DET NORSKE VERITAS™

REPORT

BASELINE SURVEY EIK 2011

NORWEGIAN ENERGY COMPANY ASA

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MANAGING RISK

Baseline Survey Eik 2011

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Summary:
The report describes the execution of the baseline surveys at Eik, located in the Barents Sea. The survey includes sediment characterisation, chemical analyses and biological analyses of the soft bottom fauna in the Eik area.

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Keywords
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Reference to part of this report which may lead to misinterpretation is not permissible.

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- Appendix E – *Baseline program (in Norwegian)*

Preface

The baseline survey at Eik was carried out by Det Norske Veritas and MOLAB on behalf of Noreco. The work was coordinated by Hans Jacob Beck (Marathon) and Robert Farestveit (Noreco).

The report presents the results from the chemical/physical analyses of sea bed sediments and the analyses of the soft bottom fauna community at Eik.

Personnel

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Biological analyses:	Øyvind Fjukmoen (Polychaeta, varia) Øystein Stokland (Polychaeta, varia) Thomas Møskeland (Crustacea) Amund Ulfsnes (Echinodermata, Mollusca) Per-Bie Wikander, Molltax (Mollusca) Fredrik Melsom (Polychaeta, varia) Rozemarijn Keuning (Polychaeta, varia, Mollusca)

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1 RESUMÉ / RESYMÉ

1.1 Resumé

The sediments are characterized by grain size distribution and total organic matter (TOM). The sediments are analyzed for hydrocarbons (THC, NPD, PAH), metals and soft bottom fauna community indices.

The sediments on Eik are dominated by silt and clay and TOM is in the 4.23-5.10 % range. The THC concentrations are low and at the same level as the regional station R106. None of the chromatograms contains traces of hydrocarbons from oil. The Ba concentrations are higher than R106 for all stations.

Eik	Variation	Description of the field
THC (mg/kg)	3-6	None of the stations at Eik have THC-concentration above LSC for region IX/X in 2010. All stations have THC concentration above or at the same level as the regional station R106.
Ba (mg/kg)	113-125	All stations have Ba concentration above the Ba level at the regional station R106. None of the stations have Ba concentration above LSC for region IX/X in 2010.
H’	4.0 – 5.0	The diversity indices of the Eik benthic fauna are high at all stations and show only minor fluctuations. The indices reflect healthy undisturbed seafloor with complex fauna communities. The regional station R106 is considered to be a suitable regional station in future monitoring.
J	0.65 – 0.85	
ES_{100}	28 - 38	

1.2 Resymé (Norwegian)

Sedimentene er karakterisert ved kornstørrelsesfordeling og innhold av totalt organisk materiale (TOM). Sedimentene er analysert for innhold av totalmengde hydrokarboner THC, NPD, PAH og metaller samt bløtbunnsfauna.

Sedimentene på Eik består hovedsakelig av silt og leire og TOM ligger mellom 4,23 og 5,10 %. THC-konsentrasjonene er lave og på samme nivå som den regionale stasjonen R106. Kromatogrammene viser kun naturlig bakgrunn. Alle stasjoner har høyere Ba-konsentrasjon enn R106.

Eik	Variasjon	Beskrivelse av feltet
THC (mg/kg)	3-6	Det er ikke funnet THC-verdier over $LSC_{2010RegionIX/X}$. Alle stasjonene ligger på samme nivå eller rett over referansestasjonen R106.
Ba (mg/kg)	113-125	Alle stasjonene har Ba-verdier som ligger over referansestasjonen R106. Ingen av stasjonene har Ba-konsentrasjon over $LSC_{2010RegionIX/X}$.
H’	4,0 – 5,0	Diversitetsindeksene er jevnt høye og reflekterer en sunn og uforstyrret bunnfauna med komplekse samfunn på alle stasjoner. Den regionale stasjonen R106 er ansett å være en egnet regional stasjon i fremtidig overvåking.
J	0,65 – 0,85	
ES_{100}	28 - 38	

2 INTRODUCTION

Eik (PL396) is located east of Ververis and Arenaria in Region X the Barents Sea. The predominant current direction at Arenaria and Ververis is towards east and the axis cross is placed in the same direction. The depth at Eik is about 350m. The program includes the new station REGX-6 which is assigned to Eik as a regional station. The station is located 8000m west of Eik.

Previous studies in the area

It was conducted visual surveys by ROV of Arenaria and Ververis in 2008. The results of these studies show that there was no coral in the survey area, it was generally low density of the sponges and it was high density of trawl tracks in sediment. None of the observed mega fauna species are regarded as particularly vulnerable.

The baseline survey at Nucula in 2006 showed that the content of THC, barium and other metals in the sediments were low. The biological analyses showed that there is great similarity in faunal composition and the diversity was high. There were no significant correlations between the faunal distribution and the measured environmental parameters, and it was therefore concluded that the fauna in the area is undisturbed.

The survey at Eik included both sediment sampling and visual mapping. The results from the visual mapping are reported in DNV 2012.

3 MATERIALS AND METHODS

3.1 Sampling strategy

The program included both conventional sediment sampling in addition to visual surveys using ROV. The results from the visual survey are reported in DNV, 2012. The program for sediment sampling and analyses is shown in Table 3.1-1.

Table 3.1-1 *Station coordinates for sampling at Eik (ED50 UTM zone 34).*

Eik Station	Dist. (m)	Dir.. (◦)	East	North	THC *	Metals *	TOM **	Grain **	Bio	PAH/NPD
Centre	-	-	740330	8098631	-	-	-	-	-	-
Eik1	60	90	740390	8098631	3	3	1	1	5	3
Eik2	250	90	740580	8098631	3	3	1	1	5	3
Eik3	500	90	740830	8098631	3	3	1	1	5	
Eik4	1000	90	741330	8098631	3	3	1	1	5	
Eik6	60	180	740330	8098571	3	3	1	1	5	
Eik7	250	180	740330	8098381	3	3	1	1	5	
Eik8	500	180	740330	8098131	3	3	1	1	5	
Eik11	60	270	740270	8098631	3	3	1	1	5	
Eik12	250	270	740080	8098631	3	3	1	1	5	
Eik13	500	270	739830	8098631	3	3	1	1	5	
Eik16	60	0	740330	8098691	3	3	1	1	5	
Eik17	250	0	740330	8098881	3	3	1	1	5	
Eik18	500	0	740330	8099131	3	3	1	1	5	
REGX-6	8000	-	732330	8098631	3	3	1	1	5	3
SUM					**42**	**42**	**14**	**14**	**70**	**9**

* Three samples from 0-1cm ** Composite sample from three grab samples

Figure 3-2 shows the location of Eik together with the other fields included in the survey conducted by DNV on behalf of several operators in June/July 2011. In this report only the Eik field is presented.

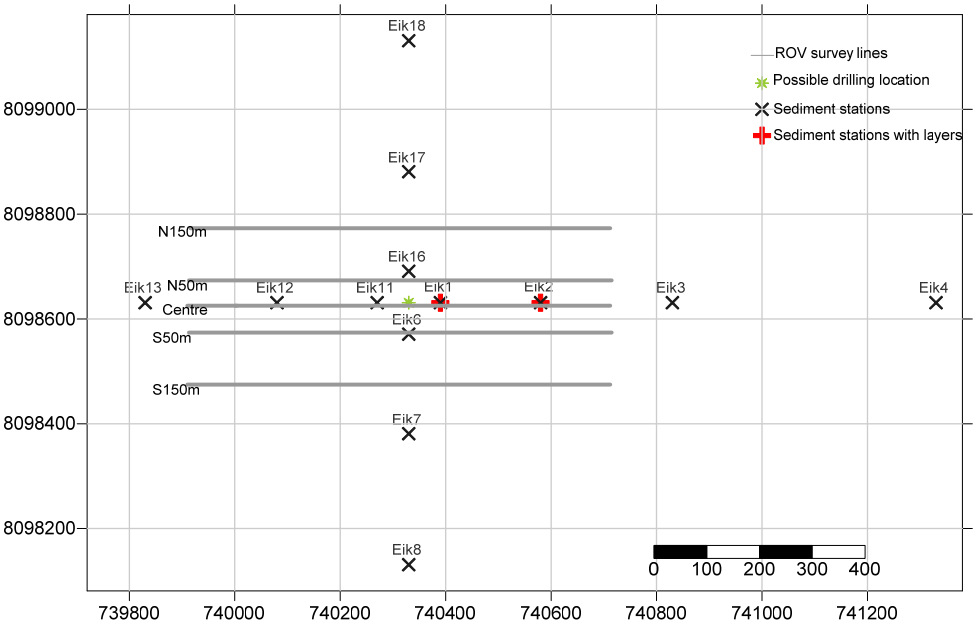

Figure 3-1 *Station map of baseline survey and planned ROV-transects at Eik (PL396) in 2011. Regional station is not included.*

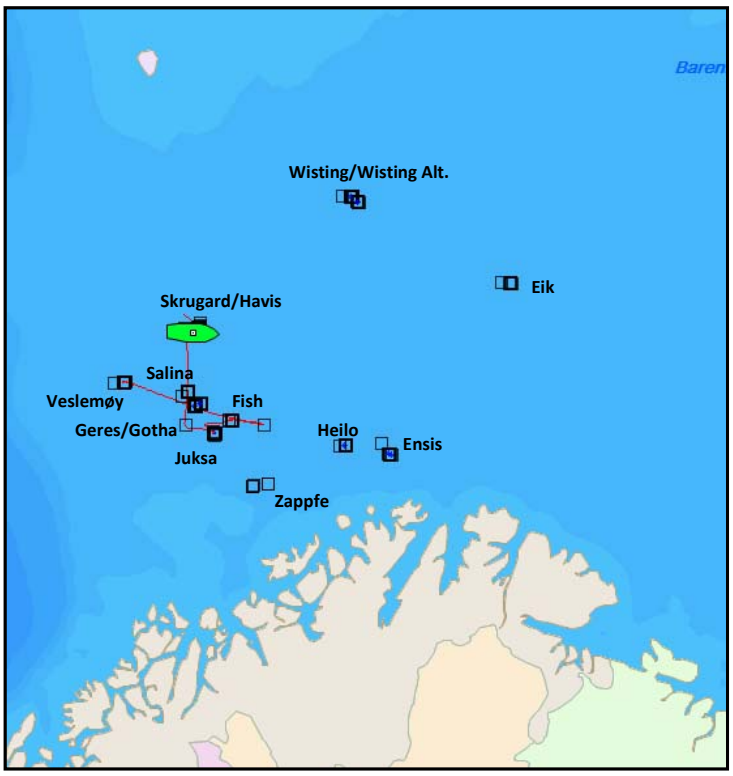

Figure 3-2 *Overview of baseline surveys conducted by DNV in the Barents Sea June/July 2011.*

3.2 Fieldwork

3.2.1 Sampling/equipment

The field work was performed by DNV in cooperation with MOLAB from the vessel "MV Birkeland". The sampling was carried out as a part of baseline surveys in the Barents Sea on behalf of several operators. Figure 3-3 shows the fields included in the survey, including regional stations.

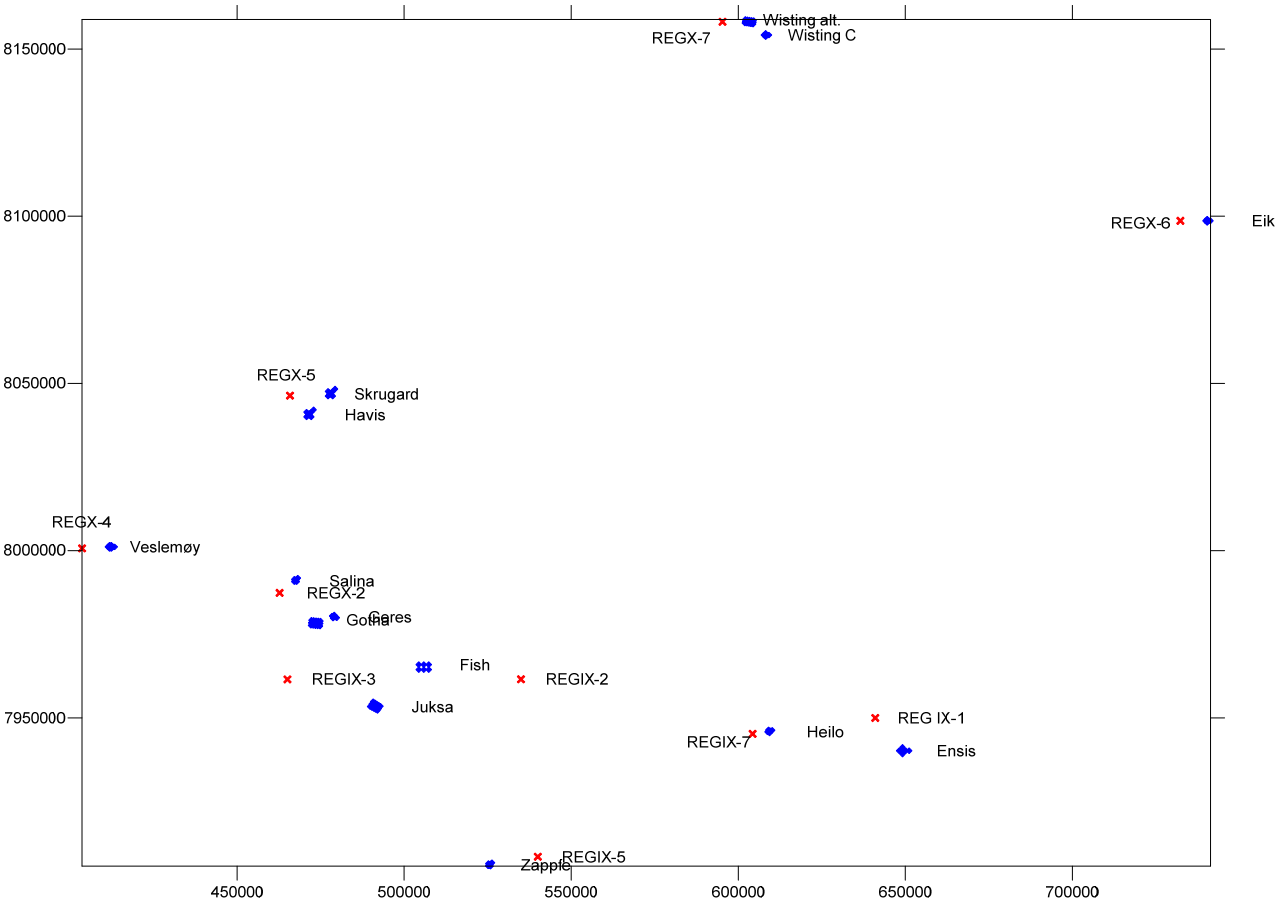

Figure 3-3 *Overview of baseline surveys including regional stations conducted by DNV in the Barents Sea June/July 2011.*

The survey was conducted 22. June - 12. July 2011. The Eik field was sampled 26-27. June. Sampling and analysis were carried out with reference to *Guidelines of offshore environment monitoring* (Klif 2849, 2011). Details from the sampling are enclosed in separate survey report, see appendix A.

Samples for chemical and biological analysis were collected with van Veen grabs (surface area 0.1 m^2). For chemical analysis the surface sediment (0-1 cm) from three replicate grab samples were collected on each location. Five grab samples were collected for fauna analyses on each location.

The main equipment was:

- Long armed van Veen grab, offshore type (Delprodukter, B15)
- Exstra long armed van Veen grab, offshore type (Delprodukter, B1)
- Long armed van Veen grab, light offshore type (Delprodukter, B22)

- Short armed van Veen grab (B17)
- 2 x Combi-grab – modified van Veen (0. 15m^2 surface area, collects chemistry- and biology samples in one haul) (B23 and B25)
- The winch from Uni Research was mounted on the ship from a survey conducted previously, and this winch was mainly used during the survey.

- Reception table for grab in stainless steel
- Washing table for biological samples
- Three sets of sieves for washing of biological samples
- Munsel's colour chart

3.2.2 Execution

Sampling was carried out in accordance with accredited procedures described in *Handbook for the Biology laboratory quality system; sampling of marine sediment and soft bottom analyses*. It was emphasized that the sediment surface in the samples should be undisturbed and that the washing/sieving of the fauna samples was carried out gently. Animals were fixed in formalin (4 % neutralized with hexamine), added pink Bengal and stored in 3.7 l plastic buckets. Sediment samples for chemical analyses and sediment characteristics were stored in rilsan bags or plastic cups. Four deep freezers were utilized for storage of chemical samples. All samples were double labeled and packed in solid boxes to avoid damage to the sample packing.

In accordance with the guidelines, samples were collected within a radius of 50 m around the planned station. In addition to the Fugro navigation system a separate navigation system (GPS from Garmin and Nobeltec software) was mounted and operated of DNV personnel. The system makes it easy to check the position of the vessel at any time and all positions are saved every 10 min. The system was placed in the working container on deck and by the DNV survey leader.

3.2.3 Quality assurance

Sampling was performed according to accredited procedures from the *Handbook of the Biology Laboratory's Quality System; Sampling of marine sediments and soft bottom analyses*. Special attention was paid to an undisturbed sediment surface and that the washing/sieving of the fauna samples was carried out with caution.

3.3 Biological analyses

3.3.1 Macro benthos – an introduction

The macro benthic fauna considered in this survey is found living either in, or on sand, silt or clay sediments. This fauna comprises the following main taxonomic groups: Polychaeta, Crustacea, Mollusca, Echinodermata and Varia (remaining groups). Only animals more than 1 mm (macro benthos) are included in the analysis.

Macro benthic fauna are traditionally included in offshore environmental monitoring. The reason for this is that the study of benthic communities can give an indication of the effects of pollution from

offshore activities, while chemical monitoring of sediments is aimed at assessing the dispersion and concentration levels of pollutants in the vicinity of offshore installations. The benthic fauna is a suitable biological parameter for monitoring the effects of pollution since most of the species have limited mobility and changes in species composition and densities of individuals can therefore easily be identified. The distribution of the fauna can be related to natural variations in environmental parameters such as depth and type of sediment, but also anthropogenic factors such as discharges of drilling fluids, cuttings and others, including accidental releases of oil and physical disturbances.

3.3.2 Sorting and species identification

In the laboratory the samples were washed on 1 mm sieves with (circular holes) to remove formaldehyde and remaining fine sediment, and then sorted by hand under a magnifying glass. The animals were split into the major taxonomic groups; Echinodermata, Polychaeta, Crustacean, Mollusca and Varia and transferred to 70 % ethanol before further identification was undertaken.

Apart from the exceptions detailed below, all animals were identified to the lowest possible taxonomic level (i.e. generally to species level) and the number of individuals per taxon in each sample was recorded.

In accordance with the Activities Regulations, Nematoda, Foraminifera and colonial organisms (i.e. Porifera and Bryozoa), were excluded from any data analyses. Some taxa (e.g. Platyhelminthes, Nemertini, Tunicata and Tanaidacea) were registered but were not identified further. A number of representative specimens of each of the species/taxa identified were included in our reference collection.

3.3.3 Statistical techniques

The statistical and mathematical methods utilized to aid interpretation of the benthic fauna data are summarized below.

- Abundance ratio
- Shannon-Wiener's diversity index, H' (Shannon & Weaver 1963)
- Evenness calculated by Pielou's "evenness" J' (Pielou 1969)
- Expected number of species in a sample of 100 individuals (ES_{100})
- Fauna similarity between stations by Bray-Curtis dissimilarity index d (Bray & Curtis 1957). The resulting similarity matrix was utilized in multivariate analyses in order to group stations and assess gradients in the benthic communities. These methods were: hierarchical agglomerative classification with group-average sorting (Lance & Williams 1966), ordination with non-metric Multi-Dimensional Scaling (MDS), (Shepard 1962, Kruskal 1964).

Classification and MDS ordination were carried out using the program-package PRIMER (**P**lymouth **R**outines **I**n **M**ultivariate **E**cological **R**esearch).

Formulas and further explanations are given in Appendix D.

The raw data is stored in MOD; *MiljøOvervåkingsDatabasen* (Environmental Monitoring Database).

3.3.4 Quality assurance

Procedures including routines for quality assurance related to sorting, species identification and recording of macro benthos samples are given in DNV's *Handbook of the Biology Laboratory's Quality System; Sampling of marine sediments and soft bottom analyses.* A brief summary is given here:

All samples are recorded and double-labelled during fieldwork, and transported in wooden boxes in a steel container. During sorting in the laboratory all relevant information about each sample is recorded (who sorted what and when, time spent, number of bottles etc.). After sorting, each sediment sample is examined for remaining organisms by approved personnel. Each identifier establishes a separate reference collection of species for comparison purpose. To maintain traceability each identifier signs a log to keep track over which grab samples and animal group(s) he or she has been working on. The project reference collection is kept at DNV, Høvik.

3.4 Chemical analyses and sediment characterisation

Analytical parameters

Analysis	Parameter
Sediment characterization	
• Grain size distribution	- Distribution of pelite (< 63 µm) and sand (> 63 µm) - Cumulative weight% distribution from 63-2000 µm - Median particle diameter (Mdϕ), standard deviation (SDϕ), skewness (Skϕ) and kurtosis (Kϕ)
• Total organic matter (TOM)	- % TOM in the sediment
Chemical analyses	
• Hydrocarbons	- THC, sum C_{12}-C_{35} - NPD, naphthalenes, phenanthrenes and dibenzothiophenes sum and single compounds - PAH, 16 EPA compounds sum and single compounds
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Ti and Zn

3.4.1 Sediment characterisation

3.4.1.1 Grain size distribution

The method for grain size distribution analysis is described in Buchanan (1984). The analysis includes a fast mechanical separation of the sand fraction (> 63 µm) from the silt and clay fraction. The sand fraction is then dried and sieved over a series of graded sieves.

From each station three subsamples (0-5 cm) from separate grab samples were mixed and homogenized, and one homogenized sample from each station was analyzed. Approximately 10 g of the sample was weighed to the nearest 0.01 g before wet sieving on a 63 µm sieve. The fraction passing this sieve was transferred to a plastic bottle. A separate sample was weighed and dried for dry weight determination. The percentage of silt and clay (< 63 µm) of total dry weight in the sample was then calculated.

The fraction > 63 µm was dried at 100 °C for 12 hours and sieved over a series of Retsch graded sieves (Endecott Test Sieves, London) with mesh sizes ranging from 2000 to 63 µm. The sample was shaken on a Retsch KG testing sieve shaker for ten minutes. The weight retained upon each sieve was determined to the nearest 0.01 g. The weight of all size fractions was used to prepare cumulative weight% distribution tables for each sampling site. This table was then used in calculating the median particle diameter and deviation, skewness and kurtosis of the particle size distribution. As the grain size distribution was not determined for the fraction < 63 µm, the ϕ-value for this fraction was given the value 8. The values for Mdϕ, SDϕ, Skϕ, and Kϕ should therefore be considered as extrapolated results.

The mathematical expressions are given below.

Mdϕ (median particle diameter):

Mdϕ = the ϕ-value of the midpoint (i.e. 50 %) of the cumulative % weight curve. This measures the central tendency of the size frequency distribution.

SDϕ (standard deviation):

SDϕ estimated as:

$$SD\phi = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

SDϕ gives a measure of the spread in particle size around the Mdϕ, and thus is a measure of the degree of sorting of the particles.

Skϕ (skewness):

Skϕ estimated as:

$$Sk\phi = \frac{\phi 16 + \phi 84 - 2Md\phi}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2Md\phi}{2(\phi 95 - \phi 5)}$$

Skϕ describes the symmetry of the spread in distribution around the Mdϕ. A completely symmetrical distribution will have Skϕ = 0, negative values indicate displacement of the distribution curve towards coarser sediment, and positive Skϕ indicates displacement towards finer sediment.

Kurtosis, Kϕ:

Kϕ estimated as:

$$K\phi = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

Kϕ describes the toppedness of the distribution, i.e. how heavy the tails are (expressed by the ϕ5 and ϕ95 fractions) compared to the central portion of the distribution. For a normal distribution the expression above will give a Kϕ value of 1.00.

Interpretation tables are enclosed in Table 3.4-1 and Table 3.4-2.

Table 3.4-1 *Grain size distribution. Interpretation of descriptive indiced (Buchanan, 1984).*

Parameter	Index value	Verbal classification
Standard deviation (SDϕ)	< 0.35	Very well sorted
	0.25-0.50	Well sorted
	0.50-0.70	Moderately well sorted
	0.70-1.00	Moderately sorted
	1.00-2.00	Poorly sorted
	2.00-4.00	Very poorly sorted
	> 4.00	Extremely poorly sorted
Skewness (Skϕ)	+1.00 to +0.30	Strongly fine skewed
	+0.30 to +0.10	Fine skewed
	+0.10 to -0.10	Symmetrical
	-0.10 to -0.30	Coarse skewed
	-0.30 to -1.00	Strongly coarse skewed
Kurtosis (Kϕ)	<0.67	Very platykurtic
	0.67-0.90	Platykurtic
	0.90-1.11	Mesokurtic (nearly normal)
	1.11-1.50	Leptokurtic
	1.50-3.00	Very leptokurtic

Table 3.4-2. *Grain size distribution. Mesh sizes used and Wentworth grade classification (Buchanan, 1984).*

Mesh diameter (μm)	ϕ	Description
4000	-2	Gravel
2000	-1	Very coarse sand
1000	0	Coarse sand
500	+1.0	
355	+1.5	Medium sand
250	+2.0	
180	+2.5	Fine sand
125	+3.0	
90	+3.5	Very fine sand
63	+4.0	
< 63	> +4.5	Silt and clay (pelite)

3.4.1.2 Total organic material

Three grab-samples (0-5 cm layer) for each station was mixed and homogenized, and one homogenized sample was analyzed. Ca 20 g of wet sediment was weighed into a porcelain dish. The sample was heated at 105 °C for minimum 20 hours, cooled and weighed, and then heated to 480 °C for minimum 16 hours. The percent weight loss after the combustion was then calculated, and this value represents the total organic matter content (TOM) in the sediment. Two sediment standards with known TOM and calcium carbonate were heated together with the sediment samples. The calcium carbonate was used as a cross check on potential weight loss due to the conversion of carbonate to oxide.

3.4.2 Chemical analyses

3.4.2.1 Hydrocarbones

The chemical analysis comprises determination of the total hydrocarbon content from n-C_{12} to n-C_{35} (THC) and selected hydrocarbons (NPD and PAH). The analytical steps are shown in Figure 3.4-1. The sediment samples were worked up by saponification, followed by extraction with dichloromethane. The extract was then separated in a non-polar and a polar fraction using a silica column. The non-polar fractions were analyzed for hydrocarbons by use of gas chromatography (GC).

Sample preparation procedure:

The sediment samples were taken in Rilsan bags. Homogenization was performed by stirring in the Rilsan bag, and small portions of the wet sample were taken randomly giving a total weight of about 50 g. Internal standards were added. The sample was refluxed with KOH in methanol for 2 hours. The mixture was then extracted by dichloromethane. The extract was evaporated to approximately 1 mL, re-dissolved in hexane and fractionated (cleaned up) on Bond-Elut silica columns (Isolute, International Sorbent Technology). The hexane fraction was concentrated and analyzed for hydrocarbons.

An aliquot of the wet and homogenized sediment was weighed and dried for 48 hours at 105 °C, for determination of the dry weight.

Quantification:

THC (total hydrocarbon content) was determined by gas chromatography with flame ionization detector, in the boiling range of n-C_{12} alkane to n-C_{35} alkane. The quantification was carried out according to an external standard of the reference oil, HDF 200, a drilling mud base oil. The reported values were corrected for background levels from procedural blanks.

NPD and PAH were determined by gas chromatography/mass spectrometry operated in the selected ion recording mode (SIR). The quantification was carried out according to the added internal standards and integration of the molecular ions. The following compounds were determined: Naphthalene, phenanthrene, anthracene, dibenzothiophene and their C_1-, C_2- and C_3-alkylated derivatives, acenaphtene, acenaphthylene, fluorene, pyrene, fluoranthene, chrysene/ triphenylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene/benzo(j)fluoranthene/ benzo(k)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene.

For each of the C_1 - C_3 alkyl homologue groups one of the isomers was used as reference in the quantification. The reported values were corrected for background levels from procedural blanks.

GC-FID conditions:

Gas chromatograph		:	Perkin Elmer Autosystem XL
Column		:	12 m x 0.20 mm i.d., fused silica, crosslinked with dimethyl silicone
Temperatures:	Column	:	50 °C (2 min) - 20 °C/min - 350 °C (8 min)
	Injector	:	320 °C
	Detector	:	350 °C
Carrier gas		:	Helium
Injection volume		:	1 µL
Data system		:	TotalChrom 6.2
HDF 200		:	0.1 – 10 mg/mL hexane

GC/MS conditions:

Mass spectrometer		:	Clarus 500 and Clarus 600 Mass Spectrometer, Perkin Elmer
Data system		:	TurboMass
Gas chromatograph		:	Clarus 500 and Clarus 600 Gas Chromatograph, Perkin Elmer
Column:		:	30 m fused silica, 0.25 µm DB-5ms
Temperatures:	Column	:	40 °C (2 min) - 20 °C/min - 120 °C -
			10 °C/min - 300 °C (15 min)
	Injector	:	300 °C
	Ion source	:	180 °C
Carrier gas		:	Helium
Ionization		:	Electron impact, 70 eV
Masses (m/z)			
C_0-C_3 naphthalene		:	128, 141, 156, 170
C_0-C_3 phenanthrene		:	178, 192, 206, 220
C_0-C_3 dibenzothiophene		:	184, 198, 212, 226
PAH		:	152, 153, 166, 202, 228, 252, 276, 278
Deuterated standards		:	136, 164, 188, 212, 240, 264
Injection volume		:	1 µL

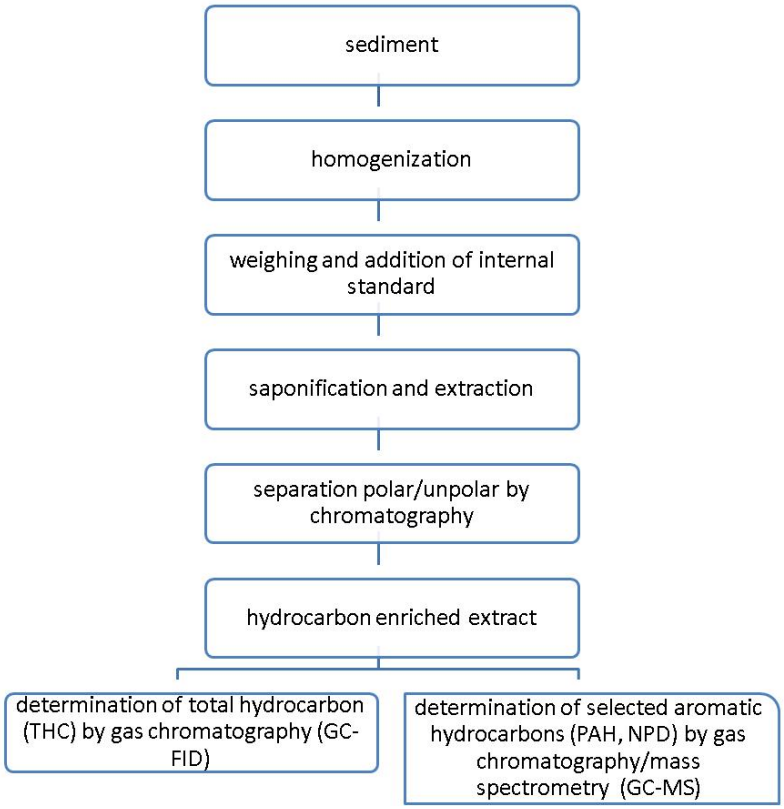

Figure 3.4-1 *Flow scheme of essential steps in the hydrocarbon analyses of sediments.*

3.4.2.2 Metals

The metal analyses include determination of Ba, Cd, Cr, Cu, Hg, Pb, Ti and Zn after digestion with nitric acid (NS 4770).

The wet sediment sample was dried at 40 °C for two days, homogenized and sieved through a 500 µm nylon sieve. The fractions larger and smaller than 0.5 mm were weighed. 1 g of the fraction smaller than 0.5 mm was extracted with 20 mL 7 M nitric acid in a Pyrex decomposition bottle in an autoclave at 120 °C for 30 min. After cooling, 80 mL of distilled water was added to the Pyrex bottle. The clear solution was decanted into a polyethylene bottle until analysis.

Ba, Cr, Cu, Ti and Zn were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) according to NS-EN ISO 11885/ICP-AES. Cd and Pb were determined by inductively coupled plasma mass spectrometry (ICP-MS) according to NS-EN 14385. Hg was determined by atomic adsorption cold vapor technique (CV-AAS) according to an in-house method based on NS 4768.

ICP-AES:

Instrument: Thermo iCAP 6500

Analytical lines: Ba: 455.403 nm, Cr: 267.716 nm, Cu: 324.754 nm, Zn: 213.856 nm og Ti: 336.12

ICP-MS:
Instrument: PerkinElmer Elan DRC II.

Mass: Cd: 111 og 114

Mass: Pb: 208

CVAAS:

Instrument: CETAC M-7500A

Analytical line: Hg: 253.7 nm

3.4.2.3 Determination of Quantification limits

The limit of detection (LOD) and limit of quantification (LOQ) for THC is calculated as 3 SD (standard deviation) and 10 SD above the measured average blank values respectively. This is according to *"Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry"*, Anal.chem. 52 (1980) p. 2242-2249. The limit of detection (LOD) and limit of quantification (LOQ) are given in Table 3.4-3.

Table 3.4-3 *Limit of detection (LOD) and limit of quantification (LOQ), hydrocarbons and metals.*

Analysis parameter	**LOD**	**LOQ**
	mg/kg	**mg/kg**
THC	1	3
Sum NPD*	0.01	0.03
Sum PAH*	0.005	0.02
Ba	1	3
Cd (ICP-MS)	0.01	0.03
Cr	0.1	0.3
Cu	0.5	2
Hg	0.01	0.03
Pb (ICP-MS)	0.5	2
Ti	1	3
Zn	1	3

* calculated from analysis of blank samples.

3.4.3 Quality assurance

All the analyses are accredited. Molab AS is accredited by Norsk Akkreditering to perform chemical analyses, accreditation number Test 032. The accreditation is according to NS-EN ISO/IEC 17025. Detailed results are given in appendix C.

Quality assurance for grain size distribution:
The method was validated by analyzing an International Soil-Analytical Exchange (ISE). An in house standard was analyzed for every 10.sample using the same procedure as the samples. A control card was used for the results.

Quality assurance for total organic matter:
Calcium carbonate together with the samples was heated to 480 °C, and the weight loss was monitored and controlled. In house standards were analyzed regularly during the project period.

Quality assurance for hydrocarbons:
The analytical procedures are regularly controlled by analysis of standards, blank samples and quality assurance samples. Standards of mineral oil are analyzed together with the THC samples. The results for in house standards are plotted on control charts. The accuracy of the THC and PAH analysis is documented by participation in the international intercalibration exercise SETOC. The accuracy is also controlled by analysis of sediments containing certified amount of THC and PAH. In addition PAH and NPD results are compared with results from another laboratory.

Quality assurance for metals:
All reagents are of pro analysis grade. A certified reference material, house reference and blank samples are included in the analyses. Certified values are for total decomposition. Certified values for NS 4770 (partial decomposition) are not available. Accuracy and reproducibility are controlled by the results obtained for the in house reference materials. The indicated intervals are given by two standard deviations of the measured means. It is established an in-house “reference value” for partial decomposition for analysis of the reference material in the period 1999-2011. The samples are re-analyzed if the reference material results are outside predefined values. The accuracy and reproducibility are controlled by analyses of certified reference material.

3.5 Deviations from the Guidelines

The survey is performed according to the guidelines.

4 RESULTS

The depth at Eik was 350-361m. The observations from the sampling were that the sea bottom was homogenous and consists of greyish clay with a browner top layer.

The stations names are abbreviated after the program was prepared and the fieldwork was carried out, and EI is the name used in this chapter. REGX-6 is named R106.

4.1 Sediment characterization

The main results are given in Table 4.1-1 and Figure 4.1-1. Detailed results are given in appendix.

All samples from the stations consist mainly of silt and clay (84.4-97.0 %). All sediments are classified as silt and clay. The highest level of sand was found at EI6 (15.6 %). The sediment at the regional station R106 is classified as silt and clay, but contains more sand (27.2 %) than all the field stations.

Total organic matter (TOM)

The content of total organic matter is given in Table 4.1-1 and Figure 4.1-1.

The content of TOM is high, and ranges between 4.23 and 5.10 %. The content is a bit lower at the regional station R106 (3.70%).

Table 4.1-1 *Eik 2011, grain size distribution and total organic matter (TOM) of dry sediment*

Station	Direction (°)	Offset (m)	Depth (m)	TOM (%)	Classification	Silt & clay %	Sand %	Gravel %	Median (Φ)
EI1	90	60	358	4.59	Silt and clay	93.4	6.6	0.0	5.86
EI2	90	250	363	4.23	Silt and clay	84.9	14.2	1.0	5.64
EI3	90	500	358	4.65	Silt and clay	97.0	3.0	0.0	5.94
EI4	90	1000	356	4.35	Silt and clay	87.5	12.5	0.0	5.71
EI6	180	60	353	4.49	Silt and clay	84.4	15.6	0.0	5.63
EI7	180	250	360	4.53	Silt and clay	86.4	13.5	0.1	5.68
EI8	180	500	361	4.91	Silt and clay	96.2	3.8	0.0	5.92
EI11	270	60	356	4.55	Silt and clay	90.2	9.8	0.0	5.78
EI12	270	250	355	4.83	Silt and clay	92.0	8.0	0.0	5.83
EI13	270	500	355	4.87	Silt and clay	94.2	5.8	0.0	5.88
EI16	0	60	357	5.10	Silt and clay	94.9	5.1	0.0	5.89
EI17	0	250	350	4.69	Silt and clay	90.1	9.8	0.1	5.78
EI18	0	500	356	4.45	Silt and clay	90.8	9.2	0.0	5.80
R106			303	3.70	Silt and clay	72.7	27.2	0.1	5.25
Min.*				4.23		84.4	3.0	0.0	5.63
Max.*				5.10		97.0	15.6	1.0	5.94

*: The regional station is not included

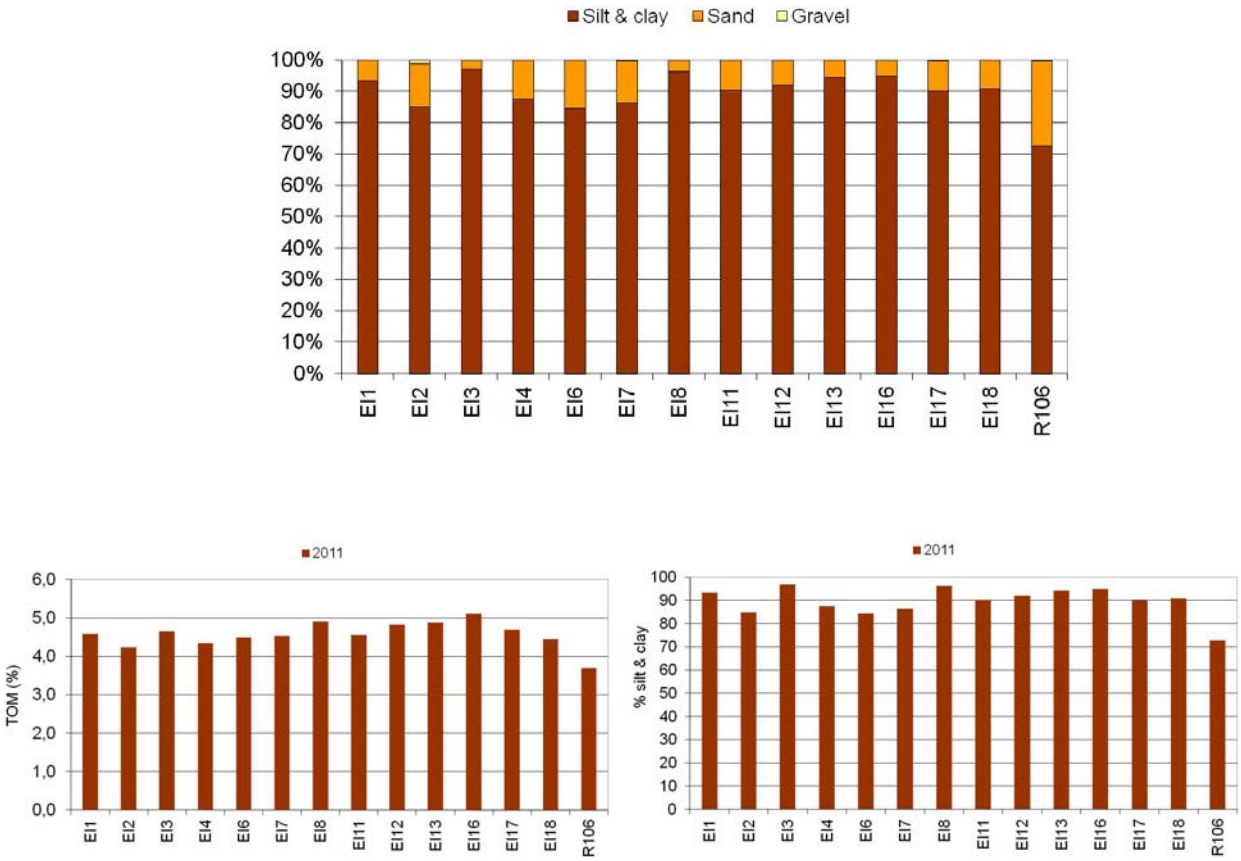

Figure 4.1-1 *Eik 2011, sediment characterization, silt & clay, sand and gravel content on top.*

4.2 Chemical analysis

Hydrocarbons

Summarized results of hydrocarbon analyses are given in Table 4.2-1 and Figure 4.2-1. The distribution of THC related to the field centre is also shown in Figure 4.2-1. Detailed results are given in appendix.

The content of THC is low (3-6 mg/kg) with the highest concentration found at E16 (6 ± 1 mg/kg). All stations are above or at the same level as the regional station R106. None of the measured THC concentrations are above LSC-level ($LSC_{2010RegIX/X}$: 12.8 mg/kg). All chromatograms show natural background levels. Content of PAH and NPD are low, and at the same level as R106. All stations have PAH- and NPD concentrations at roughly the same level as $LSC_{2010RegIX/X}$ (0.255 mg/kg for PAH and 0.499 mg/kg for NPD).

Table 4.2-1 *Eik 2011, the content of hydrocarbons in sediments. All values in mg/kg dry sediment.*

Station	Direction (°)	Offset (m)	THC average	SD	PAH average	SD	NPD average	SD
EI1	90	60	4	0	0.344	0.021	0.34	0.01
EI2	90	250	4	1	0.280	0.037	0.31	0.02
EI3	90	500	5	0				
EI4	90	1000	5	1				
EI6	180	60	5	1				
EI7	180	250	4	0				
EI8	180	500	6	1				
EI11	270	60	3	0				
EI12	270	250	4	1				
EI13	270	500	4	0				
EI16	0	60	4	0				
EI17	0	250	3	1				
EI18	0	500	3	0				
R106			3	0	0.238	0.027	0.27	0.02
Min.*			3		0.280		0.31	
Max.*			6		0.344		0.34	

*: The regional station is not included

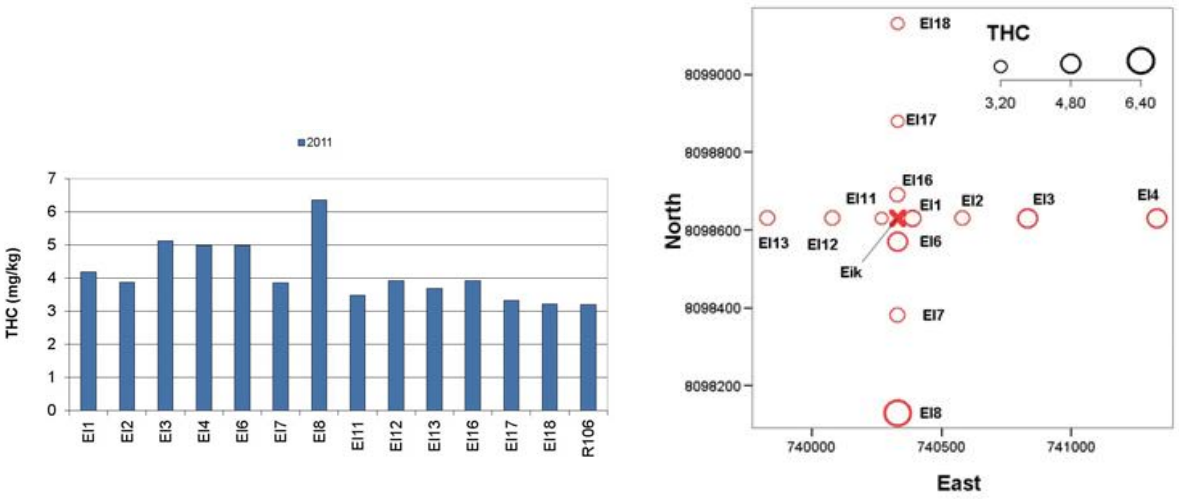

Figure 4.2-1 *Eik 2011, average content of THC (left), The figure to the right shows the distribution of THC in sediments at the sampling sites, the size of the circle indicate the amount of THC. The field centre is marked with an X.*

Metals

Summarized results of metals analyses are given in Table 4.2-2 and Figure 4.2-2. The distribution of Ba related to the field centre is shown in Figure 4.2-3. Detailed results are given in appendix.

Table 4.2-2 *Eik 2011, the content of metals in sediments. All values in mg/kg dry sediment.*

Station		Ba		Cd		Cr		Cu		Hg		Pb		Ti		Zn	
	(°/m)	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD
EI1	90/60	120	4	<0.03	-	38.5	0.7	13.6	0.3	0.02	0.00	14.9	0.3	478	9	69	1
EI2	90/250	114	0	<0.03	-	36.7	0.2	12.9	0.4	0.02	0.00	13.9	0.5	439	23	66	2
EI3	90/500	125	2	<0.03	-	39.6	1.1	13.8	0.4	0.03	0.00	15.2	0.4	494	16	72	3
EI4	90/1000	113	2	<0.03	-	39.0	0.7	13.9	0.3	0.02	0.00	13.6	1.1	482	19	74	7
EI6	180/60	116	5	<0.03	-	36.3	0.3	12.7	0.1	0.02	0.00	13.7	0.2	451	4	66	2
EI7	180/250	113	2	<0.03	-	36.6	0.7	12.8	0.3	0.02	0.00	13.6	0.8	463	7	66	4
EI8	180/500	124	2	<0.03	-	39.9	0.5	13.9	0.1	0.02	0.00	15.0	0.3	505	8	77	12
EI11	270/60	119	4	<0.03	-	39.1	0.6	13.5	0.2	0.02	0.00	14.9	0.2	495	16	79	17
EI12	270/250	120	8	<0.03	-	38.5	0.7	13.5	0.4	0.02	0.00	14.3	0.6	481	7	98	53
EI13	270/500	125	3	<0.03	-	39.6	0.2	13.9	0.1	0.03	0.00	15.5	0.4	487	4	75	2
EI16	0/60	121	4	<0.03	-	38.5	0.8	13.7	0.2	0.03	0.00	14.9	0.3	471	13	80	17
EI17	0/250	119	5	<0.03	-	37.6	1.2	13.0	0.3	0.03	0.00	14.4	0.3	475	20	73	8
EI18	0/500	120	3	<0.03	-	37.4	1.4	13.3	0.3	0.03	0.00	14.1	0.6	454	32	70	3
R106		82	3	<0.03	-	25.9	1.0	8.9	0.6	0.02	0.00	11.5	0.5	298	8	51	7
Min. *		113		<0.03		36.3		12.7		0.02		13.6		439		66	
Max. *		125		<0.03		39.9		13.9		0.03		15.5		505		98	

*: The reference station is not included

The content of Ba is in the range 113 - 125 mg/kg. The highest Ba concentration is measured at EI3 (125 ± 2 mg/kg) and EI13 (125 ± 3 mg/kg). All stations are above the regional station R106. None of the Ba concentrations are above LSC-level ($LSC_{2010RegIX/X}$: 134 mg/kg). Overall the concentrations of metals except Cd and Hg are above R106. In general the concentrations of metals are below $LSC_{2010RegIX/X}$.

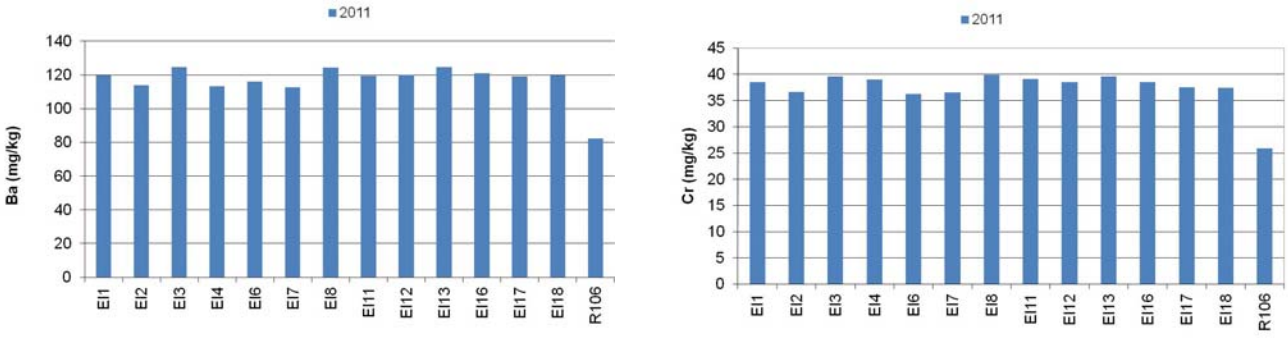

Figure 4.2-2 *Eik 2011, average content of metals in top sediment (0-1 cm) from three parallel samples.*

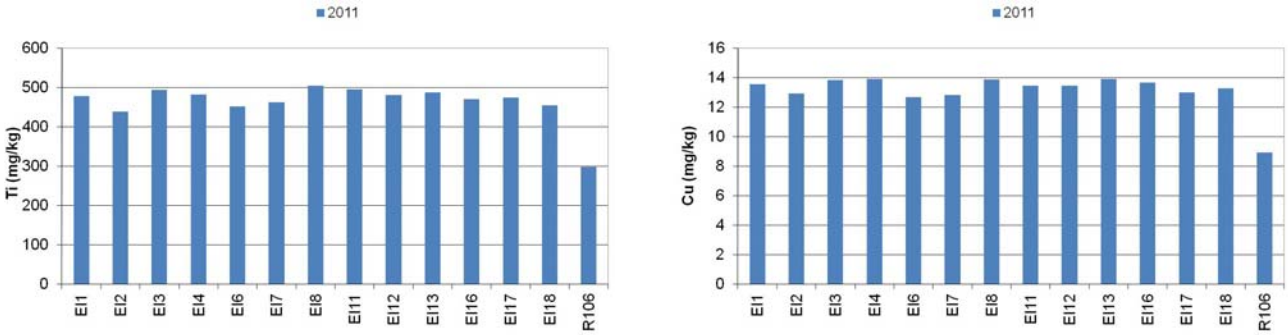

Figure 4.2-2 *cont.*

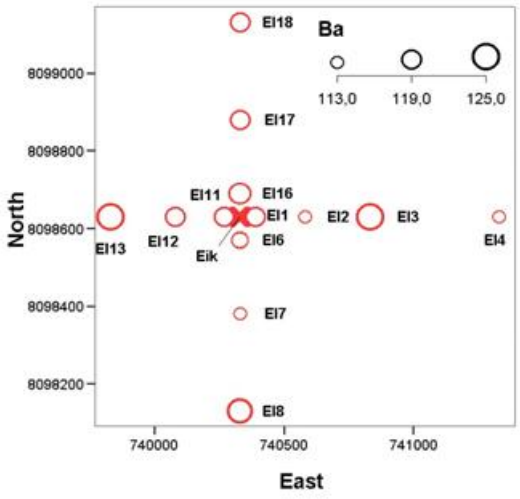

Figure 4.2-3 *Eik 2011, distribution of Ba in sediments at the sampling sites, the size of the circle indicate the amount of Ba. The field centre is marked with an X.*

4.3 Biological analyses

Diversity and dominant species

Table 4.3-1 shows the number of individuals and species at Eik by animal groups. There were 35 juvenile individuals recorded at Eik. Polychaetes dominated the samples, contributing 76% of the number of individuals by animal group.

Figure 4.3-1 shows the number of individuals and species at the individual stations on the field and the average per grab per station.

Table 4.3-1 *Number of individuals (N) and species (S) distributed between the main animal groups, Eik 2011.*

Animal group	N	%	S	%
Varia	279	4,5	10	5,7
Polychaeta	4771	76,1	83	47,4
Crustacea	293	4,7	40	22,9
Mollusca	854	13,6	29	16,6
Echinodermata	71	1,1	13	7,4
Total	6268	100,0	175	100,0

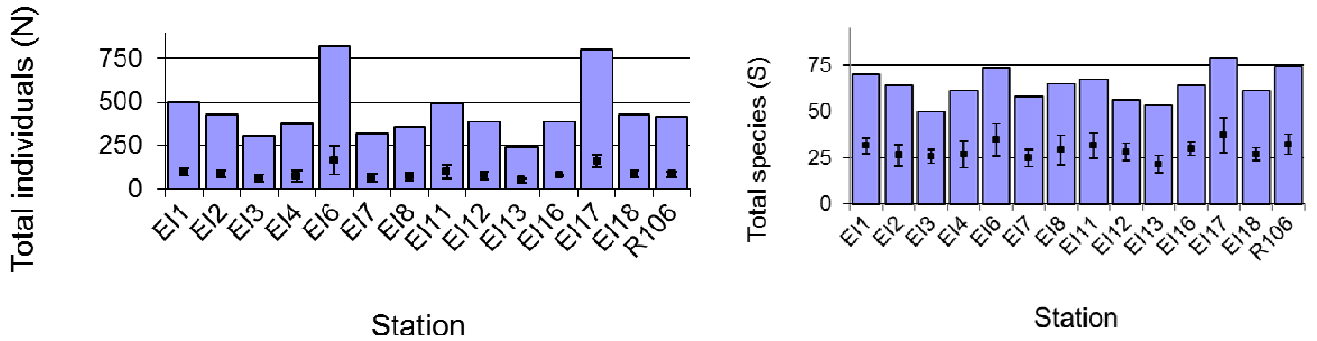

Figure 4.3-1 *Number of individuals (N) and species (S) per 0.5m^2, average and standard deviation between grab samples (0.1m^2), Eik 2011.*

Table 4.3-2 and Figure 4.3-2 show the various indices for each of the stations. Stations EI6 and EI17 are characterised by having higher numbers of individuals compared to the other stations. This is due to much a higher abundance of the polychaete *Maldane arctica* and to a lesser extent higher abundance of *Paramphinome jeffreysii*.

ES_{100} and Shannon diversity (H') are high at all the Eik stations, with only minor fluctuations, reflecting an undisturbed seafloor and a healthy benthic community.

Table 4.3-2 *Numbers of individuals (N) and species (S) per 0.5m^2 (juv. included), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station, Eik 2011.*

Station	Direction (°)	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
EI1	90	60	358	70	500	4.67	0.76	33
EI2	90	250	363	64	431	4.26	0.71	30
EI3	90	500	358	50	305	4.78	0.85	34
EI4	90	1000	356	61	374	4.46	0.75	32
EI6	180	60	353	73	825	4.00	0.65	28
EI7	180	250	360	58	320	4.76	0.81	34
EI8	180	500	361	65	355	4.98	0.83	38
EI11	270	60	356	67	498	4.56	0.75	33
EI12	270	250	355	56	387	4.65	0.80	33
EI13	270	500	355	53	238	4.64	0.81	34
EI16	0	60	357	64	386	4.78	0.80	35
EI17	0	250	350	79	802	4.27	0.68	30
EI18	0	500	356	61	429	4.22	0.71	31
R106			303	74	418	4.87	0.78	36

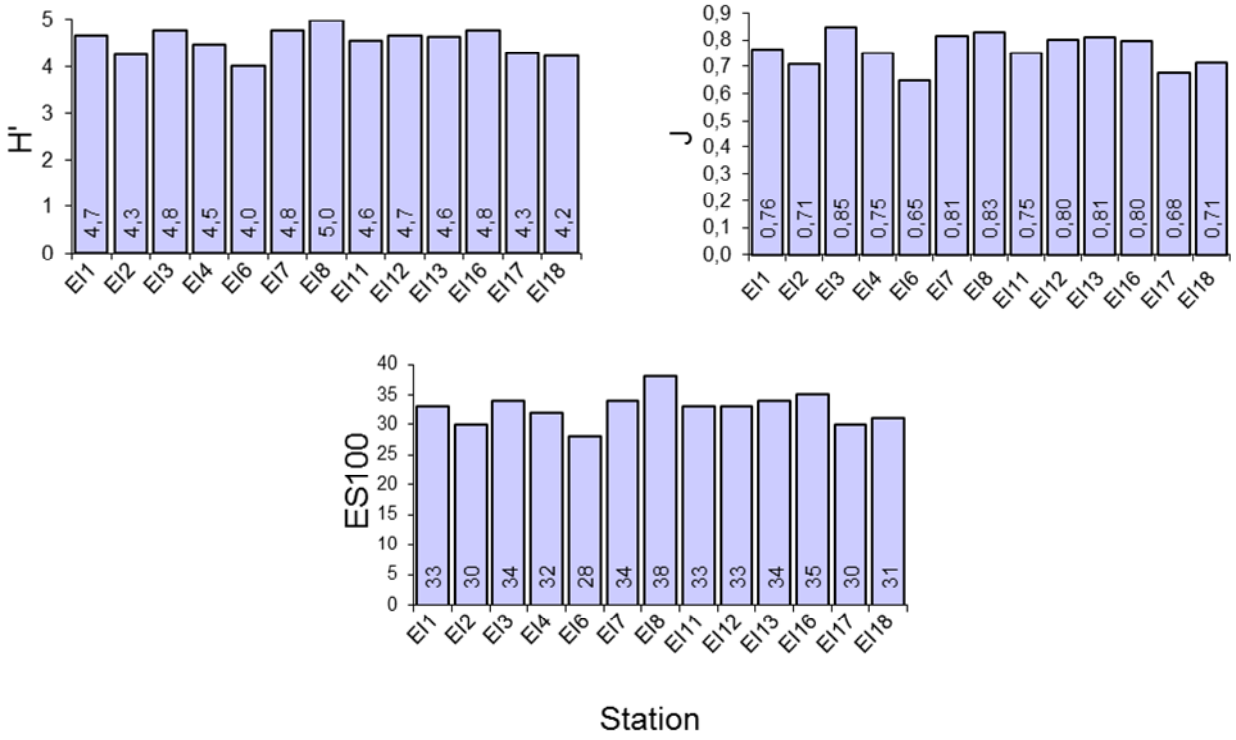

Figure 4.3-2 *Diversity, evenness and ES_{100} at Eik 2011.*

The ten most common species at each station are shown in Table 4.3-3. The stations are quite homogenous, with the same species dominant at all the stations. The ten most dominant species contribute between 59 % (EI8) and 76 % (EI6) of the total number of individuals at all the stations. The sensitive polychaete *Maldane arctica* is abundant at all stations except R106, and is the most dominant of all species at 9 stations. It contributes between 2.5 % (EI8) and 34 % (EI6) to the abundance. This species is only found at relatively undisturbed locations.

The polychaete *Paramphinome jeffreysii* is also found among the ten most dominant species at all the stations, contributing between 6.8 % (EI11) and 17.7 % (EI6). Other abundant species include the polychaete *Lumbrineris scopa complex* which is among the top 3 most dominant species at all stations, the capitellid polychaete *Notomastus latericeus*, and the bivalve mollusc *Thyasira cf equalis*.

Table 4.3-3 *The ten most dominant species at each station, Eik 2011.*

10 most dominant species							
EI1	**No**	**%**	**Cum%**	**EI2**	**No**	**%**	**Cum%**
Paramphinome jeffreysii	74	14.8	14.80	Maldane arctica	124	28.77	28.77
Maldane arctica	65	13	27.80	Notomastus latericeus	39	9.05	37.82
Lumbrineris scopa complex	57	11.4	39.20	Lumbrineris scopa complex	37	8.58	46.4
Thyasira cf equalis	45	9	48.20	Paramphinome jeffreysii	30	6.96	53.36
Notomastus latericeus	30	6	54.20	Thyasira cf equalis	28	6.5	59.86
Ophelina abranchiata	25	5	59.20	Chirimia biceps	23	5.34	65.2
Yoldiella nana	14	2.8	62.00	Heteromastus filiformis	15	3.48	68.68
Pseudoscalibregma parvum	12	2.4	64.40	Nemertea spp.	10	2.32	71
Heteromastus filiformis	12	2.4	66.80	Myriochele olgae	8	1.86	72.85
Golfingiidae spp.	11	2.2	69.00	Galathowenia fragilis	8	1.86	74.71
EI3	**No**	**%**	**Cum%**	**EI4**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	37	12.13	12.13	Maldane arctica	101	27.01	27.01
Thyasira cf equalis	33	10.82	22.95	Paramphinome jeffreysii	32	8.56	35.56
Paramphinome jeffreysii	29	9.51	32.46	Lumbrineris scopa complex	29	7.75	43.32
Heteromastus filiformis	18	5.9	38.36	Thyasira cf equalis	22	5.88	49.2
Notomastus latericeus	18	5.9	44.26	Chirimia biceps	18	4.81	54.01
Maldane arctica	16	5.25	49.51	Heteromastus filiformis	16	4.28	58.29
Pseudosphyrapus anomalus	14	4.59	54.10	Pseudoscalibregma parvum	14	3.74	62.03
Ophelina abranchiata	13	4.26	58.36	Notomastus latericeus	11	2.94	64.97
Yoldiella nana	8	2.62	60.98	Harpinia mucronata	10	2.67	67.65
Aricidea quadrilobata	7	2.3	63.28	Ophelina abranchiata	9	2.41	70.05
EI6	**No**	**%**	**Cum%**	**EI7**	**No**	**%**	**Cum%**
Maldane arctica	280	33.94	33.94	Maldane arctica	49	15.31	15.31
Paramphinome jeffreysii	146	17.7	51.64	Lumbrineris scopa complex	33	10.31	25.63
Lumbrineris scopa complex	42	5.09	56.73	Paramphinome jeffreysii	28	8.75	34.38
Notomastus latericeus	31	3.76	60.48	Heteromastus filiformis	22	6.88	41.25
Chirimia biceps	30	3.64	64.12	Thyasira cf equalis	19	5.94	47.19
Thyasira cf equalis	29	3.52	67.64	Notomastus latericeus	16	5	52.19
Heteromastus filiformis	28	3.39	71.03	Chirimia biceps	12	3.75	55.94
Maldane sarsi	16	1.94	72.97	Scoloplos (Scoloplos) armiger	10	3.13	59.06
Ophelina abranchiata	14	1.7	74.67	Mendicula cf ferruginosa	10	3.13	62.19
Euclymene sp.	13	1.58	76.24	Nemertea spp.	9	2.81	65
EI8	**No**	**%**	**Cum%**	**EI11**	**No**	**%**	**Cum%**
Paramphinome jeffreysii	45	12.68	12.68	Maldane arctica	128	25.7	25.7
Lumbrineris scopa complex	44	12.39	25.07	Lumbrineris scopa complex	41	8.23	33.94
Yoldiella nana	30	8.45	33.52	Thyasira cf equalis	37	7.43	41.37
Thyasira cf equalis	27	7.61	41.13	Paramphinome jeffreysii	34	6.83	48.19
Ophelina abranchiata	15	4.23	45.35	Heteromastus filiformis	22	4.42	52.61
Harpinia mucronata	12	3.38	48.73	Ophelina abranchiata	21	4.22	56.83

Table 4.3-3 *cont*.

Notomastus latericeus	11	3.1	51.83	Pseudoscalibregma parvum	15	3.01	59.84
Edwardsiidae spp.	10	2.82	54.65	Notomastus latericeus	15	3.01	62.85
Maldane arctica	9	2.54	57.18	Chirimia biceps	12	2.41	65.26
Pseudoscalibregma parvum	8	2.25	59.44	Maldane sarsi	12	2.41	67.67
EI12	**No**	**%**	**Cum%**	**EI13**	**No**	**%**	**Cum%**
Maldane arctica	89	23	23.00	Maldane arctica	41	17.23	17.23
Paramphinome jeffreysii	27	6.98	29.97	Lumbrineris scopa complex	26	10.92	28.15
Lumbrineris scopa complex	25	6.46	36.43	Ophelina abranchiata	20	8.4	36.55
Thyasira cf equalis	23	5.94	42.38	Paramphinome jeffreysii	20	8.4	44.96
Ophelina abranchiata	18	4.65	47.03	Thyasira cf equalis	17	7.14	52.1
Notomastus latericeus	17	4.39	51.42	Notomastus latericeus	11	4.62	56.72
Yoldiella nana	16	4.13	55.56	Pseudoscalibregma parvum	7	2.94	59.66
Heteromastus filiformis	14	3.62	59.17	Siphonodentalium lobatum	6	2.52	62.18
Mendicula cf ferruginosa	13	3.36	62.53	Chirimia biceps	6	2.52	64.71
Nemertea spp.	10	2.58	65.12	Maldane sarsi	6	2.52	67.23
EI16	**No**	**%**	**Cum%**	**EI17**	**No**	**%**	**Cum%**
Paramphinome jeffreysii	58	15.03	15.03	Maldane arctica	258	32.17	32.17
Thyasira cf equalis	42	10.88	25.91	Paramphinome jeffreysii	86	10.72	42.89
Lumbrineris scopa complex	37	9.59	35.49	Lumbrineris scopa complex	53	6.61	49.5
Maldane arctica	34	8.81	44.30	Thyasira cf equalis	42	5.24	54.74
Yoldiella nana	23	5.96	50.26	Ophelina abranchiata	39	4.86	59.6
Heteromastus filiformis	16	4.15	54.40	Notomastus latericeus	29	3.62	63.22
Aricidea quadrilobata	13	3.37	57.77	Chirimia biceps	28	3.49	66.71
Pseudoscalibregma parvum	11	2.85	60.62	Heteromastus filiformis	27	3.37	70.07
Ophelina abranchiata	11	2.85	63.47	Euclymene sp.	14	1.75	71.82
Chirimia biceps	8	2.07	65.54	Ascidiacea spp.	12	1.5	73.32
EI18	**No**	**%**	**Cum%**	**R106**	**No**	**%**	**Cum%**
Maldane arctica	134	31.24	31.24	Paramphinome jeffreysii	62	14.83	14.83
Paramphinome jeffreysii	43	10.02	41.26	Lumbrineris scopa complex	51	12.20	27.03
Lumbrineris scopa complex	41	9.56	50.82	Notomastus latericeus	44	10.53	37.56
Thyasira cf equalis	21	4.9	55.71	Ophelina abranchiata	36	8.61	46.17
Heteromastus filiformis	17	3.96	59.67	Thyasira cf equalis	16	3.83	50.00
Notomastus latericeus	16	3.73	63.40	Clymenura borealis	14	3.35	53.35
Pseudoscalibregma parvum	11	2.56	65.97	Chirimia biceps	13	3.11	56.46
Golfingiidae spp.	9	2.1	68.07	Ophelina cylindricaudata	12	2.87	59.33
Chirimia biceps	9	2.1	70.16	Aphelochaeta spp.	9	2.15	61.48
Ophelina abranchiata	9	2.1	72.26	Heteromastus filiformis	8	1.91	65.31

The cluster analysis for Eik is shown in Figure 4.3-3. The similarity between the field stations is high (> 60 %). The fauna at the regional station R106 differ marginally from the field stations. The BioEnv-analysis showed a maximum correlation coefficient of 0.67, indicating a possible correlation between the variations in the fauna community and the abiotic factors, mainly Ba, depth and TOM. The

regional station is shallower than the field stations and the content of organic matter and Ba is slightly lower at this station. However, the differences are minor and R95 is considered suitable as a regional station in future monitoring.

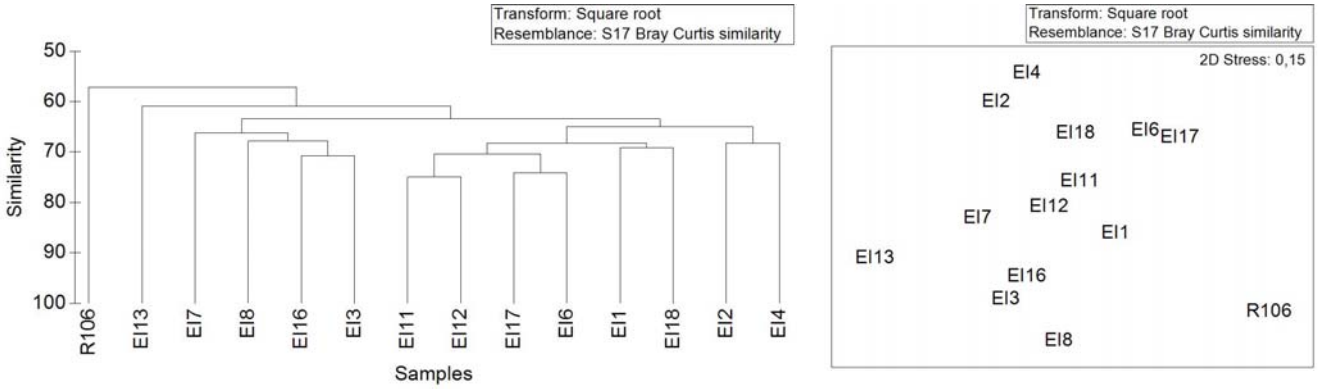

Figure 4.3-3 *Cluster- and MDS plot, Eik 2011.*

5 CONCLUSIONS

The sediments on Eik are classified as silt and clay. Content of total organic matter varies between 4.23 and 5.10 %. Generally there are no elevated levels compared to $LSC_{2010RegIX/X}$ for organic and inorganic parameters at Eik, and the seafloor is regarded as uncontaminated.

The diversity indices of the Eik benthic fauna are high at all stations and show only minor fluctuations. The indices reflect healthy undisturbed seafloor with complex fauna communities. The fauna at the regional station R106 differs marginally from the field stations, but are considered to be a suitable regional station in future monitoring.

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