DET NORSKE VERITAS™

REPORT

BASELINE SURVEY DARWIN 2011

REPSOL EXPLORATION NORGE AS

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MANAGING RISK

Baseline Survey Darwin 2011

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

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Preface

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

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

Personnel

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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 Darwin (former name is Veslemøy) are dominated by silt and clay at all stations except two and TOM is in the 3.21-8.33 % range. The THC concentrations are low and at the same level as the regional station R104. None of the chromatograms contains traces of hydrocarbons from oil. 17 of 22 stations have Ba concentration above the regional station.

The diversity indices were high at all stations, reflecting an undisturbed seafloor and a healthy benthic community. The variations between stations are related to variations in depth and sediment characteristics and possible by presence of spicules.

Darwin	Variation	Description of the field
THC (mg/kg)	<1-5	None of the stations at Darwin have THC concentration above LSC for region IX/X in 2010. All stations have THC concentration at the same level as the regional station R104.
Ba (mg/kg)	70-110	Most of the stations have Ba concentration above the regional station R104 and none of the Ba concentrations are above LSC-level for region IX/X in 2010.
H’	5.2-5.9	The diversity indices were high at all stations, reflecting a healthy benthic community. The variations between stations are related to variations in depth and sediment characteristics and possible by presence of spicules.
J	0.77-0.88	
ES_{100}	43-50	

1.2 Resymé (Norwegian)

Sedimentene er undersøkt for kornstørrelsesfordeling og innhold av organisk material. De ble også analysert for hydrokarboner (THC, PAH, NPD), metaller og bløtbunnsfauna.

Sedimentene på Darwin (tidligere Veslemøy) består hovedsakelig av silt og leire på alle stasjoner unntatt to, og TOM ligger mellom 3,21 og 8,33 %. THC-konsentrasjonene er lave og på samme nivå som den regionale stasjonen R104. Kromatogrammene viser naturlig bakgrunn. 17 av 22 stasjoner har høyere Ba-konsentrasjon enn den regionale stasjonen.

Diversitetsindeksene var høye på alle stasjonene og gjenspeiler et sunt bunndyrssamfunn. Variasjonen stasjonen I mellom er relater til variasjoner I dyp og sedimentkarakteristikk og muligens tilstedeværelsen av svampspikler.

Darwin	**Variasjon**	**Beskrivelse av feltet**
THC (mg/kg)	<1-5	Det er ikke funnet THC-verdier over $LSC_{2010RegionIX/X}$. Alle stasjonene ligger på samme nivå som den regionale stasjonen R104.
Ba (mg/kg)	70-110	De fleste stasjoner har høyere Ba-konsentrasjon enn den regionale stasjonen R104. Ingen av de Ba-konsentrasjonene ligger over $LSC_{2010RegionIX/X}$.
H’	5,2-5,9	
J	0,77-0,88	
ES_{100}	43-50	

2 INTRODUCTION

PL 531 - Darwin (named Veslemøy at the time when the program was prepared) is located between Nucula og Arenaria in the Barents Sea. The prevailing current direction in the Arenaria and Ververis area is towards east and the axis cross is in the same direction. The water depth at Darwin is about 320m.

Previous surveys in the area
Visual surveys by ROV were carried out at Arenaria and Ververis in 2008. The results from these surveys did not reveal corals in the investigated areas. In general it was low densities of sponges and high densities of trawl marks in the sediments. None of the observed mega fauna species is considered special vulnerable.

The baseline survey at Nucula in 2006 showed that the contents of THC, barium and other metals in the sediments were low. The biological analyses showed a high similarity in the species composition and high diversity indices. Significant correlations between the fauna and the abiotic factors were not revealed, and the fauna in the area was considered undisturbed.

The 2011 program included both conventional sediment sampling and visual mapping by ROV. The results from the visual mapping are reported in DNV, 2012. The program included the new station REGX-4 about 8000m west of Darwin, which is assigned to Darwin as a regional station.

Planned well locations are given in Table 1.2-1 and Figure 1.2-1, as Centre 1 and 2. They are located 520m from each other, and a program that covers both areas has been prepared. A minor change of well location has been planned (from E 411.840 N 8.001.155 to E 411.870 N 8.001.215), i.e. 30m east of station VE11.

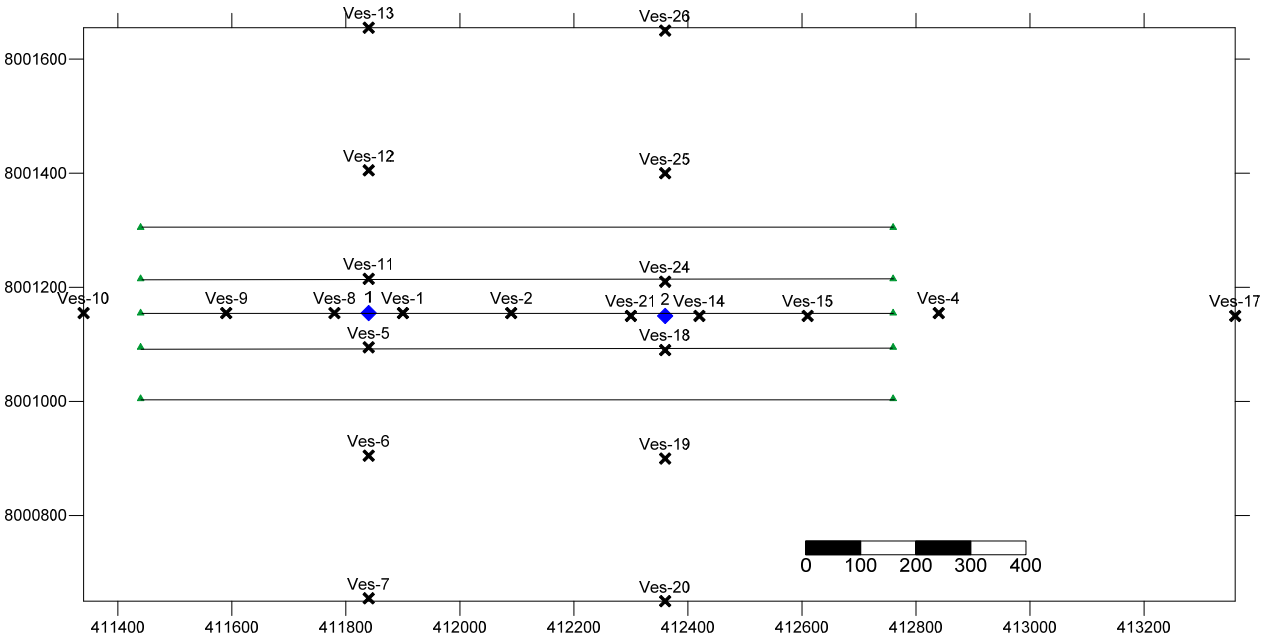

Figure 1.2-1 *Baseline stations for baseline survey and planned ROV-transects at Darwin (PL531) in 2011. The station names reflect the former name Veslemøy. The regional station is not included in the map.*

Table 1.2-1 *Positions of sampling stastions at Darwin (ED50 UTM sone 34). The station names reflect the former name Veslemøy.*

Station	°	m	East	North	THC*	Metals*	TOM**	Grain**	Bio	PAH/NPD
Centre 1			411840	8001155						
Ves-1	90	60	411900	8001155	3	3	1	1	5	3
Ves-2	90	250	412090	8001155	3	3	1	1	5	3
Ves-4	90	1000	412840	8001155	3	3	1	1	5	
Ves-5	180	60	411840	8001095	3	3	1	1	5	
Ves-6	180	250	411840	8000905	3	3	1	1	5	
Ves-7	180	500	411840	8000655	3	3	1	1	5	
Ves-8	270	60	411780	8001155	3	3	1	1	5	
Ves-9	270	250	411590	8001155	3	3	1	1	5	
Ves-10	270	500	411340	8001155	3	3	1	1	5	
Ves-11	360	60	411840	8001215	3	3	1	1	5	
Ves-12	360	250	411840	8001405	3	3	1	1	5	
Ves-13	360	500	411840	8001655	3	3	1	1	5	
Centre 2			412360	8001150						
Ves-14	90	60	412420	8001150	3	3	1	1	5	3
Ves-15	90	250	412610	8001150	3	3	1	1	5	3
Ves-17	90	1000	413360	8001150	3	3	1	1	5	
Ves-18	180	60	412360	8001090	3	3	1	1	5	
Ves-19	180	250	412360	8000900	3	3	1	1	5	
Ves-20	180	500	412360	8000650	3	3	1	1	5	
Ves-21	270	60	412300	8001150	3	3	1	1	5	
Ves-24	360	60	412360	8001210	3	3	1	1	5	
Ves-25	360	250	412360	8001400	3	3	1	1	5	
Ves-26	360	500	412360	8001650	3	3	1	1	5	
REGX-4	8000	-	403600	8000700	3	3	1	1	5	3
SUM					**69**	**69**	**23**	**23**	**115**	**15**

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

Figure 1.2-2 shows the location of Darwin (named Veslemøy) 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 Darwin field is presented.

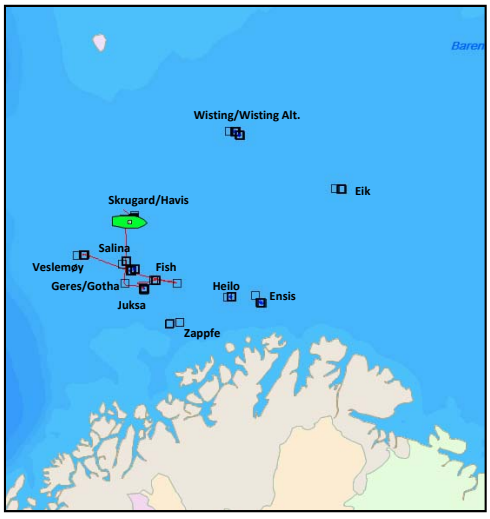

Figure 1.2-2 *Overview of baseline surveys conducted by DNV in the Barents Sea June/July 2011.*

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 3.1-1 shows the fields included in the survey, including regional stations.

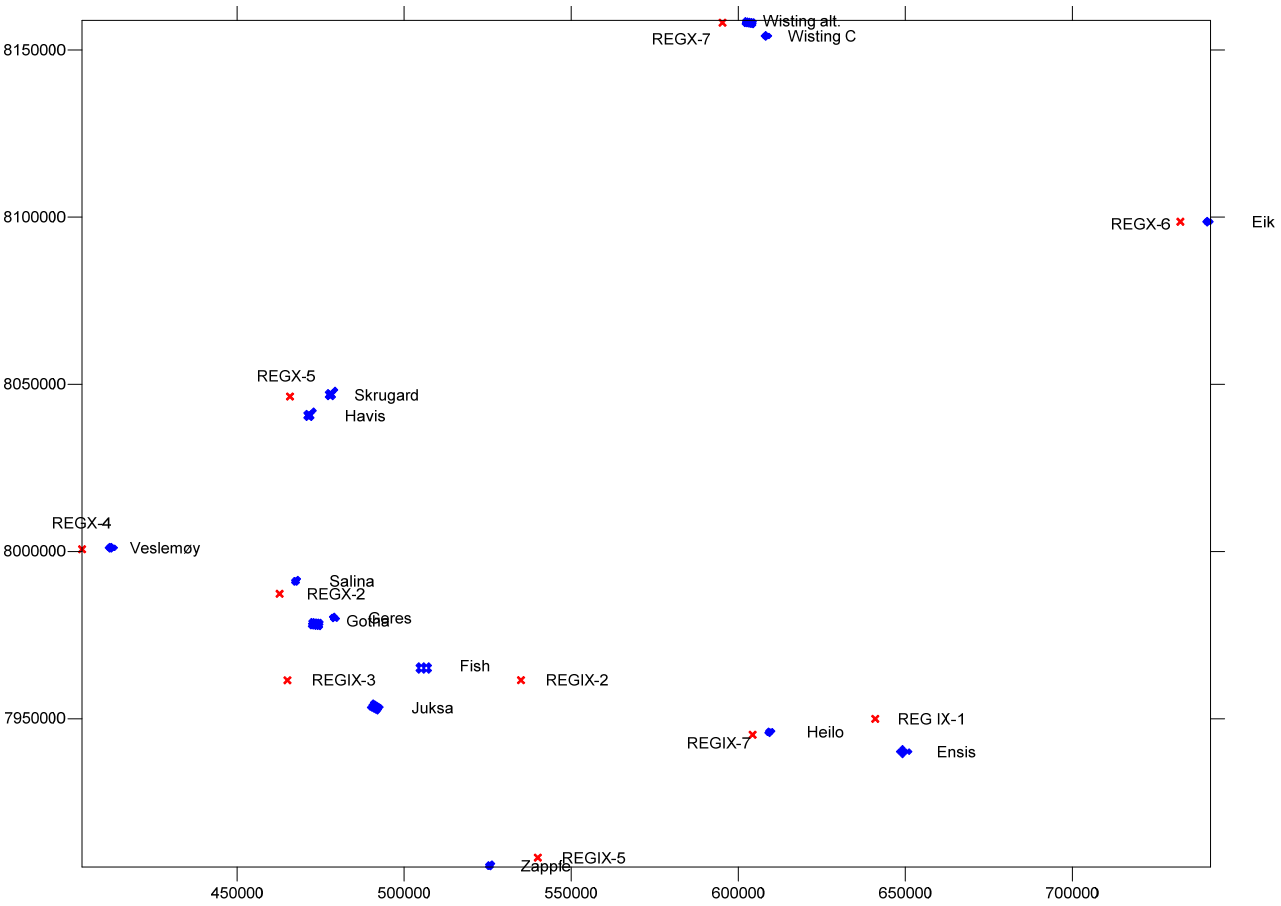

Figure 3.1-1 *Overview of baseline surveys including regional stations conducted by DNV in the Barents Sea June/July 2011.*

The survey was conducted 22. June - 12. July 2011. The Darwin/Veslemøy field was sampled 20-21. June. Sampling and analysis were carried out with reference to *Guidelines of offshore environment monitoring* (Klif 2849, 2011). Details from the sampling are enclosed in separate survey report, see appendix A.

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

The main equipment was:

- Long armed van Veen grab, offshore type (Delprodukter, B15)
- Exstra long armed van Veen grab, offshore type (Delprodukter, B1)
- Long armed van Veen grab, light offshore type (Delprodukter, B22)
- Short armed van Veen grab (B17)
- 2 x Combi-grab – modified van Veen (0. 15m^2 surface area, collects chemistry- and biology samples in one haul) (B23 and B25)
- The winch from Uni Research was mounted on the ship from a survey conducted previously, and this winch was mainly used during the survey.

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

3.1.2 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 form-aldehyde 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 3.3-1 and 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

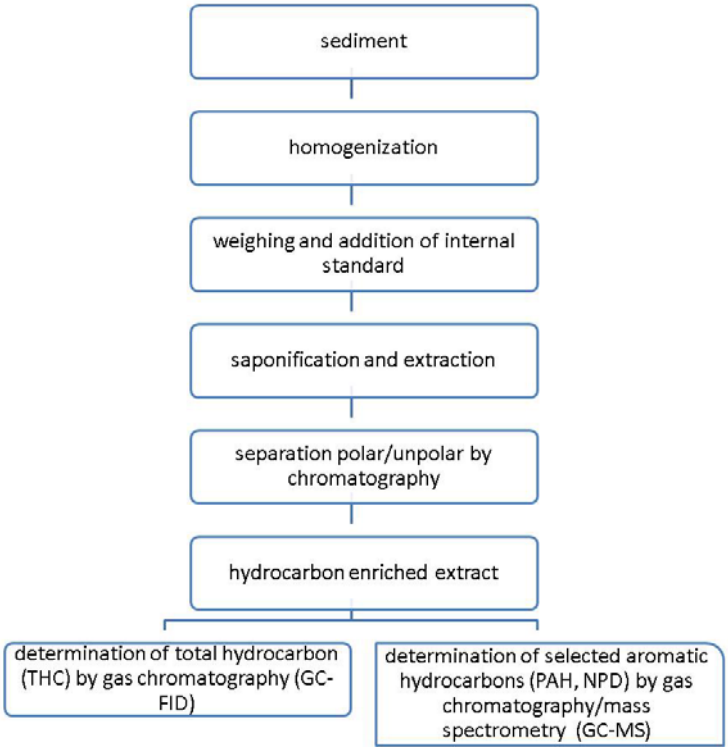

Figure 3.3-1 *Flow scheme of essential steps in the hydrocarbon analyses of sediments.*

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

4.1 Introduction

The depth at Darwin/Veslemøy was from 311 to 329m. The sea bottom consists of a mixture of soft and hard clay, with spicules, stones and pebbles. A total of 22 stations and one regional (REGX-4) were included in the survey.

The stations names are abbreviated after the program was prepared and the fieldwork was carried out, and VE is the name used in this chapter. REGX-4 is named R104.

4.2 Sediment characterization

Grain size distribution

The main results are given in Table 4.2-1 and Figure 4.2-1. Detailed results are given in appendix.

The sand content at Darwin is in the range 9.7-55.1 %. All samples, except VE6 and VE7 (very fine sand), are classified as silt and clay. The sediments at the regional station R104 is classified as silt and clay and contains 32.8 % sand.

Total organic matter (TOM)

The content of total organic matter is given in Table 4.2-1 and Figure 4.2-1.

The content of TOM is high, and range between 3.21 and 8.33 %. All stations, except VE6, VE7 and VE20, have TOM concentration higher than the regional station R104 (4.15 %).

Table 4.2-1 *Darwin 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)
VE1	90	60	325	7.23	Silt and clay	89.6	10.4	0.0	5.77
VE2	90	250	325	6.27	Silt and clay	75.1	24.4	0.5	5.34
VE4	90	1000	318	5.79	Silt and clay	84.1	15.1	0.7	5.62
VE5	180	60	324	8.33	Silt and clay	90.2	9.7	0.1	5.78
VE6	180	250	318	3.34	Very fine sand	43.1	55.1	1.8	3.37
VE7	180	500	313	3.21	Very fine sand	47.7	49.8	2.5	3.74
VE8	270	60	322	7.62	Silt and clay	90.2	9.7	0.1	5.78
VE9	270	250	322	6.47	Silt and clay	85.3	14.7	0.0	5.65
VE10	270	500	322	6.28	Silt and clay	75.8	23.0	1.2	5.36
VE11	360	60	324	7.68	Silt and clay	88.2	11.8	0.0	5.73
VE12	360	250	326	6.89	Silt and clay	80.7	19.3	0.0	5.52
VE13	360	500	327	7.39	Silt and clay	84.7	15.3	0.0	5.64
VE14	90	60	321	6.66	Silt and clay	74.6	20.7	4.7	5.32
VE15	90	250	319	5.83	Silt and clay	70.9	26.8	2.3	5.18
VE17	90	1000	316	4.19	Silt and clay	55.2	44.8	0.0	4.38
VE18	180	60	319	7.49	Silt and clay	89.1	10.9	0.0	5.75
VE19	180	250	320	8.14	Silt and clay	88.0	12.0	0.0	5.73
VE20	180	500	311	3.64	Silt and clay	71.2	26.3	2.5	5.19

Table 4.2-1 *cont.*

Station	Direction (°)	Offset (m)	Depth (m)	TOM (%)	Classification	Silt & clay %	Sand %	Gravel %	Median (Φ)
VE21	270	60	320	7.73	Silt and clay	89.6	10.4	0.0	5.77
VE24	360	60	321	7.70	Silt and clay	87.4	12.6	0.0	5.71
VE25	360	250	323	4.38	Silt and clay	63.4	34.7	1.8	4.85
VE26	360	500	329	6.78	Silt and clay	79.8	20.2	0.0	5.49
R104			321	4.15	Silt and clay	64.6	32.8	2.6	4.90
Min.*				3.21		43.1	9.7	0.0	3.37
Max.*				8.33		90.2	55.1	4.7	5.78

*: The regional station is not included

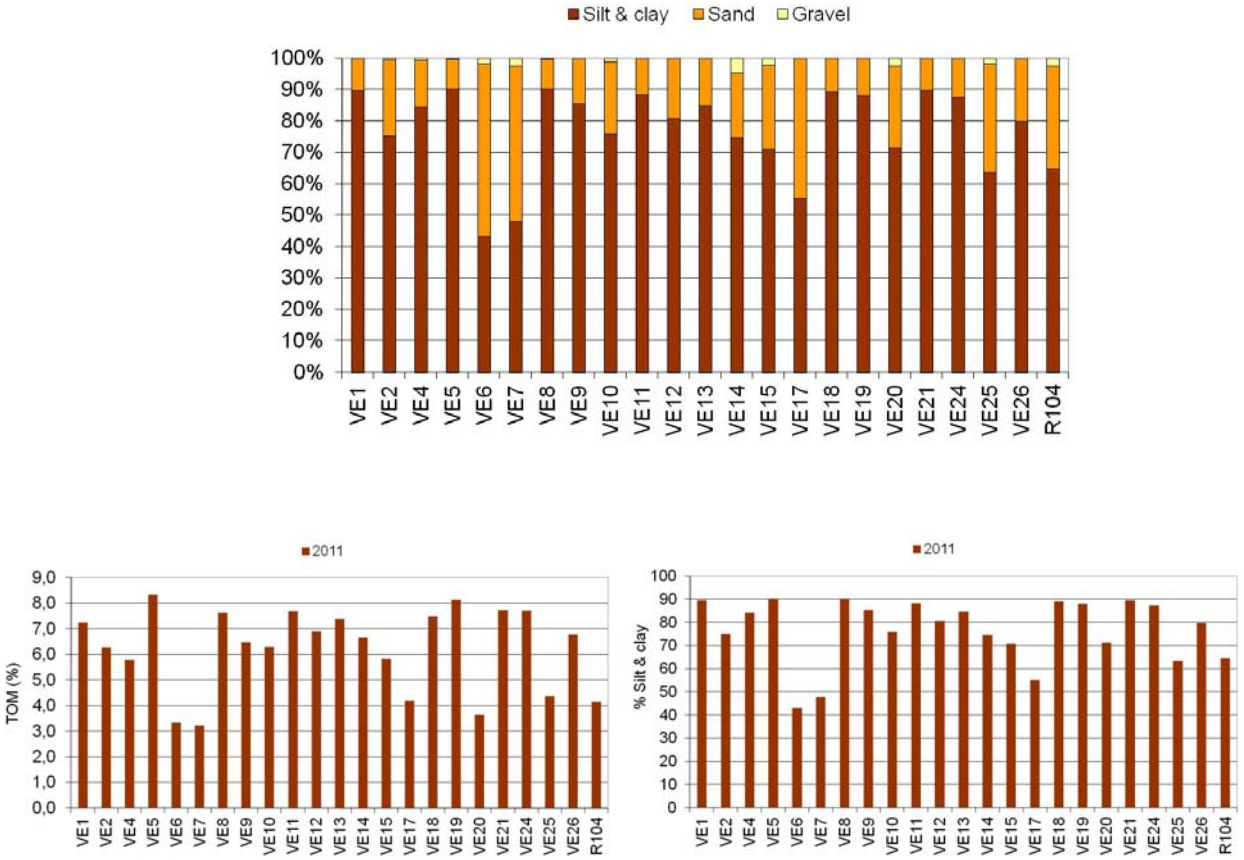

Figure 4.2-1 *Darwin 2011, sediment characterization, silt & clay, sand and gravel content on top.*

4.3 Chemical analysis

Hydrocarbons

Summarized results of hydrocarbon analyses are given in Table 4.3-1 and Figure 4.3-1. The distribution of THC is also shown in Figure 4.3-1. Detailed results are given in appendix.

Table 4.3-1 *Darwin 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
VE1	90	60	4	3	0.084	0.016	0.08	0.00
VE2	90	250	1	0	0.056	0.026	0.06	0.02
VE4	90	1000	1	0				
VE5	180	60	2	0				
VE6	180	250	2	1				
VE7	180	500	2	0				
VE8	270	60	2	1				
VE9	270	250	2	1				
VE10	270	500	2	1				
VE11	360	60	2	1				
VE12	360	250	2	1				
VE13	360	500	4	2				
VE14	90	60	1	1	0.048	0.018	0.06	0.01
VE15	90	250	<1	-	0.047	0.026	0.05	0.03
VE17	90	1000	2	1				
VE18	180	60	2	0				
VE19	180	250	3	0				
VE20	180	500	5	3				
VE21	270	60	2	1				
VE24	360	60	1	0				
VE25	360	250	4	1				
VE26	360	500	4	1				
R104			3	1	0.073	0.027	0.17	0.08
Min.*			<1		0.047		0.05	
Max.*			5		0.084		0.08	

*: The regional station is not included

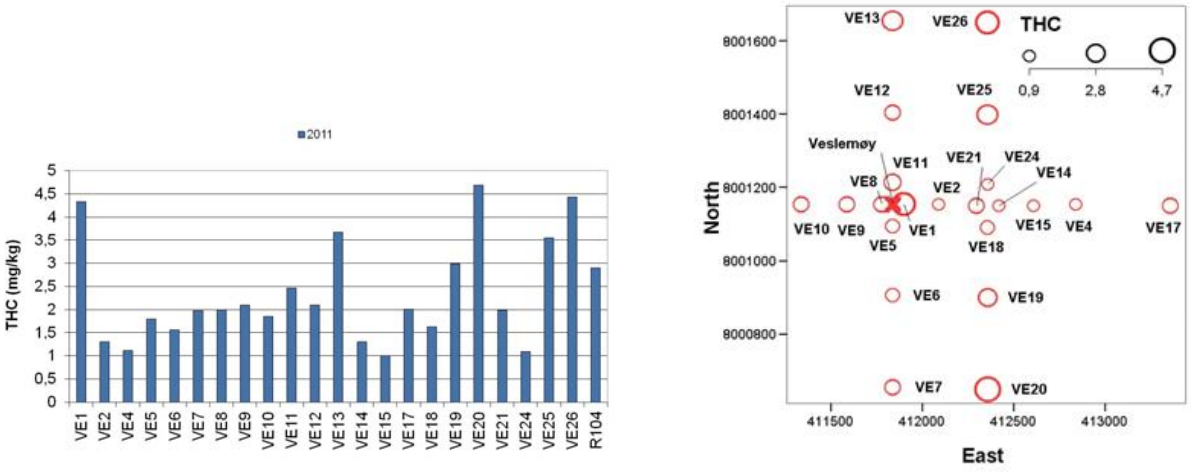

Figure 4.3-1 *Darwin 2011, average content of THC (left). The figure to the right shows the distribution of THC in sediments at the sampling sites, the size of the circle indicate the amount of THC. The field centre is marked with an X.*

THC concentration at Darwin varies between <1 and 5 mg/kg. All of the measured THC concentrations are below LSC-level ($LSC_{2010RegIX/X}$: 12.8 mg/kg) and 5 of 22 have THC concentration lower than the regional station R104. All chromatograms show natural background levels. PAH and NPD levels are also low and at the same level as the regional station and below $LSC_{2010RegIX/X}$ (0.255 mg/kg for PAH and 0.499 mg/kg for NPD).

Metals

Summarized results of metals analyses are given in Table 4.3-2 and Figure 4.3-2. The distribution of Ba is shown in Figure 4.3-3. Detailed results are given in appendix.

Table 4.3-2 *Darwin 2011. 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
VE1	90/60	99	1	0.14	0.03	25.4	0.3	12.8	0.4	0.04	0.00	20.4	1.6	511	13	53	0
VE2	90/250	97	5	0.07	0.02	24.1	2.2	10.9	2.1	0.03	0.01	14.9	5.7	494	35	48	7
VE4	90/1000	98	5	0.10	0.02	24.6	0.8	12.1	1.0	0.03	0.00	17.9	4.5	498	16	58	5
VE5	180/60	110	9	0.12	0.02	27.7	2.1	13.9	0.9	0.03	0.01	21.9	2.3	556	64	63	10
VE6	180/250	70	8	0.08	0.05	18.4	1.6	8.4	0.9	0.02	0.00	13.1	2.0	380	23	41	8
VE7	180/500	77	4	0.05	0.01	20.2	1.7	8.7	0.6	0.03	0.00	13.2	0.9	405	15	37	2
VE8	270/60	106	3	0.10	0.02	26.9	0.8	13.1	0.4	0.03	0.00	18.2	2.7	549	39	58	3
VE9	270/250	99	1	0.11	0.01	25.6	0.7	12.5	0.2	0.04	0.00	20.5	1.1	515	20	55	4
VE10	270/500	84	7	0.07	0.03	22.5	1.4	10.1	1.2	0.03	0.00	14.2	3.8	469	32	46	6
VE11	360/60	103	1	0.12	0.01	26.2	0.4	12.9	0.3	0.03	0.00	17.7	4.1	526	25	54	1
VE12	360/250	94	3	0.10	0.01	24.3	0.8	11.5	0.5	0.03	0.00	17.4	1.7	503	14	51	2
VE13	360/500	99	3	0.12	0.01	25.5	1.3	12.4	0.9	0.03	0.00	19.2	1.7	521	20	55	1
VE14	90/60	100	7	0.11	0.03	25.9	0.7	12.4	1.5	0.03	0.01	17.9	5.8	527	12	53	3
VE15	90/250	94	11	0.09	0.02	24.1	2.3	11.6	1.4	0.03	0.00	19.0	2.6	494	44	49	5
VE17	90/1000	70	2	0.06	0.00	17.9	0.8	7.8	0.5	0.02	0.00	12.4	1.0	391	16	35	1
VE18	180/60	103	5	0.11	0.02	26.1	0.5	12.7	0.6	0.04	0.00	20.8	2.2	533	20	54	1
VE19	180/250	102	4	0.12	0.02	25.7	0.3	12.8	0.5	0.04	0.00	20.7	1.3	520	8	56	4
VE20	180/500	70	7	0.05	0.02	23.2	6.2	10.5	2.9	0.02	0.00	9.5	1.6	444	64	46	16
VE21	270/60	102	2	0.12	0.01	25.7	0.5	12.7	0.2	0.04	0.00	20.6	0.8	527	18	56	4
VE24	360/60	99	2	0.14	0.02	25.8	0.4	12.9	0.2	0.04	0.00	21.0	1.2	519	8	53	1
VE25	360/250	78	5	0.08	0.03	21.8	1.9	10.0	1.0	0.02	0.00	14.0	2.3	422	23	41	3
VE26	360/500	91	10	0.10	0.04	24.3	2.0	11.5	1.3	0.02	0.00	17.0	3.0	477	32	49	5
R104		79	6	0.05	0.01	24.9	1.0	11.0	0.6	0.02	0.00	11.5	1.3	477	9	44	2
Min. *		70		0.05		17.9		7.8		0.02		9.5		380		35	
Max. *		110		0.14		27.7		13.9		0.04		21.9		556		63	

*: The reference station is not included

The content of Ba is in the range 70 to 110 mg/kg, and the highest Ba concentration (110 ± 9 mg/kg) is measured at VE5. 17 of 22 stations are above the regional station R104 (79 ± 6 mg/kg). The content of Cd is in the range 0.05 to 0.14 mg/kg, and 20 of the stations are above the regional station R104 (0.05 ± 0.01 mg/kg). The content of Pb is in the range 9.5 to 21.9 mg/kg, and 21 of the stations are above the regional station R104 (11.5 ± 1.3 mg/kg. Overall the concentrations of the rest of the metals are higher than the regional R104. None of the Ba concentrations are above LSC-level ($LSC_{2010RegIX/X}$: 134 mg/kg). All the concentrations of metals are below $LSC_{2010RegIX/X}$.

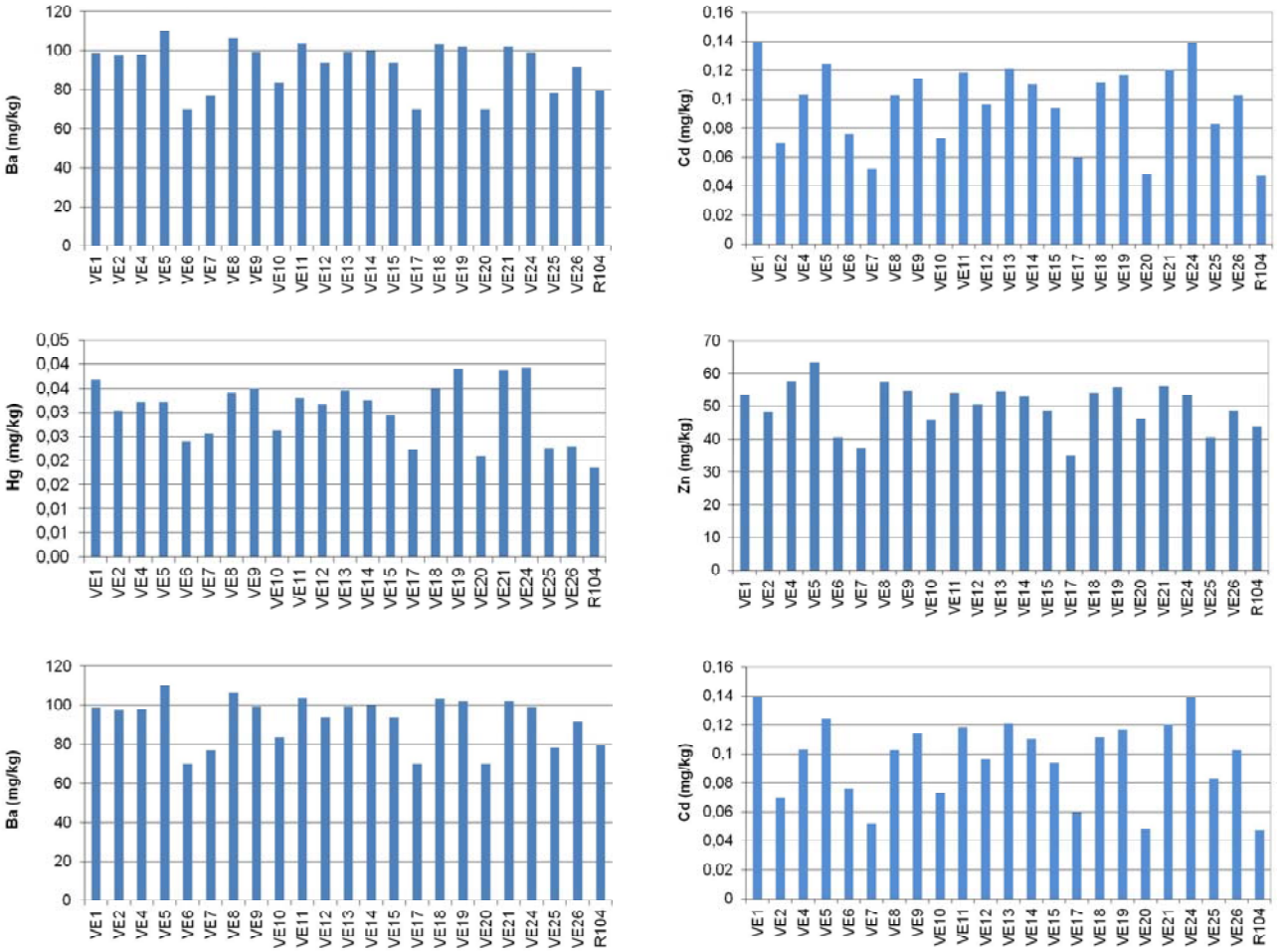

Figure 4.3-2 *Darwin 2011, the average content of metals in top sediment (0-1 cm) from three parallel samples.*

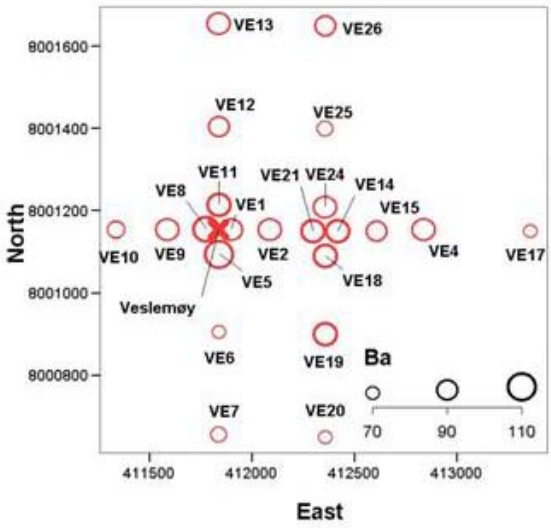

Figure 4.3-3 *Darwin 2011, distribution of Ba in sediments at the sampling sites, the size of the circle indicate the amount of Ba. The field centre is marked with an X.*

4.4 Biological analyses

Diversity and dominant species

Table 4.4-1 shows the number of individuals and species at Darwin by animal groups (juveniles excluded). There were 937 juvenile individuals recorded at Darwin, 832 of these were *Ophiuroidea* spp. juveniles. *Ophiuroidea* spp. juveniles were among the top ten most dominant species at 20 of the 23 stations, sometimes being the most dominant. *Macandrevia cranium* juveniles were also found among the top ten most dominant taxa at two stations. The data was analysed both with and without juveniles, and is presented here with juveniles excluded.

Table 4.4-1 *Number of individuals (N) and species (S) distributed between the main animal groups, Darwin 2011.*

Animal group	N	%	S	%
Varia	1881	12.0	13	4.5
Polychaeta	8192	52.5	126	43.2
Crustacea	1870	12.0	93	31.8
Mollusca	2913	18.7	47	16.1
Echinodermata	758	4.9	13	4.5
Total	15614	100.0	292	100.0

Figure 4.4-1 shows the number of individuals and species at the individual stations on the field and the average per grab per station. Table 4.4-2 and Figure 4.4-2 shows the various diversity indices for each of the stations. Both station VE7 and R104 have relatively low numbers of individuals and low numbers of species relative to the other stations. At station R104, four rather than five grabs are included in the analysis, due to loss of one grab sample. Even taking into this into consideration, N and S are still low at this station.

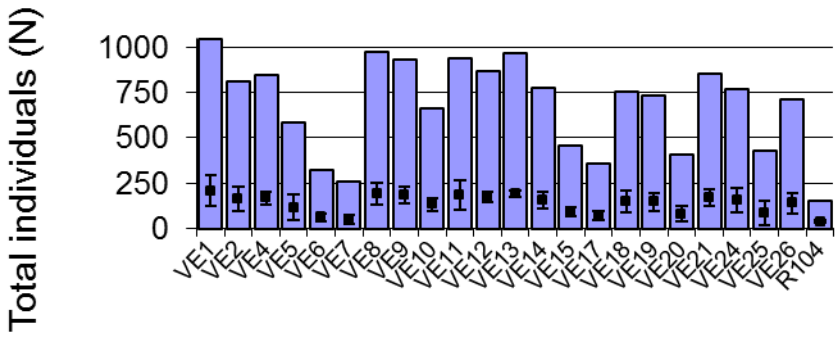

Figure 4.4-1 *Number of individuals (N) and species (S) per 0.5m^2, average and standard deviation between grab samples (0.1m^2), Darwin 2011.*

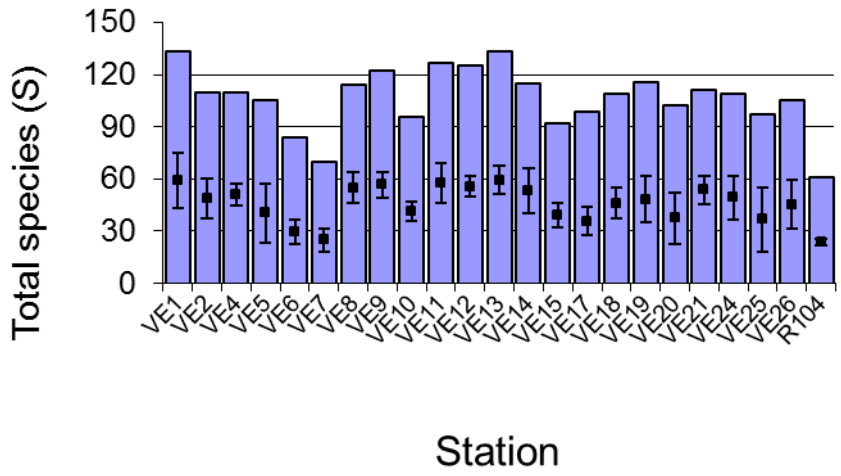

Figure 4.4-1 *cont.*

Table 4.4-2 and Figure 4.4-2 shows the various diversity indices for each of the stations.

Table 4.4-2 *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, Darwin 2011.*

Station	Direction (°)	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
VE1	90	60	325	133	1046	5.59	0.79	43
VE2	90	250	325	110	813	5.51	0.81	43
VE4	90	1000	318	110	846	5.56	0.82	43
VE5	180	60	324	105	587	5.60	0.83	44
VE6	180	250	318	84	320	5.38	0.84	46
VE7	180	500	313	70	259	5.17	0.84	44
VE8	270	60	322	114	975	5.60	0.82	44
VE9	270	250	322	122	929	5.52	0.80	43
VE10	270	500	322	96	664	5.45	0.83	43
VE11	360	60	324	127	935	5.69	0.81	45
VE12	360	250	326	125	867	5.67	0.81	45
VE13	360	500	327	133	964	5.89	0.83	47
VE14	90	60	321	115	779	5.63	0.82	45
VE15	90	250	319	92	455	5.39	0.83	43
VE17	90	1000	316	99	357	5.81	0.88	50
VE18	180	60	319	109	755	5.24	0.77	40
VE19	180	250	320	116	736	5.73	0.84	46
VE20	180	500	311	102	406	5.66	0.85	47
VE21	270	60	320	111	856	5.53	0.81	43
VE24	360	60	321	109	771	5.59	0.83	44
VE25	360	250	323	97	430	5.51	0.84	46
VE26	360	500	329	105	709	5.33	0.79	41
R104			321	61	155	5.25	0.88	47

Both station VE7 and R104 have relatively low numbers of individuals and low numbers of species relative to the other stations. At station R104, four rather than five grabs are included in the analysis, due to loss of one grab sample. Even taking into this into consideration, N and S are still low at this station.

The diversity indices were high at all stations, with Shannon's diversity H' ranging from 5.2 (VE7) to 5.9 (VE13). ES_{100} was also high at all stations reflecting an undisturbed seafloor and a healthy benthic community. Excluding juveniles from the analysis increased these indices even more at stations where O*phiuroidea* spp. juveniles were dominant.

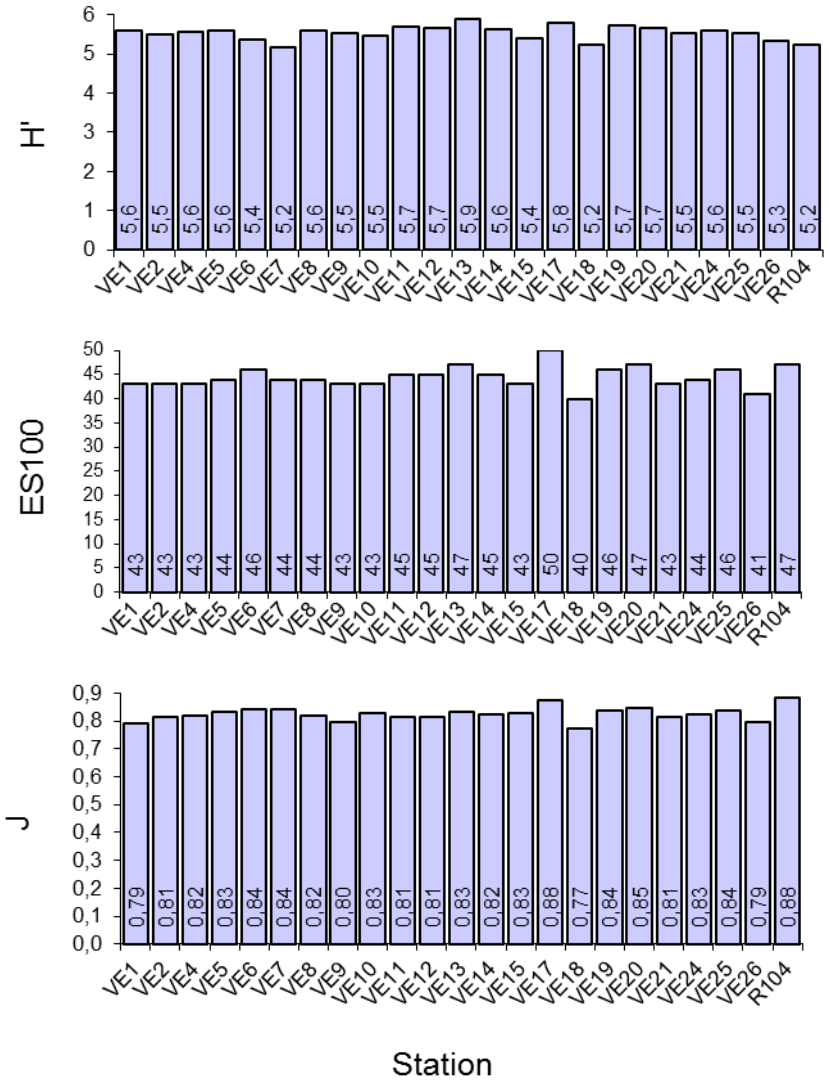

Figure 4.4-2 *Diversity, evenness and ES_{100} Darwin 2011.*

The ten most common species at each station are shown below in Table 4.4-3. The top ten most dominant species contribute between 45 % (VE17) and 62 % (VE18) of the total number of individuals at each station. The species which is most dominant varies between stations. The sabellid polychaete *Jasmineira* spp. was among the ten most dominant at all stations. Other dominant polychaetes were

Lumbrineris aniara complex which was dominant at 10 of the stations, *Trichobranchus glacialis* (at 16 stations), and *Paramphinome jeffreysii* (at 18 stations). The sensitive bivalve mollusc *Bathyarca pectunculoides* was dominant at all but one station; while sipunculids of the family *Golfingiidae* were dominant at all but 4 stations. The brachiopod *Macandrevia cranium* was among the top ten at 5 stations; at two of these (VE6 and VE7) it was the most dominant, contributing 15 % to 17 % of the total number of individuals.

Table 4.4-3 *The ten most dominant species at each station, Darwin 2011.*

10 most dominant species							
VE1	**No**	**%**	**Cum%**	**VE2**	**No**	**%**	**Cum%**
Lumbriclymene spp.	126	12,05	12.05	Paramphinome jeffreysii	85	10.46	10.46
Jasmineira spp.	88	8,41	20.46	Golfingiidae spp.	74	9.1	19.56
Trichobranchus glacialis	62	5,93	26.39	Trichobranchus glacialis	52	6.4	25.95
Bathyarca pectunculoides	55	5,26	31.64	Thyasira obsoleta	39	4.8	30.75
Golfingiidae spp.	46	4,4	36.04	Jasmineira spp.	38	4.67	35.42
Paramphinome jeffreysii	43	4,11	40.15	Nemertea spp.	31	3.81	39.24
Autonoe megacheir	39	3,73	43.88	Bathyarca pectunculoides	29	3.57	42.8
Dacrydium ockelmanni	34	3,25	47.13	Caulleriella spp.	27	3.32	46.13
Limopsis cristata	32	3,06	50.19	Lumbrineris aniara complex	25	3.08	49.2
Nemertea spp.	27	2,58	52.77	Levinsenia gracilis	22	2.71	51.91
VE4	**No**	**%**	**Cum%**	**VE5**	**No**	**%**	**Cum%**
Golfingiidae spp.	85	10,05	10.05	Jasmineira spp.	52	8.86	8.86
Paramphinome jeffreysii	61	7,21	17.26	Lumbriclymene spp.	41	6.98	15.84
Bathyarca pectunculoides	58	6,86	24.11	Trichobranchus glacialis	35	5.96	21.81
Trichobranchus glacialis	43	5,08	29.2	Golfingiidae spp.	34	5.79	27.6
Lumbriclymene spp.	42	4,96	34.16	Bathyarca pectunculoides	29	4.94	32.54
Amphipholis squamata	32	3,78	37.94	Paramphinome jeffreysii	27	4.6	37.14
Jasmineira spp.	32	3,78	41.73	Limopsis cristata	22	3.75	40.89
Autonoe megacheir	24	2,84	44.56	Nemertea spp.	22	3.75	44.63
Limopsis cristata	23	2,72	47.28	Notomastus latericeus	21	3.58	48.21
Lumbrineris scopa complex	22	2,6	49.88	Lumbrineris scopa complex	16	2.73	50.94
VE6	**No**	**%**	**Cum%**	**VE7**	**No**	**%**	**Cum%**
Macandrevia cranium	49	15,31	15.31	Macandrevia cranium	45	17.37	17.37
Paramphinome jeffreysii	35	10,94	26.25	Bathyarca pectunculoides	20	7.72	25.1
Lysilla loveni	14	4,38	30.63	Jasmineira spp.	18	6.95	32.05
Lumbrineris scopa complex	12	3,75	34.38	Paramphinome jeffreysii	16	6.18	38.22
Jasmineira spp.	11	3,44	37.81	Lumbrineris scopa complex	11	4.25	42.47
Terebellidae spp.	10	3,13	40.94	Galathowenia fragilis	11	4.25	46.72
Vargula norvegica	8	2,5	43.44	Harmothoe spp.	9	3.47	50.19
Aglaophamus malmgreni	8	2,5	45.94	Terebellidae spp.	5	1.93	52.12
Pista bansei	7	2,19	48.13	Autonoe megacheir	5	1.93	54.05
Ophelina abranchiata	7	2,19	50.31	Tunicata spp.	5	1.93	55.98

Table 4.4-3 *cont.*

VE8	No	%	Cum%	VE9	No	%	Cum%
Bathyarca pectunculoides	86	8,82	8.82	Jasmineira spp.	103	11.09	11.09
Jasmineira spp.	82	8,41	17.23	Trichobranchus glacialis	88	9.47	20.56
Trichobranchus glacialis	68	6,97	24.21	Bathyarca pectunculoides	54	5.81	26.37
Limopsis cristata	47	4,82	29.03	Golfingiidae spp.	50	5.38	31.75
Golfingiidae spp.	45	4,62	33.64	Vargula norvegica	41	4.41	36.17
Autonoe megacheir	43	4,41	38.05	Nemertea spp.	40	4.31	40.47
Galathowenia fragilis	35	3,59	41.64	Lumbriclymene spp.	40	4.31	44.78
Dacrydium ockelmanni	30	3,08	44.72	Autonoe megacheir	30	3.23	48.01
Paramphinome jeffreysii	27	2,77	47.49	Lumbrineris aniara complex	28	3.01	51.02
Lumbrineris scopa complex	26	2,67	50.15	Amphipholis squamata	27	2.91	53.93
VE10	**No**	**%**	**Cum%**	**VE11**	**No**	**%**	**Cum%**
Golfingiidae spp.	84	12,65	12.65	Lumbriclymene spp.	82	8.77	8.77
Lumbrineris scopa complex	46	6,93	19.58	Jasmineira spp.	68	7.27	16.04
Jasmineira spp.	46	6,93	26.51	Golfingiidae spp.	61	6.52	22.57
Paramphinome jeffreysii	39	5,87	32.38	Autonoe megacheir	50	5.35	27.91
Bathyarca pectunculoides	34	5,12	37.5	Paramphinome jeffreysii	49	5.24	33.16
Trichobranchus glacialis	19	2,86	40.36	Bathyarca pectunculoides	47	5.03	38.18
Autonoe megacheir	18	2,71	43.07	Trichobranchus glacialis	38	4.06	42.25
Galathowenia fragilis	17	2,56	45.63	Limopsis cristata	28	2.99	45.24
Nemertea spp.	15	2,26	47.89	Dacrydium ockelmanni	27	2.89	48.13
Limopsis cristata	15	2,26	50.15	Caudofoveata spp.	23	2.46	50.59
VE12	**No**	**%**	**Cum%**	**VE13**	**No**	**%**	**Cum%**
Bathyarca pectunculoides	97	11,19	11.19	Golfingiidae spp.	64	6.64	6.64
Trichobranchus glacialis	61	7,04	18.22	Bathyarca pectunculoides	54	5.6	12.24
Jasmineira spp.	52	6	24.22	Paramphinome jeffreysii	53	5.5	17.74
Golfingiidae spp.	36	4,15	28.37	Heteromastus filiformis	46	4.77	22.51
Chaetozone setosa complex	36	4,15	32.53	Jasmineira spp.	42	4.36	26.87
Paramphinome jeffreysii	34	3,92	36.45	Lumbriclymene spp.	39	4.05	30.91
Dacrydium ockelmanni	34	3,92	40.37	Autonoe megacheir	38	3.94	34.85
Lumbrineris aniara complex	30	3,46	43.83	Nemertea spp.	34	3.53	38.38
Autonoe megacheir	29	3,34	47.17	Amphipholis squamata	32	3.32	41.7
Lumbrineris scopa complex	23	2,65	49.83	Dacrydium ockelmanni	32	3.32	45.02
VE14	**No**	**%**	**Cum%**	**VE15**	**No**	**%**	**Cum%**
Golfingiidae spp.	80	10,27	10.27	Golfingiidae spp.	58	12.75	12.75
Jasmineira spp.	68	8,73	19	Jasmineira spp.	37	8.13	20.88
Bathyarca pectunculoides	62	7,96	26.96	Bathyarca pectunculoides	35	7.69	28.57
Dacrydium ockelmanni	38	4,88	31.84	Macandrevia cranium	22	4.84	33.41
Amphipholis squamata	29	3,72	35.56	Trichobranchus sp.	19	4.18	37.58
Trichobranchus sp.	26	3,34	38.9	Autonoe megacheir	18	3.96	41.54
Ophiocten affinis	26	3,34	42.23	Paramphinome jeffreysii	16	3.52	45.05
Autonoe megacheir	25	3,21	45.44	Lumbrineris aniara complex	16	3.52	48.57

Table 4.4-3 *cont*.

Nemertea spp.	23	2,95	48.4	Vargula norvegica	15	3.3	51.87
Lumbrineris aniara complex	17	2,18	50.58	Spiophanes kroyeri	10	2.2	54.07
VE17	**No**	**%**	**Cum%**	**VE18**	**No**	**%**	**Cum%**
Trichobranchus glacialis	27	7,56	7.56	Golfingiidae spp.	115	15.23	15.23
Bathyarca pectunculoides	18	5,04	12.61	Jasmineira spp.	68	9.01	24.24
Nemertea spp.	18	5,04	17.65	Autonoe megacheir	50	6.62	30.86
Macandrevia cranium	18	5,04	22.69	Paramphinome jeffreysii	49	6.49	37.35
Jasmineira spp.	17	4,76	27.45	Lumbriclymene spp.	48	6.36	43.71
Golfingiidae spp.	15	4,2	31.65	Bathyarca pectunculoides	39	5.17	48.87
Lumbrineris aniara complex	13	3,64	35.29	Limopsis cristata	30	3.97	52.85
Tmetonyx cicada	11	3,08	38.38	Lumbrineris aniara complex	24	3.18	56.03
Lumbrineris scopa complex	11	3,08	41.46	Amphipholis squamata	24	3.18	59.21
Spiophanes kroyeri	11	3,08	44.54	Dacrydium ockelmanni	18	2.38	61.59
VE19	**No**	**%**	**Cum%**	**VE20**	**No**	**%**	**Cum%**
Lumbriclymene spp.	62	8,42	8.42	Bathyarca pectunculoides	39	9.61	9.61
Jasmineira spp.	49	6,66	15.08	Lumbrineris aniara complex	35	8.62	18.23
Golfingiidae spp.	45	6,11	21.2	Haploops setosa	24	5.91	24.14
Bathyarca pectunculoides	42	5,71	26.9	Pista bansei	18	4.43	28.57
Limopsis cristata	39	5,3	32.2	Paramphinome jeffreysii	18	4.43	33
Paramphinome jeffreysii	30	4,08	36.28	Macandrevia cranium	18	4.43	37.44
Autonoe megacheir	28	3,8	40.08	Jasmineira spp.	16	3.94	41.38
Lumbrineris scopa complex	26	3,53	43.61	Vargula norvegica	16	3.94	45.32
Amphipholis squamata	25	3,4	47.01	Galathowenia fragilis	9	2.22	47.54
Ophiocten affinis	19	2,58	49.59	Spiophanes kroyeri	8	1.97	49.51
VE21	**No**	**%**	**Cum%**	**VE24**	**No**	**%**	**Cum%**
Jasmineira spp.	86	10,05	10.05	Golfingiidae spp.	57	7.39	7.39
Trichobranchus glacialis	71	8,29	18.34	Bathyarca pectunculoides	54	7	14.4
Golfingiidae spp.	60	7,01	25.35	Jasmineira spp.	51	6.61	21.01
Lumbriclymene spp.	58	6,78	32.13	Autonoe megacheir	48	6.23	27.24
Bathyarca pectunculoides	50	5,84	37.97	Dacrydium ockelmanni	46	5.97	33.2
Limopsis cristata	27	3,15	41.12	Lumbriclymene spp.	41	5.32	38.52
Autonoe megacheir	26	3,04	44.16	Limopsis cristata	29	3.76	42.28
Paramphinome jeffreysii	24	2,8	46.96	Paramphinome jeffreysii	29	3.76	46.04
Tmetonyx cicada	23	2,69	49.65	Trichobranchus glacialis	28	3.63	49.68
Lumbrineris scopa complex	23	2,69	52.34	Amphipholis squamata	20	2.59	52.27
VE25	**No**	**%**	**Cum%**	**VE26**	**No**	**%**	**Cum%**
Bathyarca pectunculoides	57	13,26	13.26	Bathyarca pectunculoides	124	17.49	17.49
Jasmineira spp.	43	10	23.26	Golfingiidae spp.	51	7.19	24.68
Golfingiidae spp.	23	5,35	28.6	Jasmineira spp.	44	6.21	30.89
Nemertea spp.	17	3,95	32.56	Nemertea spp.	35	4.94	35.83
Chaetozone setosa complex	15	3,49	36.05	Lumbrineris aniara complex	24	3.39	39.21
Vargula norvegica	14	3,26	39.3	Trichobranchus glacialis	24	3.39	42.6

Table 4.4-3 *cont*.

Lumbrineris scopa complex	13	3,02	42.33	Limopsis cristata	23	3.24	45.84
Lumbrineris aniara complex	12	2,79	45.12	Chaetozone setosa complex	23	3.24	49.08
Trichobranchus glacialis	12	2,79	47.91	Dacrydium ockelmanni	21	2.96	52.05
Terebellidae spp.	10	2,33	50.23	Lumbrineris scopa complex	17	2.4	54.44
R104							
Bathyarca pectunculoides	24	15,48	15.48				
Pista bansei	9	5,81	21.29				
Jasmineira spp.	8	5,16	26.45				
Lumbrineris aniara complex	8	5,16	31.61				
Harmothoe spp.	7	4,52	36.13				
Terebellidae spp.	6	3,87	40				
Caulleriella spp.	6	3,87	43.87				
Paramphinome jeffreysii	5	3,23	47.1				
Paraonidae spp.	4	2,58	49.68				
Terebellides stroemii	4	2,58	52.26				

The cluster analysis for Darwin is shown in Figure 4.4-3. Stations VE6, -7, -20 and R104 differ from the other stations

The BioEnv-analysis showed a maximum correlation coefficient of 0.80, which is a relative high value and indicates that the faunal variations covariate with the depth and the levels of TOM, pelite and some of the metals. The levels of metals are normally a secondary effect linked to the variations in the sediment characteristics; fine grained sediments containing higher concentrations of metals than coarse sediments. The four stations are among the shallowest stations, have lower content of organic material than the other stations and consist of coarser sediments. VE6 and -7 are the only stations classified as very fine sand while the rest are silt and clay. The other group separating from the main group - VE 15, -17 and -25 - consists of stations with sediment characteristics more similar, but still somewhat different, from the main group. The single parameter which explains the faunal variations best (correlation coefficient (0.76) is median particle diameter (MDΦ).

It should also be mentioned that Darwin is an area rich on sponges (DNV, 2012) which means that the sediments contain large amounts of spicules. This is not a parameter included in the abiotic factors in the BioEnv-analysis. Experiences from previous surveys in the Barents Sea (DNV, 2009) show, however, that the benthic fauna in sediments containing spicules have their own characteristics compared to sediment without spicules.

The regional station R104 is included in one of the groups and is suitable as a regional station in future monitoring.

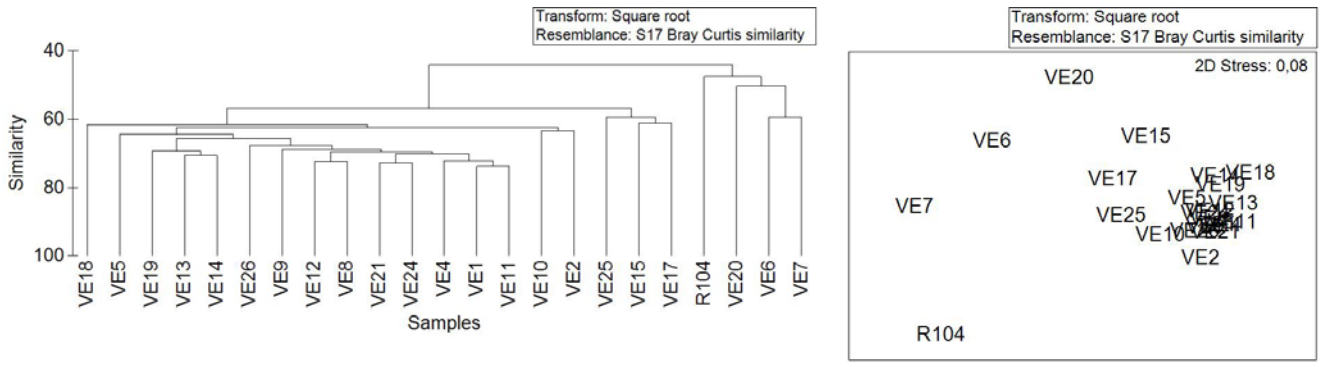

Figure 4.4-3 *Cluster- and MDS plot, Darwin 2011.*

5 CONCLUSIONS

The sediments on Darwin are classified as silt and clay and very fine sand. Content of total organic matter varies between 3.21 to 8.33 %. Generally there are no elevated levels compared to $LSC_{2010RegIX/X}$ for organic and inorganic parameters at Darwin.

The diversity indices were high at all stations, reflecting an undisturbed seafloor and a healthy benthic community. The variations between stations are related to variations in depth and sediment characteristics and possible by presence of spicules.

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