between stations, where the upper panel is based on untransformed data and the lower panel on fourth root transformed data. Stress indicates the degree of separation between groups, where values around 0.1 and lower indicates good separation. The axes in the MDS plots are dimensionless and show relative distances in similarity in two dimensions. Panels to the right show results from a hierarchical classification analysis of the corresponding data with stations in Uunartoq underlined.

In order to determine which species were the most important for the differences between Saqqaa and Uunartoq a SIMPER analysis was performed (Table 16). Of the total average dissimilarity of 62.13 %, five species, all of them polychaetes (bristle worms), accounted for >60 % of the dissimilarity (Table 16).

Table 15. Results from ANOSIM test for grouping of stations between the 3 areas: Saqqaa-impact (A), Saqqaa-control (B) and Uunartoq-control (C). Statistical significance ($P<0.05$) is indicated by bold typing.

	Untransformed R-statistic	p	Fourth root R-statistic	p
Abundance				
Global A, B, C	0.464	0.003	0.384	0.002
Pair-wise A B	-0.1	0.762	-0.02	0.484
Pair-wise A C	0.788	**0.008**	0.629	**0.008**
Pair-wise B C	0.720	**0.008**	0.488	**0.008**
Biomass (AFDW)				
Global A, B, C	0.076	0.197	0.234	0.022
Pair-wise A B	-0.044	0.603	-0.12	0.873
Pair-wise A C	0.184	0.095	0.436	**0.008**
Pair-wise B C	0.08	0.254	0.356	**0.024**

Using species composition in terms of biomass, the results of the similarity analyses were quite different from the ones on abundance. The grouping of stations with respect to similarity was much less clear than for abundance (Fig. 8) and a significant difference (P< 0.05) in composition between Saqqaa and Uunartoq was only obtained for fourth root-transformed values (Table 15). As for abundance, there were no groupings within Saqqaa. The SIMPER analysis showed that of the average total dissimilarity between Saqqaa and Uunartoq of 71.46 % 4 species accounted for >60 % of the dissimilarity (Table 16). These were the large sized sea-star *Ctenodiscus crispatus*, the 2 large deposit-feeding Yoldia-bivalves and a polychaete worm.

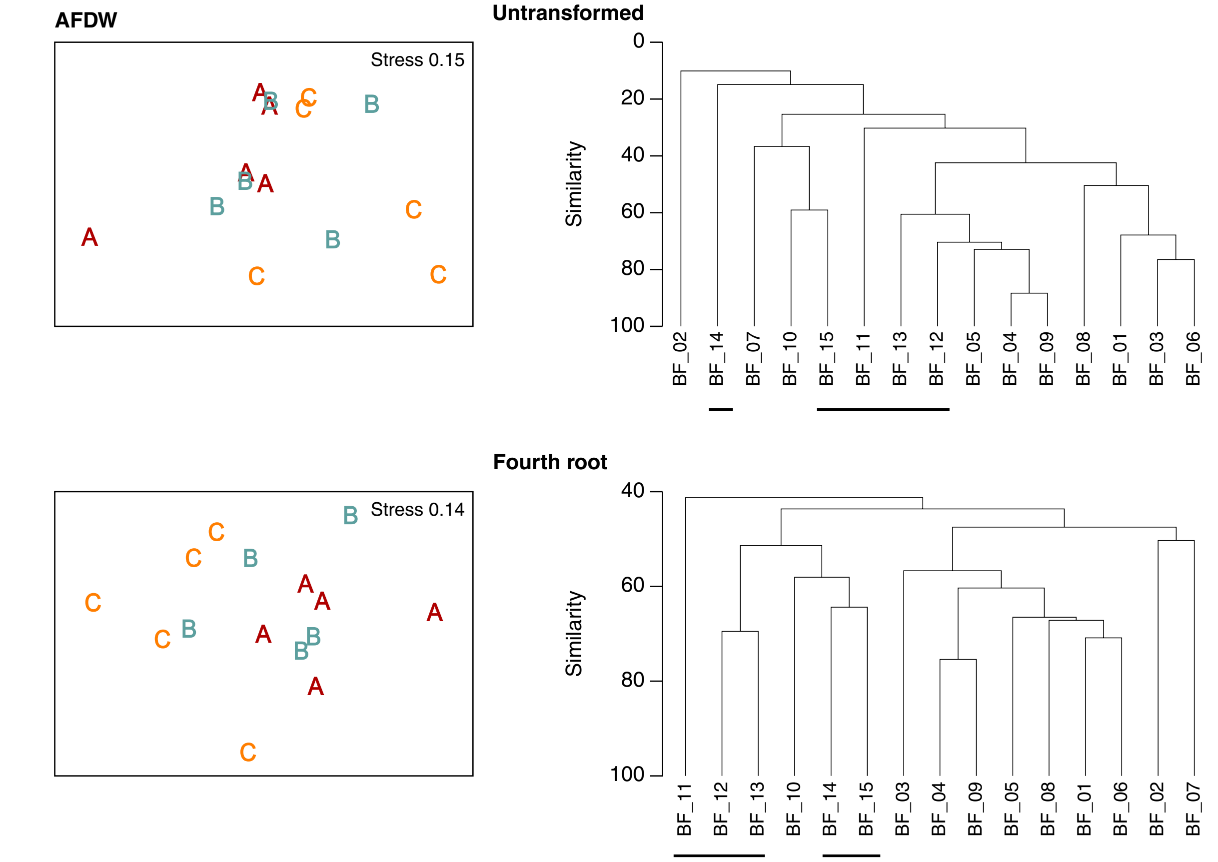

Figure 8. Results of multivariate analyses of species biomasses (AFDW) from the 15 stations in Saqqaa and Uunartoq. For further explanation see Fig. 7. Stations in Uunartoq are underlined in panels to the right.

Table 16. Results of SIMPER analysis to identify species of importance for grouping of stations. Contribution % = contribution to total dissimilarity between the two fjord areas, Cumulative % = cumulative percent of the species and more important species.

Species	Average Saqqaa	Average Uunar-toq	Contribution %	Cumulative %
Abundance (ind./m^2)				
Lumbrineris fragilis	364.8	56.0	20.9	20.9
Prionospio steenstrupi	598.7	324.8	16.0	36.9
Chaetozone setosa	232.4	30.8	12.8	49.7
Polycirrus arcticus	117.6	14.0	7.2	56.9
Myriochele heeri	106.4	0.0	6.2	63.1
Biomass (AFDW, g/m^2)				
Ctenodiscus crispatus	2.48	2.40	19.6	19.6
Yoldia hyperborea	3.61	2.28	18.4	38.0
Megayoldia thraciaeformis	0.88	2.03	15.0	53.0
Praxillella praetermissa	0.14	1.79	11.2	64.2

Biodiversity

Biodiversity can be measured by a great number of indices, most of them reflecting different aspects of the distribution of species among number of individuals and spatial units. None of the indices are truly independent of sample size or sample effort. It is therefore important when comparing diversity measures that the sampling size or effort is at least roughly the same. In this investigation we used six different measures of diversity to compare different stations and areas: the number of species (S), the Margalef's index (d), the Pielou's evenness (J'), the expected number of species by rarefaction according to Hurlbert (ES), the Shannon-Wiener diversity index with base 2 (H') and Simpson's 1-Lambda' (Table 17). Except for J' (evenness), all these indices were positively correlated with each other and some of them also with the number of individuals. When testing for differences between Saqqaa and Uunartoq and between impact and control areas within Saqqaa (Table 18), significant differences were seen only for number of species per station and for Margalef (d) between Saqqaa (highest values) and Uunartoq.

Table 17. Measures of species diversity at each station based on five HAPS samples (0.07 m^2 bottom area). S = number of species, n = number of individuals, d = Margalef's index, J' = Pielou's evenness index, ES(25) and ES(50) = Hulbert's expected number of species by rarefaction from 25 and 50 individuals respectively, H' = Shannon-Wiener diversity index with base 2 and 1-Lambda' = Simpson's 1-Lambda'.

Stn	S	n	d	J'	ES(25)	ES(50)	H'(log2)	1-Lambda'
BF 01	15	96	3.07	0.76	8.81	11.88	2.98	0.83
BF 02	31	180	5.78	0.79	12.17	17.24	3.92	0.91
BF 03	22	125	4.35	0.72	9.61	13.58	3.21	0.83
BF 04	17	138	3.25	0.69	8.06	11.26	2.82	0.79
BF 05	23	117	4.62	0.77	10.69	15.37	3.47	0.87
BF 06	21	135	4.08	0.70	8.66	12.22	3.08	0.83
BF 07	33	164	6.27	0.77	12.05	17.36	3.90	0.90
BF 08	15	130	2.88	0.80	9.12	11.75	3.14	0.85
BF 09	10	94	1.98	0.62	5.84	7.77	2.07	0.66
BF 10	15	111	2.97	0.68	8.00	10.83	2.65	0.74
BF 11	11	35	2.81	0.83	9.80	11.00	2.88	0.82
BF 12	12	50	2.81	0.76	9.03	12.00	2.72	0.77
BF 13	14	55	3.24	0.80	9.90	13.52	3.06	0.83
BF 14	11	55	2.50	0.71	7.72	10.54	2.46	0.73
BF 15	14	78	2.98	0.76	8.85	11.82	2.88	0.80

Table 18. Results of statistical comparison of areas with Students t-test on different measures of species diversity. stat. = station.

Diversity index	Saqqaa-Uunartoq		Saqqaa impact-Saqqaa control	
	t (n = 10.5)	p	t (n = 5.5)	p
No. species/stat.	3.217	**0.009**	0.579	0.580
Margalef (d)	2.360	**0.039**	0.648	0.538
Evenness (J)	-1.480	0.170	0.801	0.453
ES(50)	1.066	0.306	0.987	0.355
Shannon (H)	1.604	0.133	0.867	0.415
1-Lambda	1.024	0.325	0.952	0.380

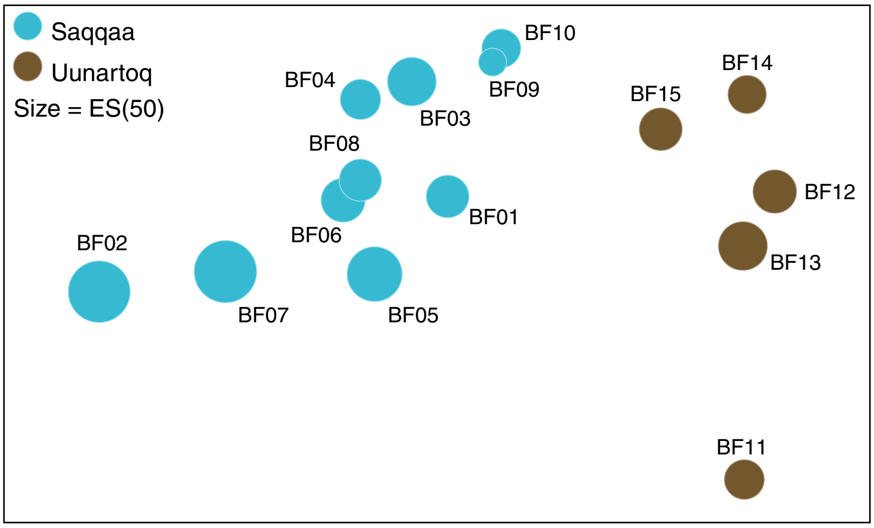

Figure 9. Bubble plot of a MDS plot showing difference in species composition between Saqqaa and Uunartoq based on species abundance and where the size of the bubbles relates to the diversity measure ES(50).

The similarity in ES(50) between Saqqaa and Uunartoq is illustrated in the MDS plot of untransformed abundances (Fig. 9).

6.3 Discussion and conclusions

This base-line study shows that the number of individuals was highly dominated by polychaete worms (Polychaeta), ~ 80 %, while the major contribution to biomass (e.g. ash free dry weight (AFDW)) was equally divided between the animal groups Polychaeta, Mollusca and Echinodermata. In general the fauna was characterised by deposit feeders, polychaete worms and protobranch bivalves. The faunal composition in terms of major taxonomic groups was typical for high latitude boreal fjord basins elsewhere (e.g. Oug 2000). All retrieved species have been recorded earlier from the high boreal/low arctic areas around Greenland.

The sampled areas within each of Saqqaa and Uunartoq fjords are highly homogeneous both with respect to sediment composition and benthic macrozoobenthos community composition, a fact that will facilitate the detection of eventual impacts from the tailings disposal. In general, biodiversity values do not differ markedly between stations, although there is a tendency towards higher diversity in Saqqaa. Compared to other similar areas (soft sediment fjord basins with similar water depths), diversity is otherwise not markedly higher in the investigated area. For instance in the Skagerrak at 200-300 m depth the ES(50) of macrofauna minus crustaceans varied between 12-17 species (Josefson 1985).

In the previous fauna survey (Greisman 2000) 107 taxa were encountered from 0.67 m^2 whereas we found 70 taxa from 1.07 m^2. There may be several reasons for this difference. First, different sampling gears and sample distributions were used in the two surveys, which may make a direct comparison difficult. The following circumstances, however, will probably partly explain why more species were found in 2000 than in 2001. **1:** In 2001 damaged and juvenile specimens were assumed to belong to the same species as the intact (determinable) adult specimens, and some groups were not determined to species like hydroids, entoprocts, etc. Using this policy on the 2000 material reduces the 107 species to some 85 species. **2:** Sampling in 2000 was performed over a longer time period (August-October) and in one additional area (South Saqqaa) compared to 2001. **3:** Different to the sample processing procedure in 2001, 7 of the 10 samples in 2000 (the ponar grab samples) were preserved before being sieved on the 1 mm screen. This can have a marked influence on the effectiveness of the sieving in that formalin-preserved animals more easily are retained by the sieve. This is simply because they become stiff and do not have the opportunity to crawl and escape through the meshes. This could also explain why the number of individuals from the ponar samples seems to be in the high end, or higher than, observed in 2001 (Greisman 2000). Other differences between fauna lists from the two surveys obviously are due to different taxonomic expertise. Of the most abundant forms (all bristle worms) the *Chaetozone* species were determined to several species in 2000, whereas in 2001 they were likely included in *Chaetozone setosa. Scoletoma hebes* found in 2000 is likely synonymous with *Lumbrineris fragilis* found in 2001. *Laphania boecki* found in 2000 is likely synonymous with *Polycirrus arcticus.* Among mussels, *Eunucula tenuis* in 2000 is called *Nuculoma tenuis* in 2001. Which terminology is the most correct is not easy to say, but it illustrates clearly the problems with different taxonomic expertise when comparing species composition. It further emphasises the importance of consistency of methods when assessing changes in macrobenthic communities, in particular on the species (lowest taxon) level.

Little is known about the sensitivity of the present fauna to increased sedimentation of inorganic and organic matter. What precisely the effects of disposal will be, will also depend of the magnitude and the particle size structure of the tailings. At high disposal rates (above c. 10 cm per year), burial and extinction of the fauna is possible, whereas at lower rates at least a change in species composition is likely to occur. At lower rates there may even be a positive response by the fauna with increased number of species and individuals as was seen in connection with sediment spills from the construction of the bridge across Øresund (Josefson & Pedersen 2001).

7 Snow crab study

Purpose of the crab study

The purpose of the snow crab study was to perform a quantitative study on the Saqqaa Fjord population and compare male size, catch per effort and distribution to other Greenland snow crab populations. A description of the snow crab fishing stock in Saqqaa Fjords prior to a possible sub-sea tailings disposal in the fjord is necessary to evaluate possible effects of the tailings on the crab population.

7.1 Methods

Details of methodology and crab catches during spring and autumn 2001 are described in chapter 3.2. The quantitative studies referred to in this chapter were performed according to the methods used by the Institute of Natural Resources of Greenland. Egg conditions were evaluated according to Table 19. The widest carapace width (CW) was measured with a slide gauge on a straight line across the carapace at the pair of third legs. The widest width of the right claw (chela) (CH) was measured with a slide gauge. The carapace was classified according to Table 22. The weight of the male crabs was measured and related to bottom type and number of traps.

7.2 Results

Catch of female crabs compared to males

At the survey in March-April 2001 a total of 622 males and one female were caught. This distribution was quite different during the survey in September-October 2001 where the number of males and females were nearly equal with 400 males and 341 females.

Egg conditions

Almost all female crabs had orange eggs in good quality. A few females had light orange eggs, which represents a less mature stadium. Also, a few female crabs had brown eggs with visible “eyes”, a stadium normally observed just before the eggs hatch. All females were released into the fjord soon after they were measured.

Table 19. Egg conditions representing stages from less to more mature. Egg quality is distinguished in either good (1) or poor (2).

Stage	Description
1	No eggs
2	Light orange eggs
3	Orange eggs
4	Dark orange eggs
5	Dark brown or purple eggs with eyes
6	Eggs degenerated or empty egg shells, perhaps mixed with dark brow eggs

Snow crab males: Weight and numbers per trap

The following results deal with male snow crabs only. Table 20 describes number and weight of males caught at 17 stations in Saqqaa and Uunartoq fjords during spring and autumn 2001.

Carapace width (CW) of males from two fjords

The carapace widths of the male crabs from Saqqaa Fjord are shown in Figure 10 and from the reference stations in Uunartoq Fjord in Figure 11. The average carapace width in March-April 2001 was 117 mm, varying between 68 and 150 mm. In September-October the average carapace width was 102 mm, with variations between 67 and 148 mm.

At the reference stations in Uunartoq Fjord the average carapace width in March-April 2001 was 124 mm, varying between 97 and 151 mm. In September-October the average carapace width was 104 mm, with variations between 53 and 148 mm.

Table 20. Number and weight of male snow crabs caught on 17 stations in Saqqaa and Uunartoq fjords during spring and autumn 2001. The stations are grouped according to sediment characteristics. Number of females is shown for September/October 2001. Only one female was caught March/April 2001. *St 11: Only 8 pots were set on September/October 2001.

		March/April 2001				September/October 2001				
	Depth (m)	**Males (No.)**	**Males (Kg)**	**Males Kg/trap**	**Males Av. kg/trap bottom type**	**Females (No.)**	**Males (No.)**	**Males (Kg)**	**Males Kg/trap**	**Males Av. kg/trap bottom type**
Mud										
St 1	272	19	17.12	1.427	3.986	0	7	5.1	0.425	1.264
St 2	265	18	20.48	1.707		0	4	5.21	0.434	
St 3	242	67	74.34	6.195		0	13	14.4	1.200	
St 4	253	59	54.20	4.517		0	17	15.54	1.295	
St 13	295	67	74.34	6.195		134	38	26.4	2.200	
St 14	281	56	46.48	3.873		128	34	24.38	2.032	
Sand										
St 5	160	7	4.15	0.346	1.092	0	7	4.4	0.367	0.383
St 6	73	13	7.58	0.632		0	2	0.55	0.046	
St 7	131	40	22.22	1.852		0	22	8.18	0.682	
St 8	71	34	18.48	1.54		0	13	5.23	0.436	
Stones with mud										
St 9	178	24	13.9	1.158	2.563	0	24	9.32	0.777	2.118
St 10	190	55	38.36	3.197		0	39	17.28	1.440	
St 11*	215	45	39.1	3.258		0	23	10.55	1.319	
St 12	253	47	48.14	4.012		48	67	54.28	4.523	
St 15	268	14	14.3	1.192		0	33	30.4	2.533	
Reference station										
Uunartoq 1	231	32	28.98	2.415	2.276	15	3	2.74	0.228	1.613
Uunartoq 2	221	26	25.64	2.137		16	54	35.96	2.997	
Total		**623**	**547.81**	**2.68**		**341**	**400**	**269.9**	**1.35**	
Mean weight, kg			0.88					0.67		

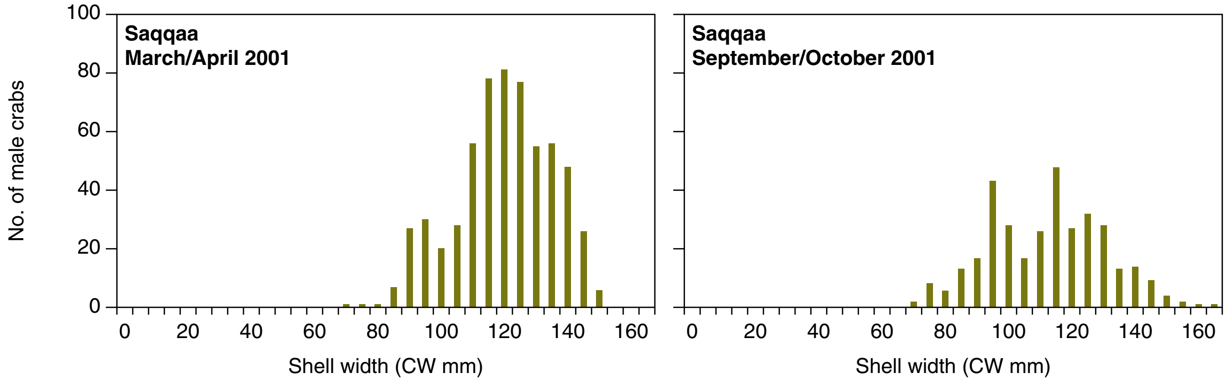

Figure 10. Carapace width (CW) in mm of male snow crabs caught in Saqqaa Fjord during March-April (left) and September-October (right) 2001.

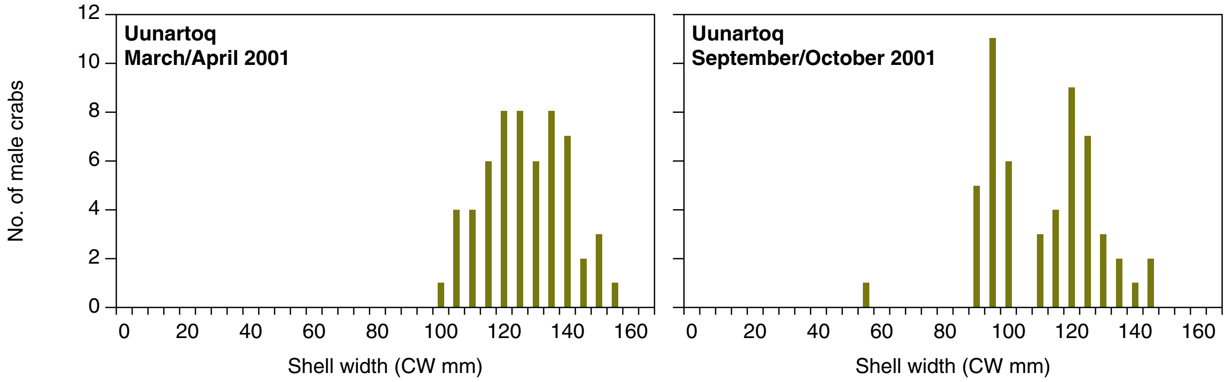

Figure 11. Carapace width (CW) in mm of male snow crabs caught in Uunartoq Fjord during March-April (left) and September-October (right) 2001.

Distribution of adult and adolescent males

The distribution of adult and adolescent males is calculated from the bivariate discriminate function of the logarithmic transferred (base e) width (CH) of the crab's right claw as a function of carapace width (CW) (Sainte-Marie et al. 1996). Figure 12 shows two groups of males with carapace widths above 60 mm. The upper group represents adult males, the lower group the adolescent males.

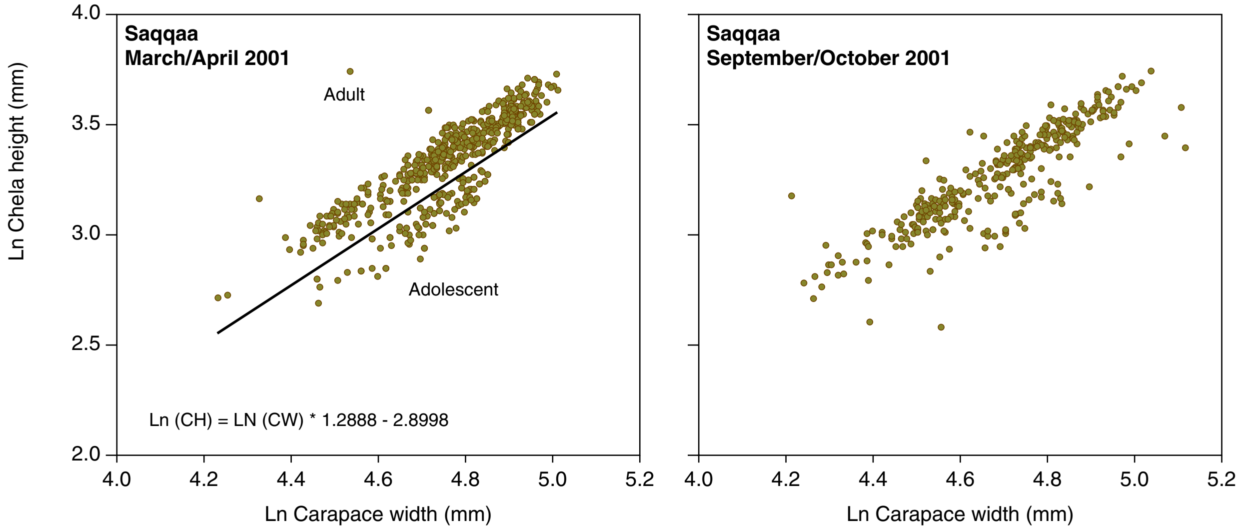

Figure 12. Male crab's right claw (chela) width (CH) as a function of carapace width (CW) in Saqqaa Fjord in March-April (left) and September-October (right) 2001.

The sample sizes from Saqqaa Fjord during September-October 2001 and from Uunartoq Fjord during both periods are too small to calculate the distribution of adult and adolescent males. However, there are indications that the major part of the males in Saqqaa Fjord in September-October 2001 is adults.

The smallest adult male crab had a carapace width of 70 mm and the largest adolescent male crab a carapace width of 130 mm. Figure 12 shows that male crabs with a carapace width of 60 and 135 mm include both adult and adolescent male crabs.

Carapace classification

Male snow crabs were grouped in classes (Table 21) according to five carapace classes (Table 22). The carapace classification can, over a period of years, give information on periods of moult, life cycles, natural fluctuations in the population and age classes. Table 21 shows that the majority of adult and adolescent crabs in Saqqaa Fjord were in classes 2 and 3. Less than 4% of the crabs had soft carapaces (class 1) during March and April 2001. The majority of crabs in Uunartoq Fjord were in both spring and autumn classified as class 3, and no crabs with soft carapaces were found.

Table 21. Percent of male snow crabs grouped in five different carapace classes. The crabs are sampled in Saqqaa and Uunartoq fjords during two periods in 2001.

Fjord and period	Carapace classification				
	1	2	3	4	5
Saqqaa March-April	3.5	53	43	0.5	0
Saqqaa Sept.-Oct.	0	23	64	12	1
Uunartoq March-April	0	22	78	0	0
Uunartoq Sept.-Oct.	0	22	68	10	0

Table 22. Definition of the five different carapace classes

Carapace classification	Description
1. Soft	The carapace is often reddish brown and the ventral surface white to reddish. The carapace is clean with no growth of plants or animals (epibionts). Often the crab will be so soft that even a gentle pressure on the carapace or claws will make them break. Moreover, legs will easily fall off when crabs are removed from the pots. Crabs from this class have typically shed their carapace during the last 4-6 weeks.
2. Hard, clean	The carapace is reddish brown, the ventral surface light red and the carapace is hard. Neither claw nor carapace must break when given a gentle pressure. The carapace is without epibionts. The claws are iridescent. The ventral surface is with no scratching or epibionts. Crabs from this class have typically shed their carapace during a period of 3-4 to 6 months.
3. Hard, few epiphytes etc.	Carapace is light brown with some epibionts and calcification. The ventral surface is cream-coloured with brown spots. The claws are slightly iridescent with brown spots on the ventral side. Crabs from this class have shed their carapace during the last two years.
4. Hard, epiphytes etc. present	The carapace is hard and brown, and covered with some epibionts. The ventral surface is brownish possibly with dark spots. The claws are not iridescent and the ventral side is brown with scratches. Crabs in this class have shed their carapace 3-4 years ago.
5. Leather-like, many epiphytes etc.	The carapace is brown with a tendency of being black-brown. The carapace is densely covered with epibionts. The ventral surface is brown. The dactyl (the uttermost joint of legs) is often black and in some cases heavily worn. Both carapace and claws seems leather-like. The crabs have shed their carapace 4-5 years ago.

Influence of water depth and temperature

There is a positive correlation between catch per effort (CPUE) and increasing water depth (Pearson-correlation analysis, Prob. > $|r|$ = 0.42595, n = 34). Figure 13 shows a tendency for higher CPUE at water depths of 240-300 m's both in spring and autumn. No such correlation was found between temperature and CPUE. The temperatures near the bottom were 2-2.5 ºC.

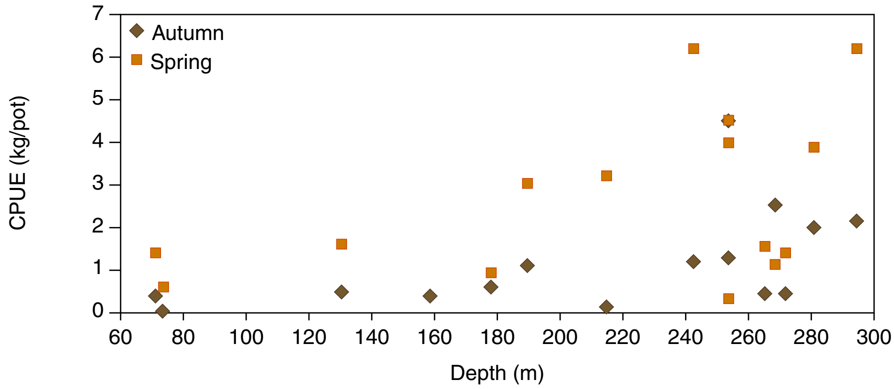

Figure 13. Catch per effort (CPUE: kg crabs per pot) as a function of water depths in Saqqaa Fjord during spring and autumn 2001.

Catch per effort (CPUE)

The catch per effort is given as CPUE (kg crabs per pot) for males with a carapace width above 90 mm. Table 23 shows that the largest average catch per pot was fished in Saqqaa and Uunartoq fjords during spring. During autumn the average CPUE was reduced to about 50% in both fjords. A one-way ANOVA showed that the difference in CPUE in spring and autumn at both fjords was significant (df = 29, F = 6.42, P = 0.017).

Table 23. Catch pr effort (CPUE = kg snow crabs per pot) in Saqqaa and Uunartoq fjords in spring and autumn 2001.
Std. dev. = Standard deviation.

CPUE	Average	Min.	Std. dev.
Saqqaa – March-April 2001	2.7	0.3	1.9
Saqqaa – Sept.-Oct. 2001	1.2	0.0	1.2
Uunartoq – March-April 2001	2.3	2.1	0.2
Uunartoq – Sept.-Oct. 2001	1.5	0.2	1.8

7.3 Discussion and conclusions

In Saqqaa Fjord, the average carapace width of male snow crabs in the size group with a carapace width above 90 mm was 117 mm during spring 2001 and 102 mm during autumn. The reason for this reduction in average carapace width could be ascribed to the commercial crab fishery performed in 2001. At the reference stations in Uunartoq Fjord a similar reduction in average carapace width was observed during the same period. According to relatively little information on the crab fishery in the Nanortalik district, no commercial crab fishery has been undertaken in the study area during 2001. Yet, an experimental crab fishery was performed in the district during February and March 2001 and probably also late in 2001. Among other areas, this fishery took place in the Saqqaa and Uunartoq fjords (Glahder 2001). So, on the basis of these findings the reduction in the average size of the male crabs is possibly a combined effect of both an experimental crab fishery and a seasonal migration of local crab populations.

The average carapace width of snow crabs from Saqqaa Fjord is not different from carapace widths from West Greenland areas. In Disko Bugt average carapace width is 114 mm, at Kangaatsiaq 119 mm, at Sisimiut 111 mm, at Maniitsoq 112 mm and at Paamiut 110 mm (Burmeister 1997a, b, 1998, 2001). Yet, in these West Greenland areas commercial crab fishery has been performed since 1995.

In Saqqaa Fjord the males are considered adult and have finalised moulting at carapace widths of 70-165 mm. Similar carapace widths of 54–155 mm are found in sheltered waters in the Sisimiut district (Burmeister 1998). Males in Saqqaa Fjord and off Sisimiut become adult faster than male crabs in the Disko Bugt area; here the smallest male had a carapace width of 68 mm (Burmeister 1998, 2001). These observed differences can be the result of both temperature and population densities. In the southern part of Gulf of Saint Lawrence, Canada, similar differences are ascribed to population densities (Moriyasu et al. 1998). In years with a high density of male crabs they will mature slower than in years with a low density. In the northern part of Gulf of Saint Lawrence males become adult earlier, i.e. they have smaller carapace widths, in areas with relatively low bottom temperatures than in areas with a higher temperature (Sainte-Marie & Gilbert 1998). It is still not clear which factors are responsible for the final male moult.

In Saqqaa Fjord in spring 2001, the majority of adult male crabs had carapace classes of 2 and 3 (Table 21) while 2/3 of male crabs in the autumn 2001 had carapace class 3. Less than 4% of the crabs had soft carapaces (class 1) in spring 2001. The majority of male crabs in Uunartoq Fjord were in both spring and autumn classified as class 3, and no crabs had a soft carapace. On the basis of the carapace classes observed in the population, it is possible to estimate the moulting period and in which part of the cycle the population is placed.

In Canada, natural fluctuations in recruitment have been demonstrated. In the northern part of Gulf of Saint Lawrence the duration of the population cycle is eight years, with four years of moderate to good recruitment and four years of poor recruitment (Sainte-Marie 1996). In the southern part of Gulf of Saint Lawrence a 10 years cycle has been observed (Moriyasu et al. 1998). The population will be in the first part of the cycle when a relatively high proportion of adolescent males have carapace classes of 1 and 2, and a fair proportion of adult males have carapace class 3. When in the middle of the cycle, the majority of the population consists of adolescent and adult males with carapace class 3, while few individuals have classes of 1, 2, 4 and 5. At the end of the cycle a high proportion of adolescent males have carapace class 3 and many adult males have carapace classes of 4 and 5 (Sainte-Marie et al. *pers. comm.*, Moriyasu et. al. 1998). The Saqqaa and Uunartoq populations are, according to the Canadian material, in the middle of the cycle with most males in classes 2 and 3 or in class 3.

The catch per effort of snow crabs in Saqqaa and Uunartoq fjords during autumn 2001 was low compared to that found at the research fishery in the area autumn 1998 (Burmeister 1998); during spring 2001 the catch per effort was comparable to the autumn 1998 catch. In general, the catch per effort is lower in South Greenland than in the West Greenland areas with a commercial crab fishery. Below is shown the snow crab catch in all studied West Greenland crab areas (Table 24).

Table 24. Catch per effort (CPUE) of snow crabs in different areas in West Greenland from Uummannaq (71°N) in the north to South Greenland (61°N).

Area, West Greenland	CPUE (kg crab per pot)	Year	Reference
Uummannaq	0.1	1994	(Andersen 1994)
Vaigat	1.5	1991	(Andersen 1993)
Disko Bugt	6.5	1998	(Burmeister 2000b)
Kangaatsiaq	4.2	1996	(Burmeister 1997a)
Sisimiut (sheltered waters)	7.5	1998	(Burmeister 2000b)
Maniitsoq (sheltered waters)	1.4	1997	(Burmeister 1997b)
Nuuk (sheltered waters)	2.1	1991	(Andersen 1993)
Paamiut (sheltered waters)	3.6	1996	(Burmeister 1997a)
South Greenland (sheltered waters)	2.6	1998	(Burmeister 2000a)

On the basis of the studies performed until now in Saqqaa Fjord it is not possible to determine if the catch per effort has decreased due to the commercial fishery in the fjord. During May–December 2001 about 96 tons of crabs were fished (Greenland Fisheries Licence Control Authority 2002, *in litt.*). It is not possible to assess the commercial catch per effort in Saqqaa Fjord because of lack of logbooks. According to recent Greenland law, logbooks are not required at crab fisheries in sheltered waters. So, to estimate the population size of Saqqaa Fjord, a possibility is that local fishermen fish for crabs in specific areas together with a biologist who collects the measurements necessary.

8 Conclusions

Contaminants in organisms

The environmental baseline study was performed during 1998-2001 around the Nalunaq gold mine site in the Nanortalik District, South Greenland. Marine samples of three fish species, snow crab, sea urchin, blue mussel, brown seaweed and terrestrial samples of the lichen *Cetraria nivalis* were sampled and 16% of the 872 samples were analysed for eight elements.

All samples were collected prior to the official start of the mine August 2004. Therefore, highly elevated concentrations were not expected in the Saqqaa and Kirkespir Valley compared to reference areas in Uunartoq Fjord or elsewhere in Greenland. Yet, some mining activities were performed in the sampling period which could increase concentrations in samples from especially the Kirkespir River and Valley. According to baseline studies on e.g. drainage from ore and waste rock performed during 1998-1999 (Lakefield 1998a, b, 1999a-d) elevated concentrations could be expected of cobalt, copper and mercury, and slightly elevated concentrations of arsenic, cadmium, lead and zinc.

Metal concentrations in organisms from the Saqqaa area were, compared to those from the local reference area, elevated only in shorthorn sculpin liver (2-3 times of cadmium, mercury and lead) and in *Cetraria nivalis* (4-5 times of arsenic, cobalt and chromium). Slightly elevated levels were seen for lead and chromium in snow crab muscle and blue mussel. Cadmium concentrations in fish livers from the study area were identical to or higher than the EU threshold value for consumption of 0.5 mg/kg w.w. Such high cadmium concentrations is not specifically related to the Nalunaq area but is observed in general in Greenland (Johansen et al. 2004).

Marine sediments

Sediment accumulation rates were measured at 10 stations in Saqqaa Fjord using the lead-210 dating technique. The mean accumulation rate was 1089 g/m^2 year.

A study on the physical and chemical composition of sediments in the Saqqaa Fjord revealed no marked differences from ordinary Greenland sediments. The fjord could be divided in three different sedimentary areas defined by a) the proximity to the Kirkespir River (large amount of sand), b) the deep middle part of the fjord (mainly fine-grained material), and c) the proximity to the Amitsoq Island (large amount of coarse material in the top core).

Benthic macrofauna

A study on the benthic macrofauna in the Saqqaa and Uunartoq fjords was performed during autumn 2001. The faunal composition of major taxonomic groups was typical for high latitude boreal fjords. By number of individuals, polycaete worms dominated with about 80 % of the total number, whereas by biomass the polycaete worms, molluscs and sea urchins were equally represented. Biodiversity values did not differ markedly between stations, although there was a tendency towards higher diversity in Saqqaa Fjord.

The number of taxa in the present study was markedly smaller than that found in a similar study (Greisman 2000). The main reason for this can be due to different sampling and processing methods. In future benthic macrofauna studies it is urgent to use same methods.

The sensitivity of the present fauna to an increase in sedimentation rate due to tailings disposal, is not known. If sedimentation rates exceed about 10 cm per year burial and extinction of the fauna is a possibility, whereas lower sedimentation rates can either change species composition or even increase number of species and individuals.

Snow crabs

During spring and autumn 2001 snow crabs were caught in Saqqaa and Uunartoq fjords. Most adult males had medium developed carapaces (carapace shed a half to two years ago) in both fjords. According to Canadian studies (Moriyasu et al. 1998) this means that the populations in Saqqaa and Uunartoq fjords should be approximately in the middle of their cycle of 8-10 years in total. The average carapace width during spring 2001 was not different from that found in West Greenland populations. During autumn the average carapace width of Saqqaa crabs was reduced by more than 10% compared to the width during spring. The catch per effort during autumn 2001 was low compared to catch per effort found in a commercial research fishery in the area autumn 1998; during spring 2001 the catch per effort was comparable to the autumn 1998 catch. The experimental commercial crab fishery in 2001 caught about 96 tonnes in the Saqqaa and Uunartoq fjords. This fishery could have an effect on both catch per effort and carapace width found autumn 2001. Yet, in West Greenland areas with more than 10 years of commercial fishery such a reduction seems not to have been taken place. A seasonal crab migration could also be a possible explanation.

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Appendix 1, Station positions

Fish

Table 25. Gill net fishing stations.

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
net-1	60	18.788	44	57.75
net-2	60	18.78	44	56.12
net-3	60	19.498	44	55.93
net-4	60	19.543	44	57.55
net-5	60	20.38	44	57.50
net-6	60	22.07	44	56.25
net-7	60	17.83	45	1.21
net-8	60	17.29	45	2.47

Table 26. Long line fishing stations.

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
LL-1	60	18.97	44	59.86
LL-2	60	19.31	45	0.78
LL-3	60	20.35	44	57.96
LL-4	60	13.675	45	24.56
LL-5	60	19.315	45	00.78
LL-6	60	20.35	44	57.96
LL-7	60	13.675	45	11.98
LL-8	60	20.515	44	57.385
LL-9	60	19.34	44	58.61
LL-10	60	20.027	44	58.18
LL-11	60	20.44	44	59.55
LL-12	60	19.264	44	57.46
LL-13	60	18.683	44	59.94
LL-14	60	19.534	45	0.65
LL-15	60	19.264	44	58.67
LL-16	60	19.355	44	58.54

Table 27. Arctic char stations in the Kirkespir River.

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
ArC-1	60	19.5	44	54.00
ArC-2	60	20.8	44	50.50
ArC-3*	60	?	44	?

* No positions given in Kirkespir River; collected by Nalunaq I/S employees

Table 28. Sigsbee trawl stations.

Station and depth (m)	Lat. deg.	Lat. min.	Long. deg.	Long. min.
Si-1, 81-100	60	19.02	44	58.34
Si-2, 25-120	60	19.37	44	58.60
Si-3, 40-41	60	18.5	44	59.78
Si-4, 11-122	60	18.81	44	58.67
Si-5, 47-51	60	18.8	44	58.67
Si-6, 34-60	60	19.06	44	56.94
Si-7, 82-95	60	18.57	45	0.63

Snow crab

Table 29. Snow crab stations in Saqqaa Fjord (1-15) and Uunartoq Fjord

Station	Start-north	Start-west	End-north	End-west	Start depth (m)	End depth (m)
Sc 1	60°17.87	45°3.612	60°17.7125	45°3.3783	274	270
Sc 2	60°18.42	45°2.41	60°18.27	45°2.2	262.5	267.5
Sc 3	60°18.84	45°1.36	60°18.65	45°1.1	267.5	217.5
Sc 4	60°19.0503	45°0.1499	60°19.2361	45°0.3678	247	260
Sc 5	60°18.2158	45°1.4557	60°18.3112	45°1.0986	205	112
Sc 6	60°18.6596	44°59.8421	60°18.7912	44°59.4328	65	82
Sc 7	60°18.9912	44°58.613	60°19.2226	44°58.4418	131	130
Sc 8	60°19.2583	44°57.8989	60°19.4259	44°57.9819	87	55
Sc 9	60°18.8571	45°0.1614	60°18.969	44°59.7322	178	178
Sc 10	60°19.292	44°59.2584	60°19.5284	44°59.0663	187	192
Sc 11	60°19.6799	45°0.3159	60°19.7903	44°59.9348	192	238
Sc 12	60°19.899	44°59.3031	60°20.1029	44°59.0147	252	255
Sc 13	60°21.416	44°57.5661	60°21.202	44°57.7238	292	297
Sc 14	60°22.4636	44°56.8177	60°22.1901	44°56.9513	287	275
Sc 15	60°18.3009	45°1.7441	60°18.1073	45°2.1769	267	270
Sc Uunar-toq 1	60°28.6837	45°18.0862	60°28.946	45°18.0553	231	231
Sc Uunar-toq 2	60°30.2174	45°17.0477	60°30.4134	45°17.1696	221	222

Blue mussel and seaweed

Table 30. Blue mussel and seaweed stations used in 1998 (e.g. T 1(98) and 2000 and 2001 (e.g. T 1).

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
T 1 (98)	60	18.65	44	58.02
T 2 (98)	60	18.75	44	56.76
T 3 (98)	60	19.57	44	56.86
T 4 (98)	60	19.47	44	56.23
T ref.	60	30.53	45	19.19
T 1	60	18.79	44	57.75
T 2	60	18.78	44	56.12
T 3	60	19.5	44	55.93
T 4	60	19.54	44	57.55
T 5	60	13.11	45	10.31
T 6	60	14.16	45	8.75
T 7	60	18.2	44	59.81
T 8	60	18.13	45	0.69
T 9	60	17.03	45	3.14
T 10	60	17.01	45	7.69
T 11	60	21.3	44	56.57
T 12	60	23.14	44	54.93
T 13	60	18.11	45	4.77
T 14	60	18.89	45	3.30
T 15	60	20.34	45	0.47
T 16	60	21	44	59.66
T 17	60	26.82	44	55.44
T 18	60	26.61	44	57.25
T 19	60	24.97	44	53.44

Lichens

Table 31. Lichen *Cetraria nivalis* stations used in 1998 (e.g. L 1(98)) in 2000 and 2001 (e.g. 1) and in 2001 (e.g. SNO).

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
L 1(98)	60	19.57	44	55.36
L 2(98)	60	19.62	44	54.74
L 3(98)	60	19.59	44	54.19
L 4(98)	60	19.71	44	53.64
L 5(98)	60	19.93	44	52.87
L 6(98)	60	20.16	44	52.30
L 7(98)	60	20.53	44	51.61
L 8(98)	60	20.74	44	51.05
L 9(98)	60	20.83	44	50.25
L 10(98)	60	20.85	44	49.97
L 11(98)	60	21.29	44	49.95
L 12(98)	60	21.47	44	49.81
L 13(98)	60	18.65	44	58.02
L 14(98)	60	18.75	44	56.76
L 15(98)	60	22.72	44	49.14
L 16(98)	60	27.38	44	49.76
L 17(98)	60	21.98	44	49.87
L 18(98)	60	19.48	44	56.52
L 1	60	18.79	44	57.75
L 2	60	18.78	44	56.12
L 3	60	19.50	44	55.93
L 4	60	19.54	44	57.55
L 5	60	13.11	45	10.31
L 6	60	14.16	45	8.75
L 7	60	18.20	44	59.81
L 8	60	18.13	45	0.69
L 9	60	17.03	45	3.14
L 10	60	17.01	45	7.69
L 11	60	21.30	44	56.57
L 12	60	23.14	44	54.93
L 13	60	18.11	45	4.77
L 14	60	18.89	45	3.30
L 15	60	20.34	45	0.47
L 16	60	21.00	44	59.66
L 17	60	26.82	44	55.44
L 18	60	26.61	44	57.25
L 19	60	24.97	44	53.44
L Ref	60	30.53	45	19.19
SNO11	60	21.00	44	48.97
SNO12	60	20.93	44	49.97
SNO13	60	21.18	44	49.93
SNO14	60	21.28	44	49.88
SNO15	60	21.30	44	49.90
SNO16	60	21.52	44	49.78

Table 32. Lichens *Cladonia rangiferina* and *Cetraria cucullata* stations used in 2001.

Lichen species	Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
Cladonia rangiferina	SNO1	60	21.70	44	49.62
Cladonia rangiferina	SNO2	60	21.62	44	49.72
Cladonia rangiferina	SNO3	60	21.55	44	49.62
Cetraria cucullata	SNO4	60	21.48	44	49.75
Cladonia rangiferina	SNO5	60	21.43	44	49.73
Cladonia rangiferina	SNO6	60	21.38	44	49.77
Cladonia rangiferina	SNO7	60	21.30	44	49.72
Cladonia rangiferina	SNO8	60	21.25	44	49.78
Cetraria cucullata	SNO9	60	21.23	44	49.83
Cetraria cucullata	SNO10	60	21.23	44	49.87

Sediments for Lead-210 dating

Table 33. Sediment stations in Saqqaa Fjord.

Station	Lat. deg.	Lat. min.	Long. deg.	Long. min.
C3B	60	19.51	45	00.07
C4A	60	19.17	45	01.08
C6	60	18.05	45	03.08
D1B	60	19.15	44	57.14
D7	60	17.95	45	02.63
E3B	60	19.05	44	59.32
F2	60	17.27	45	05.05
F3	60	21.77	44	57.31
B7B	60	19.92	45	00.45
B4B	60	18.60	45	01.90

Benthic macrofauna

Table 34. Positions, water depths and sediment description for each station.

Station No.	Date	Water depth (m)	Latitude N deg. min.	Longitude W deg. min.	Water content %	Loss on Ignition % of DW	Percent fines <63µm
Saqqaa Fjord Impact							
BF 1	Sept. 27	265	60° 19.1579	45° 00.4809	59.3	6.27	80.42
BF 2	Sept. 27	205	60° 19.3588	45° 00.9338	59.4	5.24	72.33
BF 3	Sept. 27	220	60° 19.3485	45° 00.4946	60.2	5.09	88.14
BF 4	Sept. 28	260	60° 19.3652	45° 00.0412	60.7	4.71	90.77
BF 5	Sept. 28	257	60° 19.6374	44° 59.8558	38.6	4.86	37.29
Saqqaa Fjord Reference							
BF 6	Sept. 28	255	60° 20.1029	44° 59.1625	54.7	4.35	63.11
BF 7	Sept. 28	245	60° 20.6367	44° 58.5512	56.2	5.19	68.59
BF 8	Sept. 29	305	60° 21.2547	44° 58.0499	62.1	5.52	75.6
BF 9	Sept. 29	265	60° 18.6921	45° 01.7578	61	4.88	95.23
BF 10	Sept. 29	262	60° 18.0428	45° 02.8770	63.5	5.7	97.58
Uunartoq Fjord Reference							
BF 11	Sept. 30	218	60° 30.2717	45° 17.5713	68.1	5.12	97.95
BF 12	Sept. 30	230	60° 28.9410	45°18.5257	68.5	6.51	95.33
BF 13	Oct. 01	231	60° 27.8055	45° 18.4435	54.7	2.04	61.44
BF 14	Oct. 01	265	60° 26.6066	45° 18.7180	68.1	6.71	97.61
BF 15	Oct. 01	275	60° 25.3395	45° 18.7592	65.2	5.51	97.11

Appendix 2. Metal concentrations in organisms

Fish

Table 35. Element concentrations are mg/kg w.w. D.m.% = dry matter percent. L = length. W = weight.

ID-No	Sample type	Collection date	Station	Sex	L, cm	W, g	Sub sample	D.m %	As	Cd	Co	Cr	Cu	Hg	Pb	Se	Zn
23305	Arctic char	20000921	Low land	male	23	120	liver	32.1	0.37	0.08	0.04	0.01	12.7	0.04	0.003		32.5
23307	Arctic char	20000921	Low land	fe-male	19.5	60	liver		0.64	0.05	0.07	0.07	28.0	0.03	0.006		39.2
30376	Arctic char	20010800			22	95.4	liver		0.24	0.06	0.04	0.01	2.20	0.01	0.007		28.5
30378	Arctic char	20010800			24.2	125	liver		0.49	0.05	0.03	0.02	3.62	0.02	0.010		38.7
30380	Arctic char	20010800			24.7	138	liver		0.48	0.11	0.04	0.02	2.94	0.02	0.005		35.2
23395	Shorthorn sculpin	20000925	net-3	fe-male	25.5	240	liver	32.0	1.61	1.60	0.004	0.01	2.43	0.02	0.001		29.8
23441	Shorthorn sculpin	20000926	net-3	fe-male	26.5	240	liver	34.5	1.35	0.75	0.02	0.01	1.25	0.02	0.005		31.9
23443	Shorthorn sculpin	20000926	net-3	fe-male	25.5	220	liver	26.8	3.72	1.53	0.01	0.05	2.81	0.01	0.002		30.8
23471	Shorthorn sculpin	20000927	net-3	fe-male	27.8	318	liver	29.0	5.64	0.78	0.04	0.01	1.36	0.04	0.009		33.8
23490	Shorthorn sculpin	20000928	net-3	fe-male	27	278	liver	37.9	1.42	0.83	0.01	0.003	1.56	0.04	0.001		32.8
24358	Spotted wolffish	20010401	LL14	male	61	1740	mus cle	18.0						0.07		0.28	
24379	Spotted wolffish	20010403	LL15	fe-male	78.5	4300	liver	35.7	2.59	0.26	0.004	0.00	3.51	2.87	0.009	1.74	21.2
24379	Spotted wolffish	20010403	LL15	fe-male	78.5	4300	mus cle	19.4						0.05		0.36	
24690	Spotted wolffish	20010928	LL16	fe-male	69.2	3080	liver	23.9	3.11	0.81	0.01	0.17	3.40	0.07	0.015	2.76	24.1
24690	Spotted wolffish	20010928	LL16	fe-male	69.2	3080	mus cle	190.						0.09		0.24	
24691	Spotted wolffish	20010928	LL16	male	64.7	2320	mus cle	21.9						0.08		0.31	
24692	Spotted wolffish	20010928	LL16	fe-male	64.3	2460	liver	28.1	2.72	0.22	0.15	0.03	6.71	0.04	0.032	1.69	27.5
24692	Spotted wolffish	20010928	LL16	fe-male	64.3	2460	mus cle	19.0						0.04		0.27	
24693	Spotted wolffish	20010928	LL16	male	85.4	6480	mus cle	20.4						0.12		0.35	
24760	Spotted wolffish	20010929	LL17	male	75.3	4220	mus cle	17.0						0.07		0.20	
24765	Spotted wolffish	20010930	LL18	male	93.2	7920	mus cle	20.2						0.10		0.35	
30354	Spotted wolffish	20011008	LL23	fe-male	68.7	3340	liver	40.4	1.42	0.31	0.02	0.01	9.04	0.05	0.014	2.47	23.9
30354	Spotted wolffish	20011008	LL23	fe-male	68.7	3340	mus cle	28.5						0.12		0.56	
30355	Spotted wolffish	20011008	LL23	fe-male	69.5	3260	liver	34.0	1.61	1.06	0.01	0.04	10.7	8.33	0.008	3.23	30.8
30355	Spotted wolffish	20011008	LL23	fe-male	69.5	3260	mus cle	20.1						0.11		0.45	

Snow crab

Table 36. Element concentrations are mg/kg w.w. D.m.% = dry matter percent. L = length. No. of ind. = number of individuals.

ID-No	Collection date	Station	No. of ind.	Cara-pace l. av. (cm)	Cara-pace l. min (cm)	Cara-pace l. max (cm)	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
23323	20000923	Trap 245 m		130											
23324	20000923	Trap 245 m		128											
23325	20000923	Trap 245 m		125											
23326	20000923	Trap 245 m		121											
23327	20000923	Trap 245 m		105											
23328	20000923	Trap 245 m		115											
23329	20000923	Trap 245 m		121											
23330	20000923	Trap 245 m		133											
23331	20000923	Trap 245 m		120											
23332	20000923	Trap 245 m		119											
23333	20000923	Trap 245 m		113											
23334	20000923	Trap 245 m		118											
23335	20000923	Trap 245 m		136											
23336	20000923	Trap 245 m		119											
23337	20000923	Trap 245 m		116											
23338	20000923	Trap 245 m		120											
23339	20000923	Trap 245 m		128											
23340	20000923	Trap 245 m		120											
23341	20000923	Trap 245 m		128											
23342	20000923	Trap 245 m		145											
23343	20000923	Trap 245 m		113											
23427	20000925	Trap 223 m	5	133											
23428	20000925	Trap 223 m	5	113											
23429	20000925	Trap 223 m	4	98											
23456	20000926	Trap 262m	6	143			33.6	34.6	2.58	0.20	0.11	3.58	0.04	0.18	26.6
23456	20000926	Trap 262m	6	143			16.6	18.4	0.01	0.03	0.13	4.60	0.01	0.17	18.3
23457	20000926	Trap 262m	6	117			43.8	30.7	2.86	0.13	0.09	4.59	0.03	0.09	23.2
23457	20000926	Trap 262m	6	117			22.9	22.3	0.01	0.04	0.05	6.96	0.03	0.19	26.3
23474	20000927	Trap 252m	5	130											
23475	20000927	Trap 252m	6	120											
23496	20000928	Trap 345m	6	121											
23497	20000929	Trap 300m	7	129											
23498	20000930	Trap 302m	6	116			46.3	24.4	4.02	0.14	0.08	7.66	0.03	0.08	24.8
23498	20000930	Trap 302m	6	116			22.0	13.4	0.01	0.05	0.04	6.89	0.02	0.11	25.2
23499	20000930	Trap 302m	6	132			38.8	35.0	2.51	0.14	0.14	3.16	0.03	0.10	25.8
23499	20000930	Trap 302m	6	132			20.2	22.9	0.01	0.02	0.03	4.19	0.02	0.04	23.2
23779	20001002	Trap 252 m	6	108			44.1	40.7	2.42	0.17	0.08	3.70	0.04	0.10	24.5
23779	20001002	Trap 252 m	6	108			22.6	24.6	0.01	0.04	0.04	7.73	0.01	0.05	25.5
23780	20001002	Trap 252 m	6	130			40.4	33.3	1.87	0.18	0.09	3.71	0.05	0.10	23.7
23780	20001002	Trap 252 m	6	130			18.9	21.3	0.01	0.03	0.03	5.48	0.01	0.04	21.7
24301	20010329	Trap 1	5	103.5											
24302	20010329	Trap 1	5	138.1			15.2								
24303	20010329	Trap 2	4	117.1			13.0								
24304	20010329	Trap 2	5	140.3			13.1								
24305	20010329	Trap 3	5	112.7			46.3	28.7	5.07	0.09	0.06	3.95	0.02	0.05	20.7
24305	20010329	Trap 3	5	112.7			21.8	26.5	0.02	0.04	0.05	5.87	0.02	0.06	24.3

ID-No	Collection date	Station	No. of ind.	Cara-pace l. av. (cm)	Cara-pace l. min. (cm)	Cara-pace l. max. (cm)	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
24306	20010329	Trap 3	5	129.2			38.2	40.6	2.14	0.18	0.34	4.30	0.03	0.11	22.6
24306	20010329	Trap 3	5	129.2			24.9	28.3	0.01	0.04	0.03	5.43	1.77	0.05	26.8
24313	20010330	Trap 4	5	113.2			14.3								
24314	20010330	Trap 4	5	137			12.0								
24315	20010330	Trap 5	4	100.9			11.0								
24316	20010330	Trap 5	2	124.3											
24317	20010330	Trap 6	5	95.6											
24318	20010330	Trap 6	2	126.8											
24330	20010331	Trap 7	5	104.5											
24331	20010331	Trap 7	5	120.6											
24332	20010331	Trap 8	5	99.6											
24333	20010331	Trap 8	5	118.9											
24334	20010331	Trap 9	5	97.3											
24335	20010331	Trap 9	5	126.7											
24351	20010401	Trap 10	5	104.5											
24352	20010401	Trap 10	5	128.4											
24353	20010401	Trap 11	5	112.8											
24354	20010401	Trap 11	5	124.8											
24355	20010401	Trap 12	5	105.1			42.4	30.6	7.82	0.11	0.10	5.35	0.02	0.06	20.3
24355	20010401	Trap 12	5	105.1			22.1	21.3	0.02	0.05	0.02	5.91	0.02	0.07	26.3
24356	20010401	Trap 12	5	136			41.1	38.4	2.38	0.15	0.09	3.64	0.03	0.08	21.3
24356	20010401	Trap 12	5	136			20.4	25.4	0.01	0.03	0.02	4.93	0.02	0.04	22.5
24375	20010402	Trap Uunartoq 2	5	106			47.1	26.1	1.77	0.09	0.13	4.87	0.01	0.04	16.9
24375	20010402	Trap Uunartoq 2	5	106			23.2	28.0	0.01	0.03	0.03	6.55	0.04	0.05	25.3
24376	20010402	Trap Uunartoq 2	5	135.5			44.2	21.5	2.07	0.07	0.07	2.67	0.02	0.09	16.4
24376	20010402	Trap Uunartoq 2	5	135.5			21.1	18.4	0.01	0.03	0.02	5.27	0.04	0.03	24.9
24377	20010402	Trap Uunartoq 1	5	111.1											
24378	20010402	Trap Uunartoq 1	5	130.2											
24384	20010404	Trap 13	5	119.7											
24385	20010404	Trap 13	5	134.2											
24386	20010404	Trap 14	5	101.9											
24387	20010404	Trap 14	5	131.9											
24388	20010404	Trap 15	3	109.6											
24389	20010404	Trap 15	5	137.9											
24674	20010927	Trap 1	4	105.8	92.8	114									
24675	20010927	Trap 1	3	119.6	113.7	131.2									
24685	20010928	Trap 2	4	134.9	118	142.8									
24686	20010928	Trap 3	3	109.8	108.2	110.7	36.4	37.6	4.10	0.13	0.15	4.27	0.04	0.08	26.1
24686	20010928	Trap 3	3	109.8	108.2	110.7	20.7	20.1	0.01	0.03	0.01	5.02	0.02	0.04	23.4
24687	20010928	Trap 3	5	138.2	129.9	145.6	36.3	36.2	2.00	0.15	0.08	3.87	0.04	0.13	28.5
24687	20010928	Trap 3	5	138.2	129.9	145.6	19.4	27.7	0.01	0.03	0.02	4.40	0.02	0.06	23.6
24756	20010929	Trap 5	4	98.2	91.8	105.1									
24757	20010929	Trap 5	2	133.0	128.1	137.9									
24758	20010929	Trap 4	5	109.0	91.4	125.3									
24759	20010929	Trap 4	5	137.6	129.9	147.3									
24763	20010930	Trap 7	5	92.2	89.6	95.5									
24764	20010930	Trap 7	3	109.9	104.4	114.3									
24771	20011001	Trap Uunartoq 1	3	120.8	117.9	126.0									

ID-No.	Collection date	Station	No. of ind.	Cara-pace l. av. (cm)	Cara-pace l. min. (cm)	Cara-pace l. max. (cm)	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
24772	20011001	Trap Uunartoq 2	5	99.6	86.6	124.1	24.6	52.6	8.19	0.15	0.40	31.0	0.04	0.07	36.2
24772	20011001	Trap Uunartoq 2	5	99.6	86.6	124.1	20.6	17.7	0.04	0.03	0.03	5.19	0.07	0.03	23.3
24773	20011001	Trap Uunartoq 2	5	133.2	121.8	144.1	38.9	29.3	2.63	0.08	0.08	2.91	0.03	0.06	25.3
24773	20011001	Trap Uunartoq 2	5	133.2	121.8	144.1	28.2	20.7	2.07	0.03	3.03	6.52	4.51	0.04	32.5
24774	20011001	Trap 8	5	93.5	86.7	98.6									
24786	20011002	Trap 9	5	100.3	91.9	109.5									
24790	20011004	Trap 10	5	93.5	90.4	96.1									
24791	20011004	Trap 10	5	116.6	109.8	129.9									
24792	20011004	Trap 11	5	96.5	89.7	100.2									
24793	20011004	Trap 11	5	122.7	112.5	129.3									
24796	20011005	Trap 15	5	112.4	105.7	119.5									
24797	20011005	Trap 15	5	140.9	122.9	164.9									
24798	20011005	Trap 12	5	96.3	90	108.8	40.1	35.7	5.62	0.12	0.09	8.11	0.03	0.08	31.8
24798	20011005	Trap 12	5	96.3	90	108.8	22.4	18.5	0.03	0.06	0.03	7.33	0.05	0.04	25.9
24799	20011005	Trap 12	5	123.1	123.0	124.6	35.6	35.3	4.43	0.15	0.08	4.17	0.04	0.09	33.5
24799	20011005	Trap 12	5	123.1	123.0	124.6	20.3	25.5	0.01	0.05	0.01	6.32	0.02	0.04	25.0
30327	20011006	Trap 14	5	101.9	91.4	107.6									
30328	20011006	Trap 14	5	122.3	116.0	134.1									
30329	20011006	Trap 13	5	100.2	92.1	103.9									
30330	20011006	Trap 13	5	122.2	112.9	136.1									

Sea urchin

Table 37. Element concentrations are mg/kg w.w. D.m.% = dry matter percent. No. of ind. = number of individuals

ID-No.	Collection date	Station	No. of ind.	Size mm	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
23347	20000923	Si-3	9	54-62	20.8	2.32	0.115	0.039	0.083	0.406	0.0063	0.0129	21.8
23348	20000923	Si-3	9	51-54	14.6	1.89	0.053	0.028	0.109	0.386	0.0047	0.0231	11.8
23349	20000923	Si-3	12	51-54	18.7	2.1	0.068	0.043	0.091	0.36	0.0079	0.0161	31.7
30318	20011005	Si-8	9	49-56	14.8	4.27	0.053	0.025	0.153	0.419	0.0053	0.015	24.7
30319	20011005	Si-8	10	53-64	17.2	3.88	0.045	0.029	0.074	0.419	0.0048	0.0093	36.1
30319	20011005	Si-8	10	53-64	17.2	4.34	0.054	0.039	0.084	0.448	0.0064	0.0096	46.8

Blue mussel

Table 38. Element concentrations are mg/kg w.w. D.m.% = dry matter percent. L = length. No. of ind. = number of individuals.

ID-No.	Collection date	Sta-tion	No. of ind.	Shell l. av. (mm)	Shell l. min. (mm)	Shell l. max. (mm)	Sam-ple w.w.	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
23601	20000926	T1	13	56.9	50	60	73.6	11.8	1.84	0.57	0.03	0.08	0.96	0.02	0.18	10.2
23602	20000926	T1	19	66.8	60	75	172.1	12.9	1.63	0.53	0.03	0.09	1.00	0.02	0.32	12.4
30209	20010930	T1	13	52.1	40	60	64.5	15.3	2.17	0.59	0.04	0.10	1.23	0.02	0.16	14.4
30210	20010930	T1	11	67.7	60	80	110.8	13.4	1.82	0.60	0.03	0.10	0.97	0.03	0.24	11.8
20351	19980527	T1 (98)						16.8	2.13	0.52	0.03	0.09	1.30	0.01	0.16	16.5
23627	20000929	T10	20	45.5	40	50	95.6									
23628	20000929	T10	20	55.0	50	60	155.1									
23629	20000929	T10	20	64.7	60	70										
30296	20011006	T10	20	43.0	30	50	64.5									
30297	20011006	T10	20	54.9	50	60	136.5									
30298	20011006	T10	20	65.0	60	70	202.7									
23666	20000929	T11	18	49.3	40	60	101.9									
23667	20000929	T11	12	69.3	60	80	151.1									
30270	20011005	T11	20	55.5	50	60	89.6									
30271	20011005	T11	18	65.2	60	70	148.9									
30287	20011005	T11	14	75.0	70	80	180.9									
23668	20000929	T12	27	51.2	40	60	142.5									
23669	20000929	T12	20	65.1	60	70	208									
23670	20000929	T12	19	83.0	80	90	403.6									
30260	20011004	T12	20	55.4	50	60	117.2									
30261	20011004	T12	18	64.1	60	70	156.5									
30262	20011004	T12	17	75.3	70	80	218.1									
23685	20001001	T13	20	35.1	30	40	53.7									
23686	20001001	T13	20	45.0	40	50	61.5									
23687	20001001	T13	20	53.7	50	60	107.4									
23688	20001001	T13	11	68.0	60	90	109.2									
30201	20010929	T13	20	36.1	30	40	29.1									
30202	20010929	T13	20	44.2	40	50	59.1									
30203	20010929	T13	20	55.0	50	60	101.3									
30204	20010929	T13	20	70.1	60	90	210.9									
23689	20001001	T14	20	45.0	40	50	65.5	13.9	1.49	0.49	0.04	0.10	1.08	0.02	0.11	12.1
23690	20001001	T14	20	55.1	50	60	104.9									
23691	20001001	T14	20	64.4	60	70	183.9	14.3	1.59	0.95	0.035	0.11	1.03	0.02	0.16	12.2
24698	20010929	T14	20	46.1	40	50	57.4	15.6	1.66	0.80	0.05	0.10	1.27	0.02	0.13	16.6
24699	20010929	T14	20	55.6	50	60	16.4									
24700	20010929	T14	16	67.8	60	80	169.6	15.4	1.65	0.88	0.04	0.13	1.10	0.02	0.16	14.7
23692	20001001	T15	20	45.5	40	50	78.9	15.3	1.27	0.69	0.03	0.07	1.15	0.02	0.09	17.5
23693	20001001	T15	20	55.0	50	60	134.1									
23694	20001001	T15	20	65.1	60	70	192.2	15.5	1.51	0.95	0.03	0.10	1.11	0.02	0.18	14.3
30272	20011005	T15	20	45.3	40	50	39.6	22.5	2.30	0.87	0.07	0.13	1.84	0.03	0.17	22.4
30273	20011005	T15	20	55.0	50	60	77.7									
30274	20011005	T15	20	64.3	60	70	156.3	14.4	1.56	0.81	0.05	0.09	1.03	0.02	0.16	13.3
23695	20001001	T16	20	45.2	40	50	80.1									
23696	20001001	T16	20	55.0	50	60	134.8									
23697	20001001	T16	20	65.4	60	70	201.4									
23698	20001001	T16	20	75.7	70	90	270.5									

ID-No.	Collection date	Station	No. of ind.	Shell l. av. (mm)	Shell l. min. (mm)	Shell l. max. (mm)	Sample w.w.	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
30275	20011005	T16	20	44.9	40	50	58.4									
30276	20011005	T16	20	55.0	50	60	106.5									
30277	20011005	T16	17	63.9	60	70	145									
23742	20001002	T17	20	44.9	40	50	70									
23743	20001002	T17	20	55.0	50	60	110.1									
23744	20001002	T17	20	64.5	60	70	167.9									
30245	20011004	T17	20	51.8	40	60	118.3									
30246	20011004	T17	20	64.4	60	70	193.2									
30247	20011004	T17	18	74.4	70	90	280.4									
23750	20001002	T18	20	45.9	40	50	73.9									
23751	20001002	T18	20	55.0	50	60	126.9									
23752	20001002	T18	20	64.1	60	70	199									
30254	20011004	T18	20	45.0	40	50	57.8									
30255	20011004	T18	20	54.5	50	60	92									
30256	20011004	T18	16	63.6	60	70	142.1									
23753	20001002	T19	20	55.0	50	60	135.4									
23754	20001002	T19	20	65.0	60	70	189.1									
23755	20001002	T19	20	75.0	70	80	292.4									
30257	20011004	T19	20	55.3	50	60	95.1									
30258	20011004	T19	14	64.1	60	70	112.4									
30259	20011004	T19	19	78.5	70	90	290.8									
23603	20000926	T2	18	59.7	50	70	156.2	16.7	1.83	0.71	0.03	0.10	1.19	0.02	0.29	11.8
23604	20000926	T2	20	76.1	70	80	319.1									
23605	20000926	T2	20	83.9	80	90	376.1	15.2	1.97	1.04	0.03	0.12	1.02	0.02	0.25	14.1
30211	20010930	T2	12	70.8	60	80	129	13.3	1.90	1.37	0.04	0.10	1.09	0.02	0.24	16.1
30212	20010930	T2	10	85.5	80	92	206.5	14.1	1.69	0.89	0.03	0.13	1.06	0.02	0.23	11.8
20352	19980528	T2 (98)						16.0	2.09	0.60	0.03	0.09	1.15	0.02	0.16	12.6
23606	20000926	T3	20	60.3	50	70	181.4	14.3	1.91	0.61	0.04	0.10	1.15	0.02	0.15	13.5
23607	20000926	T3	20	76.2	70	80	303.3									
23608	20000926	T3	20	84.2	80	90	408.1	15.8	1.77	0.85	0.03	0.11	1.05	0.02	0.19	12.3
24680	20010928	T3	9	51.3	40	60	44	12.1	1.83	0.44	0.04	0.31	1.29	0.02	0.14	12.2
24681	20010928	T3	9	66.8	60	80	86.5	13.1	1.88	1.15	0.03	0.10	1.16	0.02	0.16	9.39
20350	19980526	T3 (98)						14.8	1.69	0.60	0.03	0.12	0.97	0.02	0.18	12.1
23609	20000926	T4	20	60.5	50	70	164.3	13.8	1.33	0.92	0.03	0.10	1.16	0.02	0.20	14.4
23610	20000926	T4	18	76.2	70	80	287.2	16.0	1.57	1.36	0.04	0.12	1.15	0.02	0.25	14.8
24682	20010928	T4	17	59.9	50	70	122.3	15.7	1.97	1.62	0.05	0.11	1.38	0.02	0.22	13.2
24683	20010928	T4	9	76.7	70	90	129	17.4	2.01	1.40	0.04	0.12	1.15	0.03	0.29	11.7
20349	19980525	T4 (98)						14.7	2.02	0.63	0.03	0.17	1.03	0.02	0.15	11.5
23611	20000927	T5	22	46.6	40	50	97									
23612	20000927	T5	20	55.3	50	60	130.2									
23613	20000927	T5	20	65.0	60	70	224.1									
23614	20000927	T5	13	77.1	70	90	201.3									
24669	20010927	T5	20	45.5	40	50	65.5									
24670	20010927	T5	20	55.1	50	60	113.6									
24671	20010927	T5	20	64.9	60	70	174.9									
24672	20010927	T5	9	74.9	70	90	132.2									
23615	20000927	T6	20	45.7	40	50	85.9									
23616	20000927	T6	20	55.0	50	60	131.4									
23617	20000927	T6	14	65.3	60	80	147.9									
30294	20011006	T6	20	45.1	40	50	61.8									

ID-No.	Collection date	Station	No. of ind.	Shell l. av. (mm)	Shell l. min. (mm)	Shell l. max. (mm)	Sample w.w.	D.m. %	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
30295	20011006	T6	20	55.0	50	60	119.5									
30299	20011006	T6	16	67.0	60	80	166.4									
23618	20000928	T7	20	45.2	40	50	77.9									
23619	20000928	T7	20	55.0	50	60	122.9									
23620	20000928	T7	20	65.0	60	70	193.9									
23621	20000929	T7	20	55.1	50	60	136.9									
30267	20011005	T7	20	55.5	50	60	99.3									
30268	20011005	T7	20	65.0	60	70	156.4									
30269	20011005	T7	20	73.8	70	80	232.8									
23622	20000929	T8	17	66.7	60	70	177.9									
23623	20000929	T8	20	79.1	70	90	319.4									
23624	20000929	T8	20	55.0	50	60	116.8									
30233	20011002	T8	20	49.7	40	60	101.5									
30234	20011002	T8	15	63.6	60	70	153.3									
30235	20011002	T8	15	74.6	70	80	213.3									
23625	20000929	T9	20	64.9	60	70	172.4									
23626	20000929	T9	17	77.7	70	90	240.1									
30236	20011002	T9	20	55.2	50	60	116.5									
30237	20011002	T9	15	64.1	60	70	119.4									
30238	20011002	T9	14	79.5	70	90	134.6									
23673	20000930	Tref	20	45.3	40	50	61.2	15.5	1.55	0.53	0.04	0.08	1.19	0.01	0.11	11.7
23674	20000930	Tref	20	55.0	50	60	111.1									
23675	20000930	Tref	20	65.0	60	70	179.9	14.8	1.58	0.98	0.03	0.09	1.07	0.02	0.17	14.2
30224	20011001	Tref	20	44.1	40	50	58.8	19.0	1.80	0.61	0.04	0.08	1.32	0.02	0.09	12.0
30225	20011001	Tref	20	54.8	50	60	107.5									
30226	20011001	Tref	16	69.3	60	80	167.9	15.1	1.49	1.07	0.04	0.08	0.10	0.03	0.16	13.4

Seaweed

Table 39. Element concentrations are mg/kg d.w.

ID-No.	Collection date	Station	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
23630	20000926	T1	44.5	1.85	0.16	0.07	1.09	0.02	0.15	5.05
23631	20000926	T1	35.4	1.84	0.15	0.06	0.65	0.01	0.10	5.22
30205	20010930	T1	39.4	1.62	0.21	0.02	0.70	0.003	0.09	6.32
30206	20010930	T1	44.9	1.83	0.20	0.00	0.74	0.004	0.08	5.07
20341	19980500	T1 (98)	40.0	2.04	0.16	0.13	1.31	0.02	0.11	8.28
20342	19980500	T1 (98)	37.1	2.21	0.18	0.08	1.24	0.02	0.08	9.48
23648	20000928	T10								
23649	20000928	T10								
30292	20011006	T10								
30293	20011006	T10								
23650	20000929	T11								
23651	20000929	T11								
30281	20011005	T11								
30282	20011005	T11								
23652	20000929	T12								
23653	20000929	T12								
30248	20011004	T12								
30249	20011004	T12								
23677	20001001	T13								
23678	20001001	T13								
24696	20010929	T13								
24697	20010929	T13								
23679	20001001	T14	53.9	2.77	0.21	0.05	0.68	0.01	0.07	3.94
23680	20001001	T14	59.5	2.72	0.21	0.02	0.70	0.01	0.04	4.62
24694	20010929	T14	55.4	2.83	0.23	0.04	0.92	0.01	0.22	6.32
24695	20010929	T14	52.0	2.73	0.26	0.15	0.87	0.008	0.13	5.23
23681	20001001	T15	28.2	1.36	0.15	0.02	0.72	0.007	0.05	11.6
23682	20001001	T15	33.2	1.99	0.19	0.01	0.83	0.004	0.07	8.31
30283	20011005	T15	41.0	2.46	0.24	0.06	0.71	0.006	0.08	4.77
30284	20011005	T15	49.7	2.18	0.25	0.07	0.76	0.007	0.07	4.41
23683	20001001	T16								
23684	20001001	T16								
30285	20011005	T16								
30286	20011005	T16								
23699	20001002	T17								
23700	20001002	T17								
30239	20011004	T17								
30240	20011004	T17								
23745	20001002	T18								
23746	20001002	T18								
30241	20011004	T18								
30242	20011004	T18								
23747	20001002	T19								
23748	20001002	T19								
30243	20011004	T19								
30244	20011004	T19								
23632	20000926	T2	41.7	0.93	0.21	0.09	0.94	0.006	0.19	7.90

ID-No.	Collection date	Station	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
23633	20000926	T2	41.5	1.08	0.21	0.12	0.87	0.005	0.18	7.18
30207	20010930	T2	49.6	0.93	0.26	0.04	0.88	0.004	0.09	6.11
30208	20010930	T2	36.9	1.02	0.25	0.03	0.86	0.005	0.07	6.63
20343	19980500	T2 (98)	56.0	1.74	0.22	0.38	1.33	0.02	0.11	10.5
20344	19980500	T2 (98)	47.7	1.88	0.21	0.17	1.21	0.02	0.08	10.8
23634	20000926	T3	47.7	1.19	0.24	0.05	1.32	0.006	0.13	6.70
23635	20000926	T3	40.7	0.90	0.22	0.02	1.12	0.004	0.15	5.49
24676	20010928	T3	66.8	1.29	0.35	0.01	1.26	0.004	0.09	6.27
24677	20010928	T3	49.6	0.96	0.27	0.002	1.25	0.004	0.10	5.87
20345	19980500	T3 (98)	39.2	2.02	0.17	0.06	1.47	0.02	0.05	9.77
20346	19980500	T3 (98)	39.8	1.90	0.17	0.11	1.15	0.02	0.07	8.90
23636	20000926	T4	40.1	1.80	0.20	0.02	0.89	0.005	0.21	6.17
23637	20000926	T4	47.3	2.22	0.16	0.00	1.02	0.005	0.16	5.82
24678	20010928	T4	56.0	2.33	0.26	0.001	1.14	0.004	0.12	5.82
24679	20010928	T4	55.4	2.38	0.26	0.12	1.13	0.006	0.07	10.0
20347	19980500	T4 (98)	50.7	1.77	0.19	0.09	1.40	0.02	0.12	10.0
20348	19980500	T4 (98)	46.9	1.41	0.25	0.10	1.27	0.01	0.10	8.80
23638	20000927	T5								
23639	20000927	T5								
24667	20010927	T5								
24668	20010927	T5								
23640	20000927	T6								
23641	20000927	T6								
30290	20011006	T6								
30291	20011006	T6								
23642	20000928	T7								
23643	20000928	T7								
30279	20011005	T7								
30280	20011005	T7								
23644	20000928	T8								
23645	20000928	T8								
30229	20011002	T8								
30230	20011002	T8								
23646	20000928	T9								
23647	20000928	T9								
30227	20011002	T9								
30228	20011002	T9								
30221	20011001	Tref	60.9	1.29	0.25	0.06	0.92	0.003	0.10	5.00
30222	20011001	Tref	46.2	1.29	0.19	0.05	0.85	0.005	0.11	4.94
23671	20000930	Tref.	50.6	1.65	0.15	0.08	1.04	0.01	0.10	8.48
23672	20000930	Tref.	39.6	1.07	0.12	0.03	0.80	0.009	0.11	6.17

Lichens, Cetraria nivalis

Table 40. Element concentrations are mg/kg d.w.

ID-No.	Collection date	Station	Comments	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
20353	19980522	L 1(98)		0.13	0.09	0.07	0.10	0.61	0.03	1.19	28.6
20354	19980522	L 2(98)									
20355	19980522	L 3(98)									
20356	19980522	L 4(98)									
20357	19980522	L 5(98)									
20358	19980522	L 6(98)		0.1	0.06	0.08	0.43	0.50	0.03	1.29	11.8
20359	19980522	L 7(98)									
20360	19980522	L 8(98)									
20361	19980522	L 9(98)									
20362	19980522	L 19(98)									
20363	19980522	L 11(98)		0.08	0.07	0.04	0.06	0.49	0.03	0.85	20.9
20364	19980522	L 12(98)									
20365	19980522	L 13(98)									
20366	19980522	L 14(98)									
20367	19980522	L 15(98)		0.16	0.09	0.16	0.14	0.54	0.03	1.19	28.0
20368	19980522	L 16(98)									
20369	19980522	L 17(98)		0.08	0.07	0.08	0.27	0.50	0.04	1.17	28.3
20370	19980522	L 18(98)									
23571	20000930	A	North of the camp	0.29	0.07	0.20	0.25	0.68	0.03	1.49	15.2
23572	20000930	C	At crusher								
23573	20000930	D	South of crusher								
23574	20000930	E	500m S of crusher	0.59	0.09		0.66	2.87	0.05	1.04	18.1
23575	20000930	F	At water fall								
23576	20000930	G	South of water fall	0.89	0.09	0.47	0.48	2.03	0.04	1.17	16.0
23654	20000926	L 1									
23655	20000926	L 2		0.11	0.06	0.05	0.52	0.62	0.03	0.73	18.3
23656	20000926	L 3		0.14	0.16	0.22	0.15	0.61	0.03	1.76	29.7
23657	20000926	L 4									
23658	20000927	L 5									
23659	20000927	L 6									
23660	20000927	L 7									
23661	20000928	L 8									
23662	20000928	L 9									
23663	20000928	L 10									
23664	20000929	L 11									
23665	20000929	L 12									
23676	20000930	L ref.		0.03	0.13	0.05	0.05	0.50	0.03	0.35	24.7
23781	20001001	L 13									
23782	20001001	L 14									
23783	20001001	L 16									
23784	20001002	L 18									
23785	20001001	L 15									
23786	20001002	L 17									
23787	20001002	L 19									
24820	20010800	SNO11	SNO11	0.75	0.10	0.50	0.92	2.39	0.04	1.37	13.8
24821	20010800	SNO17	SNO17	0.18	0.05	0.11	2.96	1.01	0.03	0.94	23.5
24822	20010800	SNO18	SNO18	0.14	0.05	0.15	0.26	0.70	0.03	0.86	37.1
24860	20011000	SNO12	SNO12								

ID-No	Collection date	Station	Comments	As	Cd	Co	Cr	Cu	Hg	Pb	Zn
24861	20011000	SNO13	SNO13								
24862	20011000	SNO14	SNO14								
24863	20011000	SNO15	SNO15								
24864	20011000	SNO16	SNO16								
30213	20010930	L 1									
30214	20010930	L 2		0.10	0.05	0.06	0.16	0.59	0.03	0.72	16.6
30215	20010929	L 3									
30216	20010929	L 4									
30217	20010927	L 5									
30218	20010928	L 13									
30219	20010928	L 14									
30220	20011001	L Ref		0.06	0.07	0.03	0.29	0.62	0.04	0.95	14.3
30231	20011002	L 8									
30232	20011002	L 9									
30250	20011004	L 17									
30251	20011004	L 18									
30252	20011004	L 19									
30253	20011004	L 12									
30263	20011005	L 7									
30264	20011005	L 11									
30265	20011005	L 15									
30266	20011005	L 16									
30288	20011006	L 6									
30289	20011006	L 10									

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Appendix 3, Benthic macrofauna species list for abundance

Abundance (individuals m^{-2}) is given for each station with means and standard errors (SE).

Table 41. A. Saqqaa impact area.

	BF01 Mean	SE	BF02 Mean	SE	BF03 Mean	SE	BF04 Mean	SE	BF05 Mean	SE
Hydractinidae	0	0	14	14	0	0	0	0	0	0
Lafoea dumosa	0	0	0	0	14	14	0	0	0	0
Nemertini	0	0	28	17	0	0	0	0	28	28
Lineidae	0	0	0	0	14	14	0	0	0	0
Polynoidae	0	0	0	0	14	14	0	0	0	0
Eunoe nodosa	0	0	42	28	0	0	0	0	14	14
Gattyana cirrosa	0	0	14	14	0	0	14	14	0	0
Pholoe minuta	0	0	98	42	0	0	14	14	0	0
Eteone longa	0	0	14	14	0	0	28	17	0	0
Eusyllis blomstrandi	0	0	0	0	14	14	0	0	0	0
Nephtys ciliata	14	14	14	14	70	22	28	17	28	17
Onuphis conchylega	0	0	28	28	0	0	0	0	0	0
Lumbrineris fragilis	336	90	378	47	210	44	392	93	462	65
Orbiniidae	0	0	0	0	14	14	0	0	0	0
Laonice cirrata	14	14	0	0	0	0	14	14	42	17
Prionospio steenstrupi	406	90	1399	38	615	190	741	154	294	102
Chaetozone setosa	168	47	294	81	252	112	280	73	196	75
Scalibregmidae	0	0	0	0	0	0	0	0	14	14
Mediomastus sp.	0	0	0	0	0	0	0	0	14	14
Maldanidae	28	17	112	28	28	17	42	17	112	57
Praxillella praetermissa	14	14	0	0	0	0	0	0	0	0
Praxillella gracilis	0	0	14	14	14	14	0	0	14	14
Praxillella sp.	0	0	0	0	14	14	0	0	0	0
Nicomache trispinata	42	17	14	14	0	0	14	14	112	47
Myriochele heeri	84	51	504	105	168	95	56	41	28	28
Pectinaria hyperborea	42	28	0	0	14	14	0	0	14	14
Lysippe labiata	0	0	14	14	0	0	28	17	14	14
Axionice maculata	0	0	0	0	28	28	0	0	0	0
Polycirrus arcticus	70	22	112	42	98	36	70	31	14	14
Euchone analis	0	0	0	0	0	0	0	0	14	14
Philomedes globosus	0	0	14	14	0	0	0	0	0	0
Cumacea	0	0	0	0	14	14	0	0	0	0
Mysidacea	14	14	0	0	0	0	0	0	0	0
Gnathia sp.	0	0	14	14	0	0	0	0	0	0
Odius carinatus	0	0	14	14	0	0	0	0	0	0
Lepeta caeca	0	0	14	14	0	0	0	0	14	14
Oenopota obliqua	0	0	0	0	0	0	28	17	0	0
Nuculoma tenuis	28	17	84	41	0	0	0	0	42	28
Jupiteria minuta	0	0	70	31	0	0	0	0	14	14
Yoldia hyperborea	70	22	14	14	84	51	140	44	84	41
Dacrydium vitreum	0	0	28	17	0	0	0	0	0	0
Thyasira gouldi	14	14	112	28	28	17	0	0	42	28
Phascolion strombi	0	0	14	14	0	0	0	0	0	0
Golfingia sp.	0	0	238	85	0	0	0	0	0	0
Bryozoa	0	0	28	17	0	0	0	0	0	0
Ctenodiscus crispatus	0	0	0	0	0	0	28	17	28	17
Ophiuroidea	0	0	28	17	14	14	0	0	0	0
Ophiacantha bidentata	0	0	0	0	14	14	0	0	0	0
Ophiura affinis	0	0	14	14	0	0	0	0	0	0
Enteropneusta	0	0	0	0	14	14	14	14	0	0

Table 42. B. Saqqaa control area.

	BF06 Mean	BF06 SE	BF07 Mean	BF07 SE	BF08 Mean	BF08 SE	BF09 Mean	BF09 SE	BF10 Mean	BF10 SE
Calcarea	0	0	14	14	0	0	0	0	0	0
Actinaridae	14	14	0	0	0	0	0	0	0	0
Nemertini	0	0	0	0	14	14	0	0	0	0
Nematoda	14	14	0	0	0	0	0	0	0	0
Eunoe nodosa	0	0	0	0	14	14	0	0	0	0
Pholoe minuta	14	14	28	28	14	14	0	0	14	14
Phyllodocidae	0	0	14	14	0	0	0	0	0	0
Eteone longa	0	0	0	0	0	0	14	14	28	28
Eusyllis blomstrandi	0	0	14	14	0	0	0	0	0	0
Nephtys ciliata	14	14	112	47	42	17	56	26	56	26
Onuphis conchylega	14	14	14	14	0	0	0	0	0	0
Lumbrineris fragilis	531	95	517	47	420	22	196	46	196	78
Apistobranchus tullbergi	0	0	0	0	0	0	0	0	14	14
Laonice cirrata	28	17	14	14	70	38	0	0	0	0
Polydora caullery	0	0	14	14	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	14	14
Prionospio steenstrupi	420	88	210	66	448	200	713	142	741	124
Chaetozone setosa	238	47	308	42	196	64	224	26	168	82
Flabelligeridae	0	0	14	14	0	0	0	0	0	0
Scalibregmidae	0	0	14	14	0	0	0	0	0	0
Mediomastus sp.	0	0	14	14	0	0	0	0	0	0
Maldanidae	98	36	126	34	84	41	14	14	112	65
Praxillella praetermissa	0	0	14	14	0	0	28	17	98	28
Praxillella gracilis	0	0	28	28	28	28	0	0	0	0
Nicomache trispinata	0	0	70	44	0	0	0	0	0	0
Owenia fusiformis	0	0	14	14	0	0	0	0	0	0
Myriochele heeri	14	14	112	28	98	47	0	0	0	0
Pectinaria hyperborea	14	14	0	0	0	0	0	0	0	0
Lysippe labiata	14	14	0	0	0	0	0	0	0	0
Polycirrus arcticus	280	101	280	111	224	41	14	14	14	14
Terebellides stroemi	14	14	0	0	0	0	0	0	14	14
Philomedes globosus	0	0	14	14	0	0	0	0	0	0
Ampelisca macrocephala	0	0	14	14	0	0	0	0	0	0
Westwoodilla caecula	0	0	0	0	0	0	0	0	14	14
Nuculoma tenuis	28	17	0	0	0	0	0	0	0	0
Jupiteria minuta	14	14	28	17	42	42	0	0	0	0
Yoldia hyperborea	56	26	0	0	98	36	42	17	42	17
Megayoldia thraciaeformis	0	0	14	14	0	0	0	0	28	17
Dacrydium vitreum	0	0	14	14	0	0	0	0	0	0
Thyasira gouldi	42	17	70	0	28	17	0	0	0	0
Sipuncula	0	0	14	14	0	0	0	0	0	0
Phascolosoma sp.	0	0	14	14	0	0	0	0	0	0
Golfingia sp.	14	14	112	82	0	0	0	0	0	0
Ctenodiscus crispatus	0	0	14	14	0	0	14	14	0	0
Ophiuroidae	0	0	28	28	0	0	0	0	0	0
Ophiacantha bidentata	14	14	0	0	0	0	0	0	0	0
Terebratulina retusa	0	0	14	14	0	0	0	0	0	0

Table 43. C. Uunartoq control area.

	BF11 Mean	BF11 SE	BF12 Mean	BF12 SE	BF13 Mean	BF13 SE	BF14 Mean	BF14 SE	BF15 Mean	BF15 SE
Nemertini	0	0	0	0	0	0	14	14	0	0
Lineidae	0	0	0	0	0	0	14	14	28	17
Harmothoe impar	0	0	0	0	14	14	14	14	0	0
Gattyana cirrosa	42	17	0	0	0	0	0	0	0	0
Nephtys ciliata	0	0	84	26	98	17	56	14	112	36
Lumbrineris fragilis	56	26	14	14	84	41	0	0	126	26
Laonice cirrata	42	17	0	0	0	0	0	0	28	28
Prionospio steenstrupi	196	75	322	84	280	59	378	69	448	84
Chaetozone setosa	0	0	28	17	28	28	84	56	14	14
Maldanidae	28	17	0	0	28	17	0	0	0	0
Praxillella praetermissa	0	0	56	26	84	26	112	17	112	17
Pectinaria hyperborea	28	17	14	14	14	14	0	0	0	0
Polycirrus arcticus	0	0	0	0	0	0	0	0	70	31
Cumacea	14	14	0	0	0	0	14	14	0	0
Lysianassidae	0	0	0	0	0	0	0	0	14	14
Maera loveni	0	0	0	0	14	14	0	0	0	0
Nuculoma tenuis	28	28	28	17	42	17	0	0	14	14
Jupiteria minuta	0	0	14	14	0	0	0	0	0	0
Yoldia hyperborea	14	14	42	28	28	28	28	17	14	14
Megayoldia thraciaeformis	0	0	14	14	14	14	42	28	70	22
Thyasira gouldi	14	14	56	41	0	0	14	14	28	17
Macoma calcarea	28	17	0	0	0	0	0	0	14	14
Golfingia sp.	0	0	0	0	28	17	0	0	0	0
Ctenodiscus crispatus	0	0	28	17	14	14	0	0	0	0

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Appendix 4, Benthic macrofauna species list for biomass

Biomass (SFDW, mg per m^2) is given for each station with means and standard errors (SE).

Table 44. A. Saqqaa impact area

	BF01 Mean	SE	BF02 Mean	SE	BF03 Mean	SE	BF04 Mean	SE	BF05 Mean	SE
Hydractinidae	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Lafoea dumosa	0.0	0.0	0.0	0.0	8.4	8.4	0.0	0.0	0.0	0.0
Nemertini	0.0	0.0	18.3	18.1	0.0	0.0	0.0	0.0	40.6	40.6
Lineidae	0.0	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0
Polynoidae	0.0	0.0	0.0	0.0	2.8	2.8	0.0	0.0	0.0	0.0
Eunoe nodosa	0.0	0.0	47.6	33.0	0.0	0.0	0.0	0.0	2.8	2.8
Gattyana cirrosa	0.0	0.0	14.0	14.0	0.0	0.0	12.6	12.6	0.0	0.0
Pholoe minuta	0.0	0.0	4.5	4.1	0.0	0.0	1.4	1.4	0.0	0.0
Eteone longa	0.0	0.0	9.8	9.8	0.0	0.0	7.1	7.0	0.0	0.0
Eusyllis blomstrandi	0.0	0.0	0.0	0.0	8.4	8.4	0.0	0.0	0.0	0.0
Nephtys ciliata	265.7	265.7	35.0	35.0	369.2	182.7	144.1	115.2	99.3	80.0
Onuphis conchylega	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Lumbrineris fragilis	290.9	72.4	299.3	74.4	267.1	111.1	469.9	111.5	455.9	37.5
Orbiniidae	0.0	0.0	0.0	0.0	9.8	9.8	0.0	0.0	0.0	0.0
Laonice cirrata	437.8	437.8	0.0	0.0	0.0	0.0	531.5	531.5	1026.6	571.8
Prionospio steenstrupi	257.3	41.7	89.5	45.6	439.2	107.6	532.9	124.7	125.9	42.2
Chaetozone setosa	46.3	19.1	88.3	34.0	50.3	30.4	67.1	24.5	60.1	21.3
Scalibregmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Mediomastus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4
Maldanidae	23.8	15.6	61.5	29.0	23.8	20.5	70.1	43.3	92.4	56.9
Praxillella praetermissa	716.1	716.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Praxillella gracilis	0.0	0.0	7.0	7.0	107.7	107.7	0.0	0.0	9.8	9.8
Praxillella sp.	0.0	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0
Nicomache trispinata	100.7	72.4	21.0	21.0	0.0	0.0	28.0	28.0	86.7	39.1
Myriochele heeri	12.6	9.5	469.9	247.3	62.9	30.0	11.2	7.2	21.0	21.0
Pectinaria hyperborea	426.6	265.5	0.0	0.0	1.4	1.4	0.0	0.0	221.0	221.0
Lysippe labiata	0.0	0.0	37.8	37.8	0.0	0.0	29.4	19.6	42.0	42.0
Axionice maculata	0.0	0.0	0.0	0.0	71.3	71.3	0.0	0.0	0.0	0.0
Polycirrus arcticus	325.9	112.4	187.4	97.8	387.4	131.9	285.3	169.0	16.8	16.8
Euchone analis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Philomedes globosus	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cumacea	0.0	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0
Mysidacea	12.6	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gnathia sp.	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Odius carinatus	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Lepeta caeca	0.0	0.0	8.4	8.4	0.0	0.0	0.0	0.0	11.2	11.2
Oenopota obliqua	0.0	0.0	0.0	0.0	0.0	0.0	226.6	139.6	0.0	0.0
Nuculoma tenuis	229.4	199.4	293.7	130.1	0.0	0.0	0.0	0.0	2215.4	2175.4
Jupiteria minuta	0.0	0.0	72.7	33.1	0.0	0.0	0.0	0.0	12.6	12.6
Yoldia hyperborea	7595.8	2588.2	0.1	0.1	5422.4	3690.6	5693.7	2416.1	2917.5	2293.5
Dacrydium vitreum	0.0	0.0	11.2	7.2	0.0	0.0	0.0	0.0	0.0	0.0
Thyasira gouldi	5.6	5.6	92.3	31.0	16.8	15.1	0.0	0.0	44.8	32.6
Phascolion strombi	0.0	0.0	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Golfingia sp.	0.0	0.0	65.7	46.7	0.0	0.0	0.0	0.0	0.0	0.0
Bryozoa	0.0	0.0	23.8	16.5	0.0	0.0	0.0	0.0	0.0	0.0
Ctenodiscus crispatus	0.0	0.0	0.0	0.0	0.0	0.0	7064.3	4411.3	6844.7	4403.2
Ophiuroidea	0.0	0.0	51.7	50.0	1.4	1.4	0.0	0.0	0.0	0.0
Ophiacantha bidentata	0.0	0.0	0.0	0.0	520.3	520.3	0.0	0.0	0.0	0.0
Ophiura affinis	0.0	0.0	30.8	30.8	0.0	0.0	0.0	0.0	0.0	0.0
Enteropneusta	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Table 45. B. Saqqaa control area.

	BF06 Mean	SE	BF07 Mean	SE	BF08 Mean	SE	BF09 Mean	SE	BF10 Mean	SE
Calcarea	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Actinaridae	7.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nemertini	0.0	0.0	0.0	0.0	124.5	124.5	0.0	0.0	0.0	0.0
Nematoda	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunoe nodosa	0.0	0.0	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0
Pholoe minuta	0.1	0.1	4.2	4.2	0.1	0.1	0.0	0.0	0.1	0.1
Phyllodocidae	0.0	0.0	0.1	0.1	0.0	0.0	0	0.0	0.0	0.0
Eteone longa	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.6	5.6
Eusyllis blomstrandi	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Nephtys ciliata	97.9	97.9	753.8	389.5	4135.7	2806.1	235.0	111.5	125.9	56.4
Onuphis conchylega	16.8	16.8	30.8	30.8	0.0	0.0	0.0	0.0	0.0	0.0
Lumbrineris fragilis	349.7	69.0	2987.4	2432.2	495.1	58.5	1738.5	1539.2	214.0	110.0
Apistobranchus tullbergi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Laonice cirrata	818.2	563.4	602.8	602.8	1353.8	875.8	0.0	0.0	0.0	0.0
Polydora caullery	0.0	0.0	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Polydora cornuta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.8
Prionospio steenstrupi	349.7	86.5	183.2	57.5	400.0	149.9	418.3	130.6	746.9	195.3
Chaetozone setosa	49.1	18.4	114.7	31.3	55.9	14.0	69.9	11.5	51.9	27.0
Flabelligeridae	0.0	0.0	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Scalibregmidae	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Mediomastus sp.	0.0	0.0	26.6	26.6	0.0	0.0	0.0	0.0	0.0	0.0
Maldanidae	46.3	20.4	139.9	48.6	69.9	43.8	7.0	7.0	197.2	131.1
Praxillella praetermissa	0.0	0.0	0.1	0.1	0.0	0.0	32.2	20.5	611.2	426.3
Praxillella gracilis	0.0	0.0	37.8	37.8	16.8	16.8	0.0	0.0	0.0	0.0
Nicomache trispinata	0.0	0.0	43.4	27.7	0.0	0.0	0.0	0.0	0.0	0.0
Owenia fusiformis	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Myriochele heeri	2.8	2.8	102.1	36.2	74.3	48.3	0.0	0.0	0.0	0.0
Pectinaria hyperborea	194.4	194.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lysippe labiata	9.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polycirrus arcticus	496.5	162.4	681.1	219.5	429.4	40.3	88.1	88.1	7.0	7.0
Terebellides stroemi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Philomedes globosus	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Ampelisca macrocephala	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Westwoodilla caecula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5.6
Nuculoma tenuis	46.2	44.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jupiteria minuta	95.1	95.1	26.6	16.6	74.1	74.1	0.0	0.0	0.0	0.0
Yoldia hyperborea	4137.1	1785.9	0.0	0.0	2876.9	862.4	5502.1	3111.8	1991.6	1361.5
Megayoldia thraciaeformis	0.0	0.0	3875.5	3875.5	0.0	0.0	0.0	0.0	4882.5	4872.0
Dacrydium vitreum	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Thyasira gouldi	50.3	21.4	57.3	16.5	22.4	15.2	0.0	0.0	0.0	0.0
Sipuncula	0.0	0.0	15.4	15.4	0.0	0.0	0.0	0.0	0.0	0.0
Phascolosoma sp.	0.0	0.0	26.6	26.6	0.0	0.0	0.0	0.0	0.0	0.0
Golfingia sp.	0.1	0.1	19.6	13.7	0.0	0.0	0.0	0.0	0.0	0.0
Ctenodiscus crispatus	0.0	0.0	4525.9	4525.8	0.0	0.0	6400.0	6399.9	0.0	0.0
Ophiuroidae	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Ophiacantha bidentata	767.8	767.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terebratulina retusa	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0

Table 46. C. Uunartoq control area.

	BF11 Mean	SE	BF12 Mean	SE	BF13 Mean	SE	BF14 Mean	SE	BF15 Mean	SE
Nemertini	0.0	0.0	0.0	0.0	0.0	0.0	279.7	279.7	0.0	0.0
Lineidae	0.0	0.0	0.0	0.0	0.0	0.0	2446.2	2446.1	600.1	600.0
Harmothoe impar	0.0	0.0	0.0	0.0	9.8	9.8	4.2	4.2	0.0	0.0
Gattyana cirrosa	18.3	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nephtys ciliata	0.0	0.0	408.5	370.3	293.7	121.0	214.0	69.1	174.8	57.2
Lumbrineris fragilis	144.1	63.4	2.8	2.8	155.2	73.8	0.0	0.0	70.1	23.7
Laonice cirrata	465.7	272.3	0.0	0.0	0.0	0.0	0.0	0.0	951.0	951.0
Prionospio steenstrupi	303.6	126.2	275.5	40.8	236.4	79.7	247.6	25.7	335.7	91.2
Chaetozone setosa	0.0	0.0	7.1	7.0	0.1	0.1	25.2	16.8	4.2	4.2
Maldanidae	1461.5	935.1	0.0	0.0	30.8	29.1	0.0	0.0	0.0	0.0
Praxillella praetermissa	0.0	0.0	1604.2	856.0	2197.2	734.7	2500.7	1016.0	2644.8	641.9
Pectinaria hyperborea	513.3	385.0	511.9	511.9	55.9	55.9	0.0	0.0	0.0	0.0
Polycirrus arcticus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.7	31.1
Cumacea	75.5	75.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Lysianassidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	18.2
Maera loveni	0.0	0.0	0.0	0.0	3042.0	3041.9	0.0	0.0	0.0	0.0
Nuculoma tenuis	134.3	134.3	163.6	108.2	75.5	43.3	0.0	0.0	23.8	23.8
Jupiteria minuta	0.0	0.0	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Yoldia hyperborea	1752.4	1752.4	2904.9	2050.8	5404.2	5404.1	249.0	154.7	1093.7	1093.7
Megayoldia thraciaeformis	0.0	0.0	489.5	489.5	0.1	0.1	341.3	329.2	9337.1	5522.6
Thyasira gouldi	11.2	11.2	26.6	18.0	0.0	0.0	9.8	9.8	7.0	4.4
Macoma calcarea	1116.1	803.4	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8
Golfingia sp.	0.0	0.0	0.0	0.0	293.7	276.6	0.0	0.0	0.0	0.0
Ctenodiscus crispatus	0.0	0.0	7974.8	4978.2	4044.8	4044.7	0.0	0.0	0.0	0.0

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Appendix 5, Sediment description

Table 47. Saqqaa Fjord.

Station No.	Date	Water depth (m)	Latitude N deg. min.	Longitude W deg. min.	Comment
BF 1	Sept. 27	265	60° 19.1579	45° 00.4809	Sediment soft silt and mud with stones (2-8 cm longest distance). No smell of sulphide.
BF 2	Sept. 27	205	60° 19.3588	45° 00.9338	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide. 15 trials.
BF 3	Sept. 27	220	60° 19.3485	45° 00.4946	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide.
BF 4	Sept. 28	260	60° 19.3652	45° 00.0412	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide.
BF 5	Sept. 28	257	60° 19.6374	44° 59.8558	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide.
BF 6	Sept. 28	255	60° 20.1029	44° 59.1625	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide. Note sediment sample contains some bottom water.
BF 7	Sept. 28	245	60° 20.6367	44° 58.5512	Sediment soft silt and mud with stones (1-8 cm longest distance). No smell of sulphide.
BF 8	Sept. 29	305	60° 21.2547	44° 58.0499	Sediment mud with tough clay, only few stones. No smell of sulphide.
BF 9	Sept. 29	265	60° 18.6921	45° 01.7578	Sediment very soft mud without stones. Some smell of sulphide.
BF 10	Sept. 29	262	60° 18.0428	45° 02.8770	Sediment soft mud without stones. Some smell of sulphide.

Table 48. Uunartoq Fjord.

Station No.	Date	Water depth (m)	Latitude N deg. min.	Longitude W deg. min.	Comment
BF 11	Sept. 30	218	60° 30.2717	45° 17.5713	Sediment very soft mud without stones. Some smell of sulphide.
BF 12	Sept. 30	230	60° 28.9410	45°18.5257	Sediment very soft mud without stones. Some smell of sulphide.
BF 13	Oct. 01	231	60° 27.8055	45° 18.4435	Sediment very soft mud with some stones (2-4 cm). Some smell of sulphide.
BF 14	Oct. 01	265	60° 26.6066	45° 18.7180	Sediment very soft mud without stones. Some smell of sulphide.
BF 15	Oct. 01	275	60° 25.3395	45° 18.7592	Sediment very soft mud without stones. Some smell of sulphide.

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An environmental baseline study was performed during 1998-2001 around the Nalunaq gold mine site, Nanortalik district, South Greenland. Official mine start was August 2004. The purposes were to determine background levels of contaminants, accumulation rates and structure of marine sediments, diversity and biomass of the benthic macrofauna and population abundance and composition of snow crabs. Compared to a local reference area only few contaminants had elevated concentrations. Mean sediment accumulation rate was 1089 g/m^2 year. The benthic fauna composition was typical for high latitude boreal fjords and biodiversity in Saqqaa Fjord was not markedly different from biodiversity in Uunartoq Fjord. Studies on snow crab determined catch per effort, carapace width and hardness.

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