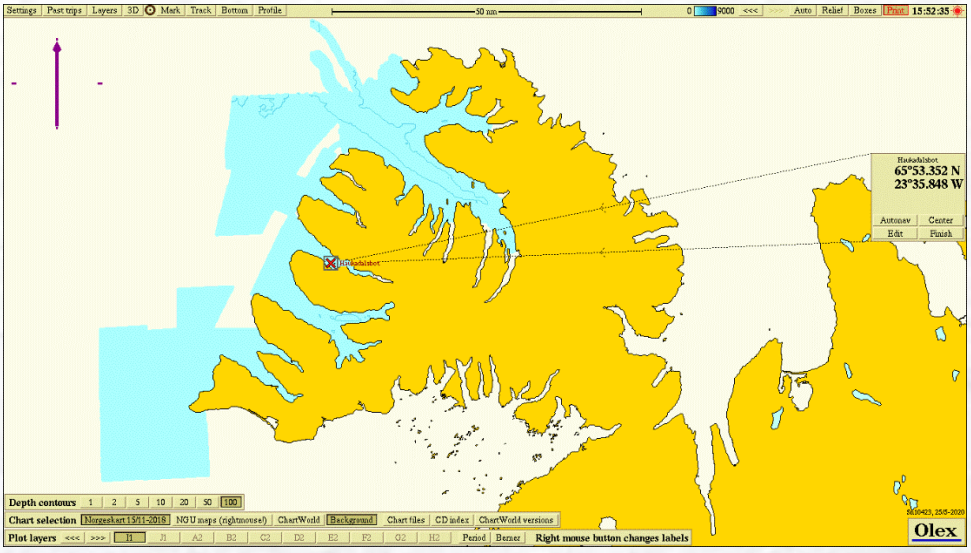
Akvaplan niva

Rapport Report

Arctic Sea Farm hf

C-survey

Haukadalsbot (fallow period), 2020



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Arctic Sea Farm hf. C-survey Haukadalsbot (fallow period), 2020.

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Summary / Sammendrag
The results from the monitoring at the farming site Haukadalsbot in March 2020 showed that the fauna might be considered as undisturbed at all stations (nEQR > 0.6). No pollution indicators were recorded among the top-10 at any of the stations. The sediments had relatively low levels of organic carbon at all stations. The level of copper varied from 44.2 to 53.5 mg/kg,which is within natural levels reported for bottom sediments around Iceland (Egilsson *et al*., 1999). The redox measurements (pH/Eh) gave points 0 acc. Appendix D in NS 9410:2016 for all the sampling stations. The oxygen saturation in March was good in the whole water column with 93 % in the bottom water.

Project manager / Prosjektleder

Snorri Gunnarsson

Quality control / Kvalitetskontroll

Roger Velvin

Contents

Foreword

Akvaplan-niva completed an environmental survey of the type C at the Haukadalsbot site. The C-survey is carried out in accordance with NS 9410:2016. The survey is done following a fallow period. The survey includes pH/redox measurements (Eh), hydrography, geochemical analyses and analyses of the bottom fauna at the fish farming site. Results from five stations are included in the C-survey. This survey is done upon request from Arcticc Sea Farm hf.

The following personnel have contributed in this work:

Snorri Gunnarsson	Akvaplan-niva	Field work, report, project leader.
Hans-Petter Mannvik	Akvaplan-niva	Identification of bottom fauna (Echinodermata). Report, professional assessments and interpretations.
Roger Velvin	Akvaplan-niva	Identification of bottom fauna (Various taxa). QA report, professional assessments and interpretations.
Rune Palerud	Akvaplan-niva	Identification of bottom fauna (Crustaceans). Statistics.
Thomas Hansen	Akvaplan-niva	Identification of bottom fauna (Mollusca).
Charlotte P. Ugelstad	Akvaplan-niva	Identification of bottom fauna (Polychaeta).
Stine Hermansen	Akvaplan-niva	Hydrographical vertical profiles
Kristine H Sperre	Akvaplan-niva	Coordination of sorting of bottom fauna.
Ingar H. Wasbotten	Akvaplan-niva	Coordination of geo-chemical analyses.

Akvaplan-niva would like to thank Evu Dögg Jóhanssdóttur, Arctic Sea Farm hf for good cooperation.

Accreditation information:

The survey is done by Akvaplan-niva AS with ALS Laboratory Group (Czech Republic) as a sub-contractor.

NORSK AKKREDITERING TEST 079	Akvaplan-niva AS er akkreditert av Norsk Akkreditering for feltinnsamlinger av sediment og fauna, analyser av TOC, TOM, TN, kornstørrelse, makrofauna og faglig vurderinger og fortolkninger, akkrediteringsnr. TEST 079. Akkrediteringen er i hht. NS-EN ISO/IEC 17025.
Czech Accreditation Institute (Lab nr 1163)	ALS Laboratory Group er akkreditert av Czech Accreditation Institute (Lab nr 1163) for analyser av kobber.

Sted, 25.05 2020

Snorri Gunnarsson

Project leader

1 Summary of C-results

Information client			
Title :	C-survey Haukadalsbót, 2020.		
Report nr.	62024.01	Site:	Haukadalsbót
Site nr.		Map coordinates (construction):	65°53,352 N 23°35,848 W
		Municipal:	Isafjörður
MTB-permission:	4000	Operations manager: rett navn	Egill Ólafsson
Client:	Arctic Sea Farm hf		

Biomass/production status at time of survey 25.03.2020			
Fish group:	Salmon	Biomass on examination:	0
Feed input:	0	Produced amount of fish:	0
Type/time of survey			
Maximum biomass:		Follow up study:	
Fallow (resting period):	X	New locationi:	

Results from the C study /NS 9410 (2016) – Main results from soft bottom fauna			
Faunal index nEQR (Veileder 02:2018)		**Diversity index H' (Shannon-Wiener)**	
Fauna C1 (closest to farm)	0,639	Fauna C1 (closest to farm)	3,05
Fauna C2	0,692	Fauna C2	3,42
Fauna C3	0,635	Fauna C3	3,13
Fauna C4 (deep area)	0,632	Fauna C4 (deep are)	3,00
Fauna C5	0,645	Fauna C5	3,05
Date fieldwork:	25.03.2020	**Date of report:**	25.05 2020
Notes to other results (sediment, pH/Eh, oxygen)			nTOC from 20.1 to 22.1 mg/g TS. Copper 53.5 mg/kg dw at C1 Eh positive at all stations O_2-conditions were good throughout the water column.
Responsible for field work:	Snorri Gunnarsson	Signature:	

2 Introduction

2.1 Background and aim of study

Akvaplan-niva on behalf of Arctic Sea Farm hf completed a survey (type C) for a fish farming site Haukadalsbot in Dýrafjörður, Iceland (Figure 1).

The survey fulfils the requirements from the Icelandic authorities regarding bottom surveys referring to the standard ISO 12878 and the requirements for environmental bottom surveys (according to Vöktunaráætlun). An environmental study was simultaneously undertaken, with reference to chapter 5.0 in NS 9410:2016 which follows the methodology for C- study. A pre-survey (type C) is aimed at studying the environmental conditions of the bottom sediments along a transect sector from the fish farm that extends from the local, to the intermediate and to the regional impact zones. The main emphasis is on the study of the soft bottom fauna which is conducted according to standards ISO 5567-19:2004 and ISO 16665:2014. The obligatory parameters that are included in the survey are described in NS 9410:2016.

A classification or threshold values for this type of survey have not been developed Icelandic officials so it is not possible to apply the classification based on Norwegian threshold values to Icelandic conditions. We do however report the results with these same indexes with reference to Norwegian threshold values but it should be emphasized that some of these such as criterias regarding faunal indexes and values of copper are not developed according to Icelandic conditions. For further descriptions of these indexes see details in Appendix 1 and Miljødirektoratets Veileder 02:2018.

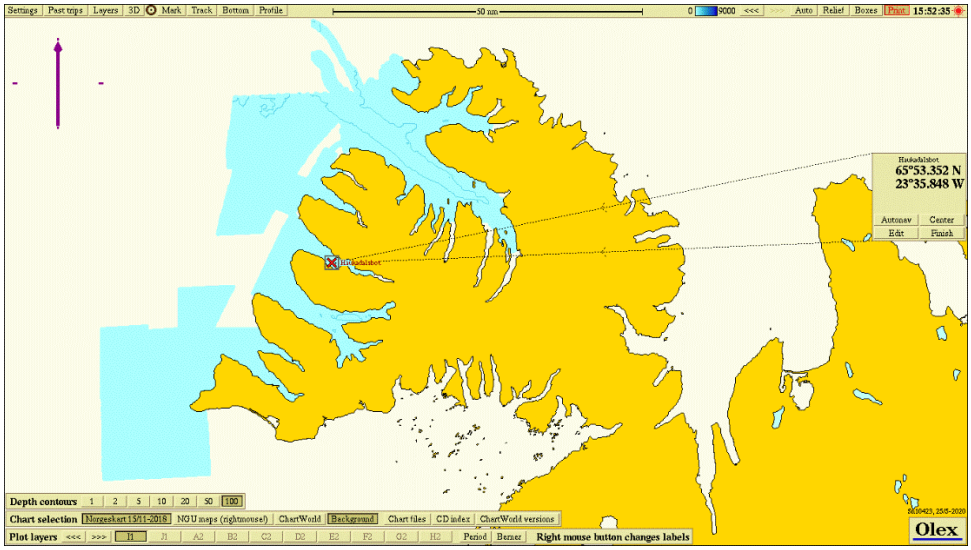

Figure 1. Overview of Vestfirðir Iceland with the farming site Haukadalsbót (red cross) in Dýrafjörður. The map coordinates for the midpoint of the farming site are given at right site of the picture.

2.2 Site operation and feed use

The Haukadalsbót site is has been in fallow state for over two years. Previously there have been farmed two generations of fish at the site. The planned fish farm at the site will be a two frame mooring system, each frame having 6 cages total 12 cages each with 160 m circumference. The planned timing for putting smolts into sea is May/June 2020. The first generation at Haukadalsbót was salmon farmed from August 2012 to late fall 2014. The second generation was farmed rainbow trout from spring 2015 until late 2016 early year 2017.

In Iceland, the MTB (maximum allowed biomass) limit is not given a site level as in Norway. The MTB limit determines how much live fish the holder of the permit can have standing in the sea at any time. In Iceland the allowed production is regulated at two levels, site level and

company level. For this site the estimated maximal standing biomass for the next generation is 4.000 tonnes, used as MTB here (Jóhannsdóttir, pers reference).

2.3 Previous surveys

Akvaplan-niva has not done any previous environmental surveys of the type C (NS 9410) at the Haukadalsbót site. There have been three transect monitoring-surveys at the site. In 2009 there was done a study at the site prior to any farming activity and describing the bottom type as soft muddy bottom with no smell and Shannon wiener index at two stations 2,46 and 1,86 and Pielou's evenness index (J) at 0.66 and 0.51 (Þórisson et al. 2010). Second transect-survey was done at the end of farming the first generation salmon at the site in 2014 (Gallo, 2015). Bottom at stations closest to the farm were described at black, muddy with small smell and SW diversity index was in the range from 2.76 – 4.23. The third transect monitoring-survey was done in November 2016 (Gallo, 2017) at the end of the farming of second generation (trout) at the site. The two stations closest to the cages were described having soft bottom, black in color and some smell. Redox values were positive for all stations. The fauna diversity was 3 or higher at all stations except for three stations closest to the farm (<= 30m).

3 Materials and methods

3.1 Professional program

The choice of study parameters, placement of sampling stations and other criteria for the study is based on descriptions in NS 9410 (C-surveys). An overview of the planned professional program is given in Table 1.

Akvaplan-niva is accredited for field work, analyses of samples and professional evaluation of results in accordance with applicable standards and guidelines (Veiledere). For implementation and follow through, the following standards and quality assurance systems were used:

- ISO 5667-19:2004: *Guidance on sampling of marine sediments.*
- ISO 16665:2014. *Water quality – Guidelines for quantitative sampling and sample processing of marine soft-bottom macro fauna.*
- NS 9410:2016. *Miljøovervåking av bunnpåvirkning fra marine oppdrettsanlegg.*
- Internal procedures. *Kvalitetshåndbok for Akvaplan-niva.*
- Veileder 02:2018. *Klassifisering av miljøtilstand i vann*. Norsk klassifiseringssystem for vann i henhold til Vannforskriften. Veileder fra Direktoratgruppen.
- M-608/2016. Grenseverdier for klassifisering av vann, sediment og biota. Miljødirektoratet, 2016.

Table 1. The planned professional program for the C-survey at Haukadalsbot, 2020. TOC = total organic carbon. Korn = grain size in sediment. TOM = total organic material. TN = total nitrogen. Cu = Copper. pH/Eh = acidity and redox potential.

Station	Type analyses/parameters
C1 (local impact zone)	Quantitative analyses of bottom fauna. TOC. Korn. TOM. TN. Cu. pH/Eh.
C2 (transect zone)	Quantitative analyses of bottom fauna. TOC. Korn. TOM. TN. 2 x Cu. pH/Eh.
C3 (transect zone)	Quantitative analyses of bottom fauna. TOC. Korn. TOM. TN. 2 x Cu. pH/Eh.
C4 (transect zone, deep area)	Quantitative analyses of bottom fauna. TOC. Korn. TOM. TN. 2 x Cu. Hydrography/O_2. pH/Eh.
C5 (transect zone)	Quantitative analyses of bottom fauna. TOC. Korn. TOM. TN. 2 x Cu. pH/Eh.

Field work was completed on 25.03.2020.

3.2 Placement of stations and local conditions

The number of stations were calculated with reference to the sites estimated maximal standing biomass for the first generation which is 4.000 tonnes (used as MTB here). According to the standard five sampling stations should be examined. Depth and position of the stations are given in Table 2 and shown in Figure 2. The stations were placed in accordance to the direction of the main oceanic current direction at 32 m depth (Akvaplan-niva current measurements un.published data).

Table 2. Depth for each station and distance between the nearest frame of the fish farm and sampling stations and coordinates for C-stations at Haukadalsbot, 2020.

Station	Depth, m	Distance from frame, m	Position N	W
C1	34	25	65º53.279	23º35.446
C2	26	500	65º53.068	23º35.089
C3	34	55	65º53.266	23º35.426
C4	35	125	65º53.299	23º35.120
C5	34	125	65º53.232	23º35.380

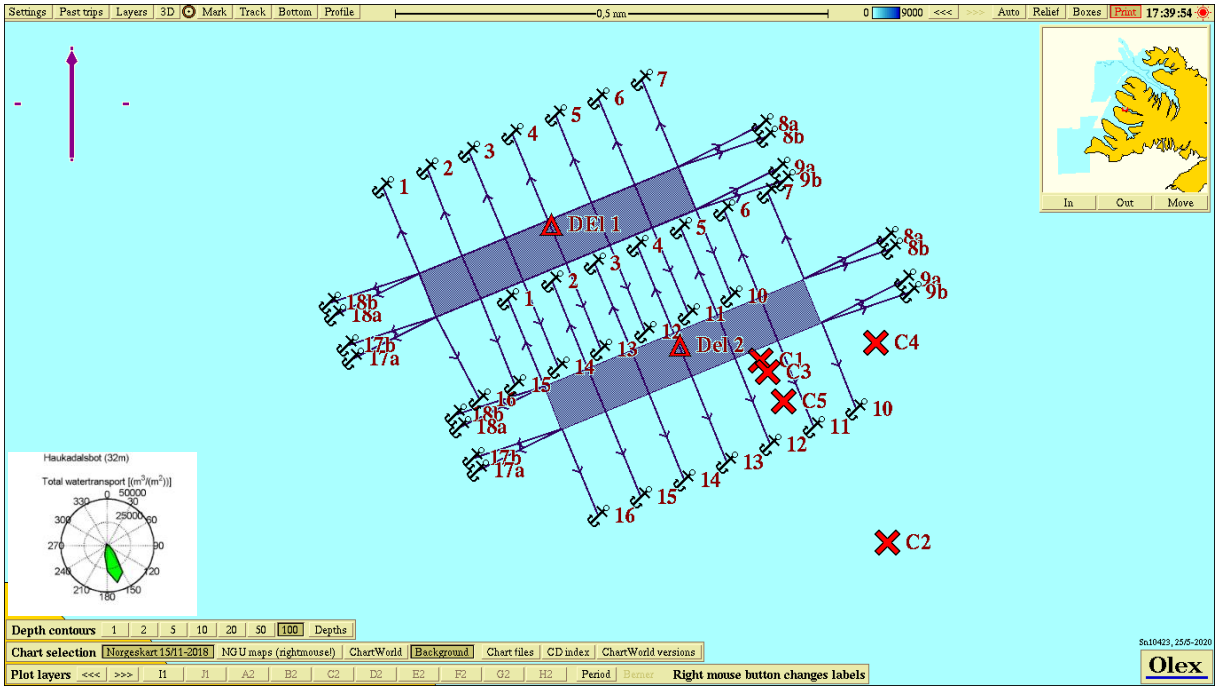

Figure 2. Map showing the sampling stations for the C-survey at Haukadalsbot, 2020. Current measurements used were from 32 m depth (Akvaplan-niva current measurements).

3.3 Hydrography and oxygen

At station C4, hydrographic measurements, salinity, temperature, density and oxygen saturation, were carried out for vertical profiles for from surface to bottom. These were carried out using a Sensordata CTDO 204 probe.

3.4 Soft bottom sampling and analyses

3.4.1 Fieldwork

The samples were collected with a 0.1 m^2 bottom grab (van Veen). The sample material was collected through inspection openings. Samples for TOC, TN and Cu were taken off from the top 1 cm layer of the sediment and for TOM and grain size analyses from the top 5 cm using a hollow pipe. Only samples with an undisturbed surface were approved. The samples were frozen for further processing in the laboratory.

3.4.2 Total organic material (TOM)

The amount of TOM in sediment was determined by weight loss after combustion at 495 °C. The percent weight loss was calculated. The reproducibility of the TOM analyses is checked during the analyses by using a standard household sediment that contains TOM with a known

level. Standard calcium carbonate was burned together with the samples as a control of the amount of carbonate that was not burned in the analyses process.

3.4.3 Total nitrogen (TN)

After drying the samples at 40°C, the amount of total nitrogen (TN) was quantified by electrochemical determination. The internal method is based on NS-EN 12260:2003 (Vannundersøkelse – Bestemmelse av bundet nitrogen (TNb) etter oksidasjon til nitrogenoksider).

3.4.4 Total organic carbon (TOC) and grain size

The proportion of fine material, the fraction less than 63 μm, was determined gravimetrically after wet-sieving of the samples. The results are presented as proportion of fine material on a dry weight basis.

After drying the samples at 40 °C, the content of total organic carbon (TOC) was determined by NDIR-detection in accordance with DIN19539:2016 (Investigation of solids – Temperature-dependent differentiation of total carbon (TOC_{400}, ROC, TIC_{900})). In order to classify the environmental conditions based on the content of TOC, the measured concentrations are normalized for proportion of fine substance (nTOC) using the equation: nTOC = TOC + 18 (1 – F), where TOC and F represent a measured TOC value and the proportion of fine substance (%) in the sample (Aure *et al.*, 1993).

The classification of the environment conditions for the sediment is based on normalized TOC, and was carried out according to "Veileder" 02:2018.

Classification of condition for organic content in the marine sediment.

nTOC, mg/g	< 20 I Very good	20 - 27 II Good	27 - 34 III Average	34 - 41 IV Bad	> 41 V Very bad

3.4.5 Metal analysis - copper (Cu)

The samples for metal analysis were freeze-dried before being placed in a microwave oven in a sealed Teflon container with concentrated ultrapure nitric acid and hydrogen peroxide. The concentration of copper (Cu) was determined by means of ICP-SFMS.

Classification of the environmental condition with respect to Cu is based on reference to the Norwegian Environmental Directorate's veileder M-608/2016.

Classification for copper in the marine sediment.

Cu mg/kg	< 20 Klasse I	20 - 84 Klasse II	20 - 84 Klasse III	84 - 147 Klasse IV	> 147 Klasse V

3.4.6 Redox- and pH measurements

At all the stations, a quantitative chemical examination of the sediment was carried out. Acidity (pH) and redox potential (Eh) were measured using electrodes and the YSI Professional Plus instrument. In accordance to the manual of the instrument, 200 mV was added to the measured ORP (the Oxydation Reduction Potential) value.

3.5 Soft bottom fauna investigation

3.5.1 About effect of organic material on bottom fauna

The emission of organic material from fish farms can contribute to the deterioration of conditions for many of the organisms living in the bottom sediment. Negative effects in the bottom fauna can best be assessed through quantitative bottom fauna analyses. Many soft

bottom species have low mobility, the fauna composition will largely reflect the local environmental conditions. Changes in the bottom fauna communities are a good indication of unwanted organic loads. Under natural conditions, the communities typically consist of many species. High number of species (diversity) is, amongst other things, dependent on favorable conditions for the fauna. However, moderate increases in organic load can stimulate the fauna and result in an increased number of species found. Larger organic loads can result in less favourable conditions where opportunistic species increase their individual numbers, while the species not suited are knocked out resulting in a reduced diversity of species. Changes in species diversity near emission points of feed and fecal matter can, to a large degree, be attributed to changes in organic content (from the feed and fecal matter) in the sediment.

3.5.2 Sampling and fixation

All the bottom fauna samples were taken with a 0.1 m^2 van Veen grab. Only grab samples where the grab was completely closed and the surface undisturbed were approved. After approval, the contents were washed through a 1 mm seive and the remaining material fixed with 4 % formalin with Bengal Rose dye added and neutralized with borax. In the laboratory, the animals were sorted from the remaining sediment.

3.5.3 Quantitative bottom fauna analysis

At all stations, two samples (replicates) were collected in accordance with guidelines in NS 9410 (2016). After sorting the sample material was processed quantitatively. The bottom fauna was identified to the lowest level possible, and quantified by specialists (taxonomists). The quantitative lists of species were analyzed statistically. See Appendix 1 for description of analysis methods. The following statistical methods were used to describe community structure and to assess the similarity between different communities:

- Shannon-Wiener diversity index (H')
- Hurlberts diversity index (ES_{100}) – expected number of species pr. 100 individuals
- Pielou's evenness index (J)
- Sensitivities index (Ømfintlighet) (ISI_{2012}), unsuitable at low individual/species number
- Sensitivity index (NSI)
- Composite index for diversity of species and sensitivity (NQI1)
- Sensitivities index which is included in NQI1 (AMBI)
- Normalized EQR (nEQR)
- Number of species plotted against the number of individuals in geometric arts classes
- Clusteranalyes
- The ten most dominant taxa per station (top-ten)

4 Results

4.1 Hydrography

The hydrographical profile for the deep station C4 in March 2020 is presented in Figure 3. Temperature was around 0.5 ºC from top to bottom, and oxygen saturation 93 % in the bottom layer.

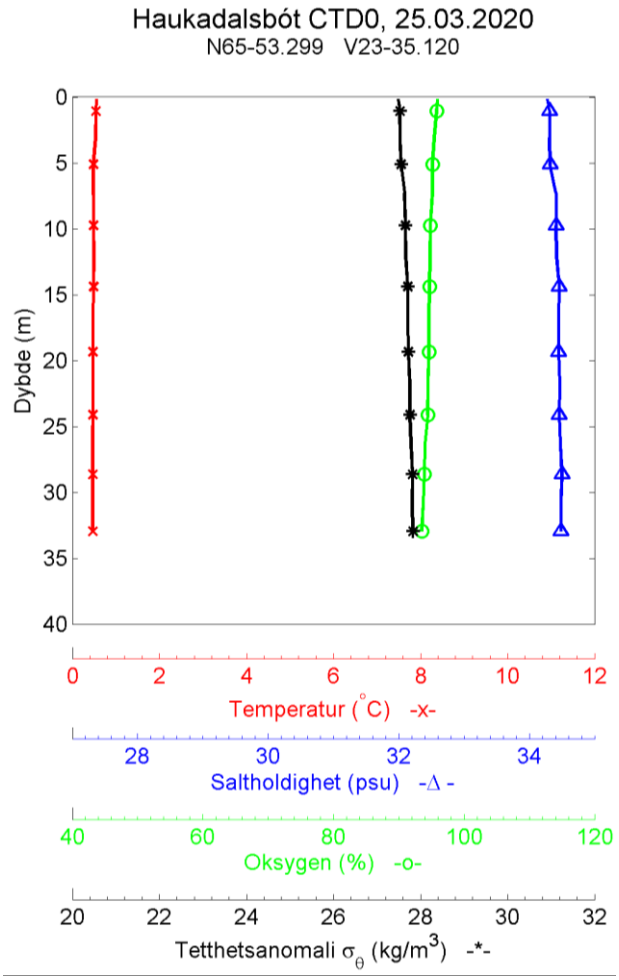

Figure 3. Vertical profiles. Temperature, salinity, density and oxygen at C4 at Haukadalsbot, 2020.

4.2 TOC, TOM, TN, C/N, grain size and pH/Eh

The level of total organic material (TOM), total organic carbon (TN), C/N-relationship, grain size distribution in sediment (Pelitt) and pH/Eh in the sediment is presented in Table 3.

TOM-levels varied from 5.9 to 8.5 %. TN-levels were low (2.1 – 4.1 mg/g) as was the C/N-ratio. TOC was relatively low at all stations and nTOC varied from 16.5 to 22.1 mg/g TS. The bottom sediments grain size were relatively fine with pelite ratio between 67.1 and 90.1 %.

Redox measurements (pH/Eh) gave a point of 0 for all the sampling stations according to Appendix D in NS 9410:2016.

Table 3. Sediment description, TOM (%), TOC (mg/g), TN (mg/g), C/N, grain size distribution (pelitt ratio % <0,063 mm) and pH/Eh. Haukadalsbot, 2020.

St.	Sediment description	TOM	TOC	nTOC*	TN	C/N	Pelitt	pH/Eh
C1	Muddy, no smell, grey/olive green color	8.3	18	22.1	3.3	5.5	79.6	7.8/ 280
C2	Muddy, no smell, grey/olive green color. Some crushed shell	5.9	11	16.5	2.1	5.0	67.1	7.7/ 266
C3	Muddy, no smell, grey/olive green color	7.9	19	21.6	4.1	4.6	85.5	7.8/ 296
C4	Muddy, no smell, grey/olive green color	8.5	18	20.1	3.9	4.7	90.1	7.9/ 157
C5	Muddy, no smell, grey/0live green color	7.9	17	20.6	3.5	4.9	82.1	7.7/ 265

4.3 Copper

The level of copper in the bottom sediments are shown in Table 4. The level of copper varied from 44.2 to 53.5 mg/kg.

Table 4. Copper (Cu), mg/kg dw. C Haukadalsbot, 2020.

St.	Cu repl. 1	Cu repl. 2
C1	53.5	-
C2	47.5	44.2
C3	51.6	52.2
C4	51.9	51.0
C5	52.5	52.4

4.4 Soft bottom fauna

4.4.1 Faunal indexes and ecological classification

Results from the quantitative soft bottom faunal analyses at the C-stations are presented in Table 5. Faunal index nEQR is presented without the density index (DI) in accordance with recommendations from the Norwegian Environment Agency (Miljødirektoratet).

The number of individuals varied from 1000 (C2) to 1730 (C5) and number of species from 41 (C3) to 66 (C2). The diversity H' varied from 3.00 to 3.42. At all stations, the overall index of nEQR was higher than 0.6. The nEQR values indicate good conditions and no disturbance of the communities.

J (Pielous evenness index) is a measure of how equally individuals are divided between species, and will vary between 0 and 1. A station with low-value has a "crooked" individual distribution between the species, indicating a disturbed bottom fauna community. The index varied from 0,59 to 0,63 which indicates a somewhat uneven distribution.

Table 5. Number of species and individuals pr. 0,2 m^2. H´ = Shannon-Wieners diversity index. ES100 = Hurlberts diversity index. NQI1 = overall index (diversity and sensitivity). ISI2012 = sensitivity index. NSI = sensitivity index. J = Pielous evenness index. AMBI = AZTI marine biotic index (part of NQI1). nEQR = normalized EQR (excl. DI). C-stations at Haukadalsbot, 2020.

St.	Numb. ind.	Numb. species	H´	ES_{100}	NQI1	ISI_{2012}	NSI	nEQR	AMBI	J
C1	1594	46	3,05	15,28	0,692	8,32	22,35	0,639	2,13	0,59
C2	1000	66	3,42	23,54	0,742	8,79	22,38	0,692	2,10	0,62
C3	1644	41	3,13	14,87	0,687	8,17	22,46	0,635	2,05	0,63
C4	1545	44	3,00	14,18	0,691	8,37	22,32	0,632	2,10	0,59
C5	1730	49	3,05	15,27	0,702	8,42	22,60	0,645	2,00	0,59

4.4.2 NS 9410 Evaluation of the bottom fauna at station C1 (local impact zone).

According to NS 9410 the classification of the environmental status in the local impact zone can also be evaluated based on the number of species and their dominance in the bottom faunal community (see chapter 8.6.2 in NS 9410:2016).

The soft bottom communities were classified to environmental condition 1 "Very good". The criteria for condition 1 is that there are at least 20 species/0,2 m^2 and that none of these are in numbers exceeding 65 % of the individuals (Table 6). The data for number of species and dominating taxa at station C1 is given in Table 5 and Table 7.

Table 6. Classification of the environmental status of the soft bottom fauna at station C1 at the Haukadalsbot site 2020.

Station	Site name	Num. species	Dominating taxa	Environmental condition-NS 9410
C1	Haukadalsbot	46	Ennucula tenuis - 29 %	1 – Very good

4.4.3 Geometric classes

Figure 4 shows the number of species plotted against the number of individuals, where the number of individuals is divided into geometric classes. For an explanation of the concept of geometric classes is given in Appendix 3.

All curves started relatively low (≥ 15 species) and stretched out in varying degrees towards higher classes. These did not give any clear indications of fauna condition.

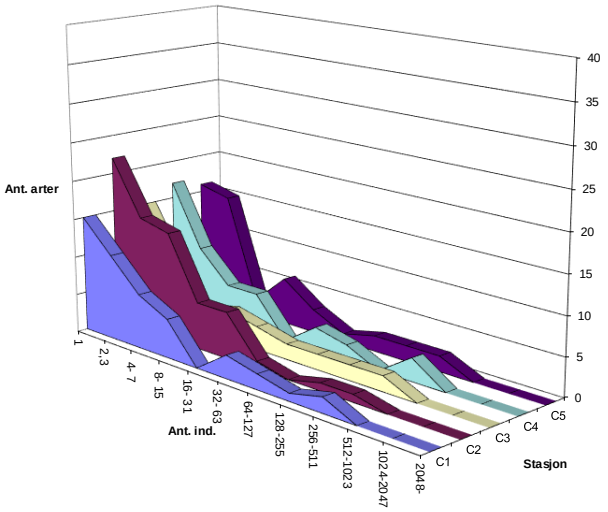

Figure 4. The soft bottom fauna shown as number of species against number of individuals pr. species in geometric classes. Haukadalsbot, 2020.

4.4.4 Cluster analyses

To investigate the similarity of the faunal composition between the sampling stations, the multivariate technique cluster analysis was used. The results of this are presented in dendrogram in Figure 5.

The fauna composition was more than 60 % similar for all stations.

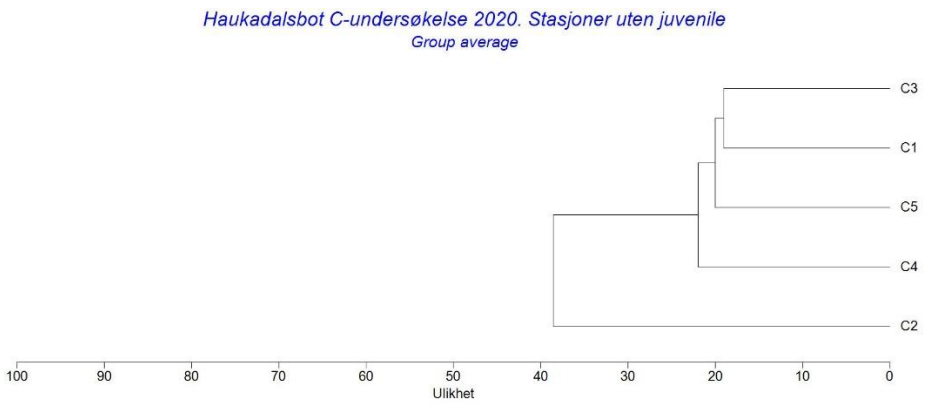

Figure 5. Cluster diagram for the soft bottom fauna at the C- sampling stations at Haukadalsbot, 2020.

4.4.5 Species composition

The main features of the species composition are shown in the form of a top ten species list from each station in Table 7.

In Rygg and Norling (2013) the species are divided into five ecological groups (EG) based on the value of the sensitivity index. These groups run from sensitive species (group I) to pollution indicators (group V).

At C2, the tolerant mussel dominated the fauna with 37 % of the individuals. The other most dominant species at the stations were a mixture of neutral and tolerant species.

At the other stations, the fauna were dominated by the neutral bivalve *Ennucula tenuis* with between 26 and 29 % of the individuals. The other most dominant species at the stations were a mixture of neutral, tolerant and opportunistic species.

No pollution indicators were recorded among the top-10 at any of the stations.

Table 7. Number of individuals, cumulative percentage and ecological group for the ten most dominant species on the C stations. Haukadalsbot, 2020.*

C1	Numb.	Cum.	EG	C2	Numb.	Cum.	EG
Ennucula tenuis	478	29 %	II	Abra nitida	385	37 %	III
Abra nitida	425	55 %	III	Ennucula tenuis	248	61 %	II
Galathowenia oculata	219	68 %	III	Parvicardium pinnulatum	60	67 %	Ik
Owenia sp.	110	75 %	II	Ophiuroidea indet. juv.	28	70 %	II
Sternaspis scutata	85	80 %	Ik	Axinopsida orbiculata	24	72 %	Ik
Nuculana pernula	59	83 %	II	Nuculana pernula	23	74 %	II
Ophiuroidea indet. juv.	58	87 %	II	Galathowenia oculata	17	76 %	III
Thyasira sarsii	38	89 %	IV	Levinsenia gracilis	16	78 %	II
Levinsenia gracilis	34	91 %	II	Polynoidae indet.	16	79 %	II
Axinopsida orbiculata	15	92 %	Ik	Sternaspis scutata	16	81 %	Ik
C3	**Numb.**	**Cum.**	**EG**	**C4**	**Numb.**	**Cum.**	**EG**
Ennucula tenuis	446	26 %	II	Ennucula tenuis	422	26 %	II
Abra nitida	405	50 %	III	Abra nitida	397	51 %	III
Galathowenia oculata	230	64 %	III	Galathowenia oculata	287	69 %	III
Owenia sp.	148	73 %	II	Nuculana pernula	101	75 %	II
Sternaspis scutata	90	78 %	Ik	Owenia sp.	78	80 %	II
Nuculana pernula	80	83 %	II	Ophiuroidea indet. juv.	65	84 %	II
Levinsenia gracilis	48	86 %	II	Sternaspis scutata	53	87 %	Ik
Ophiuroidea indet. juv.	47	88 %	II	Thyasira gouldi	46	90 %	IV
Thyasira gouldi	34	90 %	IV	Levinsenia gracilis	43	93 %	II
Thyasira sarsii	26	92 %	IV	Lagis koreni	13	93 %	IV

C5	Numb.	Cum.	EG
Ennucula tenuis	511	29 %	II
Abra nitida	462	56 %	III
Galathowenia oculata	213	68 %	III
Owenia sp.	171	77 %	II
Nuculana pernula	76	82 %	II
Sternaspis scutata	72	86 %	Ik
Levinsenia gracilis	35	88 %	II
Thyasira gouldi	25	89 %	IV
Ophiuroidea indet. juv.	20	91 %	II
Praxillella praetermissa	18	92 %	IV

*Ecological groups: EG I = sensitive species. EG II = neutral species. EG III = tolerant species. EG IV = opportunistic species. EG V = pollution indicator species. From Rygg and Norling, 2013. Ik = unidentified group.

4.5 Summary and conclusions – C-survey

4.5.1 Summary

The results from the environmental monitoring (type C) at Haukadalsbot in March 2020, can be summarized as follows:

- The hydrography measurements showed good oxygen conditions throughout the water column with 93 % saturation in the bottom layer in March 2020.
- The number of individuals varied from 1000 (C2) to 1730 (C5) and number of species from 41 (C3) to 66 (C2). The diversity H' varied from 3.00 to 3.42. At all stations, the overall index of nEQR was higher than 0.6. The nEQR values indicate good conditions and no disturbance of the communities.

- TOC was relatively low at all stations and nTOC varied from 16.5 to 22.1 mg/g TS. TN-levels were low (2.1 – 4.1 mg/g) as was the C/N-ratio. The level of copper varied from 44.2 to 53.5 mg/kg, but well within reported natural levels in Icelandic coastal areas (Egilsson *et al*. 1999). The bottom sediments were relatively fine with pelite ratio between 67.1 and 90.1 %. The redox measurements (pH/Eh) gave points 0 acc. Appendix D in NS 9410:2016 for all the stations.

4.5.2 Conclusion

The results from the monitoring at the farming site Haukadalsbot in March 2020 showed that the fauna might be considered as undisturbed at all stations (nEQR > 0.6). No pollution indicators were recorded among the top-10 at any of the stations. The sediments had relatively low levels of organic carbon at all stations. The level of copper varied from 44.2 to 53.5 mg/kg, which is within natural levels reported for bottom sediments around Iceland (Egilsson *et al*., 1999). The redox measurements (pH/Eh) gave points 0 acc. Appendix D in NS 9410:2016 for all the sampling stations. The oxygen saturation in March was good in the whole water column with 93 % in the bottom water.

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Appendix 1. Bunndyrstatistikk og artslister (in norwegian)

Diversitetsmål

Diversitet er et begrep som uttrykker mangfoldet i dyre- og plantesamfunnet på en lokalitet. Det finnes en rekke ulike mål for diversitet. Noen tar mest hensyn til artsrikheten (mål for artsrikheten), andre legger mer vekt på individfordelingen mellom artene (mål for jevnhet og dominans). Ulike mål uttrykker derved forskjellige sider ved dyresamfunnet. Diversitetsmål er "klassiske" i forurensningsundersøkelser fordi miljøforstyrrelser typisk påvirker samfunnets sammensetning. Svakheten ved diversitetsmålene er at de ikke alltid fanger opp endringer i samfunnsstrukturen. Dersom en art blir erstattet med like mange individer av en ny art, vil ikke det gjøre noe utslag på diversitetsindeksene.

Shannon-Wieners indeks (Shannon & Weaver, 1949) er gitt ved formelen:

$$H' = -\sum_{i=1}^{s} \frac{n_i}{N} \log_2 \left(\frac{n_i}{N} \right)$$

der n_i = antall individer av art *i* i prøven
N = total antall individer
s = antall arter

Indeksen tar hensyn både til antall arter og mengdefordelingen mellom artene, men det synes som indeksen er mest følsom for individfordelingen. En lav verdi indikerer et artsfattig samfunn og/eller et samfunn som er dominert av en eller få arter. En høy verdi indikerer et artsrikt samfunn.

Pielous mål for jevnhet (Pielou, 1966)

har følgende formel, der symbolene er som i Shannon-Wieners indeks

$$J = \frac{H'}{\log_2 s}$$

Hurlberts diversitetskurver

Grafisk kan diversiteten uttrykkes i form av antall arter som funksjon av antall individer. Med utgangspunkt i total antall arter og individer i en prøve søker man å beregne hvor mange arter man ville vente å finne i delprøver med færre individer. Diversitetsmålet blir derved uavhengig av prøvestørrelsen og gjør at lokaliteter med ulik individtetthet kan sammenlignes direkte. Hurlbert (1971) har gitt en metode for å beregne slike diversitetskurver basert på sannsynlighetsberegning.

ES_n er forventet antall arter i en delprøve på n tilfeldig valgte individer fra en prøve som inneholder total N individer og s arter og har følgende formel:

$$ES_n = \sum_{i=1}^{s} \left[1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right]$$

der N = total antall individ i prøven
N_i = antall individ av art *i*
n = antall individ i en gitt delprøve (av de N)
s = total antall arter i prøven

Plott av antall arter i forhold til antall individer

Artene deles inn i grupper/klasser etter hvor mange individer som er registrert i en prøve. Det vanlige er å sette klasse I = 1 individ pr. art, klasse II = 2-3 individer, klasse III = 4-7 individer, klasse IV = 8-15 individer, osv., slik at de nedre klassegrensene danner en følge av ledd på formen 2^x, x=0,1,2, … En slik følge kalles en geometrisk følge, derfor kalles klassene for geometriske klasser. Hvis antall arter innenfor hver klasse plottes mot klasseverdien på en lineær skala, vil det fremkomme en kurve som uttrykker individfordelingen mellom artene i samfunnet. Det har vist seg at i prøver fra upåvirkede samfunn vil det være mange arter med lavt individantall og få arter med høyt individantall, slik at vi får en entoppet, asymmetrisk kurve med lang "hale" mot høye klasseverdier. Denne kurven vil være godt tilpasset en log-normal fordelingskurve.

Ved moderat forurensing forsvinner en del av de individfattige artene, mens noen som blir begunstiget, øker i antall. Slik flater kurven ut, og strekker seg mot høyere klasser eller den får ekstra topper. Under slike forhold mister kurven enhver likhet med den statistiske log-normalfordelingen. Derfor kan avvik fra log-normalfordelingen tolkes som et resultat av en påvirkning/forurensing. Det har vist seg at denne metoden tidlig gir utslag ved miljøforstyrrelse. Ved sterk forurensning blir det bare noen få, men ofte svært tallrike arter tilbake. Log-normalfordelingskurven vil da ofte gjenoppstå, men med en lavere topp og spredt over flere klasser enn for uforstyrrede samfunn.

Faunaens fordelingsmønster

Variasjoner i faunaens fordelingsmønster over området beskrives ved å sammenligne tettheten av artene på hver stasjon. Til dette brukes multivariate klassifikasjons- og ordinasjons-analyser (Cluster og MDS).

Analysene i denne undersøkelsen ble utført ved hjelp av programpakken PRIMER v5. Inngangsdata er individantall pr. art, pr. prøve. Prøvene kan være replikater eller stasjoner. Det tas ikke hensyn til hvilke arter som opptrer. Forut for klassifikasjons- og ordinasjonsanalysene ble artslistene dobbelt kvadratrot-transformert. Dette ble gjort for å redusere avviket mellom høye og lave tetthetsverdier og dermed redusere eventuelle effekter av tallmessig dominans hos noen få arter i datasettet.

Clusteranalyse

Analysen undersøker faunalikheten mellom prøver. For å sammenligne to prøver ble Bray-Curtis ulikhetsindeks benyttet (Bray & Curtis, 1957):

$$d_{ij} = \frac{\sum_{k=1}^{n} \left| X_{ki} - X_{kj} \right|}{\sum_{k=1}^{n} (X_{ki} + X_{kj})}$$

der n = antall arter sammenlignet
X_{ki} = antall individ av art k i prøve nr. i
X_{kj} = antall individ av art k i prøve nr. j

Indeksen avtar med økende likhet. Vi får verdien 1 hvis prøvene er helt ulike, dvs. ikke har noen felles arter. Identiske arts- og individtall vil gi verdien 0. Prøver blir gruppert sammen etter graden av likhet ved å bruke "group-average linkage". Forholdsvis like prøver danner en gruppe (cluster). Resultatet presenteres i et trediagram (dendrogram).

Ømfintlighet (AMBI, ISI og NSI)

Ømfintligheten bestemmes ved indeksene ISI og AMBI. Beregning av ISI er beskrevet av Rygg (2002). Sensitivitetsindeksen AMBI (Azti Marin Biotic Index) tilordner en ømfintlighetsklasse (økologisk gruppe, EG): EG-1: sensitive arter, EG-II: indifferente arter, EG-III: tolerante arter, EG-IV: opportunistiske arter, EG-V: forurensningsindikerende arter. Sammensetningen av makroevertebratsamfunnet i form av andelen av økologiske grupper indikerer omfanget av en forurensningspåvirkning.

NSI er en sensitivitetsindeks som ligner AMBI, men er utviklet med basis i norske faunadata og ved bruk av en objektiv statistisk metode. En prøves NSI verdi beregnes ved gjennomsnittet av sensitivitetsverdiene av alle individene i prøven.

Sammensatte indekser (NQI1 og NQI2)

Sammensatte indekser NQI1 og NQI2 bestemmes både ut fra artsmangfold og ømfintlighet. NQI1 er brukt i NEAGIG (den nordøst-atlantiske interkalibreringen). De fleste land bruker nå sammensatte indekser av samme type som NQI1 og NQI2.

NQI1 indeksen er beskrevet ved hjelp av formelen:

NQI1 (Norwegian quality status, version 1) = [0.5* (1-AMBI/7) + 0.5*(SN/2.7)* (N/(N+5)]

Diversitetsindeksen SN = lnS/ln(lnN), hvor S er antall arter og N er antall individer i prøven

Referanser:

Bray, R.T. & J.T. Curtis, 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.*, 27:325-349.

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Statistikk resultater Haukadalsbot, 2020:

Antall arter og individer per stasjon

st.nr.	tot.	C1	C2	C3	C4	C5
no. ind.	7513	1594	1000	1644	1545	1730
no. spe.	89	46	66	41	44	49

Bunndyrindekser per replikat

st.nr.	tot.	C1_01	C1_02	C2_01	C2_02	C3_01	C3_02	C4_01	C4_02	C5_01	C5_02
no. ind.	7513	838	756	788	212	773	871	770	775	841	889
no. spe.	89	33	37	57	38	32	31	34	33	29	45
Shannon-Wiener:		2,9	3,2	3,2	3,6	3,2	3,0	3,0	3,0	2,9	3,2
Pielou		0,57	0,62	0,55	0,69	0,64	0,62	0,60	0,59	0,60	0,58
ES100		14	16	21	26	15	14	15	14	14	17
SN		1,83	1,91	2,13	2,17	1,83	1,80	1,86	1,85	1,77	1,99
ISI-2012		8,48	8,15	8,75	8,83	8,52	7,82	9,15	7,58	8,67	8,17
AMBI		2,129	2,132	2,158	2,037	2,033	2,066	2,134	2,071	2,064	1,943
NQI1		0,69	0,70	0,74	0,75	0,69	0,68	0,69	0,69	0,68	0,73
NSI		22,4	22,3	22,4	22,4	22,5	22,4	22,4	22,2	22,5	22,7

Bunndyrindekser, gjennomsnitt per stasjon

st.nr.		C1	C2	C3	C4	C5
Shannon-Wiener:		3,05	3,42	3,13	3,00	3,05
Pielou		0,59	0,62	0,63	0,59	0,59
ES100		15,3	23,5	14,9	14,2	15,3
SN		1,87	2,15	1,81	1,85	1,88
ISI-2012		8,32	8,79	8,17	8,37	8,42
AMBI		2,131	2,098	2,050	2,103	2,004
NQI1		0,69	0,74	0,69	0,69	0,70
NSI		22,35	22,38	22,46	22,32	22,60
Tilstandsklasse nEQR		0,639	0,692	0,635	0,632	0,645

Geometriske klasser

int.	C1	C2	C3	C4	C5
1	15	22	15	17	16
2,3	11	15	8	9	15
4- 7	7	14	3	5	2
8- 15	5	6	4	5	6
16- 31	0	6	3	0	3
32- 63	3	1	2	3	1
64-127	2	0	2	2	2
128-255	1	1	2	0	2
256-511	2	1	2	3	2
512-1023	0	0	0	0	0
1024-2047	0	0	0	0	0
2048-	0	0	0	0	0

Artsliste

Haukadalsbot C-undersøkelse

Rekke	Klasse	Art/Taxa	01	02	Sum
Stasjonsnr.: C1					
CNIDARIA					
	Anthozoa				
		Edwardsia sp.	1	1	2
NEMERTINI					
		Nemertea indet.	1	2	3
ANNELIDA					
	Polychaeta				
		Chaetozone setosa		1	1
		Cistenides hyperborea	2		2
		Diplocirrus longisetosus	1		1
		Eteone flava/longa	1		1
		Euchone papillosa	2	1	3
		Galathowenia oculata	117	102	219
		Lagis koreni		7	7
		Laphania boecki		2	2
		Levinsenia gracilis	14	20	34
		Maldane sarsi		1	1
		Mediomastus fragilis		1	1
		Myriochele malmgreni/olgae	4	2	6
		Nephtys ciliata	2	5	7
		Nephtys pente	1		1
		Owenia sp.	49	61	110
		Praxillella gracilis	2	5	7
		Praxillella praetermissa	6	8	14
		Prionospio steenstrupi		3	3
		Proclea graffii	3		3
		Rhodine gracilior		1	1
		Scalibregma inflatum		1	1
		Spio limicola	1	1	2
		Sternaspis scutata	34	51	85
		Syllis cornuta	1		1
CRUSTACEA					
	Malacostraca				
		Campylaspis sp.	1		1
		Dulichiidae indet.		1	1
		Eudorella sp.		1	1
		Leucon sp.	3	1	4
		Oedicerotidae indet.	2	3	5
MOLLUSCA					
	Caudofoveata				
		Caudofoveata indet.		1	1
	Bivalvia				
		Abra nitida	242	183	425
		Arcticca islandica		1	1
		Axinopsida orbiculata	9	6	15
		Bivalvia indet.	2		2
		Ennucula tenuis	266	212	478
		Macoma calcarea	6	5	11
		Mytilus edulis		2	2
		Nuculana pernula	32	27	59
		Parvicardium pinnulatum	2	2	4

Rekke	Klasse	Art/Taxa	01	02	Sum
		Thyasira gouldi	5	9	14
		Thyasira sarsii	20	18	38
		Yoldia hyperborea	3	7	10
ECHINODERMATA					
	Ophiuroidea				
		Ophiocten affinis	2	1	3
		Ophiura albida	1		1
		Ophiuroidea indet. juv.	32	26	58
		Maks:	266	212	478
		Antall:	34	38	47
		Sum:			1652

Stasjonsnr.: C2

NEMERTINI					
		Nemertea indet.	3	4	7
ANNELIDA					
	Polychaeta				
		Aphrodita aculeata	1	1	2
		Aricidea sp.	1	1	2
		Bradabyssa villosa	1		1
		Chaetozone setosa		2	2
		Cirratulus cirratus	1	1	2
		Cistenides hyperborea	12	1	13
		Eteone flava/longa	2	4	6
		Euchone papillosa		1	1
		Galathowenia oculata	17		17
		Gattyana cirrhosa		1	1
		Lagis koreni	6		6
		Laonice cirrata	5	2	7
		Laphania boecki		4	4
		Lepidonotus squamatus	1		1
		Levinsenia gracilis	8	8	16
		Maldane sarsi	6		6
		Mediomastus fragilis		5	5
		Melinna cristata	1		1
		Nephtys ciliata	1	3	4
		Nephtys paradoxa	2		2
		Nephtys pente	7	4	11
		Nicomache sp.	1		1
		Nothria conchylega	1		1
		Pholoe assimilis	1		1
		Polynoidae indet.	11	5	16
		Praxillella gracilis	4		4
		Praxillella praetermissa	1		1
		Prionospio steenstrupi	1	1	2
		Proclea graffii	1		1
		Rhodine gracilior	10		10
		Scalibregma inflatum	1	1	2
		Scoletoma fragilis		1	1
		Scoloplos armiger	2	4	6
		Spio limicola	1		1
		Sternaspis scutata	16		16
		Syllis cornuta	3		3
		Terebellides sp.	1	1	2

Rekke	Klasse	Art/Taxa	01	02	Sum
		Tharyx killariensis		1	1
CRUSTACEA					
	Malacostraca				
		Hyas sp.	1		1
		Leucon sp.	1		1
		Oedicerotidae indet.	3	1	4
		Pleurogonium spinosissimum	1		1
		Protomedeia fasciata	2	3	5
		Westwoodilla caecula	1	1	2
MOLLUSCA					
	Caudofoveata				
		Caudofoveata indet.	1		1
	Prosobranchia				
		Euspira sp. juv.	1		1
		Lepeta caeca	1		1
		Onoba semicostata	2		2
		Propebela sp.	1	1	2
	Opistobranchia				
		Doridina indet.		1	1
		Fionoidea indet.	1		1
		Retusa obtusa	2		2
	Bivalvia				
		Abra nitida	320	65	385
		Arcticca islandica	8	3	11
		Astarte sp. juv.	2		2
		Axinopsida orbiculata	23	1	24
		Bivalvia indet.	1	1	2
		Ennucula tenuis	204	44	248
		Macoma calcarea	8		8
		Mytilus edulis	1		1
		Nuculana pernula	19	4	23
		Parvicardium pinnulatum	35	25	60
		Thyasira gouldi	10	3	13
		Thyasira sarsii	6	1	7
		Thyasiridae indet.	4	1	5
ECHINODERMATA					
	Ophiuroidea				
		Ophiocten affinis	2		2
		Ophiura albida		1	1
		Ophiuroidea indet. juv.	24	4	28
	Holothuroidea				
		Psolus sp. juv.	1		1
		Maks:	320	65	385
		Antall:	61	39	70
		Sum:			1032

Stasjonsnr.: C3

NEMERTINI					
		Nemertea indet.	1		1
ANNELIDA					
	Polychaeta				
		Chaetozone setosa	1		1
		Dipolydora caulleryi		1	1
		Eteone flava/longa		1	1
		Euchone sp.		1	1
		Galathowenia oculata	126	104	230

Rekke	Klasse	Art/Taxa	01	02	Sum
		Lagis koreni	5	11	16
		Laonice cirrata	1		1
		Laphania boecki	1	1	2
		Levinsenia gracilis	20	28	48
		Maldane sarsi		1	1
		Mediomastus fragilis	1		1
		Melinna cristata	1	2	3
		Nephtys ciliata	4	3	7
		Owenia sp.	82	66	148
		Praxillella gracilis		1	1
		Praxillella praetermissa	14	10	24
		Prionospio steenstrupi	2	1	3
		Proclea graffii		2	2
		Rhodine gracilior	5		5
		Scoloplos armiger		1	1
		Spio limicola	1	1	2
		Sternaspis scutata	50	40	90
		Syllides longocirratus	1		1
		Syllis cornuta	1	1	2
		Terebellides sp.	1		1
CRUSTACEA					
	Malacostraca				
		Eudorella sp.	1		1
		Leucon sp.	4	5	9
		Oedicerotidae indet.	3	2	5
		Crustacea indet. juv.		1	1
MOLLUSCA					
	Bivalvia				
		Abra nitida	175	230	405
		Arcticca islandica		1	1
		Axinopsida orbiculata	9	1	10
		Ennucula tenuis	187	259	446
		Kurtiella bidentata	1		1
		Macoma calcarea	4	9	13
		Nuculana pernula	36	44	80
		Parvicardium pinnulatum		2	2
		Thyasira gouldi	21	13	34
		Thyasira sarsii	7	19	26
		Yoldia hyperborea	4	10	14
ECHINODERMATA					
	Ophiuroidea				
		Ophiocten affinis	3		3
		Ophiuroidea indet. juv.	18	29	47
		Maks:	187	259	446
		Antall:	33	33	43
		Sum:			1692

Stasjonsnr.: C4

SIPUNCULIDA					
		Sipuncula indet.	1		1
ANNELIDA					
	Polychaeta				
		Chaetozone setosa	1	1	2
		Eteone flava/longa		1	1

Rekke	Klasse	Art/Taxa	01	02	Sum
		Euchone papillosa	2		2
		Galathowenia oculata	140	147	287
		Lagis koreni	2	11	13
		Levinsenia gracilis	25	18	43
		Mediomastus fragilis		1	1
		Myriochele malmgreni/olgae	1		1
		Mystides caeca		1	1
		Nephtys ciliata	4	2	6
		Nephtys paradoxa		1	1
		Nephtys pente	1		1
		Owenia sp.	41	37	78
		Pholoe assimilis		1	1
		Praxillella gracilis	3		3
		Praxillella praetermissa	4	7	11
		Prionospio steenstrupi	2	1	3
		Proclea graffii	1	1	2
		Scoloplos armiger		1	1
		Spio limicola	1		1
		Sternaspis scutata	31	22	53
		Terebellides sp.	1		1
CRUSTACEA					
	Malacostraca				
		Dulichiidae indet.	2		2
		Eudorella sp.	1		1
		Leucon sp.	3	2	5
		Oedicerotidae indet.	2	2	4
MOLLUSCA					
	Caudofoveata				
		Caudofoveata indet.	1		1
	Opistobranchia				
		Retusa obtusa		1	1
	Bivalvia				
		Abra nitida	204	193	397
		Arcticca islandica	3	1	4
		Axinopsida orbiculata	8	1	9
		Crenella decussata	1		1
		Ennucula tenuis	206	216	422
		Kurtiella bidentata		1	1
		Macoma calcarea		1	1
		Nuculana pernula	41	60	101
		Parvicardium pinnulatum	1	1	2
		Thyasira gouldi	20	26	46
		Thyasira sarsii	5	7	12
		Thyasiridae indet.	2	1	3
		Yoldia hyperborea	5	6	11
ECHINODERMATA					
	Ophiuroidea				
		Ophiocten affinis	4	1	5
		Ophiura albida		2	2
		Ophiuroidea indet. juv.	34	31	65
		Maks:	206	216	422
		Antall:	35	34	45
		Sum:			1610

Stasjonsnr.: C5

NEMERTINI

Rekke	Klasse	Art/Taxa	01	02	Sum
		Nemertea indet.	1	2	3
SIPUNCULIDA					
		Sipuncula indet.		1	1
ANNELIDA					
	Polychaeta				
		Chaetozone setosa		1	1
		Dipolydora coeca	1		1
		Eteone flava/longa		1	1
		Euchone papillosa	1	2	3
		Galathowenia oculata	110	103	213
		Goniada maculata		1	1
		Lagis koreni	3	8	11
		Laonice cirrata		1	1
		Laphania boecki		2	2
		Levinsenia gracilis	17	18	35
		Maldane sarsi	1	2	3
		Maldanidae indet.		1	1
		Melinna cristata		2	2
		Myriochele malmgreni/olgae		2	2
		Nephtys ciliata	6	5	11
		Nephtys pente		1	1
		Owenia sp.	57	114	171
		Pholoe baltica		1	1
		Praxillella gracilis	1		1
		Praxillella praetermissa	7	11	18
		Prionospio steenstrupi	2	1	3
		Proclea graffii	1	1	2
		Rhodine gracilior		3	3
		Sternaspis scutata	40	32	72
		Syllis cornuta	1	2	3
		Terebellides sp.		1	1
CRUSTACEA					
	Malacostraca				
		Dulichiidae indet.		2	2
		Eudorella sp.		2	2
		Leucon sp.	1	2	3
		Lysianassidae indet.		1	1
		Oedicerotidae indet.		3	3
		Protomedeia fasciata	1		1
MOLLUSCA					
	Opistobranchia				
		Odostomia unidentata		1	1
	Bivalvia				
		Abra nitida	230	232	462
		Arcticca islandica		1	1
		Astarte montagui	1		1
		Astarte sp. juv.		1	1
		Axinopsida orbiculata	11	4	15
		Ennucula tenuis	266	245	511
		Macoma calcarea	10	6	16
		Nuculana pernula	42	34	76
		Parvicardium pinnulatum	4	2	6
		Thyasira flexuosa		6	6
		Thyasira gouldi	12	13	25

Rekke	Klasse	Art/Taxa	01	02	Sum
		Thyasira sarsii	7	5	12
		Thyasiridae indet.	1	1	2
		Yoldia hyperborea	3	5	8
ECHINODERMATA					
	Ophiuroidea				
		Ophiocten affinis	3	5	8
		Ophiuroidea indet. juv.	13	7	20
		Maks:	266	245	511
		Antall:	30	47	51
		Sum:			1751
				TOTAL:	***Maks:*** 511
					Sum: 7737

Akvaplan-niva AS, 9296 Tromsø
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Appendix 2. Analyserapport – Geokjemiske analyser (in norwegian)

Framsenteret
Postboks 6606 Langnes, 9296 Tromsø
Foretaksnr.: NO 937 375 158 MVA
Tel: 77 75 03 00
E-post: kjemi@akvaplan.niva.no

ANALYSERAPPORT
Sedimentprøver

Kunde:	**Arctic Sea Farm hf**
Kunde referanse:	**Haukadalsbot C og B undersøkelse brakklegging 2020**
Kontaktperson kunde:	
e-post:	
Kontaktperson Akvaplan-niva:	Snorri Gunnarsson
Dato:	14.05.2020
Rapport nr.:	**62024**
Analyseparameter(e):	Korn, TOM, TOC, TN, Cu
Kontaktperson:	Oda S. Bye Wilhelmsen
Analyseansvarlig:	(sign.)
Underskriftsberettiget:	Digitally signed by Lisa Torske Date: 2020.05.14 14:02:43 +02'00' (sign.)

Prøvene ble sendt/levert til Akvaplan-Niva AS av oppdragsgiver, og merket som angitt i tabellen på side 2.
Resultater av analysene er gitt fra side 3.

MERKNADER:
Prøve C2 inneholder skjellbiter større enn 15 mm som ikke er inkludert i kornanalysen. Skjellbitene ville utgjøre 5.2 vekt% av den totale prøven.

Lab-id.	Kundens id.	Materiale	Mottatt lab	Parametere	Analyse-periode
62024/C1	C1	Frossent	21.04.2020	Korn, TOM, TOC, TN, Cu	23.04.20 - 11.05.20
62024/C2	C2	Frossent	21.04.2020	Korn, TOM, TOC, TN, 2x Cu	23.04.20 - 11.05.20
62024/C3	C3	Frossent	21.04.2020	Korn, TOM, TOC, TN, 2x Cu	23.04.20 - 11.05.20
62024/C4	C4	Frossent	21.04.2020	Korn, TOM, TOC, TN, 2x Cu	23.04.20 - 11.05.20
62024/C5	C5	Frossent	21.04.2020	Korn, TOM, TOC, TN, 2x Cu	23.04.20 - 11.05.20

Følgende analysemetoder er benyttet

Parameter	Metodereferanse
Kornfordeling (splitt i to)	Sikting, basert på Bale, A.J. & Kenny, A.J. 2005. Sediment analysis and seabed characterisation . In: Eleftheriou,A; McIntyre, A.D. "Methods for the study of marine benthos", 3rd ed. Blackwell Science, Oxford, UK. ISBN 0-632-05488-3, pp. 43-86
Totalt organisk materiale-TOM	Intern metode basert på NS 4764:1980
Totalt organisk karbon-TOC	NDIR-deteksjon. Intern metode basert på DIN 19539:2016
Totalt bundet nitrogen - Total-N	Elektrokjemisk deteksjon. Intern metode basert på NS-EN 16168:2012. MERK: ved TOC-verdier større enn ca 60 mg/g TS kan TN-resultater bli underestimert
Kobber-Cu / Kadmium-Cd (utført av underlev.)	EPA 200.7, ISO 11885, EPA 6010 og SM 3120

Resultater

Kundens id.:	TOC mg/g TS	TN mg/g TS	TOM % TS	Pelitt vekt%	> 0,063 mm vekt%	Cu* mg/kg TS	Cu* mg/kg TS	N TOC mg/g TS	C/N
C1	18	3,3	8,3	79,6	20,4	53,5	ia	22,1	5,5
C2	11	2,1	5,9	67,1	32,9	47,5	44,2	16,5	5,0
C3	19	4,1	7,9	85,5	14,5	51,6	52,2	21,6	4,6
C4	18	3,9	8,5	90,1	9,9	51,9	51,0	20,1	4,7
C5	17	3,5	7,9	82,1	17,9	52,5	52,4	20,6	4,9

* Analysen er utført av ALS Laboratory Group, ALS Czech Republic s.r.o, Na Harfě 9/336, Praha, Tsjekkia

Akkreditering: Czech Accreditation Institute, labnr. 1163

N TOC (Normalisert TOC) = målt TOC mg/g + 18*(1-F), der F=andel finstoff (pelitt) gitt ved %pelitt/100.

ia = ikke analysert

Tilstandsklassifisering for organisk innhold i marine sedimenter ihht. Veileder 02:2018:

Normalisert TOC, mg/g TS	< 20	20-27	27-34	34-41	> 41
	I Svært god	II God	III Moderat	IV Dårlig	V Svært dårlig

Tilstandsklassifisering for kobber (Cu) i marine sedimenter (grenseverdier fra M-608/2016):

Cu, mg/kg TS	< 20	20-84	84 - 147	> 147
	Klasse I	Klasse II/III	Klasse IV	Klasse V