DET NORSKE VERITAS™

REPORT

BASELINE SURVEY ZAPFFE 2011

DONG E & P NORGE AS

REPORT NO./DNV REG NO.: 2012-0419 / 13DO39S-16
REV 01, 2012-03-27

MANAGING RISK

Baseline Survey Zapffe 2011

For:
DONG E & P Norge AS
Rosenborggata 99
4007 STAVANGER
Norway

Account Ref.:
Øyvind Tvedten

Det Norske Veritas AS
P.O.Box 300
1322 Høvik, Norway
Tel: +47 67 57 99 00
Fax: +47 67 57 99 11
http://www.dnv.com

Date of Current Issue:		Project No.:	PP014672
Revision No.:	01	Organisation Unit:	Environmental Risk Management
DNV Reg. No.:	13DO39S-16	Report No.:	2012-0419

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

Prepared by:	S. A. Nøland, H. Karlsen, L. Brooks, W. Brennbakk, C. Volan, H. Tvete, L. Hankinson, T. K. Dokka, Ø. Fjukmoen	*Signature*
Verified by:	*Name and Position* Thomas Møskeland Principal Specialist	*Signature*
Approved by:	*Name and Position* Tor Jensen Head of Department	*Signature*

☒ Unrestricted distribution (internal and external)
☐ Unrestricted distribution within DNV
☐ Limited distribution within DNV after 3 years
☐ No distribution (confidential)
☐ Secret

Keywords
Sediments, hydrocarbons, benthic fauna, metals

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

Table of Contents *Page*

Appendix A – E are enclosed in the CD

- Appendix A – *Survey Report* (in Norwegian)
- Appendix B – *Test Report – biology*
- Appendix C – *Analysis Report - chemistry*
- Appendix D – *Statistical analyses techniques*
- Appendix E – *Baseline program (in Norwegian)*

Preface

The baseline survey at Zapffe was carried out by Det Norske Veritas and MOLAB on behalf of DONG E & P Norge AS. The work was coordinated by Hans Jacob Beck (Marathon), Robert Farestveit (Noreco) and Øyvind Tvedten (DONG).

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

Personnel

Fieldwork:	Tor Jensen (DNV, Survey Leader) Lee Hankinson (DNV, shift Leader) Øyvind Fjukmoen (DNV, shift Leader) Lara Varoveska (DNV) (22.06 – 05.07) Erik Karlsson (DNV) (05-12.07) Ludvig Søgnen Jensen (DNV) Odd Strandvoll (MOLAB) Thomas Trulsen (MOLAB)

Øyvind Tvedten and Lars Petter Myhre were client representatives during the survey.

Analyses:	
Grain size distribution:	Terje Kolberg, Eli Ellingsen
Total organic material:	Terje Kolberg, Eli Ellingsen
Metals:	Terje Pedersen, Gunn-Mari Michaelsen, Maja Lisa Olsen, Pål Torgersen, Wenche Brennbakk, Tove Kristin Dokka
THC:	Gaute Botten, Helene Tvete, Tove Kristin Dokka
NPD and PAH:	Helene Tvete, Tove Kristin Dokka

The chemical analyses are performed at Molab AS, sections in Oslo, Mo i Rana and in Porsgrunn. The grain size distribution is determined at Molab AS, section Glomfjord.

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)

Sorting is carried out at DNV's Biology Laboratory at Høvik. Christian Volan, Ludvig Søgnen Jensen and Kasper Nøland have been responsible for sorting of the biological samples.

Univariate analyses:	Lucy Brooks, Thomas Møskeland, Christian Volan, Lee Hankinson
Multivariate analyses:	Sam-Arne Nøland
Preparation of report:	
Chemistry:	Wenche Brennbakk, Helene Tvete, Tove Kristin Dokka, Hege Karlsen
Biology:	Lucy Brooks, Christian Volan, Lee Hankinson, Øyvind Fjukmoen, Sam-Arne Nøland
Main report:	Sam-Arne Nøland
Verification:	Thomas Møskeland
Project Manager:	Sam-Arne Nøland

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 Zapffe are dominated by silt and clay for all stations except two. TOM is in the 1.44-3.14 % range. The THC-concentrations are low and at the same level as the regional station R95. None of the chromatograms contains traces of hydrocarbons from oil. All stations except one have Ba-concentration above the regional station. The levels are however low and there is no indication of any specific pollution of the sediments.

Zapffe	Variation	Description of the field
THC (mg/kg)	<1-1	None of the stations at Zapffe have THC concentration above LSC for region IX/X in 2010 or the regional station R95.
Ba (mg/kg)	34-50	All the stations, except one, have Ba concentration higher than the regional station R95. None of the measured Ba concentrations are above LSC-level for region IX/X in 2010.
H’	5.6 – 6.0	The diversity indices reflect a healthy undisturbed seafloor with complex fauna communities. The fauna at the regional station R95 differs slightly from the field stations, but are still considered to be a suitable regional station in future monitoring.
J	0.82 – 0.89	
ES_{100}	44 - 50	

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 Zapffe består hovedsakelig av silt og for alle stasjoner unntatt to, og TOM ligger mellom 1,44 og 3,14 %. THC-konsentrasjonene er lave og på samme nivå som den regionale stasjonen R95. Kromatogrammene viser kun naturlig bakgrunn. Alle stasjoner unntatt en har høyere Ba-konsentrasjon enn R95. Nivåene er likevel lave og indikerer et uforurenset sediment.

Zapffe	Variasjon	Beskrivelse av feltet
THC (mg/kg)	<1-1	Det er ikke funnet THC-verdier over $LSC_{2010RegionIX/X}$. Alle stasjoner ligger også under den regionale stasjonen R95.
Ba (mg/kg)	34-50	Alle stasjoner, unntatt en, har høyere Ba-konsentrasjon enn R95. Ingen av de målte Ba-konsentrasjonene ligger over $LSC_{2010RegionIX/X}$.
H’	5,6 – 6,0	Diversitetsindeksene reflekterer en sunn og uforstyrret bunnfauna med komplekse samfunn. Faunaen på den regionale stasjonen R95 er noe forskjellig fra feltstasjonene, men er fremdeles ansett å være en egnet regional stasjon i fremtidig overvåking.
J	0,82 – 0,89	
ES_{100}	44 - 50	

2 INTRODUCTION

The drilling location at Zapffe (7121/9-1) is located in the Barents Sea (Figure 2-1) with the coordinates (ED50, UTM34):

E525526.0 N7906075.8

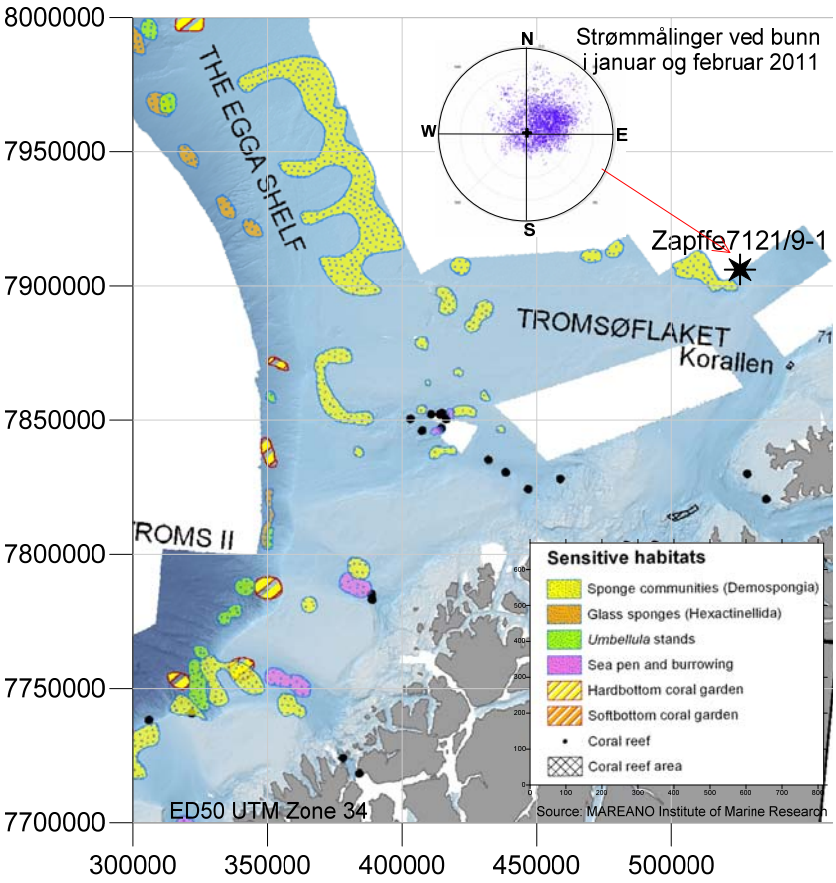

Figure 2-1 *Sea bed characterised by the MAREANO-program. Rose diagram of the current measurements 3m above sea floor at Zapffe in the period 20th of January – 14th of February, 2011.*

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

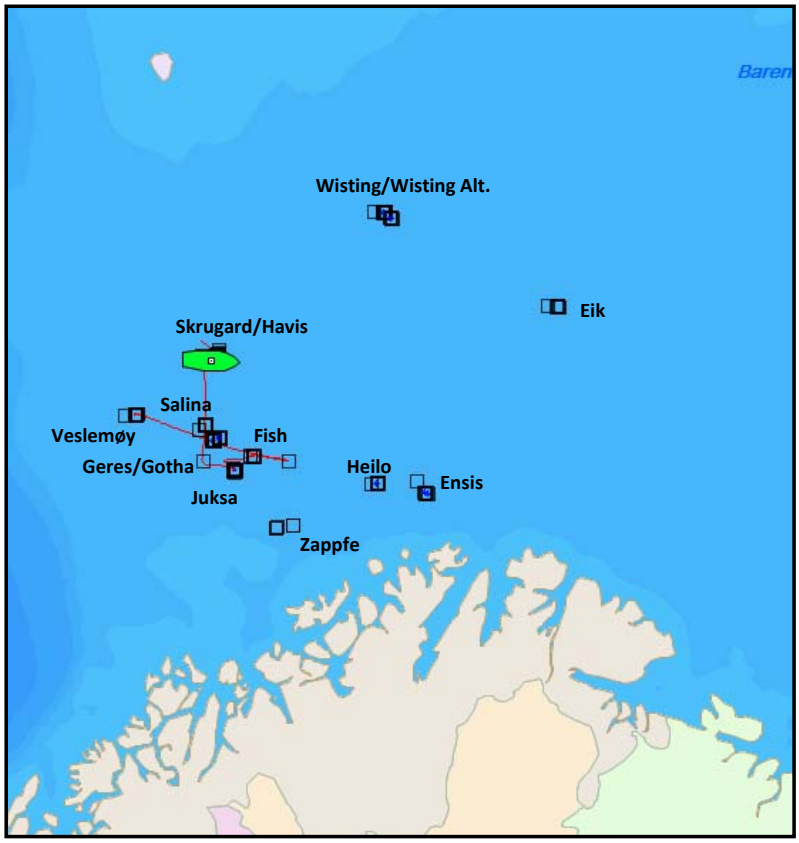

Figure 2-2 *Overview of baseline surveys conducted by DNV in the Barents Sea June/July 2011.*

Previously surveys at Zapffe

In February 2011, as part of the site survey, a visual baseline survey was carried out at Zapffe, which included mapping of five traverses, each ~400m in the immediate proximity to drilling location (Figure 2-3). In addition, one traverse was surveyed next to one of the proposed anchor locations. The survey revealed that that there are no identified corals in the area, or any denser aggregations of larger slow growing sponges (DNV 2011a). During the later drilling preparation it was decided not to use anchor assisted positioning, hence no anchors or chains were applied during the drilling of the well in the autumn of 2011.

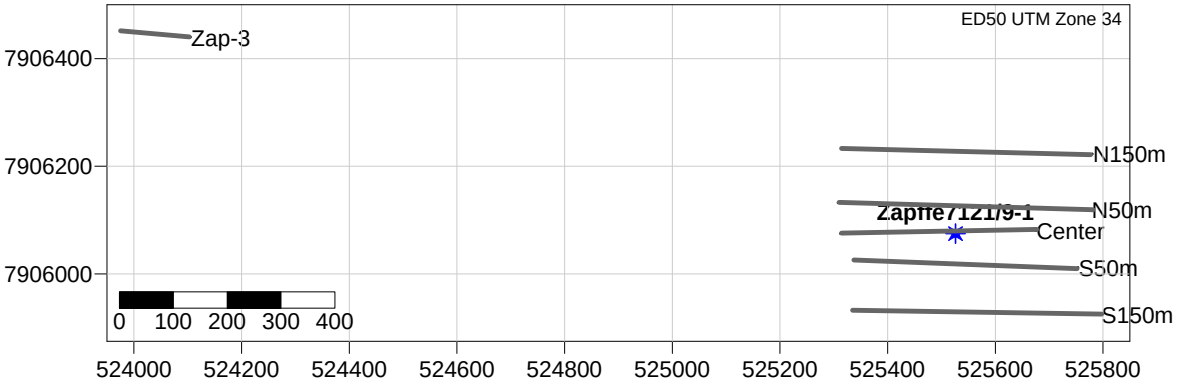

Figure 2-3 *Survey lines during the visual mapping carried out in February 2011 at Zapffe.*

Anticipated current direction

Current measurements have been carried out in the vicinity of the Zapffe location, in the period 20th of January – 14th of February, 2011. The results from the measurements revealed a net current direction of 50 degrees with a mean speed of 13 cm/s at 3m above sea floor (at the depth of 345m) (Figure 2-4).

The sampling program for the baseline sediment survey is based on these measurements.

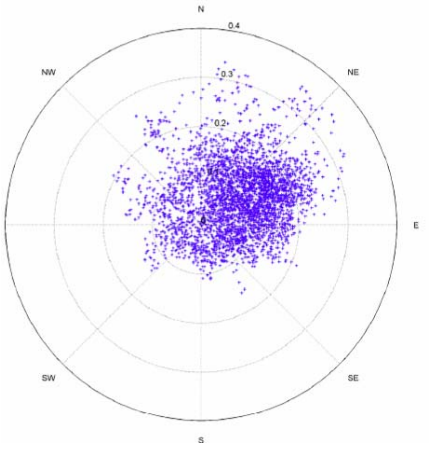

Figure 2-4 *Diagram of the current measurements 3m above sea floor at Zapffe in the period 20th of January – 14th of February, 2011.*

3 MATERIALS AND METHODS

3.1 Sampling strategy

The environmental baseline program for the exploration drilling at Zapffe 7121/9-1 was developed and revised following Klif requirements addressed in a meeting 22.3.2011. The developed sampling strategy is more comprehensive than previously programs for Region IX and X 2010 (Akvaplan-niva rap. 4878.01), due to changes in the discharge legislation for exploration drilling in the Barents Sea. Depending on whether the drilling location has been decided prior to the baseline survey or not, two sampling strategies can be followed. Axis cross is used if the drilling location is known before the fieldwork, while the grid strategy is used in a known location in the opposite case. The drilling location has been decided at Zapffe and therefore the axis cross alternative is suggested. Sampling and analysis should be performed in accordance with the Guidelines for sediment monitoring (Klif, TA2586, 2009).

The program for the baseline survey at Zapffe included sampling at 14 sediment stations (including nearby regional station) in 2011:

- One station with a distance of 100m, 250m and 500m from centre location in four directions (50º, 140º, 230º and 320º) => 12 stations overall
- One station with a distance of 1000m downstream from centre location (50º)
- The regional station REGIX-5

The locations for sediment samples are presented in Figure 3-1 and the coordinates are given in Table 3-1.

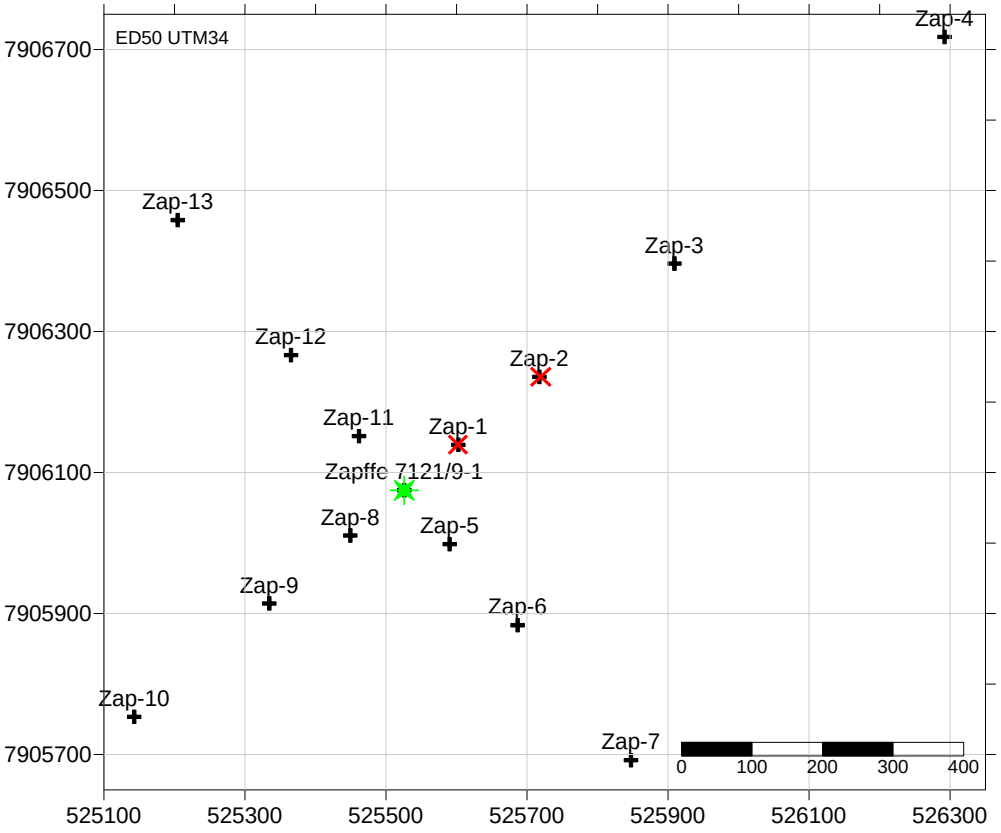

Figure 3-1 *Planned sampling location for sediment (+) at Zapffe, 2011. At two stations downstream, two extra layers should also be analysed. Coordinates are given in ED50 UTM34.*

Table 3-1 *Sediment stations at Zapffe, 2011. Coordinates are given in ED50 UTM34*

	Bearing	Distance	Easting	Northing	Comment
Zapffe 7121/9-1	0	0	525526	7906075	Planned drilling location - no samples
Zap-1	50	100	525603	7906139	
Zap-2	50	250	525718	7906236	
Zap-3	50	500	525909	7906396	
Zap-4	50	1000	526292	7906718	
Zap-5	140	100	525590	7905998	
Zap-6	140	250	525687	7905883	
Zap-7	140	500	525847	7905692	
Zap-8	230	100	525449	7906011	
Zap-9	230	250	525334	7905914	
Zap-10	230	500	525143	7905754	
Zap-11	320	100	525462	7906152	
Zap-12	320	250	525365	7906267	
Zap-13	320	500	525205	7906458	
REGIX-5			540000	7908500	

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 3-2 shows the fields included in the survey, including regional stations.

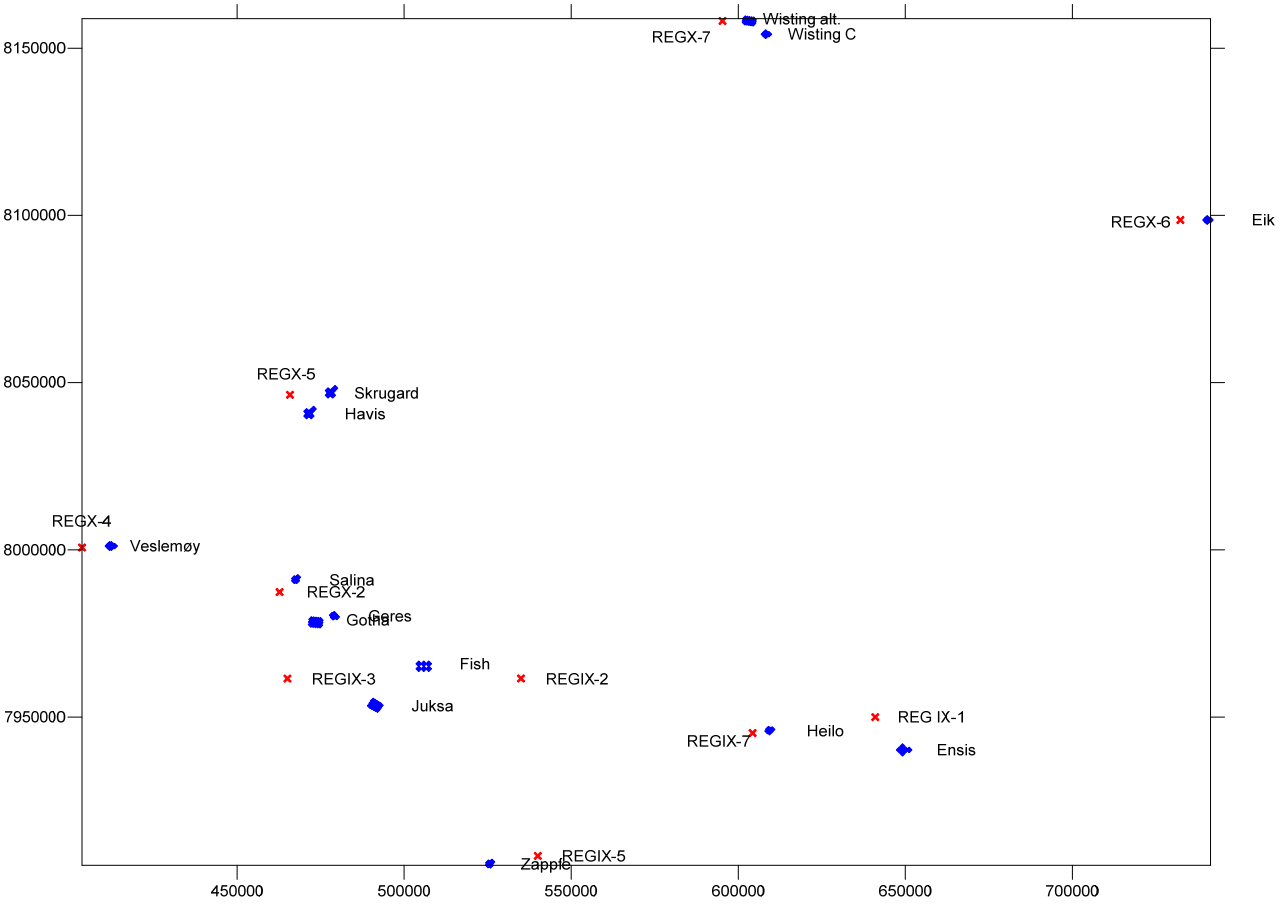

Figure 3-2 *Overview of baseline surveys including regional stations conducted by DNV in the Barents Sea June/July 2011.*

The survey was conducted 22. June - 12. July 2011. The Zapffe field was sampled 4-5. 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

3.2.2 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

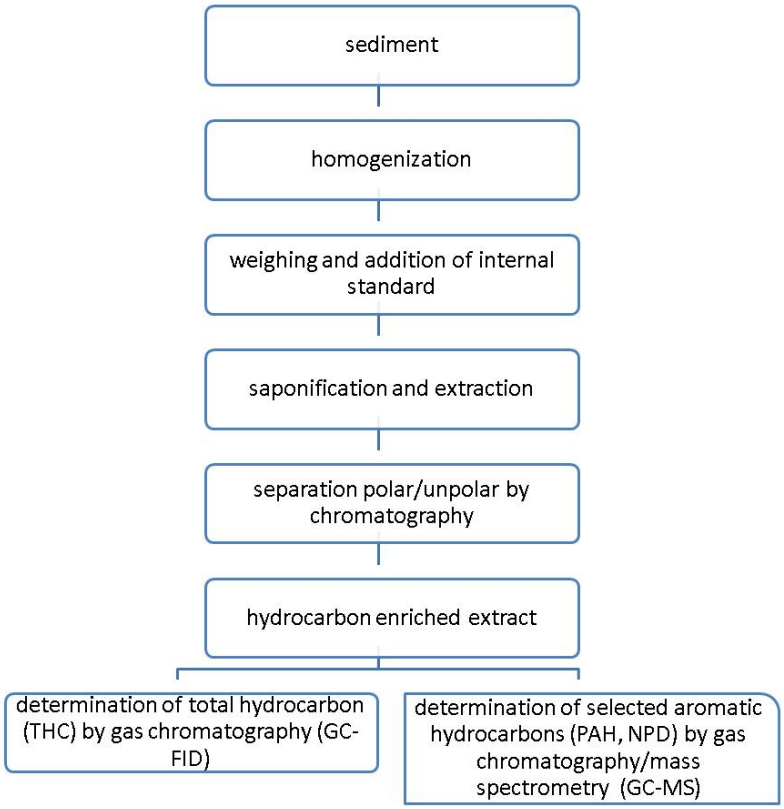

Figure 3.4-1 *Flow scheme of essential steps in the hydrocarbon analyses of sediments.*

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 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.

3.4.3 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 Zapffe was 300-313m. The observations from the sampling were that the sea bottom consists of homogenous fine sediments, described as “grey/brown fine sand/silt”.

The stations names are abbreviated after the program was prepared and the fieldwork was carried out, and Za is the name used in this chapter.

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.

The sand content at Zapffe is in the range 24.0-70.4 %. All samples, except Za11 and Za13 (silt and clay), are classified as very fine sand. The sediments at the regional station R95 is classified as very fine sand and contains 62.0 % sand.

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 in the range 1.44 - 3.14 %. All stations, except Za11, have TOM concentrations lower than the regional station R95 (2.27 %).

Table 4.1-1 *Zapffe 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)
Za1	50	100	310	1.87	Very fine sand	36.9	62.9	0.2	3.81
Za2	50	250	311	1.71	Very fine sand	43.3	56.6	0.1	3.90
Za3	50	500	311	1.90	Very fine sand	41.7	58.2	0.1	3.87
Za4	50	1000	313	1.44	Very fine sand	35.5	62.9	1.5	3.77
Za5	140	100	309	2.15	Very fine sand	47.6	52.3	0.1	3.96
Za6	140	250	309	1.67	Very fine sand	34.0	65.3	0.7	3.72
Za7	140	500	308	2.10	Very fine sand	45.7	53.9	0.4	3.92
Za8	230	100	308	2.10	Very fine sand	40.1	59.9	0.0	3.85
Za9	230	250	305	2.15	Very fine sand	42.0	58.0	0.0	3.87
Za10	230	500	299	1.76	Very fine sand	29.5	70.4	0.2	3.61
Za11	320	100	309	3.14	Silt and clay	76.0	24.0	0.0	5.37
Za12	320	250	309	1.94	Very fine sand	39.9	60.1	0.0	3.82
Za13	320	500	310	2.09	Silt and clay	52.5	47.5	0.0	4.19
R95			309	2.27	Very fine sand	36.9	62.0	1.0	3.65
Min.*				1.44		29.5	24.0	0.0	3.61
Max.*				3.14		76.0	70.4	1.5	5.37

*: The regional station is not included

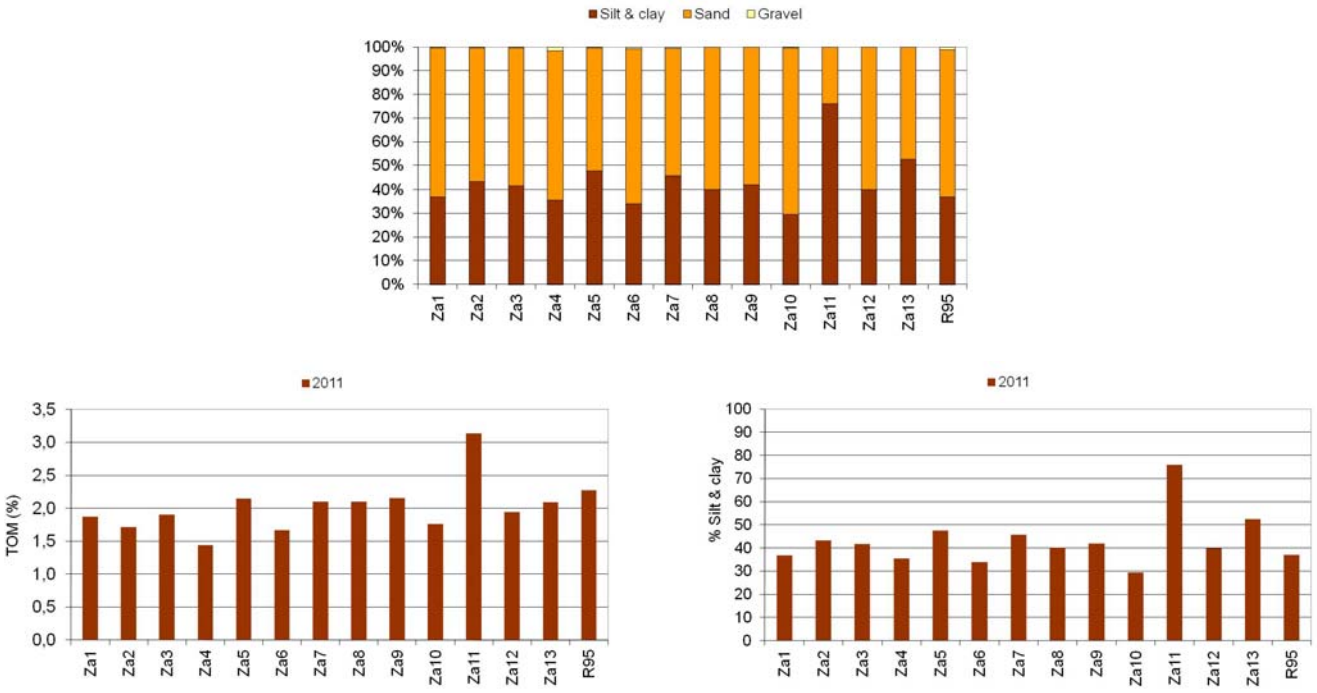

Figure 4.1-1 *Zapffe 2011, sediment characterization. Silt & clay, sand and gravel content on top.*

4.2 Chemical analysis

Hydrocarbons

Summarized results of hydrocarbon analyses are given in Table 4.2-1, see appendix for detailes.

Table 4.2-1 *Zapffe 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
Za1	50	100	<1	-	<0.005	-	<0.01	-
Za2	50	250	<1	-	<0.005	-	<0.01	-
Za3	50	500	<1	-				
Za4	50	1000	1	0				
Za5	140	100	1	1				
Za6	140	250	1	0				
Za7	140	500	1	1				
Za8	230	100	<1	-				
Za9	230	250	<1	-				
Za10	230	500	<1	-				
Za11	320	100	<1	-				
Za12	320	250	<1	-				
Za13	320	500	<1	-				
R95			1	1	0.007	0.010	0.01	0.01
Min.*			<1		<0.005		<0.01	
Max.*			1		<0.005		<0.01	

*: The reference station is not included

THC concentration at Zapffe varies between <1 and 1 mg/kg. All of the THC concentrations are below LSC-level ($LSC_{2010RegIX/X}$: 12.8 mg/kg) and at the same level as the regional station R95. All chromatograms show natural background levels. PAH and NPD levels are also low, less than $LSC_{2010RegIX/X}$ and at the same level as the regional station. THC, PAH and NPD concentrations for R95 measured in 2011 are at the same level as in 2010.

Metals

Summarized results of metals analyses are given in Table 4.2-2 and Figure 4.2-1. The distribution of Ba is shown in Figure 4.2-2. Detailed results are given in appendix.

Table 4.2-2 *Zapffe 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
Za1	50/100	39	4	<0.03		11.1	0.2	3.2	0.1	0.02	0.00	5.7	0.6	296	7	19	1
Za2	50/250	39	2	<0.03		12.5	2.2	3.8	0.8	0.01	0.00	5.3	0.8	325	37	20	3
Za3	50/500	41	2	<0.03		13.7	1.3	4.1	0.5	0.01	0.00	4.7	0.8	353	17	24	3
Za4	50/1000	41	6	<0.03		11.6	0.1	3.5	0.0	0.02	0.00	6.1	0.3	306	3	20	1
Za5	140/100	47	3	0.03	0.01	12.6	0.5	3.9	0.1	0.02	0.00	6.1	0.3	321	5	29	7
Za6	140/250	39	5	0.03	0.01	11.3	0.6	3.6	0.2	0.02	0.00	5.8	0.1	296	15	39	34
Za7	140/500	41	6	<0.03		14.4	2.6	4.6	1.1	0.01	0.00	5.1	0.6	341	32	25	7
Za8	230/100	37	2	0.03	0.01	11.1	0.7	3.4	0.2	0.02	0.00	6.0	0.1	294	14	29	18
Za9	230/250	39	1	0.03	0.01	11.3	0.3	3.7	0.4	0.01	0.00	6.0	0.3	291	26	18	0
Za10	230/500	34	3	<0.03		10.2	0.4	2.9	0.1	0.01	0.00	5.0	0.0	289	5	15	0
Za11	320/100	50	9	<0.03		17.4	6.2	4.8	1.1	0.01	0.00	5.3	0.8	397	83	27	10
Za12	320/250	37	4	<0.03		11.1	0.9	3.1	0.3	0.01	0.00	5.4	0.7	306	17	17	2
Za13	320/500	43	8	0.03	0.00	12.1	0.9	3.6	0.3	0.01	0.00	5.6	0.8	325	24	19	2
R95		35	4	0.03	0.01	12.8	0.6	3.6	0.4	0.01	0.00	5.1	1.1	348	6	19	2
Min. *		34		<0.03		10.2		2.9		0.01		4.7		289		15	
Max. *		50		0.03		17.4		4.8		0.02		6.1		397		39	

*: The reference station is not included

The content of Ba is in the range from 34 to 50 mg/kg, and the highest Ba-concentration is measured at Za11 (50 ± 9 mg/kg). All stations except Za10 (34 ± 3 mg/kg) are above the regional station R95 (35 ± 4 mg/kg). In general the concentrations of the rest of the metals are at the same level as R95, with some exceptions. None of the Ba concentrations are above LSC-level ($LSC_{2010RegIX/X}$: 134 mg/kg). All the concentrations of the rest of the metals are below $LSC_{2010RegIX/X}$. The concentrations of metals at R95 are slightly higher in 2011 than in 2010.

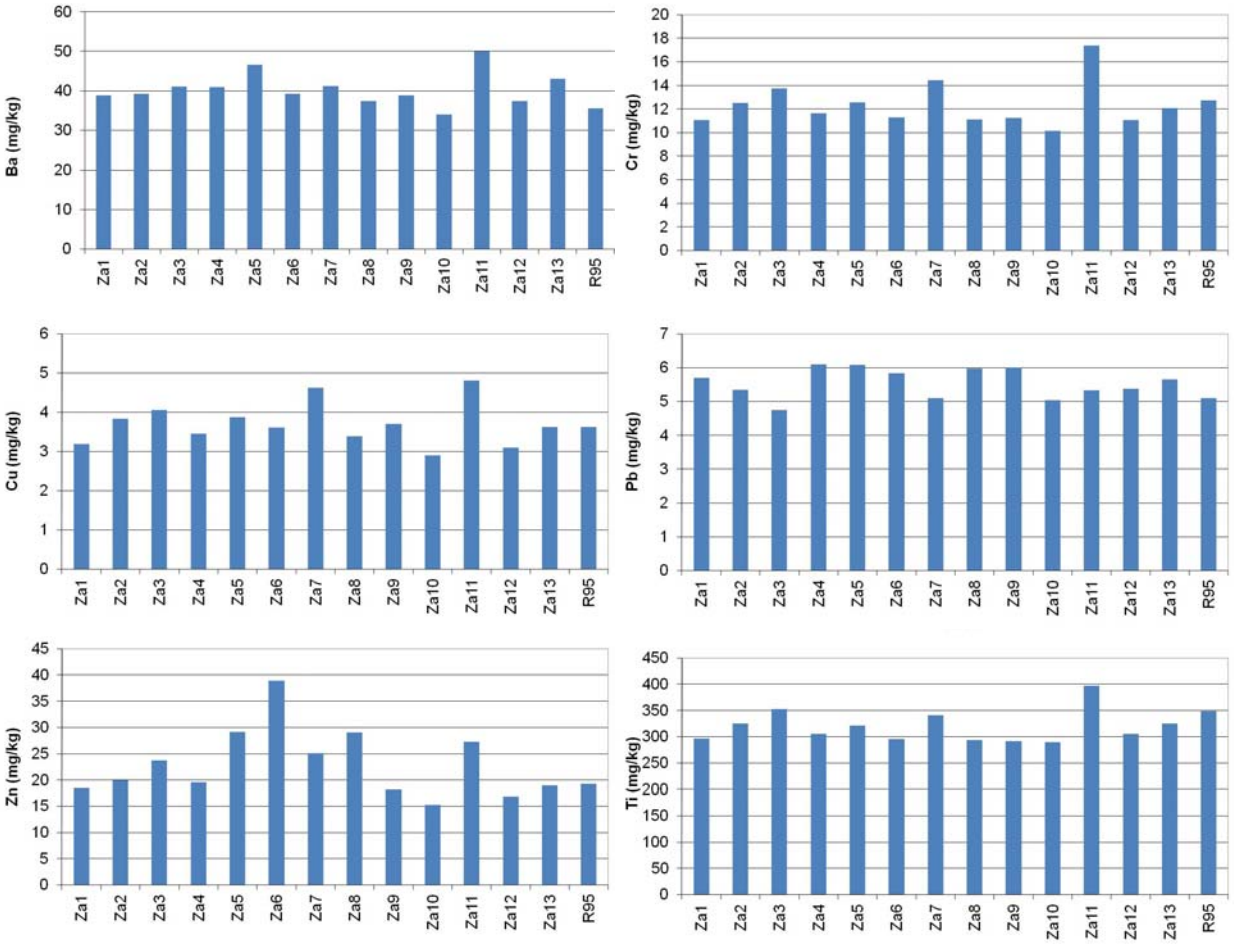

Figure 4.2-1 *Zapffe 2011, the average content of metals in top sediment (0-1 cm) from three parallel samples.*

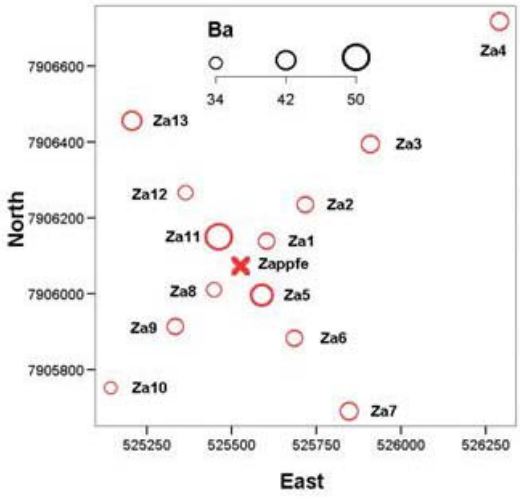

Figure 4.2-2 *Zapffe 2011, distribution of Ba in sediments at the sampling sites, the size of the circle indicate the amount of Ba. The drilling location is marked with an X.*

4.3 Biological analyses

Diversity and dominant species

Table 4.3-1 shows the number of individuals and species at Zapffe by animal groups. Juveniles of *Ophiuroidea* spp. were among the top ten most abundant species at every station and were often the most dominant species. There were 727 *Ophiuroidea* spp. juveniles at all stations together, (out of 756 juveniles in total). The data was analysed both with and without juveniles; it is presented here with juveniles excluded.

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, Zapffe 2011.*

Animal group	N	%	S	%
Varia	1104	9,3	17	6,1
Polychaeta	7062	59,4	109	39,2
Crustacea	1543	13,0	94	33,8
Mollusca	1635	13,8	48	17,3
Echinodermata	535	4,5	10	3,6
Total	11879	100,0	278	100,0

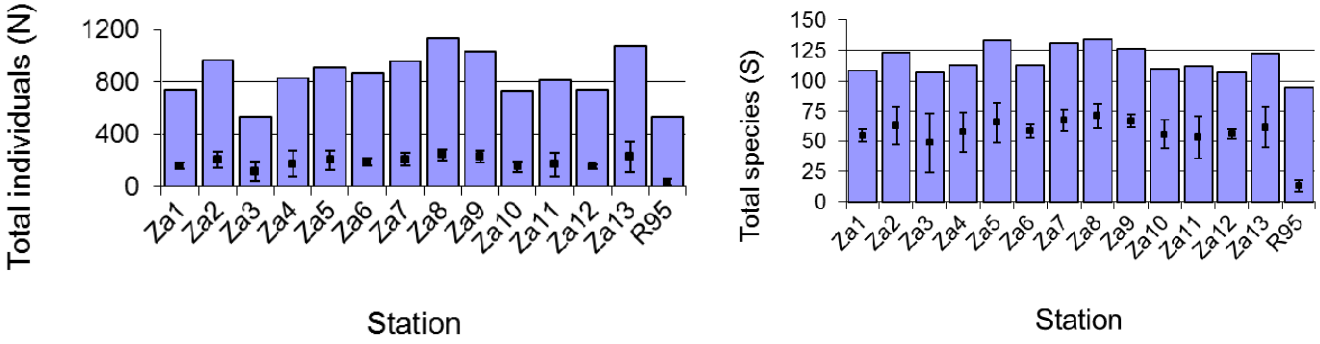

Figure 4.3-1 *Number of individuals (N) and species (S) per 0.5m^2, average and standard deviation between grab samples (0.1m^2), Zapffe 2011.*

Table 4.3-2 and Figure 4.3-2 shows the various diversity indices for each of the stations. The indices are high at all the Zapffe stations and show only minor fluctuations. The indices reflect healthy undisturbed seafloor with complex fauna communities.

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, Zapffe 2011.*

Station	Direction (°)	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
Za1	50	100	310	108	738	5,60	0,83	44
Za2	50	250	311	123	969	5,81	0,84	47
Za3	50	500	311	107	534	6,00	0,89	52
Za4	50	1000	313	113	829	5,77	0,85	47
Za5	140	100	309	133	910	5,92	0,84	49
Za6	140	250	309	113	872	5,64	0,83	44
Za7	140	500	308	131	958	5,98	0,85	50
Za8	230	100	308	134	1136	5,90	0,83	48
Za9	230	250	305	126	1035	5,81	0,83	47
Za10	230	500	299	110	732	5,80	0,86	47
Za11	320	100	309	112	817	5,71	0,84	45
Za12	320	250	309	107	742	5,77	0,86	47
Za13	320	500	310	122	1073	5,67	0,82	45
R95			309	94	534	5,63	0,86	44

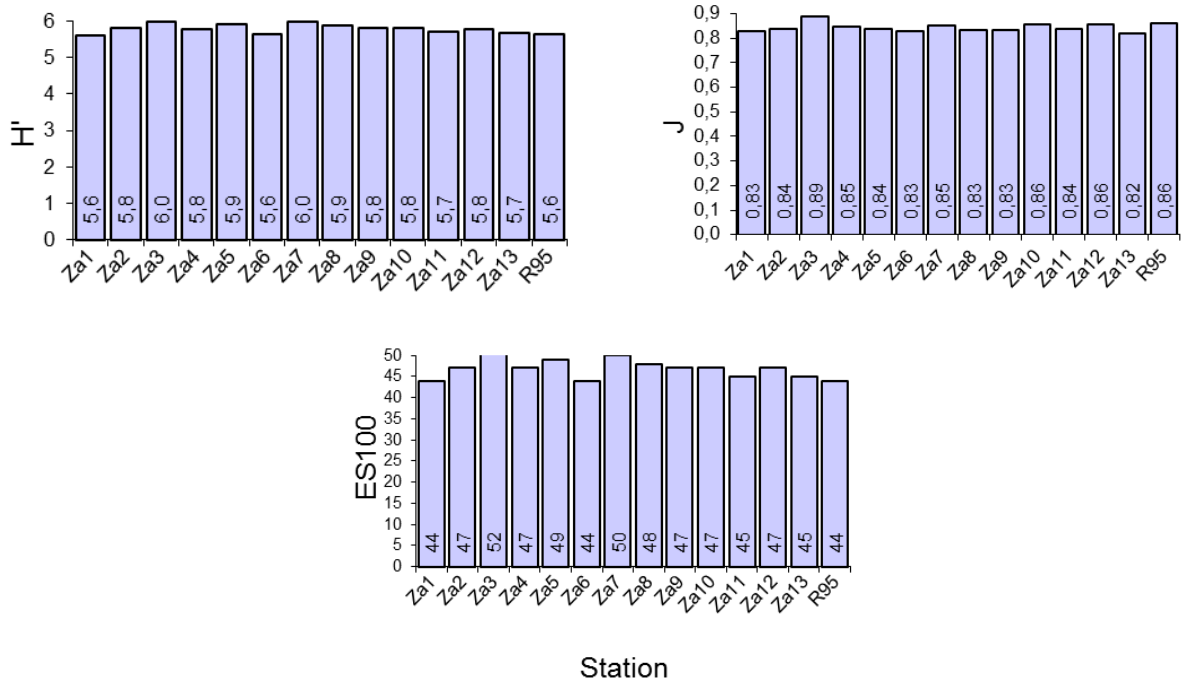

Figure 4.3-2 *Diversity, evenness and ES_{100} Zapffe 2011.*

The ten most common species at each station are shown below in Table 4.3-3.
The ten most dominant species contribute between 38.9 % (Za7) and 47.9 % (Za6) of the total number of individuals at each station. The robust cirratulid polychaete *Chaetozone setosa* complex is the most dominant species at 6 stations, and contributes 4.5 % (Za13) to 9.6% (Za1). Other dominant species

are the polychaetes *Exogene (Parexogone) hebes, Paramphinome jeffreysii* and *Notomastus latericeus*; and the brachiopod *Macandrevia cranium*.

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

10 most dominant species							
Za1	**No**	**%**	**Cum%**	**Za2**	**No**	**%**	**Cum%**
Chaetozone setosa complex	71	9,62	9,62	Exogone (Parexogone) hebes	74	7,64	7,64
Exogone (Parexogone) hebes	59	7,99	17,62	Chaetozone setosa complex	71	7,33	14,96
Notomastus latericeus	39	5,28	22,9	Myriochele olgae	45	4,64	19,61
Ophiocten affinis	34	4,61	27,51	Paramphinome jeffreysii	45	4,64	24,25
Galathowenia fragilis	31	4,2	31,71	Macandrevia cranium	43	4,44	28,69
Pista cristata	28	3,79	35,5	Ophiocten affinis	37	3,82	32,51
Thyasira obsoleta	23	3,12	38,62	Vargula norvegica	37	3,82	36,33
Ophelina cylindricaudata	21	2,85	41,46	Notomastus latericeus	29	2,99	39,32
Vargula norvegica	21	2,85	44,31	Ophelina abranchiata	27	2,79	42,11
Myriochele olgae	20	2,71	47,02	Aricidea (Acmira) catherinae	24	2,48	44,58
Za3	**No**	**%**	**Cum%**	**Za4**	**No**	**%**	**Cum%**
Chaetozone setosa complex	33	6,18	6,18	Chaetozone setosa complex	69	8,32	8,32
Paramphinome jeffreysii	28	5,24	11,42	Thyasira obsoleta	55	6,63	14,96
Jasmineira spp.	23	4,31	15,73	Paramphinome jeffreysii	50	6,03	20,99
Thyasira obsoleta	21	3,93	19,66	Exogone (Parexogone) hebes	45	5,43	26,42
Exogone (Parexogone) hebes	20	3,75	23,41	Jasmineira spp.	37	4,46	30,88
Notomastus latericeus	19	3,56	26,97	Notomastus latericeus	35	4,22	35,1
Ophiocten affinis	16	3	29,96	Pista cristata	26	3,14	38,24
Galathowenia fragilis	15	2,81	32,77	Vargula norvegica	21	2,53	40,77
Pista cristata	15	2,81	35,58	Ophelina abranchiata	19	2,29	43,06
Ophelina cylindricaudata	13	2,43	38,01	Dacrydium ockelmanni	18	2,17	45,24
Za5	**No**	**%**	**Cum%**	**Za6**	**No**	**%**	**Cum%**
Macandrevia cranium	72	7,91	7,91	Exogone (Parexogone) hebes	70	8,03	8,03
Paramphinome jeffreysii	54	5,93	13,85	Chaetozone setosa complex	66	7,57	15,6
Chaetozone setosa complex	53	5,82	19,67	Macandrevia cranium	63	7,22	22,82
Notomastus latericeus	47	5,16	24,84	Paramphinome jeffreysii	51	5,85	28,67
Exogone (Parexogone) hebes	45	4,95	29,78	Notomastus latericeus	36	4,13	32,8
Jasmineira spp.	36	3,96	33,74	Octobranchus floriceps	36	4,13	36,93
Pista cristata	30	3,3	37,03	Thyasira obsoleta	26	2,98	39,91
Lumbrineris scopa complex	25	2,75	39,78	Amythasides macroglossus	26	2,98	42,89
Thyasira obsoleta	24	2,64	42,42	Pista cristata	24	2,75	45,64
Octobranchus floriceps	19	2,09	44,51	Vargula norvegica	20	2,29	47,94
Za7	**No**	**%**	**Cum%**	**Za8**	**No**	**%**	**Cum%**
Chaetozone setosa complex	91	9,5	9,5	Chaetozone setosa complex	88	7,75	7,75
Vargula norvegica	59	6,16	15,66	Exogone (Parexogone) hebes	84	7,39	15,14
Exogone (Parexogone) hebes	49	5,11	20,77	Ophiocten affinis	47	4,14	19,28

Table 4.3-3 *cont.*

Notomastus latericeus	34	3,55	24,32	Notomastus latericeus	46	4,05	23,33
Paramphinome jeffreysii	31	3,24	27,56	Vargula norvegica	43	3,79	27,11
Jasmineira spp.	24	2,51	30,06	Pista cristata	41	3,61	30,72
Dacrydium ockelmanni	23	2,4	32,46	Octobranchus floriceps	38	3,35	34,07
Lumbrineris scopa complex	21	2,19	34,66	Dacrydium ockelmanni	36	3,17	37,24
Bathyarca pectunculoides	21	2,19	36,85	Paramphinome jeffreysii	35	3,08	40,32
Aricidea (Acmira) catherinae	20	2,09	38,94	Jasmineira spp.	35	3,08	43,4
Za9	**No**	**%**	**Cum%**	**Za10**	**No**	**%**	**Cum%**
Macandrevia cranium	92	8,89	8,89	Paramphinome jeffreysii	48	6,56	6,56
Chaetozone setosa complex	62	5,99	14,88	Galathowenia fragilis	41	5,6	12,16
Pista cristata	56	5,41	20,29	Chaetozone setosa complex	38	5,19	17,35
Notomastus latericeus	54	5,22	25,51	Macandrevia cranium	35	4,78	22,13
Octobranchus floriceps	49	4,73	30,24	Pista cristata	32	4,37	26,5
Exogone (Parexogone) hebes	36	3,48	33,72	Exogone (Parexogone) hebes	29	3,96	30,46
Ophiocten affinis	34	3,29	37	Thyasira obsoleta	28	3,83	34,29
Thyasira obsoleta	31	3	40	Octobranchus floriceps	26	3,55	37,84
Paramphinome jeffreysii	28	2,71	42,71	Jasmineira spp.	25	3,42	41,26
Exogone (Parexogone) longicirris	26	2,51	45,22	Nemertea spp.	22	3,01	44,26
Za11	**No**	**%**	**Cum%**	**Za12**	**No**	**%**	**Cum%**
Paramphinome jeffreysii	63	7,71	7,71	Chaetozone setosa complex	61	8,22	8,22
Chaetozone setosa complex	60	7,34	15,06	Pista cristata	45	6,06	14,29
Exogone (Parexogone) hebes	49	6	21,05	Exogone (Parexogone) hebes	40	5,39	19,68
Ischnomesus bispinosus	32	3,92	24,97	Notomastus latericeus	31	4,18	23,85
Galathowenia fragilis	32	3,92	28,89	Jasmineira spp.	28	3,77	27,63
Notomastus latericeus	27	3,3	32,19	Macandrevia cranium	28	3,77	31,4
Aricidea (Acmira) catherinae	26	3,18	35,37	Ophelina cylindricaudata	22	2,96	34,37
Pista cristata	25	3,06	38,43	Spiophanes kroyeri	22	2,96	37,33
Ophelina cylindricaudata	25	3,06	41,49	Dacrydium ockelmanni	22	2,96	40,3
Macandrevia cranium	24	2,94	44,43	Galathowenia fragilis	22	2,96	43,26
Za13	**No**	**%**	**Cum%**	**R95**	**No**	**%**	**Cum%**
Macandrevia cranium	114	10,62	10,62	Paramphinome jeffreysii	31	5,81	5,81
Exogone (Parexogone) hebes	74	6,9	17,52	Chaetozone setosa complex	27	5,06	10,86
Pista cristata	60	5,59	23,11	Thyasira obsoleta	27	5,06	15,92
Notomastus latericeus	52	4,85	27,96	Lumbrineris scopa complex	27	5,06	20,97
Chaetozone setosa complex	48	4,47	32,43	Exogone (Parexogone) hebes	26	4,87	25,84
Jasmineira spp.	40	3,73	36,16	Pista cristata	26	4,87	30,71
Octobranchus floriceps	37	3,45	39,61	Spiophanes kroyeri	23	4,31	35,02
Oligochaeta sp.	30	2,8	42,4	Dacrydium ockelmanni	22	4,12	39,14
Cadulus spp.	25	2,33	44,73	Amythasides macroglossus	18	3,37	42,51
Dacrydium ockelmanni	25	2,33	47,06	Ophelina cylindricaudata	17	3,18	45,69

The cluster analysis for Zapffe is shown in Figure 4.3-3. The similarity between the field stations is high (approx. 70 %). The fauna at the regional station differ somewhat from the field stations, but the differences cannot be related to the abiotic parameters included in the program. The BioEnv-analysis showed a maximum correlation coefficient of 0.41, which is a low value and indicates that the faunal variations cannot be explained by the variations in the other parameters such as sediment characteristics, THC and metals. However, the differences are not conspicuous and R95 is suitable to be used as a regional station in future monitoring.

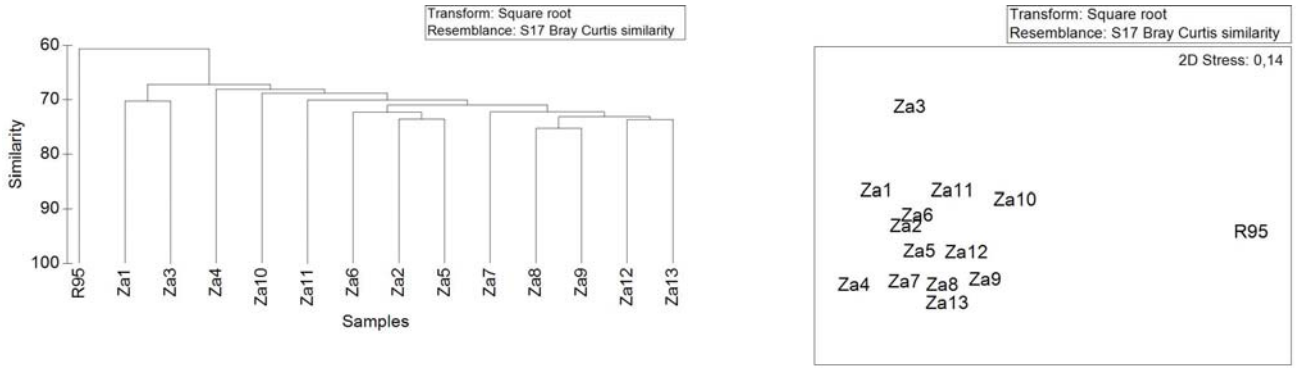

Figure 4.3-3 *Cluster- and MDS plot, Zapffe 2011.*

5 CONCLUSIONS

The sediments on Zapffe are very fine sand and silt and clay. Content of total organic matter varies between 1.44 to 3.14 %. Generally there are no elevated levels compared to $LSC_{2010RegIX/X}$ for organic or inorganic parameters at Zapffe, hence the area was unpolluted.

The diversity indices of the Zapffe 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 R95 differs slightly from the field stations, but are still considered to be a suitable regional station in future monitoring.

6 REFERENCES

ACS Committee on Environmental Improvements (1980). *Guidelines for Data Aquisition and Data Quality Evaluation in Environmental Chemistry*, Anal.chem. 52 (1980) p. 2242-2249.

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

Buchanan, J.B. (1984), *Sediment analysis.* In "Methods for the study of marine benthos". Editors: Holme, N.A., and A.D. McIntyre. Blackwell Scientific Publications, Oxford, UK, pp. 41-65.

DNV, 2011. Baseline Survey Zapffe 2011. Toktrapport. DNV-rapp. 2011-1222.

DNV 2011a. Visuell grunnlagsundersøkelse PL 518. DNV report: 2011-0431/ 132NAWT-8 Rev. 01, 2011-04-27

Klif 2011. Retningslinjer for miljøovervåking. TA 2848.

Kruskal, J.B. & M. Wish. 1978. *Multidimensional scaling.* Sage Publishers. California. 93s.

Lance, G. N. & W.T. Williams, 1967: *A general theory of classificatory sorting strategies. II*. Clustering systems. -Computer Jour. 10: 271-277.

Pielou, E.C., 1969: *An introduction to mathematical ecology.* Wiley-Interscience, New York.

Ptil, SFT, SHdir, 2005. Petroleumstilsynet, Statens forurensningstilsyn, Sosial- og helsedirektoratet, 2005. Activities Regulation Appendix 1 – *Requirements to Environmental Monitoring of the Petroleum Activities on the Norwegian Shelf.*. Technical appendix 2: Sediment monitoring. Vedlegg 1; Krav til miljøovervåking av petroleumsvirksomheten på norsk kontinentalsokkel - Teknisk Vedlegg 2; Sedimentovervåking

Shannon, C.E. & W.W. Weaver 1963: *The mathematical theory of communities.* University of Illinois Press. Urbana, Illinois. 117 s.

Det Norske Veritas:

DNV is a global provider of knowledge for managing risk. Today, safe and responsible business conduct is both a license to operate and a competitive advantage. Our core competence is to identify, assess, and advise on risk management, and so turn risks into rewards for our customers. From our leading position in certification, classification, verification, and training, we develop and apply standards and best practices. This helps our customers to safely and responsibly improve their business performance.

Our technology expertise, industry knowledge, and risk management approach, has been used to successfully manage numerous high-profile projects around the world.

DNV is an independent organisation with dedicated risk professionals in more than 100 countries. Our purpose is to safeguard life, property and the environment. DNV serves a range of industries, with a special focus on the maritime and energy sectors. Since 1864, DNV has balanced the needs of business and society based on our independence and integrity. Today, we have a global presence with a network of 300 offices in 100 countries, with headquarters in Oslo, Norway.

Global impact for a safe and sustainable future:

Learn more on www.dnv.com