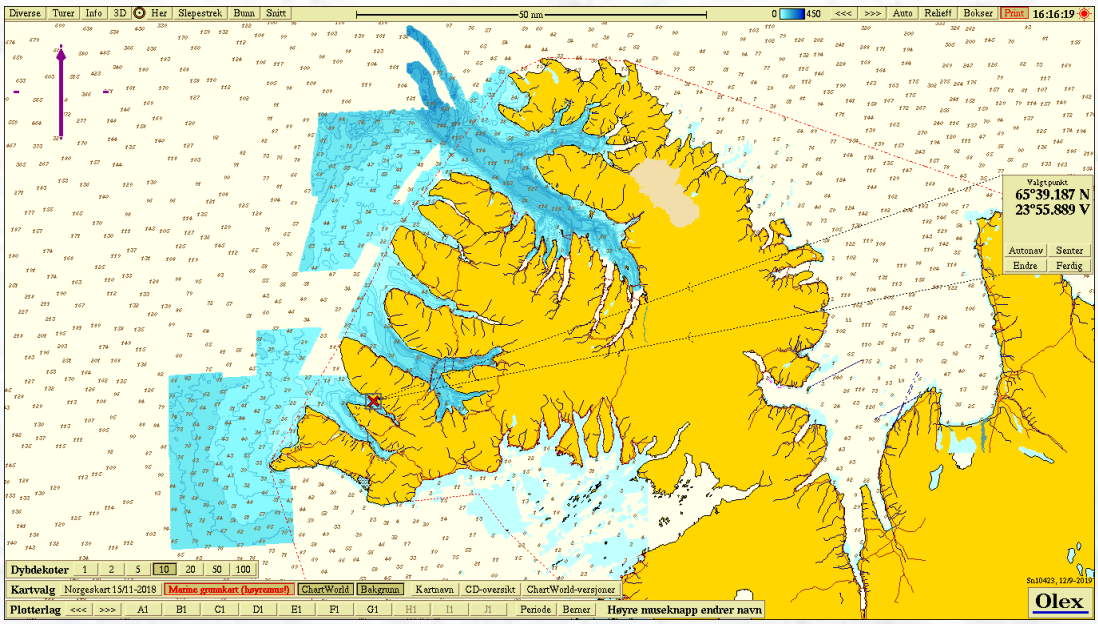
Akvaplan niva

Rapport Report

Arnarlax

C-survey fish farming site Laugardalur, 2019.



NORSK AKKREDITERING TEST 079

Akvaplan-niva AS Report: 60938.01

Akvaplan-niva AS
Rådgivning og forskning innen miljø og akvakultur
Org.nr: NO 937 375 158 MVA
Framsenteret
9296 Tromsø
Tlf: 77 75 03 00, Fax: 77 75 03 01
www.akvaplan.niva.no

Report title / Rapporttittel

Arnarlax. C-survey at fish farming site Laugardalur, 2019.

Author(s) / Forfatter(s)
Hans-Petter Mannvik
Snorri Gunnarsson

Akvaplan-niva report nr / rapport no
60938.01

Date /Dato
23.09 2019

No. of pages / Antall sider
17 + vedlegg

Distribution / Distribusjon
Gjennom oppdragsgiver

Client /Oppdragsgiver
Arnarlax, Strandgata 1, 465 Bíldudalur. Iceland

Client's reference / Oppdragsg. referanse
Silja Baldvinsdóttir

Summary / Sammendrag
The results of the monitoring at the fish farming site Laugardalur in 2019 indicated that the sediments had slightly high levels of organic carbon and normalized TOC from 21.7 to 33.2. The copper concentrations ranged from 29.7 to 38.0 mg/kg which are low levels compared to natural levels in Iceland. No pollution indicators were detected on any of the sampling stations. The fauna index nEQR ranged from 0.567 to 0.716. The oxygen saturation in May was good in the whole water column with 80 to 90 % in the bottom water.

Project manager / Prosjektleder

Snorri Gunnarsson

Quality control / Kvalitetskontroll

Roger Velvin

INNHOLDSFORTEGNELSE

Foreword

Akvaplan-niva has done an environmental survey of the type C at the fish farming site Laugardalur. The survey is done following a fallow period of eight months. The survey includes pH/redox measurements (Eh), hydrography, geochemical analyses and analyses of the bottom fauna by the fish farming site. Results from six stations are included in the C-survey. This survey is done upon request from Arnarlax hf and is a part of their environmental monitoring of their fish farming sites.

The following personnel have 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.
Roger Velvin	Akvaplan-niva	Identification of bottom fauna (Varia). QS report, professional assessments and interpretations.
Rune Palerud	Akvaplan-niva	Identification of bottom fauna (Crustaceans). Statistics.
Jesper Hansen	Akvaplan-niva	Identification of bottom fauna (molluscs).
Andrey Sikorski	Akvaplan-niva	Identification of bottom fauna (bristle worms).
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 Arnarlax, Silja Baldvinsdóttir, 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.

None-accredited services: Hydrography measurements and mapping of bottom depth (Olex).

Kópavogur, 23.09 2019

Snorri Gunnarsson

Project leader

1 Summary of C-survey results

1.1 Summary results C-survey

Client information			
Title :	C-survey Laugardalur, 2019.		
Report nr.	60938.01	Location:	Laugardalur
Location nr.		Map co/ordinates (construction):	65°39,187 N 23°55,889 V
Fylke:		Kommune:	
MTB-permission:	Site MTB	Operations manager:	Rolf Ørjan Nordli
Client:	Arnarlax		

Biomass/production status at date of investigation 27.05.2019			
Fish group:	Salmon	Biomass on examination:	0
Feed input	0	Produced quantity	0
Type/tidspunkt for undersøkelse			
Maximum biomass		Follow up study:	
Fallow:	x	New location:	

Results from C study /NS 9410 (2016) - Main result soft bottom fauna			
Faunal index nEQR (Veileder 02.2018)		**Diversity index (Shannon-Wiener)**	
Fauna C1 (inner)	0.610	Fauna C1 (inner)	2.98
Fauna C2 (outer)	0.604	Fauna C2 (outer)	2.76
Fauna C3	0.672	Fauna C3	3.27
Fauna C4 (depth layers)	0.567	Fauna C4 (depth layers)	2.46
Fauna C5	0.604	Fauna C5	2.71
Fauna C6	0.716	Fauna C6	4.26
Date fieldwork:	27.05.2019	**Date of report:**	23.09 2019
Notes to other results (sediment, pH/Eh, oxygen)			nTOC from 27.6 - 33.2 Copper from 29.7 - 38.0 mg/kg pH/Eh level 0 (all st.) O_2-conditions were good throughout the water column.
Responsible for fieldwork:	Snorri Gunnarson	Signature:	

2 Introduction

2.1 Background and aim of study

Akvaplan-niva has on behalf of Arnarlax done a C-survey for the site Laugardalur in Tálknafjörður, Iceland. The survey was conducted following guidelines and descriptions with reference to chapter 8.0 in NS 9410:2016 and follows the methodology for C- study described in NS 9410:2016.The survey also fulfils the requirements from Icelandic authorities regarding bottom surveys referring to the standard ISO 12878 and demand for environmental bottom surveys from Icelandic authorities (according to Vöktunaráætlun).

The C-survey is a trend monitoring of the bottom sediment condition in the operational transect zone with main focus on quantitative study of the bottom fauna. In addition there are included in the survey hydrographic, geological and chemical parameters.

An overview of Laugardalur is presented on map in Figure 1.

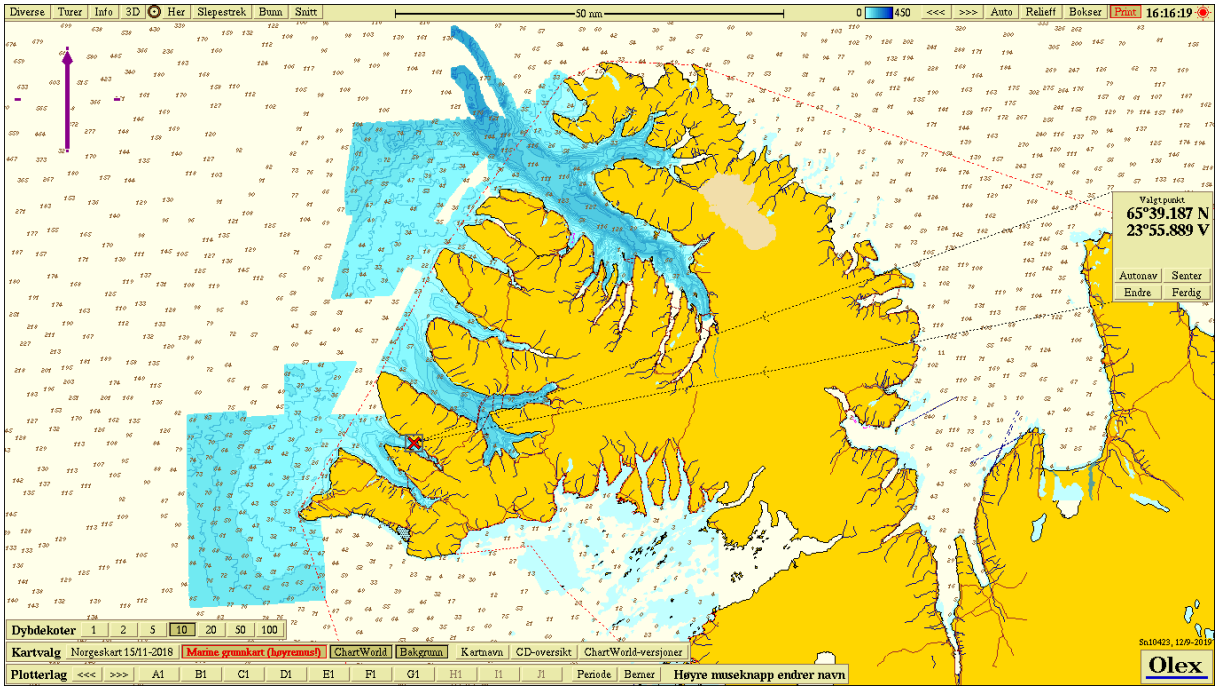


Figure 1. Overview of Westfjords with the farming site Laugardalur (red cross) in Tálknafjörður. The map coordinates for the midpoint of the farming site is given at right site of the picture.

2.2 Site operation and feed use

The fish farming site Laugardalur is a single frame mooring with 2 x 6 cages, or total of 12 cages with 160 m circumference each. The present sampling was done after about 8 months fallow period with no fish at the site. Next planned introduction of fish into cages was planned in June 2019 (Personal communication, Silja Baldvinsdóttir Quality manager Arnarlax). Previously there have been farmed two generation at the site the first from June 2013 through spring 2015 (Þórisson, Gallo and Jóhannsdóttir, 2015) and the second generation from January 2017 to September 2018. The farming site has been changed slightly from the first generation. For the second generation and the planned next generation frame lies about 250 m to the east compared to the first frame at the site.

In Iceland there is not used a MTB (max allowed biomass) for fish farming sites as in Norway. The MTB sets the level for how much fish the farmer can have standing in the sea at each time point. Here we use the estimated/planned max biomass for the next generation fish at

Laugardalur as the MTB level for the fish farm which is 10.700 ton (Personal communication, Silja Baldvinsdóttir, Quality manager Arnarlax).

The production for previous generation at Laugardalur is shown in Table 1.

Biomasse i forhold til MTB for lokaliteten gjennom hele driftsperioden er vist i **Error! Reference source not found.**

Table 1: Production at Laugardalur.

Time fish in sea	Production of salmon (ton, round weight).	Feed use (ton)
June 2013	4.498	8.107
January 2017	8.750	10.891

2.3 Previous surveys

Akvaplan-niva AS has done one previous C-survey for the present fish farming site at Laugardalur with sampling date 1. November 2017 at max biomass for the previous generation at the site (Velvin og Gunnarsson, 2018). In addition the fish farmer has presented at soft bottom fauna survey for the old Laugardalur site where results from samplings before first generation was put into sea (June 2013) and at max biomass with sampling date 3rd of September 2014 (Þórisson, Gallo and Jóhannsdóttir, 2015).

Table 2 gives overview over previous environmental bottom surveys conducted at Laugardalur.

Table 2. Previous surveys conducted at Laugardalur.

Date Sampling	Report number (Author, 2019	Type survey	Classification	Site Condition
June 2013 and September 2014	NV NR. 10-15. Thorsteinsson, Gallo og Johannsdottir, 2015	NA	NA*	NA*
01.11 2017	APN rapport 9207.01. Velvin og Gunnarsson, 2018	C-survey	NA*	NA*

*Icelandic officials have not presented any threshold values or criteria that are adjusted to Icelandic conditions and could be used up against classification of different parameters and site condition.

3 Materials and methods

3.1 Professional program

Choice of study parameters, placement of sampling stations and other criteria for the study is based on descriptions in NS 9410 (C-undersøkelser). An overview of the planned professional program is given in Tabell 3.

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 have been 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.

Tabell 3. The planned professional program for C-survey at Laugardalur, 2019. TOM = total organic material. TOC = total organic carbon. Korn = grain size in sediment. TN = total nitrogen. Cu = cobber. pH/Eh = acidity and redox potential.

Station	Type analyses/parameters
C1	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. pH/Eh.
C2	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. Cu. pH/Eh.
C3	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. Cu. pH/Eh.
C4	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. Cu. Hydrography/O_2. pH/Eh.
C5	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. Cu. pH/Eh.
C6	Quantitative analyses of bottom fauna. TOM. TOC. Korn. TN. Cu. pH/Eh.

Pictures of samples at each station, see appendix 3.

The date for field work was 27.05.2019.

3.2 Placement of stations and local conditions

Figure 3 shows the overview map where the Laugardalur site and the frame with the sample stations is plotted. Laugardalur is located on the north side of Tálknafjörður in Vesturbyggð municipality, Iceland. The depth at the site is in the range from 30 m closer to land and up to 52 m into the fjord to the south.

The results from current measurements the depth of 42 meters show that the main current and mass transport of water is defined in northwest directions (315 degrees). The average current speed was 4.2 cm/s (Heggem, 2019).

Coordinates, depth and distance of stations from frame of fish farm is given in Table 4 and Figure .

Table 4. Laugardalur, 2019. Distance between the frame of the fish farm and sampling stations, coordinates for stations and depth.

Station	Depth, m	Distance from frame, m	Position
C1	51	35	N 65°39,251 – V 23°56,307
C2	47	745	N 65°39,442 – V23°57,182
C3	45	75	N 65°39,316 – V 23°56,344
C4	53	75	N 65°39,244 – V 23°56,670
C5	44	75	N 65°39,058 – V 23°55,421
C6	34	35	N 65°39,125 – V 23°55,454

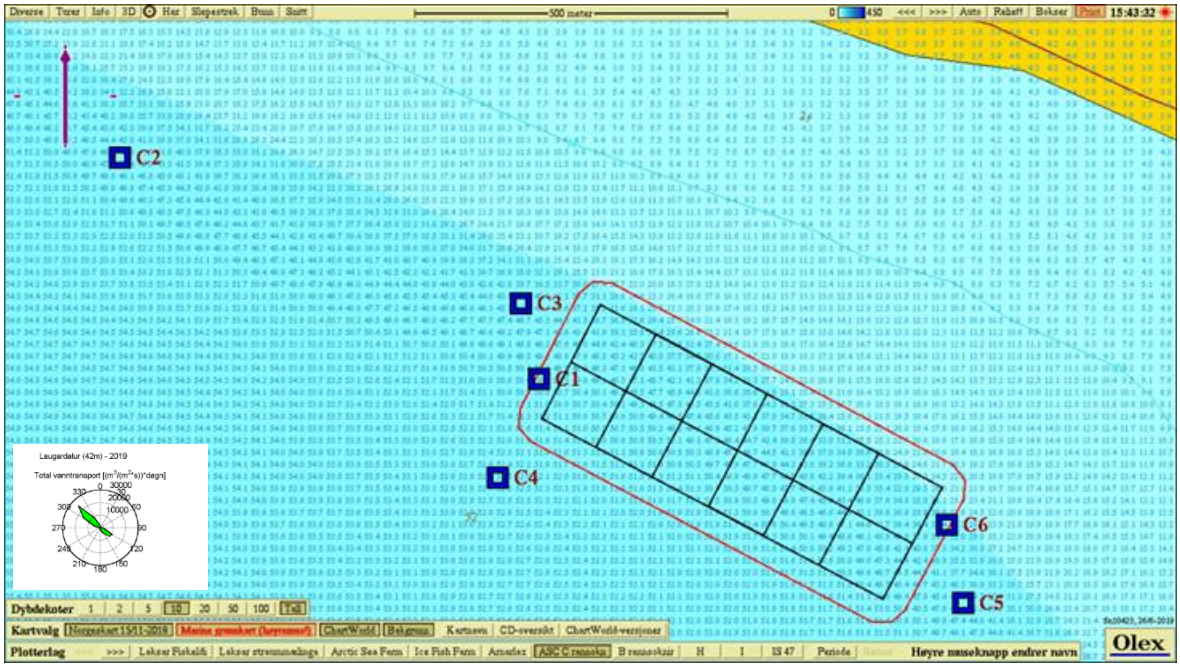


Figure 2. Sampling stations, Laugardalur, 2019.

3.3 Hydrography and oxygen

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

3.4 Soft bottom collection/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 after the sediment surface was approved. Samples for TOC, TOM, TN and Cu were taken off from the top 1 cm layer of the sediment and for grain size analyses from the top 5 cm using a hollow pipe. Only samples with an undisturbed surface were approved, and the collected 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. Weight loss in percent after combustion 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, ie. fraction less than 63 µm, was determined gravimetric 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 condition 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 *m.fl.*, 1993).

The classification of the environment condition 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 sample for metal analysis was freeze-dried before it was 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 life conditions for many of the living organisms in the bottom sediment. Negative effects in the bottom fauna can best be assessed through quantitative bottom fauna analyses. Because most

soft bottom species are little mobile, 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 still stimulate the fauna and result in an increase in number of species found. Larger organic loads will result in - inferior conditions where opportunistic species increase their individual numbers, while the delicate ones are knocked out. This means reduced diversity of species. Changes in species diversity near emission points of feed and fecal can to a large degree be attributed to changes in organic content (feed and fecal) 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 content was washed in a 1 mm strainer and remaining material fixated with 4% formalin added the dye bengalrosa and neutralized with borax. In the lab, 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 preferably identified to species level or else other appropriate taxonomical level and quantified by specialists (taxonomers). 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 structures 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 and oxygen

The hydrography profile (temperature, salinity, density and oxygen saturation) for the deep station C4 at Laugardalur, 2019 is presented in Figure . The temperature sank from 8 º C in the surface to 5 º C at 10 m and then to 3.5 º C at the bottom. The oxygen saturation was 120% in the surface and sank to 80 to 90% in the bottom water.

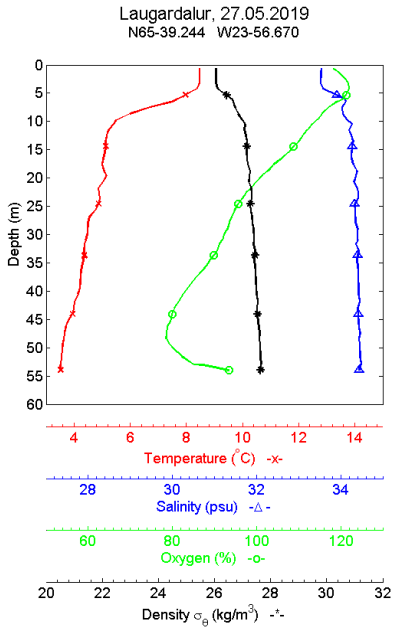


Figure 3. Vertical profiles. Temperature, salinity, density and oxygen at station C4 (deep station), Laugardalur 2019.

4.2 Sediment

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

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

Table 5.

TOM-levels were relatively low with values between 4,1 and 12,8 %. TN-levels were also low (1,3 - 4,0 mg/g) and the same was for the C/N-relationship. TOC-levels were slightly high at the sampling stations and nTOC varied from 21,7 to 33,2. The sediments were moderately coarse- to moderately fine grained with pelitt ratio between 22,6 and 64,9 %.

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

Table 5. Sediment description, TOM (%), TOC (mg/g), TN (mg/g), C/N, grain size distribution (pelitt ratio % <0,063 mm) and pH/Eh. Laugardalur, 2019.

St.	Sediment description	TOM	TOC	nTOC	TN	C/N	Pelitt	pH/Eh
C1	Clay, silt, sand	8,4	17,6	29,0	2,7	6,5	36,7	7,8/ 278
C2	Clay and sand	9,5	23,9	33,2	4,0	6,0	48,1	7,8/ 288
C3	Clay, silt, sand	4,4	8,4	23,8	1,7	5,6	20,2	7,7/ 312
C4	Clay, sand, some dead shells	12,8	24,0	30,3	3,7	6,4	64,9	7,6/ 231
C5	Clay and sand	7,2	15,5	27,6	2,8	5,6	32,8	7,8/ 240
C6	Sand and dead shells	4,1	7,7	21,7	1,3	6,0	22,6	7,6/ 282

4.2.2 Copper in sediment

The level of copper in the sediment is presented in Table 6. The levels varied between 29,7 to 38,0 mg/kg.

Table 6. Sediment analyses for Copper (Cu) in mg/kg TS at C1-station, Laugardalur, 2019

St.	Cu
C1	-
C2	37,6
C3	31,2
C4	38,0
C5	33,6
C6	29,7

4.3 Soft bottom fauna

4.3.1.1 Fauna indexes and ecological classification

Results from the quantitative soft bottom fauna analyses is presented in Table 7. Faunal index nEQR in the table is presented without the density index (DI) in accordance with recommendations from the Norwegian Environment Agency (Miljødirektoratet).

Number of individuals varied from 1345 (C6) to 5351 (C5) and number of species from 37 (C4) to 76 (C6). The diversity H' was over 3,0 at C3 and C6 and lower at the other four stations. The overall index of nEQR varied from 0,567 (C4) to 0,716 (C6).

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, indicates a disturbed bottom fauna community. The distribution was somewhat uneven at some stations and varied from 0,50 (C5) to 0,73 (C6).

Table 7. . Number of species and individuals pr. 0,2 m^2. H´ = Shannon-Wieners diversity index. ES_{100} = Hurlberts diversity index. NQI1 = overall index (diversity and sensitivity). ISI_{2012} = sensitivity index. NSI = sensitivity index. J = Pielous evenness index. AMBI = AZTI marine biotic index (part of NQI1). nEQR = normalized EQR (excl. DI). Laugardalur, 2019.

St.	Numb. ind.	Numb. species	H´	ES_{100}	NQI1	ISI_{2012}	NSI	nEQR	AMBI	J
C1	1451	42	2,98	16,35	0,68	7,27	21,33	0,610	2,19	0,60
C2	3200	55	2,76	14,99	0,66	8,05	20,83	0,604	2,60	0,51
C3	4292	68	3,27	18,33	0,72	9,05	21,88	0,672	2,05	0,57
C4	1602	37	2,46	12,45	0,65	7,50	21,07	0,567	2,44	0,51
C5	5351	58	2,71	13,52	0,65	8,48	21,29	0,604	2,53	0,50
C6	1345	76	4,26	27,36	0,76	9,11	20,87	0,716	1,99	0,73

4.3.2 NS 9410 Evaluation of the bottom fauna in the local impact zone (C1)

According to NS 9410 can the classification of the environmental status in the local impact be based on evaluation of the number of species in relation to their dominance within the bottom fauna community (see chapter 8.6.2 in NS 9410:2016). Table 8 shows number of species, cumulative percent for dominating taxa and the classification of the environmental condition for the soft bottom fauna in the local impact zone station C1.

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 them are in numbers more than 65 % of the individuals. The data for number of species and dominating taxa at station C1 is collected from Table 7 and Table 9.

Table 8. NS 9410:2016. Classification of the environmental status of the soft bottom fauna at station C1 at the Laugardalur site, 2019.

Station	Site name	Num. species	Dominating taxa	Environmental condition-NS 9410
C1	Laugardalur	42	Ennucula tenuis - 33 %	1 – Very good

4.3.2.1 Geometric classes

Figure 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 and description of methods it is referred to Appendix 1. The reason for the analysis approach is that an unaffected fauna community consists of many species of low individual numbers, so that the curve starts high on the y-axis. A disturbed species community has fewer species and a few of them very numerous, so the curve flattens and stretches towards higher classes.

The curves for the stations started somewhat low (C1) to moderately high (other stations) and stretched to varying degrees towards higher classes. These gave no clear indications of the fauna condition of the stations.

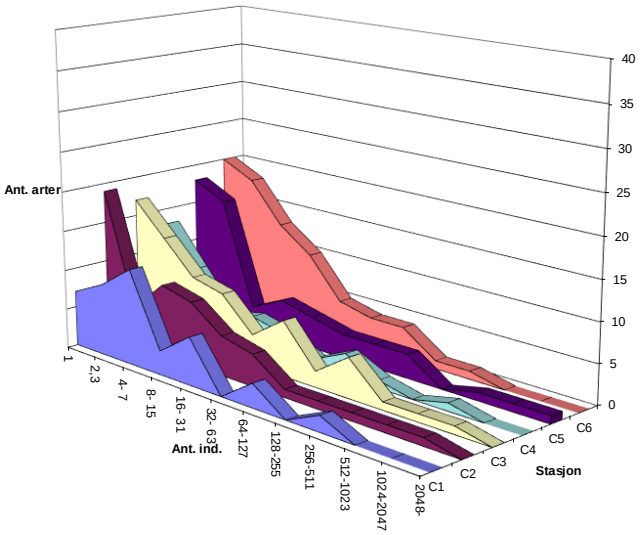


Figure 4. The soft bottom fauna shown as number of species against number of individual's pr. species in geometric classes at Laugardalur, 2019.

4.3.3 Cluster analyses

To investigate the similarity of the fauna composition between the sampling stations, the multivariate technique cluster analysis was used (see description of methods in Appendix 1). The results are presented in dendrogram i Figure .

Two stations with identical species and individual distribution will get 0 (0%) unlikeness, while two stations without like species, will get 100 (100%) unlikeness. This method allows you to identify groups of stations with similar species and individual conditions. In addition, it makes it easier to visualize any anomalies that, for example, can be linked to anthropogenic influences (effects related to human activities) on the bottom fauna communities.

The fauna composition was more than 50 % similar between the stations were station C6 most unlike.

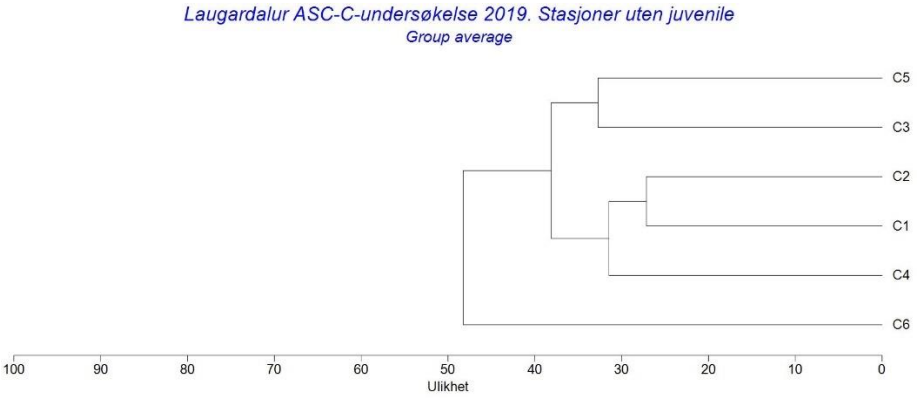


Figure 5. Clusterplott for the soft bottom fauna at Laugardalur, 2019.

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 9. 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 C1 the domination species was the neutral clam *Ennucula tenuis* with 33% of the individuals. The other most dominant species at the station were a mixture of neutral, tolerant and opportunistic species.

At the other stations, the tolerant bristle worm *Galathowenia oculata* dominated with between 23 and 53% of the individuals. The other most dominant species at the stations were mainly a mixture of neutral, tolerant and opportunistic species.

No pollution indicators were registered among the top-10 for any of the stations.

Table 9. Number of individuals, cumulative percentage and ecological group for the ten most dominant species on the stations. Laugardalur, 2019.*

C1	Numb.	Cum.	EG	C2	Numb.	Cum.	EG
Ennucula tenuis	480	33 %	II	Galathowenia oculata	1504	47 %	III
Galathowenia oculata	411	61 %	III	Ennucula tenuis	531	63 %	II
Owenia sp.	104	68 %	II	Abra nitida	388	75 %	III
Lagis koreni	102	75 %	IV	Thyasira sarsii	216	82 %	IV
Thyasira sarsii	96	82 %	IV	Lagis koreni	109	85 %	IV
Abra nitida	28	84 %	III	Maldane sarsi	56	87 %	IV
Pholoe baltica	28	86 %	III	Owenia sp.	55	89 %	II
Syllis cornuta	25	88 %	III	Sternaspis scutata	38	90 %	Ik
Eteone flava/longa	22	89 %	Ik	Yoldia hyperborea	36	91 %	Ik
Axinopsida orbiculata	19	90 %	Ik	Nuculana pernula	26	92 %	II
C3	**Numb.**	**Cum.**	**EG**	**C4**	**Numb.**	**Cum.**	**EG**
Galathowenia oculata	1570	36 %	III	Galathowenia oculata	846	53 %	III
Ennucula tenuis	898	57 %	II	Ennucula tenuis	242	68 %	II
Scoloplos sp.	276	63 %	Ik	Abra nitida	125	76 %	III
Pectinaria sp.	231	69 %	I	Owenia sp.	98	82 %	II
Abra nitida	176	73 %	III	Thyasira sarsii	85	87 %	IV
Owenia sp.	170	77 %	II	Macoma calcarea	54	90 %	IV
Lagis koreni	149	80 %	IV	Yoldia hyperborea	26	92 %	Ik
Macoma calcarea	137	83 %	IV	Prionospio steenstrupi	23	94 %	II
Thyasira sarsii	68	85 %	IV	Myriochele olgae	18	95 %	Ik
Pholoe inornata	66	86 %	III	Sternaspis scutata	10	95 %	Ik
C5	**Numb.**	**Cum.**	**EG**	**C6**	**Numb.**	**Cum.**	**EG**
Galathowenia oculata	2134	39 %	III	Galathowenia oculata	309	23 %	III
Abra nitida	1124	60 %	III	Abra nitida	177	35 %	III
Ennucula tenuis	976	78 %	II	Maldane sarsi	122	44 %	IV
Lagis koreni	206	82 %	IV	Macoma calcarea	95	51 %	IV
Owenia sp.	162	85 %	II	Scoloplos sp.	70	56 %	Ik
Thyasira sarsii	147	87 %	IV	Ennucula tenuis	65	61 %	II
Nuculana pernula	87	89 %	II	Thyasira gouldi	57	65 %	IV
Sternaspis scutata	82	90 %	Ik	Nuculana pernula	44	68 %	II
Maldane sarsi	68	92 %	IV	Thyasira sarsii	38	71 %	IV
Thyasiridae indet.	59	93 %	Ik	Goniada maculata	32	74 %	II

*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 Laugardalur, 2019, can be summarized as follows:

- The hydrography measurement did not reveal any critical oxygen levels at the deep station C4. The oxygen saturation in the bottom layer was 80 to 90 % in May 2019.
- TOM-levels were relatively low. TN-levels were also low and the same was the case for the C/N relationship. TOC was slightly high at the sampling stations and nTOC varied from 21,7 to 33,2. The copper level varied from 29,7 to 38,0 mg/kg. Sediments grain size were moderately coarse to moderately fine. The redox measurements (pH/Eh) gave points 0 for all the stations.
- Number of individuals were high (1345 to 5351) but number of species were moderate (37 to 76). The diversity index H ' was over 3,0 at station C3 and C6 but lower at the other four stations. The overall index of nEQR varied from 0,567 (C4) to 0,716 (C6). With reference evaluation based on NS 9410;2016 the environmental condition of the fauna in the local impact zone is grated as 1 (Very good). There were not found any pollution indicator species among the top-10 species at any of the sampling stations.

5.2 Conclusion

The results from the monitoring at the farming site Laugardalur in 2019 showed that the sediment had somewhat high levels of organic carbon with normalized TOC from 21,7 to 33,2. Copper concentrations varied from 29,7 to 38,0 mg/kg which are within natural levels reported for bottom sediment around Iceland (Egilsson et al., 1999). There were not found any pollution indicator species at any of the sampling stations. The overall index nEQR varied from 0,567 to 0,716. The oxygen saturation in May was good in the whole water column with 80 to 90% in the bottom water.

5.2.1 Environmental trend since the last C- survey

A C survey was conducted at the site in 2017 (Velvin & Gunnarsson, 2018). The conclusion was: *"The results from the C-survey at the site Laugardalur in November 2017 at max biomass showed that the sediment at stations C3 and C6 was slightly loaded with organic carbon, C1 and C4 were clearly loaded and the other stations moderately loaded. Species diversity was low on C1, C2 and C4, and higher on the remaining stations. Overall fauna index nEQR showed, however, good fauna condition at C1, C3, C5 and C6, and moderate fauna condition on C2 and C4. NS 9410 classification of soft bottom communities on stations C1 and C6 in the local impact zone gave the environmental condition 1 "very good" for both communities. No pollution indicators were recorded among the 10 most occurring taxa at any of the sampling stations. Oxygen conditions were good in the entire water column in November 2017. "*

nTOC was roughly at the same level in the two surveys (21 to 46 in 2017 and 22 to 33 in 2019) and so was the case with the overall index nEQR (0.578 to 0.679 in 2017 and 0.567 to 0.716 in 2019). Also the number of individuals and taxa are relatively similar in the two surveys. The scallop *Ennucula tenuis* dominated the fauna of C1 and the bristle worm *Galathowenia oculata* on the other stations in both surveys.

6 References

Aure, J., Dahl, E., Green, N., Magnusson. J., Moy, F., Pedersen, A., Rygg, B & Walday, M., 1993. Langtidsovervåking av trofiutviklingen i kystvannet langs Sør-Norge. Årsrapport 1990 og samlerapport 1990-91. Statlig program for forurensningsovervåking. *Rapport 510/93.*

Direktoratgruppen, 2018. Klassifisering av miljøtilstand i vann. Veileder 02:2018.

Egilsson, D, Ólafsdóttir E. D., Yngvadóttir E., Halldórsdóttir H., Sigurðsson F.H., Jónsson G.S., Jensson H., Gunnarsson K., Þráinsson S.A., Stefánsson A., Indriðason H.D., Hjartarson H., Torlacius J., Ólafsdóttir K., Gíslason S.R. og Svavarsson J. (1999). Mælingar á mengandi efnum á og við Ísland. Niðurstöður vöktunarmælinga. Starfshópur um mengunarmælingar. Mars 1999, 138 s.

Heggem, T., 2019. Arnarlax. Strømmålinger Laugardalur spredningsstrøm 42 m, 2019. APN-rapport 61178.01.

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.

Miljødirektoratet, 2016. Grenseverdier for klassifisering av vann, sediment og biota. M-608/2016. 24 s.

NS 9410:2016. Norsk standard for miljøovervåking av bunnpåvirkning fra marine akvakulturanlegg.

Rygg, B. & K. Norling, 2013. Norwegian Sensitive Index (NSI) for marine macro invertebrates, and an update of Indicator Species Index (ISI). NIVA report SNO 6475-2013. 48 p.

Velvin, R. & Gunnarsson, S., 2018. Arnarlax. ASC- og C-undersøkelse Laugardalur, 2017. APN-rapport 9207.01.

Þórisson, B., Gallo, C. og Jóhannsdóttir, E.D., 2015. Vöktun á botndýralífi við fiskeldiskvíar út af Laugardal í Tálknafirði 2013-14. Náttúrustofa Vestfjarða, NAVE rapport NV. Nr.10-15.

Pers. communication. Silja Baldvinsdóttir, Quality manager, Arnarlax hf.

7 Appendix (in norwegian)

Appendix 1 Bunndyrsstatistikk og artslister

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.

Hurlbert, S.N., 1971. The non-consept of the species diversity: A critique and alternative parameters. *Ecology* 52:577-586.

Pielou, E. C., 1966. Species-diversity and pattern-diversity in the study of ecological succession. *Journal of Theoretical Biology* 10, 370-383.

Rygg, B., 2002. Indicator species index for assessing benthic ecological quality in marine water of Norway. *NIVA report* SNO 4548-2002. 32 p.

Shannon, C.E. & W. Weaver, 1949. The Mathematical Theory of Communication. *Univ Illinois Press*, Urbana 117 s.

Statistikk resultater Laugardalur, 2019:

Antall arter og individer per stasjon

st.nr.	tot.	C1	C2	C3	C4	C5	C6
no. ind.	17241	1451	3200	4292	1602	5351	1345
no. spe.	121	42	55	68	37	58	76

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	C6_01	C6_02
no. ind.	17241	867	584	1476	1724	2096	2196	780	822	2844	2507	629	716
no. spe.	121	37	27	45	40	56	54	29	28	41	44	57	58
Shannon-Wiener:		3,2	2,8	2,8	2,7	3,2	3,4	2,7	2,3	2,7	2,7	4,2	4,3
Pielou		0,61	0,58	0,51	0,52	0,55	0,59	0,55	0,47	0,51	0,49	0,73	0,73
ES100		17	15	16	14	19	18	13	12	13	14	28	27
SN		1,89	1,78	1,92	1,84	1,98	1,95	1,78	1,75	1,79	1,84	2,17	2,16
ISI-2012		7,60	6,94	7,60	8,49	9,33	8,78	7,58	7,43	8,57	8,38	9,06	9,15
AMBI		2,226	2,152	2,607	2,585	2,107	1,999	2,425	2,452	2,408	2,658	2,174	1,815
NQI1		0,69	0,67	0,67	0,65	0,72	0,72	0,65	0,65	0,66	0,65	0,74	0,77
NSI		21,2	21,4	20,8	20,8	21,4	22,4	21,0	21,2	21,5	21,0	20,8	20,9
DI		0,888	0,716	1,119	1,187	1,271	1,292	0,842	0,865	1,404	1,349	0,749	0,805

Bunndyrindekser, gjennomsnitt per stasjon

st.nr.		C1	C2	C3	C4	C5	C6
Shannon-Wiener:		2,98	2,76	3,27	2,46	2,71	4,26
Pielou		0,60	0,51	0,57	0,51	0,50	0,73
ES100		16,3	15,0	18,3	12,5	13,5	27,4
SN		1,83	1,88	1,97	1,76	1,82	2,16
ISI-2012		7,27	8,05	9,05	7,50	8,48	9,11
AMBI		2,189	2,596	2,053	2,439	2,533	1,995
NQI1		0,68	0,66	0,72	0,65	0,65	0,76
NSI		21,33	20,83	21,88	21,07	21,29	20,87
Tilstandsklasse nEQR		0,610	0,604	0,672	0,567	0,604	0,716

Geometriske klasser

int.	C1	C2	C3	C4	C5	C6
1	7	19	17	13	18	20
2,3	9	5	13	8	16	18
4- 7	12	9	9	3	3	13
8- 15	3	8	8	4	5	10
16- 31	6	5	4	3	4	5
32- 63	0	4	7	1	3	4
64-127	3	1	2	3	3	4
128-255	0	1	5	1	3	1
256-511	2	1	1	0	0	1
512-1023	0	1	1	1	1	0
1024-2047	0	1	1	0	1	0
2048-	0	0	0	0	1	0

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
Stasjonsnr.: C1						
NEMERTINI						
			Nemertea indet.	2	2	4
PRIAPULIDA						
			Priapulus caudatus		2	2
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	4	1	5
			Levinsenia gracilis	1		1
			Aricidea catherinae	3		3
			Aricidea hartmani		1	1
		Cossurida				
			Cossura longocirrata	1		1
		Spionida				
			Prionospio steenstrupi		6	6
			Spio limicola	6	5	11
			Chaetozone sp.	2		2
		Capitellida				
			Heteromastus filiformis	1		1
			Maldane sarsi	3	2	5
			Praxillella gracilis	4		4
			Praxillella praetermissa	4		4
		Opheliida				
			Scalibregma inflatum	2	1	3
		Phyllodocida				
			Eteone flava/longa	15	7	22
			Harmothoe sp.	2		2
			Pholoe baltica	22	6	28
			Syllis cornuta	11	14	25
			Goniada maculata	1		1
			Nephtys ciliata	4	2	6
			Nephtys sp.	2		2
		Eunicida				
			Schistomeringos sp.	1	1	2
		Sternaspida				
			Sternaspis scutata	3	2	5
		Oweniida				
			Galathowenia oculata	237	174	411
			Owenia sp.	73	31	104
		Flabelligerida				
			Brada villosa	1		1
		Terebellida				
			Cistenides hyperborea	2		2
			Lagis koreni	88	14	102
		Sabellida				
			Chone sp.		4	4
			Euchone sp.	2		2
CRUSTACEA						
	Malacostraca					
		Cumacea				
			Leucon sp.	6	4	10
		Amphipoda				
			Lysianassidae indet.		1	1

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
MOLLUSCA						
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	259	221	480
			Nuculana pernula	3	1	4
			Yoldia hyperborea	6	6	12
		Veneroida				
			Axinopsida orbiculata	10	9	19
			Thyasira gouldi	6		6
			Thyasira sarsii	45	51	96
			Thyasiridae indet.	7		7
			Macoma calcarea	8	8	16
			Abra nitida	20	8	28
ECHINODERMATA						
	Ophiuroidea					
			Ophiuroidea indet. juv.	3		3
			Maks:	259	221	480
			Antall:	38	27	43
			Sum:			1454

Stasjonsnr.: C2

NEMERTINI						
			Nemertea indet.	2	1	3
SIPUNCULIDA						
			Golfingiidae indet.		1	1
			Sipuncula indet. juv.		1	1
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	2	5	7
			Aricidea albatrossae		1	1
			Aricidea catherinae		1	1
			Aricidea cerrutii	2		2
		Cossurida				
			Cossura longocirrata	2		2
		Spionida				
			Prionospio steenstrupi	5	7	12
			Spio limicola	15	9	24
			Chaetozone sp.	4	3	7
		Capitellida				
			Heteromastus filiformis	3	1	4
			Maldane sarsi	20	36	56
			Praxillella gracilis	1	2	3
			Praxillella praetermissa	7	6	13
		Opheliida				
			Scalibregma inflatum	1		1
		Phyllodocida				
			Eteone flava/longa	7	6	13
			Harmothoe sp.	1		1
			Pholoe assimilis		1	1
			Pholoe baltica	2	7	9
			Pholoe inornata	3	5	8
			Microphthalmus sczelkowii	1		1

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
			Syllis cornuta		5	5
			Nephtys ciliata	2	3	5
			Nephtys sp.	1		1
		Eunicida				
			Protodorvillea kefersteini	2		2
			Schistomeringos sp.	4		4
		Sternaspida				
			Sternaspis scutata	17	21	38
		Oweniida				
			Galathowenia oculata	720	784	1504
			Myriochele olgae	16	7	23
			Owenia sp.	17	38	55
		Terebellida				
			Lagis koreni	33	76	109
			Lanassa venusta	1		1
			Laphania boecki		1	1
		Sabellida				
			Chone sp.	5		5
			Euchone papillosa		1	1
			Euchone sp.	3	1	4
CRUSTACEA						
	Malacostraca					
		Cumacea				
			Leucon sp.	9	4	13
		Amphipoda				
			Byblis gaimardii		1	1
			Oedicerotidae indet.	1		1
			Caprellidae indet.		1	1
MOLLUSCA						
	Prosobranchia					
		Neogastropoda				
			Propebela cancellata	1		1
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	225	306	531
			Nuculana pernula	13	13	26
			Yoldia hyperborea	18	18	36
		Veneroida				
			Axinopsida orbiculata	4	5	9
			Thyasira gouldi	5	3	8
			Thyasira sarsii	106	110	216
			Thyasiridae indet.	2	2	4
			Astarte montagui	1		1
			Macoma calcarea	7	9	16
			Abra nitida	172	216	388
			Arctica islandica juv.		1	1
		Myoida				
			Mya sp. juv.	1	1	2
PHORONIDA						
			Phoronis sp.		1	1
ECHINODERMATA						
	Asteroidea					
		Forcipulatida				
			Leptasterias muelleri	1		1
	Ophiuroidea					
		Ophiurida				
			Ophiocten affinis	11	6	17
			Ophiuroidea indet. juv.	7	11	18

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
TUNICATA						
	Ascidiacea					
			Ascidiacea indet. (solit)	1		1
			Maks:	720	784	1504
			Antall:	47	44	59
			Sum:			3222

Stasjonsnr.: C3

NEMERTINI						
			Nemertea indet.	6	3	9
PRIAPULIDA						
			Priapulus caudatus		6	6
ECHIURIDA						
			Echiurus echiurus	1	1	2
SIPUNCULIDA						
			Sipuncula indet. juv.	1		1
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	151	125	276
			Aricidea albatrossae	1		1
		Spionida				
			Dipolydora sp.	9		9
			Laonice cirrata	2	2	4
			Prionospio steenstrupi	1	1	2
			Spio armata	2		2
			Spio filicornis	1		1
			Spio limicola	7	9	16
			Chaetozone sp.	7	1	8
			Cirratulus cirratus	1		1
		Capitellida				
			Capitella capitata		1	1
			Heteromastus filiformis	22	9	31
			Rhodine loveni		2	2
			Maldane sarsi	27	26	53
			Praxillella gracilis		9	9
			Praxillella praetermissa	17	41	58
		Opheliida				
			Ophelina acuminata		1	1
			Scalibregma inflatum		1	1
		Phyllodocida				
			Eteone flava/longa	17	16	33
			Harmothoe imbricata	1	1	2
			Harmothoe sp.		2	2
			Pholoe assimilis	3	1	4
			Pholoe baltica	28	26	54
			Pholoe inornata	44	22	66
			Syllis cornuta	10	13	23
			Goniada maculata	5	4	9
			Nephtys ciliata	1	4	5
			Nephtys paradoxa		1	1

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
		Eunicida				
			Scoletoma fragilis	1		1
			Scoletoma sp.	1		1
			Schistomeringos sp.	1		1
		Sternaspida				
			Sternaspis scutata	6	2	8
		Oweniida				
			Galathowenia fragilis	1	1	2
			Galathowenia oculata	844	726	1570
			Owenia sp.	91	79	170
		Terebellida				
			Cistenides hyperborea		1	1
			Lagis koreni	26	123	149
			Pectinaria sp.	3	228	231
			Laphania boecki	2	2	4
		Sabellida				
			Euchone sp.	8	1	9
CRUSTACEA						
	Malacostraca					
		Cumacea				
			Leucon sp.	3	1	4
			Leptostylis sp.	1		1
		Amphipoda				
			Protomedeia fasciata	16	3	19
			Lysianassidae indet.	2		2
			Oedicerotidae indet.	3	4	7
			Podoceridae indet.	1	1	2
			Gammaridea indet.	1		1
			Caprellidae indet.	1		1
		Decapoda				
			Paguridae indet.	1	1	2
MOLLUSCA						
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	452	446	898
			Nuculana pernula	23	15	38
			Yoldia hyperborea	2	2	4
		Mytiloida				
			Crenella decussata	1		1
		Ostreoidea				
			Heteranomia squamula		1	1
		Veneroida				
			Axinopsida orbiculata	13	20	33
			Thyasira gouldi	17	19	36
			Thyasira sarsii	32	36	68
			Thyasiridae indet.	4	5	9
			Astarte montagui	2	1	3
			Astarte sp. juv.	1	3	4
			Macoma calcarea	79	58	137
			Abra nitida	91	85	176
			Arctica islandica	1		1
			Arctica islandica juv.	1	3	4
		Myoida				
			Mya sp. juv.	6	12	18
ECHINODERMATA						
	Ophiuroidea					
		Ophiurida				
			Amphipholis squamata		2	2
			Ophiocten affinis	2	3	5

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
			Ophiura albida		2	2
			Ophiuroidea indet. juv.		6	6
			Maks:	844	726	1570
			Antall:	60	58	73
			Sum:			4325
Stasjonsnr.: C4						
CNIDARIA						
	Anthozoa					
			Edwardsia sp.		2	2
NEMERTINI						
			Nemertea indet.		1	1
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	2	1	3
			Aricidea albatrossae	1	2	3
		Cossurida				
			Cossura longocirrata	2		2
		Spionida				
			Prionospio steenstrupi	9	14	23
			Spio decorata	1		1
			Spio limicola	2		2
			Chaetozone sp.	1	1	2
		Capitellida				
			Heteromastus filiformis	3	1	4
			Maldane sarsi	4	2	6
			Praxillella gracilis	1		1
			Praxillella praetermissa		1	1
		Phyllodocida				
			Eteone flava/longa		1	1
			Pholoe assimilis	1		1
			Syllis cornuta	4	2	6
			Nephtys ciliata	2	6	8
		Eunicida				
			Schistomeringos sp.		1	1
		Sternaspida				
			Sternaspis scutata	7	3	10
		Oweniida				
			Galathowenia oculata	361	485	846
			Myriochele olgae	13	5	18
			Owenia sp.	44	54	98
		Terebellida				
			Lagis koreni	1	2	3
			Lanassa venusta	1		1
		Sabellida				
			Euchone papillosa		1	1
CRUSTACEA						
	Malacostraca					
		Cumacea				
			Leucon sp.	7	2	9
		Amphipoda				
			Westwoodilla caecula	1		1
MOLLUSCA						
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	143	99	242

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
			Nuculana pernula	6	3	9
			Yoldia hyperborea	13	13	26
		Veneroida				
			Axinopsida orbiculata	3		3
			Thyasira sarsii	74	11	85
			Macoma calcarea	4	50	54
			Abra nitida	68	57	125
ECHINODERMATA						
	Asteroidea					
		Paxillosida				
			Ctenodiscus crispatus		1	1
		Forcipulatida				
			Leptasterias muelleri		1	1
	Ophiuroidea					
		Ophiurida				
			Ophiocten affinis	1		1
			Ophiuroidea indet. juv.	1		1
			Maks:	361	485	846
			Antall:	30	28	38
			Sum:			1603

Stasjonsnr.: C5

NEMERTINI						
			Nemertea indet.		2	2
PRIAPULIDA						
			Priapulus caudatus		2	2
ECHIURIDA						
			Echiurus echiurus		1	1
SIPUNCULIDA						
			Phascolion strombus		1	1
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	32	22	54
			Aricidea catherinae		1	1
		Spionida				
			Dipolydora sp.	1	1	2
			Prionospio cirrifera	1		1
			Prionospio steenstrupi	5	6	11
			Spio limicola	1		1
			Chaetozone sp.	2		2
		Capitellida				
			Maldane sarsi	33	35	68
			Praxillella gracilis	8	4	12
			Praxillella praetermissa	9	8	17
		Opheliida				
			Scalibregma inflatum	1	1	2
		Phyllodocida				
			Phyllodoce groenlandica		1	1
			Harmothoe fragilis		1	1
			Harmothoe sp.	2		2
			Pholoe baltica	2	4	6
			Pholoe inornata	1	3	4

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
			Syllis cornuta		1	1
			Goniada maculata	1		1
			Nephtys ciliata	3	2	5
		Eunicida				
			Nothria hyperborea	1	1	2
			Scoletoma fragilis		1	1
		Sternaspida				
			Sternaspis scutata	43	39	82
		Oweniida				
			Galathowenia oculata	1027	1107	2134
			Myriochele olgae		8	8
			Owenia sp.	93	69	162
		Flabelligerida				
			Diplocirrus longisetosus	1		1
		Terebellida				
			Cistenides hyperborea		1	1
			Lagis koreni	90	116	206
			Melinna cristata	2		2
			Lanassa venusta		1	1
			Laphania boecki		2	2
		Sabellida				
			Chone sp.		1	1
CRUSTACEA						
	Ostracoda					
			Ostracoda indet.	2		2
	Malacostraca					
		Cumacea				
			Leucon sp.	2		2
			Leptostylis sp.	2		2
		Amphipoda				
			Byblis gaimardii	1	1	2
			Lysianassidae indet.	1		1
			Oedicerotidae indet.	6	5	11
MOLLUSCA						
	Prosobranchia					
		Neogastropoda				
			Propebela cancellata	1		1
	Opistobranchia					
		Cephalaspidea				
			Retusa obtusa		1	1
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	708	268	976
			Nuculana pernula	54	33	87
			Yoldia hyperborea	17	27	44
		Mytiloida				
			Crenella decussata	1		1
			Musculus sp. juv.		1	1
		Veneroida				
			Axinopsida orbiculata	12	9	21
			Thyasira gouldi	13	10	23
			Thyasira sarsii	74	73	147
			Thyasiridae indet.	43	16	59
			Astarte sp. juv.	1	1	2
			Parvicardium pinnulatum		2	2
			Macoma calcarea	8	18	26
			Abra nitida	528	596	1124
			Arctica islandica	2		2
			Arctica islandica juv.	10	8	18

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
		Myoida				
			Mya sp. juv.	23	24	47
		Pholadomyoida				
			Thracia sp. juv.		1	1
ECHINODERMATA						
	Ophiuroidea					
		Ophiurida				
			Ophiocten affinis	10	4	14
			Ophiura albida		2	2
			Ophiuroidea indet. juv.	16	9	25
			Maks:	1027	1107	2134
			Antall:	45	50	64
			Sum:			5445

Stasjonsnr.: C6

NEMERTINI						
			Nemertea indet.	3	2	5
SIPUNCULIDA						
			Phascolion strombus	2		2
ANNELIDA						
	Polychaeta					
		Orbiniida				
			Scoloplos sp.	23	47	70
			Levinsenia gracilis		1	1
		Spionida				
			Dipolydora sp.	2	2	4
			Laonice cirrata	5	8	13
			Prionospio steenstrupi	4	4	8
			Spio armata	3	3	6
			Spio limicola	5	3	8
			Chaetozone sp.		1	1
			Cirratulus cirratus	10		10
			Dodecaceria concharum	3		3
		Capitellida				
			Rhodine gracilior	1	6	7
			Rhodine loveni	8	7	15
			Nicomache lumbricalis	1		1
			Nicomache sp.	4		4
			Petaloproctus tenuis	13	3	16
			Maldane sarsi	56	66	122
			Praxillella gracilis	1	2	3
		Phyllodocida				
			Eteone flava/longa	2		2
			Eulalia viridis	1		1
			Gattyana amondseni	1	2	3
			Gattyana cirrhosa	2	2	4
			Harmothoe fragilis	1		1
			Harmothoe glabra	2		2
			Harmothoe imbricata		1	1
			Harmothoe sp.	3		3
			Pholoe assimilis	2	2	4
			Pholoe baltica	3	3	6
			Pholoe inornata	4	9	13
			Nereimyra punctata		1	1

Rekke	Klasse	Orden	Art/Taxa	01	02	Sum
			Syllis armillaris	1		1
			Syllis cornuta	7	8	15
			Goniada maculata	18	14	32
			Nephtys ciliata	2	2	4
			Nephtys paradoxa		1	1
		Eunicida				
			Nothria hyperborea	3	7	10
			Scoletoma fragilis	5	4	9
		Sternaspida				
			Sternaspis scutata		2	2
		Oweniida				
			Galathowenia oculata	161	148	309
		Flabelligerida				
			Diplocirrus longisetosus	2		2
		Terebellida				
			Lagis koreni	15	3	18
			Pectinaria sp.	1	1	2
			Eupolymnia nesidensis	1		1
			Lanassa venusta		1	1
			Laphania boecki	1		1
			Polychaeta indet.	1		1
CRUSTACEA						
	Ostracoda					
			Ostracoda indet.	2		2
	Malacostraca					
		Cumacea				
			Eudorellopsis deformis		1	1
			Leucon sp.		1	1
			Brachydiastylis resima	3	2	5
			Leptostylis sp.		1	1
		Amphipoda				
			Byblis gaimardii		3	3
			Protomedeia fasciata		16	16
			Lysianassidae indet.	1	1	2
			Oedicerotidae indet.	4		4
MOLLUSCA						
	Prosobranchia					
		Archaeogastropoda				
			Lepeta caeca	1		1
		Mesogastropoda				
			Euspira pallida		1	1
		Neogastropoda				
			Propebela cancellata		2	2
	Opistobranchia					
		Cephalaspidea				
			Retusa obtusa		1	1
	Bivalvia					
		Nuculoida				
			Ennucula tenuis	22	43	65
			Nuculana pernula	21	23	44
		Veneroida				
			Axinopsida orbiculata	1	6	7
			Thyasira gouldi	12	45	57
			Thyasira sarsii	20	18	38
			Thyasiridae indet.	14	4	18
			Astarte elliptica	1	6	7
			Astarte montagui		3	3
			Astarte sp. juv.	4	6	10

Rekke	Klasse	Orden	Art/Taxa	01	02		Sum
			Parvicardium pinnulatum	14	8		22
			Ciliatocardium ciliatum		1		1
			Macoma calcarea	35	60		95
			Abra nitida	89	88		177
			Arctica islandica		3		3
		Pholadomyoida					
			Thracia myopsis	2	1		3
ECHINODERMATA							
	Ophiuroidea						
		Ophiurida					
			Ophiocten affinis		2		2
			Ophiura albida	4	10		14
			Ophiuroidea indet. juv.	10	6		16
			Maks:	161	148		309
			Antall:	59	60		78
			Sum:				1371
					TOTAL:	***Maks:***	2134
						Sum:	17420

Appendix 2. Analysebeviser

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:	**Arnarlax**
Kunde referanse:	**Laugardalur C /B undersøkelse vor 2019**
Kontaktperson kunde:	
e-post:	
Kontaktperson Akvaplan-niva:	Snorri Gunnarsson
Dato:	16.08.2019
Rapport nr.:	**60938**
Analyseparameter(e):	Korn, TOM, TOC, TN, Cu
Kontaktperson:	Anja Sjøvoll
Analyseansvarlig:	Ida Gravem Tvedt (sign.)
Underskriftsberettiget:	Anja Sjøvoll (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:

Analysene gjelder bare for de prøver som er testet. De oppgitte analyseresultat omfatter ikke feil som måtte følge av prøvetagningen, inhomogenitet eller andre forhold som kan ha påvirket prøven før den ble mottatt av laboratoriet. Rapporten får kun kopieres i sin helhet og uten noen form for endringer. En eventuell klage skal leveres laboratoriet senest en måned etter mottak av analyseresultat. Nærmere informasjon om analysemetodene (måleusikkerhet, metodeprinsipp etc.) fås ved henvendelse til Akvaplan-Niva AS

Lab-id.	Kundens id.	Materiale	Mottatt lab	Parametere	Analyse-periode
60938/C1	60938/C1	Sediment	06.06.2019	Korn, TOM, TOC, Cu	07.06.-03.07.19
60938/C2	60938/C2	Sediment	06.06.2019	Korn, TOM, TOC, 2xCu	07.06.-03.07.19
60938/C3	60938/C3	Sediment	06.06.2019	Korn, TOM, TOC, 2xCu	07.06.-03.07.19
60938/C4	60938/C4	Sediment	06.06.2019	Korn, TOM, TOC, 2xCu	07.06.-03.07.19
60938/C5	60938/C5	Sediment	06.06.2019	Korn, TOM, TOC, 2xCu	07.06.-03.07.19
60938/C6	60938/C6	Sediment	06.06.2019	Korn, TOM, TOC, 2xCu	07.06.-03.07.19

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 12260:2003. 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

	TOC	TN	TOM	Pelitt	> 0,063 mm	Cu*	Cu*	N TOC	C/N#
Kundens id.:	mg/g TS	mg/g TS	% TS	vekt%	vekt%	mg/kg TS	mg/kg TS	mg/g TS	
60938/C1	17.6	2.7	8.4	36.7	63.3	36.3	ia	29.0	6.5
60938/C2	23.9	4.0	9.5	48.1	51.9	35.2	37.6	33.2	6.0
60938/C3	9.4	1.7	4.4	20.2	79.8	31	31.2	23.8	5.6
60938/C4	24.0	3.7	12.8	64.9	35.1	38.3	38	30.3	6.4
60938/C5	15.5	2.8	7.2	32.8	67.2	34.6	33.6	27.6	5.6
60938/C6	7.7	1.3	4.1	22.6	77.4	30.3	29.7	21.7	6.0

* 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 (pellitt) gitt ved %pellitt/100.

ia = ikke analysert

#) TOC-resultat større enn ca 60 mg/g TS kan gi underestimert TN-resultat og derved gi forhøyet C/N-verdi

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

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

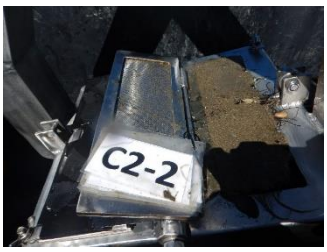
Tilstandsklassifisering for kobber (Cu) i marine sedimenter (grenseverdier fra M-608/2016):

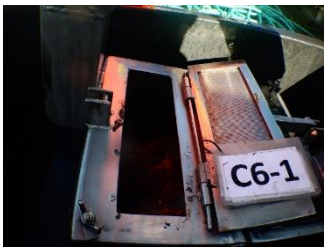
Cu, mg/kg TS	< 20 Klasse I	20-84 Klasse II/III	84 - 147 Klasse IV	> 147 Klasse V

Tilstandsklassifisering for kadmium (Cd) i marine sedimenter (grenseverdier fra M-608/2016):

Cd, mg/kg TS	< 0,2 Klasse I	0,2 - 2,5 Klasse II	2,5 - 16 Klasse III	16 - 157 Klasse IV	> 157 Klasse V

Appendix 3 – Pictures of samples at Laugardalur

St 1		
St 2		
St 3		
St 4		
St 5		NA

St 6		NA