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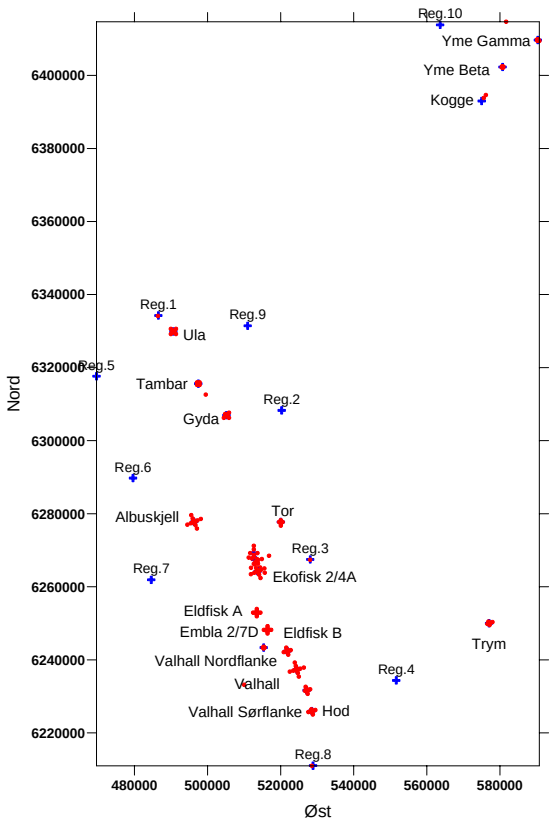

MANAGING RISK

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Appendix A – A complete overview of the sampling.

Preface

The environmental baseline survey at Vilje 2005 is carried out jointly by Det Norske Veritas and Molab AS, on behalf of the operators in the region; BP, ConocoPhillips, Statoil, Shell, Talisman and Exxon. The work has been coordinated through BP and ConocoPhillips.

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THC analysis:	Mariam Bouzga, Gaute Botten, Frøydis Oreld, Tove Kristin Dokka Torstensen
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The chemical analyses are performed at Molab AS, section Oslo. The grain size distribution is analysed at Molab AS, section Glomfjord.

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Sorting has taken place at DNV's Biology Laboratory. Karen Marie Brinchmann and Mikkel Petersen have been in charge of the sorting.

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Verification:	Tor Jensen
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Molab AS is accredited by Norwegian Accreditation to perform chemical analyses, accreditation number Test 032. The accreditation is according to NS-EN ISO/IEC 17025.
The accreditation includes methods for determination of total hydrocarbon content (THC), polycyclic aromatic hydrocarbons (PAH), selected hydrocarbons (NPD), metals and total organic matter (TOM).

DNV's Biology laboratory (DNV Consulting) is accredited by Norsk Akkreditering for sampling of marine sediments for chemical and biological analyses, and to perform out biological analyses, accreditation number TEST 083. Accreditation is according to NS-EN ISO/IEC 17025.

1.0 Conclusive summary

This report presents the results from the environmental survey in the EKOFISK region (Region I) in 2005. Det Norske Veritas and Molab As carried out the survey jointly, on the behalf of ConocoPhillips, BP and Statoil.

The report presents results from the regional stations and from the following installations: Valhall, Valhall Flanke Nord og Sør, Hod, Ula, Gyda, Tambar, Ekofisk Centre and 2/4 B&K, Ekofisk 2/4 A, Eldfisk 2/7 A/FTP, Eldfisk 2/7 B, Embla, Tor, Yme Gamma, Yme Beta, Kogge and Trym.

The results from the 2005 survey in Region I show:

- Generally, the results from the 2005 survey at Region I show that the level of THC, Ba and metals has decreased compared to the 2002 survey.
- The sediments at Region I consist mainly of fine sand.
- The total organic matter content in the sediments is low and ranges from 0.4 % to 1.5 %.
- The chemical results are in agreement with the drilling history.
- The regional stations and the reference stations are still unaffected by the drilling chemicals - no contamination or elevated concentrations are found in these sediments.
- The Kogge and Trym areas are not polluted by THC, Ba or metals from oil activity.
- Relatively high THC levels are still found at most of the fields. However, the concentrations are, with a few exceptions, distinctly lower compared to 2002 survey.
- Base liquids from pseudo-oil based drilling mud (olefins) are observed at most stations at the fields drilled with these systems.
- Base liquids from ester based drilling mud are found in low concentrations at Ekofisk 2/4 A (Finagreen) and Yme Gamma (Petrofree).
- At Tor, ethers from ether based drilling mud (Aquamul B and Aquamul BII) were found for all the stations analysed. These ethers are in addition observed at Ula and Ekofisk Centre and 2/4 B&K. Thus, the ether compounds are not breaking down as fast as previously anticipated.
- Three stations in Region I are analysed for PFOS (PerFluoroOctyl Sulphonate). The highest content is found at Yme Gamma Central in 120° direction and 100m distance. At Valhall the PFOS concentration was considerably lower, and at the station analysed at Ekofisk Centre and 2/4 B&K no PFOS was detected.
- Dispersion of drill cuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found at most of the stations. Generally the Ba concentrations are similar or slightly lower compared to the 2002 survey. For some stations at Valhall Flanke Nord and Sør and at Ula the content of Ba has increased, in agreement with their discharge history.
- The concentrations of the heavy metals are low, and elevated levels are only found at some stations.
- Two core samples from the drill cuttings pile at Ekofisk 2/4 A are analysed. Elevated concentrations of all the chemical parameters analysed, except esters and PCB, are found to 130 cm depth. The levels of THC in the core samples are generally higher in 2005 than in 2002.

- Samples from the Installation Centre at Yme Gamma and at Yme Beta are analysed. High concentrations of THC and Ba are found, but the content is distinctly lower compared to the 2002 survey.
- The fauna community in the central part of the Ekofisk region is disturbed to varying extents. This is a consequence of physical disturbances, the activities in the area and a diffuse organic load from various sources affecting the North Sea.
- The Ekofisk region is exposed to some general temporal and geographical changes. The great variations in the presence of *M. oculata* from 1996 to 2005 have complicated the faunal picture. Adding the 2005 results to the trend data has made it possible to obtain a pattern in the overall temporal variations in the entire region.
- The biodiversity and numbers of species have increased. An increase in the numbers of individuals on the expense of *M. oculata* indicates a general improvement in the fauna community in the Ekofisk region.
- There has been a distinct improvement in the fauna at least 500 m from the field centers. At a radius of 250 m no clear trend is observed from the last survey in 2002, except at Ekofisk A where some stations have improved.
- The organic load is highest around regional stations 2 and 6 and the improvement of the fauna communities seems to be slowest around the fields Ula, Gyda, Tambar and Tor. However, the densities of individuals in the region still indicate a relatively high, though decreasing supply of organic matter to the macrofauna.
- In 2005 an area about 100 km^2 have THC concentrations higher than the LSC (4.6 mg/kg). The estimate is considered to be more reliable than the 2002 calculations (somewhere between 61 and 266 km^2). For limits of 10 and 50 mg/kg the corresponding estimated areas are 24 and 1.4 respectively.
- All in all, the statistical analyses show increasing biodiversity indices and increasing numbers of species. Some increase in the numbers of individuals on the expense of *M. oculata* reveals a general improvement in the fauna community in the Ekofisk region. Species that are numerous all over the region in 2005 are the brittle star *Amphiura filiformis* and the bristle worms *Paramphinome jeffreysii* and *Apistobranchus tullbergi*. In general the fauna communities are dominated by suspension feeders (*M. oculata*, *Ditrupa arietina*, *A.filiformis, Thyasira* species, hydroids and anthozoa species) and carnivore species like *P. jeffreysii*.

The main parameters and the variation at each field:

Regional stations	Variation	Main characteristics
THC (mg/kg)	1.3 – 5,8	The concentrations of THC, Ba and metals are low. No elevated levels are found.
Ba (mg/kg)	4 – 72	Four of the regional stations located in the central part of the region, are somewhat disturbed. There are indications of improvements since 2002.
No. of species (S)	55 – 82	
No. of individuals (N)	341 – 2495	The high abundance of *M. oculata* which had a peak in 2002 has to some extent been replaced by other species in 2005.
Diversity (H')	2,7 – 5,1	
Evenness (J)	0,4 – 0,8	
E_{100}	17 – 38	

Valhall	Variation	Main characteristics
THC (mg/kg)	4.3 – 130	Elevated levels of THC and Ba out to 1000m. Also slightly elevated levels of THC out to 2000m. Olefins from Novaplus discharged in 1996 are found at 500m.
Ba (mg/kg)	28 – 5587	
No. of species (S)	60 – 93	Indications of a positive trend in the fauna. Two of the 500m distance stations are slightly disturbed, correlated to the variations in the levels of THC, Ba and Cu.
No. of individuals (N)	1334 – 2300	
Diversity (H')	2,5 – 3,79	Large amounts of yellow granules were found in the samples at all the Valhall stations.
Evenness (J)	0,63 – 0,47	
E_{100}	18 – 24	

Valhall Nordflanke	Variation	Main characteristics
THC (mg/kg)	4.3 – 8,4	The contents of THC are considered to be within the natural levels. Elevated Ba levels are found at all stations, this means out to 500m. The content of Ba is higher or at the same level compared to 2002.
Ba (mg/kg)	28 – 468	
No. of species (S)	66 – 91	
No. of individuals (N)	934 – 1921	The biodiversity indices have increased considerably, which is partly due to a significant decline in the abundance of the bristle worm *M. oculata.* None of the stations are considered affected by field activities.
Diversity (H')	2,98 - 4,18	
Evenness (J)	0,47 – 0,66	
E_{100}	20 – 29	Yellow granules (see Valhall for details) were found at most of the stations.

Valhall Sørflanke	Variation	Main characteristics
THC (mg/kg)	3.6 - 5.3	The content of THC is considered to be within the background level. Elevated levels of Ba are found out to 500m in the 74° directions and limited to 250m in the 254° direction. The content of Ba is higher or at the same level compared to 2002. For most of the other stations the Ba concentration found is below the limit of contamination.
Ba (mg/kg)	28 - 190	
No. of species (S)	59 – 69	
No. of individuals (N)	614 – 2384	
Diversity (H')	2,64 – 4,53	The biodiversity has increased considerably since the baseline survey in 2001, primarily due do a significant decline in the abundance of the bristle worm *M. oculata*. Two stations (250 and 500m) considered somewhat disturbed.
Evenness (J)	0,43 – 0,77	
E_{100}	18 – 30	Yellow granules (see Valhall for details) were found in several of the samples.

Hod	Variation	Main characteristics
THC (mg/kg)	4.3 – 36	Elevated THC values are found at HOD8 164°/500m. For the other stations the THC levels are low. Olefins are found at the six stations analysed. Probably originating from discharges of Novasol and Novaplus in 1994/1995. Elevated Ba levels are found at all the stations. That is maximum range out to 1000m in the 164° direction, and to 250m in the 344° direction.
Ba (mg/kg)	32 – 900	
No. of species (S)	56 – 84	
No. of individuals (N)	539 – 1516	
Diversity (H')	3,6 – 4,0	
Evenness (J)	0,6	The biodiversity has increased since 2002 because of a significant decline in *M. oculata*, indicating a positive trend in the area.
E_{100}	24 – 28	

Ula	Variation	Main characteristics
THC (mg/kg)	3.9 - 58	Elevated THC levels are found out to 500m in 45° and 135° direction and to 250m in the 120° and 225° direction. For the other stations the THC level are low.
Ba (mg/kg)	35 - 4172	
No. of species (S)	68 – 81	Elevated levels of Ba for all the stations, this means out to 500m (45° and 135°) and limited to 250m for the other directions. The levels of Ba have increased since 2002.
No. of individuals (N)	944 – 5193	
Diversity (H')	1,4 – 4,4	The base oil Aquamul BII (ethers) is found at some stations.
Evenness (J)	0,2 – 0,7	
E_{100}	10 – 30	The positive trend observed in the fauna community from 1996 to 1999 has not continued and the stations sampled in 2005 (250 and 500 m) are considered to be disturbed.

Gyda	Variation	Main characteristics
THC (mg/kg)	4.0 - 43	High THC contents at the stations at 250m in 45°, 135° and 225° directions. Elevated levels of Ba for all the stations investigated. High Ba contents at stations 250m from the platform in the 45° and 225° directions.
Ba (mg/kg)	36 - 1566	
No. of species (S)	20 – 89	
No. of individuals (N)	249 – 6446	High contents of heavy metals for GYDA18, 135°/250m. The results at the other stations are similar to previous surveys.
Diversity (H')	1,3 – 3,0	
Evenness (J)	0,2 – 0,6	The biodiversity indices indicate a general disturbance in the fauna at Gyda in 2005. One of the 250m station consists of anoxic sediment and is clearly disturbed.
E_{100}	10 – 21	
		There are indications that the fauna is influenced by the field activities.
		Variations in the fauna between years seem to coincide with the variations in Ba, Pb, TOM and pelite.

Tambar	Variation	Main characteristics
THC (mg/kg)	3.3 – 15.2	The THC concentration is generally low and elevated levels are only found at TAMBAR5, 135°/250m. Elevated Ba contents are found at all the stations, this means out to 250m for all directions investigated. The Ba contents are lower or at the same level as in the 2002 survey. The fauna community at 250m stations indicates some disturbance, possibly influenced by field activities. The results indicate no major alterations in the state of the fauna community since 2002. A decline in *M. oculata* is not observed.
Ba (mg/kg)	106 - 563	
No. of species (S)	75 – 85	
No. of individuals (N)	2735 – 4130	
Diversity (H')	2,14 – 2,63	
Evenness (J)	0,34 – 0,41	
E_{100}	15 – 18	

Ekofisk Centre and 2/4 B&K	Variation	Main characteristics
THC (mg/kg)	3.5 – 188	THC contents have decreased distinctly and are, for many of the stations investigated, only slightly above or below the limit of contamination. The highest concentrations are found at EKO14, 140°/850m. Elevated Ba concentrations are found at all stations. This means out to maximum range 1800m from 2/4T in the 84° direction. The concentrations are similar or slightly lower compared to previous surveys. Olefins and ethers (Aquamul B) are found, and are in accordance with reported discharges. The fauna community has improved since 2002. The four stations located closest to 2/4 W are still somewhat disturbed. The decline in *M. oculata* partly explains the improvement in the fauna community. The changes in the fauna during the years are not directly related to variations in investigated sediment characteristics or chemical data.
Ba (mg/kg)	46 – 3860	
No. of species (S)	58 – 78	
No. of individuals (N)	1385 – 3175	
Diversity (H')	2,8 – 3,8	
Evenness (J)	0,4 – 0,6	
E_{100}	18 – 22	

Ekofisk 2/4 A	Variation	Main characteristics
THC (mg/kg)	8 – 106	Elevated levels of THC out to 2000m. Olefins and esters (Finagreen) are found. THC generally increases going down in the sediment. The highest THC concentration found is 1031 mg/kg at EKOA5, 67°/100m in the 3-6 cm layer. Elevated levels of Ba are found at all stations, this means out to 500m in all the directions measured. Elevated levels of heavy metals at most of the stations. Drill cuttings piles, corers to 130 cm depth: Elevated levels of hydrocarbons, Ba and heavy metals in all layers. Higher concentrations in the deeper layers. The THC concentrations are higher and the Ba concentrations are lower in the 2005 survey compared to
Ba (mg/kg)	887 - 5110	
No. of species (S)	62 – 105	
No. of individuals (N)	944 – 3693	
Diversity (H')	2,2 – 4,2	
Evenness (J)	0,4 – 0,6	
E_{100}	13 – 29	

		2002. The fauna community has in general improved and there has been a significant decrease in the number of *M. oculata* since 2002. There are disturbances in the fauna at three of the 100 m stations, and the disturbance seems to be related to the activity at the field. There is a good correlation between the fauna and the complex of the parameters THC, Ba, Cd, TOM and gravel.

Eldfisk 2/7 A/FTP	**Variation**	**Main characteristics**
THC (mg/kg)	4.3 - 120	High THC contents at ELDA4, 360°/250m. Slightly elevated out to 370m and 250m in the 180° and 90° directions. However, the THC content is low at most stations, either below or just above the limit of contamination.
Ba (mg/kg)	590 – 1700	
No. of species (S)	63 – 90	
No. of individuals (N)	1677 – 3580	Elevated Ba levels are found at all stations analysed. This means out to maximum 625m in the 360° direction. Olefins are found, but the content has decreased since 2002. Mainly, the results agree with the drilling history.
Diversity (H')	2,4 – 3,4	
Evenness (J)	0,4 – 0,6	
E_{100}	16 – 23	There are indications of some disturbance in the fauna community out to 625 m from the field centre. A decline in the numbers of *M. oculata* as described at several other fields in the area has not been the case at Eldfisk A and the biodiversity indices are almost unchanged since 2002. However, a shift in the fauna community is observed, indicating a slow improvement.

Eldfisk 2/7 B	**Variation**	**Main characteristics**
THC (mg/kg)	5.8 - 30	The THC content has decreased since 2002.
Ba (mg/kg)	644 – 1706	The highest THC content is found at three stations at 250m. Slightly elevated level out to 500m in 90° direction. The level is lower or just above limit of contamination for the other stations. Low content of olefins are found. Decalins are detected.
No. of species (S)	82 – 95	
No. of individuals (N)	2086 – 3196	
Diversity (H')	3,0 – 3,2	
Evenness (J)	0,5	Elevated Ba levels for all the stations out to 500m. Level similar to 2002 survey. The results mainly agree with the drilling history.
E_{100}	19 - 22	
		A slightly disturbed fauna was observed at all sampled 500m stations. The biodiversity in the fauna community has in general increased slightly since 2002. The improvement is, however, slow. A general decline in the numbers of *M. oculata* as described at several other fields in the area is not the case at Eldfisk B.

Embla 2/7 D	**Variation**	**Main characteristics**
THC (mg/kg)	3.9 - 18.2	Lowest THC concentrations in the Ekofisk area and slightly elevated levels are only found out to 250m in the 90° and

Ba (mg/kg)		180°direction. No discharges since 1999.

Tor 2/4 E	Variation	Main characteristics
THC (mg/kg)	6.6 - 20	Elevated levels of THC/ethers out to 500m (180°) and out to 250m (90° and 360°). Elevated Ba levels out to 500m in the 180° direction.
Ba (mg/kg)	341 - 1505	
No. of species (S)	85 – 93	Ethers from the base oil Aquamul B, discharged in 1990, are found,.
No. of individuals (N)	1107 – 4092	
Diversity (H')	2,52 – 4,36	A general improvement in the fauna community is seen at both the 500m station and the 250 m station. The abundance of *M. oculata*, higher levels of THC and metals combined with field observations of oil film/black spots, still indicate some disturbance at 250 m.
Evenness (J)	0,39 – 0,68	
E_{100}	19 – 29	

Yme Gamma	Variation	Main characteristics
THC (mg/kg)	2.4 - 32	Elevated THC levels out to 250m in the 120° direction.
Ba (mg/kg)	10 – 4490	Elevated levels of Ba are found for all stations, this means out to maximum range 500m in the 120° direction. The Olefin and ester contents are low and are lower or similar to the 2002 survey. Olefins and esters from Petrofree. The results agree with the drilling history.
No. of species (S)	62 – 99	
No. of individuals (N)	213 – 1852	
Diversity (H')	2,97 – 5,27	Installation Centre: High silt and clay content. High THC, olefins and Ba levels (up to ~0.6 %). Elevated metal levels.
Evenness (J)	0,49 – 0,89	
E_{100}	18 – 43	The silt and clay content has increased, so has the contents of THC, NPD, PAH, decalins, Cd and Cr to varying degrees.
		In general, the structure in the fauna community at Yme Gamma indicates a healthy environment. A slight improvement in the fauna community since 2002, also at the 100 m stations, even though these stations still are characterized as disturbed.
		Based on observations from the sampling and a qualitative analysis the Installation Centre is characterized as heavily disturbed.

Yme Beta	Variation	Main characteristics
THC (mg/kg)	0.3 – 5.8	No elevated THC concentrations. Ba level below the limit of contamination in the 330° direction. Elevated Ba levels are found at 250m in the other directions. Lower concentrations than at Yme Gamma. The results agree with the drilling history.
Ba (mg/kg)	11 – 520	
No. of species (S)	48 – 91	
No. of individuals (N)	232 – 581	
Diversity (H')	4,45 – 5,46	Installation Centre: Less silt and clay contents than at Yme Gamma. High THC, olefins, Ba and metals levels at 0°/0m. Lower levels at the 100m stations.
Evenness (J)	0,76 – 0,86	
E_{100}	32 – 44	The structure in the fauna community and the biodiversity indices characterize a healthy fauna community. There are

	indications of general improvements. However, the 100 m stations and Installation Centre are still characterized as disturbed. During sampling there were observed large amounts of yellow granules (similar to findings at Valhall) in the samples from the Installation Centre and the 100m stations.

Kogge	Variation	Main characteristics
THC (mg/kg)	0.5	Low contents of THC and Ba. The Kogge area is not polluted by THC or metals from oil activity. The study has shown that the Kogge field is not contaminated by hydrocarbons or metals, and the fauna at the two Kogge stations are characterised as diverse and healthy.
Ba (mg/kg)	3 – 4	
No. of species (S)	78 – 88	
No. of individuals (N)	448 – 609	
Diversity (H')	5,1 – 5,2	
Evenness (J)	0,8	
E_{100}	39	

Trym	Variation	Main characteristics
THC (mg/kg)	1.7 – 3.8	Low contents of THC and Ba. The Trym area is not polluted by THC or metals from oil activity. The baseline study at Trym revealed a relatively healthy fauna community, not influenced by field activities. However, the fauna community seems to be slightly disturbed, which is probably due to the high energy environment together with a general diffuse organic enrichment in the central parts of the Ekofisk region.
Ba (mg/kg)	14 - 42	
No. of species (S)	64 – 83	
No. of individuals (N)	937 – 2040	
Diversity (H')	3,25 – 4,54	
Evenness (J)	0,5 – 0,7	
E_{100}	22 – 30	

2.0 Introduction

2.1 The Ekofisk Region

This report presents results from the environmental survey in the EKOFISK region (Region I) in 2005. The main subject in regional monitoring is to study any environmental effects from petroleum activities in larger areas. Regional environmental monitoring has been carried out since 1996.

The report presents results from 17 different field/installations within the region. Fields and installations included in the regional monitoring are listed in Table 2.1.1. An overview of the region including installations is shown i Figure 2.1.1.

Table 2.1.1. *Fields and installations included in the regional monitoring 2005.*

Field/Installation	Operator
Ula	BP
Valhall	BP
Valhall Nordflanke	BP
Valhall Sørflanke	BP
Hod	BP
Tambar	BP
Ekofisk Centre and 2/4B&K	ConocoPhillips
Ekofisk 2/4 A	ConocoPhillips
Eldfisk 2/7 A/FTP	ConocoPhillips
Eldfisk 2/7 B	ConocoPhillips
Embla 2/7 D	ConocoPhillips
Tor	ConocoPhillips
Albuskjell (separate report)	ConocoPhillips
Yme Gamma	Statoil
Yme Beta	Statoil
Gyda	Talisman
Trym	Shell
Kogge	Exxon

The survey programme has been prepared according to the *Activities Regulation Appendix 1 – Requirements to Environmental Monitoring of the Petroleum Activities on the Norwegian Shelf*. (Ptil, SFT, SHdir 2005). The selection of sampling stations at the various fields are based on the results from the survey conducted in 2002 and the drilling- and discharge history after the previous survey (in 2002), see *Program for sedimentovervåking Region I – Ekofisk 2005* version 3, January 2005 (enclosed in Appendix E).

The Ekofisk region is limited to the Norwegian Continental shelf from 56º02'N to 57º52'N and from 02º46'E to 04º32'E, i.e. the southern part of the Norwegian sector in the North Sea. The depth varies from approximately 65m in the south to 90m in the north. The tidal current direction in the area is in the NE – SW direction while the residual current direction is in the SE direction.

The report is divided into three main sections; the Summary Report (rep. no. 2006-0353)/Sammendragsrapport (rep. nr. 2006-0354) where the main results are presented, the Main Report (rep. no. 2006-0187) which gives detailed results and the Appendix Report (rep. no. 2006-0512) consisting of field report, analyses report and other details. Stations for each field are shown in fold-out maps in the main report.

There are no additional regional stations included in the 2005 survey compared to the previous survey in 2002. Previous surveys has shown that depth, sediment characteristics and carbon content are very homogenous in the region and the existing regional stations represent the general features of the region in a fulfilling way.

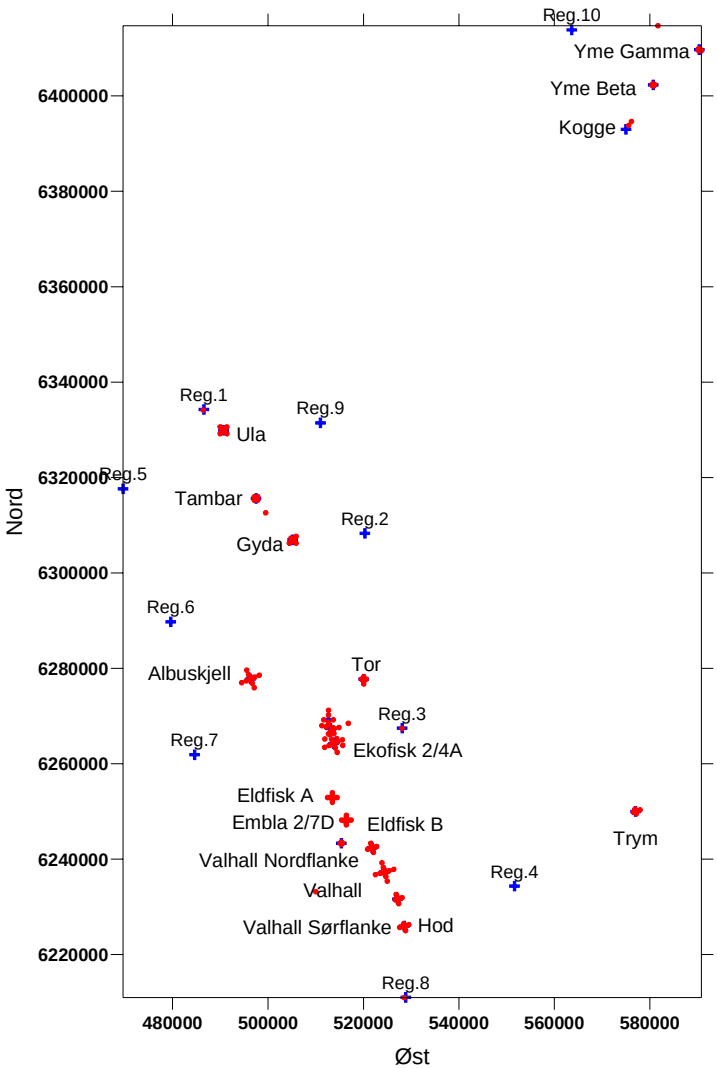

Figure 2.1.1 *Regional stations (1 – 10) and an overview of fields included in the 2005 survey, Region I – Ekofisk.*

Table 2.1.2. *Regional stations, Region I 2005.*

Station no.	North	East
Reg. 1 (= ref. st. Ula)	57°09.01'	02°46.67'
Reg. 2	56°55'	03°20'
Reg. 3 (= ref. st. Ekofisk)	56°32.97'	03°27.42'
Reg. 4	56°15'	03°50'
Reg. 5	57°00'	02°30'
Reg. 6	56°45'	02°40
Reg. 7	56°30'	02°45
Reg. 8 (= ref. st. Hod)	56°02,54'	03°27,80'
Reg. 9	57°07.50''	03°10.89'
Reg. 10	57°51.63'	04°04.35'

3.0 Materials and Methods

The sediments are analysed for the following analytical parameters.

Analytical method	Parameter
Sediment characterization	
• Grain size distribution	- Distribution of pelit (< 63 µm) and sand (> 63 µm) - Cumulative weight% distribution 63-2000 µm - Median particle diameter (Mdϕ), deviation (SDϕ), skewness (Skϕ) and kurtosis (Kϕ)
• Total organic matter	- % TOM in the sediment
Chemical analyses	
• Hydrocarbons	- THC, sum C_{12}-C_{35} - NPD, naphtalene, phenanthrene/anthracene and dibenzothiophene and their C_1-C_3 alkylated derivatives. Sum and single compounds. - PAH, 16 EPA compounds. Sum and single compounds. - Decalins, sum of C_5-C_8 alkyl decalins - Olefins, compounds in the area $C_{14}H_{28}$ to $C_{20}H_{42}$
• Esters	- Petrofree and Finagreen
• Ethers	- Aquamul B
• Chlorinated biphenyls	PBC, 7 congeners
• Perfluorooctyl sulphonate	- PFOS
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn
Biological analyses	
• Macrobenthic fauna	- Numbers of species and individuals
	- Unvariate and multivariate analyses

Details from the field work are described in a separate field report (DNV rep. 2005-0966), which is enclosed in the Appendix Report (DNV rep. 2006-0512). A complete overview from the sampling is enclosed in Appendix A of this report.

4.0 Results and Discussion

4.1 Summary

Region I

A summary of the sediment characterizations and the chemical analyses of the sediments at Region I is shown in the table below. The mean values of the three replicates are given. The TOM values are based on one sample. The results summarized are for the top 0-1 cm layer.

Summary of chemical results, Region I 2005.

Parameter		**Regional stations** (10 stations)	**Valhall** (12 stations)	**Valhall Nordflanke** (13 stations)	**Valhall Sørflanke** (13 stations)	**Hod** (8 stations)	**Ula** (9 stations)
Sand	%	95 – 99	85 - 98	93 - 100	93 – 97	91 - 97	95 – 97
TOM	%	0.7 - 1.1	0.8 - 1.5	0.8 – 0.9	0.6 - 0.8	0.8 - 1.3	0.8 - 1.1
THC	mg/kg	1.3 - 5.8	4.3 - 130	4.3 – 8.4	3.6 - 5.3	4.3 - 36	3.9 – 58
Olefins	mg/kg					0.7 - 7.1	
Esters	mg/kg						
NPD	mg/kg	nd – 0.020	0.04 – 1.24	0.014	nd	0.025 – 0.085	0.043 – 0.16
PAH	mg/kg	0.018 – 0.062	0.062 – 0.21	0.043	0.020	0.065 – 0.077	0.073 – 0.12
Decalins	mg/kg	nd – 0.24	nd – 2.7	nd	nd	nd – 0.91	0.19 – 2.4
Ba	mg/kg	4.1 – 72	28 - 5587	28 - 468	28 – 194	32 - 900	35 – 4170
Cr	mg/kg	5.8 - 9.1	7.7 - 10.5	7.6 – 9.4	6.3 - 7.7	6.9 - 8.9	6.2 - 8.0
Cu	mg/kg	nd - 0.5	nd - 9.6	nd	nd	nd - 1.0	nd - 5.5
Pb	mg/kg	4.0 - 7.2	6.5 - 19.1	6.5 – 8.5	5.9 - 7.4	5.8 - 10.5	6.2 - 16.4
Zn	mg/kg	3.1 - 6.8	5.6 - 33	5.6 – 7.7	4.9 - 5.8	5.9 - 8.6	5.4 – 43
Cd	mg/kg	nd - 0.2	nd - 0.03	nd	nd	nd	nd
Hg	mg/kg	nd	nd - 0.02	nd	nd	nd	nd

Summary of chemical results, Region 2005 cont.

Parameter		**Gyda** (8 stations)	**Tambar** (8 stations)	**Ekofisk Centre og 2/4 B&K** (20 stations)	**Ekofisk 2/4 A** (27 stations)	**Eldfisk 2/7 A/FTP** (9 stations)	**Eldfisk 2/7 B** (8 stations)
Sand	%	94 – 100	93 – 98	65 – 97	83 – 95	92 – 97	95 - 97
TOM	%	0.6 - 0.8	0.8 - 1.0	0.9 – 1.3	0.76 – 1.50	0.9 - 1.0	0.9 - 1.0
THC	mg/kg	4.0 – 43	3.3 - 15.2	5.8 – 188	8 – 106	4.3 – 120	5.8 - 30
Olefins	mg/kg			1.1 – 86	2 – 61	0.5 - 0.6	0.5 - 0.9
Esters	mg/kg				nd – 3		
NPD	mg/kg	0.018 – 0.70	0.015 – 0.030	0.08 – 0.20	0.03 – 0.94	0.10 – 0.20	0.03 – 0.12
PAH	mg/kg	nd - 0.056	0.039 – 0.046	0.073 – 0.10	0.029 – 0.248	0.024 – 0.22	0.03 – 0.07
Decalins	mg/kg	nd – 1.0	nd – 1.4	0.12 – 7.7	nd – 0.9	0.6 – 33*	0.07 – 1.80
Ba	mg/kg	36 – 1566	106 - 563	46 – 3860	887 – 5110	590 – 1700	644 - 1706
Cr	mg/kg	6.5 – 24	6.8 - 7.4	5.6 - 11.7	4.7 – 14.2	6.7 - 7.6	4.8 - 7.2
Cu	mg/kg	nd – 21	0.5 - 0.7	Nd - 5.3	1.4 – 17.5	0.7 - 1.4	0.7 - 1.2
Pb	mg/kg	5.8 – 24	5.3 - 6.8	6.1 - 22.2	9.0 – 51.7	9.7 - 13.5	7.0 - 14.4
Zn	mg/kg	4.9 – 88	5.7 - 6.5	5.4 – 48	11.5 – 154	7.6 - 11.7	5.8 - 10.4
Cd	mg/kg	nd	nd	nd - 0.09	0.02 – 0.40	nd	nd
Hg	mg/kg	nd	nd	nd - 0.07	0.01 – 0.12	~0.03	nd

nd: not detected
Detection limits: olefins 0.3 - 0.5 mg/kg (varies with the field), esters: 0.2 mg/kg, decalins: 100 µg/kg, NPD: 10 µg/kg, PAH: 5 µg/kg, Ba: 1 mg/kg, Cr: 0.2 mg/kg, Cu: 0.5mg/kg, Pb: 0.5 mg/kg, Zn: 1 mg/kg, Cd 0.01 mg/kg, Hg 0.01mg/kg
*: only in one grab sample.

Summary of chemical results, Region I 2005 cont.

Parameter		**Embla 2/7 D**	**Tor 2/4 E**	**Yme Gamma***	**Yme Beta***	**Kogge**	**Trym**
		(4 stations)	(5 stations)	(5 stations)	(4 stations)	(2 stations)	(9 stations)
Sand	%		97 – 98	94 – 98	98 - 100	95 – 98	92 – 98
TOM	%		0.8 - 0.9	0.5 - 0.7	0.4	0.4	0.7 - 0.9
THC	mg/kg	3.9 - 18.2	6.6 – 20	2.4 – 32	0.3 – 5.8	0.5	1.7 - 3.8
Olefins	mg/kg			nd - 2.5	nd		
Ether	mg/kg		1.3 – 28				
Esters	mg/kg			0.5 – 0.66			
NPD	mg/kg		0.04 – 0.07	0.05 – 8.7	0.011		0.010 – 0.014
PAH	mg/kg		0.05 – 1.6**	0.035 – 0.44	0.010		0.032 – 0.033
Decalins	mg/kg		nd	nd – 0.17	nd		nd
Ba	mg/kg		341 – 1505	10 – 4490	10 - 520	3 – 4	14 – 42
Cr	mg/kg		8.4 - 8.5	5.8 - 9.5	7.3 – 9.1	8.6 - 9.3	6.2 - 6.8
Cu	mg/kg		0.7 - 2.3	nd -20	nd	nd	0.3 - 0.4
Pb	mg/kg		10.4 - 18.3	5.5 - 11	6.6 – 7.3	5.2 - 5.6	6.6 - 7.2
Zn	mg/kg		10.0 - 19.0	7.0 - 56	4.9 – 7.0	5.0 - 5.6	4.9 - 7.2
Cd	mg/kg		nd - 0.03	nd - 0.02	nd	nd	nd
Hg	mg/kg		nd - 0.05	nd	nd		nd

na: not analysed
nd: not detected
Detection limits: olefins 0.3 – 0.5 mg/kg (varies with the field), esters: 0.2 mg/kg, 100 µg/kg, Cu: 0.5mg/kg, Cd 0.01 mg/kg, Hg 0.01mg/kg
* Installation centre excluded
** High concentration in one grab sample.

In addition to the results shown in Table 5.1.1 the following analyses are performed:

- At Ekofisk 2/4 A drill cuttings pile: PCB analyses of the core samples
- At Valhall: PFOS analyses for one station (500m)
- At Ekofisk Centre og 2/4 B&K: PFOS analyses for one station (500m)
- At Yme Gamma: PFOS analyses for one station (100m)
- At Yme Gamma: Installation centre 0°/0m and 100m stations
- At Yme Beta: Installation centre 0°/0m and 100m stations

PFOS: PerFluoroOctyl Sulphonate.

The results from the Drill cuttings pile and the Installations centre are discussed separately.

Grain size distribution

The sediments from most of the fields in Region I consist of fine sand. At Yme Gamma, Yme Beta and Kogge the sediments are coarser and characterized as medium sand.

The sand content in the sediment dominates at all stations. At the regional stations the average sand content is 96.8 %, and the average silt and clay content (pelite) is 3.1 %. This mean value is representative for the region.

The sand content in Region I varies from 64.8 % (EKO14, 140°/850m) to ~100 % (VAN2, 74°/500m, GYDA reference station (315°/8000m) and YMEB12 (330°/250m). The lowest sand content and thus the highest silt and clay contents are found at some stations at Ekofisk Centre, Ekofisk 2/4 A and Valhall. EKO14 appears different compared to the other stations at Ekofisk Centre and has the lowest sand content (64.8 %) and the highest silt and clay content (35.2 %) observed in this survey.

Generally, only slight differences are observed in the silt and clay content compared to the previous surveys.

During sampling there were observed large amounts of yellow granules in the sediments in the Valhall and Yme Beta. Traces of the granules were also observed in samples from other areas like Ekofisk Centre and 2/4 A, Eldfisk A and Tor, possibly originating from other areas. An investigation group has been established by BP to find out more about the granules.

Total organic matter (TOM)

The total organic matter content in the sediments is low. The concentrations vary from 0.4 % (Yme Beta and Kogge) to 1.5 % (Valhall). The results are similar to previous surveys.

Hydrocarbons

The hydrocarbon contents in the sediments that originates from the drilling mud base oil or base liquid, depend on the drilling history, and will thus vary from field to field.

Generally a tendency of vertical transport of hydrocarbons is observed, with increased concentrations in the 1-3 cm and 3-6 cm sediment layers.

At the Regional stations and the additional reference stations, the THC concentrations are low and vary from 1.3 mg/kg to 5.8 mg/kg. No increase is observed since the last survey in 2002.

At Valhall and Hod 500m stations were included in the 2002 survey. These stations are also analysed in this survey. In addition two new 500m stations, in 74° and 254° direction, are included at Valhall in the survey. The maximum THC concentrations observed are 130 mg/kg at Valhall and 35.9 mg/kg at Hod, at stations 500m from the platform. Elevated THC concentrations are found out to 1000m distance at Valhall and out to 500m distance at Hod. In general the THC concentrations have decreased distinctly compared to the 2002 survey. Olefins from pseudo-oil based drilling mud base liquids are found at all stations at Hod, except for the reference station. However, the olefin concentrations are low and have decreased compared to previous surveys for all stations investigated. At Valhall olefins were not analysed.

At Valhall Flanke Nord and Valhall Sørflanke the content of THC are below or just above the limit of contamination. The concentrations are at the same level as in the 2001 baseline survey.

At Ula and Gyda 250m and 500m stations were included in the 2002 survey. These stations are also analysed in this survey and in addition new 250m stations are included (45°, 135° and 225°).

At Ula the highest THC concentration in the top layer is found at one of the 250m stations. Maximum concentration is, however, observed in the vertical layers for the same station, with 416 mg/kg. Elevated THC concentrations are observed for Ula out to 500m in the 45° and 135° direction and to 250m in 120° and 225° direction. The general trend is a decrease in the THC concentrations since 2002. The ether drilling fluid Aquamul BII is also found in the sediment, and give a contribution to the THC content.

At Gyda, elevated concentrations of THC are observed out to 250m, for three stations in the 45°, 135 and 225° direction. Maximum THC concentration observed in the top 0-1 cm layer is 43 mg/kg. In general the THC levels for the other stations are low and similar to those found in 2002 and 1999. Only slightly elevated THC concentrations are found at the 500m stations in the 45°, 135° and 225° directions.

Tambar is situated in the area between Gyda and Ula. As for Gyda the THC concentrations are relatively low. The content is similar or lower compared to the 2002 survey. The highest THC concentrations are found at one of the 250m stations, 15.2 mg/kg. The other stations have THC content below the limit of contamination.

In the Ekofisk area high THC concentrations are found at some of the stations at Ekofisk Centre and at Ekofisk 2/4 A. Maximum concentration observed is 188 mg/kg in the top 0-1 cm layer. The THC concentration is generally increasing going down in the sediment. Highest concentration found is 1031 mg/kg at EKOA5 in the 3-6 cm layer. Slightly elevated THC concentrations are found out to 4400m (7.4 mg/kg) and 2500m (8.7 mg/kg), respectively. Generally the THC content in the 0-1 cm layer has decreased, for most of the stations, since the last survey. Thus, the THC content for most of the stations is only slightly above or below the limit of contamination for the region. Olefins/ethers are found at the stations analysed.

At Eldfisk 2/7 A/FTP, and Eldfisk 2/7 B, the highest concentration of THC found are 120 mg/kg at Eldfisk 2/7 A/FTP and 30 mg/kg at Eldfisk 2/7 B. Elevated THC concentrations are found out to 370m (Eldfisk 2/7 A/FTP) and to 500m (Eldfisk 2/7 B). Only, low content of olefins are found. The THC and olefin content in the Eldfisk area has decreased since the 2002 survey.

At Embla the four 250m stations, analysed in this survey, have not been investigated since 1993. Elevated THC content is found at 180° (18.2 mg/kg) and 90° (15.0 mg/kg) direction, respectively.

At Tor the highest THC concentrations are 20 mg/kg. Ethers were found at all the stations analysed with maximum concentration 28 mg/kg. Elevated THC concentrations are found for the 250m stations. The level is similar to the 2002 survey.

The Yme fields are located north-east in Region I. The fields are more recently established, with baseline surveys in 1994. At Yme Gamma elevated THC concentrations are found out to 250m distance in the 120° direction (32 mg/kg). The THC concentrations have decreased for all the stations compared to the 2002 survey. Olefins are found at most of the stations, but the content is reduced or similar to 2002. Olefins and esters come probably from Petrofree. At Yme Beta no elevated THC concentrations are found.

The baseline survey of Kogge and Trym show low content of THC. The Trym and Kogge area is not polluted by THC from oil activity.

The results for the selected hydrocarbons NPD, PAH and C_5 - C_8 alkyl decalins generally confirm the THC results. Particularly the presence of decalins gives indication of drilling mud base oil in the sediment. The base oil HDF 200 contains approx. 2 % of C_5 - C_8 alkyl decalins.

The present survey indicates that ether compounds from the drilling fluids Aquamul BII and Aquamul B are not breaking down as fast as previously anticipated. Discharges performed in 1990/1991 and 1993 are still present in the sediments.

Esters

Esters from the drilling mud base liquids Petrofree and Finagreen are only analysed at Ekofisk 2/4 A and Yme Gamma.

At Ekofisk 2/4 A, Finagreen is found in the sediments at 100m in the 67° and 157° directions. The concentrationas are low, approximately 3 mg/kg.

At Yme Gamma, Petrofree is found at the two stations analysed, 0.5 mg/kg and 3.4 mg/kg, respectively. The concentrations are similar to the 2002 survey. As in 2002, Finagreen is not detected.

PFOS (perfluorooctyl sulphonate)

Three stations are analysed for PFOS (perfluorooctyl sulphonate). Highest content is found at the one station at Yme Gamma Central at direction 120° and distance 100m. PFOS is not detected at the station analysed at Ekofisk Centre and 2/4 B&K.

Barium

Ba is found in the sediments due to use of barite during drilling with water based drilling mud, oil based drilling mud or pseudo-oil based drilling mud as well. Thus higher concentrations of Ba in the sediments the greater dispersal area will be found compared to THC.

As for THC a vertical transport of Ba down in the sediment layers is observed.

At the Regional stations and the additional reference stations, the Ba concentrations are low and vary from 4 mg/kg to 72 mg/kg. No increase is observed since the last survey in 2002.

The Trym and Kogge area has low content of Ba and is not polluted by Ba from oil activity.

The Ba concentrations vary from background levels to 5590 mg/kg. The maximum concentrations found at each field will depend on the location of the stations and their distance from the platform, as most of the barite will deposit near the drilling sites.

Generally, elevated Ba concentrations are found at most of the stations. At Valhall Flanke Nord and Sør, Tambar and Yme Beta the Ba concentrations are relatively low. Mainly the Ba concentrations are similar or lower compared to the survey in 2002.

Metals

Generally, low concentrations of the heavy metals are found in the sediments. However, some exceptions are observed.

At Gyda one 250m station shows high metal concentrations, 0.14 mg/kg Cd, 48 mg/kg Cr, 21 mg/kg Cu, 24 mg/kg Pb and 88 mg/kg Zn.

At Ula relatively high Zn concentrations, 43 mg/kg, are found in one 250m station. The same station had also high content of Zn in 2002.

At Ekofisk Centre three of the stations (at 500m and 850m) show relatively high Pb and Zn concentrations, maximum 22 mg/kg Pb and 48 mg/kg Zn.

At Ekofisk 2/4 A elevated metal concentrations are found at most of the stations. The highest concentrations in the 0-1 cm layer are 14.2 mg/kg Cr, 0.40 mg/kg Cd, 17.5 mg/kg Cu, 0.12 mg/kg Hg, 52 mg/kg Pb and 154 mg/kg Zn.

At Yme Gamma one 250m station shows relatively high Cu and Zn concentrations, 20 mg/kg Cu and 56 mg/kg Zn.

Drill cuttings pile at Ekofisk 2/4 A – Core samples VC-2

Two core samples are analysed, VC-2 (I) and VC-2 (II).

Elevated concentrations of all the chemical parameters analysed are found downwards to 130 cm depth in the drill cuttings pile, except for esters and PCB.

The sediment consists mainly of silt and clay. The TOC content vary from 5.3 % to 13.8 %. Lowest TOC content is found in the deepest layers.

The THC concentrations including olefins vary from 998 - 1153 mg/kg in the 45-65 cm layer to 88088 mg/kg in the 0-5 cm layer. The levels of THC in the core samples are generally higher in 2005 than in 2002. A major part of the THC content results from olefins, up to ~70 % in the most contaminated samples. As in correlation with THC also the levels of olefins in the samples are generally higher in 2005 than in 2002.

In 2005 no ester or PCB was found in the corer samples. The ester content has decreased considerably since the 2002 survey.

The concentration of NPD ranges from 5.4–13.1 mg/kg in the 40-65 cm layers to 42.5-80.5 in the 0-10 cm layers. The concentration of PAH ranges from 0.4 mg/kg to 22.4 mg/kg. The concentration of decalins ranges from 2.2 mg/kg to 105 mg/kg. The levels of NPD, PAH and decalins in the samples are generally higher in 2005 than in 2002.

The Ba concentrations are relatively high and vary for VC-2(I) from 343 mg/kg in the 35-40 cm layer to 2100 mg/kg in the 15-20 cm layer. In the VC-2(II) the concentrations vary from 313 mg/kg in the 40-45 cm layer to 1500 mg/kg in the 80-115 cm layer. Compared to 2002 the concentrations are generally lower. Ba seems to be very heterogeneous distributed in the sediment layers.

Elevated levels of heavy metals are found in all layers. Lowest concentrations of the heavy metals are found in the 40-45 cm layer. Highest concentrations of heavy metals are found in the deepest layer investigated (90-130 cm and 80-115 cm).

Installation Centre at Yme fields

Also included in the survey are samples from the Installation Centre 0°/0m and from stations at 100m distance at Yme Gamma and Yme Beta.

At Yme Gamma the sediments at the Installation Centre consist mainly of silt and clay, while the 100m stations are characterized as medium sand. The total organic matter content at the Centre is high, 5.6 %. The TOM content at the 100m stations vary from 0.7 % to 2.8 %.The THC concentration is high at the Centre, 4510kg. High levels are also found at the some of the 100m stations, maximum 706 mg/kg. However, the THC content has decreased considerably since 2002. The “central” sediments also contain olefins, however these are not quantified.

The Ba concentration at the Centre is 700 mg/kg and at the 100m stations, from 2250 mg/kg to 5630 mg/kg. The Ba content has decreased markedly since 2002.

Elevated levels of all the metals are found both at the Centre and at the 100m stations.

At Yme Beta Installation Centre, the silt and clay content is less than at Yme Gamma. At the 100m stations the silt and clay content is similar to the regular Yme Beta monitoring stations. The total organic matter content is lower than at Yme Gamma, 2.5 % at the Centre and 0.4 % to 0.6 % at the 100m stations.

The THC concentrations at the Centre are 350 mg/kg, and lower at the 100m stations, which varies from 2.3 mg/kg to 58 mg/kg. Olefins are found at some stations. The THC content has decreased considerably since 2002.

PFOS (25.8 µg/kg) is found at the one station analysed at Yme Gamma Central, YMEG-II, 120°/100m.

The Ba concentration is high at the Centre, 3040 mg/kg. Elevated Ba concentrations are found at the 100m stations, from 90 mg/kg to 1340 mg/kg. The Ba content has decreased considerably since 2002. Elevated levels of the metals are found at the Centre.

Macro benthic fauna

The results from 2005 reveal that the fauna community in the central part of the Ekofisk region is disturbed to varying extents. This is a consequence of physical disturbances, the activities in the area and a diffuse organic load from various sources affecting the North Sea.

The results reflect that the Ekofisk region is exposed to some general temporal and geographical changes. The great variations in the presence of *M. oculata* from 1996 to 2005 have complicated the faunal picture, making it difficult to draw conclusions about the state of the fauna community. Adding the 2005 results to the trend data have, however, strengthened the data set, and has made it possible to obtain a pattern in the overall temporal variations in the entire region.

The statistical analyses show increased biodiversity and increasing numbers of species. A increase in the numbers of individuals on the expense of *M. oculata* indicates a general improvement in the fauna community in the Ekofisk region. Species that are numerous all over the region in 2005 are the brittle star *Amphiura filiformis* and the bristle worms *Paramphinome jeffreysii* and *Apistobranchus tullbergi*. In general the fauna communities are dominated by suspension feeders (*M. oculata*, *Ditrupa arietina*, *A.filiformis, Thyasira* species, hydroids and anthozoa species) and carnivore species like *P. jeffreysii*.

The trend analyses reveal a distinct improvement in the fauna at least 500 m from the field centers. At a radius of 250 m from the field centers the trend data are somewhat diffuse and no clear trend is observed from the last survey in 2002. An exception is the Ekofisk A field in 2005, where some stations have improved. The analyses indicate that the organic load is highest around the regional stations 2 and 6 and the improvement of the fauna communities is slowest around Ula, Gyda, Tambar and Tor. However, the densities of individuals in the region still indicate a relatively high, though decreasing supply of organic matter to the macro fauna.

4.2 Regional stations

4.2.1 Chemical analyses and sediment structure

The sediments at the Regional stations consist mainly of fine sand, and the sand contents vary from 95 % to 99 %, see Table 4.2.1. The gravel contents are low, and only small amounts are found at four of the stations. The silt and clay contents are in general similar to previous observations.

The total organic matter contents in the sediments are low and only small variations are found at the Regional stations, from 0.7 % to 1.1 %, see Table 4.2.1. The contents correspond to the grain size distribution with low pelite contents. The results are similar to the previous surveys in 2002, 1999 and 1996.

The concentrations of hydrocarbons, barium and heavy metals are low, and the sediments are not contaminated, see Table 4.2.2. The THC concentrations in the sediments vary from 1.3 mg/kg to 5.8 mg/kg. The NPD concentrations vary from below 0.01 mg/kg to 0.02 mg/kg, and the PAH concentrations vary from 0.013 mg/kg to 0.051 mg/kg. Small amount of decalins are detected in some of the grab samples. The concentrations of Ba vary from 4 mg/kg to 72 mg/kg. The concentrations of the heavy metals are similar to previous surveys.

Three subregions are identified from Region I:

- Subregion A: Regional 1, Regional 3, Regional 4, Regional 5, Regional 6, Regional 7, Regional 8, Gyda ref. and Valhall ref.
- Subregion B: Regional 10 and Yme ref.
- Subregion C: Regional 2 and Regional 9.

For Subregion A and for Subregion B a limit of contamination value (LSC) is calculated for each parameter, see Table 4.2.3. Subregion C is not representative for any of the fields, and thus no LSC is calculated.

Table 4.2.1. *Regional stations, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station	Silt and clay			TOM			THC			
	2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
REG1, Ula Ref	4.3	5.3	3.5	0.84	0.86	1.06	3.9	3.3	4.1	3.9
REG2	2.2	2.4	3.5	0.85	0.84	0.94	2.5	2.8	2.6	4.3
REG3, Ekofisk Ref	2.6	2.6	5.3	0.88	0.82	0.95	5.8	5.9	5.5	5.4
REG4	4.8	5.5	2.9	0.86	0.87	0.93	5.1	5.4	5.3	6.3
REG5	5.2	4.1	4.4	0.98	0.92	1.14	2.5	3.7	3.6	6.8
REG6	4.3	4.5	3.7	1.02	0.92	1.13	2.3	4.0	4.1	6.5
REG7	3.3	3.8	3.3	1.05	0.89	1.11	3.4	5.0	4.3	4.2
REG8,Hod Ref.	1.0	3.0	2.8	0.78	0.78	0.71	4.3	4.1	3.9	5.3
REG9	1.9	2.3	1.4	0.68	0.61	0.78	2.2	1.6	1.4	
REG10	1.6	1.0	3.2	0.69	0.68	0.85	1.3	1.9	1.9	

Table 4.2.1. *cont.*

	NPD			PAH		
	2005	2002	1999	2005	2002	1999
REG1, Ula Ref.	n.d	0.022	0.022	0.029	0.041	0.034
REG2	n.d	0.015	0.008	0.030	0.042	0.023
REG3, Ekofisk Ref.	n.d	0.021	0.010	0.039	0.048	0.035
REG4	0.01	0.025	0.016	0.057	0.056	0.041
REG5	n.d	0.019	0.016	0.049	0.052	0.051
REG6	n.d	0.026	0.012	0.052	0.057	0.047
REG7	0.01	0.020	0.012	0.062	0.051	0.043
REG8, Hod Ref.	0.02	0.019	0.013	0.047	0.046	0.038
REG9	n.d	0.019	0.004	0.019	0.018	0.016
REG10	n.d	0.008	0.005	0.018	0.018	0.018

Table 4.2.2. *Regional stations 2005, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Stasjon	Ba	Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cr	Cu	Cu	Cu
	2005	2002	1999	1996	2005	2002	2005	2002	1999	2005	2002	1999
REG1, Ula ref	35	29	33	52	<0.01	<0.02	7	6.9	6.9	<0.5	1.3	0.6
REG2	18	18	13	23	<0.01	0.01	6.9	6.3	6.1	<0.5	0.8	0.4
REG3, Ekofisk ref	46	72	41	68	<0.01	<0.01	7.6	7.7	7.1	<0.5	1.0	0.8
REG4	72	67	67	102	<0.01	0.01	7.1	6.7	7.5	<0.5	1.0	0.6
REG5	35	35	28	42	<0.01	0.01	7.1	6.5	6.2	<0.5	1.0	0.5
REG6	31	27	31	35	<0.01	0.01	7.5	7.3	7.0	<0.5	1.2	0.6
REG7	55	48	31	58	<0.01	0.01	8.2	7.4	7.4	<0.5	1.1	0.5
REG8, Hod ref	32	45	31	51	<0.01	<0.04	7.1	6.9	6.6	<0.5	1.0	0.4
REG9	6	8	6		<0.01	<0.01	5.8	5.8	5.8	<0.5	0.9	<0.3
REG10	4	7	5		<0.01	<0.01	9.1	9.1	9.2	<0.5	1.0	0.5

Table 4.2.2. *cont.*

Station	Hg	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
	2005	2002	1999	2005	2002	1999	2005	2002	1999
REG1, Ula ref	<0.01	<0.01	0.01	6.2	6.1	7.3	5.4	6.2	5.6
REG2	<0.01	<0.01	0.01	4.7	4.6	4.5	4.9	4.9	3.6
REG3, Ekofisk ref	<0.01	<0.01	nd	6.1	6.3	5.8	5.4	5.6	4.7
REG4	<0.01	0.01	0.02	7.2	6.9	7.2	5.7	5.9	6.7
REG5	<0.01	0.01	0.02	6.7	6.8	6.8	6.3	7.4	5.3
REG6	<0.01	0.01	0.02	6.1	6.1	6.9	6	6.0	5.9
REG7	<0.01	0.01	0.02	6.8	7.0	7.3	6.4	6.4	5.4
REG8, Hod ref	<0.01	<0.01	0.01	5.8	6.1	6.2	5.9	6.0	5.3
REG9	<0.01	<0.01	nd	4	3.7	3.9	3.1	3.5	2.7
REG10	<0.01	<0.01	nd	5.4	6.0	6.4	6.8	8.2	6.7

Table 4.2.3. LSC values Region I 2005 (mg/kg dry sediment). 95 % confidence level, one-tailed t-test.

Parameter	**Subregion A**			**Subregion B** (Yme fields)		
	Mean	SD	LSC	Mean	SD	LSC
THC	4.6	1.1	6.6	2.4	0.9	4.6
Ba	44.9	17.5	76.2	6.4	2.3	12.1
Cr	7.2	0.5	8.0	8.3	1.1	11.1
Cu	0.7	0.3	1.3	0.6	0.3	1.4
Pb	6.5	0.5	7.4	6.6	1.0	9.0
Zn	5.8	0.6	6.9	7.2	0.6	8.8
NPD	0.016	0.008	0.030	0.004	0.003	0.012
PAH	0.045	0.009	0.061	0.016	0.003	0.024

4.2.2 Biology

The similarity analysis and the biodiversity indices indicate that the fauna at stations REG-02, -03, -04 and -06, located in the central part of the region, are somewhat disturbed, see Figure 4.2.1 and Table 4.2.4.

The trend analysis indicated that the fauna community at REG-10 has been unaltered since at least 1999. At Reg-04 and -08, which are located further south in the Valhall and Hod area, the fauna is improving, indicating a higher ecological quality in this area than earlier. The fauna at REG-2, -3 and -6 is still somewhat disturbed and there are signs of reduced ecological quality. But there are indications of improvements since the previous surveys. At the other regional stations there have been changes in the fauna community over the years, but the changes can not be related to increased disturbances of the fauna.

The high abundance of *M. oculata* which had a peak in 2002 seems to some extent to have been replaced by Amphiuridae (mainly *A. filiformis*), Amphinomidae (mainly *P. jeffreysii)* and Apistobranchidae (mainly *A. tullbergi)* in 2005, indicating a general positive trend in some areas.

The results reflect that the Ekofisk region is exposed to some general temporal and geographical changes. The great variations in the presence of *M. oculata* from 1996 to 2005 have complicated the faunal picture, making it difficult to draw conclusions about the state of the fauna community. Adding the 2005 results to the trend data have, however, strengthened the data set, and has made it possible to obtain a pattern in the overall temporal variations in the entire region (see General Trends in the Region).

Table 4.2.4. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Regional stations 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
Reg-01	315	6000	73	82	944	4.4	4.7	0.7	30	33.3
Reg-02			68	73	2278	2.9	3.9	0.5	18	24.7
Reg-03	90	15000	70	75	1635	3.2	4.4	0.5	22	29.6
Reg-04			72	59	908	3.7	4.0	0.6	23	26.1
Reg-05			72	77	744	4.7	4.7	0.7	33	33.4
Reg-06			70	72	2265	2.7	4.0	0.4	17	26.6
Reg-07			73	66	862	3.9	3.9	0.6	25	27.4
Reg-08	180	15000	70	53	527	3.7	3.6	0.6	23	25.0
Reg-09			69	64	773	4.4	4.5	0.7	27	28.2
Reg-10			87	67	327	5.1	5.1	0.8	38	39.2

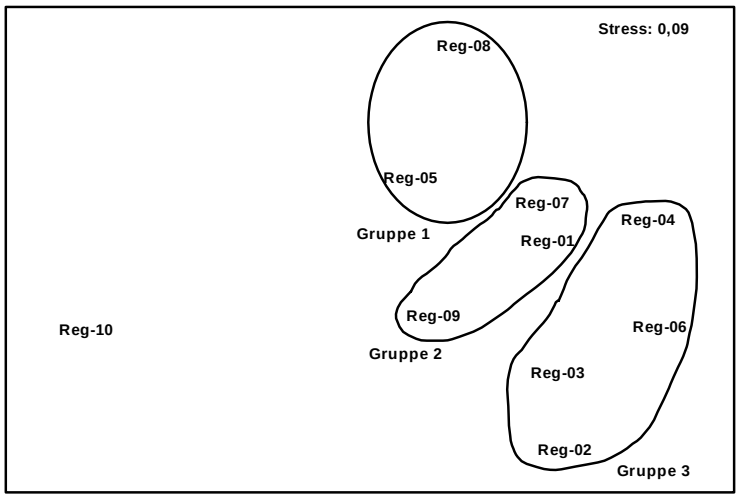

Figure 4.2.1. *MDS plot of Regional stations 2005 (excl. juv.).*

4.3 Valhall

4.3.1 Chemical analyses and sediment structure

The sediments at Valhall consist mainly of fine sand, and the sand content varies from 85 % at VAL8 (164°/500m) to 98 % at VAL reference station (254°/15000m), see Table 4.3.2. The gravel content is low. The silt and clay content is similar or slightly higher than previously observed.

The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.8 % to 1.5 %, see Table 4.3.2. The results are similar to the previous surveys in 2002, 1999 and 1996.

The mean THC concentrations in the top 0-1 cm layer vary from 4.3 mg/kg at VAL reference station to 130 mg/kg at VAL2, 74°/500m, see Table 4.3.2. VAL2 was not investigated in 2002. The concentration of THC has decreased distinctly for all stations since last survey. Relative high concentrations of THC are found for VAL8 and VAL15 at 500m distance from the platform, about 75 mg/kg. Generally, the concentration of THC is higher down in the layers. The maximum concentration found is 726 mg/kg in the 1-3 cm at VAL8. All the stations except for VAL16, 254°/2000m and the reference station have elevated THC levels, however, some stations just slightly elevated.

As in the survey of 2002, small amounts of olefins were found at VAL 8, (164°/500m), but not quantified.

Elevated levels of NPD and PAH are found at VAL8, 164°/500m, both in the top layer and in the vertical layers, see Table 4.3.2. The maximum concentration of NPD is found in the 1-3 cm layer (2.9 mg/kg). High concentrations of decalins are found in the vertical layers with maximim 11.1 mg/kg, while the content of decalins has decreased significantly in the top layer.

At VAL109 the content of NPD, PAH and decalins has decreased since last survey to about the level of significant contamination.

Station VAL8, 164°/500m is analysed for PFOS (perfluorooctyl sulphonate), see Table 4.3.1. The content was found to be 1.25 µg/kg.

Elevated Ba concentrations are found at all stations, except for the reference station, see Table 4.3.3. In general the Ba levels are similar to previous surveys. High Ba concentrations are also found in the deeper sections at VAL8 and VAL9.

The highest concentrations of the heavy metals are found at VAL2, 74°/500m and elevated concentrations are observed, see Table 4.3.3. Slightly elevated concentrations are also found at the other stations. The levels are similar or slightly lower than previous surveys.

The chemical results are in correspondence with the drilling history at Valhall.

Table 4.3.1. *Valhall 2005, PFOS (perfluorooctyl sulphonate), µg/kg dry sediment.*

Station		PFOS
VAL8	74°/500m	1.32
		1.05
		1.38
Mean		**1.25**
SD		0.14

Limit of detection: 0.1 µg/kg

Table 4.3.2. *Valhall, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
VAL2	74°/500m	7.5			1.04			130			
VAL3	74°/1000m	6.0	5.8		0.97	1.01		21	60.5		
VAL4	74°/2000m		4.7	5.5		0.89	0.41	8.5	12.7	10.8	14.9
VAL8	164°/500m	7.7	7.6		0.97	1.20		78	274		
	1-3 cm							726	313		
	3-6 cm							83	396		
VAL109	160°/1000m	6.0	5.8	4.1	0.89	0.94	0.90	13.5	27	65	42
	1-3 cm							41	71	81	51
	3-6 cm							49	74.3	49	11.4
VAL110	160°/2000m		6.0	3.4		0.90	0.76	6.8	12.8	11.0	13.2
VAL15	254°/500m	9.9			1.52			75			
VAL16*	254°/1000m		5.0	4.5		0.96	0.90	7.9	16.5	34	137
VAL16	254°/2000m		5.2	4.7		0.73	0.69	5.6	7.9	10.2	
VAL21	344°/500m	14.9	6.1		0.95	0.89	-	8.0	17.2		
VAL22	344°/1000m		5.4	4.8		0.83	0.84	8.0	12.1	14.9	22
VAL123	340°/2000m		4.2	6.1		0.76	1.13	7.4	8.2	8.2	8.7
VAL Ref.	254°/15000m	1.6	4.2	3.2	0.82	0.72	0.74	4.3	4.8	5.1	6.1
	1-3 cm							8.6	5.6	6.4	3.7
	3-6 cm							6.8	6.9	7.2	5.5

Table 4.3.2. *cont.*

Station		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
VAL8	164°/500m	0.59	0.782		0.125	0.174		0.8	7.9	
	1-3 cm	2.89	1.11		0.153	0.159		11.1	7.4	
	3-6 cm	1.90	1.15		0.197	0.209		6.8	12.4	
VAL109	160°/1000m	0.04	0.084	0.084	0.062	0.106	0.080	n.d	0.28	0.78
	1-3 cm	0.13	0.12	0.105	0.123	0.095	0.156	0.3	0.89	2.04
	3-6 cm	0.08	0.20	0.090	0.165	0.123	0.165	0.1	1.42	1.32
VAL Ref.	254°/15000m	0.01	0.015	0.015	0.051	0.035	0.048	0.8	nd	nd
	1-3 cm	0.018	0.018	0.020	0.057	0.046	0.063	11.1	nd	nd
	3-6 cm	0.016	0.026	0.026	0.067	0.074	0.085	6.8	nd	nd

Table 4.3.3. *Valhall, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999	Cu 2005	Cu 2002	Cu 1999
VAL2	74°/500m	5587				0.03			10.4			9.6		
VAL3	74°/1000m	1727	2120			<0.01	0.02		8.2	7.6		1.4	2.9	
VAL8	164°/500m	4005	5120			0.01	0.08		7.8	8.5		3.9	7.8	
	1-3 cm	5077	5270			0.12	0.16		8.6	8.6		3.7	6.4	
	3-6 cm	4583	1040			0.07	0.05		9.2	9.0		2.7	2.6	
VAL109	160°/1000m	1373	1060	2160	2420	<0.01	0.01	<0.02	8.1	6.5	7.8	1.0	1.8	1.2
	1-3 cm	2787	1550	1910		0.02	0.02	<0.02	8.9	6.4	8.0	1.4	3.2	1.1
	3-6 cm	1346	2160	989		0.02	0.02	0.02	9.6	7.4	9.6	1.4	2.2	1.2
VAL15	254°/500m	2711				0.03			10.5			2.6		
VAL21	344°/500m	653	840			<0.01	0.01		8.7			1.2	2.2	
VAL Ref	254°/15000m	28	35	47	67	<0.01	<0.01	<0.02	7.7	7.7	8.1	<0.5	1.2	0.5
	1-3 cm	40	52	68		<0.01	<0.01	<0.02	8.3	7.7	8.1	0.18	0.8	0.5
	3-6 cm	88	94	139		<0.01	<0.01	<0.02	8.2	7.9	8.8	0.26	1.0	1.0

Table 4.3.3. *cont.*

Station		Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
VAL2	74°/500m				19.1			32.5		
VAL3	74°/1000m				10.3	11.8		9.9	12.3	
VAL8	164°/500m	0.02	0.03		10.7	19.5		13.7	31.8	
	1-3 cm	0.02	0.03		21.2	23.5		29.6	36.5	
	3-6 cm	0.02	0.02		17.1	11.1		24.4	18.7	
VAL109	160°/1000m	<0.01	0.01	0.02	11.1	8.4	10.8	7.8	9.0	8.7
	1-3 cm	0.02	0.02	0.02	12	8.7	11.3	11.2	6.8	10.0
	3-6 cm	0.01	0.02	0.03	12.2	11.0	11.4	11.1	12.7	11.7
VAL15	254°/500m				13.3			17.5		
VAL21	344°/500m				9.9	9.4		8.7	10.9	
VAL Ref.	254°/15000m	<0.01	0.01	0.02	6.5	6.8	8.1	5.6	6.3	6.1
	1-3 cm	<0.01	0.01	0.02	7.6	6.6	8.3	6.2	5.9	6.4
	3-6 cm	<0.01	0.01	0.02	7.3	7.0	9.3	6.6	6.3	8.1

4.3.2 Biology

The biodiversity indices are relatively high compared to several other fields in the central Ekofisk region, see Table 4.3.4. However, they indicate a small general disturbance in the fauna community which presumably reflects physical disturbance as well as a diffuse organic load in the area. The fauna at the reference station (254°/15000m) has slightly lower biodiversity indices than the other stations. The station also differs with a slightly coarser type of sediment. The similarity analysis indicates a slight disturbance at VAL-02 (74°/500m) and -08 (164°/500m) correlated to THC, Ba and Cu, see Figure 4.3.1.

The samples from stations VAL-02 and -08 contained oil lumps. The observation from VAL-08 corresponds with the elevated concentrations of THC, NPD and decalins in the deeper sections of the sample (1-6 cm).

In general, the biodiversity at Valhall (including *M. oculata*[1]), has increased significantly since 2002, indicating a positive trend in the fauna community.

The sediment characteristics and thus the fauna composition at the Valhall reference station deviates somewhat from the field stations and should be considered replaced, see Figure 4.3.1.

Large amounts of yellow granules were found in the samples at all the Valhall stations. BP has established an investigation group to find out more about the origin and properties of the observed granules.

Table 4.3.4. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Valhall 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
VAL-02	74	500	74	69	1424	3.6	3.6	0.6	24	23
VAL-03	74	1000	74	60	1439	3.7	3.7	0.6	21	23
VAL-08	164	500	73	93	2300	3.4	3.4	0.5	23	26
VAL-109	160	1000	72	79	1900	3.3	3.8	0.5	21	27
VAL-15	254	500	74	66	1334	3.8	3.7	0.6	24	24
VAL-21	344	500	75	76	1864	3.4	3.8	0.5	22	27
VAL-REF	254	15000	72	63	1771	2.5	4.3	0.4	18	30

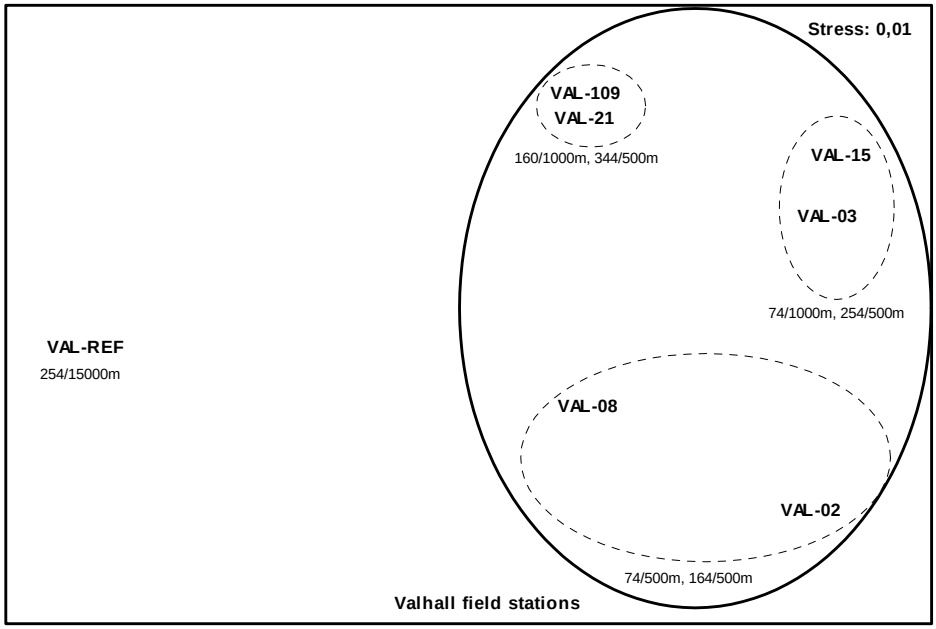

Figure 4.3.1. *MDS plot of stations from Valhall 2005 (excl. juv.).*

[1] On the basis of trend analyses of the entire region the data including *M. oculata* has been emphasized, see also General Trends in the Region.

4.4 Valhall Nordflanken

4.4.1 Chemical analyses and sediment structure

The sediments at Valhall Nordflanke consist mainly of fine sand, and the sand content varies from 93 % at VAN10, 254°/500m, to ~100 % at VAN2, 74°/500m, see Table 4.4.1. The average sand content is 95.6 %. The gravel content is low, and small amounts are only found at two of the stations. The silt and clay content is also low. The average silt and clay concentration found is 4.4 %.

The total organic matter is low, see Table 4.4.1. The values vary from 0.8 % to 0.9%. This is in accordance with the sediments of homogeneous, fine sand.

The concentrations of hydrocarbons are low and at the same level as in the 2001 baseline survey, see Table 4.4.1. In the present investigation the THC concentrations in the top 0-1 cm layer vary from 5.1 mg/kg at VAN14 344°/500 m to 8.4 mg/kg at VAN11 254°/1000 m. At one station the sediment layers, 1-3 cm and 3-6 cm are analysed. A tendency of slightly higher concentrations of THC down in the sediments is observed. The content of THC is considered to be within the natural level at Valhall Nordflanke and none of the stations are contaminated.

The concentrations of NPD, PAH and decalins are low for the one station investigated, VAN5 164°/250m, see Table 4.4.1. The content is below or just about the limit of contamination.

In the present survey the Ba concentrations vary from 94 mg/kg at VAN10, 254°/500m to 468 mg/kg at VAN9, 254°/250m, see Table 4.4.2. Elevated Ba concentrations are found at all stations, except for the reference station. Thus elevated levels of Ba are found out to 500m in all directions. High Ba concentrations are also found in the vertical sections at VAN5 and the Ba concentration increases downwards in the sediments. The content of Ba has increased since the 2001 survey. This is in accordance with discharge of barite and cuttings in 2003.

The concentration of heavy metals are low and at the same level as found in the baseline survey, see Table 4.4.2. The chemical results are in correspondence with the drilling history at Valhall Nordflanke.

Table 4.4.1. *Valhall Nordflanke, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment.*

		Silt and clay		TOM		THC	
		2005	2001	2005	2001	2005	2001
VAN1	74°/250m	3.4	2.7	0.8	0.9	7.5	6.7
VAN2	74°/500m	0.3	4.7	0.8	0.8	5.2	6.5
VAN3	74°/1000m		4.6		0.8	5.3	9.8
VAN5	164°/250m	3.3	5.3	0.9	0.9	6.8	7.8
	1-3cm					7.7	8.4
	3-6cm					12.1	7.8
VAN106	155°/500m	3.8	4.1	0.9	0.8	5.6	8.0
VAN107	155°/850m		4.4		0.8	6.4	8.2
VAN8	164°/2000m		3.9		0.8	6.2	7.3
VAN9	254°/250m	4.8	1.8	0.9	0.8	5.8	7.6
VAN10	254°/500m	7.1	4.1	0.9	0.8	5.7	7.0
VAN11	254°/1000m		2.0		0.7	8.4	7.1
VAN13	344°/250m	5.7	4.0	0.9	0.7	5.8	7.6
VAN14	344°/500m	6.4	4.3	0.9	0.8	5.1	8.1
VAN15	344°/1000m		2.5		0.8	5.6	7.7
VAL Ref	254°/15000m	1.6	2.7	0.8	0.7	4.3	6.1
	1-3cm					8.6	6.9
	3-6cm					6.8	9.5

Table 4.4.1. *cont.*

		NPD		PAH		Dekalins	
		2005	2001	2005	2001	2005	2002
VAN5	164°/250m	0.01	0.017	0.043	0.053	0.1	nd
	1-3cm	0.02	0.032	0.060	0.075	0.1	
	3-6cm	0.03	0.023	0.102	0.066	0.1	
VAL Ref,	254°/15000m	0.013	0.011	0.051	0.040	0.17	nd
	1-3cm	0.018	0.012	0.057	0.040	0.26	nd
	3-6cm	0.016	0.030	0.067	0.053	nd	nd

Table 4.4.2. *Valhall Nordflanke, Ba, Cd, Cr, Cu, Hg, Pb og Zn (mg/kg dry sediment).*

Stasjon		Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001
VAN1	74°/250m	248	106	<0.01	0.03	8.3	7.6	0.7	0.6			8.0	7.4	6.9	6.3
VAN2	74°/500m	166	132	<0.01	<0.01	8.1	7.8	0.6	0.6			7.0	7.9	6.5	6.5
VAN5	164°/250m	111	111	<0.01	<0.01	8.2	7.8	0.6	0.7	<0.01	<0.01	7.8	7.6	6.8	6.4
	1-3 cm	225	209	<0.01	<0.01	9.4	8.3	0.7	0.7	<0.01	<0.01	8.9	8.4	8.6	7.7
	3-6 cm	317	467	<0.01	<0.01	9.1	8.8	0.7	0.8	<0.01	0.01	8.9	9.2	7.7	8.1
VAN106	155°/500m	205	133	<0.01	<0.01	9.1	8.1	0.7	0.6			8.5	8.0	7.7	6.8
VAN9	254°/250m	468	78	<0.01	<0.01	8.5	7.8	0.9	0.7			8.5	7.7	7.7	6.0
VAN10	254°/500m	94	94	<0.01	<0.01	7.6	7.6	0.6	0.6			6.9	7.3	6.0	5.8
VAN13	344°/250m	122	100	<0.01	<0.01	7.9	7.9	0.7	0.6			7.9	7.9	6.7	6.1
VAN14	344°/500m	168	110	<0.01	<0.01	7.7	8.1	0.6	0.7			7.6	7.9	6.1	6.7
VAL Ref	254°/15000m	28	53	<0.01	<0.01	7.7	8.1	<0.5	0.5	<0.01	<0.01	6.5	7.7	5.6	6.6

4.4.2 Biology

The biodiversity indices are relatively high compared to several other fields in the central Ekofisk region, see Table 4.3.3. However, they indicate a small disturbance in the fauna community which presumably reflects a general physical disturbance as well as a diffuse organic load in the area.

Since the baseline survey the THC levels have decreased at Valhall Nordflanke and the biodiversity indices (incl. *M. oculata*) have increased considerably since the baseline survey in 2001, which is partly due to a significant decline in the abundance of the bristle worm *M. oculata.*

Yellow granules were found at most of the stations.

None of the stations are considered affected by field activities, see Figure 4.4.1.

Table 4.4.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Valhall Nordflanke 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
VAN-01	74	250	71	91	1833	3.5	4.6	0.5	24	32
VAN-02	74	500	70	66	1657	3.3	4.8	0.6	22	34
VAN-05	164	250	71	80	1666	3.0	4.3	0.5	22	29
VAN-106	155	500	71	71	1007	4.0	4.8	0.7	26	34
VAN-09	254	250	69	70	1038	3.8	4.6	0.6	26	32
VAN-10	254	500	70	82	934	4.2	4.4	0.7	29	29
VAN-13	344	250	70	77	1921	3.0	4.3	0.5	20	30
VAN-14	344	500	70	79	1381	3.7	4.6	0.6	25	32
VAL-REF	254	15000	72	63	1771	2.5	4.3	0.4	18	29

M. o.= *M. oculata*

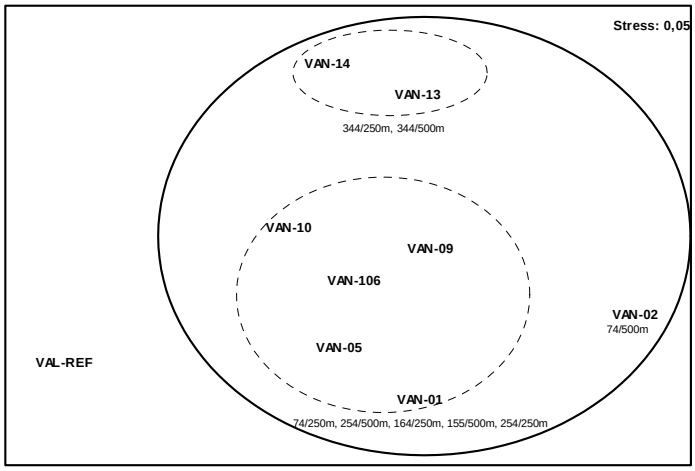

Figure 4.4.1. *MDS plot of stations from Valhall Nordflanke 2005 (excl. juv.).*

4.5 Valhall Sørflanken

4.5.1 Chemical analyses and sediment structure

The sediments at Valhall Sørflanke consist mainly of fine sand, and the sand content varies from 93.1 % at VAS113, 325°/250m, to 97.4 % at VAS10, 254°/500m, see Table 4.5.1. The average sand content is 95.4 %. The gravel content is low, and small amounts are only found at three of the stations. The silt and clay content is also low. The average silt and clay concentration found is 4.3%.

The total organic matter is low, see Table 4.5.1. The values vary from 0.6 % to 0.8 %. This is in accordance with the sediments of homogeneous, fine sand.

The concentrations of hydrocarbons are low and at the same level as in the 2001 baseline survey, see Table 4.5.1. In the present investigation the THC concentrations in the top 0-1 cm layer vary from 3.6 mg/kg at VAS7 164°/1000m to 5.3 at VAS1 74°/250m. At one station the sediment layers, 1-3 cm and 3-6 cm are analysed. A tendency of slightly higher concentrations of THC downwards in the sediments is observed. The content of THC is considered to be within the background level at Valhall Sørflanke and none of the stations are contaminated.

The concentrations of NPD, PAH and decalins are low for the station investigated, VAS5 at 164°/250m, see Table 4.5.1. The content is below or just about the limit of contamination.

In the present investigation the Ba concentrations vary from 43 mg/kg at VAS6, 164°/500m to around 190 mg/kg at VAS1, 74°/250m and VAS9, 254°/250m, see Table 4.5.2. Elevated Ba concentrations are only found at VAS1, 74°/250m, VAS2, 74°/500m and VAS9, 254°/250m. Thus elevated levels of Ba are found out to 500m in the 74° directions and limited to 250m in the 254° direction. For the other stations the Ba concentration found is below the limit of contamination. Elevated Ba concentrations are also found in the deeper section 3-6 cm at VAS5. The Ba concentration increases downwards in the sediments. The content of Ba has increased at VAS1, 74°/250m, VAS2, 74°/500m and VAS9, 254°/250m since the 2001 survey. This is in accordance with discharge of barite and cuttings in 2003 and 2004.

The concentration of heavy metals are low and at the same level as found in the baseline survey, see Table 4.5.2.

The chemical results are in correspondence with the drilling history at Valhall Sørflanke.

Table 4.5.1. *Valhall Sørflanke, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

		Silt og leire		TOM		THC	
		2005	2001	2005	2001	2005	2001
VAS1	74°/250m	5.0	2.8	0.6	0.7	5.3	6.4
VAS2	74°/500m	2.5	3.0	0.7	0.7	4.2	6.0
VAS3	74°/1000m					4.1	6.4
VAS5	164°/250m	3.5	0.7	0.7	0.7	4.8	5.3
	1-3 cm						5.5
	3-6 cm						
VAS6	155°/500m	6.6	2.0	0.7	0.7	4.0	6.0
VAS7	164°/1000m					3.6	5.2
VAS9	254°/250m	3.7	0.8	0.7	0.6	5.0	6.2
VAS10	254°/500m	2.6	2.8	0.8	0.7	4.6	6.2
VAS11	254°/1000m					4.5	-
VAS113	325°/250m	6.8	4.5	0.7	0.7	4.7	7.1
VAS14	344°/500m	3.9	3.8	0.8	0.7	4.6	6.9
VAS15	344°/1000m					4.8	6.4
VAL Ref.	254°/15000m	1.6	2.7	0.8	0.7	4.3	6.1
	1-3cm					8.6	6.9
	3-6cm					6.8	9.5

Table 4.5.1. *cont.*

		NPD		PAH		Dekalins	
		2005	2001	2005	2001	2005	2002
VAS5	164°/250m	nd	0.010	0.020	0.034	nd	nd
	1-3 cm	0.013	0.012	0.043	0.041	0.0	
	3-6 cm	0.014	0.019	0.061	0.058	0.0	
VAL Ref.	254°/15000m	0.013	0.011	0.051	0.040	0.17	nd
	1-3cm	0.018	0.012	0.057	0.040	0.26	nd
	3-6cm	0.016	0.030	0.067	0.053	nd	nd

Table 4.5.2. *Valhall Sørflanke, Ba, Cd, Cr, Cu, Hg, Pb og Zn (mg/kg dry sediment).*

Stasjon		Ba 2005	Ba 2001	Cd 2005	Cd 2001	Cr 2005	Cr 2001	Cu 2005	Cu 2001	Hg 2005	Hg 2001	Pb 2005	Pb 2001	Zn 2005	Zn 2001
VAS1	74°/250m	193	38	<0.01	<0.01	6.7	6.9	0.6	0.5			6.2	6.2	5.6	5.2
VAS2	74°/500m	175	36	<0.01	<0.01	6.6	6.9	0.7	0.4			6.6	6.3	5.6	5.3
VAS5	164°/250m	56	33	<0.01	<0.01	6.8	6.8	<0.5	0.4	0.01	<0.01	6.1	6.1	5.5	5.4
	1-3 cm	75	51	<0.01	<0.01	6.6	7.4	0.5	0.9	0.01	<0.01	6.4	6.7	5.9	6.8
	3-6 cm	150	79	<0.01	<0.01	7.8	7.3	0.6	0.6<	<0.01	<0.01	7.7	6.3	6.5	5.6
VAS6	164°/500m	43	36	<0.01	<0.01	6.3	6.6	<0.5	0.4			5.9	6.0	4.9	5.2
VAS9	254°/250m	194	38	<0.01	0.01	7.2	7.1	0.5	0.4			7.4	6.5	5.8	5.4
VAS10	254°/500m	57	41	<0.01	<0.01	7.1	7.4	<0.5	0.5			6.7	6.5	5.5	5.4
VAS113	325°/250m	63	68	<0.01	<0.01	6.9	7.3	<0.5	0.5			5.8	6.7	5.3	6.0
VAS14	344°/500m	53	70	<0.01	<0.01	7.2	7.4	<0.5	0.5			6.9	6.5	5.3	5.7
VAL Ref	254°/15000m	28	53	<0.01	<0.01	7.7	8.1	<0.5	0.5	<0.01	<0.01	6.5	7.7	5.6	6.6

4.5.2 Biology

The biodiversity indices are relatively high compared to several other fields in the central Ekofisk region, see Table 4.5.3. However, they indicate a small disturbance in the fauna community which presumably reflects a physical disturbance as well as a general diffuse organic load in the area. The fauna community at station VAS-01 (74/250m) in particular but also station VAS-02 (74/500m) differed slightly from the other Valhall sørflanke stations in the similarity analysis (Figure 4.5.1), and also showed somewhat lower biodiversity indices. However, the levels of metals and THC in the sediments were not elevated at these stations. The oil and organic matter that was observed in the VAS-01 and VAS-02 samples, probably originated from somewhat deeper layers of the sediment.

The indices have increased considerably since the baseline survey in 2001 and the reason for this is partly a significant decline in the abundance of the bristle worm *M. oculata* since 2001. In general the levels of THC and metals in the sediments have decreased since 2001.

Yellow granules were found in most of the samples.

Table 4.5.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Valhall Sørflanke 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H' Incl. M. o.	H' Excl. M. o.	J	ES_{100} Incl. M. o.	ES_{100} Excl. M. o.
VAS-01	74	250	68	69	2384	2.6	4.3	0.4	18	28
VAS-02	74	500	68	61	1316	3.4	4.2	0.6	22	29
VAS-05	164	250	68	60	668	4.3	4.7	0.7	28	31
VAS-06	164	500	68	59	614	4.5	4.5	0.8	30	30
VAS-09	254	250	68	69	925	4.0	4.1	0.7	26	28
VAS-10	254	500	68	64	778	4.0	4.2	0.7	27	29
VAS-113	325	250	69	63	942	3.9	3.9	0.7	24	25
VAS-14	344	500	69	67	799	4.1	4.4	0.7	27	30
VAL-REF	254	15 000	72	63	1771	2.5	4.3	0.4	18	29

M. o.= *M. oculata*

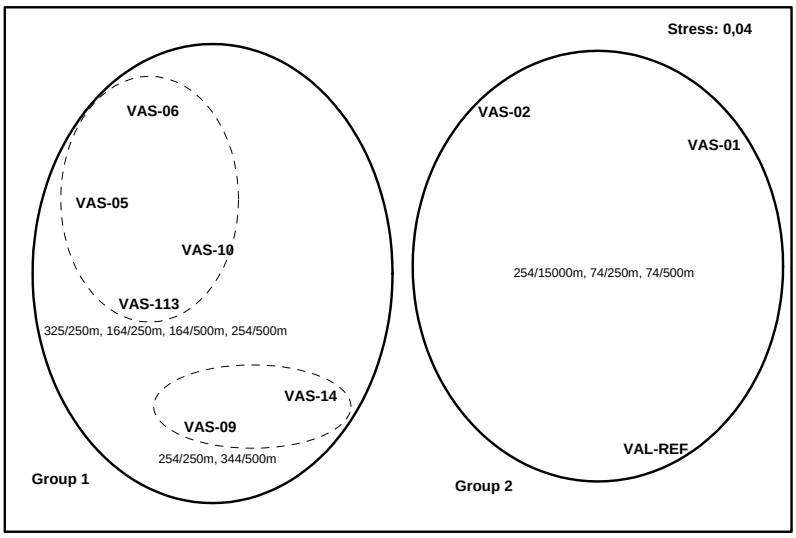

Figure 4.5.1. *MDS plot of stations from Valhall Sørflanke 2005 (excl. juv.).*

4.6 Hod

4.6.1 Chemical analyses and sediment structure

The sediments at Hod consist mainly of fine sand, and the sand content varies from 91 % at to 97 %, see Table 4.6.1. The gravel content is low. The silt and clay content is similar to previous observations.

The total organic matter content in the sediments is low and only small variations are found at the field, from 0.8 % to 1.3 %, see Table 4.6.1. The TOM content is similar to the result from the previous surveys in 2002, 1999 and 1996.

The mean THC concentrations vary from 4.3 mg/kg at HOD reference station, 180°/15000m to 36 mg/kg at HOD8, 164°/500m, see Table 4.6.1. HOD2, 74°/500m was the most contaminated station, concerning THC and olefins in the 2002 survey. Compared to this survey the concentrations of THC have now decreased almost to the background level. The content of olefins has also decreased from 17.6 mg/kg to 0.9 mg/kg.

At HOD8, a decrease in the THC concentration is observed in the 0-1 cm top layer, and in the deeper layers 1-3 cm and 3-6 cm compared to previous surveys. At the other stations the concentrations are similar to previous surveys.

Elevated THC levels are found at HOD8, 164°/500m. The stations HOD2, 74°/500m and HOD13, 254°/315m are only slightly elevated. The other stations have THC content below the limit of contamination for this region.

Olefins are detected at the six stations analysed, and varies from 0.7 mg/kg at HOD3, 74°/1000m to 7.1 mg/kg at HOD8, 164°/500m, see Table 4.6.1. The olefin concentrations have decreased compared to previous surveys for all the stations investigated. This is also in agreement with the results observed for THC.

No discharges of olefins have taken place since 1994 (337 tonnes of Novasol) and 1995 (85 tonnes of Novaplus), see Table 4.6.1. The olefin concentration is low and at the same level for all the stations, in average 1 mg/kg. An exception is observed for HOD8 with an olefin concentration of 7 mg/kg.

Elevated concentrations of NPD are found at HOD8, 164°/500m in all three layers and in the vertical sections of HOD9, 164°/1000m, see Table 4.6.1. HOD8 and HOD9 has PAH

concentrations just at the limit of contamination in the top 0-1 cm layer, while the PAH content in the deeper layers are higher. The decalin content is similar or lower compared to the 2002 survey.

The Ba concentrations vary from 32 mg/kg at HOD reference station 180°/15000m to 900 mg/kg at HOD2, 74°/500m, see Table 4.6.2. Elevated Ba concentrations are found at all stations, except for the reference station. This means out to 1000m in the 164° direction, to 500m in the 74° direction, to 315m in the 254° direction and to 250m in the 344° direction. In general the Ba levels are similar to the levels found in previous surveys. Elevated Ba concentrations are found in the vertical sections at HOD8 and HOD9, and the concentration increases going down in the sediments.

The concentrations of the heavy metals are low, but slightly elevated concentrations of Pb and Zn are found, see Table 4.6.2.

No drilling activity has taken place at Hod since the survey in 1996. However, hydrocarbons originating from drilling discharges are still present in the sediments.

Table 4.6.1. *Hod, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay			TOM			THC			Olefins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
HOD2	74°/500m	7.8	6.0		1.1	1.02		7.8	165		0.9	17.6	
HOD3	74°/1000m		6.3	6.5		0.95	0.94	4.5	10.6	13.2	0.7	1.7	1.2
HOD8	164°/500m	5.6	6.3	6.6	1.3	0.93	1.05	36	37	135	7.1	11.2	7.8
	13 cm							41	210	59			
	36 cm							10.6	27	47			
HOD9	164°/1000m		6.0	4.7		0.87	0.95	6.2	9.6	12.6	0.9	1.5	1.5
	13 cm							5.6	10.5				
	36 cm							5.4	17.1				
HOD13	254°/315m	8.6			1.0			8.5			1.1		
HOD14	254°/500m		4.6			0.90		5.4	9.6		0.9	2.0	
HOD19	344°/250m	2.7			0.96			4.5					
HOD20	344°/500m		5.6	4.6		0.92	0.51	5.3	8.1	10.3			
HOD Ref.	180°/15000m	1.0	3.0	3.6	0.78	0.78	0.71	4.3	4.1	3.9			
	13 cm								5.3	3.8			
	36 cm								6.0	6.2			

Table 4.6.1. *cont.*

Station		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
HOD8	164°/500m	0.09	0.066	0.22	0.065	0.064	0.074	0.9	0.49	4.7
	13 cm	0.18	0.54	0.13	0.18	0.15	0.16	1.6	8.3	2.1
	36 cm	0.06	0.086	0.14	0.23	0.20	0.20	0.4	0.36	1.5
HOD9	164°/1000m	0.03	0.026		0.077	0.058		n.d	nd	
	13 cm	0.04	0.030		0.12	0.071		n.d	nd	
	36 cm	0.07	0.058		0.23	0.13		n.d	0.095	
HOD Ref.	180°/15000m	0.02	0.019	0.013	0.047	0.046	0.038	0.2	nd	nd
	13 cm	0.016	0.037	0.014	0.070	0.076	0.040	n.d	nd	nd
	36 cm	0.020	0.033	0.25	0.080	0.074	0.32	n.d	nd	nd

Table 4.6.2. *Hod, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
HOD2	74°/500m	901	1520		1180	<0.01	0.04		8.0	7.1	
HOD8	164°/500m	727	762	1600	1990	<0.01	<0.01	0.02	7.3	7.0	7.8
	1-3 cm	1227	1330	1680		0.02	0.03	0.03	8.2	8.9	8.8
	3-6 cm	1660	1252	1780		0.07	0.04	0.04	12.6	9.6	9.9
HOD13	254°/315m	527				<0.01			6.9		
HOD9	164°/1000m	187	320	332	515	<0.01	<0.01	<0.02	7.6	7.2	7.8
	1-3 cm	250	854			<0.01	0.02		7.6	8.4	
	3-6 cm	422	839			0.01	0.03		8.8	9.4	
HOD19	344°/250m	287				<0.01			6.9		
HOD Ref.	180°/15000m	32	45	31	48	<0.01	<0.04	<0.02	7.1	6.9	6.6
	1-3 cm	45	51	29		<0.01	<0.01	<0.02	7.8	7.0	6.8
	3-6 cm	86	89	53		<0.01	<0.01	<0.02	8.4	7.2	7.2

Table 4.6.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
HOD2	74°/500m	0.9	1.9					10.5	14.2		8.6	12.6	
HOD8	164°/500m	1.0	1.5	1.1	<0.01	0.02	0.03	8.9	9.4	11.7	7.2	7.7	11.2
	1-3 cm	1.4	2.3	1.3	0.01	0.02	0.03	11.0	12.2	12.9	10.6	18.7	13.1
	3-6 cm	2.6	2.5	1.4	0.02	0.02	0.04	18.3	13.0	13.3	20.8	14.3	17.4
HOD9	164°/1000m	0.6	1.8	0.6	<0.01	0.01		9.1	8.7	7.3	7.4	8.4	7.5
	1-3 cm	0.8	1.8		0.01	0.02		8.7	11.1		7.4	11.6	
	3-6 cm	1.0	2.8		<0.01	0.02		9.6	12.7		9.3	12.9	
HOD13	254°/315m	0.8						8.7			7.1		
HOD19	344°/250m	0.6						7.4			6.5		
HOD Ref.	180°/15000m	<0.5	1.0	0.4	<0.01	0.01	0.01	5.8	6.1	6.2	5.9	6.0	5.3
	1-3 cm	<0.5	1.1	0.4	<0.01	0.01	0.01	6.5	6.1	6.3	6.7	6.6	5.3
	3-6 cm	<0.5	1.2	0.5	<0.01	0.02	0.01	8.2	6.9	6.7	7.4	6.8	5.9

4.6.2 Biology

In general the indices reflect a slightly disturbed benthic fauna in the Hod area, which is difficult to relate to direction or distance from the field centre, see Table 4.6.3. The indices are, however, relatively high compared to other fields in the central Ekofisk region.

The fauna at stations HOD-2, -8 and -13 differ somewhat from the others (Figure 4.6.1), but the deviations can not be related to the field activities. The fauna at the reference station (180/15000m) differs from the rest of the HOD stations and should be reconsidered as a reference station.

The biodiversity in the fauna community at Hod has increased relatively much since 2002, approaching the results from surveys prior to 2002. There has been a significant decrease in the numbers of species *M. oculata* and an increase in *P. jeffreysii* at Hod since 2002. This alteration

n in the fauna community between years seems to be a general positive trend in some parts of the Ekofisk region.

Table 4.6.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J) and expected number of species per 100 individuals (ES_{100}), Hod 2005.*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
HOD-2	74	500	73	78	1516	3.6	3.4	0.6	24	24.4
HOD-8	164	500	72	68	1155	3.7	3.6	0.6	24	24.8
HOD-13	254	315	73	84	1332	3.9	3.8	0.6	25	26.4
HOD-19	344	250	74	80	1159	4.0	3.9	0.6	28	28.2
HOD-REF	180	15000	70	56	539	3.7	3.7	0.6	24	25.2

M. o.= *M. oculata*

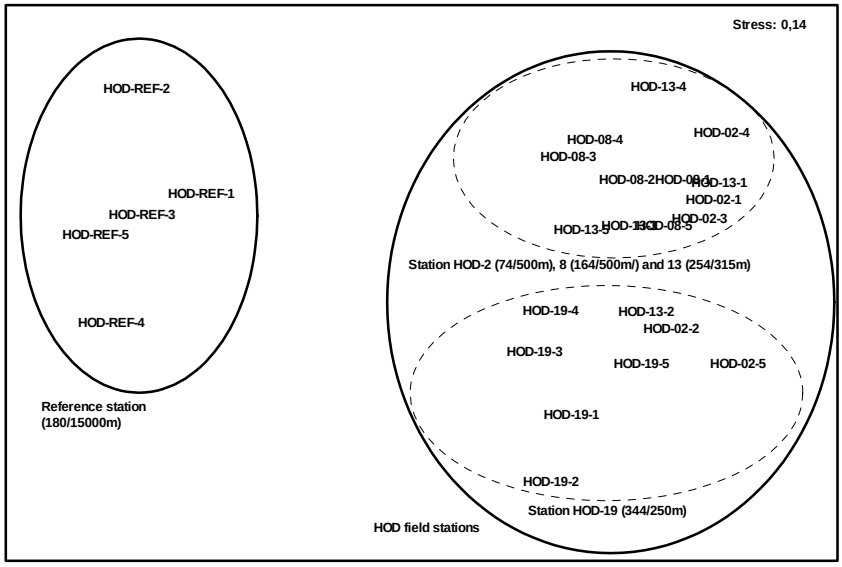

Figure 4.6.1. *MDS plot of grab samples from Hod 2005.*

4.7 Ula

4.7.1 Chemical analyses and sediment structure

The sediments at Ula consist mainly of fine sand, and the sand content varies from 95 % to 97 %, see Table 4.7.1. The gravel content is low. The silt and clay content is similar or slightly higher than previously observed.

The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.84 % to 1.1 %, see Table 4.7.1. The results are similar to the previous surveys.

In the present survey the stations are situated closer to the platform than previously. The THC concentrations in the top 0-1 cm layer vary from 3.9 mg/kg at ULA reference station, 315°/6000m to 58 mg/kg at ULA18, 135°/250m, see Table 4.7.1. Highest concentrations are found in the 1-3 cm and 3-6 cm layers at ULA18, 336 mg/kg and 416 mg/kg, respectively. The present level is similar to that found in 2002. However, the concentration of THC at ULA18 (135°/250m) in the top 0-1 cm layer has decreased from 143 mg/kg in 2002 to 58 mg/kg in the present survey. Elevated levels of THC are found out to 500m in 45° and 135° direction and out to 250m in the 120° and 225° direction. The other stations have THC content similar to the reference station.

The base oil Aquamul BII is found in the sediments, but not quantified separately. The highest concentrations are observed in the deeper layers at ULA18, 135°/250m. At this station Aquamul BII gives an important contribution to the THC content.

Elevated levels of NPD, PAH and decalins were found at ULA18, 135°/250m in all three layers, see Table 4.7.1. At ULA119, 125°/500m levels of NPD and PAH are only slightly above the limit of contamination. Highest content of NPD and PAH is found in the vertical layers at ULA18. The NPD content is ~1.9mg/kg in both layers and the PAH content is 1.3 mg/kg in the 1-3 cm layer and 0.8 mg/kg in the 3-6 cm layer. ULA18 has also the highest content of decalins, in the vertical section maximum 25 mg/kg. This is in agreement with high THC content for the same station. Generally, the level of NPD, PAH and decalins has not changed since 2002 survey.

The Ba concentrations vary from 35 mg/kg at ULA reference station to 4170 mg/kg at ULA18, 135°/250m, see Table 4.7.2. Elevated levels are found at all stations except for the reference station. Thus, elevated levels of Ba are found out to 500m in 45° and 135° direction and out to 250m in the other directions. The Ba concentrations are similar or higher compared to the previous surveys. This may be due to acute discharge of oil based mud in 2002 (2. half) and acute discharges of produced water in 2005 (1. half).

The concentrations of the heavy metals are low, see Table 4.7.2. The highest concentrations are found at ULA18, 120°/250m, and elevated concentrations are observed. Slightly elevated concentrations are also found at some of the other stations, except for Cr and Hg.

The chemical results agree with the drilling history. The mud system Aquamul BII was used on a few wells in 1993.

Table 4.7.1. *Ula, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
ULA4	45°/1000m		3.7	2.6		0.77	0.71	4.7	11.2	4.4	10.2
ULA5	45°/ 500m	4.8	4.6		0.93	0.88		17.9	69		19.6
ULA7	225°/250m	2.9			0.87			13.4			
ULA8	225°/500m		3.8			0.87		3.9	6.7		40
ULA116	330°/500m		2.8			0.81		4.3	3.9		14.1
ULA117	300°/250m	4.1			0.90			4.1			
ULA18	135°/250m	4.8	7.5		1.10	0.93		58	143		
	1-3 cm							336	359		
	3-6 cm							416	358		
ULA119	125°/500m	3.2	4.8	3.8	0.91	0.89	0.74	13.1	25	5.0	17.3
	1-3 cm							7.3	19.3	6.8	16.5
	3-6 cm							9.6	11.7	10.4	11.0
ULA20	135°/1000m							4.7			
ULA Ref.	315°/6000m	4.3	5.3	3.5	0.84	0.86	0.71	3.9	3.3	4.1	4.2
	1-3 cm							4.7	3.3	5.0	2.6
	3-6 cm							4.8	3.8	4.6	7.1

Table 4.7.1. *cont.*

Station		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
ULA18	135°/250m	0.16	0.30		0.12	0.12		2.4	6.1	
	1-3 cm	1.92	0.63		1.32	0.13		16.7	9.9	
	3-6 cm	1.97	0.30		0.77	0.14		25	9.9	
ULA119	125°/500m	0.043	0.072	0.020	0.073	0.044	0.029	0.19	0.71	nd
	1-3 cm	0.024	0.035	0.022	0.068	0.080	0.038	0.14	0.48	nd
	3-6 cm	0.024	0.042	0.035	0.10	0.11	0.065	0.26	0.35	0.20
ULA Ref.	315°/6000m	nd	0.022	0.022	0.029	0.041	0.034			
	1-3 cm	nd	0.029	0.021	0.036	0.045	0.040			
	3-6 cm	nd	0.026	0.026	0.062	0.063	0.057			

Table 4.7.2. *Ula, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba	Ba	Ba	Ba	Cd	Cd	Cd	Cr	Cr	Cr
		2005	2002	1999	1996	2005	2002	1999	2005	2002	1999
ULA5	45°/500m	2618	1320		1200	<0.01	0.02		7.4	7.0	
ULA7	225°/250m	1614				<0.01			6.8		
ULA117	300°/250m	461				<0.01			6.2		
ULA18	135°/250m	4172	3500			<0.01	0.08		8.0	6.8	
	1-3 cm	4597	3750			<0.01	0.10		7.9	8.0	
	3-6 cm	3683	2250			<0.01	0.06		7.7	7.8	
ULA119	125°/500m	825	979	612	704	<0.01	0.02	<0.02	7.2	6.3	6.2
	1-3 cm	1668	1120	1150		<0.01	0.04	<0.02	7.1	6.9	5.8
	3-6 cm	648	1050	1210		<0.01	0.04	<0.02	6.9	7.3	6.1
ULA Ref.	315°/6000m	35	29	33	60	<0.01	<0.02	<0.02	7.0	6.9	6.9
	1-3 cm	49	33	41		<0.01	<0.01	<0.02	7.4	7.0	6.9
	3-6 cm	60	48	160		<0.01	<0.01	<0.02	7.6	6.9	7.8

Table 4.7.2. *cont.*

Station		Cu	Cu	Cu	Hg	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
ULA5	45°/500m	2.0	3.1					12.5	11.8		14.6	14.6	
ULA7	225°/250m	1.3						9.8			14.6		
ULA117	300°/250m	0.7						6.8			7.1		
ULA18	135°/250m	5.5	7.6		0.02	0.02		16.4	18.5		43	57	
	1-3 cm	8.8	7.7		0.01	0.03		21	25		47	59	
	3-6 cm	4.8	4.7		0.02	0.02		18.5	18.5		42	50	
ULA119	125°/500m	1.2	2.0	0.8	<0.01	0.01	0.02	8.8	8.8	9.2	10.1	13.3	8.4
	1-3 cm	0.9	2.4	1.1	<0.01	<0.01	0.02	8.7	8.9	9.6	8.3	13.0	9.1
	3-6 cm	0.9	2.0	0.9	<0.01	0.01	0.01	7.5	8.7	8.6	7.9	9.5	7.0
ULA Ref.	315°/6000m	<0.5	1.3	0.6	<0.01	<0.01	<0.01	6.2	6.1	7.3	5.4	6.2	5.6
	1-3 cm	<0.5	1.4	0.6	<0.01	0.01	0.01	6.6	6.4	7.4	6.2	7.1	5.9
	3-6 cm	<0.5	1.5	0.8	<0.01	<0.01	0.02	6.6	6.3	8.4	6.2	6.3	7.4

4.7.2 Biology

The fauna at Ula is disturbed and have reduced biodiversity indices mainly due to high numbers of the bristle worm *M. oculata,* see Table 4.7.3. However, this species was found in normal numbers at the Ula reference station, indicating that the fauna is influenced by the field activities. The biodiversity indices have decreased at the field stations since 2002, but increased at the reference station.

There was a shift in the fauna community from 1996 to 1999 which indicated a slight improvement in the environment, however the improvement does not seem to continue and the fauna community at the sampled stations (250 and 500 m) at Ula is considered to be disturbed. This is supported by visual observations and chemical data from the deeper layers, showing elevated concentrations of THC, decalins, PAH and NPD.

Table 4.7.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Ula 2005.*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
ULA-05	45	500	72	73	3734	2.3	3.4	0.4	14	22
ULA-07	225	250	70	79	3684	2.1	4.0	0.3	14	27
ULA-117	300	250	73	77	4140	1.9	3.7	0.3	13	25
ULA-18	135	250	70	68	3396	2.3	3.3	0.4	13	19
ULA-119	125	500	71	78	5193	1.4	3.8	0.2	10	27
ULA-Ref	315	6000	73	81	944	4.4	4.7	0.7	30	33

M.o.= *M. oculata*

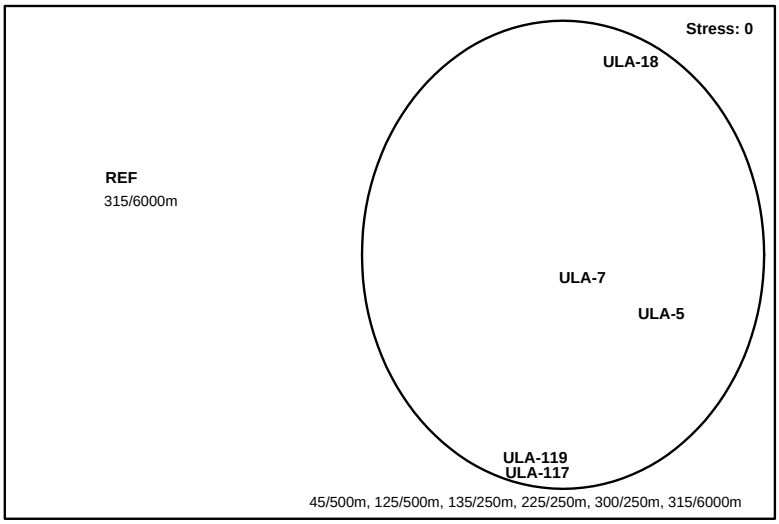

Figure 4.7.1. *MDS plot of stations from Ula 2005.*

4.8 Gyda

4.8.1 Chemical analyses and sediment structure

The sediments at Gyda consist mainly of fine sand, and the sand content varies from 94.4 % to 99.7 %, see Table 4.8.1. The gravel content is low, and small amounts are found only at GYDA19. The average silt and clay concentration found is similar to the previous observations. Station GYDA18, 135°/250m appears different from rest of the stations. The sediments at this station consist mainly of silt and clay, with silt and clay content of 99.5 %.

The total organic matter content in the sediments is low and only small variations are found at the field, from 0.62 % to 0.78 %, see Table 4.8.1. The content corresponds to the grain size distribution with low pelite (silt and clay) content. The results are similar to the previous survey. An exception is GYDA18. This station has a content of total organic matter of 5.3%. This is in agreement with the high content of silt and clay found for this station.

Three new stations are included in the present survey at a distance 250m from the field centre. These are GYDA6, 45°/250m, GYDA7, 225°/250m and GYDA18, 135°/250m. Elevated THC concentrations are found, respectively 40 mg/kg at GYDA6, 43 mg/kg at GYDA7 and 18 mg/kg at GYDA18, see Table 4.8.1. In general the THC levels for the other stations are low and similar to those found in 2002 and 1999. Only slightly elevated THC concentrations are found at the 500m stations in the 45°, 135° and 225° directions.

Elevated NPD and decalin content is found in grab #3 at GYDA6, see Table 4.8.1. This is in accordance with high THC content found in this sample. The PAH content is low. The NPD concentrations in the top layer at GYDA19 are below the limit of contamination. However, the NPD content in the deeper layers are slightly elevated and similar or slightly higher compared to 2002. The PAH levels are low, just at the limit of contamination. The decalin concentrations are still relatively high in the deeper layers.

The Ba concentrations vary from 36 mg/kg at GYDA reference station to 1566 mg/kg at GYDA7, see Table 4.8.2. The new stations GYDA6 and GYDA7 are the most contaminated, with Ba values respectively 1171 mg/kg and 1566 mg/kg. The new station GYDA18, 135°/250m has the lowest Ba content observed in the Gyda field. However, this station appears different from the others, with high content of silt and clay, relative high content of total organic matter and high level of heavy metals. The Ba concentration has not changed since 2002. Elevated Ba concentrations are found at all the stations except for GYDA18, 135°/250m and the reference station. Thus elevated levels of Ba are found out to 500m in the 135°, 225° and 315° direction and limited to 250m in the 45° direction. Elevated concentrations are also found in the deeper sections.

The concentrations of the heavy metals are low, except for GYDA18, 135°/250m, which has high content of heavy metals, see Table 4.8.2. Slightly elevated concentrations of Pb and Zn are found at some of the other stations.

Table 4.8.1. *Gyda, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
GYDA5	45°/500m							8.0	6.9		
GYDA6	45°/250m	3.2			0.61			40			
GYDA7	225°/250m	4.3			0.78			43			
GYDA8	225°/500m	3.2	5.4		0.77	0.77		7.5	7.4		
GYDA16	315°/500m	4.3	3.9	3.3	0.69	0.77	0.78	4.0	5.4	4.1	3.0
GYDA17	315°/250m							4.8	4.9		
GYDA18	135°/250m	99.5			5.3			17.9			
GYDA19	135°/500m	5.0	2.9	2.5	0.78	0.71	0.61	6.9	9.2	9.2	7.4
	1-3 cm							23	22.0	15.0	2.2
	3-6 cm							12.5	17.5	16.6	9.9
GYDA ref.	315°/8000m	0.3	3.0	3.5	0.75	0.82	0.74	4.2	3.8	3.7	5.6
	1-3 cm							3.4	3.8	3.0	4.4
	3-6 cm							5.2	4.7	4.7	7.0

Table 4.8.1. *cont.*

		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
GYDA19	135°/500m	0.018	0.052	0.043	0.030	0.064	0.028	0.13	0.33	0.40
	1-3 cm	0.082	0.039	0.19	0.12	0.057	0.16	1.9	0.96	0.46
	3-6 cm	0.037	0.026	0.025	0.10	0.036	0.010	0.80	1.0	0.83
GYDA ref.	315°/8000m	<0.13	0.013	0.018	0.032	0.035	0.038	<01.8	nd	nd
	1-3 cm	0.012	0.014	0.016	0.045	0.035	0.031	nd	nd	nd
	3-6 cm	0.013	0.015	0.018	0.080	0.049	0.037	nd	nd	nd

Table 4.8.2. *Gyda, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
GYDA6	45°/250m	1171				<0.01			6.3		
GYDA7	225°/250m	1566				<0.01			6.7		
GYDA8	225°/500m	294	382			<0.01	<0.01		6.5	6.1	
GYDA16	315°/500m	89	106	84	218	<0.01	<0.01	<0.02	6.9	6.2	
GYDA18	135°/250m	62				0.14			48.0		
GYDA19	135°/500m	399	542	379	935	<0.01	0.01	<0.02	7.2	5.9	6.1
	1-3 cm	994	651	382		0.03	0.02	<0.02	8.4	6.6	6.0
	3-6 cm	409	437	320		0.02	0.03	0.03	8.7	7.4	6.5
GYDA Ref.	315°/8000m	36	40	47	63	<0.01	0.01	<0.02	7.0	6.7	7.1
	1-3 cm	53	40	46		0.01	<0.01	<0.02	7.5	6.7	6.9
	3-6 cm	111	78	112		0.01	0.01	0.02	8.0	6.7	7.7

Table 4.8.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
GYDA6	45°/250m	1.4						9.4			8.9		
GYDA7	225°/250m	1.4						11.7			11.9		
GYDA8	225°/500m	0.9	1.4					6.8	7.1		5.6	9.0	
GYDA16	315°/500m	0.7	1.2	0.6				6.5	6.4	7.4	8.6	5.1	5.6
GYDA18	135°/250m	21						24			88		
GYDA19	135°/500m	1.4	1.8	0.7	<0.01	0.01	<0.02	8.2	6.7	6.2	9.0	8.1	5.3
	1-3 cm	2.1	1.8	0.6	<0.01	0.01	0.01	8.6	7.2	5.7	11.1	7.8	4.7
	3-6 cm	1.2	1.6	0.5	<0.01	0.01	0.03	7.3	7.1	5.6	9.4	9.1	6.8
GYDA Ref.	315°/8000m	<0.05	1.3	0.5	<0.01	0.01	0.02	5.8	5.8	6.5	4.9	5.7	5.5
	1-3 cm	<0.05	0.9	0.5	<0.01	<0.01	0.01	5.8	6.1	6.7	5.6	5.2	4.5
	3-6 cm	<0.05	1.1	0.7	0.01	<0.01	0.02	6.5	6.3	7.1	6.6	6.9	6.7

4.8.2 Biology

The biodiversity indices indicate a general disturbance in the fauna at Gyda in 2005, see Table 4.8.3. The fauna at Gyda-18 (135°/250m) differ from the other stations with anoxic sediment and is clearly disturbed, see Figure 4.8.1. The fauna at the reference station (254°/15000m) is less disturbed than the field stations located 250 m and 500 m from the centre. The similarity analysis revealed that the stations are clustering in a pattern that reflects the distance from the field centre, which indicates that the fauna at Gyda is influenced by the field activities.

The biodiversity indices show a slight increase since 2002 at the reference station. At GYDA-08 (225°/500m) and -16 (315°/500m), the indices have not changed since 2002, while slight decreases are observed at GYDA-19 (135°/500m). Variations in the fauna between years seem to coincide with the variations in Ba, Pb, TOM and pelite.

Table 4.8.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Gyda 2005.*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
Gyda-06	45	250	67	59	4608	1.9	3.0	0.3	10	16
Gyda-07	225	250	63	53	4035	2.0	3.1	0.3	11	17
Gyda-08	225	500	64	85	6446	1.6	3.3	0.2	10	22
Gyda-16	315	500	68	80	4664	1.8	3.5	0.3	12	25
Gyda-18	135	250	65	20	249	2.8	3.3	0.6	14	17
Gyda-19	135	500	69	56	4915	1.3	3.7	0.2	10	23
Gyda-RefA	315	8000	69	89	2154	3.0	4.2	0.5	21	32

M. o.= *M. oculata*

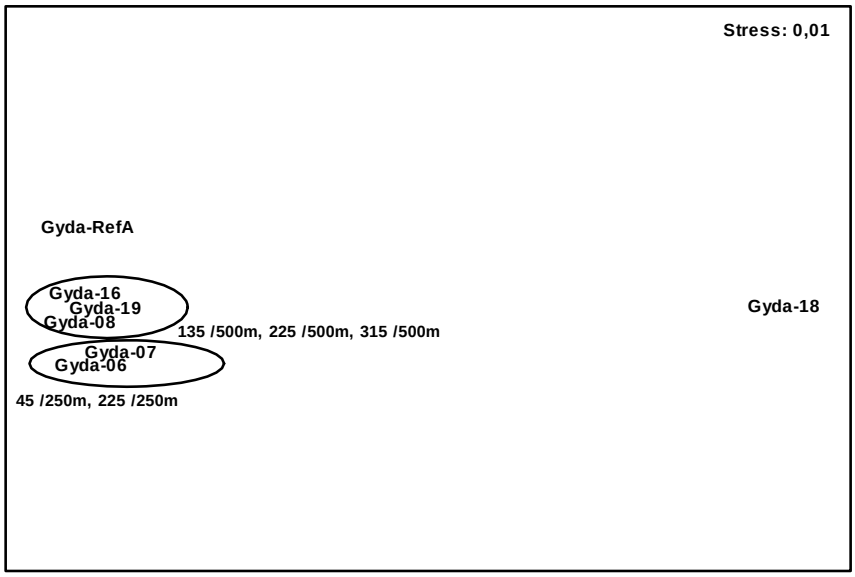

Figure 4.8.1. *MDS plot of stations from Gyda 2005.*

4.9 Tambar

4.9.1 Chemical analyses and sediment structure

The sediments at Tambar consist of fine sand, and the sand content varies from 92.6 % at TAMBAR13, 315°/250m to 97.8 % at TAMBAR5, 135°/250m, see Table 4.9.1. Small amounts of gravel are only found at TAMBAR1, 45°/250m. The average silt and clay content is similar to the previous survey in 2002.

The total organic matter content in the sediments is low, ~ 0.85 %, and only small variations are found at the field, see Table 4.9.1. The results are similar to the previous surveys.

The concentration of THC is generally low, and elevated concentrations that might originate from an incident in 1998 are limited to the 250m station in the 135° direction (TAM5) , see Table 4.9.1. The concentration in the top 0-1 cm layer is unchanged since 2002, however, a significant reduction is observed in the vertical layers.

Two stations are analysed for NPD, PAH and decalins, TAMBAR5, 135°/250m and TAMBAR6, 315°/500m, see Table 4.9.1. The levels of NPD and PAH are below the limit of contamination. The NPD concentrations at the two stations, vary from 0.015 mg/kg to 0.030 mg/kg, and the

PAH concentrations from 0.039 mg/kg to 0.046 mg/kg. Decalins are found in some of the grab samples. The content is at the same level as in 2002 in the top 0-1 cm layer, while the content in the vertical layers has decreased.

The Ba concentrations vary from 106 mg/kg at TAMBAR13, 315°/250m to 563 mg/kg at TAMBAR5, 135°/250m, see Table 4.9.2. The Ba concentrations are lower or at the same level as the 2002 survey. Elevated Ba concentrations are found at all stations, except for the reference station. Thus elevated levels are found out to 250m in all directions investigated.

The concentrations of heavy metals are low, see Table 4.9.2.

The chemical results are in correspondence with the drilling history at Tambar.

Table 4.9.1. *Tambar, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
TAMBAR1	45°/250m	4.1	4.0	4.2	0.85	0.80	0.76	3.5	6.2	5.6
TAMBAR2	45°/500m							3.3	3.7	4.1
TAMBAR5	135°/250m	2.6	4.0	4.9	0.95	0.83	0.75	15.2	15.8	50
	1-3 cm							3.9	27	9.6
	3-6 cm							8.7	17.8	11.5
TAMBAR6	135°/500m							4.9	5.0	5.3
	1-3 cm							4.4	10.5	
	3-6 cm							3.7	17.6	
TAMBAR9	225°/250m	2.2	5.4	5.3	0.83	0.71	0.84	3.8	4.5	107
TAMBAR10	225°/500m							4.2	3.2	5.3

Table 4.9.1. *cont.*

Station		Silt and clay			TOM			THC		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
TAMBAR13	315°/250m	7.4	4.1	5.2	0.81	0.86	0.72	4.3	3.0	3.5
TAMBAR14	315°/500m							4.3	2.9	4.0
GYDA ref.	315°/8000 m				0.75	0.82	0.74	4.2	3.8	3.7
	1-3 cm							3.4	3.8	3.0
	3-6 cm							5.2	4.6	4.6

Table 4.9.1 *cont.*

		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
TAMBAR5	135°/250m	0.030	0.034	0.032	0.046	0.027	0.036	<2.3	1.05	3.5
	1-3 cm	n.d	0.036	0.024	0.017	0.032	0.053	0.1	2.8	0.36
	3-6 cm	0.012	0.036	0.027	0.031	0.071	0.062	0.54	1.2	0.41
TAMBAR6	135°/500m	0.015	0.014		0.039	0.024		<0.12	0.19	
	1-3 cm	0.01	0.017		0.032	0.025		0.1	0.61	
	3-6 cm	0.01	0.037		0.025	0.059		nd	1.1	
GYDA ref.	315°/8000m	<0.13	0.013	0.018	0.032	0.035	0.038	<1.8	nd	nd
	1-3 cm	0.012		0.016	0.045		0.031	nd		nd
	3-6 cm	0.013		0.018	0.080		0.037	nd		nd

Table 4.9.2. *Tambar, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
TAMBAR1	45°/250m	251	538	276		<0.01	<0.02	<0.02	6.8	6.5	6.9
TAMBAR5	135°/250m	563	451	677		<0.01	<0.01	<0.02	7.7	6.6	7.5
	1-3 cm	1035	473	1890		<0.01	0.01	<0.02	8.4	6.8	7.3
	3-6 cm	536	431	489		<0.01	0.03	<0.02	8.6	7.6	8.0
TAMBAR9	225°/250m	129	232	4040		<0.01	<0.01	<0.02	6.9	6.9	8.0
TAMBAR13	315°/250m	106	90	280		<0.01	<0.01	<0.02	7.3	6.8	6.9
GYDA Ref.	315°/8000m	36	40	47	63	<0.01	0.01	<0.02	7.0	6.7	7.1
	1-3 cm	53	40	46		0.01	<0.01	<0.02	7.5	6.7	6.9
	3-6 cm	111	78	112		0.01	0.01	0.02	8.0	6.7	7.7

Table 4.9.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
TAMBAR1	45°/250m	0.6	1.4	0.7				6.8	6.3	6.2	5.7	7.5	5.1
TAMBAR5	135°/250m	0.8	1.4	0.8	<0.01	0.01	<0.01	7.0	5.8	6.3	7.7	6.3	5.7
	1-3 cm	1.1	1.6	0.9	<0.01	<0.01	<0.01	8.9	6.1	7.6	10.8	5.5	5.6
	3-6 cm	0.9	1.5	1.2	<0.01	0.01	<0.01	8.0	6.8	6.4	11.2	6.8	6.2
TAMBAR9	225°/250m	0.5	1.5	3.5				6.3	5.8	8.5	6.0	7.7	7.5
TAMBAR13	315°/250m	0.6	1.0	2.1				5.3	5.6	5.7	5.8	5.1	5.3
GYDA Ref.	315°/8000m	<0.5	1.3	0.5	<0.01	0.01	0.02	5.8	5.8	6.5	4.9	5.7	5.5
	1-3 cm	<0.5	0.9	0.5	<0.01	<0.01	0.01	5.8	6.1	6.7	5.6	5.2	4.5
	3-6 cm	<0.5	1.1	0.7	0.01	<0.01	0.02	6.5	6.3	7.1	6.6	6.9	6.7

4.9.2 Biology

The results indicate no major alterations in the state of the fauna community since 2002. The decline in *M. oculata* which is observed in several fields in the region, is not observed at Tambar. The fauna community at the Tambar 250m stations are somewhat disturbed, possibly influenced by the field activities, see Figure 4.9.1. However, the diversity indices (H') have increased slightly at some stations possibly indicating a positive development, see Table 4.9.3.

Table 4.9.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Tambar 2005.*

Station	Direction °	Distance m	Depth	S	N	H' Incl. M. o.	H' Excl. M. o.	J	ES_{100} Incl. M. o.	ES_{100} Excl. M. o.
TAM-01	45	250	68	81	3866	2.5	4.2	0.4	17	27
TAM-05	135	250	72	75	3017	2.5	4.1	0.4	17	26
TAM-09	225	250	69	77	4130	2.1	4.0	0.3	15	28
TAM-113	305	250	69	85	2735	2.6	4.2	0.4	18	30

M. o.= *M. oculata*

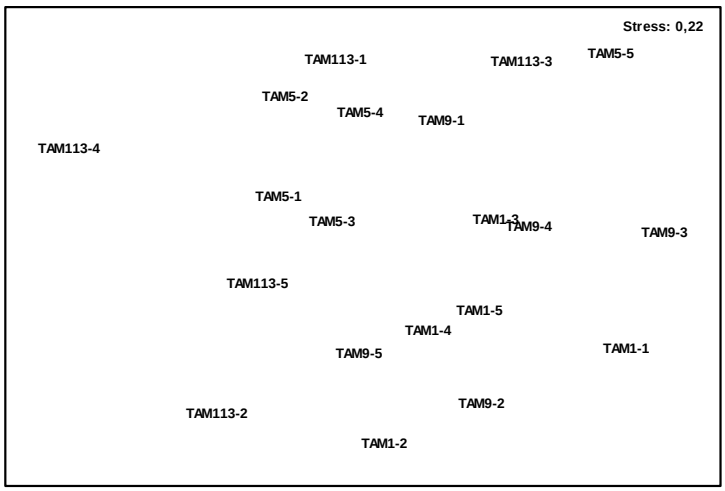

Figure 4.9.1. *MDS plot of grab samples from Tambar 2005.*

4.10 Ekofisk Center and 2/4 B&K

4.10.1 Chemical analyses and sediment structure

The sediments at Ekofisk Centre consist mainly of fine sand, and the sand content varies from 90.6 % at EKO15, 175°/500m to 97.4 % at the reference station EKO42, 90°/15000m, see Table 4.10.2. The gravel content is low. The silt and clay content is at the same level as the 2002 survey. The average silt and clay concentration found is 6.8 % compared to 8.1 % in 1999 and 4.9 % in 1996 for the same stations. EKO14 appears different compared to the other stations, with 35 % silt and clay content, 65 % sand content and a median particle diameter of 3,29ϕ.

The total organic matter content in the sediments is low, and the concentrations vary from 0.88 % to 1.28 %, see Table 4.10.2. The concentrations are similar to previous surveys.

The mean THC concentrations (including ether drilling fluid) vary from 5.8 mg/kg at the reference station, EKO42, 90°/15000m to 188 mg/kg at EKO14, 140°/850m, see Table 4.10.2. The THC content has decreased considerably, for all the stations analysed, since the last survey. Maximum concentrations are found at EKO14, 140°/850m, both at the surface and in the deeper layers, with respectively 188 mg/kg (top layer), 408 mg/kg (1-3 cm) and 152 mg/kg (3-6 cm). Relatively high THC concentrations are also found at EKO15, 175°/500m, a mean value of 34 mg/kg. Thus, elevated levels of THC are observed out to 1000m in the 90° and 180° direction, out to 800-850m in the 94° and 140° direction and out to 500m in the 70° direction. The other stations are either below or slightly above the limit of contamination for the region.

Gas chromatograms from previous surveys have shown that the major part (approx 45 %) of the elevated THC concentrations observed at EKO14 results from didecyl ethers in Aquamul B drilling fluid. It is, however, important to realise that the sediments are not analysed for ether compounds. Thus, we can not estimate the total concentrations of Aquamul B in the sediment due to possible losses during sample preparation.

Olefins/ethers are found at the four stations analysed, with maximum 86 mg/kg at EKO14, 140°/850m, see Table 4.10.2. The content of olefins has also decreased distinctly since 2002. The contribution from ethers could not be estimated, since the sediments are not analysed for ether compounds.

The gas chromatograms from the stations at Ekofisk Centre and 2/4 B&K are quite complex, and they show different profiles with additional compounds in the HDF 200 area, in the olefin areas and in the heavier hydrocarbon area. In addition ether compounds originating from Aquamul B are identified in the olefin area.

The concentration of NPD, PAH and decalins has decreased for all three stations analysed, see Table 4.10.2. Highest concentration of NPD, PAH and decalins are found at station EKO14, 140°/850m, in the vertical layer 1-3 cm.

PFOS was not detected at the one station analysed, EKO32, 180°/500 m, see Table 4.10.1.

The mean Ba concentrations vary from 46 mg/kg at EKO42 reference station, 90°/15000m to 3860 mg/kg at EKO15, 175°/500m, see Table 4.10.3. Elevated Ba concentrations are found at all stations, except for the reference station. Thus elevated levels are observed out to 1800m in the 84° direction and limited to 500m in the 74°, 175° and 180° direction. The concentrations are similar or slightly lower compared to previous surveys. High concentrations of Ba are also found in vertical layers, similar or higher concentrations than in the top 0-1 cm layer.

The concentrations of heavy metals are low, but concentrations above the limit of contaminations are found at most of the stations, see Table 4.10.3. Highest concentrations are found at EKO14, 140°/850m and EKO15, 175°/500m.

The chemical results agree with the drilling history at Ekofisk Centre and 2/4 B&K. Smaller amounts of barite and cuttings have been discharged related to drilling of top sections with water based mud since the previous survey in 2002. The ether based drilling fluid Aquamul B was discharged in 1990/1991. The ether content is decreasing, but obviously these ether compounds are not breaking down as fast as previously anticipated.

Table 4.10.1. Ekofisk Centre and 2/4 B&K 2005, PFOS (perfluorooctyl sulphonate), µg/kg dry sediment.

Station		**PFOS** (one grab sample)
EKO32	180°/500m	<0.1

Limit of detection: 0.1 µg/kg

Table 4.10.2. *Ekofisk Centre and 2/4 B&K, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
EKO7	74°/3900m							7.4			
EKO8	84°/1800m	7.7	7.5	6.3	1.05	1.19	1.03	7.5	14.3	12.2	10.4
EKO9	94°/800m	6.1	8.4		0.89	1.40		16.1	60		17.3
EKO9a	70°/500m	7.4	8.6		0.98	1.36		18.6	40		
EKO11	144°/4400m							7.4	9.6	9.7	8.3
EKO12	148°/2500m							8.7	15.8	16.4	15.9
EKO13	146°/1300m	5.4	6.9	5.3	1.18	1.32	1.14	9.9	18.0	16.0	15.3
	1-3 cm							12.9	21		
	3-6 cm							17.9	25		
EKO14	140°/850m	35.2	9.5	3.2	1.21	1.67	0.99	188	601	52	26
	1-3 cm							408		47	204
	3-6 cm							152		100	246
EKO15	175°/500m	9.4	13.0	3.2	1.28	2.10		34	105		
EKO18	208°/2500m							7.8	10.9	12.3	18.3
EKO19	200°/1200m							8.1	19.1		20
EKO21	287°/4000m							5.2			
EKO22	288°/1900m							3.5	14.6	15.7	

Table 4.10.2. *cont.*

EKO23	290°/1000m							8.3	19.6	13.8	21
EKO28	360°/1000m							4.6	35	12.0	
EKO29	360°/500m							4.3			
EKO32	180°/500m	8.7	8.4	4.3	1.10	1.28	1.07	16.3	38	19.4	38
	1-3 cm							18.0	39	4.0	54
	3-6 cm							41	46	5.7	30
EKO33	180°/1000m							10.6	19.6	13.3	44
EKO34	270°/1000m							6.8	11.6	11.9	12.3
EKO39	90°/1000m							11.7	16.2	16.7	16.7
EKO Ref. 42	90°/15000m	2.6	2.6	5.3	0.88	0.82	0.95	5.8	5.9	5.5	6.4
	1-3 cm							7.3	7.9	9.0	10.0
	3-6 cm							7.6	8.5	5.9	8.7

Table 4.10.2. *cont.*

		Olefins			NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
EKO9a	70°/500m	1.1	3.5										
EKO13	146°/1300m	1.1	2.1		0.031	0.094		0.073	0.12		0.12	0.12	
	1-3 cm	1.5	3.0		0.034	0.072		0.087	0.095		0.12	0.11	
	3-6 cm	2.1	4.1		0.10	0.080		0.21	0.13		0.29	0.12	
EKO14	140°/850m	86	361		0.20	0.35	0.026	0.10	0.22	0.055	7.7	13.6	0.23
	1-3 cm	275	867		0.43	0.27	0.058	1.25	0.24	0.10	4.2	8.1	0.094
	3-6 cm	98	830		0.09	0.27	0.17	0.11	0.085	0.29	0.82	1.42	0.048
EKO32	180°/500m	1.4	3.9	2.9	0.08	0.15	0.060	0.076	0.092	0.042	0.26	0.39	0.16
	1-3 cm				0.07	0.19	0.010	0.14	0.081	0.008	0.32	0.34	nd
	3-6 cm				0.35	0.10	0.043	0.57	0.090	0.008	0.88	0.50	0.12
EKO Ref. 42	90°/15000m				nd	0.021	0.010	0.039	0.048	0.035	0.11	nd	nd
	1-3 cm				nd	0.028	0.032	0.049	0.068	0.094	nd	nd	nd
	3-6 cm				0.014	0.033	0.015	0.080	0.081	0.048	nd	nd	nd

Table 4.10.3. *Ekofisk Centre and 2/4 B&K, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
EKO8	84°/1800m	669	840	1030	1510	<0.01	0.02	<0.02	5.9	7.7	8.8
EKO9	94°/800m	1635	3750		3240	0.01	0.05		7.6	9.6	
EKO9a	74°/500m	3213	3200			0.08	0.08		10.0	9.4	
EKO13	146°/1300m	867	1550	1310	1540	0.02	0.02	<0.02	8.3	8.4	9.0
	1-3 cm	1633	2590			0.05	0.05		9.7	9.4	
	3-6 cm	2744	2620			0.09	0.06		10.6	9.7	
EKO14	140°/850m	3142	4680	1490	2410	0.03	0.14	<0.02	9.9	10.1	7.4
	1-3 cm	4184	4708	2740		0.07	0.11	0.02	10.0	9.3	8.0
	3-6 cm	5255	4673	3700		0.11	0.13	0.04	10.7	8.9	6.7
EKO15	175°/500m	3861	4180			0.09	0.16		11.7	14.4	
EKO32	180°/500m	3047	2900	1920	3700	0.02	0.04	0.02	8.5	8.4	7.2
	1-3 cm	4037	3830	1370		0.05	0.08	0.02	9.5	9.7	4.6
	3-6 cm	4226	2780	563		0.08	0.07	<0.02	10.2	9.5	4.6
EKO Ref.	90°/15000m	46	72	41	67	<0.01	<0.01	<0.02	7.6	7.7	7.1
	1-3 cm	50	88	50		<0.01	<0.01	<0.02	8.1	7.7	7.2
	3-6 cm	72	331	141		<0.01	0.01	<0.02	8.0	8.1	7.8

Table 4.10.3. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
EKO8	84°/1800m	<0.5	1.6	1.1				6.7	11.5	13.4	7.6	10.0	7.1
EKO9	94°/800m	1.5	6.1					13.0	18.4		14.6	31	
EKO9a	74°/500m	3.4	4.9					19.4	20.6		38.2	32	
EKO13	146°/1300m	1.0	1.9	1.4	0.01	0.02		11.1	11.6	16.3	11.7	12.2	11.5
	1-3 cm	1.0	3.0		0.02	0.03		13.3	15.3		14.2	17.0	
	3-6 cm	1.3	2.5		0.03	0.03		16.5	16.8		18.2	20.3	
EKO14	140°/850m	3.2	70.1	2.0	0.07	0.05	0.02	17.5	15.3	9.2	25.2	65	12.2
	1-3 cm	4.9	10.0	2.1	0.18	0.05	0.02	15.4	36.4	10.6	42.8	65	15.0
	3-6 cm	4.6	5.4	1.9	0.02	0.04	0.02	45.0	43.3	14.0	59.3	81	17.6
EKO15	175°/500m	5.3	14.1					22.2	30.5		47.6	82	
EKO32	180°/500m	1.4	3.4	1.8	0.02	0.04	0.02	13.3	16.9	11.8	14.1	20.9	17.6
	1-3 cm	3.1	4.5	0.5	0.03	0.05	<0.01	23.2	29.8	3.3	25.1	35.6	5.5
	3-6 cm	2.5	3.2	0.4	0.03	0.03	<0.01	27.8	21.1	3.2	29.2	27.5	4.0
EKO Ref.	90°/15000m	<0.5	1.0	0.5	<0.01	<0.01	<0.01	6.1	6.3	6.1	5.4	5.6	4.7
	1-3 cm	<0.5	1.1	0.5	<0.01	0.01	<0.01	6.4	6.3	6.0	5.8	5.6	5.1
	3-6 cm	<0.5	1.8	0.8	<0.01	<0.01	<0.01	6.6	7.2	7.3	5.8	6.9	5.8

4.10.2 Biology

The biodiversity indices at Ekofisk C are in general slightly lower than 4, but relatively high compared to several other fields in the central parts of the Ekofisk region, see Table 4.10.4. The stations EKO-9, -9A, -14 and -15, which where characterized as disturbed in 2002, separates somewhat in the similarity analyses, see Figure 4.10.1. It should also be noted that the four stations are closest to the discharge point, 2/4 W (i.e. the distances are shorter than the station names, referring to 2/4 T, indicate). However, the biodiversity indices at these stations have increased, and are not lower than the other stations. The stations are still considered to be disturbed, which is strongly supported by visual observations from sampling and sample processing, but showing a positive trend.

The 2005 data show a good correlation between the variations in the fauna composition and the variations in the concentrations of the metal complex Cu, Pb and Zn. The levels of these metals are relatively low, but above LSC. The highest concentrations are found at EKO-14 and -15. It should, however, be noted that the the correspondance analyses only includes the results from the sediment surface, while considerably higher consentrations of organic and inorganic parameters are found in the deeper layers.

The biodiversity in the fauna community at Ekofisk C has increased since 2002 (data including *M. oculata)* also at the stations characterised as disturbed in 2002. The decline in *M. oculata* partly explains the increased biodiversity indices. The changes in the fauna during the years are not directly related to variations in investigated sediment characteristics or chemical data from the sediment surface.

Table 4.10.4. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Ekofisk Center and 2/4 B&K 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
EKO8	84	1800	78	97	3011	2.8	4.8	0.4	20	34.4
EKO9	94	800	98	76	2356	3.3	3.6	0.5	20	22.9
EKO9a	70	500	81	73	1361	3.7	3.9	0.6	22	25.0
EKO13	146	1300	80	96	2775	3.3	3.8	0.5	20	24.9
EKO14	140	850	80	81	2097	3.3	3.5	0.5	18	20.6
EKO15	175	500	80	70	1641	3.8	3.9	0.6	21	22.5
EKO32	180	500	78	90	2491	2.9	4.6	0.4	21	34.4
EKOREF	90	15000	70	76	1634	3.2	4.6	0.5	22	31.5

M. o.= *M. oculata*

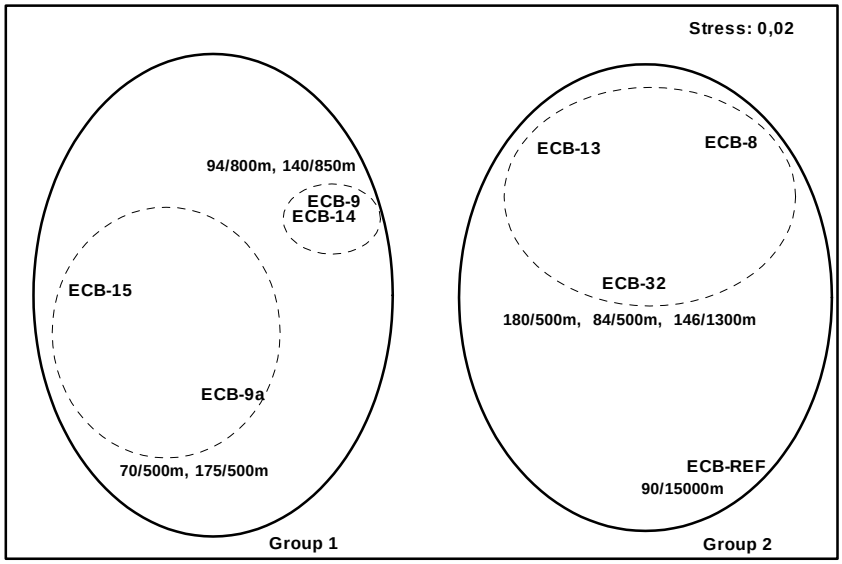

Figure 4.10.1. *MDS plot – station level, Ekofisk Center and 2/4 B&K 2005 (excl. juv.). ECB-x = EKOx.*

4.11 Ekofisk 2/4 A

4.11.1 Chemical analyses and sediment structure

Samples were taken from 100 m out to 2000 m distance in four directions from the installations. THC was analysed in all samples. Heavy metals (including Ba), olefins, esters, NPD, PAH and decalins were analyzed in selected samples.

Two core samples, VC-2 (I) and VC-2 (II), were analyzed for THC, olefins, esters, PCB, NPD, PAH, decalins, Ba and heavy metals.

4.11.1.1 Ekofisk 2/4 A – the sea bed surrounding the drill cuttings pile

The sediments at Ekofisk 2/4 A consist of fine sand. The content of sand ranges from 82.9 % to 97.3 %, the content of silt and clay from 2.6 % to 16.8 % and the content of gravel is below 1.3 % (see Table 4.11.1). In average the median particle diameter is 2.86 and the average sediment consist of 91.8 % sand, 8.0 % silt and clay and 0.2 % gravel.

The total organic matter (TOM) ranges from 0.76 % at 337°/100 m to 1.50 % at 247°/100 m, with a mean value of 1.16 % and a median value of 1.18 % (see Table 4.11.1). The median value was measured to 1.15 % in 2002 and 1.05 % in 1999.

THC in the 0-1 cm layer is below 50 mg/kg from 67°/200 m, 157°/150 m, 247°/150 m and 337°/<100 m (see Table 4.11.2). This means that the area with a THC concentration larger than 50 mg/kg has decreased since 2002. However, to a distance at least 200 m from the centre, the THC concentrations in the deeper layers are somewhat higher.

The concentration of THC in the 0-1 cm layer ranges from 8 mg/kg at 157°/2000 m to 195 mg/kg at 67°/100 m. The concentration at the reference station at 90°/15000 m is 6 mg/kg. The mean concentration is 32 mg/kg and the median 17 mg/kg. In 2002 the median concentration was found to be 24 mg/kg, and in 1999 16 mg/kg.

Generally, the levels of THC appear to decrease from 1999 to 2005 in the 0-1 cm layer. This is also the case for the olefins from 2002 to 2005. However, the level of THC generally increases from the upper 0-1 cm layer to the 1-9 cm layers.

The concentration of olefins in the 0-1 cm layer ranges from 2 mg/kg to 61 mg/kg, with a mean value of 12 mg/kg and a median value of 5 mg/kg (see Table 4.11.2). In 2002 the mean and median value was 31 mg/kg and 35 mg/kg, respectively.

The highest measured concentration of THC and olefins is 1030 mg/kg and 465 mg/kg, respectively, in the 3-6 cm layer at 67°/100 m.

The content of esters is generally very low and close to the detection limits. Small amount of esters are found at 67°100 m (3 mg/kg) and at 157°/100 m (1-3 mg/kg) (see Table 4.11.2).

Elevated concentrations of NPD and PAH are found at all stations analyzed (see Table 4.11.3).

The concentration of Ba in the 0-1 cm layer ranges from 890 mg/kg at 157°/500 m to 5110 mg/kg at 247°/100 m, with a mean concentration of 2950 mg/kg and a median of 3070 mg/kg (see Table 4.11.4). The highest measured concentration of Ba in 2005 is 5940 mg/kg in the 1-3 cm layer at 157°/100 m. No general trend is obvious for the concentrations of Ba from 1999 to 2005.

Elevated levels of heavy metals are found at most of the stations.

The chemical results agree with the drilling history of at Ekofisk 2/4 A. Olefins and esters are found in the sediments due to discharges in 1994.

Table 4.11.1. *Ekofisk 2/4 A, silt and clay and TOM (%).*

		Silt and clay			TOM		
Station		**2005**	**2002**	**1999**	**2005**	**2002**	**1999**
EKOA1	337°/100m	3.8	5.4	9.1	0.76	0.77	1.00
EKOA1B	337°/150m		8.4			1.09	
EKOA1C	337°/200m		7.2			1.01	
EKOA2	337°/250m	2.9	8.2	7.3	1.04	1.21	0.90
EKOA3	337°/500m	2.9	5.4	5.5	1.22	1.05	0.90
EKOA4	337°/1000m		6.5	7.0		1.26	1.00
EKOA5	67°/100m	2.9	14.3	9.9	1.31	1.31	1.70
EKOA5B	67°/150m		19.6			1.86	
EKOA5C	67°/200m		13.2			1.58	
EKOA6	67°/250m	2.9	11.1	8.3		1.40	1.20
EKOA7	67°/500m	2.9	7.2	6.7	1.08	1.17	1.00
EKOA8	67°/1000m		7.2	4.5		1.08	1.10
EKOA9	157°/100m	3.1	18.2	7.9	1.36	2.06	1.30
EKOA9B	157°/150m		12.1			1.90	
EKOA9C	157°/200m		13.0			1.55	
EKOA10	157°/250m	2.9	8.8	5.2	1.33	1.33	1.30
EKOA11	157°/500m	2.8	8.8	5.2	1.24	0.97	1.00
EKOA12	157°/1000m		6.2	6.4		0.91	1.40
EKOA12A	157°/2000m		6.4			0.91	
EKOA13*	247°/100m	2.8	14.8		1.50	1.54	
EKOA13B	247°/150m		11.9			1.40	
EKOA13C	247°/200m		10.5			1.13	
EKOA14	247°/250m	2.9	8.5	6.9	1.14	1.04	1.20
EKOA15	247°/500m	2.9	7.9	5.5	1.10	0.95	1.10
EKOA16	247°/1000m		8.0	2.4		0.91	0.70
EKOA REF	90°/15000m	2.6	2.6	5.3	0.88	0.82	1.00

Table 4.11.2. *Ekofisk 2/4 A, THC, olefins and esters (mg/kg dry sediment).*

		layer	THC			Olefins		Esters	
Station		**cm**	**2005**	**2002**	**1999**	**2005**	**2002**	**2005**	**2002**
EKOA1	337°/100m	0-1	17	28	49	5	8	<1	<1
		1-3	25	35		7	11	<1	<1
		3-6	39	58		14	17	<1	<1
		6-9	20					<1	
EKOA1B	337°/150m	0-1	16	24		3	6		<1
		1-3	24	32					
		3-6	23	55					
		6-9	28	35					
		9-12	11	42					
EKOA1C	337°/200m	0-1	13	15		2	3		<1
		1-3	30	24					
		3-6	22	61					
		6-9	34	93					
		9-12	18	64					
EKOA2	337°/250m	0-1	18	20	12				
EKOA3	337°/500m	0-1	12	12	11				

Table 4.11.2. *cont.*

EKOA4	337°/1000m	0-1	11	16	14				
EKOA5	67°/100m	0-1	195	141	384	61	54	3	1
		1-3	409	152		168	60	3	<1
		3-6	1031	92		465	12	3	<1
EKOA5B	67°/150m	0-1	106	146		20	51		1
		1-3	213						
		3-6	216						
		6-9	200						
		9-11	132						
EKOA5C	67°/200m	0-1	42	125		7	44		<1
		1-3	51						
		3-6	84						
		6-9	52						
		9-12	10						
EKOA6	67°/250m	0-1	29	83	58				
EKOA7	67°/500m	0-1	13	16	9				
EKOA8	67°/1000m	0-1	12	16	13				
EKOA19	67°/2000m	0-1	9						
EKOA9	157°/100m	0-1	73	119	311	16	46	3	2
		1-3	246	155		77	43	2	<1
		3-6	245	50		74	8	1	<1
		6-9	649						
		9-12	476						
		12-15	407						
		15-20	18						
EKOA9B	157°/150m	0-1	24	109		3	34		1
		1-3	52	285					
		3-6	73	104					
		6-9	35	60					
		9-12	8	30					
EKOA9C	157°/200m	0-1	17	88		2	22		<1
		1-3	44	110					
		3-6	44	52					
		6-9	26	23					
		9-12	14						
EKOA10	157°/250m	0-1	22	41	59				
		1-3	54	46	114				
		3-6	61	54	69				
EKOA11	157°/500m	0-1	11	16	16				
		1-3	8	16					
		3-6	10	21					
EKOA12	157°/1000m	0-1	10	10	14				
EKOA12A	157°/2000m	0-1	8	8					

Table 4.11.2. *cont.*

EKOA13*	247°/100m	0-1	90	93		14	35	1
		1-3	142	205		24	97	<1
		3-6	307	111		14	26	<1
		6-9	122					
		9-12	8					
		12-15	6					
		15-25	12					
EKOA13B	247°/150m	0-1	33	125		4	54	<1
		1-3	82					
		3-6	73					
		6-9	80					
		9-12	20					
EKOA13C	247°/200m	0-1	24	36		3	12	<1
		1-3	131					
		3-6	31					
		6-9	20					
		9-12	13					
EKOA14	247°/250m	0-1	21	24	189			
EKOA15	247°/500m	0-1	12	13	18			
EKOA16	247°/1000m	0-1	10	11	10			
EKOA17	247°/2000m	0-1	9					
EKOA REF	90°/15000m	0-1	6	6	6			
		1-3	7	8	9			
		3-6	8	9	6			

Table 4.11.3. *Ekofisk 2/4 A, NPD, PAH and decalins (mg/kg dry sediment).*

			NPD			PAH			Decalins		
Station		**cm**	**2005**	**2002**	**1999**	**2005**	**2002**	**1999**	**2005**	**2002**	**1999**
EKOA1	337°/100m	0-1	0.03	0.08		0.029	0.088		<0.1	0.2	
		1-3	0.05	0.10		0.040	0.141		<0.1	0.2	
		3-6	0.06	0.14		0.045	0.119		0.1	0.5	
EKOA1B	337°/150m	0-1	0.03	0.12		0.066	0.092		<0.1		
EKOA1C	337°/200m	0-1	0.02	0.11		0.056	0.128		<0.1		
EKOA5	67°/100m	0-1	0.94	0.67		0.170	0.179		0.9	0.9	
		1-3	1.42	0.49		1.54	0.162		1.2	1.3	
		3-6	1.12	0.32		0.102	0.285		3.2	1.0	
EKOA5B	67°/150m	0-1	0.72	0.50		0.248	0.218		0.7	1.2	
		1-3	0.56			0.109			1.2		
		3-6	0.53			0.326			4.1		
		6-9	0.64			0.161			4.1		
		9-12	0.80			0.516			2.2		
EKOA5C	67°/200m	0-1	0.24	0.31		0.083	0.336		0.2	1.3	
		1-3	0.19			0.068			0.2		
EKOA9	157°/100m	0-1	0.53	0.72		0.126	0.322		0.2	1.3	
		1-3	0.44	8.17		0.140	23.4		1.1	1.4	
		3-6	0.48	0.26		0.127	0.309		3.0	0.6	
		6-9	1.18			0.155			27.9		

Table 4.11.3. *cont*.

EKOA9B	157°/150m	0-1	0.27	0.54		0.118	0.475		0.4	0.9	
		1-3	0.32			0.069			0.4		
		3-6	0.31			0.278			1.8		
EKOA9C	157°/200m	0-1	0.24	0.49		0.100	0.181		0.1	0.5	
EKOA10	157°/250m	0-1	0.16	0.21	0.15	0.080	0.092	0.065	0.2	0.2	0.4
		1-3	0.69	0.18	0.17	0.188	0.132	0.067	0.4	0.3	1.1
		3-6	0.16	0.41	0.20	0.189	0.362	0.367	0.5	0.4	2.6
EKOA11	157°/500m	0-1	0.03	0.07		0.074	0.064		<0.1	0.1	
		1-3	0.03	0.06		0.065	0.074		<0.1	0.1	
		3-6	0.03	0.08		0.069	0.106		<0.1	0.1	
EKOA13*	247°/100m	0-1	0.37	0.27		0.090	0.106		0.4	0.5	
		1-3	0.40	0.54		0.104	0.137		1.5	1.6	
		3-6	1.01	0.43		0.271	0.097		8.1	1.3	
		6-9	0.27			0.080			3.8		
EKOA13B	247°/150m	0-1	0.09	0.32		0.092	0.150		0.1	1.5	
EKOA13C	247°/200m	0-1	0.04	0.19		0.060	0.191		0.1	0.3	
EKOAREF	90°/15000m	0-1	<0.01	0.02	0.01	0.039	0.048	0.035	0.1		
		1-3	<0.01	0.03	0.03	0.049	0.068	0.094	<0.1		
		3-6	0.01	0.03	0.02	0.080	0.081	0.048	<0.1		

Table 4.11.4. *Ekofisk 2/4 A, metals (mg/kg dry sediment).*

Station		**layer cm**	**Ba 2005**	**2002**	**1999**	**Cd 2005**	**Cr 2005**	**Cu 2005**	**Hg 2005**	**Pb 2005**	**Zn 2005**
EKOA1	337°/100m	0-1	1120	2330	3750	0.04	4.7	1.4	0.01	9.0	11.5
		1-3	2120	4500		0.04	6.7	2.2	0.01	15.4	17.2
		3-6	4340	4980		0.06	6.9	2.7	0.02	16.8	22.3
EKOA1B	337°/150m	0-1		1820							
EKOA1C	337°/150m	0-1		2290							
EKOA2	337°/250m	0-1	2480	1690	2430	0.02	8.9	1.7		20.4	13.2
EKOA3	337°/500m	0-1	925	945	739	0.01	6.4	0.8		9.7	8.5
EKOA4	337°/1000m	0-1		896	1170						
EKOA5	67°/100m	0-1	4320	4740	5680	0.40	10.0	13.2	0.12	40.2	154
		1-3	5400	4950		0.72	14.0	18.6	0.17	66.0	273
		3-6	5130	4310		0.73	15.8	20.7	0.39	115	272
EKOA5B	67°/150m	0-1		4960							
EKOA5C	67°/200m	0-1		4150							
EKOA6	67°/250m	0-1	4730	4480	4340	0.12	11.5	5.9		29.2	39.5
EKOA7	67°/500m	0-1	2280	2290	1860	0.02	6.8	2.0		14.4	10.6
EKOA8	67°/500m	0-1		1190	1310						
EKOA9	157°/100m	0-1	4150	4260	4710	0.12	7.8	6.5	0.07	28.0	57.3
		1-3	5940	5620		0.27	11.5	15.5	0.08	55.1	139
		3-6	4340	4820		0.81	10.5	19.5	0.29	120	302
EKOA9B	157°/100m	0-1		5470							
EKOA9C	157°/100m	0-1		3400							
EKOA10	157°/250m	0-1	3650	4340	2990	0.03	9.5	2.6	0.03	24.3	21.9
		1-3	3070	6060	5240	0.04	10.1	2.7	0.02	28.3	24.8
		3-6	4230	5180	4810	0.08	10.7	3.2	0.04	31.9	34.6
EKOA11	157°/500m	0-1	887	1350	1670	0.02	9.3	1.1	0.02	14.4	11.6
		1-3	820	2970		0.04	10.1	1.0	0.01	10.8	10.3
		3-6	1320	4480		0.06	10.3	1.2	0.01	11.0	11.3
EKOA12	157°/1000m	0-1		476	605						
EKOA12A	157°/2000m	0-1		268							

Table 4.11.4. *cont.*

EKOA13*	247°/100m	0-1	5110	4350		0.2	14.2	17.5	0.09	51.7	125
		1-3	5330	5790		0.33	14.3	18.4	6.64	59.9	152
		3-6	4770	4290		0.53	16.8	42.1	0.15	113	263
EKOA13*B	247°/150m	0-1		4790							
EKOA13*C	247°/200m	0-1		3460							
EKOA14	247°/250m	0-1	4000	2300	4540	0.07	11.9	17.4		29.7	39.4
EKOA15	247°/500m	0-1	1690	1960	2900	0.02	6.6	4.7		13.2	11.0
EKOA16	247°/500m	0-1		957	567						
EKOA REF	90°/15000m	0-1	46	72	41	<0.01	7.6	<0.5	<0.01	6.1	5.4
		1-3	50	88	50	<0.01	8.1	<0.5	<0.01	6.4	5.8
		3-6	72	331	141	<0.01	8.0	<0.5	<0.01	6.6	5.8

4.11.1.2 Ekofisk 2/4 A, Drill cuttings pile

The sediment in the two corer samples consist mainly of silt and clay down to 40 cm depth (see Table 4.11.5). From 40 cm and down, different classifications of sand are found in both VC-2(I) and VC-2(II).

TOM ranges from 5.3-5.4 % in the deepest layers to 12.0-13.8 % in the 40-45 cm layer. The TOM content is 10.0-12.4 % in the top layer (0-5 cm), and decreases to 6.7-6.9 % in the 10-15 cm layer. It then increases to 12.0-13.8 % in the 40-45 cm layer, followed by a decrease to 5.3-5.4 % at 80-130 cm.

The 2005 TOM results are quite different from the 2002 results. In 2002 the TOM content was 1.4 % at 40-45 cm, compared to 12.0-13.8 % in 2005. The TOM results are generally higher in 2005 than in 2002.

The concentrations of THC in the corer samples from the 2005 survey ranges from 998-1150 mg/kg in the 45-65 cm layers to 77400 mg/kg in the 20-25 cm layer in VC-2 (I) and 88100 mg/kg in the 0-5 cm layer in VC-2 (II) (Table 4.11.6).The levels of THC in the 2005 samples are generally higher than in 2002. The maximum in the 2002 sample is 71900 mg/kg in the 10-15 cm layer, while the maxima in the 2005 samples are 88100 mg/kg in the 0-5 cm layer and 77400 mg/kg in the 20-25 cm layer. The depth profile for one of the 2005 samples and the one sampled in 2002 show the same pattern, except for higher levels and also at deeper layers for the 2005 sample. The other 2005 samples seems to be more heterogeneous than the others.

The concentrations of olefins in the 2005 survey ranges from 170-565 mg/kg in the 45-65 cm layers to 44400 mg/kg in the 20-25 cm layer in VC-2 (I) and 52500 mg/kg in the 0-5 cm layer in VC-2 (II) (Table 4.11.6). The levels of olefins in the samples are generally higher in 2005 than in 2002 and are in correlation with THC. A large share of the THC is olefins. This is not the case, however, for the deepest layers.

In 2005 no ester or PCB was found in the corer samples. This was not the case in 2002, when both ester and PCB were detected.

The levels of NPD in the samples are generally higher in 2005 than in 2002. The depth profiles for NPD show maxima in the top (0-10 cm) and bottom layers (80-130 cm in 2005, 35-40 cm in 2002) (see Table 4.11.6)

The levels of PAH in the samples are generally higher in 2005 than in 2002. The PAH concentrations for the 2002 sample are evenly distributed down the sediment layers. In 2005 the VC-2 (I) sample has maxima in the 0-10 cm, 15-20 cm and 30-35 cm layers, while the VC-2 (II) sample has a maximum in the 20-35 cm layers (see Table 4.11.6)

The levels of decalins in the samples are generally higher in 2005 than in 2002. A closer look at the depth profiles reveals an impression that the decalins are layered in the corer samples. In 2002 the maxima are found in the 15-20 cm and the 35-40 cm layers. In 2005 the maxima are found in the 0-5 cm, 20-30 cm and 80-130 cm layers (Table 4.11.6).

The Ba concentrations in VC-2 (I) ranges from 343 mg/kg in the 35-40 cm layer to 2100 mg/kg in the 15-20 cm layer (Table 4.11.7). In VC-2 (II) the concentrations ranges from 313 mg/kg in the 40-45 cm layer to 1500 mg/kg in the 80-115 cm layer. Compared to 2002 the concentrations are generally lower. In VC-2 (I) the Ba is distributed with maxima in the 10-20 cm, 25-30 cm and the 40-45 cm layers. In VC-2 (II) the Ba is distributed with maxima in the 10-15 cm, 20-25 cm and 80-115 cm layers. In the 2002 sample the maxima were found in the 0-5 cm, 25-30 cm and the 40-45 cm layers. The differences between VC-2 (I) and VC-2 (II) suggest that the Ba is very heterogeneous distributed in the sediment layers. The results from 2002 strengthen that impression.

Elevated concentrations of heavy metals are found in most of the samples, with the highest concentrations in the deepest layers.

The chemical results mainly agree with the drilling history. Olefins and esters were discharged in 1994. Only small discharges have taken place since 1994. As ester drilling fluids were discarged in 1994, only lower concentrations could be expected, due to the relatively easy decomposion of ester compounds. This is in agreement with that the ester content has decreased considerably since last survey and could not be detected in this survey.

Table 4.11.5. *Ekofisk 2/4 A Drill cuttings pile, silt and clay and TOM (%). 2005(I), 2005 (II) and 2002 correspond to the VC-2 (I), VC-2 (II) and VC-2 cores sampled and analysed in 2005 and 2002, respectively.*

parameter	Cores	layer (cm)										
	2005(I)	0-5	5-10	10-15	15-20	20-25	25-30	3s-35	35-40	40-45	50-60	90-130
	2005(II)										45-65	80-115
	2002										45-58	
Silt og leire	2005(I)	89,7	93,5	91,6	85,9	76,9	91,3	89,0	72,9	32,7	42,7	48,9
	2005(II)	58,8	94,1	93,0	83,6	88,6	89,8	92,6	78,1	47,6	72,2	69,7
	2002	36,6	47,7	63,5	34,5	14,2	9,3	8,0	47,2	6,2	7,3	
TOM	2005(I)	10,0	8,52	6,87	7,45	8,39	9,18	11,0	9,38	12,0	6,97	5,42
	2005(II)	12,4	9,30	6,65	7,33	7,13	9,40	9,58	9,21	13,8	6,37	5,29
	2002	6,26	10,4	9,24	8,70	5,17	4,47	3,83	2,71	1,40	1,27	

Table 4.11.6. *Ekofisk 2/4 A, Drill cuttings pile, Core sample VC-2: silt and clay, TOM (%), THC, olefins, esters, PCB, NPD, PAH and decalins (mg /kg dry sediment), 2005.*

Station	layer cm	Silt and clay 2005	TOM 2005	THC 2005	Olefins 2005	Ester 2005	PCB 2005	NPD 2005	PAH 2005	Decalins 2005
VC-2 (I)	0-5	89.7	10.0	48141	26400	<15	<0.1	69.0	18.0	48.3
	5-10	93.5	8.52	56670	32771	<15	<0.1	72.4	14.9	41.0
	10-15	91.6	6.87	20013	11546	<15	<0.1	37.2	6.7	18.1
	15-20	85.9	7.45	71677	36771	<15	<0.1	54.5	18.9	36.7
	20-25	76.9	8.39	77422	44397	<15	<0.1	52.0	14.9	73.4
	25-30	91.3	9.18	41228	29054	<15	<0.1	22.9	13.8	36.5
	30-35	89.0	11.0	49377	31464	<15	<0.1	31.2	22.4	67.1
	35-40	72.9	9.38	12540	7405	<15	<0.1	10.4	1.5	4.6
	40-45	32.7	12.0	15956	10568	<15	<0.1	9.3	1.4	3.9
	50-60	42.7	6.97	1153	565	<15	<0.1	5.4	0.4	2.3
	90-130	48.9	5.42	1855	<5	<15	<0.1	68.7	1.8	63.3
VC-2 (II)	0-5	58.8	12.4	88088	52487	<15	<0.1	80.5	3.4	105
	5-10	94.1	9.30	46341	25660	<15	<0.1	42.5	2.7	19.6
	10-15	93.0	6.65	41455	23577	<15	<0.1	48.0	2.9	21.9
	15-20	83.6	7.33	49648	28369	<15	<0.1	53.2	3.4	20.4
	20-25	88.6	7.13	43848	22817	<15	<0.1	43.4	17.6	37.6
	25-30	89.8	9.40	69221	38828	<15	<0.1	53.5	14.5	76.6
	30-35	92.6	9.58	44943	23099	<15	<0.1	30.8	13.8	48.2
	35-40	78.1	9.21	37754	19143	<15	<0.1	21.4	8.9	32.9
	40-45	47.6	13.8	4378	2066	<15	<0.1	05.7	0.9	2.2
	45-65	72.2	6.37	998	170	<15	<0.1	13.1	0.7	6.3
	80-115	69.7	5.29	7811	<5	<15	<0.1	35.8	1.0	39.5

Table 4.11.7. *Ekofisk 2/4 A, Drill cuttings pile, Core sample VC-2: Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment) 2005.*

Station	layer cm	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Hg 2005	Pb 2005	Zn 2005
VC-2 (I)	0-5	958	0.47	40.6	55.00	0.09	54.00	112
	5-10	930	0.46	37.9	83.00	0.09	67.00	128
	10-15	2079	0.39	36.7	79.00	0.09	57.00	103
	15-20	2104	0.37	40.4	77.00	0.14	70.00	133
	20-25	808	0.73	35.0	75.00	0.47	209.00	551
	25-30	2069	0.47	40.6	51.00	0.23	98.00	244
	30-35	576	0.58	43.2	46.00	0.11	129.00	271
	35-40	343	0.31	38.7	32.00	0.21	60.00	170
	40-45	1088	0.09	13.0	20.00	0.04	23.00	59
	50-60	693	0.46	46.2	57.00	0.13	138.00	230
	90-130	358	11.30	183.0	103.00	1.70	1201.00	2173

Table 4.11.7. *cont.*

Station	layer cm	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Hg 2005	Pb 2005	Zn 2005
VC-2 (II)	0-5	640	0.40	50.0	68.00	0.06	75.00	123
	5-10	847	0.44	40.8	77.00	0.08	70.00	102
	10-15	1432	0.56	38.8	81.00	0.11	46.00	135
	15-20	807	0.26	42.2	66.00	0.10	61.00	118
	20-25	1148	0.38	36.1	73.00	0.22	130.00	187
	25-30	558	0.63	48.0	81.00	0.28	103.00	299
	30-35	650	0.48	42.2	54.00	0.26	103.00	265
	35-40	480	0.43	43.3	47.00	0.18	101.00	244
	40-45	313	0.34	28.0	37.00	0.08	49.00	259
	45-65	573	0.80	40.8	49.00	0.21	237.00	390
	80-115	1502	1.29	66.9	37.00	0.37	272.00	432

4.11.2 Biology

In general the biodiversity indices are relatively high compared to several other fields in the central Ekofisk region, see Table 4.11.8. However, the fauna at EKOA-05 (67°/100m), EKOA-09 (157°/100m) and EKOA-13* (247°/100m) differ from the other stations at Ekofisk A and the disturbance in the fauna at these 100 m stations seem to be related to field activities, see Figure 4.11.1 .

The Bioenv analysis reveals a high correlation (0.9) between the fauna and the complex of the parameters THC, Ba, Cd, TOM and gravel, indicating that the variations in the fauna composition could be explained by the variations of these parameters.

The biodiversity at Ekofisk A has in general increased and there has been a significant decrease in the numbers of *M. oculata* since 2002.

Table 4.11.8. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Ekofisk 2/4 A 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H' Incl. M. o.	H' Excl. M. o.	J	ES_{100} Incl. M. o.	ES_{100} Excl. M. o.
EKOA-01	337	100	78	65	851	3.7	3.7	0.6	23	24
EKOA-02	337	250	77	100	1943	3.9	4.5	0.6	27	35
EKOA-03	337	500	78	84	1902	3.8	4.6	0.6	25	31
EKOA-05	67	100	76	69	3658	2.2	3.7	0.4	13	21
EKOA-06	67	250	76	84	2245	3.4	4.5	0.5	23	31
EKOA-07	67	500	77	81	1736	3.5	4.5	0.5	24	32
EKOA-09	157	100	76	79	2915	2.9	4.0	0.5	17	23
EKOA-10	157	250	76	103	1796	3.8	4.8	0.6	27	35
EKOA-11	157	500	76	84	2081	3.4	4.7	0.5	24	35
EKOA-13*	247	100	77	61	3295	2.8	3.5	0.5	15	19
EKOA-14	247	250	77	93	1559	4.2	4.9	0.6	29	36
EKOA-15	247	500	77	93	1923	3.7	4.6	0.6	25	34

M. o.= *M. oculata*

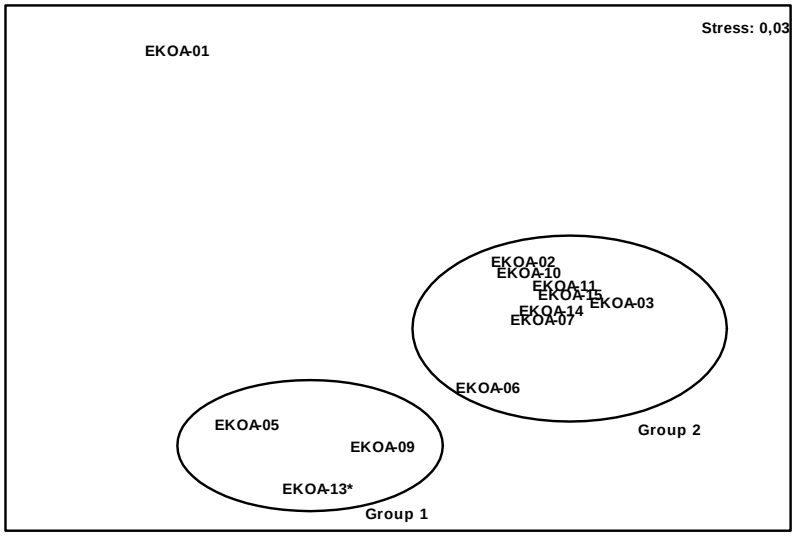

Figure 4.11.1 *MDS plot of stations from Ekofisk 2/4 A 2005 (excl. juv.).*

4.12 Eldfisk 2/7 A/FTP

4.12.1 Chemical analyses and sediment structure

The sediments at Eldfisk 2/7 A/FTP consist of fine sand, and the sand content varies from 92 % to 97%, see Table 4.12.1. The gravel content is zero. The silt and clay content is similar to the previous surveys and the average silt and clay concentration found is 5.7 %.

The total organic matter content in the sediments is low, see Table 4.12.1. Only small variations are found at the field, from 0.88 % to 0.97 %. The concentrations are similar to the previous surveys and the content corresponds to the grain size distribution.

The THC content has decreased for all the stations analysed, comparing with previous surveys, see Table 4.12.1. The mean THC concentrations vary from 4.3 mg/kg (ELDA7) to 120 mg/kg (ELDA4). Elevated THC concentrations are found at ELDA4, 360°/250m (120 mg/kg), at ELDA6, 180°/370m (11.2 mg/kg) and ELDA13, 90°/250m (14 mg/kg). Relative high concentrations of THC are also found in the vertical sections at ELDA6; 20 mg/kg and 23 mg/kg respectively. Thus elevated levels of THC are observed out to 370m in the 180° direction and to 250m in the 90° and 360°. For the other stations the THC content is low, either below or slightly above the limit of contamination.

Olefins are also detected at the two stations analysed, with 0.5 mg/kg at ELDA6, 180°/370m to 0.6 mg/kg at ELDA14, 90°/500m, see Table 4.12.1. The concentrations have decreased since the previous survey in 2002. The last discharge of olefins is reported in 2000.

The NPD and PAH concentrations at ELDA6, 180°/370m have only increased slightly since 2002 to 0.10 mg/kg of NPD and 0.22 mg/kg of PAH, see Table 4.12.1. The content of decalins has decreased in the same period for all three layers. However, elevated level of decalins in the vertical layers is still observed. These trends are in agreement with the THC results.

Elevated levels of NPD and decalins are observed at ELDA4 (grab #3). The relative high concentration of decalins (33 mg/kg) confirms the high level of THC (306 mg/kg) found in this sample. The content of PAH in this sample is low, below the limit of contamination.

The Ba concentrations vary from 590 mg/kg at ELDA3, 360°/625m to 1699 mg/kg at ELDA11, 270°/500m, see Table 4.12.2. Elevated Ba concentrations are found at all stations. This means out to maximum 625m in the 360° direction and limited to 370m in the 180° directions. The

concentrations are similar to the previous surveys. This is in agreement with the drilling history. No discharge of barite has taken place since 2000.

The concentrations of heavy metals are low, and no increases are observed since 2002, see Table 4.12.2. Slightly elevated concentrations of Pb and Zn are found, also in the vertical layers.

Mainly the chemical results are in correspondence with the drilling history at Eldfisk 2/7 A/FTP. No barite has been discharged since 2000.

Table 4.12.1. *Eldfisk A, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
ELDA3	360°/625m	4.0	4.10		0.88	0.76		4.8	8.3		
ELDA4	360°/250m							120			
ELDA5	180°/250m							8.2			
ELDA6	180°/370m	5.3	5.1	5.7	0.97	0.89	0.81	11.2	33	16.3	18.8
	1-3cm							20.4	48	16.0	10.3
	3-6cm							23	52	15.9	33.9
ELDA7	180°/870m		4.4	5.9		0.85	0.87	4.3	7.6	11.8	10.2
ELDA12	270°/250m							8.3			
ELD11	270°/500m	5.0			0.97			6.6			
ELDA13	90°/250m							14.0			
ELDA14	75°/500m	8.3	5.5		0.94	0.90		7.7	16.9		
ELDA106	180°/500m							5.7			
EKO42 Ref.	90°/15000m	2.6	2.6	5.3	0.88	0.82	0.95	5.8	5.9	5.5	6.4
	1-3cm							7.3			
	3-6cm							7.6			

Table 4.12.1. *cont.*

		Olefiner			NPD			PAH			Dekaliner		
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
ELDA6	180°/370m	0.5	1.3	0.9	0.10	0.062	0.076	0.224	0.064	0.042	0.084	0.084	0.165
	1-3cm	0.5		0.9	0.05	0.071	0.043	0.094	0.064	0.049	2.5	4.20	0.104
	3-6cm	0.6		0.9	0.08	0.057	0.042	0.161	0.060	0.053	1.4	4.62	0.120
EKO42 Ref.	90°/15000m				nd	0.021	0.010	0.039	0.048	0.035	0.1	nd	nd
	1-3cm				nd		0.032	0.049		0.094	nd		nd
	3-6cm				0.014		0.015	0.080		0.048	nd		nd
ELDA11	270°/500m	nd											
ELDA14	75°/500m	0.6	1.3										

Table 4.12.2. *Eldfisk 2/7 A/FTP, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba	Ba	Ba	Ba	Cd	Cd	Cd	Cr	Cr	Cr
		2005	2002	1999	1996	2005	2002	1999	2005	2002	1999
ELDA3	360°/625m	590	593			<0.01	0.01		6.7	6.7	
ELDA6	180°/370m	1007	1150	1130	2390	<0.01	0.02	<0.03	7.3	7.2	7.8
	1-3 cm	1820	2330	1280		0.02	0.04	<0.02	8.5	7.9	7.2
	3-6 cm	2599	2600	2740		0.03	0.04	0.03	9.1	7.6	8.0
ELDA11	270°/500m	1699				<0.01			7.2		
ELDA14	90°/500m	1646	1540			<0.01	0.02		7.6	7.5	
EKO42 Ref.	90°/15000m	46	72	41	67	<0.01	<0.01	<0.02	7.6	7.7	7.1
	1-3 cm	50	88	50		<0.01	<0.01	<0.02	8.1	7.7	7.2
	3-6 cm	72	331	141		<0.01	0.01	<0.02	8.0	8.1	7.8

Table 4.12.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
ELDA3	360°/625m	0.7	1.5					9.7	9.3		7.6	10.2	
ELDA6	180°/370m	1.2	2.4	1.4	0.03	0.02	0.02	10.3	10.2	14.5	10.1	10.6	13.7
	1-3 cm	1.6	2.7	1.1	0.03	0.02	0.04	12.3	14.6	14.3	13.5	18.8	12.1
	3-6 cm	2.0	2.7	1.9	0.02	0.03	0.03	15.8	15.3	17.5	21.8	19.0	20.7
ELDA11	270°/500m	1.1						10.9			10.2		
ELDA14	90°/500m	1.4	2.4					13.5	14.0		11.7	12.5	
EKO42 Ref.	90°/15000m	<0.5	1.0	0.5	<0.01	<0.01	<0.01	6.1	6.3	6.1	5.4	5.6	4.7
	1-3 cm	<0.5	1.1	0.5	<0.01	0.01	<0.01	6.4	6.3	6.0	5.8	5.6	5.1
	3-6 cm	<0.5	1.8	0.8	<0.01	<0.01	<0.01	6.6	7.2	7.3	5.8	6.9	5.8

4.12.2 Biology

In general the reduced biodiversity indices at Eldfisk A reflect some disturbance in the fauna community in 2005 out to 625 m from the field centre (Table 4.12.3). A decline in the numbers of *M. oculata* in 2005 as described at several other fields in the area has not been the case at Eldfisk A and the biodiversity indices are almost unchanged since the survey in 2002. Taking the general trend in the region into account, the positive trend seems to go somewhat slower at Eldfisk A. However, there has been a shift in the fauna community from a fauna where *C. setosa,* a strong indicator species able to act as a deposit feeder, was the dominating species in the 1990's towards a fauna community where the transition species *M. oculata* dominates the fauna together with a higher share of other suspenison feeding species. This development in the fauna indicates a slow improvement in the environment at Eldfisk A.

Table 4.12.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Eldfisk 2/7 A/FTP/E 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
ELDA-03	360	625	74	88	3580	2.4	4.2	0.4	16	30
ELDA-06	180	370	75	63	2486	3.3	3.6	0.6	16	18
ELDA-11	270	500	74	90	1677	3.4	4.2	0.5	23	32
ELDA-14	90	500	74	83	2833	2.5	4.8	0.4	19	35

M. o.= *M. oculata*

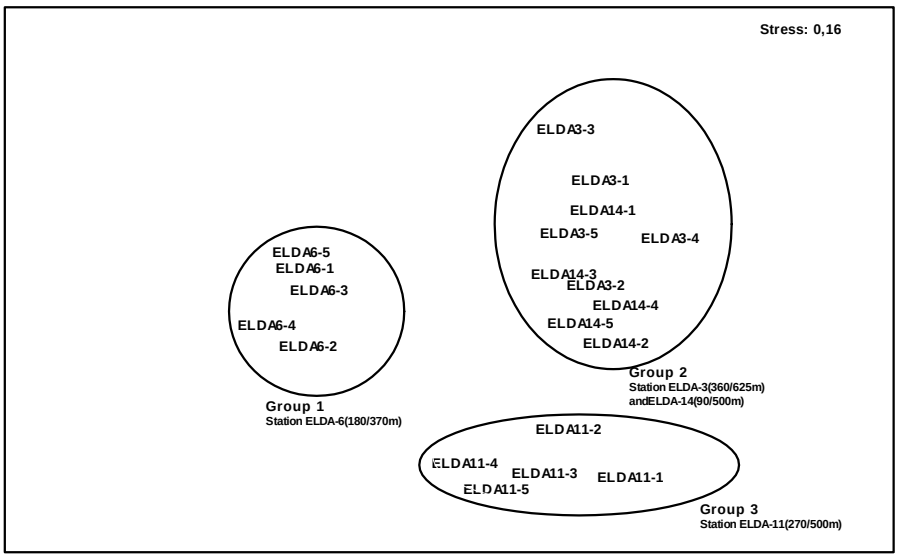

Figure 4.12.1. *MDS plot of grab samples from Eldfisk 2/7 A/FTP/E 2005.*

4.13 Eldfisk 2/7 B

4.13.1 Chemical analyses and sediment structure

The sediments at Eldfisk 2/7 B consists of fine sand and varies from 95 % to 97 %, see Table 4.13.1. The gravel content is zero or very low. Silt and clay content is similar to previous surveys.

The total organic matter content in the sediments is low, see Table 4.13.1. Only small variations are found at the field, from 0.88 % to 1.02 %. The content corresponds to the grain size distribution.

The mean THC concentrations vary from 5.8 mg/kg at ELDB11, 270°/500m to 30 mg/kg at ELDB13, 90°/250m, see Table 4.13.1. Elevated THC content is observed for three stations, respectively 15.8 mg/kg at ELDB5, 180°/250m, 13.2 mg/kg at ELDB12, 270°/250m and 30 mg/kg at ELDB13, 90°/250m. Thus elevated levels of THC are observed out to 500m in the 90° direction and to 250m in the 180° and 270° direction. For the other stations the THC content is below or just above the limit of contamination. The THC content for these stations has decreased since 2002. Elevated THC concentrations are observed in the deeper sections at ELDB6 and ELDB13.

Olefins are detected at the three stations analysed, and varies from 0.5 mg/kg at ELDB14, 90°/500m to 0.9 mg/kg at ELDB13, 90°/250m, see Table 4.13.1. The content of olefins has decreased since the last survey.

Low concentrations of NPD and PAH are found for ELDB5, 180°/250m, ELDB6, 180°/500m and ELDB13, 90°/250m, but the content is increasing slightly going down in the sediment, see Table 4.13.1. The content of decalins is relatively high, 0.52 mg/kg at ELDB5, 180°/250m and 1.8 mg/kg at ELDB13, 90°/250m. The content is also high in the deeper layers, up to 2.6 mg/kg at ELDB13 in the 1-3 cm layer. At ELDB6 the decalin content is low and has decreased considerably since the 2002 survey. The relatively high contents of decalins found are in agreement with the relatively high contents of THC observed at ELDB5 and ELDB13.

The Ba concentrations vary from 644 mg/kg at ELB3, 360°/500m to 1706 mg/kg at ELD14, 90°/500m, see **Error! Reference source not found.**. The Ba concentrations are similar to the previous survey, and elevated concentrations are found at all stations. This means out to 500m

in all directions. The highest Ba concentrations are found in the 3-6 cm layer at ELDB6, 180°/500m, 2674 mg/kg.

The concentrations of heavy metals are low, and no increases are observed since 2002, see Table 4.13.2. Slightly elevated concentrations of Pb and Zn are found, also in the vertical layers.

The chemical results are mainly in correspondence with the drilling history at Eldfisk 2/7 B. Pseudo-oil based drilling fluids (olefins) and barite are not discharged since the last survey in 2002.

Table 4.13.1. *Eldfisk B, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
ELDB3	360°/500m	4.0	4.5	5.6	0.88	0.98	0.75	6.5	11.6	8.5	
ELDB4	360°/250m							7.5			
ELDB5	180°/250m							15.8			
	1-3cm							18.9			
	3-6cm							23			
ELDB6	180°/500m	4.3	5.4	5.1	0.92	0.96	1.07	6.1	15.0	22.0	12.7
	1-3cm							8.8			
	3-6cm							22			
ELDB11	270°/500m	3.6	6.4	4.5	1.02	0.88	0.81	5.8	12.2	11.9	
ELDB12	270°/250m							13.2			
ELDB13	90°/250m							30			
	1-3cm							54			
	3-6cm							76			
ELDB14	90°/5000m	4.6	6.1	3.6	0.89	0.88		11.2	16.4	14.1	
EKO42 Ref.	90°/15000m	2.6	5.4	4.8	0.88	0.82	0.95	5.8	5.9	5.5	6.4
	1-3cm							7.3			
	3-6cm							7.6			

Table 4.13.1. *cont.*

		Olefiner			NPD			PAH			Dekaliner		
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
ELDB5	180°/250m	0.6			0.07			0.07			0.52		
	1-3cm	1.0			0.09			0.11			0.69		
	3-6cm	1.7			0.07			0.08			0.74		
ELDB6	180°/500m				0.03	0.060	0.444	0.03	0.056	0.858	0.07	0.626	0.091
	1-3cm				0.04	0.061	0.070	0.06	0.061	0.114	0.14	0.986	0.058
	3-6cm				0.07	0.070	0.078	0.12	0.102	0.129	0.69	0.481	0.111
ELDB13	90°/250m	0.9			0.12			0.07			1.80		
	1-3cm	2.8			0.11			0.11			2.57		
	3-6cm	1.9			0.16			0.17			1.65		
	1-3cm				nd		0.032	0.049		0.094	nd		nd
	3-6cm				0.014		0.015	0.080		0.048	nd		nd
ELDB14	90°/5000m	0.5	1.1	1.2									
EKO42 Ref	90°/15000m				nd	0.021	0.010	0.039	0.048	0.035	0.1	nd	nd

Table 4.13.2. *Eldfisk 2/7 B, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
ELDB3	360°/500m	644	1020	1000		<0.01	0.01	<0.02	7.2	6.9	6.2
ELDB6	180°/500m	1082	1480	1460	1630	<0.01	0.02	<0.02	6.4	6.1	7.1
	1-3 cm	1109	1730	1500		<0.01	0.03	0.02	6.7	6.1	6.6
	3-6 cm	2674	2740	2930		0.02	0.03	0.03	7.7	7.0	6.9
ELDB11	270°/500m	1005	1210	1450		<0.01	0.01	<0.02	4.8		
ELDB14	90°/500m	1706	1850	1740		<0.01	0.02	<0.02	7.2	6.8	7.3
EKO42 Ref.	90°/15000m	46	72	41	67	<0.01	<0.01	<0.02	7.6	7.7	7.1
	1-3 cm	50	88	50		<0.01	<0.01	<0.02	8.1	7.7	7.2
	3-6 cm	72	331	141		<0.01	0.01	<0.02	8.0	8.1	7.8

Table 4.13.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
ELDB3	360°/500m	0.8	1.7	0.6				9.2	9.5	8.7	7.5	9.3	6.2
ELDB6	180°/500m	1.2	1.9	1.2	0.01	0.02	0.03	10.8	10.3	12.6	8.3	13.6	13.1
	1-3 cm	0.9	1.9	1.1	<0.01	0.02	0.02	10.7	11.1	12.3	8.2	9.7	12.3
	3-6 cm	1.6	3.7	1.2	0.01	0.03	0.04	15.2	15.3	13.5	12.6	19.0	12.1
ELDB11	270°/500m	0.7	1.9	1.1				7.0	10.6	12.8	5.8	10.7	9.3
ELDB14	90°/500m	1.2	2.5	1.4				14.4	15.6	17.3	10.4	14.3	11.4
EKO42 Ref.	90°/15000m	<0.5	1.0	0.5	<0.01	<0.01	<0.01	6.1	6.3	6.1	5.4	5.6	4.7
	1-3 cm	<0.5	1.1	0.5	<0.01	0.01	<0.01	6.4	6.3	6.0	5.8	5.6	5.1
	3-6 cm	<0.5	1.8	0.8	<0.01	<0.01	<0.01	6.6	7.2	7.3	5.8	6.9	5.8

4.13.2 Biology

The biological analysis at Eldfisk B reveals a slightly disturbed fauna at the stations sampled near the field centre (out to 500 m from the field centre), see Figure 4.13.1. There was no significant correlation between the fauna composition and the chemical parameters. The biodiversity in the fauna community has in general increased slightly since the survey in 2002 (Table 4.13.3), together with an ongoing shift in the fauna community. *C. setosa* which is a strong indicator species able to act as deposit feeder, was the dominating species in the fauna in the 1990's. In 2002 this species decreased and *M. oculata,* a transition species, dominated the fauna together with a higher share of other suspension feeding species which has increased towards 2005. However, a general decline in the numbers of *M. oculata* as described at several other fields in the area in 2005 has not been the case at Eldfisk B, but the development in the fauna could indicate a slowly improvement in the environment at Eldfisk B.

Table 4.13.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Eldfisk 2/7 B 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H' Incl. M. o.	H' Excl. M. o.	J	ES_{100} Incl. M. o.	ES_{100} Excl. M. o.
ELDB-03	360	500	75	95	3196	3.0	4.2	0.5	19	28.1
ELDB-06	180	500	76	86	2086	3.1	4.6	0.5	22	34.4
ELDB-11	270	500	75	88	2222	3.2	4.1	0.5	20	27.0
ELDB-14	90	500	76	82	2269	3.1	4.1	0.5	20	28.7

M. o.= *M. oculata*

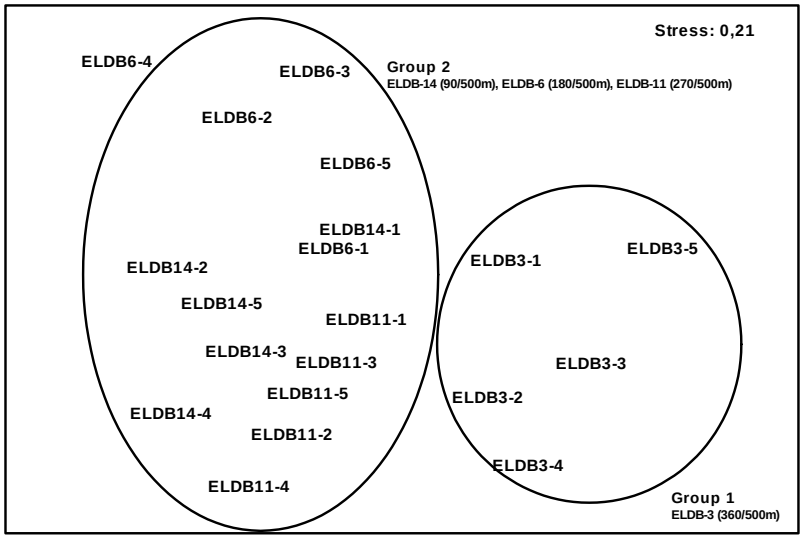

Figure 4.13.1. *MDS plot of grab samples from Eldfisk 2/7 B 2005 (excl. juv.).*

4.14 Embla

4.14.1 Chemical analyses and sediment structure

Previous surveys show that the sediments at Embla 2/7 D consist of fine sand and that the gravel content is low. The total organic matter content in the sediments is also low, in average ~0.85 %. The mean THC concentrations vary from 3.9 mg/kg at EMBLA4, 360°/250m to 18.2 mg/kg at EMBLA5, 180°/250m, see Table 4.14.1. Concentrations above the limit of contamination are found for station EMBLA5, 180°/250m and EMBLA13, 90°/250m. For EMBLA4, 360°/250m and EMBLA12, 270°/250m, the content of THC is below the limit of contamination for the region. The chemical results agree with the drilling history. No discharges have taken place at Embla 2/7 D since 1999, except for some small amounts of oil discharges/spills in 2002 and 2003.

Table 4.14.1. *Embla THC (mg/kg dry sediment).*

Station		THC 2005
Embla-04	360°/250m	3.9
Embla-05	180°/250m	18.2
Embla-12	270°/250m	4.4
Embla-13	90°/250m	15.0
EKO Ref. 42	90°/15000m	5.8

Based on the results biological analyses should be included at Embla in the next monitoring survey.

4.15 Tor 2/4 E

4.15.1 Chemical analyses and sediment structure

The sediments at Tor 2/4 E consist of fine sand, and the sand content is in average 97.5 %, see Table 4.15.1. The gravel content is low. The silt and clay content is similar to the previous survey.

The total organic matter content in the sediments is low, see Table 4.15.1. Only small variations are found at the field, from 0.86% to 0.93 % for the two stations surveyed. The content is at the same level as found in the 2002 survey.

The mean THC concentrations vary from 6.6 mg/kg at TOR12, 270°/500m to 20 mg/kg at TOR5, 180°/250m, see Table 4.15.1.

Ethers were found at all stations analysed, see Table 4.15.3. The mean concentrations varied from 1.3 mg/kg at TOR12 to 28 mg/kg at TOR4. Grab # 3 at TOR4 showed ether content of 75 mg/kg.

The highest concentrations of THC and ethers were found in the vertical layers at TOR5, with 23 mg/kg THC and 93 mg/kg ethers in the 1-3 cm layer and 23 mg/kg THC and 56 mg/kg ethers in the 3-6 cm layer. Station TOR12 has a content of THC (or sum THC plus ether) close to the limit of contamination. The other stations analysed show elevated levels of THC (or THC plus ethers). Thus elevated levels of THC (or THC/ether) are observed out to 500m in the 180° direction and to 250m in the 90 and 360° direction.

Slightly elevated NPD concentrations are found at the two stations analysed, TOR5, 180°/250m and TOR6, 180°/500m, see Table 4.15.1. At TOR5 elevated levels of NPD are also found in the deeper layers, as for TOR6 concentration of NPD is low in the deeper layers and has decreased since 2002.

The PAH content has increased slightly since 2002 survey, see Table 4.15.1. The mean concentration of PAH is 0.053 mg/kg at TOR5 and 1.6 ± 2.5 mg/kg at TOR6. The elevated level at TOR6 is mainly due to grab #3. The standard deviation for the mean value at TOR6 is thus high. Decalins are not found in the top 0-1 cm layers, but small amounts are found in the deeper layers at TOR5.

The Ba concentrations vary from 341 mg/kg at TOR6, 180°/500m to 1505 mg/kg at TOR5, 180°/250m, see Table 4.15.2. Elevated Ba concentrations are found at the two stations analysed. This means out to 500m in the 180° direction. The concentrations are similar to the 2002 and 1999 survey. High concentrations are also found in the vertical layers at TOR5, 180°/250m, with respectively 2744 mg/kg and 3501 mg/kg.

The concentrations of the heavy metals are low, however some elevated concentrations of heavy metals are found, particularly at TOR5, 180°/250m and in the layer samples as well, see Table 4.15.2. No increases are observed since 2002.

The chemical results agree with the drilling history. No drilling activities has taken place at Tor 2/4 E since 1990 and only minor discharges has taken place in the periode 2002-2005.

In 1990 the drilling fluid Aquamul B was added as a lubricant in the water based mud drilling.

Table 4.15.1. *Tor, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
TOR2/4E4	360°/250m							8.0		
TOR2/4E5	180°/250m	1.6	4.1	3.5	0.93	0.96	0.80	20.3	31	46
	1-3cm							22.9	122	174
	3-6cm							22.7	238	192
TOR2/4E6	180°/500m	3.1	4.0	3.6	0.86	0.92	0.77	9.5	8.5	19
	1-3cm							7.5	9.3	
	3-6cm							20.8	13	
TOR2/4E12	270°/250m							6.6		
TOR2/4E13	90°/250m							11.1		
EKO Ref. 42	90°/15000m	2.6	2.6	5.3	0.88	0.82	0.95	5.8	5.9	5.5

Table 4.15.1. *cont.*

Station		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
TOR2/4E5	180°/250m	0.065	0.12	0.13	0.053	0.045	0.17	nd	0.072	0.15
	1-3cm	0.25	0.13	0.16	1.04	0.039	0.097	0.17	0.21	0.38
	3-6cm	0.065	0.16	0.20	0.27	0.046	0.050	0.12	0.57	0.46
TOR2/4E6	180°/500m	0.039	0.048		1.6	0.043		nd	nd	
	1-3cm	0.016	0.026		0.77	0.052		nd	nd	
	3-6cm	0.023	0.061		0.095	0.11		nd	0.056	

Table 4.15.2. *Tor 2/4 E,Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba	Ba	Ba	Ba	Cd	Cd	Cd	Cr	Cr	Cr
		2005	2002	1999	1996	2005	2002	1999	2005	2002	1999
TOR5	180°/250m	1505	1420	1470	2590	0.03	0.04	0.06	8.5	7.9	6.6
	1-3 cm	2744	2110	2350		0.04	0.09	0.03	9.3	8.4	8.0
	3-6 cm	3501	2330	2190		0.11	0.06	0.20	10.1	7.9	8.9
TOR6	180°/500m	341	448	385	1300	0.01	0.02	<0.02	8.4	8.0	7.2
	1-3 cm	674	1390			0.02	0.03		9.0	9.0	
	3-6 cm	1195	1090			0.04	0.05		9.9	9.8	
EKO Ref.	90°/15000m	46	72	41	67	<0.01	<0.01	<0.02	7.6	7.7	7.1
	1-3 cm	50	88	50		<0.01	<0.01	<0.02	8.1	7.7	7.2
	3-6 cm	72	331	141		<0.01	0.01	<0.02	8.0	8.1	7.8

Table 4.15.2. *cont.*

Station		Cu	Cu	Cu	Hg	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
TOR5	180°/250m	2.3	1.5	0.7	0.05	0.04	0.03	18.3	24.3	15.3	19.0	25.3	26.5
	1-3 cm	3.2	4.2		0.03	0.05	0.06	24.0	26.6	21.0	26.1	40.9	40.2
	3-6 cm	3.9	2.7		0.04	0.03	0.04	28.8	21.9	31.3	48.5	32.1	126
TOR6	180°/500m	0.7	1.9	0.9	<0.01	0.02		10.4	12.6	11.9	10.0	9.0	9.5
	1-3 cm	0.9	2.1		0.01	0.02		11.8	14.4		11.0	12.4	
	3-6 cm	1.1	2.5		0.01	0.02		10.7	10.3		11.8	13.5	
EKO Ref.	90°/15000m	<0.5	1.0	0.5	<0.01	<0.01	<0.01	6.1	6.3	6.1	5.4	5.6	4.7
	1-3 cm	<0.5	1.1	0.5	<0.01	0.01	<0.01	6.4	6.3	6.0	5.8	5.6	5.1
	3-6 cm	<0.5	1.8	0.8	<0.01	<0.01	<0.01	6.6	7.2	7.3	5.8	6.9	5.8

Table 4.15.3. *Tor, ether (mg/kg)*

Stasjon		Ether 2005
TOR2/4E4	360°/250m	28
TOR2/4E5	180°/250m	17
	1-3cm	93.1
	3-6cm	56.2
TOR2/4E6	180°/500m	2.0
	1-3cm	2.3
	3-6cm	2.4
TOR2/4E12	270°/250m	1.3
TOR2/4E13	90°/250m	10.4

4.15.2 Biology

The fauna community at station TOR-06 (180º/500m) is characterized as relatively healthy, independent of the abundance of *M. oculata*. The biodiversity indices have increased at both stations since the last survey, indicating improvement in the fauna community, see Table 4.15.4. However, the decline in *M. oculata* observed at TOR-06 was not observed at TOR-05, located 250m from the centre, see Figure 4.15.1. The abundance of *M. oculata*, higher levels of THC and metals combined with field observations of oil film/black spots, still indicate some disturbance.

Table 4.15.4. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Tor 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
TOR-05	180	250	69	93	4092	2.5	4.4	0.4	19	30
TOR-06	180	500	69	85	1107	4.4	4.3	0.7	29	29

M. o.= *M. oculata*

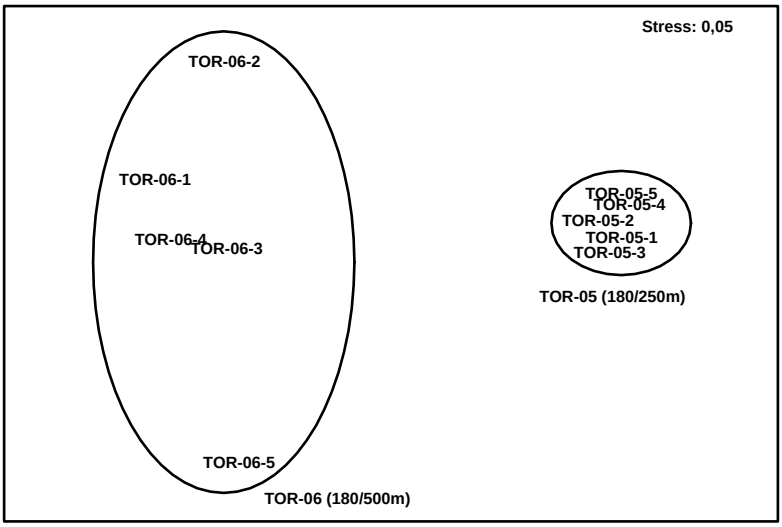

Figure 4.15.1. *MDS plot of stations from Tor 2005 (excl. juv.).*

4.16 Yme Gamma

4.16.1 Chemical analyses and sediment structure

The sediments at the regular monitoring stations at Yme Gamma consist of medium sand, and the sand content varies from 94 % at YMEG5, 120°/500m to 98 % at YMEG18, reference station, 300°/10000m, see Table 4.16.1. The gravel content is low, only small amounts are found at some stations. The silt and clay content is similar to the previous surveys.

Samples were also taken from the Installation Centre and from stations at 100m distance. At the Centre 0°/0m the sediment consists of 81 % silt and clay. High content of silt and clay is found for YMEG-II, 120°/100m and YMEG-III, 210°/100m with 38 % and 25 % respectively. At YMEG-I, 30°/100m and YMEG-IV, 300°/100m, the silt and clay content is similar to the ordinary Yme Gamma stations and the sand content varies from 93.6 % to 94.9 %. The sediments at the 100m stations are characterized as medium sand.

The total organic matter content in the sediments outside 100m distance is low, see Table 4.16.1. The concentrations vary from 0.52 % to 0.69 %. The results are similar to the previous surveys. At the Installation Centre 0°/0m the TOM content is high, 5.6 %. Relatively high TOM content is also found for YMEG-II, 2.8 % and YMEG-III, 2.4 %, respectively. The results are similar to the 2002 survey and the results correspond to the grain size distribution.

The mean THC concentrations at the regular monitoring stations vary from 2.4 mg/kg at YMEG10, 210°/250m to 32 mg/kg at YMEG5, 120°/250m, see Table 4.16.1. Correspondingly, the concentrations of olefins vary from <0.4 mg/kg to 2.5 mg/kg. The maximum concentrations of THC found are at YMEG5, with 32 mg/kg in the top 0-1 cm layer, 53 mg/kg in the 1-3 cm layer and 91 mg/kg in the 3-6 cm layer. Thus, the THC concentrations increase downwards in the sediment. This seems also to be the pattern for YMEG6 (120°/250m), increasing slightly from 7.2 mg/kg in the top 0-1 cm layer to 8.5 mg/kg in the 3-6 cm layer.

At stations YMEG5 and YMEG1, the concentration of THC in the top 0-1 cm layer has decreased distinctly since the 2002 survey, YMEG5 from 87 mg/kg to 32 mg/kg and YMEG1 from 39 mg/kg to 5.7 mg/kg. At the other stations the THC concentrations are low, with contents around the limit of contamination. Thus elevated THC concentrations are only observed out to 250m in 120°direction. The THC content in the vertical deeper investigated has not changed since 2002.

Generally, the olefins are closely related to the THC contents and thus a similar pattern might be observed, see Table 4.16.1. The mean olefin concentration at the regular monitoring stations is low and vary from not detectable (<0.4 mg/kg) to 2.5 mg/kg at YMEG5, 120°/250m. At YMEG5, the olefin concentration in the top 0-1 cm layer has decreased from 35 mg/kg in 1999 to 4.8 mg/kg in 2002 to 2.5 mg/kg in 2005. The olefins concentrations in the layers increase downwards in the sediments. The maximum concentration is found in the 3-6 cm layer. The concentrations of olefins at YMEG1 have decreased from 9.9 mg/kg in 2002 to not detectable (<0.4 mg/kg) in the present survey. At the other stations investigated the concentrations of olefins are low (<0.4 mg/kg).

At the Installation Centre, 0°/0m, the THC concentration is high (4510 mg/kg). However, the concentration in the top 0-1 cm layer has decreased considerably compared to the 2002 survey where a THC content of 1.3% was found. Vertical sections to 15 cm depth have been sampled, and the THC concentrations decrease gradually downwards. The level of the THC concentration in the deeper layers is similar to the 2002 level.

High concentrations are also found at the 100 m stations in the 30°, 120° and 210° directions. The mean concentrations vary from 34 mg/kg in the 30° direction to 706 mg/kg in the 120° direction. The THC concentration is only 8.5 mg/kg in the 300° direction. However, the THC content has decreased distinctly for all directions compared to the 2002 survey.

The sediments from the central station also contain olefins, however these are not quantified. The olefins found agree with the constituents of the pseudo-oil based drilling fluid Ultidril, C14 and C16 olefins, see Table 4.16.4.

The ester based drilling fluid Petrofree is found at the two stations analysed, 3.4 mg/kg at YMEG5, 120°/250m and 0.5 mg/kg at YMEG6, 120°/500m, see Table 4.16.4. The Petrofree concentrations are similar to the 2002 survey. Finagreen is not detected. The results correspond with the discharge history and with the relatively easy degradation of ester compounds.

Elevated levels of NPD, PAH and decalins are found at YMEG5, 120°/250m, see Table 4.16.1. The NPD and PAH concentrations have increased since 2002. The decalin concentrations have decreased. Only slightly elevated NPD and PAH concentrations are found at YMEG6, 120°/500m. Decalins are not detectable. The mean NPD concentrations vary from not

detectable at the reference station to 0.66 mg/kg at YMEG5. Correspondingly the PAH concentrations vary from 0.013 mg/kg to 0.44 mg/kg. The decalin concentrations vary from not detectable to 0.17 mg/kg.

At the installation Centre the concentrations of NPD, PAH and decalins are high (8.7 mg/kg of NPD, 1.9 mg/kg of PAH and 186 mg/kg of decalins). High concentrations of NPD, PAH and decalins are also found for all the deeper layers in the 1-15 cm section, where the NPD content varies from 7.3 mg/kg to 13.7 mg/kg, the PAH content from 1.1 mg/kg to 1.5 mg/kg and the decalins content from 6.7 mg/kg to 174 mg/kg. High levels of NPD, PAH and decalins at the 100m stations are also found. The decalins concentrations are in accordance with the THC contents and represent 2-4 %.

PFOS (perfluorooctyl sulphonate) is analysed at one station at Yme Gamma Central, YMEG-II, 120°/100m, see Table 4.16.2. The PFOS content at YMEG-II was 25.8 µg/kg.

The mean Ba concentrations at the regular monitoring stations vary from 10 mg/kg at YMEG18 reference station, 300°/10000m to 4489 mg/kg at YMEG5, 120°/250m, see Table 4.16.3. High Ba concentrations are also found at YMEG1, 30°/250m, YMEG6, 120°/500m, 1778 mg/kg and 1466 mg/kg respectively. The Ba concentrations are similar or slightly lower compared to the 2002 and 1999 surveys. Elevated Ba concentrations are found at all stations, except for at the reference station. This is out to 500m in the 120° direction and out to 250m in the other directions. The concentrations of the heavy metals are low and unchanged since 2002.

At the Installation Centre the Ba concentration has decreased from 6050 mg/kg in 2002 to 705 mg/kg in this survey. The same decrease is observed in the layers 1–3 cm and 3-6 cm. High concentrations of Ba are observed at the 100m stations in all four directions, ranging from 2247 mg/kg in the 300° direction to 5630 mg/kg in the 210° direction. Elevated levels of heavy metals are found both at 0°/0m and at the 100m stations, see Table 4.16.3.

Generally the results agree with the drilling history at Yme Gamma.

Table 4.16.1. *Yme Gamma, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
YMEG1	30°/250m	3.8	3.0		0.52	0.65		5.7	39		8.6
YMEG5	120°/250m	6.1	4.5	5.6	0.69	0.93	0.86	32	87	3.7	4.2
	1-3 cm							53	97	73	7.2
	3-6 cm							91	69	26	6.5
YMEG6	120°/500m	2.9	5.2	2.9	0.56	0.70	0.64	7.2	6.5	18.1	8.4
	1-3 cm							6.4	3.8		
	3-6 cm							8.5	5.0		
YMEG10	210°/250m	2.9	2.0		0.55	0.53		2.4	4.1		6.7
YMEG14	300°/250m	3.4	1.6		0.57	0.61		4.2	6.7		6.9

Table 4.16.1. *cont.*

		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
YMEG Central	0°/0m	81.1	75.4		5.61	6.58		4511	13100		
	1-3 cm							4619	6180		
	3-6 cm							1714	1100		
	6-9 cm							1036	635		
	9-12 cm							1242			
	12-15 cm							651			
YMEG-I	30°/100m	4.6	11.1		0.78	1.28		34	567		
YMEG-II	120°/100m	38.0	16.2		2.81	6.58		707	537		
YMEG-III	210°/100m	25.3	9.3		2.43	1.39		322	1257		
YMEG-IV	300°/100m	0.3	10.2		0.68	2.82		8.5	6500		
YMEG Ref	300°/10000m	1.6	0.5	2.8	0.52	0.63	0.59	2.7	1.8	1.9	3.6
	1-3 cm							3.1	1.34	1.8	4.0
	3-6 cm							1.4	1.36	2.5	1.4

Table 4.16.1. *cont.*

Station		NPD			PAH			Decalins		
		2005	2002	1999	2005	2002	1999	2005	2002	1999
YMEG5	120°/250m	0.66	0.398	1.770	0.441	0.124	0.292	0.2	2.72	1.870
	1-3 cm	0.53	0.241	0.410	0.140	0.062	0.120	0.5	2.85	0.983
	3-6 cm	0.50	0.224	0.191	0.114	0.078	0.068	1.9	2.38	0.298
YMEG6	120°/500m	0.05	0.027		0.035	0.046		n.d	0.104	
	1-3 cm	0.11	0.022		0.039	0.051		n.d	0.105	
	3-6 cm	0.23	0.029		0.061	0.046		n.d	0.102	
YMEG Central	0°/0m	8.70	16.4		1.915	2.51		186	201	
	1-3 cm	9.10	12.8		1.420	1.38		174	163	
	3-6 cm	7.26	4.97		1.523	0.994		44	37.9	
YMEG Ref	300°/10000m	n.d	0.006	0.005	0.013	0.011	0.015	n.d	nd	nd
	1-3 cm	n.d	0.006	0.004	0.013	0.011	0.015	n.d	nd	nd
	3-6 cm	0.021	0.006	0.007	0.036	0.010	0.025	1.167	nd	nd

Table 4.16.2. *Yme Gamma 2005, PFOS (perfluorooctyl sulphonate), µg/kg dry sediment.*

Station		**PFOS**
YMEG-II	120°/100m	19.4
		21.7
		36.3
Mean		**25.8**
SD		7.5

Limit of detection: 0.1 µg/kg

Table 4.16.3. *Yme Gamma, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
YMEG1	30°/250m	1778	1240		2420	<0.01	0.01		5.8	5.4	
YMEG5	120°/250m	4489	4350	4520	1110	<0.01	0.03	0.03	8.4	7.9	6.9
	1-3 cm	4105	5206	4760		<0.01	0.02	0.05	7.7	9.5	7.4
	3-6 cm	6521	3170	4690		0.04	0.02	0.02	9.9	6.9	7.5
YMEG6	120°/500m	1466	2100	994	426	<0.01	<0.01	<0.02	6.6	6.6	5.9
	1-3 cm	1534	2378			<0.01	<0.01		6.4	6.0	
	3-6 cm	2616	2483			<0.01	0.01		7.2	7.1	
YMEG10	210°/250m	181	387		662	0.02	0.01		9.5	5.6	
YMEG14	300°/250m	515	771		464	<0.01	<0.01		5.8	6.0	
YMEG Cent	0°/0m	705	6050			0.52	0.49		50	39	
	1-3 cm	524	4966			0.80	0.46		48	41	
	3-6 cm	517	4736			0.33	0.17		50	38	
YMEG-I	30°/100m	4628	5700			0.03	0.09		4.9	8.9	
YMEG-II	120°/100m	2801	7410			0.27	0.14		37	17.7	
YMEG-III	210°/100m	5631	5790			0.04	0.09		13.6	11.2	
YMEG-IV	300°/100m	2247	4080			<0.01	0.13		3.8	15.8	
YMEG18 Ref.	300°/10000m	10	6	6	6	<0.01	<0.01	<0.2	7.3	6.9	9.8
	1-3 cm	5	6	9		<0.01	<0.01	<0.02	7.1	6.9	9.7
	3-6 cm	13	9	14		<0.01	0.01	<0.02	7.3	6.8	9.2

Table 4.16.3. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
YMEG1	30°/250m	3.2	4.2					7.4	8.0		12.4	14.4	
YMEG5	120°/250m	6.3	5.2	7.2	<0.01	0.01	0.02	11.0	10.4	11.9	18.6	18.8	19.7
	1-3 cm	5.1	4.5	6.6	<0.01	0.01	0.02	9.8	9.9	11.8	15.4	17.6	28
	3-6 cm	5.5	3.9	3.6	0.01	0.01	0.02	14.7	8.3	9.0	25	19.0	10.1
YMEG6	120°/500m	1.0	2.7	2.1	<0.01	0.02		5.5	6.8	6.7	7.8	10.2	10.1
	1-3 cm	1.2	1.8		<0.01	0.03		7.1	6.9		7.8	7.5	
	3-6 cm	2.0	2.0		0.02	0.01		8.2	7.8		9.5	10.2	
YMEG10	210°/250m	20.3	4.5					6.3	7.2		56	17.2	
YMEG14	300°/250m	515	3.1					6.8	7.2		8.4	11.2	
YMEG Cent	0°/0m	78	76		0.14	0.16		99	95		134	136	
	1-3 cm	84	59		0.09	0.15		179	63		136	115	
	3-6 cm	81	39		0.06	0.04		156	31		103	77	
YMEG-I	30°/100m	4628	5700			0.03	0.09		4.9	8.9			
YMEG-II	120°/100m	2801	7410			0.27	0.14		37	17.7			
YMEG-III	210°/100m	5631	5790			0.04	0.09		13.6	11.2			
YMEG-IV	300°/100m	2247	4080			<0.01	0.13		3.8	15.8			
YMEG18 Ref	300°/10000m	<0.5	0.8	0.3	<0.01	<0.01	<0.05	7.7	7.5	9.9	7.0	5.4	7.4
	1-3 cm	<0.5	0.8	0.4	<0.01	<0.01	0.03	6.8	7.2	10.1	5.8	5.1	7.6
	3-6 cm	<0.5	1.4	0.7	<0.01	0.01	0.03	6.9	7.7	9.2	6.5	5.7	7.8

Table 4.16.4. *Yme Gamma, olefins and esters (mg/kg)*

Stasjon		Olefins 2005	Olefins 2002	Olefins 1999	Esters 2005	Esters 2002	Esters 1999
YMEG1	30°/250m	<0,4	9,9				
YMEG5	120°/250m	2,5	4,8	34,5	3,4	4,3	16,4
	1-3 cm	6,4		1,6	4,7		12,8
	3-6 cm	10		<0,1	6,1		4,5
YMEG6	120°/500m	<0,4	0,7	2,3	0,5	0,4	0,9
	1-3 cm	<0,4			0,5		
	3-6 cm	<0,4			0,4		
YMEG10	210°/250m	<0,4	0,3				
YMEG14	300°/250m	<0,4	0,3				

4.16.2 Biology

In general, the structure in the fauna community at Yme Gamma indicates a healthy environment. However, the biodiversity indices together with the similarity analyses indicate slight disturbances in the fauna at station YMEG-II (120°/100m), and also at YMEG-I (30°/100m) and -III (210°/100m) (Table 4.16.5 and Figure 4.16.1). This is supported by the observations from the field work and during the sample processing. Also YMEG-05 (120°/250m) differs somewhat in the similarity analyses. Based on observations from the sampling and a qualitative analysis the Installation Centre (0°/0) is characterized as heavily disturbed.

The biodiversity indices reflect slight increases at most of the stations since 2002. The similarity analyses indicate a slight overall improvement since 2002, particularly at the 100 m station YMEG-IV (300°/100m). YMEG-II is the only station that has a noticeably lower diversity index than the other stations. This station seems to have only small improvements in just some of the biological and chemical parameters measured.

Table 4.16.5. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Yme Gamma 2005, (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'	J	ES_{100}
YMEG-01	30	250	94	97	788	4.7	0.7	36
YMEG-05	120	250	95	88	757	4.8	0.7	34
YMEG-06	120	500	95	94	533	5.2	0.8	42
YMEG-10	210	250	95	99	789	5.0	0.8	38
YMEG-14	300	250	95	62	213	5.3	0.9	43
YMEG-Ref	300	10000	90	90	633	5.0	0.8	39
YMEG-I	30	100	93	89	1643	4.1	0.6	28
YMEG-II	120	100	94	66	1852	3.0	0.5	18
YMEG-III	210	100	93	85	1052	4.0	0.6	27
YMEG-IV	300	100	94	84	686	5.0	0.8	35

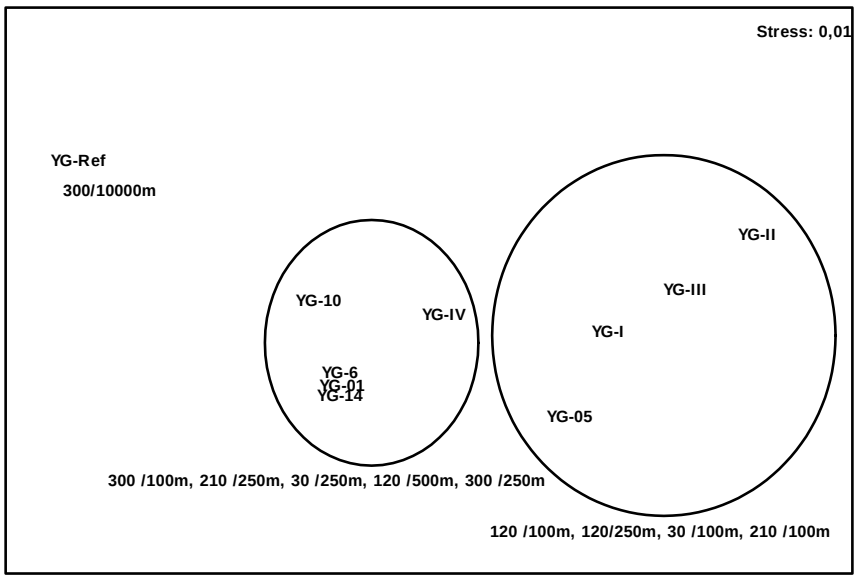

Figure 4.16.1. *MDS plot of stations from Yme Gamma 2005 (excl. juv.).*

4.17 Yme Beta

4.17.1 Chemical analyses and sediment structure

The sediments at the Yme Beta field consist of medium sand, and the sand content varies from 97.7 % at YMEB1, 60°/250m to 99.8 % at YMEB12, 330°/250m, see Table 4.17.1. The gravel content is low. The silt and clay content is similar to the previous surveys.

Samples from the Installation Centre and from stations at 100m distance are included in the investigation. At the centre 0°/0m the sediments consist of 70 % sand and 30 % silt and clay. The median diameter for YMEB Central is 2.52ϕ and the sediment is characterized as fine sand. At the 100m stations the silt and clay content is similar to the ordinary Yme Beta stations, and the sand content varies from 95.2 % at YMEB-II, 150°/100m to 99.3 % at YMEB-IV, 330°/100m. The sediments are characterized as medium sand.

The contents of total organic matter in the sediments are very low, and only small variations are found at the regular monitoring stations, see Table 4.17.1. The concentrations vary from 0.36 % at YMEB9, 240°/250m to 0.42 % at YMEB4, 150°/250m. The results are similar to the previous surveys. At the Installation Centre the TOM content is 2.45 %, compared to 1.56 % found in the 2002 survey. At the 100m stations the concentrations vary from 0.39 % to 0.59 %. The contents of TOM are similar to the 2002 survey and are considerably lower than at Yme Gamma.

The mean THC concentrations at the regular monitoring stations vary from 0.3 mg/kg at YMEB9, 240°/250m to 5.8 mg/kg at YMEB4, 150°/250m, see Table 4.17.1. Elevated levels are not found. The concentrations are approximate at the same level as in 2002.

Olefins are only found in one grab sample at YMEB4, 150°/250m (0.4 mg/kg) and in one grab sample in the 3-6 cm layer (3.5 mg/kg) , see Table 4.17.1. The levels of olefins are the same as in the 2002 survey.

At the Installation Centre the THC concentration is relatively high, 354 mg/kg. A patchy distribution is observed. Elevated THC levels are found in the deeper sections and vary from 9 mg/kg to 99 mg/kg. The mean THC concentrations at the 100m stations vary from 2.5 mg/kg at

YMEB-IV to 63 mg/kg at YMEB-II. Elevated concentrations are found at the YMEB-I (40 mg/kg) and YMEB-II. The sediments contain olefins, however these are not quantified.

Compared to the 2002 survey it is emphasized that the THC contents have decreased considerably at the Installation Centre for all the deeper layers. At the 100m stations the THC content has decreased at YMEB-III. The other stations have THC contents similar to the 2002 survey.

Elevated levels of NPD, PAH and decalins are not found at YMEB4, 150°/250m, see Table 4.17.1. At the installation Centre the NPD and decalin concentrations are relatively high, 2.22 mg/kg of NPD and 7.4 mg/kg of decalins. The concentration of NPD in the top 0-1 cm layer is at the same level as in 2002, but the concentration of decalins has decreased. However, the concentrations of NPD and decalins in the deeper layers 1-3 cm, 3-6 cm and 6-9 cm have increased significantly since the previous survey. A similar trend is seen for PAH. An enhanced level of PAH is found in the 1-9 cm section, but the level of PAH in the top layer is unchanged. Deeper in the sediment the concentrations of NPD, PAH and decalins are relatively low. The distributions seen for NPD, PAH and decalins are consistent with the distribution observed for THC at the same station. Relatively high contents of decalins are found at YMEB-II, 150°/100m, in agreement with the high content of THC found at this station.

The mean Ba concentrations at the regular monitoring stations vary from 11 mg/kg at YMEB12, 330°/250m to 520 mg/kg at YMEB4, 150°/250m, see Table 4.17.2. Elevated Ba concentrations are found at the stations at 250m in the 60°, 150° and 240° directions. The levels of Ba are similar or slightly higher compared to the levels found in the 2002 survey. Compared to Yme Gamma the Ba levels at Yme Beta are low. The concentrations of the heavy metals are low, and elevated concentrations are not found, see Table 4.17.2.

At the Installation Centre the Ba concentration is relatively high, 3038 mg/kg. However, the Ba content is halved since the 2002 survey. The same trend is also observed in the deeper layers. The Ba contents have decreased from 3030 mg/kg to 460 mg/kg and from 3280 mg/kg to 755 mg/kg respectively for the layers 1-3 cm and 3-6 cm. Elevated concentrations of Ba are found at the 100m stations in all four directions, ranging from 89 mg/kg in the 330° direction to 1339 mg/kg in the 150° direction. Elevated levels of the metals are found at the Installation Centre in all layers investigated. For the other 100m stations the content of heavy metals are low.

Generally the results agree with the drilling history at Yme Beta.

Table 4.17.1. *Yme Beta, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
YMEB1	60°/250m	2.3	1.2		0.38	0.44		1.6	0.9		17.1
YMEB4	150°/250m	0.7	1.9	2.9	0.42	0.53	0.42	5.8	4.1	1.6	4.5
	1-3 cm							3.4	2.5	1.1	<1.2
	3-6 cm							20.8	2.5	1.5	<1.2
YMEB9	240°/250m	0.2	2.4		0.36	0.40		0.3	0.4		15.2
YMEB12	330°/250m	0.2	1.5		0.39	0.42		0.9	0.3		1.6
YMEB Cent.	0°/0m	29.9	19.2		2.45	1.56		174	5000		
	1-3 cm							79	406		
	3-6 cm							91	756		
	6-9 cm							99	400		
	9-12 cm							14.9			
	12-15 cm							9.0			
YMEB-I	60°/100m	1.9	1.1		0.42	0.53		19.0	15.1		
YMEB-II	150°/100m	4.7	1.4		0.59	0.54		63	31		
YMEB-III	240°/100m	1.0	4.6		0.39	1.02		2.5	69		

Table 4.17.1. *cont.*

Station		Silt and clay			TOM			THC			
		2005	2002	1999	2005	2002	1999	2005	2002	1999	1996
YMEB-IV	330°/100m	0.7	0.7		0.39	0.40		5.7	1.2		
YMEG Ref	300°/10000m	1.6	0.5	2.8	0.52	0.63	0.59	2.7	1.8	1.9	3.6
	1-3 cm							3.1	1.34	1.8	4.0
	3-6 cm							1.4	1.36	2.5	1.4

Table 4.17.1. *cont.*

		Olefiner			NPD			PAH			Dekaliner		
		2005	2002	1999	2005	2002	1999	2005	2002	1999	2005	2002	1999
YMEB4	150°/250m	<0.3	0.3		0.01	0.020	0.003	0.010	0.020	0.003	0.0	0.103	nd
	1-3 cm	<0.3	0.3		0.00	0.010	0.004	0.004	0.010	0.004	0.0		nd
	3-6 cm	3.5	<0.2		0.00	0.013	0.005	0.004	0.013	0.005	0.0		nd
YMEB Cent.	0°/0m				2.22	2.44		0.369	2.44		7.4	52.1	
	1-3 cm				7.56	0.204		1.286	0.204		20.9		
	3-6 cm				8.04	0.332		1.391	0.332		30.1		
	6-9 cm				1.29			0.227			3.3		
	9-12 cm				0.09			0.023			0.8		
	12-15 cm				0.04			0.010			1.5		
YMEG Ref	300°/10000m				nd	0.006	0.005	0.013	0.011	0.015	nd	nd	nd
	1-3 cm				nd	0.006	0.004	0.013	0.011	0.015	nd	nd	nd
	3-6 cm				0.021	0.006	0.007	0.036	0.010	0.025	1.167	nd	nd

Table 4.17.2. *Yme Beta, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Ba 2005	Ba 2002	Ba 1999	Ba 1996	Cd 2005	Cd 2002	Cd 1999	Cr 2005	Cr 2002	Cr 1999
YMEB1	60°/250m	105	93		1840	<0.01	<0.01		7.6	6.5	
YMEB4	150°/250m	520	404	103	87	<0.01	<0.01	<0.02	9.1	8.0	8.2
	1-3 cm	300	183	81		<0.01	<0.01	<0.02	9.3	8.1	8.6
	3-6 cm	996	359	91		<0.01	<0.01	<0.02	9.4	8.0	8.8
YMEB9	240°/250m	19	20		1320	<0.01	<0.01		8.1	7.5	
YMEB12	330°/250m	11	29		691	<0.01	<0.01		7.8	6.9	
YMEB Cent	0°/0m	3038	6060			0.04	0.10		14.7	10.5	
	1-3 cm	460	3050			0.09	0.02		41	4.4	
	3-6 cm	755	3280			0.12	0.02		47	3.4	
YMEB-I	60°/100m	763	631			<0.01	<0.01		8.4	7.3	
YMEB-II	150°/100m	1339	951			<0.01	<0.01		8.5	8.0	
YMEB-III	240°/100m	282	2540			<0.01	<0.01		8.4	11.5	
YMEB-IV	330°/100m	89	209			<0.01	<0.01		7.0	7.1	
YMEB18 Ref.	300°/10000m	10	6	6	6	<0.01	<0.01	<0.2	7.3	6.9	9.8
	1-3 cm	5	6	9		<0.01	<0.01	<0.02	7.1	6.9	9.7
	3-6 cm	13	9	14		<0.01	0.01	<0.02	7.3	6.8	9.2

Table 4.17.2. *cont.*

Station		Cu 2005	Cu 2002	Cu 1999	Hg 2005	Hg 2002	Hg 1999	Pb 2005	Pb 2002	Pb 1999	Zn 2005	Zn 2002	Zn 1999
YMEB1	60°/250m	<1	0.5					7.0	5.6		5.5	4.9	
YMEB4	150°/250m	<1	0.8	<0.3	<0.01	0.01	<0.01	7.1	6.5	7.1	6.4	5.1	4.5
	1-3 cm	<1	0.4	<0.3	<0.01	0.01	<0.01	7.2	6.0	6.9	5.7	5.2	4.0
	3-6 cm	<1	0.5	<0.3	<0.01	0.01	<0.01	7.2	6.4	6.9	6.7	6.4	4.2
YMEB9	240°/250m	<1	0.4					6.6	5.6		4.9	4.0	
YMEB12	330°/250m	<1	0.4					7.3	5.7		5.0	6.8	
YMEB Cent	0°/0m	15	8.0		0.02	0.03		25	9.8		17.7	27	
	1-3 cm	61	3.0		0.04	0.01		74	2.7		55	4.7	
	3-6 cm	35	1.6		0.04	0.01		47	6.7		63	3.3	
YMEB-I	60°/100m	<1	0.8					5.3	5.2		5.6	5.4	
YMEB-II	150°/100m	<1	1.0					5.0	6.1		6.7	6.3	
YMEB-III	240°/100m	<1	5.1					6.2	9.6		5.8	14	
YMEB-IV	330°/100m	<1	0.5					5.0	5.4		4.4	4.0	
YMEG18 Ref	300°/10000m	<0.5	0.8	0.3	<0.01	<0.01	0.05	7.7	7.5	9.9	7.0	5.4	7.4
	1-3 cm	<0.5	0.8	0.4	<0.01	<0.01	0.03	6.8	7.2	10.1	5.8	5.1	7.6
	3-6 cm	<0.5	1.4	0.7	<0.01	0.01	0.03	6.9	7.7	9.2	6.5	5.7	7.8

4.17.2 Biology

The structure in the fauna community and the biodiversity indices characterize a healthy fauna community at Yme Beta. However, the similarity analyses indicate a slight disturbance in the fauna at the Installation Centre and at most of the 100m stations (Figure 4.17.1). This is in accordance with the observations made in the field and during sample processing (oily substances). Station YMEB-IV (330°/100m) seems to have improved the most since 2002. Station YMEB-III is also believed to have improved slightly. However, all of the 100m stations are still slightly disturbed. In general the numbers of species and the biodiversity indices have increased slightly since the last survey, indicating general improvements in the fauna communities, see Table 4.17.3.

During sampling there were observed large amounts of yellow granules in the sediment samples from the Installation Centre and the 100m stations.

Table 4.17.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Yme Beta 2005, (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'	J	ES_{100}
YMEB-Central	0	0	74	48	232	4.8	0.9	33
YMEB-01	60	250	80	85	478	5.5	0.9	44
YMEB-04	150	250	74	84	414	5.4	0.9	42
YMEB-09	240	250	74	88	578	5.4	0.8	42
YMEB-12	330	250	74	81	514	5.3	0.8	42
YMEB-I	60	100	79	77	443	4.8	0.8	37
YMEB-II	150	100	74	57	343	4.5	0.8	32
YMEB-III	240	100	79	75	496	5.0	0.8	35
YMEB-IV	330	100	74	91	581	5.5	0.8	42

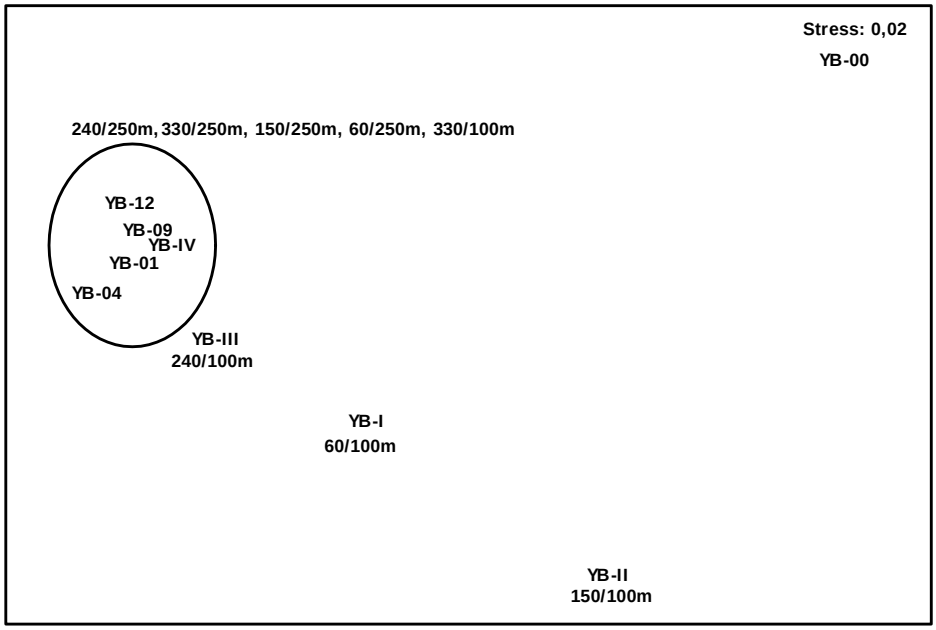

Figure 4.17.1. *MDS plot of the stations from Yme Beta 2005 (excl. juv.). YB-00 = YMEB Central.*

4.18 Kogge

4.18.1 Chemical analyses and sediment structure

A baseline survey of sediments from two stations is performed at Kogge 2005. The intention of the survey was to estimate the background levels of the chemical components in the sediments and the status of the benthic fauna.

The sediments at Kogge consist mainly of medium sand, and the sand content ranges from 94.5 % to 97.7 %, see Table 4.18.1. The content of silt and clay is low and ranges from 1.9 % to 2.1 %. The content of gravel is also low and varies from 0.4 %to 3.4 %.The content of total organic matter is low and the average value is 0.44 %. This low content of organic matter is in consistency with the high sand content of the sediments, see Table 4.18.1.

The sediments are not contaminated by THC, see Table 4.18.1. The THC concentration is 0.5 mg/kg for both stations surveyed. The concentration of Ba is 3.5 mg/kg as an average, see Table 4.18.2. The concentration of hydrocarbons, barium and heavy metals are low and within the limits of what can be characterized as the natural background level for the area.

Table 4.18.1. *Kogge 2005, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay 2005	TOM 2005	THC 2005
KOG1	45°/1000m	2.1	0.45	0.5
KOG2	45°/2000m	1.9	0.42	0.5

Table 4.18.2. *Kogge 2005, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station	Sample	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Pb 2005	Zn 2005
KOG1 45°/1000m	1	3	<0.01	8.7	<0.5	5.3	5.1
	2	3	<0.01	8.4	<0.5	6.2	5.0
	3	3	<0.01	8.8	<0.5	5.3	4.9
	Mean	**3**	<0.01	**8.6**	**<0.5**	**5.6**	**5.0**
	SD	**0**	**-**	**0.2**	**-**	**0.5**	**0.1**
KOG2 45°/2000m	1	3	<0.01	9.3	<0.5	5.5	6.3
	2	3	<0.01	9.3	<0.5	4.6	4.9
	3	7	<0.01	9.3	<0.5	5.4	5.6
	Mean	**4**	<0.01	**9.3**	<0.5	**5.2**	**5.6**
	SD	**2**	**-**	**0.0**	**-**	**0.5**	**0.7**
LSC Subregion A		*76.2*		*8.0*	*1.3*	*7.4*	*6.9*
LSC Subregion B		*12.1*		*11.1*	*1.4*	*9.0*	*8.8*

4.18.2 Biology

The study has shown that the Kogge field is polluted by neither hydrocarbons nor metals, and the fauna at the two Kogge stations are characterised as diverse and healthy (Table 4.18.3. and Figure 4.18.1)

Table 4.18.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Kogge 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'	J	ES_{100}
KOGGE-01	1000	45	76	88	609	5.2	0.8	39
KOGGE-02	2000	45	78	78	448	5.1	0.8	39

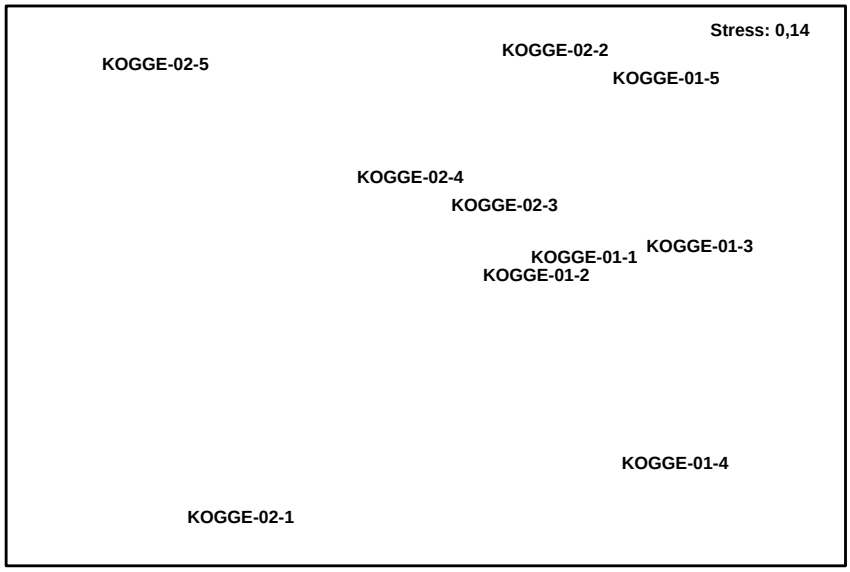

Figure 4.18.1. *MDS plot of grab samples from Kogge 2005 (excl. juv.).*

4.19 Trym

4.19.1 Chemical analyses and sediment structure

A baseline survey of sediments from 9 stations is performed at Trym 2005. The intention of the survey was to estimate the background levels of the chemical components in the sediments.

The sediments at Trym consist mainly of fine sand, and the sand content varies from 91.6 to 97.5 %, see Table 4.19.1. The grain size distribution is uniform. The content of silt and clay varies from 0 to 8.4 %. Gravel is only found in small amounts at two stations. The content of total organic matter varies from 0.65 to 0.89 %, see Table 4.19.1. This low content of organic matter is consistent with the high sand content of the sediments.

The sediments are not contaminated by THC, see Table 4.19.1. The THC concentrations in the top layer range from 1.7 mg/kg to 3.8 mg/kg. In the vertical layers the THC concentrations vary from 2.9 mg/kg to 5.3 mg/kg.

The mean concentrations of NPD are low (0.010 – 0.015 mg/kg) for both stations investigated, see Table 4.19.1. The mean PAH concentrations are also low, about 0.030 mg/kg. Both NPD and PAH contents are slightly increasing downwards in the sediments. Decalines were not detected in the present survey.

The concentration of Ba in the top layer ranges from 14 to 42 mg/kg and in the deeper layers from 21 to 167 mg/kg, see Table 4.19.2.

The concentrations of hydrocarbons, barium and heavy metals are within what can be characterized as the natural background level for the area, see Table 4.19.2. The survey has shown that the Trym field is not polluted by hydrocarbons and metals.

Table 4.19.1. *Trym 2005, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).*

Station		Silt and clay 2005	TOM 2005	THC 2005	NPD	PAH	Decalins
TRYM1	70°/250m	7.4	0.70	3.2			
TRYM2	70°/500m	5.5	0.76	3.8			
TRYM3	70°/1000m	4.2	0.85	3.4			
TRYM4	160°/250m	6.1	0.69	2.3	0.01	0.032	nd
	1-3cm			2.9	0.01	0.043	nd
	3-6cm			3.3	0.02	0.073	nd
TRYM5	160°/500m	0.0	0.67	2.8	0.01	0.033	nd
	1-3cm			3.8	0.01	0.041	
	3-6cm			5.3	0.03	0.095	
TRYM6	250°/250m	8.4	0.71	2.3			
TRYM7	250°/500m	5.3	0.72	2.3			
TRYM8	340°/250m	3.7	0.71	1.7			
TRYM9	340°/500m	2.5	0.68	1.9			

Table 4.19.2 *Trym 2005, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).*

Station		Sample	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Hg 2005	Pb 2005	Zn 2005
TRY1	70°/250m	1	20	<0.01	6.2	<0.5		6.3	5.8
		2	25	<0.01	7.4	<0.5		6.0	5.3
		3	27	<0.01	6.4	<0.5		7.7	5.7
		Mean	**24**	<0.01	**6.7**	**<0.5**		**6.7**	**5.6**
		SD	**4**		**0.7**			**0.9**	**0.3**
TRY2	70°/500m	1	22	<0.01	6.3	<0.5		6.7	4.9
		2	37	<0.01	6.6	<0.5		7.2	9.5
		3	47	<0.01	6.9	0.5		6.6	7.2
		Mean	**35**	<0.01	**6.6**	**<0.5**		**6.9**	**7.2**
		SD	**13**		**0.3**			**0.3**	**2.3**
TRY3	70°/1000m	1	20	<0.01	6.5	<0.5		6.6	4.8
		2	44	<0.01	6.6	<0.5		7.1	5.5
		3	63	<0.01	7.1	0.6		7.6	8.2
		Mean	**42**	<0.01	**6.8**	**<0.5**		**7.1**	**6.2**
		SD	**21**		**0.3**			**0.5**	**1.8**
TRY4	160°/250m	1	21	<0.01	6.3	<0.5	<0.01	6.2	5.2
		2	24	<0.01	6.2	<0.5	<0.01	6.7	5.4
		3	20	<0.01	6.2	<0.5	<0.01	7.1	5.1
		Mean	**22**	<0.01	**6.2**	**<0.5**	**<0.01**	**6.7**	**5.2**
		SD	**2**		**0.1**			**0.5**	**0.2**
		1-3cm	30	<0.01	6.1	<0.5	<0.01	7.2	5.2
		3-6cm	167	0.01	7.5	1.4	<0.01	8.3	7.6
TRY5	160°/500m	1	14	<0.01	6.1	<0.5	<0.01	6.8	4.7
		2	20	<0.01	6.0	<0.5	<0.01	6.4	4.8
		3	27	<0.01	6.2	<0.5	<0.01	6.7	5.2
		Mean	**21**	<0.01	**6.1**	**<0.5**	**<0.01**	**6.6**	**4.9**
		SD	**6**		**0.1**			**0.2**	**0.3**
		1-3cm	33	<0.01	6.5	<0.5	<0.01	7.7	5.3
		3-6cm	99	<0.01	7.4	0.9	<0.01	8.2	6.9
TRY6	250°/250m	1	44	<0.01	6.5	<0.5		8.6	5.9
		2	32	<0.01	6.1	<0.5		6.3	5.2
		3	14	<0.01	5.7	<0.5		6.7	4.6
		Mean	**30**	<0.01	**6.1**	**<0.5**		**7.2**	**5.2**
		SD	**15**		**0.4**			**1.2**	**0.6**

Table 4.19.2 *cont.*

Station		Sample	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Hg 2005	Pb 2005	Zn 2005
TRY7	250°/500m	1	17	<0.01	6.2	<0.5		7.1	4.8
		2	29	<0.01	6.3	<0.5		6.6	5.3
		3	44	<0.01	6.2	<0.5		7.4	5.6
		Mean	**30**	<0.01	**6.2**	**<0.5**		**7.0**	**5.3**
		SD	**14**		**0.1**			**0.4**	**0.4**
TRY8	340°/250m	1	12	<0.01	5.6	<0.5		7.5	4.6
		2	19	<0.01	5.8	<0.5		6.9	5.2
		3	13	<0.01	5.6	<0.5		7.1	5.7
		Mean	**14**	<0.01	**5.7**	**<0.5**		**7.2**	**5.2**
		SD	**4**		**0.1**			**0.3**	**0.5**

Table 4.19.2 *cont.*

Station	Sample	Ba 2005	Cd 2005	Cr 2005	Cu 2005	Hg 2005	Pb 2005	Zn 2005
TRY9 340°/500m	1	21	<0.01	6.0	<0.5		7.0	8.9
	2	31	<0.01	6.5	<0.5		7.2	5.8
	3	23	<0.01	6.1	<0.5		8.0	5.2
	Mean	**25**	<0.01	**6.2**	**<0.5**		**7.4**	**6.6**
	SD	**5**		**0.2**			**0.6**	**2.0**
LSC Subregion A		*76.2*		*8.0*	*1.3*		*7.4*	*6.9*
LSC Subregion B		*12.1*		*11.1*	*1.4*		*9.0*	*8.8*

4.19.2 Biology

The survey at Trym in 2005 was a baseline study and the fauna community at Trym is in general characterized as relatively healthy, not influenced by any field activities. However, the fauna community seems to be slightly disturbed, which is probably due to the high energy environment together with a general diffuse organic enrichment in the central parts of the Ekofisk region (Table 4.19.3 and Figure 4.19.1).

Table 4.19.3. *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Trym 2005 (excl. juv.).*

Station	Direction °	Distance m	Depth	S	N	H'		J	ES_{100}	
						Incl. M. o.	Excl. M. o.		Incl. M. o.	Excl. M. o.
TRYM-01	70	250	65	72	1077	4.4	4.5	0.7	28	29
TRYM-02	70	500	65	83	2040	3.3	3.3	0.5	22	23
TRYM-03	70	1000	65	77	1736	3.3	3.3	0.5	22	23
TRYM-04	160	250	65	64	937	4.2	4.2	0.7	26	27
TRYM-05	160	500	65	79	1153	4.5	4.6	0.7	30	30
TRYM-06	250	250	66	68	1567	3.3	3.3	0.5	22	23
TRYM-07	250	500	66	75	1390	4.1	4.1	0.7	27	28
TRYM-08	340	250	66	68	1195	3.7	3.8	0.6	25	26
TRYM-09	340	500	69	72	1359	4.1	4.2	0.7	27	28

M. o.= *M. oculata*

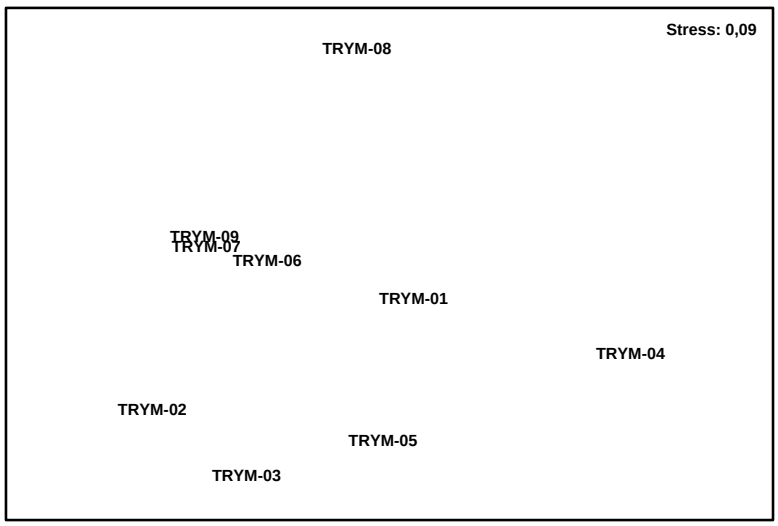

Figure 4.19.1. *MDS plot of stations from Trym 2005 (excl. juv.).*

5.0 Recommendations

Recommendation from 2002 considered

Field stations closer to the installations have been sampled in the present survey to better identify the transition zones between contaminated and uncontaminated areas.

At Tor the sediments contained compounds from synthetic based fluids that could be olefins or ethers. In the present survey ether analysis was included for this field. The main compounds are identified as ethers from the base oil Aquamul B.

Limit of Contamination

The limit of contamination was based on a confidence level of 95 %, according to the guidelines.

Recommendation for the 2008 survey

PFOS (perfluorooctyl sulphonate) is considered as a hazardous environmental substance, which has recently come into focus. Among the most important areas of use for PFOS-related substances in Norway appear to be fire fighting in the offshore industry. In 2005, the Pollution Control Authority decided to make a survey of PFOS-related substances in fire fighting foams and emissions from this source. In the 2005 survey three stations at Region I were analysed regarding PFOS. PFOS was found at two of the stations. It is recommended to get insight into the discharge history of PFOS at the various fields and prepare a sampling programme based on this information.

It is recommended for the 2008 survey to further investigate the transition zones from 500m to 250m stations. At most fields, an improvement in the fauna community was seen at the 500m stations, but not yet at the 250m stations. Valhall should be further investigated at the 250 m distance.

Biological analyses were not included at the Embla field in 2005. Considering additional knowledge about the faunal trends, and the fact that elevated THC levels were found in 2005, it is recommended that both sediment and biological samples are included in 2008.

The reference stations at Hod and Valhall were considered to be somewhat unfit with regards to the fauna communities. At Valhall this was due to a slightly coarser type of sediment which to some extent effects the fauna composition. When comparing the chemical parameters the station seems, however, to be suitable. At the reference station at Hod the sediment is considerably coarser than the field stations, making it unsuitable for faunal comparisons with the field stations. Thus when preparing the monitoring program in 2008 the need for finding alternatively reference stations at Valhall and Hod should be considered.

As the discharges have been reduced during the recent years, the sediment surface receives reduced amounts of hydrocarbons. In some cases, however, oily substances and black sediments are observed in the deeper sediment layers. Biological effects measured as disturbed macro fauna are often accompanying these observations. In order to monitor the impact of previous discharges it should be considered to focus on the relationship between biological effects and chemical parameters in the deeper layers. Aside from describing the environmental status the results would be valuable for studying restitution time and predicting the fate of contaminated sediments in general.

BP has established an investigation group to find out more about the granules found at Valhall. It is recommended that this should be considered at the other fields/operators as well.

It is recommended that the methods for calculating the contaminated areas should be standardized to ease the comparisons between different areas.

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APPENDIX A

A complete overview from the sampling.

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