DET NORSKE VERITAS™

REPORT

BASELINE SURVEY SALINA 2011

ENI NORGE AS

REPORT NO./DNV REG NO.: 2012-0447 / 13DO39S-20
REV 01, 2012-03-29

MANAGING RISK

Baseline Survey Salina 2011

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Date of Current Issue:	2012-03-29	Project No.:	PP014672
Revision No.:	01	Organisation Unit:	Environmental Risk Management
DNV Reg. No.:	13DO39S-20	Report No.:	2012-0447

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

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Keywords
Sediments, hydrocarbons, benthic fauna, metals

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0		First issue signed and verified			

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

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- Appendix B – *Test Report – biology*
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- Appendix E – *Baseline program (in Norwegian)*

Preface

The baseline survey at Salina was carried out by Det Norske Veritas and MOLAB on behalf of Eni Norge AS. The work was coordinated by Hans Jacob Beck (Marathon), Robert Farestveit (Noreco) and Erik Bjørnbom (Eni).

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

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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 Salina are dominated by silt and clay and TOM is in the 2.62-5.74 % range. The THC concentrations are low and at the same level as the regional stations R102 and R93. None of the chromatograms contains traces of hydrocarbons from oil. All stations have higher Ba concentration than the regional station R102, while only two stations are above R93.

The diversity indices for the Salina benthic fauna are high at all stations and show only minor fluctuations. The indices and species composition reflect healthy undisturbed seafloor with complex fauna communities. The fauna at the regional station R102 are similar to the Salina fauna and R102 is considered to be a suitable regional station in future monitoring.

Salina	Variation	Description of the field
THC (mg/kg)	1-6	None of the stations at Salina have THC concentration above LSC for region IX/X in 2010. All stations except one have THC concentration between the regional stations R102 and R93. One station has THC concentration above R102 and R93.
Ba (mg/kg)	63-104	All stations have Ba concentration above the regional station R102 and two stations are above R93. None of the Ba concentrations are above LSC-level for region IX/X in 2010.
H’	5.0-5.7	The diversity indices and species composition reflect healthy undisturbed seafloor with complex fauna communities. The regional station R102 is considered to be a suitable regional station in future monitoring.
J	0.75-0.88	
ES_{100}	38-49	

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.

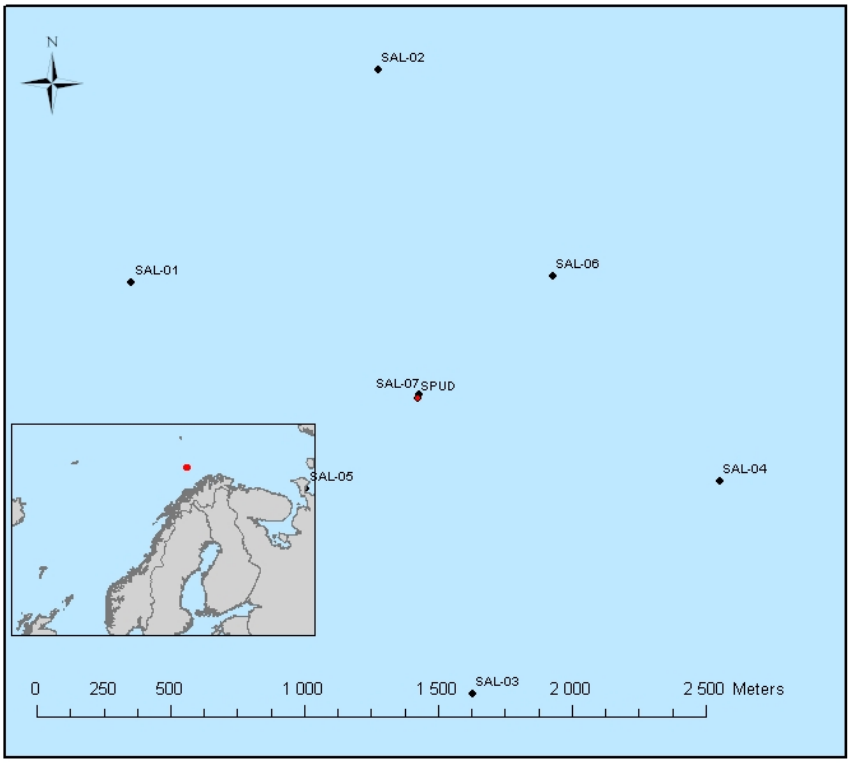
Sedimentene på Salina består hovedsakelig av silt og leire og TOM ligger mellom 2,62 og 5,74 %. THC-konsentrasjonene er lave og på samme nivå som de regionale stasjonene R102 og R93. Kromatogrammene viser kun naturlig bakgrunn. Alle stasjoner har høyere Ba-konsentrasjon enn den regionale stasjonen R102. To stasjoner har høyere Ba-konsentrasjon enn R93.

Diversitetsindeksene for bunnfaunaen på Salina er høye med kun små variasjoner. Indeksene og artssammensetningen reflekterer et sunt og uforstyrret bunnfaunasamfunn. Faunaen på den regionale stasjonen R102 er sammenlignbar med faunaen i Salinaområdet, og er godt egnet som regional stasjon i fremtidig overvåking.

Salina	Variasjon	Beskrivelse av feltet
THC (mg/kg)	1-6	Det er ikke funnet THC-verdier over $LSC_{2010RegionIX/X}$. En stasjon har høyere konsentrasjon enn de regionale stasjonene R102 og R93. Resten av stasjonene, ligger mellom de regionale stasjonene.
Ba (mg/kg)	63-104	Alle stasjoner har høyere Ba-konsentrasjon enn den regionale stasjonen R102 og to stasjoner har høyere enn R93. Ingen av de Ba-konsentrasjonene ligger over $LSC_{2010RegionIX/X}$.
H’	5,0-5,7	Diversitetsindeksene og artssammensetningen reflekterer et sunt og uforstyrret bunnfaunasamfunn. Den regionale stasjonen R102 er godt egnet som regional stasjon i fremtidig overvåking.
J	0,75-0,88	
ES_{100}	38-49	

2 INTRODUCTION

Salina (PL 533) is located in the south-western part of Region X. The regional survey in 2010 (Akvaplan-niva 2011) includede 7 sediment stations from the baseline survey at Salina organised in a grid (Figure 2-1).



Station	UTM-E-ED50-S34	UTM-N-ED50-S34
SAL-01	466464,00	7991636,00
SAL-02	467462,00	7992336,00
SAL-03	467581,00	7989976,00
SAL-04	468579,00	7990676,00
SAL-05	467037,00	7990804,00
SAL-06	468035,00	7991504,00
SAL-07	467492,00	7991109,00
SPUD	**467485,20**	**7991098,30**

Station	Station	Distanse between stations* (m)	UTM-E-ED50-S34	UTM-N-ED50-S34
SPUD	SAL-01	1160	466464	7991636
SPUD	SAL-02	1240	467462	7992336
SPUD	SAL-03	1125	467581	7989976
SPUD	SAL-04	1170	468579	7990676
SPUD	SAL-05	533	467037	7990804
SPUD	SAL-06	685	468035	7991504
SPUD	SAL-07	13	467492	7991109

* **Measured on map (not calculated)**

Figure 2-1 *Station map, Salina 2010.*

In 2011 it is included 13 new stations in an axis cross based on a prevailing current direction towards north east, see Table 1.2-1.

Table 1.2-1 *Stations, baseline survey Salina 2011.Stations on grey were sampled in 2010, and are not included in 2011.*

Year	Station	Degrees	Meters	UTM-E-ED50-S34	UTM-N-ED50-S34
2012	SPUD	0	0	**467 485**	**7 991 098**
2010	SAL-01	NA	NA	466 464	7 991 636
2010	SAL-02	NA	NA	467 462	7 992 336
2010	SAL-03	NA	NA	467 581	7 989 976
2010	SAL-04	NA	NA	468 579	7 990 676
2010	SAL-05	NA	NA	467 037	7 990 804
2010	SAL-06	NA	NA	468 035	7 991 504
2010	SAL-07	NA	NA	467 492	7 991 109
2011	SAL-8	45	100	467 556	7 991 169
2011	SAL-9	45	250	467 662	7 991 275
2011	SAL-10	45	500	467 839	7 991 452
2011	SAL11	45	1000	468 192	7 991 805
2011	SAL-12	135	100	467 556	7 991 028
2011	SAL-13	135	250	467 662	7 990 922
2011	SAL-14	135	500	467 839	7 990 745
2011	SAL-15	225	100	467 414	7 991 028
2011	SAL-16	225	250	467 308	7 990 922
2011	SAL-17	225	500	467 132	7 990 745
2011	SAL-19	315	100	467 414	7 991 169
2011	SAL-20	315	250	467 308	7 991 275
2011	SAL-21	315	500	467 132	7 991 452

Figure 2-2 shows the location of Salina 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 Salina field is presented.

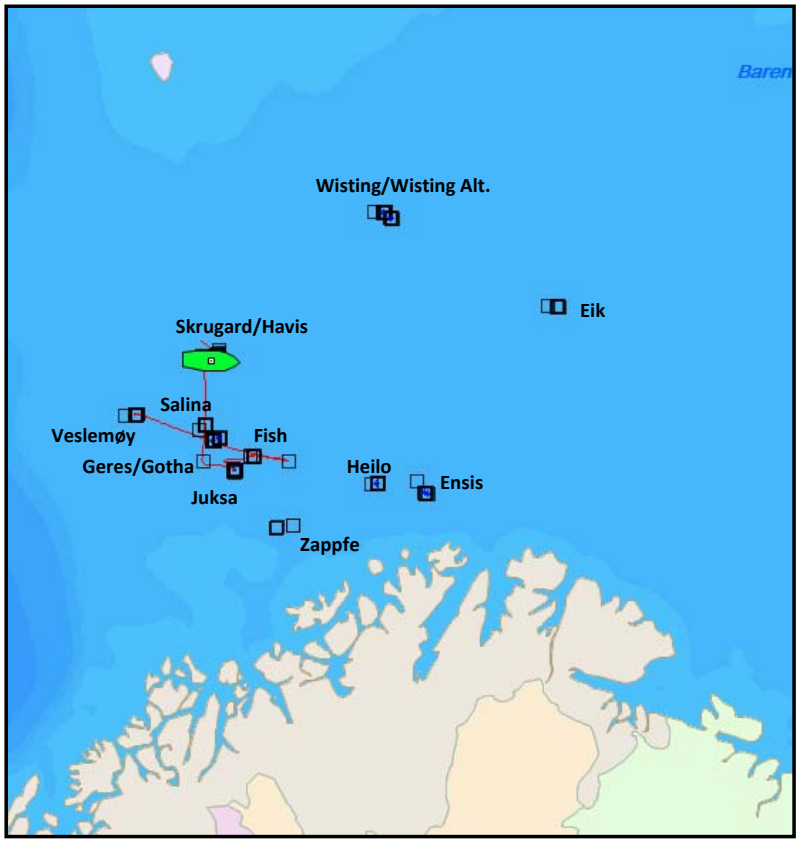


Figure 2-2 *Overview of baseline surveys conducted by DNV in the Barents Sea June/July 2011.*

3 MATERIALS AND METHODS

3.1 Fieldwork

3.1.1 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 3-1 shows the fields included in the survey, including regional stations.

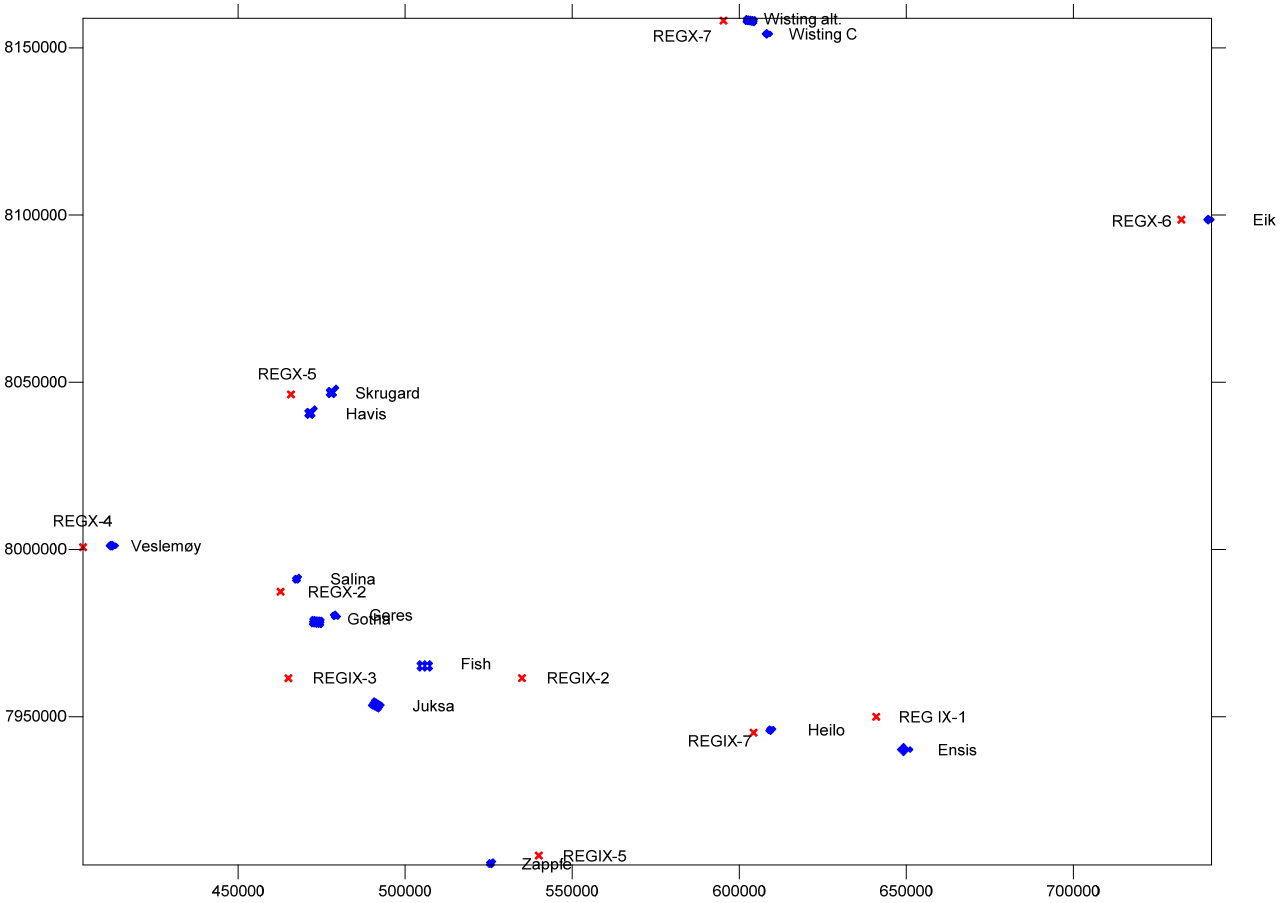


Figure 3-1 *Overview of baseline surveys including regional stations conducted by DNV in the Barents Sea June/July 2011.*

The survey was conducted 22. June - 12. July 2011. The Salina field was sampled 1. July. 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

3.1.2 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.

3.1.3 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.

3.2 Biological analyses

3.2.1 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.

3.2.2 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.

3.2.3 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).

3.2.4 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.

3.3 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

3.3.1 Sediment characterisation

3.3.1.1 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 3.3-1and Table 3.3-2.

Table 3.3-1 *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 3.3-2. *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)

3.3.1.2 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.

3.3.2 Chemical analyses

3.3.2.1 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 3.3-1. 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

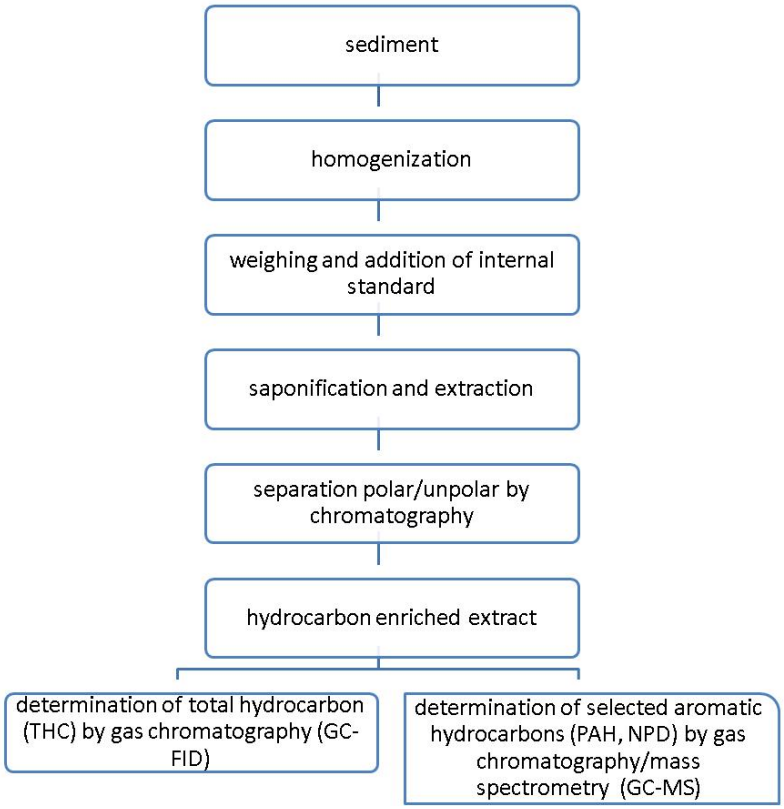


Figure 3.3-1 *Flow scheme of essential steps in the hydrocarbon analyses of sediments.*

3.3.2.2 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

3.3.2.3 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 3.3-3.

Table 3.3-3 *Limit of detection (LOD) and limit of quantification (LOQ), hydrocarbons and metals.*

Analysis parameter	LOD mg/kg	LOQ 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.

3.3.3 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.

3.4 Deviations from the Guidelines

The survey is performed according to the guidelines.

4 RESULTS

The depth at Salina was around 340 meter. The sea bottom consists of greyish clay with a browner top layer, but at some of the stations also small stones. A total of 13 stations and one regional station (REGX-2) were included in the survey.

The stations names are abbreviated after the program was prepared and the fieldwork was carried out, and SA is the name used in this chapter. The regional stations REGX-2 and REGIX-3 are named R102 and R93 respectively.

4.1 Sediment characterization

Grain size distribution

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 (53.1-90.9 %). The sediments are all classified as silt and clay. The highest level of sand was found at SA8 (45.4 %) and the lowest at SA11 (9.1 %). The sediments at the regional stations R102 and R93 are also classified as silt and clay and contain 44.4 and 14.9 % sand respectively.

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 range between 2.62 and 5.74 %. The content in the samples are lower than the regional station R93 (6.98 %) and 9 of 13 stations are lower than the reference station R102.

Table 4.1-1 *Salina 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)
SA8	45	100	344	3.04	Silt and clay	53.3	45.4	1.3	4.25
SA9	45	250	342	3.44	Silt and clay	65.1	34.0	0.9	4.93
SA10	45	500	344	3.27	Silt and clay	61.9	38.0	0.1	4.77
SA11	45	1000	348	4.57	Silt and clay	90.9	9.1	0.0	5.80
SA12	135	100	342	3.70	Silt and clay	59.6	39.4	1.0	4.64
SA13	135	250	344	3.16	Silt and clay	57.8	41.2	1.1	4.54
SA14	135	500	347	3.70	Silt and clay	62.9	37.0	0.1	4.82
SA15	225	100	341	3.42	Silt and clay	54.7	43.6	1.8	4.34
SA16	225	250	341	2.62	Silt and clay	55.7	43.1	1.2	4.41
SA17	225	500	341	4.52	Silt and clay	57.6	42.3	0.1	4.53
SA19	315	100	339	4.17	Silt and clay	53.1	43.8	3.1	4.23
SA20	315	250	339	5.74	Silt and clay	73.0	27.0	0.0	5.26
SA21	315	500	341	3.83	Silt and clay	64.1	35.7	0.1	4.88
R102			317	3.91	Silt and clay	54.0	44.4	1.6	4.29
R93			268	6.98	Silt and clay	85.1	14.9	0.0	5.65
Min.*				2.62		53.1	9.1	0.0	4.23
Max.*				5.74		90.9	45.4	3.1	5.80

*: The reference stations are not included

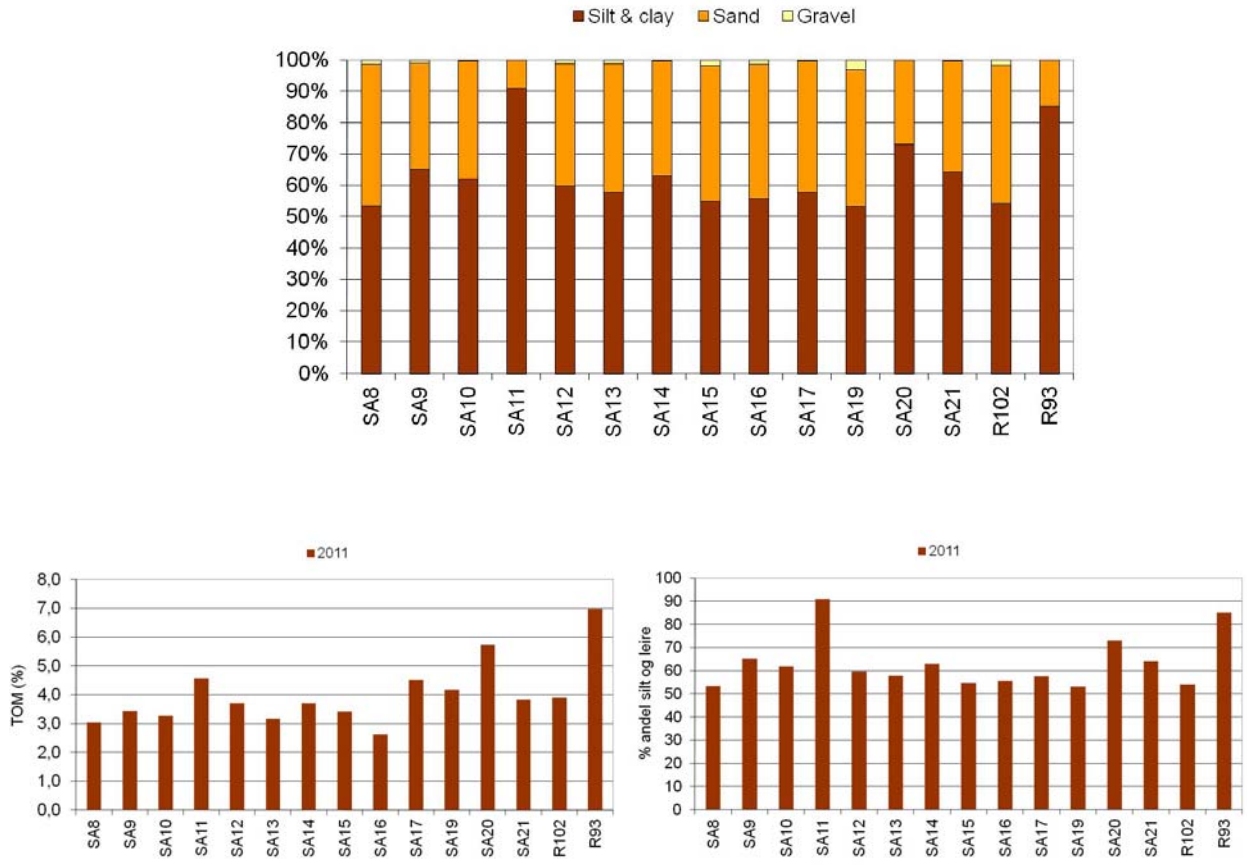


Figure 4.1-1 *Salina 2011, sediment characterization, silt & clay, sand and gravel content on top.*

1.1.1 Chemical analysis

Hydrocarbons

Summarized results of hydrocarbon analyses are given in Table 4.2-1 and Figure 4.1-2. The distribution of THC related to the field centre is also shown in Figure 4.1-2. Detailed results are given in appendix.

THC concentrations on Salina are in the range 1-6 mg/kg. All stations have THC concentration less than LSC-level ($LSC_{2010RegIX/X}$: 12.8 mg/kg). SA11 is the only station with THC concentration higher than the regional station R93. The rest of the stations has THC content in the same range as R93 and R102. All chromatograms show natural background levels. Content of PAH and NPD are lower than $LSC_{2010RegIX/X}$ (0.255 mg/kg for PAH and 0.499 mg/kg for NPD), but lower than the regional stations R102 and R93. R102 and R93 have concentrations of THC slightly lower in 2011 than in 2010. PAH and NPD concentrations are at the same level in 2011 as in 2010.

Table 4.1-2 *Salina 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
SA8	45	100	2	0	0.111	0.024	0.17	0.02
SA9	45	250	4	1	0.144	0.040	0.20	0.06
SA10	45	500	3	1	0.179	0.024	0.27	0.06
SA11	45	1000	6	4				
SA12	135	100	1	0				
SA13	135	250	2	0				
SA14	135	500	1	0				
SA15	225	100	1	0				
SA16	225	250	1	0				
SA17	225	500	1	0				
SA19	315	100	2	0				
SA20	315	250	2	0				
SA21	315	500	3	0				
R102			1	0	0.050	0.029	0.10	0.05
R93			4	1	0.056	0.003	0.08	0.01
Min.*			1		0.111		0.17	
Max.*			6		0.179		0.27	

*: The reference stations are not included

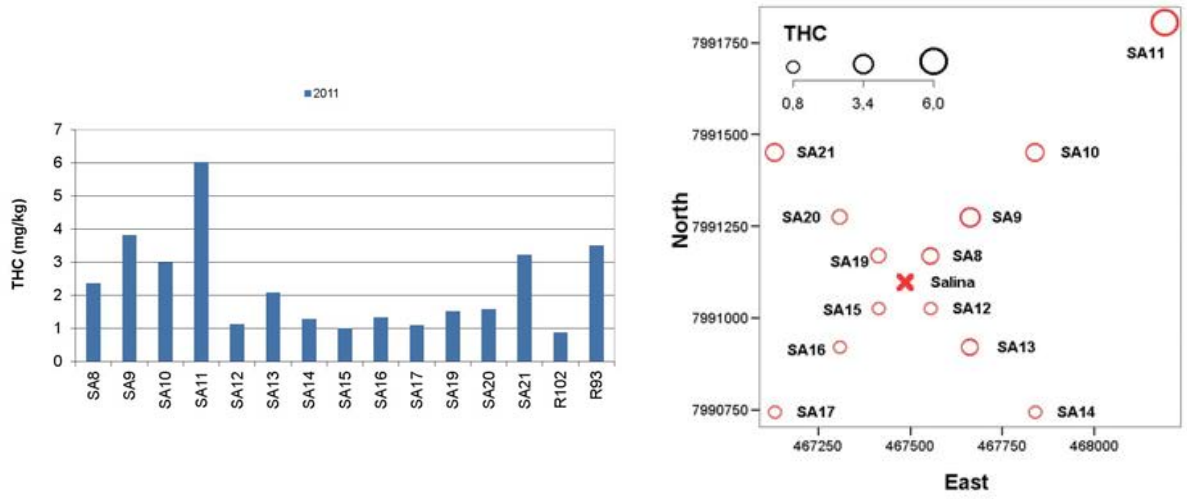


Figure 4.1-2 *Salina 2011, average content of THC (left). The figure to the right shows the distribution of THC in sediments at the sampling sites, the size of the circle indicate the amount of THC. The field centre is marked with an X.*

Metals

Summarized results of metals analyses are given in Table 4.1-3 and Figure 4.1-3. The distribution of Ba related to the field centre is shown in Figure 4.1-4. Detailed results are given in appendix.

Table 4.1-3 *Salina 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
SA8	45/100	66	6	0.04	0.01	19.6	1.5	7.6	0.8	0.02	0.00	11.2	1.2	337	27	36	4
SA9	45/250	80	10	0.05	0.00	22.9	2.0	9.0	0.8	0.03	0.00	12.9	1.0	388	29	44	3
SA10	45/500	74	4	0.05	0.01	22.8	0.7	9.0	0.4	0.03	0.00	12.4	0.5	377	6	43	1
SA11	45/1000	104	1	0.09	0.02	31.0	0.5	13.0	0.5	0.04	0.00	17.5	0.5	484	6	62	2
SA12	135/100	64	1	0.05	0.01	19.3	0.2	7.4	0.2	0.02	0.00	11.3	0.2	334	2	35	1
SA13	135/250	66	8	0.04	0.01	20.8	1.2	7.9	0.7	0.02	0.00	10.6	2.2	343	21	40	5
SA14	135/500	77	8	0.06	0.04	23.4	1.6	8.9	0.7	0.03	0.00	12.0	1.4	386	24	43	4
SA15	225/100	63	1	0.04	0.01	19.3	1.5	7.5	0.5	0.02	0.00	10.9	0.1	331	23	35	2
SA16	225/250	67	2	0.04	0.00	21.7	1.7	8.8	0.4	0.02	0.00	10.5	0.6	375	19	38	3
SA17	225/500	73	4	0.05	0.01	21.7	1.1	8.6	0.5	0.03	0.00	12.6	0.7	357	14	44	4
SA19	315/100	91	9	0.05	0.03	26.7	1.3	10.8	1.1	0.03	0.00	15.3	1.7	433	2	59	12
SA20	315/250	80	6	0.07	0.01	24.0	0.9	9.7	0.5	0.03	0.00	14.1	0.4	394	12	45	2
SA21	315/500	72	4	0.06	0.01	23.2	0.6	9.1	0.7	0.03	0.00	12.5	1.7	381	5	43	2
R102		63	6	0.06	0.01	20.3	1.4	8.2	0.6	0.02	0.00	13.0	1.5	371	23	37	3
R93		89	5	0.13	0.01	26.0	1.3	12.3	0.8	0.03	0.00	17.5	3.0	525	29	52	2
Min. *		63		0.04		19.3		7.4		0.02		10.5		331		35	
Max. *		104		0.09		31.0		13.0		0.04		17.5		484		62	

*: The reference stations are not included

The content of Ba is in the range 63 to 104 mg/kg, and the highest Ba concentration (104 ± 1 mg/kg) is measured at SA11. All the stations are above the regional stations R102 (63 ± 6 mg/kg), while two stations (SA11 and SA19) are above R93 (89 ± 5 mg/kg). SA11 is higher than the other stations for the rest of the elements and also higher than both the regional stations for Cr, Cu, Hg and Zn. SA19 is also mostly higher than the other stations, but lower than SA11. In general the other stations are at the same level as the regional R102, while the regional R93 is higher than the field stations. None of the Ba concentrations are above LSC-level ($LSC_{2010RegIX/X}$: 134 mg/kg). All the concentrations of metals are below $LSC_{2010RegIX/X}$. Compared to the analysis performed for R93 and R102 in 2010, the concentrations of metals are lower in 2011.

Figure 4.1-3 *Salina 2011, the average content of metals in top sediment (0-1 cm) from three parallel samples.*

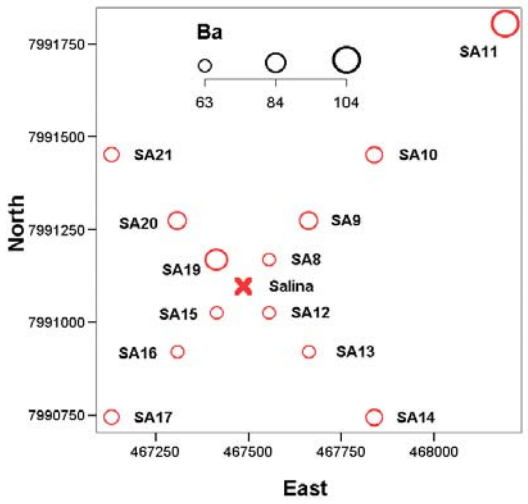


Figure 4.1-4 *Salina 2011, distribution of Ba in sediments at the sampling sites, the size of the circle indicate the amount of Ba. The field centre is marked with an X.*

4.2 Biological analyses

Diversity and dominant species

Table 4.2-1 shows the number of individuals and species at Salina by animal groups (juveniles excluded). There were 678 juvenile individuals recorded at Salina, 642 of these were *Ophiuroidea* spp. juveniles. *Ophiuroidea* spp. juveniles were among the top ten most dominant species at most stations, sometimes being the most dominant. The data was analysed both with and without juveniles, and is presented here with juveniles excluded.

Table 4.2-1 *Number of individuals (N) and species (S) distributed between the main animal groups, Salina 2011.*

Animal group	N	%	S	%
Varia	570	9,9	16	6,7
Polychaeta	3504	60,8	86	36,1
Crustacea	663	11,5	77	32,4
Mollusca	706	12,2	46	19,3
Echinodermata	321	5,6	13	5,5
Total	5764	100,0	238	100,0

Figure 4.2-1 shows the number of individuals and species at the individual stations on the field and the average per grab per station.

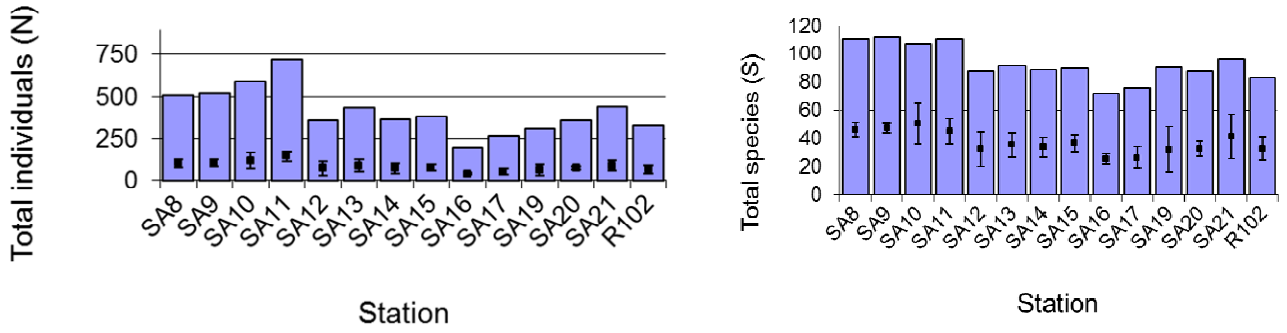


Figure 4.2-1 *Number of individuals (N) and species (S) per 0.5m^2, average and standard deviation between grab samples (0.1m^2), Salina 2011.*

Table 4.2-2 and Figure 4.2-2 shows the various diversity indices for each of the stations. Diversity and expected number of species was high at all stations, with only minor fluctuations, reflecting an undisturbed seafloor and a healthy benthic community. Excluding juveniles increased these indices even more, due to the high abundance of *Ophiuroidea* spp. juveniles.

Table 4.2-2 *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, Salina 2011.*

Station	Direction (°)	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
SA8	45	100	344	110	509	5,72	0,84	48
SA9	45	250	342	112	517	5,68	0,83	48
SA10	45	500	344	107	589	5,73	0,85	48
SA11	45	1000	348	110	720	5,07	0,75	38
SA12	135	100	342	88	357	5,44	0,84	44
SA13	135	250	344	92	437	5,15	0,79	42
SA14	135	500	347	89	364	5,36	0,83	45
SA15	225	100	341	90	380	5,49	0,85	46
SA16	225	250	341	72	198	5,45	0,88	49
SA17	225	500	341	76	262	4,99	0,80	42
SA19	315	100	339	91	309	5,50	0,84	47
SA20	315	250	339	88	357	5,21	0,81	43
SA21	315	500	341	96	438	5,69	0,86	49
R102			317	83	327	5,42	0,85	44

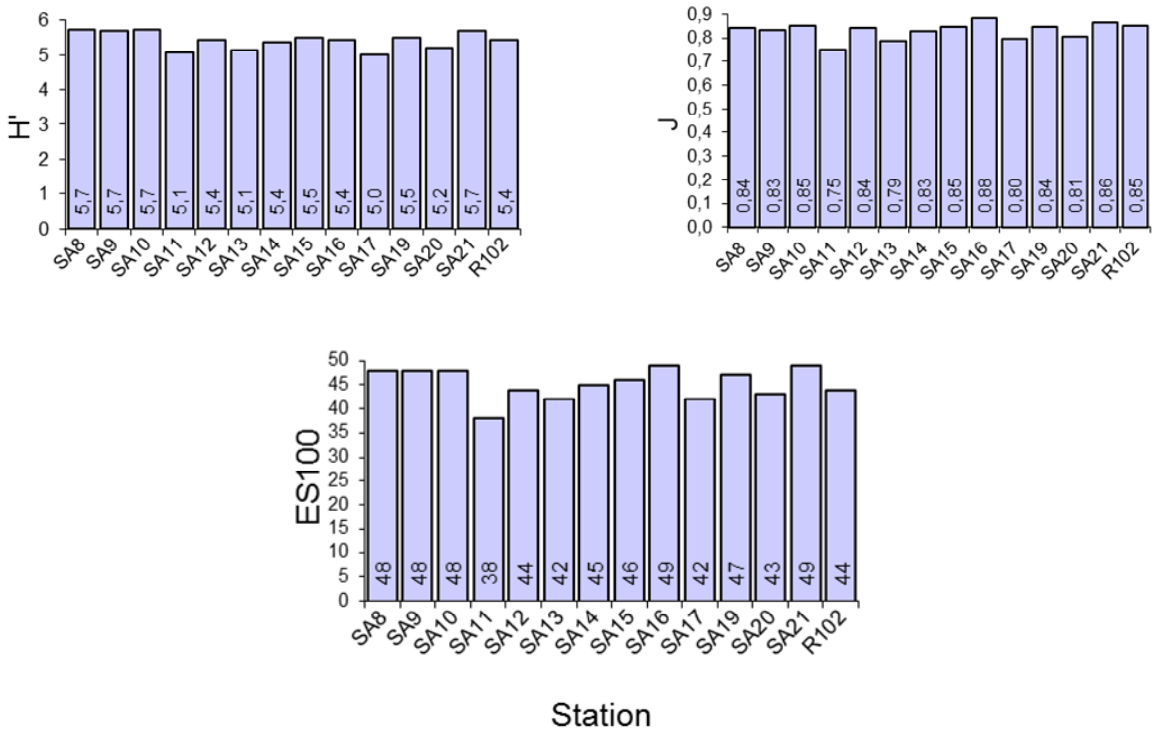


Figure 4.2-2 *Diversity, evenness and ES_{100} Salina 2011.*

The ten most common species at each station are shown below in Table 4.2-3. The top ten most dominant species contribute between 47 % (SA21) and 66 % (SA11) of the total number of individuals at each station. The stations are quite homogenous in terms of species make up, with the same species dominant at most stations.

Two polychaete species are most dominant at the Salina stations, *Lumbrineris scopa* (complex) and *Notomastus latericeus. L. scopa* (complex) contributes up to 20 % of the total number of individuals (at station SA17), while *N. latericeus* contributes up to 15 % (SA13). Station SA12 is characterized by a lower dominance of these two species. Polychaetes *Paramphinome jeffreysii* and *Galathowenia fragilis* are also found among the most dominant species at most stations. *G. fragilis* is sensitive and often found associated with undisturbed areas. The brittle star *Ophiocten affinis* and sipunculids of the family *Golfingiidae* are among the most dominant at 9 stations. *Golfingiidae* can be found at high densities in highly organic sediment, but is generally considered a sensitive species in terms of disturbance.

Table 4.2-3 *The ten most dominant species at each station, Salina 2011.*

10 most dominant species							
SA8	**No**	**%**	**Cum%**	**SA9**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	54	10,61	10,61	Lumbrineris scopa complex	61	11,8	11,8
Notomastus latericeus	47	9,23	19,84	Notomastus latericeus	52	10,06	21,86
Ophiocten affinis	35	6,88	26,72	Paramphinome jeffreysii	27	5,22	27,08
Paramphinome jeffreysii	23	4,52	31,24	Galathowenia fragilis	24	4,64	31,72
Golfingiidae spp.	18	3,54	34,77	Exogone (Parexogone) longicirris	18	3,48	35,2
Thyasira obsoleta	16	3,14	37,92	Ophiocten affinis	17	3,29	38,49
Galathowenia fragilis	15	2,95	40,86	Nemertea spp.	17	3,29	41,78
Thyasira granulosa	13	2,55	43,42	Spiophanes kroyeri	15	2,9	44,68
Aricidea (Acmira) catherinae	13	2,55	45,97	Levinsenia gracilis	12	2,32	47
Exogone (Parexogone) hebes	12	2,36	48,33	Golfingiidae spp.	9	1,74	48,74
SA10	**No**	**%**	**Cum%**	**SA11**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	64	10,87	10,87	Notomastus latericeus	103	14,31	14,31
Notomastus latericeus	48	8,15	19,02	Golfingiidae spp.	75	10,42	24,72
Paramphinome jeffreysii	38	6,45	25,47	Lumbrineris scopa complex	74	10,28	35
Galathowenia fragilis	26	4,41	29,88	Paramphinome jeffreysii	68	9,44	44,44
Ophiocten affinis	23	3,9	33,79	Thyasira obsoleta	40	5,56	50
Golfingiidae spp.	20	3,4	37,18	Galathowenia fragilis	38	5,28	55,28
Ilyarachna longicornis	16	2,72	39,9	Exogone (Parexogone) longicirris	20	2,78	58,06
Autonoe megacheir	15	2,55	42,44	Ophiocten affinis	20	2,78	60,83
Exogone (Parexogone) longicirris	15	2,55	44,99	Autonoe megacheir	17	2,36	63,19
Nemertea spp.	14	2,38	47,37	Dacrydium ockelmanni	17	2,36	65,56
SA12	**No**	**%**	**Cum%**	**SA13**	**No**	**%**	**Cum%**
Galathowenia fragilis	31	8,68	8,68	Notomastus latericeus	66	15,1	15,1
Paramphinome jeffreysii	30	8,4	17,09	Lumbrineris scopa complex	65	14,87	29,98
Lumbrineris scopa complex	28	7,84	24,93	Galathowenia fragilis	37	8,47	38,44
Thyasira obsoleta	23	6,44	31,37	Paramphinome jeffreysii	25	5,72	44,16
Notomastus latericeus	19	5,32	36,69	Nemertea spp.	17	3,89	48,05
Neohela monstrosa	17	4,76	41,46	Thyasira obsoleta	13	2,97	51,03
Macandrevia cranium	13	3,64	45,1	Pista cristata	10	2,29	53,32
Spiophanes kroyeri	12	3,36	48,46	Spiophanes kroyeri	8	1,83	55,15
Bathyarca pectunculoides	12	3,36	51,82	Tmetonyx cicada	8	1,83	56,98
Jasmineira spp.	9	2,52	54,34	Syllis cornuta	7	1,6	58,58
SA14	**No**	**%**	**Cum%**	**SA15**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	45	12,36	12,36	Lumbrineris scopa complex	50	13,16	13,16
Paramphinome jeffreysii	43	11,81	24,18	Paramphinome jeffreysii	33	8,68	21,84
Notomastus latericeus	36	9,89	34,07	Galathowenia fragilis	28	7,37	29,21
Ophiocten affinis	18	4,95	39,01	Notomastus latericeus	17	4,47	33,68
Nemertea spp.	11	3,02	42,03	Thyasira obsoleta	16	4,21	37,89
Galathowenia fragilis	10	2,75	44,78	Ophiocten affinis	15	3,95	41,84
Golfingiidae spp.	9	2,47	47,25	Spiophanes kroyeri	13	3,42	45,26

Table 4.2-3 *cont*.

Thyasira obsoleta	8	2,2	49,45	Nemertea spp.	10	2,63	47,89
Aglaophamus malmgreni	7	1,92	51,37	Harmothoe spp.	8	2,11	50
Syllis cornuta	7	1,92	53,3	Dacrydium ockelmanni	7	1,84	51,84
SA16	**No**	**%**	**Cum%**	**SA17**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	28	14,14	14,14	Lumbrineris scopa complex	53	20,23	20,23
Nemertea spp.	10	5,05	19,19	Notomastus latericeus	32	12,21	32,44
Galathowenia fragilis	9	4,55	23,74	Paramphinome jeffreysii	19	7,25	39,69
Paramphinome jeffreysii	8	4,04	27,78	Golfingiidae spp.	11	4,2	43,89
Jasmineira spp.	8	4,04	31,82	Galathowenia fragilis	11	4,2	48,09
Terebellides stroemii	8	4,04	35,86	Thyasira equalis	8	3,05	51,15
Pista cristata	7	3,54	39,39	Pseudoscalibregma parvum	7	2,67	53,82
Spiophanes kroyeri	7	3,54	42,93	Spiophanes kroyeri	7	2,67	56,49
Nothria conchylega	6	3,03	45,96	Rhabdopleura normani	5	1,91	58,4
Thyasira obsoleta	5	2,53	48,48	Haploops setosa	5	1,91	60,31
SA19	**No**	**%**	**Cum%**	**SA20**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	31	10,03	10,03	Notomastus latericeus	44	12,32	12,32
Notomastus latericeus	29	9,39	19,42	Paramphinome jeffreysii	43	12,04	24,37
Paramphinome jeffreysii	28	9,06	28,48	Lumbrineris scopa complex	42	11,76	36,13
Macandrevia cranium	21	6,8	35,28	Ophiocten affinis	20	5,6	41,74
Levinsenia gracilis	13	4,21	39,48	Galathowenia fragilis	17	4,76	46,5
Golfingiidae spp.	11	3,56	43,04	Bathyarca pectunculoides	12	3,36	49,86
Harmothoe spp.	9	2,91	45,95	Aglaophamus malmgreni	8	2,24	52,1
Aglaophamus malmgreni	9	2,91	48,87	Golfingiidae spp.	8	2,24	54,34
Syllis cornuta	6	1,94	50,81	Levinsenia gracilis	6	1,68	56,02
Ophiomitrella clavigera	5	1,62	52,43	Jasmineira spp.	6	1,68	57,7
SA21	**No**	**%**	**Cum%**	**R102**	**No**	**%**	**Cum%**
Lumbrineris scopa complex	52	11,87	11,87	Lumbrineris scopa complex	38	11,62	11,62
Notomastus latericeus	30	6,85	18,72	Paramphinome jeffreysii	22	6,73	18,35
Galathowenia fragilis	26	5,94	24,66	Notomastus latericeus	17	5,2	23,55
Paramphinome jeffreysii	25	5,71	30,37	Jasmineira spp.	17	5,2	28,75
Bathyarca pectunculoides	15	3,42	33,79	Galathowenia fragilis	17	5,2	33,94
Nemertea spp.	14	3,2	36,99	Pista cristata	15	4,59	38,53
Golfingiidae spp.	14	3,2	40,18	Cirratulus caudatus	14	4,28	42,81
Ophiocten affinis	11	2,51	42,69	Nemertea spp.	12	3,67	46,48
Exogone (Parexogone) longicirris	9	2,05	44,75	Myriochele olgae	11	3,36	49,85
Myriochele olgae	9	2,05	46,8	Ophiocten affinis	11	3,36	53,21

The cluster analysis for Salina is shown in Figure 4.2-3. The similarity between the field stations is high (approx. 60 %), except for SA16 which differ somewhat from the rest. The BioEnv-analysis did not reveal any correlation between the fauna and the other parameters that were analysed (abiotic factors). Maximum correlation coefficient was 0.25, which means that the faunal variations cannot be explained by the variations in the other parameters such as sediment characteristics, THC and metals.

The fauna community at the regional station R102 is quite similar to the field stations at Salina, and is suitable as a regional station In future monitoring.

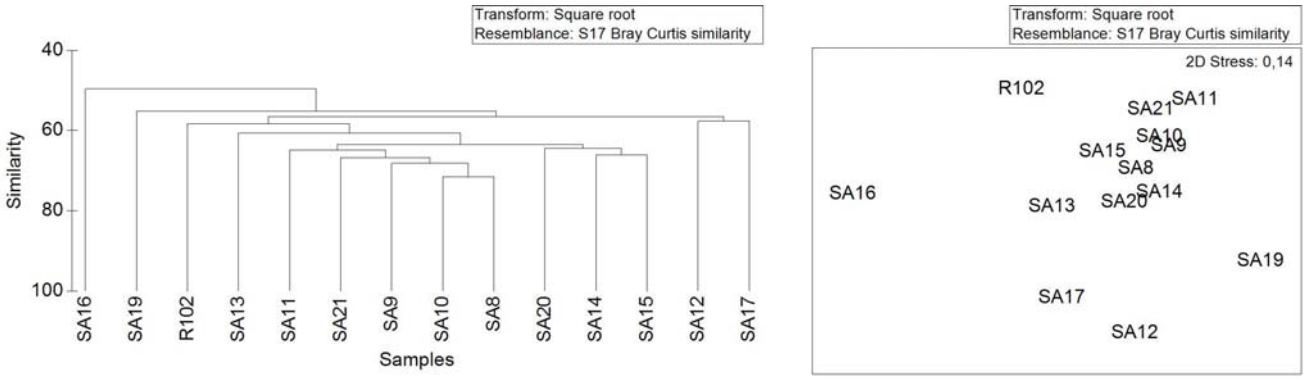


Figure 4.2-3 *Cluster- and MDS plot, Salina 2011.*

5 CONCLUSIONS

The sediments on Salina are classified as silt and clay. Content of total organic matter varies between 2.62 and 5.74 %. Generally there are no elevated levels compared to $LSC_{2010RegIX/X}$ for organic and inorganic parameters at Salina.

The diversity indices for the Salina benthic fauna are high at all stations and show only minor fluctuations. The indices and species composition reflect healthy undisturbed seafloor with complex fauna communities. The fauna at the regional station R102 are considered to be a suitable regional station in future monitoring.

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