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Data sheet

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Abstract: This fifth monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 20-27 August 2008. Fourteen shipments of ore had been transported to Canada for gold extraction since the last monitoring study performed in July 2007. Biota was collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were transplanted to the Kirkespir Valley from an uncontaminated area. Samples were analysed for 12 elements with an ICP-MS. In lichens, elevated concentrations (4-19 times) of copper, chromium, arsenic and cobalt were found at the waste rock depot and in the camp area. Temporal trends with increasing concentrations of As and Co in lichens were demonstrated. As was the only metal that showed significantly higher levels in the camp than in the depot area. All metal concentrations showed a significant decrease with increasing distance to the road. Transplanted lichens had relatively high metal concentrations indicating higher dust pollution in 2007-08. Elevated concentrations of metals could again this year be found to a distance of c. 1000 m from the road. No elevated concentrations were found in mussels and sculpins, while seaweed had slightly elevated Co concentrations at one station. In 2008, an impact from the mine was primarily seen in the Kirkespir Valley and originated from dust dispersal. The impact in the marine environment was very low.

Keywords:	Monitoring, elements, blue mussel, brown seaweed, shorthorn sculpin, Arctic char, *Cetraria nivalis*, Nalunaq Gold Mine, Greenland.
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Summary

This fifth monitoring study was carried out in the Nalunaq gold mining area, Nanortalik, South Greenland, on 20-27 August 2008. Fourteen shipments of ore had been transported to Canada for gold extraction since the last monitoring study performed July 2007.

Blue mussels, brown seaweed and shorthorn sculpin were sampled at 4 marine stations in the Kirkespir Bay, resident Arctic char were caught in the river and lichens *Cetraria nivalis* were collected at 20 stations in the valley and along the bay. In addition, lichens were transplanted from an uncontaminated area (AMI1) to the mining area (Fig. 1). Collected samples were analysed for 12 elements (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo and Au) and the results were compared both to background levels and to pervious monitoring studies.

No elevated concentrations were found in mussels and sculpin livers, while seaweed had slightly elevated Co concentrations at one sampling station. Co was also elevated in seaweed from the same station in 2006 and 2007. The impact from the mining activities on the marine environment was in 2008 found to be very low.

In resident Arctic char livers no concentrations were elevated. In previous years, Cr, Co and Cd were slightly elevated in 2004 and 2006, while no elevations were found in 2005 and 2007.

In lichens, concentrations of Cu, Cr, As and Co were, like in previous years, significantly elevated compared to the background level in the depot and the camp area. Elevations in the two areas in 2008 were 4-5 times for Cu and Cr, 19 times for As and 9 times for Co. Concentrations of the four metals in the two areas during the period 2004-2008 showed differences in temporal trends. Concentrations of As and Co increased significantly during the period in both areas, whereas concentrations of Cu and Cr did not show significant temporal trends during the period. As was the only metal that showed differences between the two areas, with significantly higher levels in the camp area. The relationship between the concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road was tested; the test included differences in levels among years. All concentrations of the four metals showed a significantly decrease with increasing distance. Metal concentrations above the background level could, as in previous years, be found to a distance of about 1000 m from the road.

It is remarkable that transplanted lichens in just one year had concentrations equal or even higher than in lichens growing naturally in the Kirkespir area. This indicates higher dust pollution in some areas (e.g. the pier and depot areas) in 2007-2008 than in 2006-2007.

In 2008, an impact from the mining activities was primarily seen in the Kirkespir Valley and originated from dust dispersal. For the first time temporal trends with increasing concentrations of As and Co in lichens were demonstrated.

Sammenfatning

Denne femte moniteringsundersøgelse blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 20. til 27. august 2008. Siden moniteringen i juli 2007 er der blevet udskibet fjorten malmladninger til Canada, hvor guldet udvindes.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4 stationer i Kirkespirbugten, standørreder blev fisket i Kirkespirelven og snekruslav *Cetraria nivalis* blev samlet på 20 stationer i Kirkespirdalen og ved bugten. Lav blev transplanteret fra et uforurenet område (AMI1) til mineområdet (Fig. 1). Alle prøver blev analyseret for 12 grundstoffer (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo og Au) og resultaterne blev sammenholdt med baggrundsniveauet målt i 1998-2001 og med resultaterne fra de tidligere moniteringsundersøgelser.

Der blev ikke fundet forhøjede koncentrationer i muslinger og i ulkelever, mens der i tang var svagt forhøjede koncentrationer af Co på én station. Co var også forhøjet i tang fra den samme station i 2006 og 2007. Det marine miljø var således også i 2008 ganske svagt påvirket af mineaktiviteterne.

I standørred lever blev der ikke fundet forhøjede metal koncentrationer. I forhold til tidligere år var Cr, Co og Cd svagt forhøjede i 2004 og 2006, mens der ikke fandtes forhøjelser i 2005 og 2007.

I laver fra områderne ved depotet for knust gråbjerg og ved lejren var koncentrationer af Cu, Cr, As og Co som i tidligere år signifikant forhøjede. Forhøjelserne i begge områder i 2008 var 4-5 gange for Cu og Cr, 19 gange for As og 9 gange for Co. Koncentrationerne af de fire metaller i de to områder viste for nogle af metallerne en i tidsmæssige udvikling i perioden 2004-2008. Således øgedes koncentrationerne af As og Co signifikant i perioden i begge områder, mens koncentrationerne af Cu og Cr ikke viste signifikante forøgelser. Kun As havde forskellige niveauer i de to områder, med et signifikant højere niveau i lejrområdet. Relationen mellem lavkoncentrationerne af Cu, Cr, As og Co og afstanden til vejen blev undersøgt for perioden 2005-08. For alle metalkoncentrationer var der et signifikant faldt med stigende afstande til vejen. Som i de tidligere år blev der også i 2008 fundet forhøjede koncentrationer af Cu, Cr, As og Co i en afstand af op til ca. 1000 m fra vejen.

Det er bemærkelsesværdigt, at de transplanterede laver på kun ét år viste metalkoncentrationer der var lige så høje eller højere end dem i laver der voksede naturligt i Kirkespirdalen. Dette tyder på en forøget støvforurening fra nogle områder, f. eks. havnen og depotet, i 2007-2008 i forhold til 2006-2007.

Også i 2008 kunne der spores en påvirkning af mineaktiviteterne i miljøet og igen var det især Kirkespirdalen, der var påvirket af støvspredning. For første gang kunne der påvises en tidsmæssig udvikling med øgede lavkoncentrationer af As og Co.

Eqikkaaneq

Taamatut tallimassaanik nalunaarsuilluni misissuineq Kujataani, Nanortallup kommuniani, Nalunap eqqaani ingerlanneqarpoq 2008-imi 20. augustusimiit 27. augustusip tungaanut. 2007-imi misissuinerup kingornanut aatsitassartalinnik 14-eriarluni Canadamut aallarussisoqarsimavoq, taakani gultitaat immikkoortinneqartarmat.

Misissugassanik uillunik, equutinik kanassunillu nalinginnaasunik Kirkespirbugtenimi katersuiffinni assigiinngitsuni sisamani katersuisuqarpoq, Kirkespirip kuuani eqaluit sisujuitsut aamma orsuaasat snekruslav *Cetraria nivalis* Kirkespirdalimi iterlattaanilu assigiinngitsuni 20-ni katersorneqarput. Orsuaasat mingutsitaanngeersut nuunneqarput aatsitassamik piiaaviup eqqaanut nuunneqarput (Fig. 1) Misissugassat tamarmik grundstoffinik 12-inik misissuiffigineqarput (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo aamma Au) misissuinerullu inerneri 1998-2001-imi sanilliussuussivimmut, aammalu siusinnerusukkut misissuisarsimanerni paasisanut uuttorneqarsimasunut sanilliussuunneqarlutik.

Uilluni kanassullu tinguini mingutitsinerup annerulersimaneranut takussutissaqanngilaq, equutinili misissuiffimmi ataatsimeersumi Co annertusiallalaarsimalluni. Co misissugassanik tigusiffimmi tassanerpiaq aamma 2006-imi 2007-imilu annertusiallannikuuvoq. Imaappoq imaq 2008-imi aatsitassarsiornermit annikitsunnguamik sunnersimaneqalaartoq.

Eqalunni sisujuitsuni aatsitassat annertunerulersimanerannut takussutissaqanngilaq. Siusinnerusumut naleqqiullugu Cr, Co aamma Cd 2004 aamma 2006-imi annertusiallannikuupput, kisiannili 2005-imi 2007-imilu annertuseriarnermik nassaartoqarani.

Ujaqqanik aatsitassartalinnik aserortikkanik toqqorsiviup eqqaani tammaarsimaffiullu eqqaani orsuaasani siusinnerusukkut misissuisarnertulli Cu, Cr, As aamma Co malunnartumik qaffariarsimapput. Pineqartuni taakkunani marlunni Cu aamma Cr 4-5-eriaammik, As 19-eriaammik Co-lu 9-riaammik qaffarsimallutik. Saffiugassat taakkua sisamat eqqarsaatigalugit misissuiffiit ilaanni piffissap ingerlanerani 2004-2008-mut allanngoriartorneq takuneqarsinnaavoq. Taamaalilluni As aamma Co marluullutik pineqartuni taakkunani marlunni malunnartumik annertusiartorput, kisiannili Cu aama Cr malunnartumik annertusisimanerannik takussutissaqaraani. As kisimi taakkuani marlunni assigiinngitsumik annertussuseqarpoq, malunnartumik tammaarsimaffiup eqqaani annertunerulluarluni. Orsuaasani Cu, Cr, As aamma Co-p aqqusinermut ungasissusiannut sanilliussuullugu 2005-2008-mut misissuiffigineqarpoq. Saffiugassat akuusut tamarmik aqqusineq ungasilliartortillugu akuunerat malunnartumik annikilliartorpoq. Ukiuni siusinnerusunisut 2008-mi paasineqarpoq Cu, Cr As aamma Co-p akuusut aqqusinermiit 1000 m missiliorlugu ungasissusilik angullugu.

Tupinnalaanngitsuunngilaq orsuaasat Kirkespirdalenini nuunneqarsimasut ukiup ataatsip ingerlanerinnaani orsuaasatut tamaaneereersutut annertunerusumilluunniit aatsitassanik akoqalersimanerat. Taamaanne-

ra takussutissaagunarpoq annertunerusumik pujoralammik mingutitsinerulersimaneq, assersuutigalugu umiarsualivimmi toqqorsivimmilu 2007-2008-mi 2006-2007-imut naleqqlullugu.

2008-missaaq aatsitassarsiorfiup avatangiisinut sunniuteqarneranut takussutissaqarpoq, pingaartumik Kirkespirdalenimi, pujoralammit siaruariartortumit sunnersimaneqartumi. Siullermeerluni piffissap ingerlanerani allanngoriartorneq takuneqarsinnaasimavoq orsuaasani Asaamma Co-mik akoqarnerulersimanikkut.

Photo 1. Brown seaweed (*Fucus vesiculosus*) is collected at station AMI1 on Amitsoq Island by Jette Sommer. At this station also blue mussels and lichens were collected.

1 Introduction

1.1 Mining activities

The Nalunaq Gold Mine A/S (NGM) opened officially on 26 August 2004. Prior to the mine start extensive exploration programmes had been carried out since the discovery of gold bearing veins in 1992. The gold mine and the camp is situated eight km from the coast in the Kirkespir Valley, which lies 40 km northeast of Nanortalik in South Greenland. The Nalunaq gold deposit is a high-grade (c. 20 g gold/ton ore) gold-only mineralization associated with quartz-veins. The ore sheet has an average strike angle of 45-50º inside the Nalunaq Mountain being 1,340 meters high. The preferred mining method is longhole mining with about 11 m vertical spacing between horizontal drifts. Nalunaq Gold Mine has no processing facilities on site. The ore is transported by 25-tonne trucks from stockpiles in the camp area to a stockpile area at the port facility about 11 km from the mine site. The camp layout currently consists of modular single occupancy living units together with other modern facilities. The camp currently has accommodation for about 100 people. A gravel road connects the mine and camp with the Kirkespir Bay. On the southern coastline of the bay a pier and a barge enable the crushed ore to be loaded into bulk carriers that sail the ore to a foreign gold extraction plant. During the period 2004 to 2006 the ore was shipped to Rio Narcea Gold Mines Ltd, Spain for gold extraction. From 7 February 2007 onwards the ore has been sailed to Nugget Pond, Newfoundland, Canada. Close to the pier is a stockpile area with an approximate capacity of 60,000 tonnes (Crewgold 2008).

Photo 2. Early morning on 25 August 2008 the bulk carrier is ready to be loaded with about 9000 tons of ore. The ore is sailed to Nugget Pond, Newfoundland, Canada, for gold extraction.

The first shipment of gold ore took place on 7 January 2004. Up until the fourth monitoring study, performed during 18-25 July 2007, a total of 16 shipments with approximately 420,000 tonnes (wet weight) of ore were transported to Spain and Canada. The fifth monitoring study, described in the present report, was performed between 20 and 27 August 2008. During the period from the fourth to the fifth monitoring study, a total of 14 shipments of c. 155,000 tonnes of ore were sailed to Canada. The latest shipment took place during the monitoring period on 26 August 2008. The bulk carriers that transport the ore to Canada have a capacity of 20-30,000 tonnes (Crewgold 2008; K. Christensen, NGM, August 2008, *in litt.*).

1.2 Environmental baseline studies

Prior to the mine start a number of environmental baseline studies have been performed. The first study was on the Arctic char population in the Kirkespir River in 1988 (Boje 1989). During the exploration phase freshwater samples from the Kirkespir River were analysed for metals and general parameters (Lakefield 1998a, b, 1999a-d). Comprehensive baseline studies performed during 1998-2001 collected fish, mussels, seaweed, snow crab, sea urchin, benthic macrofauna and sediments and analysed these for different metals (Glahder et al. 2005). The above and other studies were included in the Environmental Impact Assessment by SRK Consulting (2002). Based on the above studies and the mining methods and activities used at present, the monitoring programme presented below was designed.

1.3 Monitoring programme

Requirements for monitoring of the environment in relation to the mining activity have been set by the Bureau of Minerals and Petroleum (BMP) of the Greenland Homerule administration. These requirements are described in the BMP exploitation licence of 19 March 2004, Phase 2, §§ 10-19, chapter 5:

The objective of monitoring is to document environmental impacts associated with the activities.

The sampling stations for brown seaweed, blue mussel, shorthorn sculpin and Arctic char must be placed relatively close to, and on each side of the shipping facility. Sampling stations for the lichen *Cetraria nivalis* must be placed both in connection with the above marine stations and around existing ore stockpiles at the Kirkespir Valley campsite and along the road. The following samples must be collected at the number of stations specified:

- Brown seaweed: 4 stations with 2 samples per station; a total of 8 samples.
- Blue mussel: 4 stations with 2 samples (2 different size groups) per station; a total of 8 samples.
- Liver from shorthorn sculpin and Arctic char: 2-4 stations with a total of 20 specimens.
- Lichens *Cetraria nivalis*: 18 stations; a total of 18 samples.

The samples collected must be analysed for the following elements: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn).

BMP may demand changes to the scope and content of the environmental monitoring if it considers the existing monitoring programme inadequate based on the results obtained and experience from the mining operation.

Samples must be collected on an annual basis during operations and closure and for a period of two years after closure. Samples must be analysed immediately after being collected. The analytical findings must be data processed, and a report prepared. This report must reach BMP no later than four months after the samples have been collected.

The samples must be collected and analysed in accordance with guidelines prepared by NERI.

Monitoring studies 2004 – 2007

Since the official opening of the Nalunaq Gold Mine in August 2004, NERI has every year performed a monitoring study in the area during July or August. The monitoring studies are reported in the Nalunaq monitoring reports (Glahder & Asmund 2005, 2006, 2007; Glahder et al. 2008) and they can be found on the NERI web address: http://www.dmu.dk/International/Publications/NERI+Technical+Reports/.

Monitoring study 2008

The monitoring study was performed in the Nalunaq area during 20-27 August 2008.

Sampling was carried out in accordance with the monitoring programme described in the exploitation licence with the following divergences:

- As in the previous monitoring studies, blue mussels were sampled at one more station, AMI1, on the north-east side of the Amitsoq Island about 15 km from the Kirkespir Bay (Fig. 1). Blue mussels from this uncontaminated area were transplanted to the harbour area and they are planned to be collected for analyses in 2009. No mussels were collected in 2008 because all had disappeared probably during a storm in January 2008 where the barge was swept away from the peer.
- Brown seaweed was collected at one more station, AMI1, with a total of two more samples.
- Lichens were sampled at two more stations.
- Lichens were collected from the five transplantation stations (M2, 5, 6, 11 and 12) established in 2007 in Kirkespir Bay and Valley. New lichens, collected at AMI1, were transplanted to these five stations.
- Fish livers from 21 specimens consisted of 16 shorthorn sculpin livers from four marine stations in the Kirkespir Bay and five resident Arctic char livers from the Kirkespir River near the waterfall.

Analyses were performed according to the programme, however 61 samples were analysed instead of 54 and the following 4 elements were ad-

ded to the analytical programme: nickel (Ni), selenium (Se), molybdenum (Mo) and gold (Au).

1.4 Acknowledgements

We wish to thank K. Christensen, NGM, for transportation to and from Narsarsuaq and around in the Kirkespir area, accommodation and for providing us with technical information. J. Andersen, laboratory technician, NGM, is thanked for his participation in collecting samples, Apollus Gyllich and Svend, NGM, for sailing the boat during the marine sampling and Jette Sommer for her participation in collecting and preparing the samples.

Photo 3. The lichen (*Cetraria nivalis*) is collected at station 9 near the water fall in the Kirkespir Valley. The gravel road is winding its way westward to the Kirkespir Bay and Saqqaa Fjord.

2 Methods

2.1 Collection of samples

Sampling in the Kirkespir Bay and at the north-eastern point of Amitsoq Island (AMI1) was performed with a motor boat equipped with a small rubber dinghy for landing. Sampling of blue mussels was performed at low tides of 0.3-0.8 m (Farvandsvæsnet 2006).

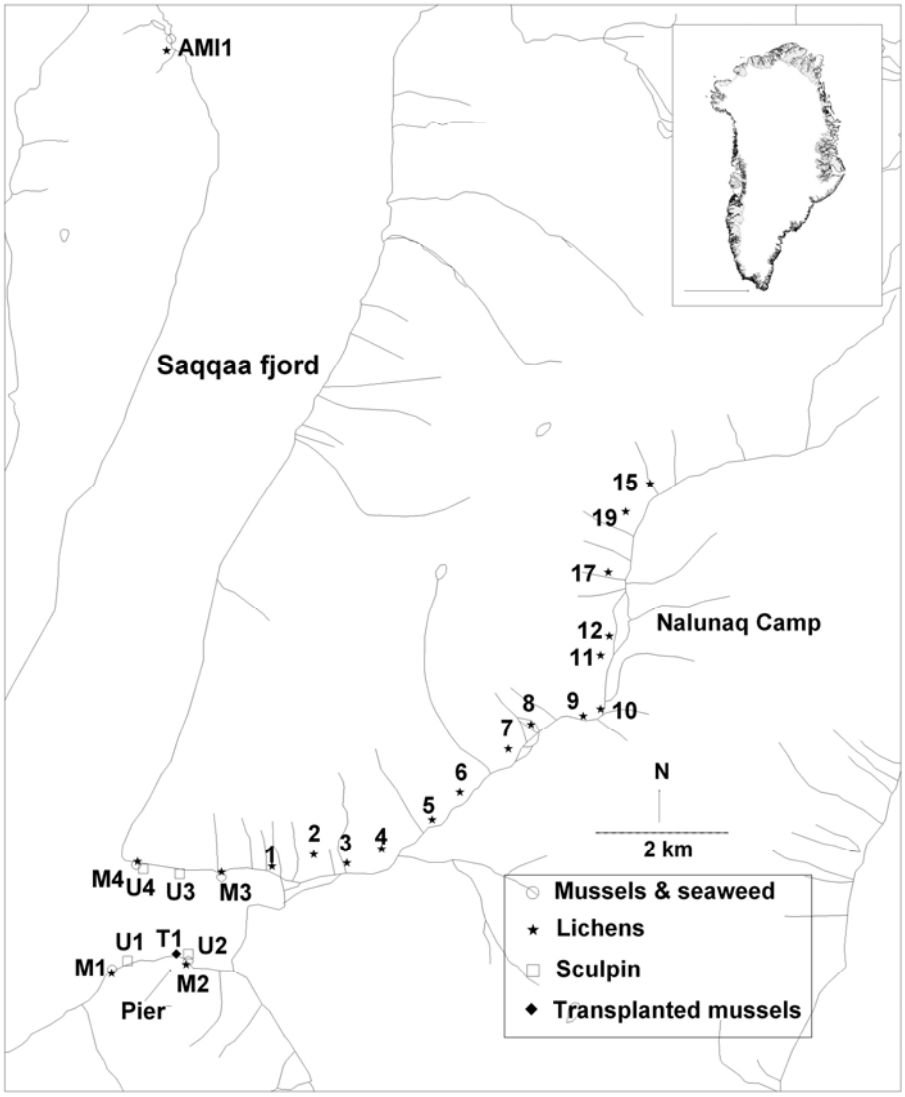

Figure 1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland.

M: Marine stations: Blue mussel and brown seaweed, including lichens. U: Shorthorn sculpin stations. T1: Blue mussels, sampled at station AMI1 on NE Amitsoq Island, were transplanted at the pier. Arctic char were caught near the lichen station 9 near the waterfall. Lichens transplanted 2007 from AMI1 were sampled at stations M2, 5, 6, 11 and 12 and replaced with new lichens from AMI1.

Two size groups (5-6 and 6-7 cm) of mussels were collected at each of the four stations M1-M4. Average shell length was calculated for each size group at each station (see Appendix 2). All mussels in a sample were opened and allowed to drain, the soft parts cut free and frozen. Blue mussels transplanted in 2007 from north-western Amitsoq Island to the barge in the harbour area (Fig. 1, station T1), had disappeared and could therefore not be analysed. New mussels from Amitsoq Island were

transplanted to T1 this year. Other mussels (size groups 6-7 cm and 7-8 cm) from Amitsoq Island, AMI1, were collected for analyses of the background level in this area. Mussels were primarily transplanted to secure that there were mussels available in the harbour area for monitoring. However, the transplanted mussels can also be used to assess if the annual accumulation rate of the elements analysed has changed.

The growth tips of seaweed from this year were cut, washed in freshwater from upstream the camp and frozen. Stations were similar to the blue mussel stations M1-M4 and AMI1.

Shorthorn sculpins were jigged for from the motor boat at the stations U1, U3, and U4. Sculpins at U2 were caught from the barge at the pier. In total 21 shorthorn sculpins were caught. All sculpins were frozen as whole fish.

Arctic char were fished in the Kirkespir River downstream from the waterfall and four resident char were caught. All Arctic char were frozen as whole fish.

Lichens were sampled at 20 stations: Ten from the Kirkespir Valley downstream the camp, three stations in the camp area, two upstream from the camp, four in the Kirkespir Bay area and one in the north-eastern part of Amitsoq Island (station AMI1). Lichens sampled at AMI1 replaced the lichens transplanted in 2007 to stations M2, 5, 6, 11 and 12 and sampled this year (Appendix 1).

2.2 Analyses

All samples were transported either frozen or dry directly to NERI on 27 August 2008. The analyses were performed according to the "Test Report no. 273" (Asmund 2008). A total of 61 samples from blue mussel (10), brown seaweed (10), livers of Shorthorn sculpin (16), livers of Arctic char (5) and the lichen *Cetraria nivalis* (20) were analysed for the following 12 elements: Mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), selenium (Se), cobalt (Co), molybdenum (Mo) and gold (Au).

Samples were opened in suprapur nitric acid under pressure in Teflon bombs in a microwave oven. The samples where then diluted to c. 25 grams and all elements were analysed in an ICP-MS (an accredited method according to DANAK, accreditation No. 411). Hg, Co, Mo and Au are not included in the accreditation No. 411. Simultaneously with the Nalunaq samples the reference materials Dorm-2, Dolt-3 and Tort-2 were analysed. In Table 1 the analytical results are compared to the certificates. In general the ICP-MS analytical results are close to those of the certificates, except for lead with satisfying results only for the Dolt-3 material. Therefore, analytical results for lead should not be over-interpreted.

Table 1. ICP-MS analytical results of reference material (Dorm-2, Dolt-3 and Tort-2) compared to the certificates. The detection limits, quantified as 3 times the standard deviation of the blind values, are also shown. Twelve different elements were analysed. Concentrations are in mg/kg. <dl: below the detection limit.

	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limit	***0.02***	***0.007***	***0.018***	***0.06***	***0.02***	***0.01***	***0.120***	***0.04***	***0.03***	***0.008***	***0.029***	***0.0004***
Dorm-2	5.39	0.030	0.031	22.68	1.85	28.53	16.261	18.39	1.25	0.133	0.295	0.0015
Dorm-2	4.81	0.040	<d.l.	22.46	1.78	29.36	16.211	15.81	1.45	0.123	0.236	<d.l.
Dorm-2	5.34	0.065	<d.l.	21.91	1.96	26.85	14.566	16.74	1.44	0.132	0.243	0.0004
Average	*5.18*	*0.045*	*<d.l.*	*22.35*	*1.86*	*28.24*	*15.679*	*16.98*	*1.38*	*0.129*	*0.258*	*0.0007*
Certificate	*4.64*	*0.043*	*0.065*	*25.60*	*2.34*	*34.70*	*19.400*	*18.00*	*1.40*	*0.182*		
Dolt-3	4.29	18.758	0.214	89.45	30.78	4.57	2.987	9.81	7.57	0.248	3.587	0.0008
Dolt-3	4.11	18.526	0.288	82.63	29.73	3.68	3.273	9.09	6.45	0.235	3.414	0.0065
Average	*4.20*	*18.642*	*0.251*	*86.04*	*30.25*	*4.12*	*3.130*	*9.45*	*7.01*	*0.242*	*3.500*	*0.0036*
Certificate	*3.37*	*19.400*	*0.319*	*86.60*	*31.20*	*<d.l.*	*2.720*	*10.20*	*7.06*			
Tort-2	0.42	25.385	0.263	158.09	97.36	0.65	2.641	19.36	5.40	0.413	1.032	0.0019
Tort-2	0.41	27.433	1.445	179.59	105.13	0.87	2.756	22.43	5.05	0.532	1.166	0.0030
Average	*0.41*	*26.409*	*0.854*	*168.84*	*101.25*	*0.76*	*2.698*	*20.89*	*5.22*	*0.473*	*1.099*	*0.0024*
Certificate	*0.27*	*26.700*	*0.350*	*180.00*	*106.00*	*0.77*	*2.500*	*21.60*	*5.63*	*0.510*	*0.950*	

Statistical analyses

Differences in Co concentrations in brown seaweed were tested with a two-sample t-test after data was tested for equal variances by a F-test.

Prior to analyses of variance (ANOVA) and covariance (ANCOVA), data were logarithmic (base e) transformed to meet the assumptions of normal distribution and variance homogeneous of the tests.

We tested separately the following two areas, the depot of crushed waste rock and the camp area, for differences in concentrations of Cu, Cr, As and Co in lichens in the years 2004-2008 compared to background concentrations using a one-way ANOVA. The post hoc Tukey's studentized range test was applied to test differences between years and background. The level of statistical significance used was p=0.05.

Also, we tested for temporal trends in element concentrations in the two areas. We used a two-way ANCOVA with year as a covariable and area as a factor. We included the interaction between the two factors in the analyses to test for differences in the temporal trend pattern between the two areas. If the interaction was not significant, the test was repeated without the interaction term.

Finally, we analysed the relationship between concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road with an ANCOVA, with logarithmic transformed (base e) distance as covariate and year as factor. The interaction between distance and year was also included to test if this relationship differed between years. The test was reduced and repeated if the interaction term was not significant.

Photo 4. Resident Arctic char (*Salvelinus alpinus*) are caught in the Kirkespir River near the water fall. This deep pool is an excellent environment for the Arctic char to survive during winter.

3 Results and discussion

Element concentrations are given in biota sampled in the marine environment in the Kirkespir Bay, in the fresh water environment in the Kirkespir River and in the terrestrial environment of the Kirkespir Valley (Fig. 1). The analytical results and detection limits, as well as background concentrations from Glahder et al. (2005) are given in Appendix 3. Element concentrations in the species analysed are considered elevated if they are significantly higher than the background concentrations.

3.1 The marine environment

Samples from the Kirkespir Bay were collected at four mussel and seaweed stations (M1-M4) and four sculpin stations (U1-U4) (Fig. 1).

No elevated concentrations were found in *blue mussel* samples.

Brown seaweed at station M3 had twice as high concentrations of Co compared to background concentrations (t-test, two-sample assuming equal variances, p=0.023, t= -3.59, df=4). None of the other seaweed stations had elevated concentrations of the elements that were analysed (Appendix 3).

In *sculpin liver* average concentrations were not elevated compared to the background concentrations. At station U3 average concentrations of Pb was four times above background concentrations. However, the average was calculated from only four different Pb concentrations in the liver and three of these were below or equal to the detection limit (Appendix 3). As shown in chapter 2, lead concentrations below 0.1 mg/kg should be regarded as uncertain; therefore, we do not regard Pb concentrations in livers from station U3 as elevated.

In 2008, Co was significantly elevated in seaweed from only one of the stations (M3). No elevations of any elements were found in the analysed mussels and sculpins.

In 2004 and 2005, concentrations of especially Cr, but also concentrations of Cu, Co and Zn were elevated in seaweed. In 2006 and 2007, Co was also elevated in seaweed from station M3 by a factor 2-3. In 2004, elevations of Cr were found in sculpin livers and of Co in blue mussel.

The impact from the mining activities on the marine environment was again found to be very low. During 2006-2008 the only significant elevation in the marine environment was Co concentrations in seaweed from station M3.

During the last three years concentrations of metals in the marine environment have been low and in general not different from the baseline level.

3.2 The freshwater environment

In resident *Arctic char* livers no average concentrations were elevated compared to baseline concentrations. Resident Arctic char stay all their life in the Kirkespir River, whereas the migratory form summers in the Kirkespir Bay and the Saqqaa Fjord. Compared to previous years, Cr was elevated 2-3 times in 2004 and 2006, Co 3 times in 2004 and Cd 2 times in 2006; no elevations were seen in 2005 and 2007. So, only minor elevations have been seen in two of the five years.

3.3 The terrestrial environment

We have compared concentrations of four metals (Cu, Cr, As and Co) in *lichens* (Cetraria nivalis) during 2004-2008. Two areas were selected, the depot of crushed waste rock (stations 5-7) and the camp area (stations 11-12). In 2007, lichens were transplanted from an uncontaminated area (station AMI1) to the stations 5, 6, 11 and 12. In 2008 these transplanted lichens were analysed together with lichens growing naturally in the Kirkespir Valley and Bay. Therefore, with the same level of pollution in 2008 as in previous years it could be expected that element concentrations in lichens from these four stations in 2008 would be lower than in 2004-2007.

We compared average concentrations in each of the two areas with background concentrations and Cu, Cr, As and Co were significantly elevated in the years 2004-2008 (Tukey's post hoc test, $p<0.05$). Elevations in the two areas in 2008 were 4-5 times for Cu and Cr, 19 times for As and 9 times for Co (Fig. 2a, Appendix 3). Also, concentrations of the four metals at the pier (station M2) appear to be elevated (Cu and Cr 4 times, Co 7 times and As 46 times) compared to background concentrations, but because we have only one sample from this area it has not been possible to test if elevations were significant (Fig. 2a).

Concentrations of the four metals in the two areas during the period 2004-2008 showed differences in temporal trends. As was the only metal that showed differences between the two areas. Concentrations of As increased significantly during the period (ANCOVA, $p<0.001$) in both areas, but in the camp area levels of As were significantly higher than in the depot area (ANCOVA, $p=0.03$). Also, Co concentrations increased significantly during the period (ANCOVA, $p=0.04$). Concentrations of Cu and Cr did not show significant temporal trends during the period (ANCOVA, $p>0.05$).

We have tested a possible relationship between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the gravel road; the test included differences in levels among years (refer to Figs. 2a, b & 3 regarding 2008). These four metals were tested because they showed the highest elevations compared to background levels. All concentrations of the four metals showed a significantly decrease with increasing distance (ANCOVA, $p<0.0001$).

Figure 2a shows concentrations of the four elements in lichens from Amitsoq Island, the Kirkespir Bay area and the Kirkespir Valley. Three areas have markedly higher concentrations of the four elements namely

the pier area, the depot of waste rock and the camp and mine area. The relatively high concentrations in these areas can mostly be explained as an effect of the nearness to the gravel road illustrated by Figure 2b. Figure 2 also indicates that the high concentrations in the camp area are higher than explained by the distance to the road and this finding is confirmed by Figure 3, where element concentrations in lichens from station 11 (situated in the camp area) also are well above the regression lines. Also lichens from station 6 (situated in the depot of crushed waste rock area) show higher metal concentrations than explained by the distance to the road (Fig. 3) as does concentrations of As in lichens from station M2 in the pier area (Fig. 3).

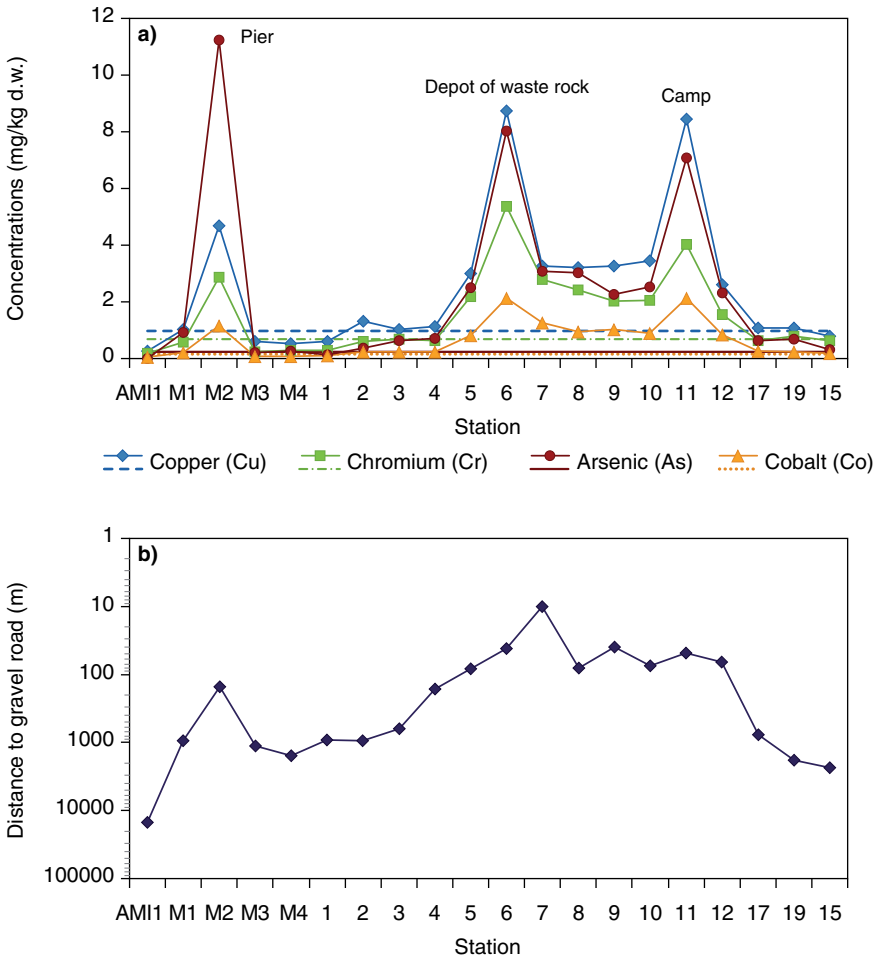

Figure 2. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis.* For localisation of lichen stations refer to Fig. 1. M1-M4 are stations in the Kirkespir Bay area, stations 1-17 are situated in the Kirkespir Valley from coast (1) to up-stream camp area (15). Horizontal lines in a) indicate average background concentrations of the four metals (Refer to Table 2). d.w. = dry weight. Fig. 2 b shows distances (in meter) from the road to the lichen stations.

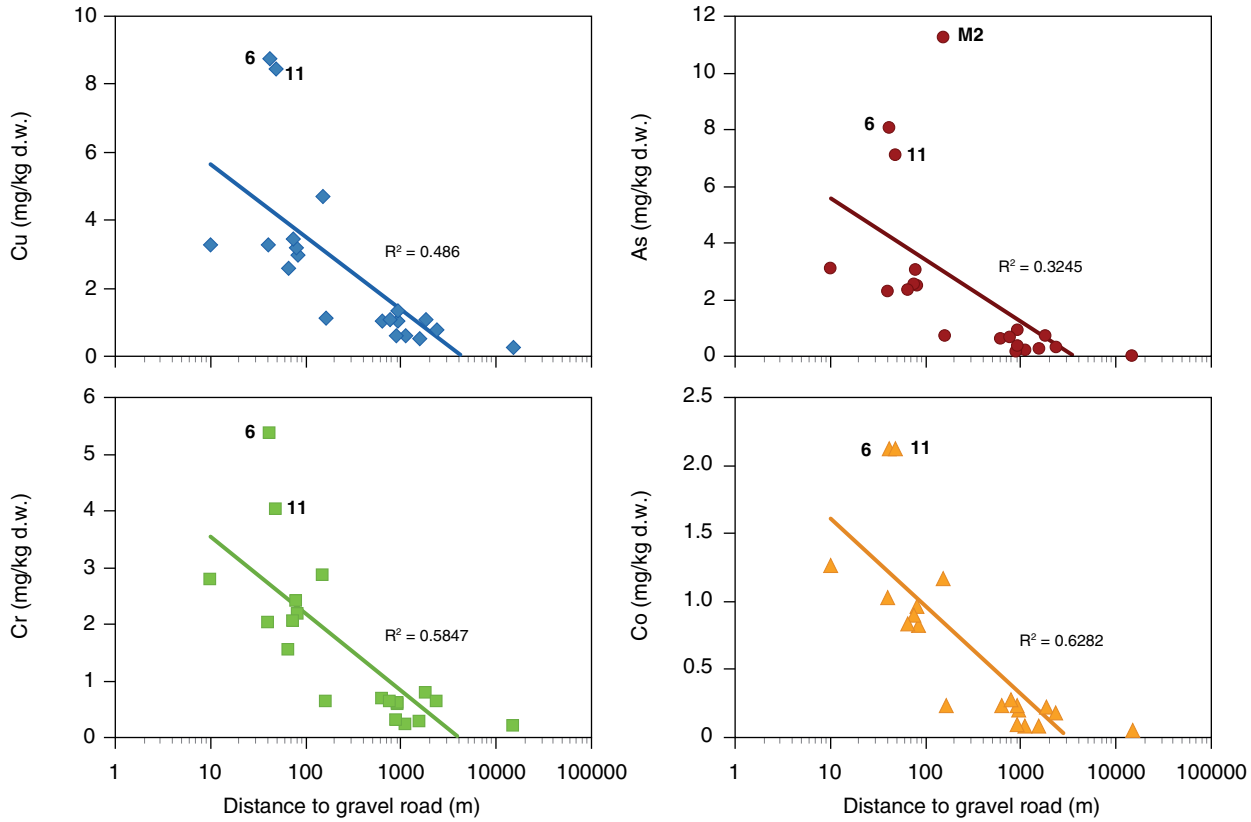

Figure 3. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis* as a function of stations distance to the gravel road (in meter). Stations 6 and 11 had metal concentrations well above the trend line, and also M2 had As concentrations well above the trend line. d.w. = dry weight.

Photo 5. Dust dispersal along the gravel road in the Kirkespir Valley.

It is concluded that concentrations of Cu, Cr, As and Co during 2004-2008 were significantly elevated compared to the background level at the depot of crushed waste rock and at the camp and mine area. Only concentrations of As were higher in the camp area than in the depot area. This was also the case during 2004-2007; Cu concentrations were also higher in the camp area during that period but not in 2008. As and Co concentrations in the two areas now showed an increase over the period 2004-2008. The relationship between concentrations and distance was significantly different during 2005-2008 for Cr, As and Co, with highest concentrations in 2007 and 2008. All metal concentrations showed a significant decrease with increasing distance. Concentrations of Cu, Cr, As and Co above the background level can, as in previous years, be found to a distance of about 1000 m from the road.

Studies at the lead-zinc mine at Maarmorilik have shown that metals are excreted from the lichens at a low rate, if at all (Johansen et al. 2008). Therefore, a reduction in the dust pollution can be difficult to detect within a few years period. In 2007, we therefore transplanted lichens from the uncontaminated Amitsoq Island to the Nalunaq area in order to determine the annual rate of dust pollution. Lichens were transplanted to the three most contaminated areas at the pier, near the depot of crushed waste rock and in the camp and mine area (Figs. 1 and 2). We have not collected naturally growing lichens from these three areas so it has not been possible to compare metal levels in transplanted and naturally growing lichens from these areas. The transplanted lichens were collected and analysed one year later in 2008. It is remarkable that the transplanted lichens in just one year had concentrations equal or even higher than lichens growing naturally in the Kirkespir area. This indicates higher dust pollution in some areas in 2007-2008 than in 2006-2007. Such areas are especially the pier area (represented by station M2) and the depot of waste rock (station 6). In the pier area (station M2) 9 out of 12 elements analysed had higher concentrations in 2008 than in 2007, where As was 3 times higher in 2008 and Cd, Cr and Co were c. 1.5 times higher. In the depot area (station 6) 7 out of the 12 elements were higher in 2008 than in 2007 and Cu and As were c. 1.5 times higher. In these two areas ore and waste rock are stored and handled in the open.

Photo 6. Aerial view from June 2008 of the Nalunaq Gold Mine and the camp situated in the upper Kirkespir Valley (Flemming Merkel, NERI).

4 Conclusions

The report describes the results of the fifth year of environmental monitoring in the Nalunaq Gold Mine area. No elevated concentrations were found in blue mussels and shorthorn sculpin livers, while brown seaweed had slightly elevated concentrations of Co at one sampling station. The impact from the mining activities on the marine environment was in 2008 found to be very low. During 2006-2008 the only significant elevation in the marine environment was Co concentrations in seaweed from station M3.

In resident Arctic char livers no average concentrations were elevated in 2008 compared to baseline concentrations. In 2004 and 2006, Cr, Co and Cd were slightly elevated, while no elevations were found in 2005 and 2007. In conclusion, only minor elevations of Cr, Co and Cd have been seen in two of the five years.

In the lichen *Cetraria nivalis* concentrations of Cu, Cr, As and Co in 2008, like in previous years, were significantly elevated compared to the background level at the depot of crushed waste rock and at the camp and mine area. Elevations in the two areas in 2008 were 4-5 times for Cu and Cr, 19 times for As and 9 times for Co.

Concentrations of the four metals in the two areas during the period 2004-2008 showed differences in temporal trends. Concentrations of As and Co increased significantly during the period in both areas, whereas concentrations of Cu and Cr did not show significant temporal trends during the period. As was the only metal that showed differences between the two areas, with significantly higher levels in the camp area.

We have tested the relationship between the concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road; the test included differences in levels among years. All concentrations of the four metals showed a significantly decrease with increasing distance. Metal concentrations above the background level could, as in previous years, be found to a distance of about 1000 m from the road.

It is remarkable that transplanted lichens in just one year had concentrations equal or even higher than in lichens growing naturally in the Kirkespir area. This indicates higher dust pollution in some areas in 2007-2008 than in 2006-2007. Such areas are especially the pier area and the depot of waste rock.

In 2008, the impact from the mining activities on the local environment was primarily observed in the Kirkespir Valley and originated from dust dispersal from road, mine, pier and depot. For the first time temporal trends with increasing concentrations of As and Co in lichens were demonstrated. In the river and in the bay, element elevations were found only in seaweed from just one station.

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Photo 7. The pier and the barge on the south side of the Kirkespir Bay. In land the stockpile area has a capacity of 60,000 tonnes of crushed ore.

Appendix 1. Samples and stations

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
38332	Lichen	Cetraria nivalis	24.08.2008	1	60	19'34''	44	55'22''
38333	Lichen	Cetraria nivalis	24.08.2008	2	60	19'38''	44	54'40''
38334	Lichen	Cetraria nivalis	24.08.2008	3	60	19'35''	44	54'10''
38335	Lichen	Cetraria nivalis	24.08.2008	4	60	19'43''	44	53'38''
38336	Lichen	Cetraria nivalis	24.08.2008	5-transplanted	60	19'57.1''	44	52'47.7''
38337	Lichen	Cetraria nivalis	24.08.2008	6-transplanted	60	20'10.1''	44	52'18.2''
38338	Lichen	Cetraria nivalis	24.08.2008	7	60	20'32''	44	51'37''
38339	Lichen	Cetraria nivalis	24.08.2008	8	60	20'44''	44	51'07''
38340	Lichen	Cetraria nivalis	24.08.2008	9	60	20'49''	44	50'14''
38341	Lichen	Cetraria nivalis	24.08.2008	10	60	20'51''	44	49'58''
38342	Lichen	Cetraria nivalis	23.08.2008	11-transplanted	60	21'16.5''	44	49'56.9''
38343	Lichen	Cetraria nivalis	23.08.2008	12-transplanted	60	21'28.1''	44	49'50.3''
38344	Lichen	Cetraria nivalis	21.08.2008	15	60	22'43''	44	49'08''
38345	Lichen	Cetraria nivalis	21.08.2008	17	60	21'59''	44	49'52''
38346	Lichen	Cetraria nivalis	21.08.2008	19	60	22'30''	44	49'31''
38356	Lichen	Cetraria nivalis	25.08.2008	M 1	60	18'41''	44	58'01''
38347	Lichen	Cetraria nivalis	23.08.2008	M2-transplanted	60	18'45.2''	44	56'48.5''
38348	Lichen	Cetraria nivalis	22.08.2008	M 3	60	19'29''	44	56'15''
38349	Lichen	Cetraria nivalis	22.08.2008	M 4	60	19'35''	44	57'37''
38350	Lichen	Cetraria nivalis	21.08.2008	AMI 1	60	26'20''	44	57'04''
38360	Brown seaweed	Fucus vesiculosus	25.08.2008	M 1	60	18'41''	44	58'01''
38361	Brown seaweed	Fucus vesiculosus	25.08.2008	M 1	60	18'41''	44	58'01''
38330	Brown seaweed	Fucus vesiculosus	23.08.2008	M 2	60	18'46''	44	56'47''
38331	Brown seaweed	Fucus vesiculosus	23.08.2008	M 2	60	18'46''	44	56'47''
38317	Brown seaweed	Fucus vesiculosus	22.08.2008	M 3	60	19'29''	44	56'15''
38318	Brown seaweed	Fucus vesiculosus	22.08.2008	M 3	60	19'29''	44	56'15''
38319	Brown seaweed	Fucus vesiculosus	22.08.2008	M 4	60	19'35''	44	57'37''
38320	Brown seaweed	Fucus vesiculosus	22.08.2008	M 4	60	19'35''	44	57'37''
38311	Brown seaweed	Fucus vesiculosus	21.08.2008	AMI1	60	26'20''	44	57'04''
38312	Brown seaweed	Fucus vesiculosus	21.08.2008	AMI1	60	26'20''	44	57'04''
38362	Shorthorn sculpin	Myoxocephalus scorpius	25.08.2008	U 1	60	18'47''	44	57'45''
38363	Shorthorn sculpin	Myoxocephalus scorpius	25.08.2008	U 1	60	18'47''	44	57'45''
38364	Shorthorn sculpin	Myoxocephalus scorpius	25.08.2008	U 1	60	18'47''	44	57'45''
38365	Shorthorn sculpin	Myoxocephalus scorpius	25.08.2008	U 1	60	18'47''	44	57'45''
38307	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 2	60	18'45''	44	56'46''
38308	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 2	60	18'45''	44	56'46''
38309	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 2	60	18'45''	44	56'46''
38310	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 2	60	18'45''	44	56'46''
38326	Shorthorn sculpin	Myoxocephalus scorpius	23.08.2008	U 3	60	19'31''	44	56'53''
38327	Shorthorn sculpin	Myoxocephalus scorpius	23.08.2008	U 3	60	19'31''	44	56'53''
38328	Shorthorn sculpin	Myoxocephalus scorpius	23.08.2008	U 3	60	19'31''	44	56'53''
38329	Shorthorn sculpin	Myoxocephalus scorpius	23.08.2008	U 3	60	19'31''	44	56'53''
38305	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 4	60	19'34''	44	57'31''
38323	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 4	60	19'34''	44	57'31''
38366	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 4	60	19'34''	44	57'31''
38367	Shorthorn sculpin	Myoxocephalus scorpius	22.08.2008	U 4	60	19'34''	44	57'31''

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
38358	Blue mussel	Mytilus edulis	25.08.2008	M 1	60	18'41''	44	58'01''
38359	Blue mussel	Mytilus edulis	25.08.2008	M 1	60	18'41''	44	58'01''
38321	Blue mussel	Mytilus edulis	23.08.2008	M 2	60	18'46''	44	56'47''
38322	Blue mussel	Mytilus edulis	23.08.2008	M 2	60	18'46''	44	56'47''
38313	Blue mussel	Mytilus edulis	22.08.2008	M 3	60	19'29''	44	56'15''
38314	Blue mussel	Mytilus edulis	22.08.2008	M 3	60	19'29''	44	56'15''
38315	Blue mussel	Mytilus edulis	22.08.2008	M 4	60	19'35''	44	57'37''
38316	Blue mussel	Mytilus edulis	22.08.2008	M 4	60	19'35''	44	57'37''
38301	Blue mussel	Mytilus edulis	21.08.2008	AMI 1	60	26'20''	44	57'04''
38302	Blue mussel	Mytilus edulis	21.08.2008	AMI 1	60	26'20''	44	57'04''
	Blue mussel	Mytilus edulis	21.08.2008	T 1	60	18'51''	44	56'57''
38352	Arctic char	Salvelinus alpinus	24.08.2008	Near waterfall	60	20'47''	44	50'32''
38353	Arctic char	Salvelinus alpinus	24.08.2008	Near waterfall	60	20'47''	44	50'32''
38354	Arctic char	Salvelinus alpinus	24.08.2008	Near waterfall	60	20'47''	44	50'32''
38351	Arctic char	Salvelinus alpinus	24.08.2008	Near waterfall	60	20'47''	44	50'32''
38355	Arctic char	Salvelinus alpinus	24.08.2008	Near waterfall	60	20'47''	44	50'32''

*) All co-ordinates are given in WGS 84.

Appendix 2. Blue mussel average shell lengths

Station	Average length (cm, in bold) in different size groups including standard deviation and number of individuals		
	5-6	6-7	7-8
M1	**5.62** 0.25; 20	**6.40** 0.27; 20	
M2	**5.55** 0.28; 20	**6.45** 0.23; 20	
M3	**5.59** 0.24; 20	**6.50** 0.28; 20	
M4	**5.45** 0.27; 20	**6.44** 0.29; 20	
AMI1		**6.43** 0.28; 20	**7.39** 0.29; 20

Appendix 3. Chemical analyses

Concentrations are given in mg/kg d.w. (dry weight) for mussels, seaweed and *Cetraria nivalis* and mg/kg w.w. (wet weight) for livers from sculpins and Arctic chars. Detection limits (d.l.) are given as well as average background concentrations and standard deviations (*SD*) for each species.

ID no.	Lab no	% d.w.	Species	Shell (cm)	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limits						*0.017*	*0.007*	*0.018*	*0.06*	*0.02*	*0.015*	*0.120*	*0.04*	*0.03*	*0.008*	*0.03*	*0.000*
38358	5546	16.98	Myt. edu.	5-6	M 1	0.076	2.440	0.416	69.17	5.84	1.157	1.534	11.85	2.99	0.285	0.48	0.001
38359	5547	17.22	Myt. edu.	6-7	M 1	0.100	2.253	0.479	59.83	5.29	0.558	1.092	10.93	3.20	0.257	0.46	0.004
38321	5544	17.3	Myt. edu.	5-6	M 2	0.080	4.045	0.462	65.87	6.20	0.761	1.768	13.27	3.50	0.294	0.45	0.002
38322	5545	18.44	Myt. edu.	6-7	M 2	0.069	3.133	0.452	77.11	7.31	0.915	1.533	13.96	2.92	0.307	0.42	0.002
38313	5539	12.66	Myt. edu.	5-6	M 3	0.135	2.368	0.577	82.66	7.16	1.019	1.566	15.11	3.22	0.433	0.56	0.004
38313	5540	12.66	Myt. edu.	5-6	M 3	0.147	2.491	0.591	87.97	7.52	1.096	1.867	16.35	3.72	0.431	0.58	0.004
38314	5541	11.57	Myt. edu.	6-7	M 3	0.130	2.653	0.693	82.27	6.98	1.148	1.497	15.24	3.64	0.455	0.56	0.003
38315	5542	18.56	Myt. edu.	5-6	M 4	0.080	3.543	0.434	72.78	6.21	0.576	1.176	10.72	3.15	0.295	0.41	0.001
38316	5543	17.35	Myt. edu.	6-7	M 4	0.130	6.391	0.621	74.58	6.77	0.714	1.745	14.01	3.58	0.361	0.58	0.005
38301	5548	18.87	Myt. edu.	6-7	AMI 1	0.085	3.607	0.713	62.14	5.06	0.438	0.974	9.57	3.05	0.212	0.44	0.002
38302	5549	17.67	Myt. edu.	7-8	AMI 1	0.119	6.039	0.728	72.47	5.21	0.564	1.147	11.20	2.99	0.247	0.53	0.002
Background			Myt. edu.	*Average*		*0.131*	*5.49*	*1.195*	*87.82*	*7.58*	*0.73*		*11.80*		*0.239*		
Background			Myt. edu.	*SD*		*0.025*	*1.97*	*0.365*	*16.42*	*1.08*	*0.28*		*1.59*		*0.053*		
38360	5535	100	Fuc. ves.		M 1	<d.l.	1.437	<d.l.	6.61	1.19	0.076	0.893	43.17	<d.l.	0.215	0.10	<d.l.
38361	5536	100	Fuc. ves.		M 1	<d.l.	1.353	<d.l.	5.27	0.96	0.037	0.829	38.68	<d.l.	0.179	0.09	<d.l.
38361	5537	100	Fuc. ves.		M 1	<d.l.	1.363	<d.l.	5.17	1.02	<d.l.	0.811	40.14	<d.l.	0.171	0.08	<d.l.
38330	5533	100	Fuc. ves.		M 2	<d.l.	0.764	<d.l.	9.15	1.41	0.096	1.349	46.98	<d.l.	0.289	0.09	0.001
38331	5534	100	Fuc. ves.		M 2	<d.l.	0.992	0.022	9.26	1.56	0.192	1.166	46.85	<d.l.	0.351	0.08	<d.l.
38317	5529	100	Fuc. ves.		M 3	<d.l.	1.113	<d.l.	8.85	1.86	0.069	1.655	52.27	0.07	0.603	0.09	0.002
38318	5530	100	Fuc. ves.		M 3	<d.l.	0.885	<d.l.	7.91	1.57	0.044	1.378	45.80	<d.l.	0.428	0.11	0.001
38319	5531	100	Fuc. ves.		M 4	<d.l.	2.029	<d.l.	7.58	1.71	0.022	1.629	50.32	<d.l.	0.495	0.12	0.001
38320	5532	100	Fuc. ves.		M 4	<d.l.	1.587	<d.l.	7.63	1.56	0.025	1.113	47.73	<d.l.	0.289	0.11	0.001
38311	5526	100	Fuc. ves.		AMI 1	<d.l.	1.399	0.033	4.47	1.28	0.213	1.434	44.02	0.15	0.180	0.13	0.001
38311	5527	100	Fuc. ves.		AMI 1	<d.l.	1.272	0.026	4.24	1.25	0.156	1.964	47.16	0.06	0.164	0.11	0.001
38312	5528	100	Fuc. ves.		AMI 1	<d.l.	1.437	0.019	3.73	0.95	0.045	1.514	35.57	0.08	0.180	0.13	0.001
Background			Fuc. ves.	*Average*		*0.01*	*1.77*	*0.105*	*7.57*	*1.04*	*0.11*		*47.55*		*0.209*		
Background			Fuc. ves.	*SD*		*0.008*	*0.51*	*0.039*	*2.38*	*0.24*	*0.12*		*8.47*		*0.045*		
38356	5501	100	Cet. niv.		M 1	0.051	0.048	0.410	23.37	1.02	0.578	0.429	0.93	0.18	0.202	<d.l.	<d.l.
38347	5497	100	Cet. niv.		M 2-*t*	0.052	0.089	1.244	15.18	4.69	2.873	2.594	11.23	0.09	1.168	0.03	0.004
38348	5498	100	Cet. niv.		M 3	<d.l.	0.025	0.370	15.37	0.60	0.229	<d.l.	0.20	0.04	0.090	<d.l.	<d.l.
38349	5499	100	Cet. niv.		M 4	<d.l.	0.066	0.764	6.80	0.54	0.289	<d.l.	0.25	0.09	0.084	<d.l.	0.001
38350	5500	100	Cet. niv.		AMI 1	<d.l.	0.020	0.520	13.48	0.27	0.195	<d.l.	<d.l.	0.08	0.051	<d.l.	<d.l.
38332	5479	100	Cet. niv.		1	0.052	0.029	0.417	11.55	0.59	0.272	0.209	0.09	0.12	0.092	0.03	0.001
38332	5480	100	Cet. niv.		1	0.035	0.018	0.544	14.99	0.61	0.320	0.279	0.20	0.06	0.097	<d.l.	0.001
38333	5481	100	Cet. niv.		2	0.073	0.104	0.689	22.15	1.32	0.611	0.660	0.37	0.12	0.240	<d.l.	0.001
38334	5482	100	Cet. niv.		3	0.042	0.050	0.682	17.85	1.04	0.679	0.507	0.63	0.12	0.238	0.03	0.001
38335	5483	100	Cet. niv.		4	0.028	0.023	0.443	26.01	1.12	0.642	0.498	0.72	0.08	0.240	<d.l.	0.001
38336	5484	100	Cet. niv.		5-*t*	0.042	0.092	1.136	12.79	2.99	2.175	1.812	2.50	0.22	0.828	<d.l.	0.001
38337	5485	100	Cet. niv.		6-*t*	0.040	0.099	1.021	13.40	8.74	5.374	5.329	8.04	0.10	2.125	0.05	0.002
38338	5486	100	Cet. niv.		7	0.038	0.072	0.857	19.33	3.27	2.791	2.796	3.08	0.15	1.265	<d.l.	0.001
38339	5487	100	Cet. niv.		8	0.025	0.052	1.163	13.12	3.20	2.408	1.882	3.02	0.17	0.960	<d.l.	0.001
38340	5488	100	Cet. niv.		9	0.059	0.085	1.490	16.73	3.26	2.021	2.065	2.27	0.12	1.029	0.04	0.001
38341	5489	100	Cet. niv.		10	0.022	0.058	1.057	12.67	3.45	2.053	1.906	2.52	0.20	0.898	0.03	0.003
38342	5490	100	Cet. niv.		11-*t*	0.031	0.078	1.162	18.49	8.45	4.021	4.522	7.08	0.12	2.129	0.05	0.002
38343	5491	100	Cet. niv.		12-*t*	0.035	0.122	1.289	15.51	2.60	1.547	1.756	2.31	0.08	0.838	<d.l.	<d.l.
38344	5492	100	Cet. niv.		15	<d.l.	0.038	0.727	13.82	0.79	0.624	0.277	0.31	0.03	0.182	<d.l.	<d.l.

ID no.	Lab no	% d.w.	Species	Shell	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
38345	5494	100	Cet. niv.		17	0.053	0.054	0.976	14.86	1.13	0.694	0.551	0.63	0.09	0.300	<d.l.	0.000
38345	5495	100	Cet. niv.		17	0.028	0.038	1.063	11.77	1.01	0.567	0.409	0.64	0.06	0.248	<d.l.	<d.l.
38346	5496	100	Cet. niv.		19	0.022	0.028	0.562	12.65	1.08	0.785	0.584	0.69	0.05	0.230	0.03	<d.l.
Background			Cet. niv.	*Average*		*0.033*	*0.081*	*1.076*	*21.61*	*0.97*	*0.68*		*0.24*		*0.157*		
Background			Cet. niv.	*SD*		*0.006*	*0.029*	*0.378*	*7.28*	*0.77*	*1.22*		*0.27*		*0.157*		
38362	5503	0	Myo. sco.		U 1	0.040	1.335	<d.l.	27.41	2.06	<d.l.	<d.l.	1.58	0.71	0.026	0.07	0.001
38363	5504	32	Myo. sco.		U 1	0.037	0.372	<d.l.	25.44	0.96	<d.l.	<d.l.	2.11	0.64	0.020	0.07	<d.l.
38364	5505	38.68	Myo. sco.		U 1	<d.l.	0.336	<d.l.	20.35	2.49	<d.l.	<d.l.	1.24	0.61	0.021	0.06	0.001
38365	5506	32.5	Myo. sco.		U 1	0.022	0.361	<d.l.	23.29	0.94	<d.l.	<d.l.	1.12	0.59	0.011	0.04	<d.l.
38307	5507	36.04	Myo. sco.		U 2	0.024	0.602	<d.l.	18.01	0.82	<d.l.	<d.l.	1.03	0.63	0.016	0.04	0.000
38308	5508	33.59	Myo. sco.		U 2	<d.l.	0.078	<d.l.	4.51	0.22	<d.l.	<d.l.	0.78	0.14	<d.l.	<d.l.	<d.l.
38309	5509	30.36	Myo. sco.		U 2	0.038	0.161	0.022	20.20	0.77	0.032	<d.l.	3.95	0.47	0.017	<d.l.	<d.l.
38309	5510	30.36	Myo. sco.		U 2	0.041	0.197	<d.l.	23.70	0.75	<d.l.	<d.l.	5.56	0.56	0.012	<d.l.	<d.l.
38310	5511	35.83	Myo. sco.		U 2	0.046	0.417	<d.l.	27.16	0.72	<d.l.	<d.l.	3.32	0.55	0.016	0.03	<d.l.
38326	5512	0	Myo. sco.		U 3	<d.l.	0.168	0.042	23.36	1.02	<d.l.	0.126	1.59	0.70	0.021	0.05	<d.l.
38327	5513	35.14	Myo. sco.		U 3	<d.l.	1.256	0.018	26.82	2.62	<d.l.	<d.l.	1.55	0.69	0.016	0.06	<d.l.
38328	5514	40.32	Myo. sco.		U 3	<d.l.	0.192	<d.l.	21.98	1.26	0.020	<d.l.	1.05	0.54	0.014	<d.l.	<d.l.
38329	5515	22.88	Myo. sco.		U 3	0.027	0.998	<d.l.	26.74	1.11	<d.l.	0.147	3.42	1.05	0.020	0.06	<d.l.
38305	5516	40.68	Myo. sco.		U 4	0.021	0.281	<d.l.	18.33	0.78	<d.l.	<d.l.	3.47	0.56	0.016	0.03	<d.l.
38323	5517	39.66	Myo. sco.		U 4	<d.l.	0.129	<d.l.	15.05	0.69	<d.l.	<d.l.	0.85	0.40	0.009	<d.l.	<d.l.
38366	5518	36.28	Myo. sco.		U 4	0.018	0.319	<d.l.	25.16	1.17	<d.l.	<d.l.	2.23	0.71	0.039	0.06	<d.l.
38367	5519	41.74	Myo. sco.		U 4	<d.l.	0.332	<d.l.	18.67	0.88	<d.l.	<d.l.	1.60	0.52	0.017	<d.l.	<d.l.
Background			Myo. sco.	*Average*		*0.028*	*1.041*	*0.004*	*32.14*	*1.80*	*0.016*		*3.23*		*0.021*		
Background			Myo. sco.	*SD*		*0.013*	*0.404*	*0.003*	*1.64*	*0.66*	*0.019*		*2.07*		*0.017*		
38352	5520	21.92	Sal. alp.			0.049	0.090	<d.l.	25.66	11.30	0.016	0.131	0.43	4.37	0.058	0.19	<d.l.
38353	5521	21.77	Sal. alp.			0.025	0.085	<d.l.	25.35	8.93	0.018	<d.l.	0.22	3.52	0.099	0.16	<d.l.
38354	5522	23.2	Sal. alp.			0.069	0.241	<d.l.	26.25	8.49	0.040	0.134	0.20	1.62	0.044	0.13	<d.l.
38351	5524	22.22	Sal. alp.			0.052	0.083	<d.l.	20.66	2.54	<d.l.	<d.l.	0.22	1.34	0.039	0.13	0.001
38355	5525	22.32	Sal. alp.			0.040	0.124	<d.l.	25.32	5.28	0.028	0.174	0.25	3.34	0.063	0.17	0.001
Background			Sal. alp.	*Average*		*0.025*	*0.077*	*0.005*	*34.88*	*8.72*	*0.025*		*0.45*		*0.041*		
Background			Sal. alp.	*SD*		*0.009*	*0.026*	*0.002*	*6.13*	*10.22*	*0.022*		*0.13*		*0.013*		

<d.l. = value below detection limit; -*t* = station with transplanted lichens; Myt. edu. = Blue mussel (*Mytilus edulis*); Fuc. ves. = Brown seaweed (*Fucus vesiculosis*); Cet. niv. = Lichen (*Cetraria nivalis*); Myo. sco. = Shorthorn sculpin (*Myoxycephalus scorpius*); Sal. alp. = Arctic char (*Salvelinus alpinus*).

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