C-survey at Hvannadalur (fallow period), September 2022

Arctic Sea Farm ehf

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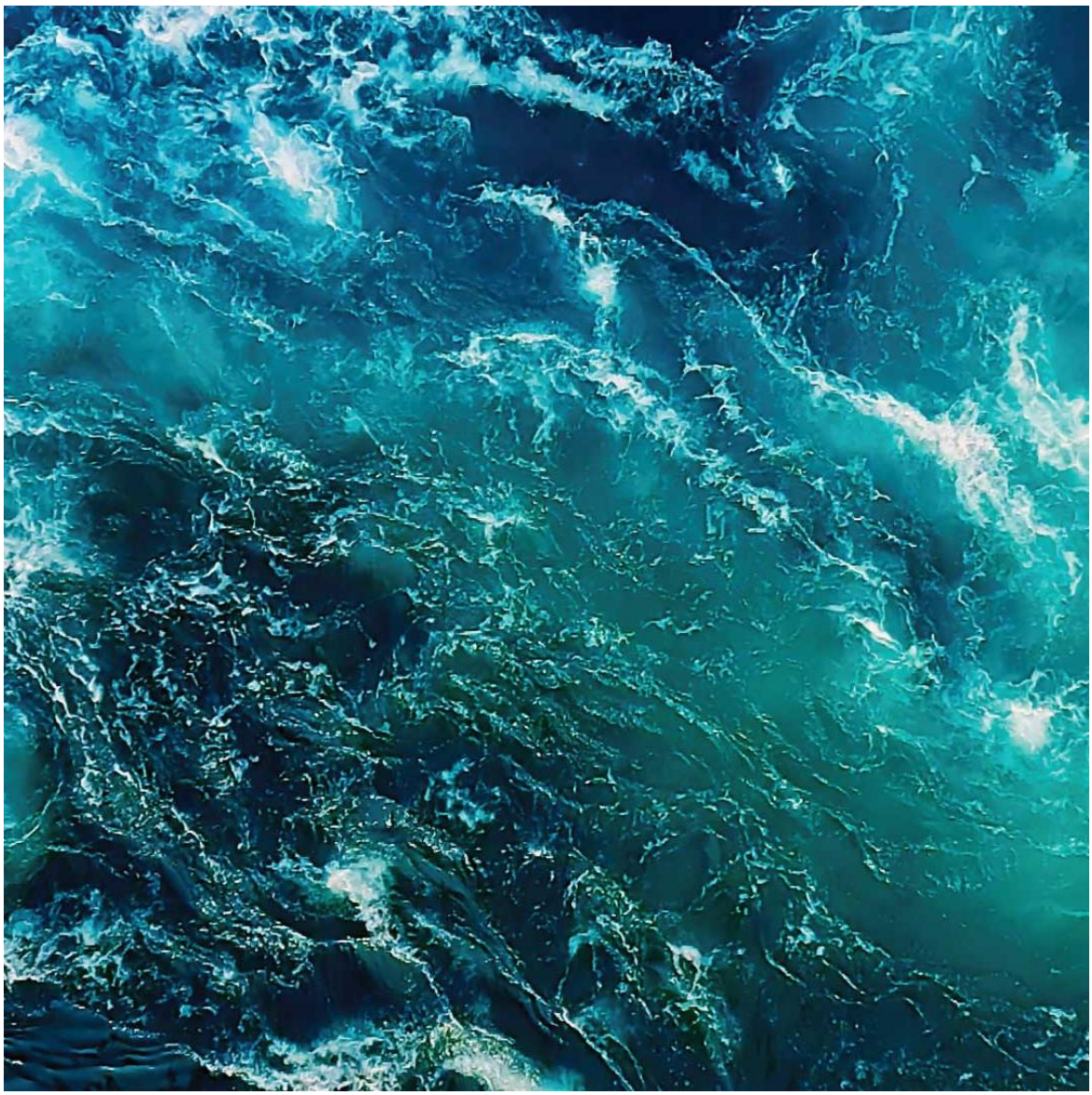

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Arctic Sea Farm ehf. C-Survey at Hvannadalur (fallow period), September 2022.

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Summary

The results from the monitoring at the farming site Hvannadalur in September 2022 showed that the sediment was somewhat loaded with organic carbon and the copper concentrations were within reported natural levels for bottom sediment around Iceland (Egilsson *et al.*, 1999).

No load effect was recorded in the fauna and faunal index nEQR which showed good conditions and no impact at any of the stations (> 0.6). The diversity index H ' was just below 3 at C3 and C5 and above 3 at the other stations and ranged from 2.54 (C5) to 3.95 (C1). The NS 9410:2016-assessment of the community in the local impact zone (C1) showed environmental condition 1 (Very good). No pollution indicators were recorded among the top-10 species on any of the stations.

The redox measurements (pH/Eh) gave point 0 acc. Appendix D in NS 9410:2016 for all the sampling stations. The oxygen saturation in September was good in the whole water column with 76 % in the bottom water.

Approval

Project leader

Kamila Sztybor
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Quality control

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Preface

Akvaplan-niva carried out a type C (NS 9410:2016) environmental survey at the Hvannadalur site. It includes pH/redox measurements (Eh), hydrography, geochemical analyses, and analyses of the bottom fauna from six stations at the fish farming site. The following personnel contributed:

Snorri Gunnarsson	Akvaplan-niva	Field work, report, project leader.
Hans-Petter Mannvik	Akvaplan-niva	Identification of bottom fauna (Echinodermata). Report, professional assessments, and interpretations.
Kamila Sztybor	Akvaplan-niva	QA report, professional assessments, and interpretations.
Roger Velvin	Akvaplan-niva	Identification of bottom fauna (Various taxa).
Rune Palerud	Akvaplan-niva	Identification of bottom fauna (Crustaceans). Statistics.
Thomas Hansen	Akvaplan-niva	Identification of bottom fauna (Polychaeta and Mollusca).
Anne T. Aasen	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 Arctic Sea Farm ehf and Steinunn G. Einarsdóttir for good cooperation

Accreditation information:

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

NORSK AKKREDITERING TEST 079

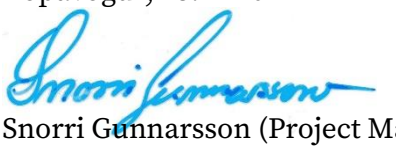
Akvaplan-niva AS is accredited under NS-EN ISO/IEC 17025 by Norwegian Accreditation for field sampling of sediments and fauna, analyses of TOC, TOM, TN, particle size and macrofauna, and for professional evaluations and interpretations. Our Accreditation number is TEST 079.

Czech Accreditation Institute (Lab nr 1163)

ALS Laboratory Group is accredited by the Czech Accreditation Institute (Lab nr 1163) for copper analyses.

Non-accredited services: Hydrographical measurements and mapping of bottom topography (Olex).

Kópavogur, 15.12 2022



Snorri Gunnarsson (Project Manager)

1 Data Summary

Client information			
Report title:	C-Survey at Hvannadalur (fallow period), September 2022.		
Report nr.	2022 64286.01	Site:	Hvannadalur
Municipality:		Map Coordinates (construction):	65°39,222 N 24°00,891 V
MTB permitted:	6.400 ton	Operations manager:	Ísak Óskarsson
Client:	Arctic Sea Farm ehf		

Biomass/production status at time of survey (05.09.2022)			
Fish group:	A. 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):	26.03 2022 - 05.09 2022	New location:	

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 (impact zone)	0.668	Fauna C1 (impact zone)	3.95
Fauna C2	0.638	Fauna C2	3.06
Fauna C3	0.622	Fauna C3	2.71
Fauna C4 (deep area)	0.709	Fauna C4 (deep area)	3.44
Fauna C5	0.618	Fauna C5	2.54
Fauna C6	0.636	Fauna C6	3.00
Date fieldwork:	(05.09.2022	**Date of report:**	13.12 2022
Notes to other results (sediment, pH/Eh, oxygen)			nTOC from 33.6 to 49.5 mg/g TS. Copper 46.2 at C1 Eh positive at all stations O_2-conditions were good throughout the water column.
Responsible for field work:	Signature: 	Project manager Snorri Gunnarsson	Signature 

2 Introduction

2.1 Background and aim of the study

On behalf of Arctic Sea Farm ehf, Akvaplan-niva completed a survey (type C) for the fish farming site at Hvannadalur (Figure 1). The survey fulfils the requirements of the Icelandic authorities for bottom surveys according to 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 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 by Icelandic officials so it is not possible to strictly 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 NSI) are developed according to Norwegian conditions. For further descriptions of these indexes see details in Appendix 1 and Miljødirektoratets Veileder 02:2018.

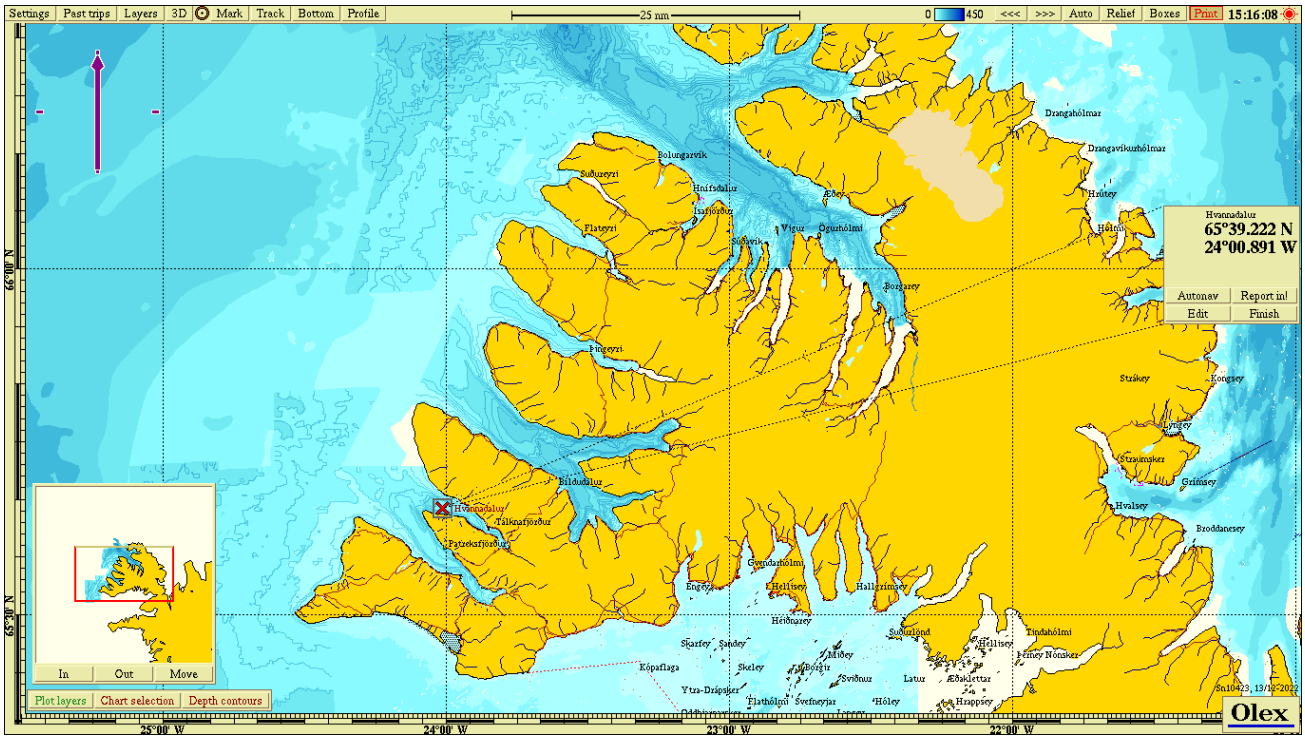


Figure 1 Overview of Vesfjords Iceland with the farming site Hvannadalur (red cross) in Tálknajörður. The map coordinates for the midpoint of the farming site are given to the right.

2.2 Site operation and feed use

The plant has a frame mooring with a total of twelve 160 m circumference cages in a 2 x 6 configuration, in two independent mooring systems. Hvannadalur had been in a fallow state since

26.03 2022 (about 24 weeks until date of sampling). Previously there had been produced one generation of Atlantic salmon at the site that started summer/fall 2019.

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 one 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 6.400 tonnes, used as MTB here (Einarsdóttir, pers reference).

2.3 Previous surveys

An overview of previous surveys carried out at Hvannadalur is shown in Table 1.

Table 1: Previous surveys at Hvannadalur.

Survey date	Report reference (author, year)	Production (tonnes)	Type of survey
05.09 2022	Mannvik and Gunnarsson, 2021	0	Fallow period
09.04 2021	Mannvik and Gunnarsson, 2021	5.221	Max biomass
15.07 2019	Mannvik and Gustavsson, 2019	0	Pre-survey

3 Materials and methods

3.1 Survey 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 2.

Akvaplan-niva is accredited for field work, analyses of samples and for the 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. *Quality Manual for Akvaplan-niva.*
- Veileder 02:2018. *Klassifisering av miljøtilstand i vann*. Norsk klassifiseringssystem for vann i henhold til Vannforskriften. Veileder fra Direktoratgruppen.

Table 2: Survey program for the C-survey at Hvannadalur, 2022. TOC = total organic carbon. GSA = grain size analysis 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. GSA, TOM. TN. Cu. pH/Eh.
C2 (transect zone outer)	Quantitative analyses of bottom fauna. TOC. GSA, TOM. TN. pH/Eh.
C3 (transect zone)	Quantitative analyses of bottom fauna. TOC. GSA, TOM. TN. pH/Eh.
C4 (transect zone, deep area)	Quantitative analyses of bottom fauna. TOC. GSA, TOM. TN. Hydrography/O_2. pH/Eh.
C5 (transect zone)	Quantitative analyses of bottom fauna. TOC. GSA, TOM. TN. pH/Eh.
C6 (transect zone)	Quantitative analyses of bottom fauna. TOC. GSA, TOM. TN. pH/Eh.

Field work was completed on 05.09.2022.

Placement of stations and local conditions

The number of stations was calculated with reference to the sites estimated maximal standing biomass for the next generation which is 6.400 tonnes (used as MTB here). According to the standard six sampling stations should be examined. Depth and position of the stations are given in Table 3 and shown in Figure 2. The stations are placed along the direction of the main oceanic current direction (SSE) measured at 48 m (Hermansen 2020).

Table 3: Depth, distance between the nearest frame of the fish farm and sampling stations and coordinates for C-stations at Hvannadalur, 2022.

Station	Depth, m	Distance from frame, m	Position	
			N	W
C1	58	25	65°39.210	24°00.493
C2	58	500	65°39.067	23°59.974
C3	58	55	65°39.352	24°00.049
C4	58	85	65°39.190	24°00.429
C5	58	150	65°39.171	24°00.365
C6	58	250	65°39.134	24°00.262

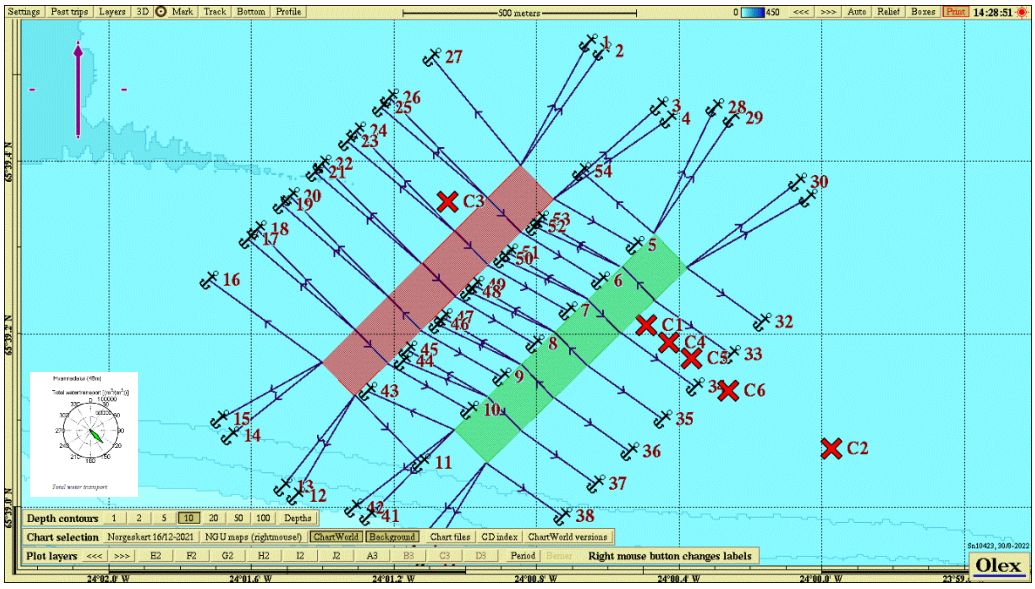


Figure 2. Map showing the sampling stations for the C-survey at Hvannadalur, 2022. Current measurements used were from 48 m depth (Hermansen, 2020).

3.2 Hydrography and oxygen

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

3.3 Soft bottom sampling and analyses

3.3.1 Fieldwork

Sediment 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 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 used. The samples were frozen prior to further processing in the laboratory.

3.3.2 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 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.

3.3.3 Total nitrogen (TN)

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

3.3.4 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})). To classify the environmental conditions based on the content of TOC, the measured concentrations are normalized for the 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).

3.3.5 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.

3.3.6 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 with the manual of the instrument, 200 mV was added to the measured ORP (the Oxidation Reduction Potential) value.

3.4 Soft bottom fauna investigation

3.4.1 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, that is dependent on favourable 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 faecal matter can, to a large degree, be attributed to changes in organic content (from the feed and faecal matter) in the sediment.

3.4.2 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. The contents were washed through a 1 mm sieve and the remaining material fixed with 4 % formalin with Bengal Rose dye added and then neutralized with borax. In the laboratory, the animals were sorted from the remaining sediment.

3.4.3 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 taxonomic level possible and quantified by specialists (taxonomists). The quantitative lists of species were statistically analysed. 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
- Cluster analyses
- The ten most dominant taxa per station (top-ten)

4 Results

4.1 Hydrography and oxygen

The hydrographical profile for the deep station C4 in September 2022 is presented in Figure 3.

Temperature was between 10.2 °C and 9.9 °C from top to bottom, with oxygen saturation 101 % in the upper layer and 76 % in the bottom layer.

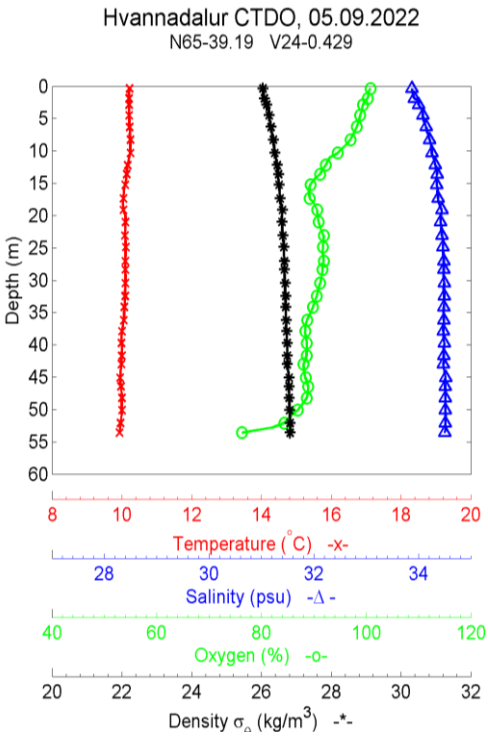


Figure 3. Vertical profiles. Temperature, salinity, density, and oxygen at C4 at Hvannadalur, 2022.

4.2 Sediment

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

Levels of total organic material (TOM), total organic carbon (TOC), total nitrogen (TN), C/N-relationship, grain size distribution in sediment (pelite) and pH/Eh in the sediment are presented in Table 4.

TOM-levels varied from 11.6 to 13.3 %. TN-levels were relatively low (4.7 – 7.6 mg/g) as was the C/N-ratio. TOC was rather high at all stations and nTOC varied from 33.6 to 49.5 mg/g TS. The bottom sediments grain size was moderately fine with a pelite ratio ranging from 60.5 to 80.7 %.

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

Table 4. Sediment description, TOM (%), TOC (mg/g), TN (mg/g), C/N, grain size distribution (pelite ratio % <0,063 mm) and pH/Eh. Hvannadalur, 2022.

St.	Sediment description	TOM	TOC	nTOC	TN	C/N	Pelite	pH/Eh
C1	Olive green clay	12.6	42	49.5	4.7*	9.0	60.5	7,7/ 172
C2	Olive green clay	12.5	30	33.6	5.3*	5.6	78.4	7,8/ 187
C3	Olive green clay	11.6	31	35.6	5.8*	5.3	73.5	7,9/ 264
C4	Olive green clay	11.9	36	39.2	5.5*	6.4	80.7	7,9/ 175
C5	Olive green clay, some black dead algae	12.1	30	34.6	7.6*	4.0	75.7	7,9/ 213
C6	Olive green clay, some black dead algae	13.3	35	39.3	6.5*	5.3	75.8	7,8/ 252

*Not accredited results.

4.2.2 Copper

Level of copper in bottom sediment at is shown in Table 5. The level of copper was 46.2 mg/kg.

Table 5. Copper (Cu), mg/kg DS. Hvannadalur, 2022.

St.	Cu
C1	46.2

4.3 Soft-bottom fauna

4.3.1 Faunal indices

Results from the quantitative soft bottom faunal analyses at the C-stations are presented in Table 6.

The number of individuals varied from 352 (C1) to 807 (C2) and number of species from 34 (C3) to 47 (C1). The diversity H' varied from 2.54 to 3.95. 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 0.53 to 0.78 which indicates a somewhat uneven distribution at some stations.

Table 6. Number of species and individuals pr. 0,2 m^2. H´ = Shannon-Wiener's 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 Hvannadalur, 2022.

St.	No. of individuals.	No. of species	H´	ES_{100}	NQI1	ISI_{2012}	NSI	nEQR	AMBI	J
C1	352	47	3.95	27	0.725	7.22	21.5	0.668	2.28	0.78
C2	807	40	3.06	16	0.711	8.07	21.5	0.638	1.78	0.65
C3	745	34	2.71	16	0.691	7.76	22.4	0.622	2.04	0.57
C4	475	43	3.44	48	0.733	7.30	21.2	0.709	2.06	0.70
C5	713	38	2.54	16	0.732	7.44	22.5	0.618	1.58	0.53
C6	640	36	3.00	19	0.714	7.51	21.8	0.636	1.88	0.62

4.3.2 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 are 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 7).

Table 7. Classification of the environmental status of the soft bottom fauna at station C1 at the Hvannadalur site 2022.

Station	Site name	Num. species	Dominating taxa	Environmental condition-NS 9410
C1	Hvannadalur	47	Ennucula tenuis – 29 %	1 – Very good

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 1.

All curves started relatively low (≤ 18 species) and stretched out in varying degrees towards higher classes. These did not give any clear indications of fauna condition.

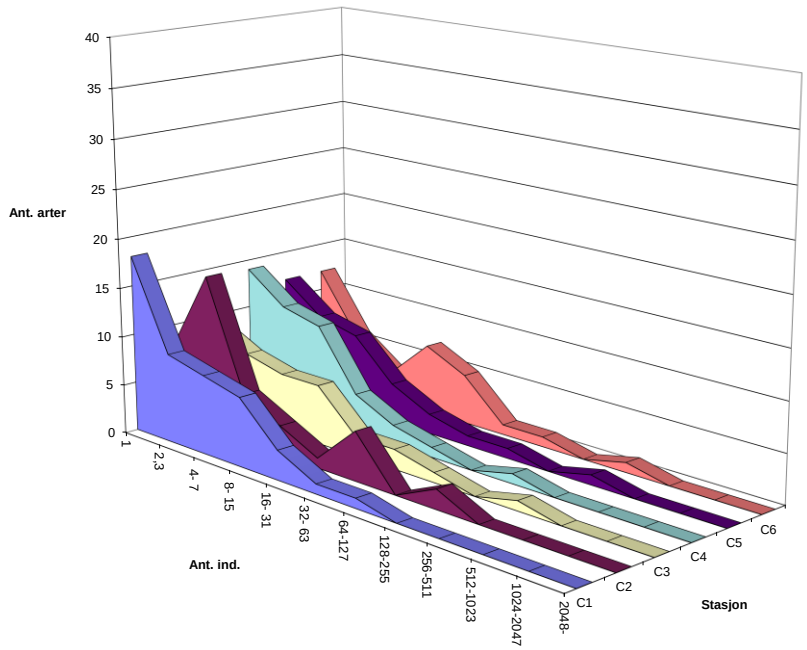


Figure 4. The soft bottom fauna shown as number of species against number of individuals pr. species in geometric classes. Hvannadalur, 2022.

4.3.3 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 58 % similar for all stations in the survey. The fauna at C4, C5 and C6 had highest similarity (more than 75 %).

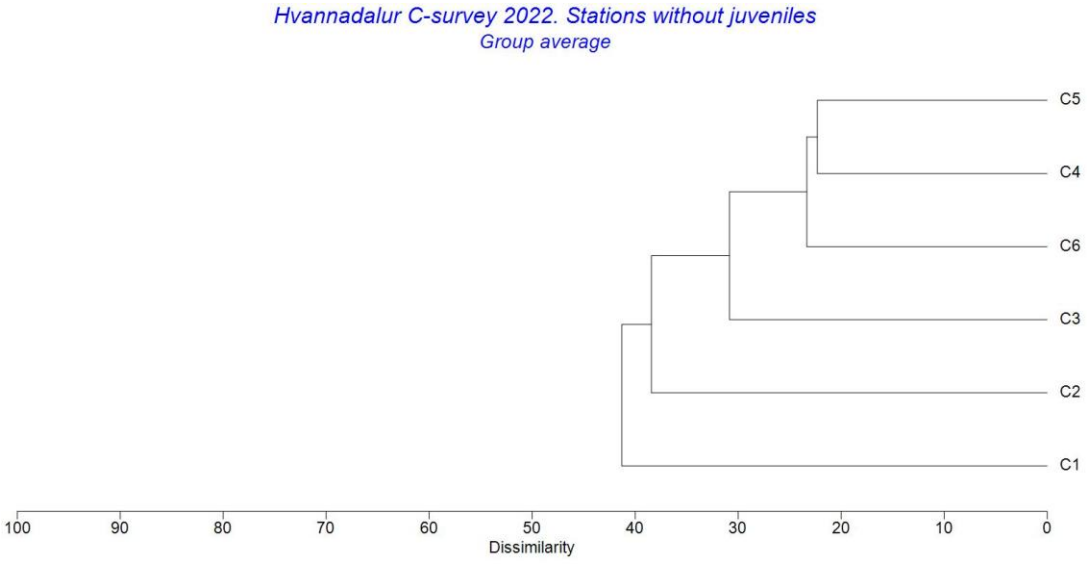


Figure 5. Cluster diagram for the soft bottom fauna at the C- sampling stations at Hvannadalur, 2022.

4.3.4 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 8.

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 (EG I) to pollution indicators (EG V).

The tolerant polychaete *Galathowenia oculata* dominated the fauna at C2 with 28 % of the individuals. The other most dominants at this station were neutral, tolerant and opportunistic species.

At the other stations the fauna was dominated by the neutral bivalve *Ennucula tenuis* with between 29 and 55 % of the individuals. The other most dominant species at the stations were a mixture of sensitive, neutral, tolerant, and opportunistic species.

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

Table 8. Number of individuals, cumulative percentage, and ecological group for the ten most dominant species at the C stations. Hvannadalur, 2022.*

C1	EG	Numb.	Cum.	C2	EG	Numb.	Cum.
Ennucula tenuis	II	103	29 %	Galathowenia oculata	III	227	28 %
Scalibregma inflatum	III	32	38 %	Ennucula tenuis	II	226	56 %
Thyasira sarsii	IV	18	43 %	Nuculana pernula	II	59	63 %
Ophelina acuminata	II	16	48 %	Thyasira sarsii	IV	53	70 %
Parougia eliasoni	Ik	16	52 %	Sternaspis scutata	Ik	49	76 %
Prionospio steenstrupi	II	15	57 %	Axinopsida orbiculata	Ik	34	80 %
Spio limicola	Ik	15	61 %	Prionospio steenstrupi	II	33	84 %
Scoloplos armiger	III	14	65 %	Yoldia hyperborea	Ik	29	88 %
Eteone flava/longa	Ik	12	68 %	Spio limicola	Ik	11	89 %
Yoldia hyperborea	Ik	11	71 %	Scoloplos armiger	III	9	90 %
C3	**EG**	**Numb.**	**Cum.**	**C4**	**EG**	**Numb.**	**Cum.**
Ennucula tenuis	II	392	53 %	Ennucula tenuis	II	253	53 %
Prionospio steenstrupi	II	86	64 %	Galathowenia oculata	III	43	62 %
Galathowenia oculata	III	56	72 %	Thyasira sarsii	IV	26	68 %
Thyasira sarsii	IV	45	78 %	Yoldia hyperborea	Ik	17	71 %
Yoldia hyperborea	Ik	29	82 %	Scoloplos armiger	III	14	74 %
Nuculana pernula	II	18	84 %	Eteone flava/longa	Ik	13	77 %
Chaetozone setosa	IV	12	86 %	Spio limicola	Ik	10	79 %
Leucon sp.	Ik	12	87 %	Prionospio steenstrupi	II	9	81 %
Spio limicola	Ik	11	89 %	Aricidea sp.	I	7	82 %
Sternaspis scutata	Ik	10	90 %	Bylgides groenlandicus	Ik	6	84 %
C5	**EG**	**Numb.**	**Cum.**	**C6**	**EG**	**Numb.**	**Cum.**
Ennucula tenuis	II	390	55 %	Ennucula tenuis	II	306	48 %
Galathowenia oculata	III	124	72 %	Galathowenia oculata	III	88	61 %
Yoldia hyperborea	Ik	35	77 %	Thyasira sarsii	IV	33	67 %
Thyasira sarsii	IV	26	81 %	Yoldia hyperborea	Ik	23	70 %
Sternaspis scutata	Ik	17	83 %	Prionospio steenstrupi	II	18	73 %
Lysianassidae indet.	I	15	85 %	Sternaspis scutata	Ik	18	76 %
Nuculana pernula	II	12	87 %	Parougia eliasoni	Ik	16	78 %
Chaetozone setosa	IV	8	88 %	Scoloplos armiger	III	16	81 %
Leucon sp.	Ik	8	89 %	Eteone flava/longa	Ik	13	83 %
Cossura sp.	Ik	7	90 %	Chaetozone setosa	IV	12	85 %

*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.

5 Summary and Conclusions

5.1 Summary

The results from the environmental monitoring (type C) at Hvannadalur, 2022, can be summarised as follows:

- The hydrography measurements showed good oxygen conditions throughout the water column with 76 % saturation in the bottom layer in September 2022.
- TOC was rather high at all stations and nTOC varied from 33.6 to 49.5 mg/g TS. TOM-levels varied from 11.6 to 13.3 %. TN-levels were relatively low (4.7 – 7.6 mg/g) as was the C/N-ratio. The copper level in the sediment at C1 was elevated (46.2 mg/kg) according to Norwegian standards, but within reported natural levels of 55 mg/kg in Icelandic coastal areas (Egilsson *et al.* 1999). The sediment was moderately fine grained with a pelite share between 60.5 and 80.7 %. The redox measurements (pH/Eh) gave point 0 acc. Appendix D in NS 9410:2016 for all the stations.
- The number of individuals varied from 352 (C1) to 807 (C2) and number of species from 34 (C3) to 47 (C1). The diversity H' varied from 2.54 to 3.95. 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.

5.2 Conclusions

The results from the monitoring at the farming site Hvannadalur in September 2022 showed that the sediment was somewhat loaded with organic carbon and the copper concentrations were within reported natural levels for bottom sediment around Iceland (Egilsson *et al.*, 1999).

No load effect was recorded in the fauna and faunal index nEQR which showed good conditions and no impact at any of the stations (> 0.6). The diversity index H ' was just below 3 at C3 and C5 and above 3 at the other stations and ranged from 2.54 (C5) to 3.95 (C1). The NS 9410:2016-assessment of the community in the local impact zone (C1) showed environmental condition 1 (Very good). No pollution indicators were recorded among the top-10 species on any of the stations.

The redox measurements (pH/Eh) gave point 0 acc. Appendix D in NS 9410:2016 for all the sampling stations. The oxygen saturation in September was good in the whole water column with 76 % in the bottom water.

5.3 Environmental changes since previous C-survey

A C-survey at max biomass was carried out at the site in April 2021 (Mannvik and Gunnarsson, 2021). The conclusion of the survey was: *The results from the monitoring at the farming site Hvannadalur in April 2021 showed that the fauna at C1 might be disturbed (nEQR below 0.4) while more or less undisturbed at the other stations (nEQR above 0.55). The NS 9410:2016-assessment of the community in the local impact zone (C1) showed environmental condition 1 (Very good). The pollution indicator species Capitella capitata was the most abundant species at C1, but not present among the top-10 at the other stations. TOC was*

relatively high at all stations and the same was nTOC that varied from 33.6 (C5) and 43 mg/g (C4). The level of copper at C1 was 38 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 stations. The oxygen saturation in April was good in the whole water column with nearly 100 % in the bottom water.

Overall, there are indications that the environmental conditions in the bottom sediment have improved since the max biomass survey in 2021. The faunal index nEQR have increased since the previous survey at stations C1, C4 and C5 and is above 0.6 at all sampling stations in the current study. The pollution indicator species *Capitella capitata,* which is the most dominant at C1 in 2021, was not registered among the top-10 species at any station in the present survey in 2022. The organic carbon content in the sediment at is at similar levels in 2022 as in the previous survey in 2021. The copper level at C1 was 38.1 mg/kg in 2021 and is now 46.2 mg/kg.

6 References

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7 Appendix (in Norwegian)

7.1 Statistiske metoder

Diversitet

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

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7.2 Statistical results Hvannadalur, 2022

Benthos indices per replicate

st.nr.	tot.	C1_01	C1_02	C2_01	C2_02	C3_01	C3_02	C4_01	C4_02	C5_01	C5_02	C6_01	C6_02
no. ind.	3732	136	216	216	591	346	399	69	406	337	376	307	333
no. spe.	76	32	36	20	35	29	24	26	38	29	28	30	27
Shannon-Wiener:		4,5	3,4	2,8	3,3	2,8	2,6	4,2	2,6	2,5	2,6	3,4	2,6
Pielou		0,90	0,66	0,65	0,65	0,58	0,56	0,90	0,50	0,51	0,54	0,69	0,55
ES100		29	25	15	17	18	14	76	20	16	16	21	16
SN		2,18	2,13	1,78	1,92	1,91	1,78	2,26	2,03	1,91	1,87	1,95	1,87
ISI-2012		6,96	7,48	8,29	7,85	7,21	8,31	6,98	7,62	7,81	7,07	7,79	7,24
AMBI		2,382	2,172	1,847	1,702	2,195	1,881	2,452	1,672	1,586	1,581	2,071	1,685
NQI1		0,72	0,73	0,69	0,73	0,69	0,69	0,71	0,75	0,74	0,73	0,71	0,72
NSI		20,5	22,5	21,4	21,7	22,2	22,6	19,8	22,6	22,5	22,5	21,3	22,2

Geometrical classes

int.	C1	C2	C3	C4	C5	C6
1	18	8	9	14	12	12
2,3	9	16	7	11	9	6
4- 7	8	5	6	10	8	3
8- 15	7	3	6	4	4	7
16- 31	3	1	2	2	2	5
32- 63	1	5	2	1	1	1
64-127	1	0	1	0	1	1
128-255	0	2	0	1	0	0
256-511	0	0	1	0	1	1
512-1023	0	0	0	0	0	0
1024-2047	0	0	0	0	0	0
2048-	0	0	0	0	0	0

7.3 Species lists

Artsliste pr stasjon

Hvannadalur C-survey 2022

Rekke	Klasse	Orden	Art/Taxa	Replikat: 01	02	-	Sum
Stasjonsnr.: C1							
CNIDARIA							
	Anthozoa						
			Edwardsia sp.		1	-	1
NEMERTINI							
			Nemertea indet.	1	1	-	2
PRIAPULIDA							
			Priapulus caudatus		1	-	1
ANNELIDA							
	Polychaeta						
		Orbiniida					
			Aricidea sp.		2	-	2
			Scoloplos armiger	7	7	-	14
		Cossurida					
			Cossura pygodactylata		1	-	1
			Cossura sp.	1	1	-	2
		Spionida					
			Chaetozone setosa		3	-	3
			Chaetozone sp.		1	-	1
			Laonice cirrata	1		-	1
			Prionospio steenstrupi		15	-	15
			Spio armata	2		-	2
			Spio limicola	7	8	-	15
		Capitellida					
			Mediomastus fragilis	3	2	-	5
			Praxillella gracilis		1	-	1
		Opheliida					
			Ophelina acuminata	9	7	-	16
			Ophelina sp.	3		-	3
			Scalibregma inflatum	18	14	-	32
		Phyllodocida					
			Bylgides groenlandicus	3	4	-	7
			Eteone barbata		1	-	1
			Eteone flava/longa	6	6	-	12
			Gattyana amondseni	5		-	5
			Goniada maculata	1		-	1
			Microphthalmus sczelkowii	8		-	8
			Nephtys ciliata		1	-	1
			Polynoidae indet.	2	2	-	4
			Syllis kas	2	1	-	3
		Eunicida					
			Parougia eliasoni	12	4	-	16
		Oweniida					
			Galathowenia oculata	1	5	-	6
		Terebellida					
			Ampharete sp.		1	-	1
			Lagis koreni	2	2	-	4
		Sabellida					
			Euchone papillosa	1		-	1
CRUSTACEA							
	Malacostraca						
		Cumacea					
			Leucon sp.	8	2	-	10
		Amphipoda					
			Gammaridea indet.	3	3	-	6
			Lysianassidae indet.	2	1	-	3
			Oedicerotidae indet.		1	-	1
		Decapoda					
			Brachyura indet.		1	-	1
MOLLUSCA							
	Opistobranchia						
		Cephalaspidea					

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
			Retusa obtusa			1	-	1
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		3	100	-	103
			Nuculana pernula		1		-	1
			Yoldia hyperborea		5	6	-	11
		Veneroida						
			Abra nitida		3		-	3
			Macoma calcarea		3	1	-	4
			Thyasira sarsii		11	7	-	18
		Myoida						
			Hiatella arctica		1		-	1
ECHINODERMATA								
	Asteroidea							
		Forcipulatida						
			Asterias rubens		1		-	1
	Ophiuroidea							
		Ophiurida						
			Ophiocten affinis			1	-	1
	Holothuroidea							
			Holothuroidea indet. juv.			1	-	1
				Maksverdi:	18	100		103
				Antall arter/taxa:	32	37		48
				Sum antall individ:				353

Stasjonsnr.: C2

Rekke	Klasse	Orden	Art/Taxa	01	02	-	Sum
CNIDARIA							
	Anthozoa						
			Edwardsia sp.		2	-	2
SIPUNCULIDA							
			Sipuncula indet.		1	-	1
ANNELIDA							
	Polychaeta						
		Orbiniida					
			Aricidea sp.	2		-	2
			Levinsenia gracilis	2	2	-	4
			Scoloplos armiger		9	-	9
		Cossurida					
			Cossura sp.	1		-	1
		Spionida					
			Chaetozone setosa		3	-	3
			Prionospio steenstrupi	11	22	-	33
			Spio limicola	5	6	-	11
			Spiophanes kroyeri		1	-	1
		Capitellida					
			Maldane sarsi	1	3	-	4
			Praxillella gracilis		2	-	2
			Praxillella praetermissa		4	-	4
		Phyllodocida					
			Bylgides groenlandicus	2		-	2
			Eteone flava/longa	2		-	2
			Nephtys ciliata	3		-	3
			Pholoe baltica		2	-	2
			Syllis kas		2	-	2
		Eunicida					
			Scoletoma sp.		1	-	1
		Sternaspida					
			Sternaspis scutata	15	34	-	49
		Oweniida					
			Galathowenia oculata	93	134	-	227
			Myriochele malmgreni/olgae		3	-	3
		Terebellida					
			Lagis koreni		3	-	3
			Melinna cristata	1	2	-	3
		Sabellida					
			Euchone papillosa	3	1	-	4
CRUSTACEA							
	Malacostraca						
		Cumacea					

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
			Leucon sp.		2	5	-	7
		Amphipoda						
			Dulichiidae indet.			1	-	1
			Lysianassidae indet.			2	-	2
			Oedicerotidae indet.		1	2	-	3
MOLLUSCA								
	Opistobranchia							
		Cephalaspidea						
			Retusa obtusa			2	-	2
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		45	181	-	226
			Nuculana pernula		7	52	-	59
			Yoldia hyperborea		5	24	-	29
		Veneroida						
			Abra nitida			8	-	8
			Arctica islandica			1	-	1
			Axinopsida orbiculata			34	-	34
			Thyasira gouldii			1	-	1
			Thyasira sarsii		14	39	-	53
ECHINODERMATA								
	Ophiuroidea							
		Ophiurida						
			Ophiocten affinis		1	1	-	2
			Ophiuroidea indet. juv.			1	-	1
TUNICATA								
	Ascidiacea							
			Ascidiacea indet. (solit)			1	-	1
				Maksverdi:	93	181		227
				Antall arter/taxa:	20	36		41
				Sum antall individ:				808

Stasjonsnr.: C3

Rekke	Klasse	Orden	Art/Taxa	01	02	-	Sum
PRIAPULIDA							
			Priapulus caudatus	2		-	2
ANNELIDA							
	Polychaeta						
		Orbiniida					
			Aricidea sp.	4	3	-	7
			Levinsenia gracilis	1	1	-	2
			Scoloplos armiger	5		-	5
		Spionida					
			Chaetozone setosa	7	5	-	12
			Prionospio steenstrupi	41	45	-	86
			Spio limicola	8	3	-	11
		Capitellida					
			Maldane sarsi		1	-	1
			Mediomastus fragilis	2		-	2
			Praxillella praetermissa	1	1	-	2
		Opheliida					
			Ophelina sp.	1		-	1
			Scalibregma inflatum	9		-	9
		Phyllodocida					
			Bylgides sp.		1	-	1
			Eteone flava/longa	6	2	-	8
			Gattyana amondseni	1		-	1
			Nephtys ciliata	1	2	-	3
			Nephtys paradoxa	1		-	1
			Syllis cornuta	3	1	-	4
		Eunicida					
			Parougia eliasoni	2		-	2
		Sternaspida					
			Sternaspis scutata	1	9	-	10
		Oweniida					
			Galathowenia oculata	10	46	-	56
		Terebellida					
			Lagis koreni	6		-	6
CRUSTACEA							
	Malacostraca						

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
		Cumacea						
			Eudorella sp.			1	-	1
			Leucon sp.		7	5	-	12
		Amphipoda						
			Gammaridea indet.		1		-	1
			Lysianassidae indet.		1	2	-	3
MOLLUSCA								
	Caudofoveata							
			Caudofoveata indet.			1	-	1
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		182	210	-	392
			Nuculana pernula		2	16	-	18
			Yoldia hyperborea		11	18	-	29
		Veneroida						
			Abra nitida		2	3	-	5
			Axinopsida orbiculata		2	3	-	5
			Thyasira gouldii			1	-	1
			Thyasira sarsii		26	19	-	45
ECHINODERMATA								
	Ophiuroidea							
			Ophiuroidea indet. juv.			1	-	1
				Maksverdi:	182	210		392
				Antall arter/taxa:	29	25		35
				Sum antall individ:				746

Stasjonsnr.: C4

PRIAPULIDA								
			Priapulus caudatus		1	3	-	4
ANNELIDA								
	Polychaeta							
		Orbiniida						
			Aricidea sp.		1	6	-	7
			Scoloplos armiger		9	5	-	14
		Cossurida						
			Cossura sp.			2	-	2
		Spionida						
			Chaetozone setosa		2	2	-	4
			Prionospio steenstrupi		2	7	-	9
			Spio limicola		3	7	-	10
		Capitellida						
			Maldane sarsi			1	-	1
			Mediomastus fragilis		2	2	-	4
			Praxillella gracilis			1	-	1
		Opheliida						
			Ophelina acuminata		1	1	-	2
			Scalibregma inflatum		3	1	-	4
		Phyllodocida						
			Bylgides groenlandicus		2	4	-	6
			Bylgides sp.			1	-	1
			Eteone flava/longa		6	7	-	13
			Gattyana amondseni		1	2	-	3
			Microphthalmus sczelkowii			1	-	1
			Nephtys ciliata			1	-	1
			Pholoe assimilis			5	-	5
			Polynoidae indet.		1	1	-	2
			Syllis cornuta			5	-	5
			Syllis kas			2	-	2
		Eunicida						
			Lumbrineris mixochaeta			1	-	1
			Parougia eliasoni		2	1	-	3
		Sternaspida						
			Sternaspis scutata			2	-	2
		Oweniida						
			Galathowenia oculata		2	41	-	43
		Terebellida						
			Lagis koreni		2	1	-	3
			Lanassa venusta		1		-	1
		Sabellida						

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
			Euchone incolor			3	-	3
CRUSTACEA								
	Malacostraca							
		Cumacea						
			Leucon sp.		2	3	-	5
		Amphipoda						
			Bathymedon obtusifrons			1	-	1
			Gammaridea indet.		1		-	1
			Lysianassidae indet.		1	1	-	2
			Oedicerotidae indet.			1	-	1
MOLLUSCA								
	Opistobranchia							
		Cephalaspidea						
			Retusa obtusa			1	-	1
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		8	245	-	253
			Nuculana pernula			6	-	6
			Yoldia hyperborea		4	13	-	17
		Veneroida						
			Abra nitida		1		-	1
			Axinopsida orbiculata			2	-	2
			Ciliatocardium ciliatum		1		-	1
			Macoma calcarea		1		-	1
			Thyasira sarsii		9	17	-	26
		Myoida						
			Mya sp. juv.			1	-	1
				Maksverdi:	9	245		253
				Antall arter/taxa:	26	39		44
				Sum antall individ:				476

Stasjonsnr.: C5

PRIAPULIDA								
			Priapulus caudatus			1	-	1
ANNELIDA								
	Polychaeta							
		Orbiniida						
			Aricidea sp.		2	2	-	4
			Levinsenia gracilis		1		-	1
			Scoloplos armiger		1	1	-	2
		Cossurida						
			Cossura sp.		2	5	-	7
		Spionida						
			Chaetozone setosa		5	3	-	8
			Prionospio steenstrupi		3	4	-	7
			Spio limicola		4	3	-	7
		Capitellida						
			Mediomastus fragilis		4		-	4
		Opheliida						
			Ophelina acuminata		2		-	2
		Phyllodocida						
			Bylgides sp.		3		-	3
			Eteone flava/longa			2	-	2
			Gattyana amondseni		2		-	2
			Nephtys ciliata		1	2	-	3
			Pholoe baltica		1		-	1
			Phyllodoce groenlandica			1	-	1
			Polynoidae indet.		1		-	1
			Syllis cornuta		3	1	-	4
		Eunicida						
			Parougia eliasoni		1	2	-	3
		Sternaspida						
			Sternaspis scutata		2	15	-	17
		Oweniida						
			Galathowenia oculata		62	62	-	124
		Terebellida						
			Lanassa venusta		1		-	1
		Sabellida						
			Euchone incolor		2	3	-	5
CRUSTACEA								
	Malacostraca							

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
		Cumacea						
			Leucon sp.			8	-	8
		Amphipoda						
			Bathymedon obtusifrons		2	1	-	3
			Lysianassidae indet.		13	2	-	15
			Oedicerotidae indet.			5	-	5
MOLLUSCA								
	Opistobranchia							
		Cephalaspidea						
			Retusa obtusa			1	-	1
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		190	200	-	390
			Nuculana pernula		1	11	-	12
			Yoldia hyperborea		11	24	-	35
		Veneroida						
			Abra nitida		2	1	-	3
			Axinopsida orbiculata			1	-	1
			Ciliatocardium ciliatum		1		-	1
			Macoma calcarea			1	-	1
			Thyasira sarsii		13	13	-	26
ECHINODERMATA								
	Asteroidea							
		Paxillosida						
			Ctenodiscus crispatus		1		-	1
	Ophiuroidea							
		Ophiurida						
			Ophiocten affinis			1	-	1
			Ophiuroidea indet. juv.		1		-	1
				Maksverdi:	190	200		390
				Antall arter/taxa:	30	28		39
				Sum antall individ:				714

Stasjonsnr.: C6

ANNELIDA								
	Polychaeta							
		Orbiniida						
			Aricidea sp.		1	1	-	2
			Levinsenia gracilis			1	-	1
			Scoloplos armiger		16		-	16
		Cossurida						
			Cossura pygodactylata			2	-	2
			Cossura sp.		5	1	-	6
		Spionida						
			Chaetozone setosa		10	2	-	12
			Prionospio steenstrupi		14	4	-	18
			Spio limicola		4	4	-	8
		Capitellida						
			Mediomastus fragilis		6	6	-	12
		Phyllodocida						
			Bylgides groenlandicus			1	-	1
			Bylgides sp.		1	1	-	2
			Eteone flava/longa		12	1	-	13
			Nephtys ciliata		6	4	-	10
			Pholoe assimilis		1		-	1
			Pholoe baltica			1	-	1
			Polynoidae indet.			1	-	1
			Syllis cornuta		1	2	-	3
		Eunicida						
			Lumbrineris mixochaeta		1		-	1
			Parougia eliasoni		3	13	-	16
		Sternaspida						
			Sternaspis scutata		7	11	-	18
		Oweniida						
			Galathowenia oculata		34	54	-	88
		Terebellida						
			Ampharete borealis		1		-	1
			Lagis koreni		6	1	-	7
			Lanassa venusta		3		-	3
		Sabellida						
			Euchone incolor		2	1	-	3
CRUSTACEA								

Rekke	Klasse	Orden	Art/Taxa	Replikat:	01	02	-	Sum
	Malacostraca							
		Cumacea						
			Leucon sp.		3	8	-	11
		Amphipoda						
			Bathymedon obtusifrons		1		-	1
			Dulichiidae indet.		1		-	1
			Lysianassidae indet.		1		-	1
			Oedicerotidae indet.			1	-	1
MOLLUSCA								
	Bivalvia							
		Nuculoida						
			Ennucula tenuis		126	180	-	306
			Nuculana pernula		2	3	-	5
			Yoldia hyperborea		13	10	-	23
		Veneroida						
			Axinopsida orbiculata		4	7	-	11
			Macoma calcarea		1		-	1
			Thyasira sarsii		21	12	-	33
ECHINODERMATA								
	Ophiuroidea							
			Ophiuroidea indet. juv.			1	-	1
				Maksverdi:	126	180		306
				Antall arter/taxa:	30	28		37
				Sum antall individ:				641

7.4 Analytical report

ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	2022-10-12
Project no.:	64286	**Date Registrered:**	2022-09-01

Lab-id. P2200156-01

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C1	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	42	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±4.2
TNb	*4.7	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±1.4
N TOC	49.5	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	9.0		2022-10-07	2022-10-07		
TOM	12.6	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	1.0	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 0.500 mm	2.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.250 mm	19.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.0
Weight% 0.125 mm	9.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.5
Vekt% 0.063 mm	6.3	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Weight% < 0.063 mm	60.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.0
Pelite	60.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.0
Sand	38.9	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.9
Gravel	0.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Copper (Cu) [a]	46.2	mg/kg TS	2022-09-28	2022-09-28	Intern metode	

[a] The analytical testing has been carried out by an external laboratory, ALS Laboratory Group

* = Non-accredited result

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ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	**2022-10-12**
Project no.:	**64286**	**Date Registrered:**	2022-09-01

Lab-id. P2200156-02

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C2	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	30	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±3.0
TNb	*5.3	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±1.6
N TOC	33.6	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	5.6		2022-10-07	2022-10-07		
TOM	12.5	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	2.3	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.500 mm	3.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.250 mm	3.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.125 mm	4.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Vekt% 0.063 mm	7.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.4
Weight% < 0.063 mm	78.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.9
Pelite	78.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.9
Sand	20.9	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.0
Gravel	0.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0

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ANALYSIS REPORT

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Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	2022-10-12
Project no.:	64286	**Date Registrered:**	2022-09-01

Lab-id. P2200156-03

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C3	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	31	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±3.1
TNb	*5.8	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±1.7
N TOC	35.6	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	5.3		2022-10-07	2022-10-07		
TOM	11.6	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	1.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.500 mm	3.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.250 mm	6.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Weight% 0.125 mm	8.2	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.4
Vekt% 0.063 mm	6.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Weight% < 0.063 mm	73.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.7
Pelite	73.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.7
Sand	26.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.3
Gravel	0.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0

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ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	2022-10-12
Project no.:	64286	**Date Registrered:**	2022-09-01

Lab-id. P2200156-04

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C4	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	36	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±3.6
TNb	*5.5	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±1.7
N TOC	39.2	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	6.4		2022-10-07	2022-10-07		
TOM	11.9	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	1.4	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.500 mm	3.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.250 mm	4.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.125 mm	3.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Vekt% 0.063 mm	5.3	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Weight% < 0.063 mm	80.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±4.0
Pelite	80.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±4.0
Sand	18.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.9
Gravel	0.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0

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ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	2022-10-12
Project no.:	64286	**Date Registrered:**	2022-09-01

Lab-id. P2200156-05

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C5	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	30	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±3.0
TNb	*7.6	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±2.3
N TOC	34.6	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	4.0		2022-10-07	2022-10-07		
TOM	12.1	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	0.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 0.500 mm	2.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.250 mm	4.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.125 mm	6.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Vekt% 0.063 mm	9.3	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.5
Weight% < 0.063 mm	75.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.8
Pelite	75.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.8
Sand	23.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.2
Gravel	0.7	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0

* = Non-accredited result

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ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	**2022-10-12**
Project no.:	**64286**	**Date Registrered:**	2022-09-01

Lab-id. P2200156-06

Sample type	Kundens ID	Description	Note	Mottatt lab
Sediment	C6	64286 - Hvannadalur		2022-09-01

Analyseresultat

Parameter	Resultat	Unit	Analysis date start	Analysis date end	Norm	Measurement uncertainty
TOC	35	mg/g TS	2022-09-21	2022-10-03	DIN 19539:2016	±3.5
TNb	*6.5	mg/g TS	2022-09-21	2022-10-03	NS-EN 16168:2012	±2.0
N TOC	39.3	mg/g TS	2022-10-07	2022-10-07	Veileder 02:2018	
C/N - ratio	5.3		2022-10-07	2022-10-07		
TOM	13.3	% TS	2022-09-19	2022-09-21	Internal method	±0.0
Weight % 2 mm	0.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0
Weight% 1 mm	1.5	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.1
Weight% 0.500 mm	4.3	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.250 mm	4.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.2
Weight% 0.125 mm	5.0	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.3
Vekt% 0.063 mm	8.6	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.4
Weight% < 0.063 mm	75.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.8
Pelite	75.8	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±3.8
Sand	24.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±1.2
Gravel	0.1	wt% TS	2022-09-19	2022-09-27	Internal method (Bale/Kenny 2005)	±0.0

* = Non-accredited result

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ANALYSIS REPORT

Customer:	Arctic Sea Farm / Arctic Fish	**Report no.:**	P2200156
Client reference:	Hvannadalur	**Revision:**	2
Client person:		**Report date**	2022-10-12
Project no.:	64286	**Date Registrered:**	2022-09-01

Analytical chemist: Ingar H. Wasbotten

Signature:

Ingar H. Wasbotten

Signatory:

Signatur:

Given results are valid only for the samples tested, and do not consider any errors due to sampling, inhomogeneities or other circumstances that may have influenced the sample condition before Akvaplan-Niva AS received it. This report can only be reproduced in its entirety and without any alterations. Complaints must be given to the laboratory within one month after reporting of the analytical results. More information about analytical methods (uncertainty, method principle etc) can be obtained by contacting Akvaplan-Niva AS.

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