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# TECHNICAL REPORT

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## CONOCOPHILLIPS/BP/STATOIL

ENVIRONMENTAL MONITORING 2002  
REGION I - EKOFISK

SUMMARY REPORT

REPORT No. 2003-0397

REVISION No. 01

DET NORSKE VERITAS/SINTEF

# TECHNICAL REPORT

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## Summary:

The report presents a summary of the results from the Environmental Survey in Region 1, Ekofisk 2002.

Sediments were sampled from the following installations: Ula, Gyda, Valhall, Tor, Hod, Ekofisk Centre 2/4 B&K, Ekofisk 2/4 A, Eldfisk 2/7 A/FTP, Eldfisk 2/7 B, Embla, Yme Gamma, Yme Beta and Tambar.

A total of 151 locations were sampled, including locations at the former Yme Gamma and Beta Installation centres and from the cuttings pile at Ekofisk 2/4 A. The samples have been analysed for chemical and biological parameters.

The report consists of three parts; Main Report, Summary Report/Sammendragsrapport and Appendix Report.

Report No.: 2003-0397	Subject Group: Marine Monitoring	
Report title: Environmental Monitoring 2002 Region I - Ekofisk Summary Report		
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Work verified by: Tor Jensen		
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## Indexing terms

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## Sampling Summary

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**PREFACE**

The environmental survey at Region I in 2002 has been carried out jointly by Det Norske Veritas and SINTEF Applied Chemistry, on behalf of ConocoPhillips, BP and Statoil.

Representation from the oil companies have been:

ConocoPhillips: Eimund Garpestad, Britt Brun

BP: Hans Grüner/Arne Skullerud

Statoil: Karl Henrik Bryne

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Work up of sediments:	Hilde Drangsholt, Nina Gjøs, Frøydis Oreld, Ingegerd Rustad, Grete Tveten
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Selected hydrocarbon analyses:	Hilde Drangsholt
PCB analyses:	Grete Tveten

The chemical analyses have been performed at SINTEF Applied Chemistry, dep. Environmental Technology and Analysis. The grain size distribution is analysed at SINTEF Applied Chemistry, dep. Marine Environmental Technology.

**Biological analyses:**

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Main Report:	Sam-Arne Nøland

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The two laboratories - SINTEF Applied Chemistry, departments of Environmental Technology & Analyses and Marine Environmental Technology - are both accredited by Norsk Akkreditering to perform chemical analyses, accreditation numbers Test 032 and Test 091. 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 (NP), polychlorinated biphenyls (PCB), metals, total organic matter (TOM) and sediment grain size distribution.

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 P083. Accreditation is according to NS-EN ISO/IEC 17025.

## 1 CONCLUSIVE SUMMARY

This report presents the results from the environmental survey in the EKOFISK region (Region I) in 2002. Det Norske Veritas and Sintef Applied Chemistry carried out the survey jointly, on behalf of ConocoPhillips, BP and Statoil.

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

The field work was carried out from 30<sup>th</sup> of May to 9<sup>th</sup> of June from the vessel *Stril Herkules*. Ten of the stations were regional stations. The fieldwork was performed without any problems. The samples were analysed for hydrocarbons, esters, PCB (selected stations at Ekofisk 2/4 A and Yme only), metals, organic matter, grain size distribution and macrobenthic fauna.

The 2002 survey at Region I shows:

- Generally, the results from the 2002 survey at Region I are very similar to the 1999 survey.
- The sediments at Region I consist mainly of fine sand.
- The total organic matter content in the sediments is low and varies from 0.4 % to 2.1 %.
- 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.
- Relatively high THC levels are still found at most of the fields, and the concentrations are, with a few exceptions, similar to 1999. This illustrates the low degradation rates for hydrocarbons. The sediments at Region I show still slightly elevated hydrocarbon concentrations out to 4000m distance at Valhall and at Ekofisk Centre.
- 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). The results agree with the fact that ester compounds are more easily degraded than hydrocarbons.
- Base liquids from ether based drilling mud (Aquamul B and Aquamul BII) are not included in the analyses, but the ether compounds are still observed at Ula, Ekofisk Centre and 2/4 B&K and at Tor. The ether compounds are not breaking down as fast as previously anticipated.
- Dispersion of drillcuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found at most of the stations, and out to 2000m distance at 6 of the 13 fields. Generally the Ba concentrations are similar to the 1999 survey. At Tambar a decrease is found.

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- The concentrations of the heavy metals are low, and elevated levels are only found at some stations.
- A core sample from the drill cuttings pile at Ekofisk 2/4 A is analysed. Elevated concentrations of all the chemical parameters analysed including PCB are found to 60 cm depth, except for Cd and Hg in the deepest layer.
- Samples from the Installation Centre at Yme Gamma and at Yme Beta are analysed. High concentrations of THC and Ba are found. PCB is not found in the one sample analysed.
- Like in 1999 the polychaete *Myriochele oculata* dominated the fauna, and contributed to a significant reduction of the diversity indices. This species is among the most common bristle worms in the North Sea. However, the high abundance of *M. oculata* seems to be distributed in a rather unsystematic manner, not correlated with the levels of hydrocarbons and metals in the sediments. Thus the species is not regarded as a suitable indicator when evaluating effects due to oil activities.
- When excluding *M. oculata* from the data the diversity indices in the Ekofisk Region are high, and only small areas can be regarded as affected:
  - At Yme Gamma, 100m from the installation centre and 250m in one direction.
  - At Yme Beta, 100m from the installation centre.
  - At Ekofisk 2/4 A, 3 of the 100m stations.
  - At Ekofisk Centre 2/4 B stations out to 850m in the east and south-east direction.
  - At Tor, 250m in the south direction.
  - At Eldfisk A, 500m in the south direction.
  - At Ula, 250m in the south-east direction.

At Valhall, Gyda, Hod, Tambar, Eldfisk 2/7B and Embla none of the investigated stations are considered to be disturbed.

- At Yme Gamma, Yme Beta and Ekofisk 2/4 A the sampling programme included stations located 100m from the centre, thus resulting in a higher number of disturbed stations than would be expected.
- In this survey *M. oculata* has been disregarded. It should, however, be noted that the rapidly increasing numbers of this species in most of the region (also at some of the regional stations), indicates some general external influence, possibly related to organic load/nutrient dynamics. This trend is not related to THC, Ba or other metals discharged from the oil activities, and should be examined in a wider context.

The main parameters and the variation at each field:

Regional stations	Variation	Main characteristics
THC (mg/kg)	1.6 – 5.9	The concentrations of hydrocarbons, barium and metals are low, and no elevated levels are found.
Ba (mg/kg)	7.0 – 72	
No. species (S)	58 – 82	The fauna is characterised as undisturbed. The bristle worm <i>Myriochele oculata</i> dominated the fauna, especially in the central part of the region. The high numbers and the distribution of this species in the area have not been found to correlate with THC, decalins, organic matters or metals, and are assumed not to be connected to the offshore activities in the area.
No. individuals (N)	414 – 706	
Diversity (H')	4.1 – 4.9	
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	28 – 36	

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Valhall	Variation	Main characteristics
THC (mg/kg)	4.8 – 274	Elevated THC and Ba levels out to 4000m. Olefins from Novaplus
Ba (mg/kg)	35 - 5120	discharged in 1996 are found at 500m.
No. species (S)	68 – 91	The fauna is dominated by <i>M. oculata</i> . None of the investigated stations
No. individuals (N)	651 – 1611	are characterised as disturbed.
Diversity (H')	4.2 – 5.1	
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	29 – 37	
Hod	Variation	Main characteristics
THC (mg/kg)	4.1 – 165	Elevated THC and Ba levels out to 2000m. Olefins are found at all
Ba (mg/kg)	45 - 1520	stations, probably from discharges of Novasol and Novaplus in
No. species (S)	60 – 85	1994/1995.
No. individuals (N)	414 – 1013	<i>Myriochele oculata</i> is, as earlier, found to dominate the benthic
Diversity (H')	4.3 – 5.3	macrofauna at the Hod stations, but in much higher numbers. None of the
Evenness (J)	0.7 – 0.8	investigated stations are characterised as disturbed.
E <sub>100</sub>	31 – 41	
Ula	Variation	Main characteristics
THC (mg/kg)	3.3 – 143	Elevated THC and Ba levels out to 1000m. THC has slightly increased
Ba (mg/kg)	29 - 3500	since 1999. The base oil Aquamul BII (ethers) is found at all stations.
No. species (S)	55 – 89	<i>Myriochele oculata</i> dominates the benthic macrofauna, as in 1999, but in
No. individuals (N)	615 – 1199	much higher numbers. One of the investigated stations (135°/250m) is
Diversity (H')	3.7 – 4.7	characterised as disturbed.
Evenness (J)	0.6 – 0.7	
E <sub>100</sub>	23 – 33	
Gyda	Variation	Main characteristics
THC (mg/kg)	3.4 – 9.2	Elevated THC and Ba levels out to 1000m. The results are similar to the
Ba (mg/kg)	40 - 542	1999 survey.
No. species (S)	63 – 95	<i>Myriochele oculata</i> dominates the benthic macrofauna, as in 1999, but in
No. individuals (N)	528 – 1321	much higher numbers. None of the investigated stations are characterised
Diversity (H')	4.1 – 4.7	as disturbed.
Evenness (J)	0.6 – 0.8	
E <sub>100</sub>	28 – 32	
Tambar	Variation	Main characteristics
THC (mg/kg)	2.9 – 15.8	Elevated THC levels out to 500m, and elevated Ba levels out to 1000m
Ba (mg/kg)	55 - 538	distance. THC concentrations are decreased since 1999. Baseline survey
No. species (S)	58 – 82	in 1999. Only $\square$ arite is discharged.
No. individuals (N)	509 – 823	<i>Myriochele oculata</i> dominates the benthic macrofauna. None of the
Diversity (H')	4.4 – 4.8	investigated stations are characterised as disturbed.
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	29 – 34	
Ekofisk Centre and 2/4 B&K	Variation	Main characteristics
THC (mg/kg)	5.9 – 601	Elevated THC and Ba levels similar to 1999/1996 out to 4400m. Olefins
Ba (mg/kg)	72 - 4680	and ethers (Aquamul B) are found, in accordance with reported
No. species (S)	48 – 86	discharges.
No. individuals (N)	384 – 1286	<i>Myriochele oculata</i> dominates the benthic macrofauna, as in 1999, but in
Diversity (H')	3.0 – 5.3	much higher numbers. Four stations (94°/800, 70°/500, 140°/850 and
Evenness (J)	0.5 – 0.8	175°/500), are characterised as disturbed.
E <sub>100</sub>	18 – 40	



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Ekofisk 2/4 A	Variation	Main characteristics
THC (mg/kg)	8.2 - 141	Elevated THC and Ba levels out to 2000m. Olefins and esters (Finagreen) are found. PCB is also found, analysed for the first time. Elevated levels of heavy metals at most of the stations.
Ba (mg/kg)	268 – 4740	
No. species (S)	63 – 90	
No. individuals (N)	550 – 1516	Drill cuttings pile, corer to 60cm depth: Elevated levels of hydrocarbons, esters (Finagreen), PCB, Ba and heavy metals in all layers. Higher concentrations in the vertical layers. No particular ”worst layer” is identified.
Diversity (H´)	4.1 – 5.2	
Evenness (J)	0.6 – 0.8	
E <sub>100</sub>	24 – 38	
<p>The deposit feeding bristle worm <i>Myriochele oculata</i> is, as in 1999, found to dominate the benthic macrofauna at the Ekofisk A stations, but the abundances are higher in 2002.</p> <p>The diversity indices (excluding <i>M. oculata</i> from the data) are high, reflecting an undisturbed fauna community except at the innermost stations located 100m from the installation centre and one located 250m in the 67° direction.</p>		

Eldfisk 2/7 A/FTP	Variation	Main characteristics
THC (mg/kg)	6.1 - 32.5	Elevated THC levels out to 500m. Elevated Ba levels out to 2000m. Olefins found are found, similar to 1999. Mainly the results agree with the drilling history.
Ba (mg/kg)	111 – 1540	
No. species (S)	64 – 85	
No. individuals (N)	622 – 1051	At all stations <i>M. oculata</i> is considerably more dominating in 2002 than in previous surveys.
Diversity (H´)	3.96 – 5.21	
Evenness (J)	0.65 – 0.82	The benthic fauna is relatively undisturbed except for fauna one station (180°/500).
E <sub>100</sub>	25 – 38	

Eldfisk 2/7 B	Variation	Main characteristics
THC (mg/kg)	7.8 - 16.4	Elevated THC and Ba levels similar to 1999 out to 2000m. Olefins are found. Decalin levels are increased. Pseudo-oil based drilling fluids (olefins) and barite are discharged since 1999.
Ba (mg/kg)	213 – 1850	
No. species (S)	61 – 78	
No. individuals (N)	693 – 888	The deposit feeding bristle worm <i>Myriochele oculata</i> dominates as in 1999, but in much higher numbers. None of the investigated stations are characterised as disturbed.
Diversity (H´)	4.4 – 5.0	
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	29 – 35	

Embla 2/7 D	Variation	Main characteristics
THC (mg/kg)	6.7 - 11.0	Lowest THC concentrations at Ekofisk area, and slightly elevated levels out to 1000m. Elevated Ba levels out to 1000m, decreased concentrations since 1999. No discharges since 1996.
Ba (mg/kg)	152 – 1170	
No. species (S)	65 – 77	
No. individuals (N)	574 – 872	None of the investigated stations are characterised as disturbed.
Diversity (H´)	4.5 – 5.1	
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	31 – 37	

Tor 2/4 E	Variation	Main characteristics
THC (mg/kg)	5.5 - 30.7	Elevated THC levels out to 500m and elevated Ba levels out to 1000m. Ethers from the base oil Aquamul B are found, discharged in 1990.
Ba (mg/kg)	123 - 1420	
No. species (S)	64 – 82	None of the investigated stations are characterised as disturbed except one station (180°/250) that is regarded as slightly disturbed.
No. individuals (N)	478 – 927	
Diversity (H´)	4.4 – 5.0	
Evenness (J)	0.7 – 0.8	
E <sub>100</sub>	32 – 37	

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Yme Gamma	Variation	Main characteristics
THC (mg/kg)	1.8 – 86.5	Elevated THC levels out to 250m and elevated Ba levels out to 1000m.
Ba (mg/kg)	6.0 – 4350	Olefins and esters from Petrofree are found at 250m and 500m. Ester concentrations are decreased since 1999. The results agree with the drilling history.
No. species (S)	43 – 101	
No. individuals (N)	374 – 1256	
Diversity (H')	1.7 – 5.6	Installation Centre: High silt and clay content. High THC, olefins and Ba levels (up to 1.3 %). Elevated metal levels.
Evenness (J)	0.3 – 0.9	
E <sub>100</sub>	12 – 45	The bristle worm <i>Myriochele oculata</i> which dominates the fauna in the central part of the Ekofisk region is not dominating the fauna at the Yme field. The benthic community at Yme Gamma is undisturbed with the exception of the stations situated 100m from the field centre and also at 120/250.

Yme Beta	Variation	Main characteristics
THC (mg/kg)	0.1 - 4.1	No elevated THC concentrations. Elevated Ba levels out to 500m, lower concentrations than at Yme Gamma. The results agree with the drilling history.
Ba (mg/kg)	7.0 – 404	
No. species (S)	53 – 92	
No. individuals (N)	425 – 641	Installation Centre: Less silt and clay content than at Yme Gamma. High THC, olefins and Ba levels at 0°/0m, and elevated metal levels. PCB is not found. Lower levels at the 100m stations.
Diversity (H')	4.1 – 5.5	
Evenness (J)	0.7 – 0.9	
E <sub>100</sub>	24 - 43	The bristle worm <i>Myriochele oculata</i> which dominates the fauna in the central part of the Ekofisk region is not dominating the fauna at the Yme field. The fauna at Yme Beta is undisturbed except for the stations located 100m from the former installation centre.

## 2 INTRODUCTION

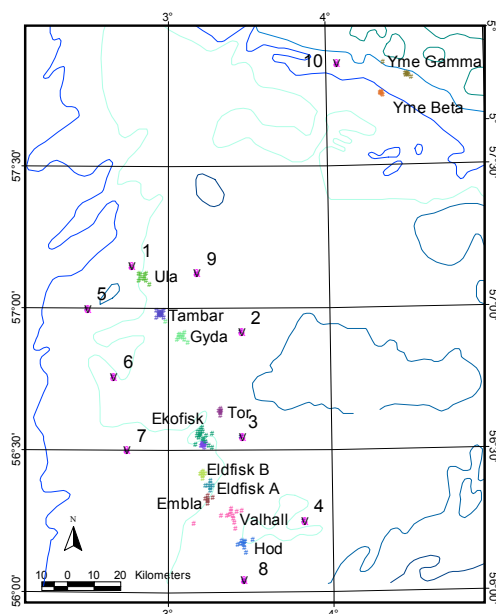
This report presents results from the environmental survey in the EKOFISK region (Region 1) in 2002. The main subject with regional monitoring is to study any environmental effects from petroleum activities in larger areas. Regional environmental monitoring has been carried out since 1996.

The report presents results from 13 different field/installations within the region. An overview of the region including installations is shown in Figure 2.1. There are no additional regional stations included in the 2002 survey compared to 1999.

The Ekofisk region includes 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. Fields and installations included in the regional monitoring are listed in Table 2.1.

The report is divided into three main sections; the Summary Report (rep. no. 2003-0397)/Sammendragsrapport (rep. nr. 2003-0398) where the main results are presented, the Main Report (rep. no. 2003-0338) which gives detailed results and the Appendix Report (rep. no. 2003-0394) consisting of field report, analyses reports and other details. Stations for each field are shown in fold-out maps in the main report.

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**Figure 2.1.** Regional stations (1 – 10) and an overview of fields included in the 2002 survey, Region I – Ekofisk area 2002.

Field/Installation	Operator
Ula	BP
Gyda	BP
Valhall	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	ConocoPhillips
Tor	ConocoPhillips
Yme Gamma	Statoil
Yme Beta	Statoil

**Table 2.1.** Fields and installations included in the regional monitoring 2002.

### 3 METHODS

The field work was carried out from 30<sup>th</sup> of May to 9<sup>th</sup> of June from the vessel *Stril Herkules*. The samples were analysed for hydrocarbons, esters, PCB (selected stations at Ekofisk 2/4 A and Yme only), metals, organic matter, grain size distribution and macrobenthic fauna.

Analysis	Parameter
<b>Sediment characterization</b>	
• Grain size distribution	- Distribution of pelite (< 63µm) and sand (>63µm) - Cumulative weight% distribution from 63-2000µm - Median particle diameter (Md), standard deviation (SD), skewness (Sk) and kurtosis (K)
• Total organic matter	- % TOM in the sediment
<b>Chemical analyses</b>	
• Hydrocarbons	- THC, sum C12-C35 olefins included - NPD, naphthalenes, phenanthrenes and dibenzothiophenes sum and single compounds - PAH, 16 EPA compounds sum and single compounds - Decalins, sum of C5-C8 alkyl decalins - Olefins, compounds in the area C14H28 to C20H42 - Petrofree and Finagreen
• Esters	- PCB, 7 congeners
• Chlorinated biphenyls	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/ boric acid
• Metals	
<b>Biological analyses</b>	
• Macrobenthic fauna	-Numbers of species and individuals

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Sampling and analyses were carried out in accordance with *Forskrifter om utføring av aktiviteter i Petroleumsvirksomheten* (3rd of September 2001) and DNV/Sintef's internal procedures for this kind of work. The sediments are analysed for the following analytical parameters. Details from the field work are described in a separate field report (DNV 2002-0737), which is enclosed in the Appendix Report. A complete overview of the sampling is enclosed in the end of this report.

## 4 RESULTS AND DISCUSSION

### Region I

A summary of the sediment characterization and the chemical analyses of the sediments at Region I is given in the table below.

#### Summary of chemical results, Region I 2002.

Parameter	Regional stations (10 stations)	Valhall (12 stations)	Hod (10 stations)	Ula (9 stations)	Gyda (10 stations)	Tambar (10 stations)	Ekofisk Centre 2/4 B&K (18 stations)
Sand %	95 - 99	92 - 96	94 - 96	92 - 97	93 - 100	94 - 97	87 - 97
TOM %	0.6 - 0.9	0.7 - 1.2	0.8 - 1.0	0.8 - 0.9	0.6 - 0.8	0.7 - 0.9	0.8 - 2.1
THC mg/kg	1.6 - 5.9	4.8 - 274	4.1 - 165	3.3 - 143	3.4 - 9.2	2.9 - 15.8	5.9 - 601
Olefins* mg/kg	na	na	1.3 - 17.6	na	na	na	2.0 - 361**
Esters* mg/kg	na	na	na	na	na	na	na
NPD* µg/kg	8 - 26	15 - 782	19 - 1230	22 - 297	13 - 52	14 - 34	21 - 392
PAH* µg/kg	18 - 57	35 - 174	46 - 113	41 - 119	28 - 64	24 - 27	48 - 366
Decalins* µg/kg	nd	nd - 7920	nd - 3840	nd - 6780	nd - 328	188 - 1050	nd - 13600
Ba mg/kg	7.0 - 72	35 - 5120	45 - 1520	29 - 3500	40 - 542	55 - 538	72 - 4680
Cr mg/kg	5.8 - 9.1	6.3 - 8.5	6.4 - 7.7	5.9 - 7.0	4.2 - 6.7	6.4 - 7.2	7.7 - 14.4
Cu mg/kg	0.8 - 1.3	1.2 - 7.8	1.0 - 1.9	1.2 - 7.6	1.2 - 1.8	1.0 - 2.4	1.0 - 70
Pb mg/kg	3.7 - 7.0	6.8 - 19.5	6.1 - 14.2	6.1 - 18.5	4.4 - 7.8	5.6 - 6.3	6.3 - 31
Zn mg/kg	3.5 - 8.2	6.3 - 31.8	6.0 - 12.6	5.9 - 56.5	4.6 - 10.8	5.1 - 13.0	5.6 - 82
Cd mg/kg	nd - 0.01	nd - 0.08	nd - 0.04	nd - 0.08	nd - 0.01	nd	nd - 0.16
Hg* mg/kg	nd - 0.01	0.01 - 0.03	0.01 - 0.02	nd - 0.02	0.01	0.01	nd - 0.05

#### Summary of chemical results, Region I 2002 cont.

Parameter	Ekofisk 2/4 A (25 stations)	Eldfisk 2/7 A / FTP (9 stations)	Eldfisk 2/7 B (9 stations)	Embla 2/7 D (6 stations)	Tor 2/4 E (6 stations)	Yme Gamma *** (10 stations)	Yme Beta *** (8 stations)
Sand %	80 - 95	94 - 97	92 - 97	94 - 97	96 - 98	95 - 100	97 - 99
TOM %	0.8 - 2.1	0.8 - 0.9	0.8 - 1.0	0.7 - 0.9	0.9 - 1.0	0.5 - 0.9	0.4 - 0.5
THC mg/kg	8.2 - 141	6.1 - 32.5	7.8 - 16.4	6.7 - 11.0	5.5 - 30.7	1.8 - 86.5	0.1 - 4.1
Olefins* mg/kg	8.0 - 54.2	0.9 - 1.3	0.8 - 0.9	na	na	nd - 9.9	nd - 4.7
Esters* mg/kg	nd - 2.1	na	na	na	na	nd - 4.3	na
NPD* µg/kg	65 - 722	27 - 51	35 - 60	26 - 30	48 - 120	6 - 398	6 - 20
PAH µg/kg	64 - 322	40 - 53	51 - 56	47 - 55	43 - 45	11 - 124	5 - 9
Decalins* µg/kg	73 - 1330	52 - 2490	87 - 626	nd	nd - 72	nd - 2720	103 - 180
Ba mg/kg	268 - 4740	111 - 1540	213 - 1850	152 - 1170	123 - 1420	6.0 - 4350	7.0 - 404
Cr mg/kg	7.2 - 12.2	6.1 - 7.6	6.1 - 7.5	7.1 - 8.0	7.1 - 8.0	5.0 - 7.9	6.5 - 8.3
Cu mg/kg	1.5 - 13.5	1.2 - 2.4	1.2 - 2.5	1.3 - 1.7	1.3 - 5.0	0.8 - 5.2	0.4 - 0.8
Pb mg/kg	8.7 - 57.9	4.9 - 14.0	7.4 - 15.6	8.1 - 12.0	6.3 - 24.3	5.6 - 10.4	5.6 - 6.5
Zn mg/kg	8.0 - 150	7.1 - 12.5	7.2 - 14.3	7.3 - 11.8	6.5 - 25.3	5.4 - 18.8	4.0 - 9.5
Cd mg/kg	0.01 - 0.27	nd - 0.02	0.01 - 0.02	nd - 0.01	nd - 0.04	nd - 0.03	nd - 0.01
Hg* mg/kg	0.02 - 0.08	0.02	0.02	nd - 0.01	0.02 - 0.04	0.01 - 0.02	nd - 0.01

\* some stations analysed    \*\*: olefins/ethers    \*\*\*: installation centre excluded    na: not analysed    nd: not detected  
quantitation limits: olefins 0.2 mg/kg, esters: 0.2 mg/kg, decalins 0.050 mg/kg, Cd 0.01 mg/kg, Hg 0.01mg/kg

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In addition to the results given in the Summary table the following analyses are performed:

- At Ekofisk 2/4 A: PCB analyses at some of the stations.  
Drill cuttings pile, core samples
- At Yme Gamma: Installation centre 0°/0m and 100m stations
- At Yme Beta: Installation centre 0°/0m and 100m stations  
PCB analyses for one sample

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 and Yme Beta 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 96.3 %, and the average silt and clay content (pelite) is 3.5 %. This mean value is representative for the region.

The sand content varies from 80.4 % (Ekofisk 2/4 A station 5B, 67°/150m) to 99.6 % (Gyda station 17, 315°/250m). The lowest sand content (< 90 %) and thus the highest silt and clay content is found at the innermost stations at 100m, 150m and 200m at Ekofisk 2/4 A and at some stations at Ekofisk Centre.

Generally only slight differences are observed in the silt and clay content compared to the previous survey in 1999. However, an increase is found at most of the stations at Ekofisk Centre and at Ekofisk 2/4 A.

### ***Total organic matter (TOM)***

The total organic matter content in the sediments is low. The concentrations vary from 0.4 % (Yme Beta) to 2.1 % (Ekofisk Centre and Ekofisk 2/4 A). The results are similar to the previous survey in 1999, however some slight increases are observed (Ekofisk Centre, Ekofisk 2/4 A and Tor).

### ***Hydrocarbons***

The hydrocarbon content in the sediments that originates from the drilling mud base oil or base liquid, depends 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 1.6 mg/kg to 5.9 mg/kg. No increase is observed since the last survey in 1999.

At Valhall and Hod 500m stations are included in the present survey. The THC concentrations are up to 274 mg/kg at Valhall and up to 165 mg/kg at Hod, both at 500m distance. Elevated THC concentrations are found out to 4000m distance at Valhall and out to 2000m distance at Hod. In general the THC concentrations are similar to 1999 at the stations that could be compared. Olefins from pseudo-oil based drilling mud base liquids are found at all stations at Hod, except for the reference station. At Valhall olefins are found in the sediments at one of the 500m stations.

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At Ula and Gyda 250m and 500m stations are included in the present survey. At Ula the highest THC concentration is found at one of the 250m stations, 143 mg/kg. The main tendency is an increase in the THC concentrations since 1999. The ether drilling fluid Aquamul BII is also found in the sediment, and give an important contribution to the THC content. Elevated THC concentrations are found out to 1000m distance. At Gyda the THC concentrations are low, and similar to 1999. The highest concentration is found at one of the 500m stations, 9.2 mg/kg. Only slightly elevated THC concentrations are found out to 500m distance.

Tambar is situated in the area between Gyda and Ula. As for Gyda the THC concentrations are also low, but decreased since 1999. The highest THC concentrations are found at one of the 250m stations, 15.8 mg/kg. Elevated THC concentrations are limited to the 250m and 500m stations in the 135° direction.

In the Ekofisk area high THC concentrations are found at Ekofisk Centre, up to 601 mg/kg, and at Ekofisk 2/4 A, up to 141 mg/kg. Elevated concentrations are found out to 4400m (9.6 mg/kg), and 2000m (8.2 mg/kg) respectively. Mainly the concentrations are similar to 1999 except for an considerable increase at one station at Ekofisk Centre, and decreases at the 100m stations at Ekofisk 2/4 A. A major part of the increases in the "THC" concentrations found at Ekofisk Centre results from didecyl ethers in Aquamul B drilling fluid.

At Eldfisk 2/7 A/FTP, Eldfisk 2/7 B, Embla 2/7 D and Tor 2/4 E the THC concentrations are lower, up to approx. 30 mg/kg at Eldfisk 2/7 A/FTP and Tor and approx. 15 mg/kg at Eldfisk 2/7 B and Embla. Mainly the results are similar to 1999. Elevated THC concentrations are found out to 2000m at Eldfisk 2/7 B, out to 1000m at Embla and out to 500m at Eldfisk 2/7 A/FTP and Tor.

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, and the concentrations are decreased or similar to the 1999 survey. Olefins are found at most of the stations, decreased or similar to 1999. At Yme Beta no elevated THC concentrations are found.

The results for the selected hydrocarbons NPD, PAH and C<sub>5</sub> - C<sub>8</sub> 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<sub>5</sub> - C<sub>8</sub> 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 three directions and also at the 150m stations in two directions. The concentrations are low, approx. 1 mg/kg.

At Yme Gamma, Petrofree is found at two of the three stations analysed, 0.4 mg/kg and 4.3 mg/kg. The concentrations are reduced since 1999. As in 1999, Finagreen is not detected.

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**PCB**

PCB (polychlorinated biphenyls) is only analysed at the 100m, 150m and 200m stations at Ekofisk 2/4 A. PCB is found in the samples analysed, and the concentrations vary from 0.004 mg/kg to 0.119 mg/kg.

**Barium**

Ba is found in the sediments due to use of baryte 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 and 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 7 mg/kg to 72 mg/kg. No increase is observed since the last survey in 1999.

The Ba concentrations vary from background levels to 5100 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 baryte will deposit near the drilling sites.

Generally elevated Ba concentrations are found at most of the stations. This means out to approx. 4000m at Valhall and Ekofisk Centre, out to 2000m at Hod, Ekofisk 2/4 A, Eldfisk 2/7 A/FTP and Eldfisk 2/7 B, out to 1000m at Ula, Gyda, Tambar, Embla 2/7 D, Tor 2/4 E and Yme Gamma, and out to 500m at Yme Beta. At Yme Beta the Ba concentrations are low. Mainly the Ba concentrations are similar to the previous survey in 1999. A decrease is observed at Tambar and also at Embla.

**Metals**

Generally low concentrations of the heavy metals are found in the sediments. However, some exceptions are observed. At Ula relatively high Zn concentrations, 57 mg/kg, are found at one 250m station. At Ekofisk Centre two of the stations show high metal concentrations, 0.16 mg/kg Cd, 70 mg/kg Cu, 31 mg/kg Pb and 82 mg/kg Zn.

At Ekofisk 2/4 A elevated metal concentrations are found at most of the stations. The highest concentrations are 12 mg/kg Cr, 0.27 mg/kg Cd, 14 mg/kg Cu, 0.08 mg/kg Hg, 58 mg/kg Pb and 150 mg/kg Zn.

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

Elevated concentrations of all the chemical parameters analysed are found downwards to 60 cm depth in the drill cuttings pile, except for Cd and Hg in the deepest layer.

The sediment varies from fine sand in the top layer, silt and clay in the 10-15 cm layer, coarse sand from 15 to 35 cm and then fine sand again at the bottom. The top 0-5 cm layer contains 6.3 % total organic matter, the next layer 10.4 % and then a decrease is found to 1.3 % at the bottom 45-58 cm layer.

The THC concentrations including olefins vary from 54.6 mg/kg in the 40-45 cm layer to 71900 mg/kg in the 10-15 cm layer. Drilling mud base oil dominates in the 35-40 cm layer, a difference from the other layers. A considerable part of the THC content results from olefins, up to 76 % in the most contaminated samples.

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The ester drilling fluid Finagreen decreases gradually downwards in the corer from 1500 mg/kg in the top layer to 1.1 mg/kg in the 40-45 cm layer.

The highest NPD concentration 40.9 mg/kg is found in the layer with the drilling mud base oil. The PAH concentrations are low, and no correlation with THC is observed. The decalin concentrations vary from 0.48 mg/kg at the bottom layer to 78 mg/kg in the 35-40 cm layer, a clear correspondence with the drilling mud base oil.

PCB is found in all the core samples, from 0.004 mg/kg in the bottom layer to 0.776 mg/kg in the 30-35 cm layer. The PCB concentration is low in the top 0-5 cm layer.

The Ba concentrations are relatively high and vary from 815 mg/kg in the 45-58 cm layer to 3700 mg/kg in the 40-45 cm layer. The 40-45 cm sediment appears different in the mineralogy, as the concentrations of the elements Al, Ca, Fe and Mg are very reduced in this sample.

High concentrations of the heavy metals are not found in the 40-45 cm layer, but in the 35-40 cm layer, above 1000 mg/kg for Pb and Zn. This is the same layer that shows drilling mud base oil.

***Installation Centre at Yme fields***

Samples are also taken 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, 6.6 %, and the TOM content at the 100m stations vary from 0.6 % to 6.6 %.

The THC concentration is extremely high at the Centre, 13100 mg/kg (1.3 %). High levels are also found at the 100m stations, from 537 mg/kg to 6500 mg/kg. High olefin concentrations are also found. The Ba concentrations are high at the Centre, 6050 mg/kg, and at the 100m stations, from 4080 mg/kg to 7410 mg/kg. 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 ordinary Yme Beta stations. The total organic matter content is lower than at Yme Gamma, 1.6 % at the Centre and 0.4 % to 1.0 % at the 100m stations. The THC concentrations are high at the Centre, 5000 mg/kg, and lower at the 100m stations, from 1.2 mg/kg to 68.5 mg/kg. Olefins are also found. The Ba concentration is also high at the Centre, 6060 mg/kg. Elevated Ba concentrations are found at the 100m stations, from 209 mg/kg to 2540 mg/kg. Elevated levels of the metals are found at the Centre.

At Yme Beta one sample is analysed for PCB; the Installation Centre 0°/0m, 6-15 cm depth. PCB is not found in the sediment.

***Biology***

A summary of the biological indices in Region I is shown in the table below.

Like in 1999 the polychaete *Myriochele oculata* dominated the fauna, and contributed to a significant reduction of the diversity indices. This species is among the most common bristle worms in the North Sea. However, the high abundance of *M. oculata* seems to be distributed in a



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rather unsystematic manner, not correlated with the levels of hydrocarbons, metals or others of the investigated parameters in the sediments.

**Summary of biological results (ex. *M. oculata* at all fields except Yme Gamma and Beta), Region I 2002.**

Parameter	Regional stations (10 stations)	Ula (10 stations)	Gyda (11 stations)	Valhall (12 stations)	Hod (10 stations)	Ekofisk Centre 2/4 B&K (18 stations)	Ekofisk 2/4 A (17 stations)
Species	58 – 82	55 – 89	63 – 86	68 – 91	60 – 85	48 – 86	63 – 90
Individuals	414 – 706	615 – 1199	528 – 1293	623 – 1611	414 – 1013	384 – 1286	550 – 1516
Diversity	4.1 – 4.9	3.7 – 4.7	4.1 – 4.7	4.2 – 5.1	4.3 – 5.1	3.0 – 5.3	4.2 – 5.2
Evenness	0.7 – 0.8	0.6 – 0.7	0.7 – 0.8	0.7 – 0.8	0.7 – 0.8	0.5 – 0.8	0.6 – 0.8
ES <sub>100</sub>	28 – 36	23 – 33	28 – 32	29 – 37	31 – 41	18 – 40	24 – 38
	Eldfisk 2/7 A / FTP (10 stations)	Eldfisk 2/7 B (9 stations)	Embla (6 stations)	Tor (6 stations)	Yme Gamma (14 stations)	Yme Beta (12 stations)	Tambar (10 stations)
Species	64 – 85	61 – 78	65 – 77	64 – 82	43 – 101	53 – 92	58 – 74
Individuals	622 – 1051	693 – 888	574 – 872	478 – 927	374 – 1256	425 – 641	509 – 823
Diversity	4.0 – 5.2	4.4 – 5.0	4.5 – 5.1	4.4 – 5.0	1.7 – 5.6	4.1 – 5.3	4.4 – 4.8
Evenness	0.6 – 0.8	0.7 – 0.8	0.7 – 0.8	0.7 – 0.8	0.3 – 0.9	0.7 – 0.9	0.7 – 0.8
ES <sub>100</sub>	25 – 38	29 – 35	31 – 37	32 – 37	12 – 45	24 – 43	29 – 34

When excluding *M. oculata* from the data the over all picture is that the fauna in the Ekofisk Region is quite undisturbed except for some of the innermost stations at some fields.

Yme Gamma and Beta has a fauna quite different from the rest of the region.

In most of the analyses *M. oculata* has been disregarded. It should, however, be noted that the rapidly increasing numbers of this species in most of the region (also at some of the regional stations), indicates some general external influence, possibly related to organic load/nutrient dynamics.

#### 4.1 Regional stations

The sediments at the Regional stations consist mainly of fine sand, and the sand content varies from 95 % at Regional stations 1, 4, 5 and 6 to 99 % at Regional 10. The gravel content is low. The silt and clay content is in general similar to the previous observations. The total organic matter content in the sediments is low, and only small variations are found at the Regional stations, from 0.6 % to 0.9 %. The results are similar to the previous surveys in 1999 and 1996.

The concentrations of hydrocarbons, barium and heavy metals are low, and the sediments are not contaminated.

The THC concentrations in the sediments vary from 1.6 mg/kg to 5.9 mg/kg. The NPD concentrations vary from 0.008 mg/kg to 0.026 mg/kg, and the PAH concentrations vary from 0.018 mg/kg to 0.057 mg/kg. Decalins are not found.

The concentration of Ba varies from 7 mg/kg to 72 mg/kg.

Additional metal analyses by use of hydrofluoric acid /aqua regia /boric acid are also performed on the sediments from the regional stations. The Ba concentrations are higher than by nitric acid

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digestion, and they vary from 162 mg/kg to 249 mg/kg. The concentrations of the heavy metals are similar to digestion by nitric acid. The results are similar to the 1999 survey.

Three subregions are identified at 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. Subregion C is not representative for any of the fields, and thus no LSC is calculated.

**Table 4.1.1.** Regional stations, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment).

Station	Silt and clay		TOM			THC			NPD			PAH		
	2002	1999	2002	1999	1996	2002	1999	1996	2002	1999	1996	2002	1999	1996
Regional 1. Ula ref	5.3	3.5	0.86	1.06	0.82	3.3	4.1	3.9	0.022	0.022	0.012	0.041	0.034	0.054
Regional 2	2.4	3.5	0.84	0.94	0.95	2.8	2.6	4.3	0.015	0.008	-	0.042	0.023	-
Regional 3. Ekofisk ref	2.6	5.3	0.82	0.95	0.86	5.9	5.5	5.4	0.021	0.010	0.026	0.048	0.035	0.045
Regional 4	5.5	2.9	0.87	0.93	0.95	5.4	5.3	6.3	0.025	0.016	-	0.056	0.041	-
Regional 5	4.1	4.4	0.92	1.14	0.94	3.7	3.6	6.8	0.019	0.016	-	0.052	0.051	-
Regional 6	4.5	3.7	0.92	1.13	0.95	4.0	4.1	6.5	0.026	0.012	-	0.057	0.047	-
Regional 7	3.8	3.3	0.89	1.11	0.93	5.0	4.3	4.2	0.020	0.012	-	0.051	0.043	-
Regional 8. Hod ref	3.0	2.8	0.78	0.71	0.92	4.1	3.9	5.3	0.019	0.013	0.020	0.046	0.038	0.081
Regional 9	2.3	1.4	0.61	0.78	-	1.6	1.4	-	0.019	0.004	-	0.018	0.016	-
Regional 10	1.0	3.2	0.68	0.85	-	1.9	1.9	-	0.008	0.005	-	0.018	0.018	-

-: not analysed      Decalins are not detected, limit of detection is 50µg/kg

**Table 4.1.2.** Regional stations, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment).

Station	Ba			Cd	Cr		Cu			Hg		Pb			Zn		
	2002	1999	1996		2002	1999	2002	1999	1996	2002	1999	2002	1999	1996	2002	1999	1996
Regional 1	29	33	52	<0.02	6.9	6.9	1.3	0.6	0.7	<0.01	0.01	6.1	7.3	6.6	6.2	5.6	5.9
Regional 2	18	13	23	0.01	6.3	6.1	0.8	0.4	0.6	<0.01	0.01	4.6	4.5	4.5	4.9	3.6	2.6
Regional 3	72	41	68	<0.01	7.7	7.1	1.0	0.8	<0.6	<0.01	nd	6.3	5.8	6.2	5.6	4.7	3.0
Regional 4	67	67	102	0.01	6.7	7.5	1.0	0.6	0.7	0.01	0.02	6.9	7.2	7.6	5.9	6.7	5.2
Regional 5	35	28	42	0.01	6.5	6.2	1.0	0.5	<0.6	0.01	0.02	6.8	6.8	7.3	7.4	5.3	4.3
Regional 6	27	31	35	0.01	7.3	7.0	1.2	0.6	<0.6	0.01	0.02	6.1	6.9	6.4	6.0	5.9	4.1
Regional 7	48	31	58	0.01	7.4	7.4	1.1	0.5	<0.6	0.01	0.02	7.0	7.3	7.2	6.4	5.4	4.2
Regional 8	45	31	51	<0.04	6.9	6.6	1.0	0.4	0.8	<0.01	0.01	6.1	6.2	6.4	6.0	5.3	3.7
Regional 9	8	6	-	<0.01	5.8	5.8	0.9	<0.3	-	<0.01	nd	3.7	3.9	-	3.5	2.7	-
Regional 10	7	5	-	<0.01	9.1	9.2	1.0	0.5	-	<0.01	nd	6.0	6.4	-	8.2	6.7	-

-: not analysed      Cd not detected in 1999

**Table 4.1.3.** Regional stations, Metals - digestion by HF /aqua regia/boric acid (mg/kg dry sediment).

Station	Ba		Cr	Cr	Cu		Pb	Pb	Zn	Zn	Al	Al	Li	Li
	2002	1999			2002	1999								
Regional 1, Ula ref	212	223	11.2	12.6	1.1	1.4	11.8	10.1	9.4	9.6	14300	15800	4.5	3.7
Regional 2	215	208	10.3	10.3	1.1	1.3	10.1	7.7	12.4	10.7	14500	15400	4.5	3.0
Regional 3, Ekofisk ref	249	218	10.6	10.7	1.0	1.2	14.7	9.5	7.8	8.0	12800	14400	4.3	3.4
Regional 4	247	235	9.6	12.3	1.1	1.9	12.4	9.8	9.4	18.6	13300	15300	4.1	4.6
Regional 5	240	231	12.5	13.2	1.3	1.5	12.6	10.8	10.4	11.8	16200	17300	4.9	4.1
Regional 6	226	221	11.0	11.9	1.3	1.2	11.1	9.8	9.3	23.0	14400	15100	4.7	3.9
Regional 7	249	229	10.6	10.9	1.3	1.1	11.4	10.7	8.6	8.4	13800	14200	4.8	3.7

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<b>Table 4.1.3 cont.</b>	Ba	Ba	Cr	Cr	Cu	Cu	Pb	Pb	Zn	Zn	Al	Al	Li	Li
Station	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
Regional 8, Hod ref	221	198	10.0	9.8	1.0	1.2	8.4	9.6	8.3	7.8	12400	13000	4.1	3.5
Regional 9	209	206	8.9	9.3	0.9	1.3	7.4	7.1	6.1	5.7	14700	15100	3.6	2.4
Regional 10	162	162	11.1	11.3	0.9	1.0	8.0	9.6	8.9	8.9	11400	11400	3.7	2.8

Cd not detected in 1999 and 2002, <0.03 mg/kg

**Table 4.1.4.** LSC values Region I 2002 (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	4.8	0.9	<b>6.4</b>	2.6	1.0	<b>5.1</b>
Ba	48.0	15.8	<b>76.4</b>	6.0	1.0	<b>8.6</b>
Cr	7.1	0.4	<b>7.9</b>	8.7	1.3	<b>12.4</b>
Cu	0.7	0.1	<b>1.0</b>	0.7	0.3	<b>1.5</b>
Pb	6.7	0.4	<b>7.5</b>	7.8	1.7	<b>12.2</b>
Zn	5.4	0.5	<b>6.3</b>	6.9	1.0	<b>9.6</b>
NPD	0.018	0.004	<b>0.026</b>	0.009	0.006	<b>0.024</b>
PAH	0.047	0.008	<b>0.062</b>	0.020	0.011	<b>0.048</b>

### The macrobenthic fauna

The deposit feeder *Myriochele oculata* dominated at most of the stations, from 13 % at Regional 9 to 80 % at Regional 3A. There were also high abundances of echinoderms, mostly due to newly settled juveniles. If *M. oculata* is excluded from the data the fauna is dominated by the brittle star *Amphiura filiformis* and juvenile at most of the stations. Other species which are found frequently in the area are the bristle worms *Paramphipneme jeffreysii*, *Scoloplos armiger* and *Goniada maculata*. These organisms are typical for areas with a mixed sandy bottom.

As in the 1999 survey *M. oculata* dominates in the central part of the region with the centre at Regional 3 (Tor/Ekofisk) and at regional stations 4, 6 and 2, which are situated nearby Hod and Gyda.

In this region, which is dominated by sand, the available amount of organic matter is less than in areas where pelite dominates the sediment. Though deposit feeders dominate the fauna (e.g. *M. oculata*) this type of sediment contains a higher proportion of species also acting as suspension- and carnivore feeders than the fauna living in/on pelitic sediment.

The *Myriochele* species are known to thrive best in mixed bottom of sand and silt, rarely in pelitic sediment, and can be found in extremely high numbers. Previous surveys have not found any correlation between distribution of *M. oculata* and the levels of hydrocarbons, metals, decalins or organic matter in the sediments (DNV 2000). The high abundance of this species is therefore assumed not to be connected to the offshore activity in the area.

The calculations of various indices and multivariate analyses have been performed on data including and excluding *M. oculata*, see Table 4.1.6.

The presence of newly settled echinoderm juvenile is considered to be of transient character (i.e. only a few of them will reach adult stage) and their geographic distribution is primarily a result of water currents and bottom topography. The large numbers do not give any added knowledge about the state of the benthic macrofauna community, but will rather be an element of

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disturbance when interpreting the data. Juveniles have therefore been excluded from the data prior to calculation of the univariate and multivariate analyses for each field. However, in the Regional chapter in the main report various approaches have been tried out in order to investigate the effect of juveniles and *M. oculata*.

**Table 4.1.6.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Ekofisk regional stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
		Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
REG-1A	70	825	615	79	78	4.1	4.4	0.7	0.7	28	32
REG-1B	70	1012	622	82	81	3.7	4.5	0.6	0.7	26	33
REG-2	73	1773	698	69	68	2.6	4.1	0.4	0.7	17	28
REG-3A	70	3734	574	66	65	1.3	4.5	0.2	0.8	11	30
REG-3B	70	3257	667	71	70	1.7	4.6	0.3	0.7	13	32
REG-4	70	1773	563	68	67	2.4	4.7	0.4	0.8	18	33
REG-5	74	539	463	72	71	4.6	4.7	0.8	0.8	34	36
REG-6	70	1886	706	72	71	2.6	4.4	0.4	0.7	18	29
REG-7	70	992	686	70	69	3.8	4.2	0.6	0.7	24	28
REG-8A	71	1004	414	61	60	2.7	4.3	0.5	0.7	20	32
REG-8B	71	1305	545	73	72	2.8	4.3	0.5	0.7	19	31
REG-9	65	504	470	59	58	4.6	4.5	0.8	0.8	29	29
REG-10	85	453	450	83	82	4.9	4.9	0.8	0.8	37	36

Depth and median grain size seems to be the most important of the investigated abiotic factors to explain the fauna structure.

The changes in the macrofauna community over the years could indicate an increasing load of organic material in the Ekofisk area. However, the TOM data do not reflect any increase in the period 1996-2002. The changes could also be random or related to physical changes (e.g. temperature) or changes in the nutrient dynamics, and are not considered to be connected to the oil industry.

## 4.2 Valhall

The sediments at Valhall consist mainly of fine sand, and the sand content varies from 92 % at station 8, 164°/500m to 96 % at station 23, 344°/2000m and the reference station, 254°/15000m. 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 0.7 % to 1.2 %. The results are similar to the previous surveys in 1999 and 1996.

The mean THC concentrations vary from 4,8 mg/kg at the reference station to 274 mg/kg at station 8, 164°/500m. The two most contaminated stations, station 8, 164°/500m and station 3, 74°/1000m were not analysed in the previous survey. At the other stations the THC concentrations

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are similar or reduced since 1999. Elevated THC concentrations are found at all stations out to 4000 m distance.

Olefins are found at station 8, 164°/500m, but not quantified. This station was not analysed in 1999 and 1996.

Elevated levels of NPD, PAH and decalins are found at the three stations analysed, station 3, station 8 and station 9, in the top 0-1 cm layer and in the 1-3 cm and 3-6 cm layers as well. The decalin concentrations are particularly high at station 8, 164°/500m, and 12.4 mg/kg which represents 3 % of the total hydrocarbon content is found in the 3-6 cm layer.

The Ba concentrations vary from 35 mg/kg at the reference station 254°/15000m to 5120 mg/kg at station 8, 164°/500m. Elevated Ba concentrations are found at all stations, except for the reference station. This means out to 2000m in the 74°, 254° and 344° directions, and out to 4000m in the 164° direction. In general the Ba levels are similar to the 1999 levels. A vertical transport of Ba down in the sediment is observed.

The concentrations of the heavy metals are low, however slightly elevated concentrations are found at station 8, and also at the other stations for Pb and Zn.

The chemical results are in correspondence with the drilling history at Valhall. Olefins are found in the sediments at the innermost station in the 164° direction, which could be expected due to discharge of cuttings contaminated with olefin based mud.

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

Station		Silt and clay		TOM		THC			NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	1996	2002	1999	2002	1999	2002	1999
St.3	74°/1000 m	5.8	-	1.01	-	60.5	-	-	0.126	-	0.104	-	1.03	-
St.4	74°/2000 m	4.7	5.5	0.89	0.41	12.7	10.8	14.9	-	-	-	-	-	-
St.8	164°/ 500 m	7.6	-	1.20	-	274	-	-	0.782	-	0.174	-	7.92	-
	1-3 cm			-	-	313	-	-	1.110	-	0.159	-	7.42	-
	3-6 cm			-	-	396	-	-	1.150	-	0.209	-	12.40	-
St.9	164°/1000 m	5.8	4.1	0.94	0.90	26.7	65.0	41.8	0.084	0.084	0.106	0.080	0.279	0.782
	1-3 cm			-	-	70.7	80.5	50.7	0.121	0.105	0.095	0.156	0.890	2.040
	3-6 cm			-	-	74.3	48.7	11.4	0.192	0.090	0.123	0.165	1.420	1.320
St.10	164°/2000 m	6.0	3.4	0.90	0.76	12.8	11.0	13.2	-	-	-	-	-	-
St.11	164°/4000 m	4.6	4.5	0.89	0.79	8.6	8.5	7.3	-	-	-	-	-	-
St.16*	254°/1000 m	5.0	4.5	0.96	0.90	16.5	34.0	137	-	-	-	-	-	-
St.16	254°/2000 m	5.2	4.7	0.73	0.69	7.9	10.2	-	-	-	-	-	-	-
St.21	344°/ 500 m	6.1	-	0.89	-	17.2	-	-	-	-	-	-	-	-
St.22	344°/1000 m	5.4	4.8	0.83	0.84	12.1	14.9	22.4	-	-	-	-	-	-
St.23	344°/2000 m	4.2	6.1	0.76	1.13	8.2	8.2	8.7	-	-	-	-	-	-
Ref.	254°/15000 m	4.2	3.2	0.72	0.74	4.8	5.1	6.1	0.015	0.015	0.035	0.048	nd	nd
	1-3 cm			-	-	5.6	6.4	3.7	0.018	0.020	0.046	0.063	nd	nd
	3-6 cm			-	-	6.9	7.2	5.5	0.026	0.026	0.074	0.085	nd	nd

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

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

Station		Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.3	74°/1000 m	2120	-	-	0.02	-	7.6	-	2.9	-	-	-	11.8	-	12.3	-
St.4	74°/2000 m	549	578	1040	0.01	<0.02	7.1	7.5	1.4	0.8	-	-	9.0	9.8	7.8	7.6
St.8	164°/ 500 m	5120	-	-	0.08	-	8.5	-	7.8	-	0.03	-	19.5	-	31.8	-
	1-3 cm	5270	-	-	0.16	-	8.6	-	6.4	-	0.03	-	23.5	-	36.5	-
	3-6 cm	1040	-	-	0.05	-	9.0	-	2.6	-	0.02	-	11.1	-	18.7	-
St.9	164°/1000 m	1060	2160	2420	0.01	<0.02	6.5	7.8	1.8	1.2	0.01	0.02	8.4	10.8	9.0	8.7
	1-3 cm	1550	1910	-	0.02	<0.02	6.4	8.0	3.2	1.1	0.02	0.02	8.7	11.3	6.8	10.0
	3-6 cm	2160	989	-	0.02	0.02	7.4	9.6	2.2	1.2	0.02	0.03	11.0	11.4	12.7	11.7
St.10	164°/2000 m	514	533	756	0.01	<0.02	7.3	7.5	1.4	0.7	-	-	10.5	11.5	8.1	7.0
St.11	164°/4000 m	140	129	159	0.01	<0.02	7.6	8.1	1.5	0.6	-	-	7.9	9.5	6.7	6.6
St.16*	254°/1000 m	1150	1050	2070	0.01	<0.02	7.7	9.2	2.0	1.9	-	-	10.0	11.5	9.5	12.2
St.16	254°/2000 m	278	405	-	<0.01	<0.02	6.3	7.3	2.2	0.6	-	-	7.0	9.3	6.5	7.0
St.21	344°/ 500 m	840	-	-	0.01	-	7.5	-	2.2	-	-	-	9.4	-	10.9	-
St.22	344°/1000 m	540	1150	774	0.01	<0.02	7.4	8.3	1.5	1.2	-	-	9.3	11.6	7.5	10.7
St.23	344°/2000 m	217	220	452	0.01	0.03	7.5	8.7	1.3	1.2	-	-	8.2	8.5	7.1	10.4
Ref.	254°/15000 m	35	47	67	<0.01	<0.02	7.7	8.1	1.2	0.5	0.01	0.02	6.8	8.1	6.3	6.1
	1-3 cm	52	68	-	<0.01	<0.02	7.7	8.1	0.8	0.5	0.01	0.02	6.6	8.3	5.9	6.4
	3-6 cm	94	139	-	<0.01	<0.02	7.9	8.8	1.0	1.0	0.01	0.02	7.0	9.3	6.3	8.1

-: not analysed

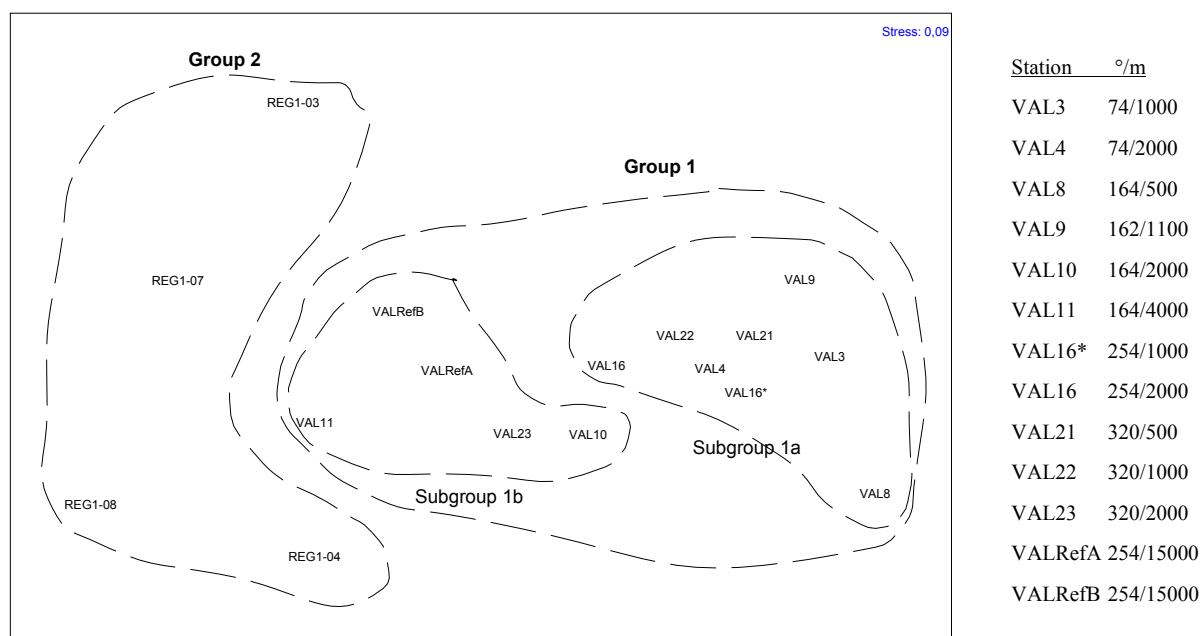
***The macrobenthic fauna***

The diversity indices at Valhall are clearly influenced by *M. oculata*. However, when excluding this species the indices are reflecting an undisturbed benthic fauna community, see Table 4.2.3.

The fauna is quite uniform, and can be divided into two main groups, see Figure 4.2.1.

**Table 4.2.3.** *Number of species (S) and individuals (N) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES<sub>100</sub>), Valhall 2002. Incl. / excl. *M. oculata*, ex. juv.*

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
VAL3	74/1000	72	3048	1182	81	80	2.8	4.7	0.4	0.7	20	32
VAL4	74/2000	72	5239	909	86	85	1.5	4.8	0.2	0.7	13	35
VAL8	164/500	73	2712	1611	92	91	3.5	4.3	0.5	0.7	22	29
VAL9	162/1100	73	4522	1142	90	89	1.9	4.3	0.3	0.7	14	31
VAL10	164/2000	72	4124	744	86	85	1.6	4.9	0.2	0.8	13	36
VAL11	164/4000	71	1851	661	69	68	2.4	4.2	0.4	0.7	18	31
VAL16*	254/1000	72	3750	920	73	72	1.9	4.7	0.3	0.7	15	32
VAL16	254/2000	72	4716	786	78	77	1.4	4.6	0.2	0.7	12	33
VAL21	320/500	72	3931	1101	84	83	2.2	4.8	0.3	0.7	17	33
VAL22	320/1000	72	3414	924	75	74	2.2	5.0	0.3	0.8	18	34
VAL23	320/2000	72	2841	651	80	79	1.9	5.1	0.3	0.8	16	37
VALRefA	254/15000	70	2788	638	74	73	1.9	4.8	0.3	0.8	15	35
VALRefB	254/15000	72	2353	623	82	81	2.1	4.9	0.3	0.8	17	36



**Figure 4.2.1.** MDS plot, Valhall and regional stations 3, 4, 7 and 8 (trans. sq.root, ex. M. oculata and juveniles), Valhall 2002.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* was, as in 1999, found to dominate the benthic macrofauna, but in considerable higher numbers. The great abundance and the distribution of this species in the area have not been found to correlate well with THC, decalins, organic matters or metals.
- The faunal variations are not correlated with variations in the measured parameters (THC, metals etc.). However, the fauna at VAL 8 (164°/500m) is slightly different from the other field stations. The highest concentrations of THC and Ba are found at this station.
- The diversity indices vary somewhat between years, but no systematic pattern can be seen. The univariate indices show a relatively undisturbed benthic fauna in the Valhall area.
- There has been a gradual alteration in the fauna composition in the period from 1996 to 2002. The change is probably not related to the offshore activities.

### 4.3 Hod

The sediments at Hod consist mainly of fine sand, and the sand content varies from 94 to 96 %. The gravel content is low. The silt and clay content is similar to the content 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 1.0 %. The results are similar to the previous surveys in 1999 and 1996.

The mean THC concentrations vary from 4.1 mg/kg at the reference station, 180°/15000m to 165 mg/kg at station 2, 74°/500m. Station 2, 74°/500m the most contaminated station, was not analysed in 1999. Compared to the 1996 survey the concentrations have increased. At station 8,

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164°/500, a decrease in the THC concentration is observed in the 0-1 cm top layer, from 135 mg/kg in 1999 to 36.6 mg/kg in the present study. However, a vertical transport of hydrocarbons is observed as the concentration has increased in the 1-3 cm layer, from 59 mg/kg in 1999 to 210 mg/kg. At the other stations the concentrations are similar to the previous surveys. Elevated THC levels are found at all stations except for the reference station, although only slightly elevated concentrations are found at the outermost stations.

Olefins are found at the six stations analysed, from 1.3 mg/kg to 17.6 mg/kg. The concentrations are similar to the previous surveys, except for an increase at station 2, 74°/500m and a decrease at station 14, 254°/500m since 1996.

Elevated levels of NPD, PAH and decalins are found at station 2, 74°/500m, station 8, 164°/500m and in the layers at station 9, 164°/1000m. The decalin concentrations are high, and thus confirm the presence of drilling mud base oil in the sediments.

The Ba concentrations vary from 45 mg/kg at the reference station 180°/15000m to 1520 mg/kg at station 2, 74°/500m. Elevated Ba concentrations are found at all stations, except for the reference station. This means out to 500m in the 344° direction, out to 1000m in the 254° direction, and out to 2000m in the 74° and 164° directions. The Ba levels are similar to the previous surveys. A vertical transport of Ba down in the sediment is observed.

The concentrations of the heavy metals are low, and slightly elevated concentrations of Cu, Pb and Zn are found.

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

Station		Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2	74°/ 500 m	6.0	-	1.02	-	165	-	17.6	-	1.230	-	0.113	-	3.84	-
St.3	74°/1000 m	6.3	6.5	0.95	0.94	10.6	13.2	1.7	1.2	-	-	-	-	-	-
St.4	74°/2000 m	5.2	4.8	0.92	0.84	9.5	9.1	-	-	-	-	-	-	-	-
St.8	164°/ 500 m	6.3	6.6	0.93	1.05	36.6	135	11.2	7.8	0.066	0.221	0.064	0.074	0.491	4.71
	1-3 cm			-	-	210	58.5	-	-	0.536	0.130	0.146	0.160	-	2.11
	3-6 cm			-	-	27.3	46.5	-	-	0.086	0.141	0.204	0.201	-	1.48
St.9	164°/1000 m	6.0	4.7	0.87	0.95	9.6	12.6	1.5	1.5	0.026	-	0.058	-	nd	-
	1-3 cm			-	-	10.5	-	-	-	-	-	0.071	-	nd	-
	3-6 cm			-	-	17.1	-	-	-	-	-	0.126	-	0.095	-
St.10	164°/2000 m	3.9	4.3	0.85	0.88	7.2	8.6	-	-	-	-	-	-	-	-
St.14	254°/ 500 m	4.6	-	0.90	-	9.6	-	2.0	-	-	-	-	-	-	-
St.15	254°/1000 m	3.6	2.4	0.78	0.76	7.1	9.2	1.3	1.3	-	-	-	-	-	-
St.20	344°/ 500 m	5.6	4.6	0.92	0.51	8.1	10.3	-	-	-	-	-	-	-	-
Ref. 180°/15000 m		3.0	3.6	0.78	0.71	4.1	3.9	-	-	0.019	0.013	0.046	0.038	nd	nd
	1-3 cm			-	-	5.3	3.8	-	-	0.037	0.014	0.076	0.040	nd	nd
	3-6 cm			-	-	6.0	6.2	-	-	0.033	0.245	0.074	0.323	nd	nd

: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg



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**Table 4.3.2.** *Hod, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2	74°/ 500 m	1520	-	1180	0.04	-	7.1	-	1.9	-	-	-	14.2	-	12.6	-
St.3	74°/1000 m	293	318	400	<0.01	<0.02	7.4	7.7	1.3	0.7	-	-	8.6	7.8	8.9	8.0
St.4	74°/2000 m	233	117	-	<0.01	<0.02	7.7	7.3	1.2	0.5	-	-	9.2	6.3	7.7	7.2
St.8	164°/ 500 m	762	1600	1990	<0.01	0.02	7.0	7.8	1.5	1.1	0.02	0.03	9.4	11.7	7.7	11.2
	1-3 cm	1330	1680	-	0.03	0.03	8.9	8.8	2.3	1.3	0.02	0.03	12.2	12.9	18.7	13.1
	3-6 cm	1250	1780	-	0.04	0.04	9.6	9.9	2.5	1.4	0.02	0.04	13.0	13.3	14.3	17.4
St.9	164°/1000 m	320	332	515	<0.01	<0.02	7.2	7.8	1.8	0.6	0.01	-	8.7	7.3	8.4	7.5
	1-3 cm	854	-	-	0.02	-	8.4	-	1.8	-	0.02	-	11.1	-	11.6	-
	3-6 cm	839	-	-	0.03	-	9.4	-	2.8	-	0.02	-	12.7	-	12.9	-
St.10	164°/2000 m	138	152	356	0.01	<0.02	7.5	8.0	1.5	0.6	-	-	8.7	7.4	8.2	7.7
St.14	254°/ 500 m	368	-	1190	0.01	-	6.7	-	1.4	-	-	-	8.1	-	7.0	-
St.15	254°/1000 m	151	200	376	<0.01	<0.02	6.4	6.8	1.3	0.6	-	-	7.3	6.7	6.4	6.6
St.20	344°/ 500 m	184	321	284	<0.01	<0.02	6.8	6.8	1.3	0.7	-	-	8.4	9.1	6.5	6.5
Ref.	180°/15000 m	45	31	48	<0.04	<0.02	6.9	6.6	1.0	0.4	0.01	0.01	6.1	6.2	6.0	5.3
	1-3 cm	51	29	-	<0.01	<0.02	7.0	6.8	1.1	0.4	0.01	0.01	6.1	6.3	6.6	5.3
	3-6 cm	89	53	-	<0.01	<0.02	7.2	7.2	1.2	0.5	0.02	0.02	6.9	6.7	6.8	5.9

-: not analysed

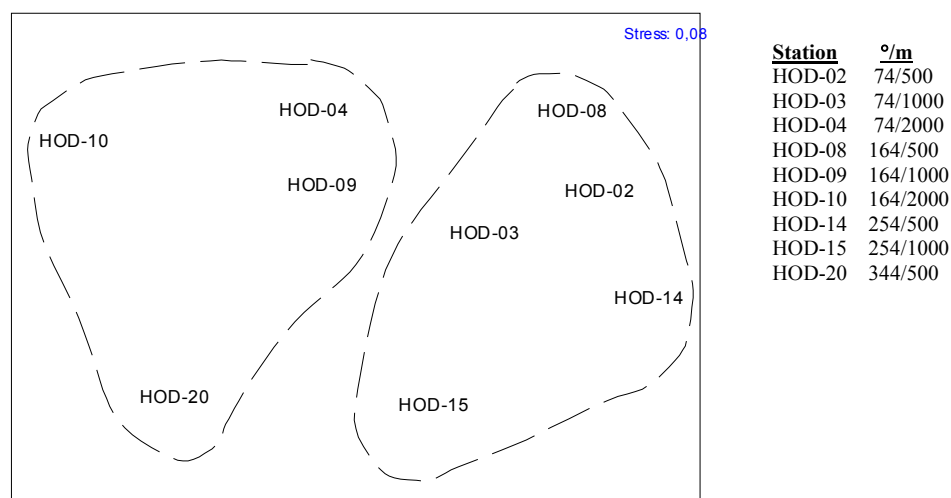
***The macrobenthic fauna***

The diversity indices excluding *M. oculata* reflect a relatively undisturbed benthic fauna community, see Table 4.3.3. The fauna in the HOD area is quite uniform, but differ from the nearby regional stations. The field stations consist of two subgroups, see Figure 4.3.1.

**Table 4.3.9.** *Number of species (S) and individuals (N) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES<sub>100</sub>) for each of the Hod stations, 2002. Incl. / ex. *M. oculata*, ex. juv.*

Station	°m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
HOD-02	74°/500	73	2405	845	80	79	2.6	4.9	0.4	0.8	20	34
HOD-03	74°/1000	73	2478	883	84	83	2.7	4.9	0.4	0.8	20	35
HOD-04	74°/2000	73	934	584	73	72	4.1	5.0	0.7	0.8	29	37
HOD-08	164°/500	72	2279	839	73	72	2.6	4.6	0.4	0.7	19	31
HOD-09	164°/1000	71	1367	687	78	77	3.5	4.9	0.5	0.8	25	35
HOD-10	164°/2000	71	1455	535	75	74	2.8	5.1	0.4	0.8	22	37
HOD-14	254°/500	72	2378	1013	86	85	3.1	4.9	0.5	0.8	23	34
HOD-15	254°/1000	72	1576	741	86	85	3.4	5.0	0.5	0.8	25	36
HOD-20	344°/500	72	836	510	76	75	4.2	5.3	0.7	0.8	32	41
HOD-24A	180°/15000	71	1004	414	61	60	2.7	4.3	0.5	0.7	20	32
HOD-24B	180°/15000	73	1305	545	73	72	2.8	4.3	0.4	0.7	19	31

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**Figure 4.3.1.** MDS plot, HOD stations (trans. sq.root, ex. *M. oculata* and juveniles), HOD 2002.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* is, as earlier, found to dominate the benthic macrofauna at the Hod stations, but in much higher numbers.
- The diversity indices (based on the results exclusive *M. oculata*) show a relatively undisturbed benthic fauna in the Hod area.
- The distribution of the macrobenthic fauna at Hod does not correlate with the abiotic parameters, i.e. the levels of hydrocarbons, metals and other measured parameters do not explain variations in the fauna.
- The fauna has changed from 1996 to 2002, but the changes do not indicate any increased influence from the oil activities in the area.

#### 4.4 Ula

The sediments at Ula consist mainly of fine sand, and the sand content varies from 92 % at station 18, 135°/250m to 97 % at station 16, 315°/500m. 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 0.77 % to 0.93 %. 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 3.3 mg/kg at the reference station, 315°/6000m to 143 mg/kg at station 18, 135°/250m. The highest concentrations at Ula are found in the 1-3 cm and 3-6 cm layers at station 18, 360 mg/kg. The main tendency is an increase in the THC concentrations, probably due to acute discharges of oilbased drilling fluid in 2000, and high levels at the 250m station analysed. The contaminated area differs depending on the direction. In the 225° and 315° directions the 500m stations are not contaminated by THC. At the 45° stations (probably the most contaminated direction) elevated concentrations are found out to 1000m. At the 135° direction elevated THC concentrations are found out to 500m, however the 1000m station is not analysed.

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The base oil Aquamul BII are found in the sediments, but not quantified separately. The highest concentrations are observed in the vertical layers at station 18, 135°/250m. At this station Aquamul BII gives an important contribution to the THC content.

Elevated levels of NPD, PAH and decalins are found at station 5 and station 18, and also at station 19 for NPD and decalins. Decalin concentrations are particularly high at station 18, 135°/250m, and 9.8 mg/kg which represent 3 % of the total hydrocarbon content is found in the 1-3cm and 3-6cm layers.

The Ba concentrations vary from 29 mg/kg at the reference station to 3500 mg/kg at station 18, 135°/250m. Elevated levels are found at all stations except for the reference station. This means out to 500m in the 135° direction and out to 1000m in the 45°, 225° and 315° directions. Stations outside 1000m are not analysed. The Ba concentrations are similar to the previous surveys. The most contaminated station, station 18, 135°/250m was not analysed in 1999 and 1996.

The concentrations of the heavy metals are low. The highest concentrations are found at station 18, 135°/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 4.4.1.** *Ula, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM		THC			NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	1996	2002	1999	2002	1999	2002	1999
St.4	45°/1000 m	3.7	2.6	0.77	0.71	11.2	4.4	10.2	0.079	-	0.046	-	6.780	-
St.5	45°/ 500 m	4.5	-	0.88	-	68.8	-	19.6	-	-	-	-	-	-
St.8	225°/ 500 m	3.8	-	0.87	-	6.7	-	40.0	-	-	-	-	-	-
St.9	225°/1000 m	4.3	2.7	0.81	0.70	4.2	3.3	9.2	-	-	-	-	-	-
St.15	315°/1000 m	4.6	6.0	0.81	0.65	4.1	4.6	9.8	-	-	-	-	-	-
St.16	315°/ 500 m	2.8	-	0.81	-	3.9	-	14.1	-	-	-	-	-	-
St.18	135°/ 250 m	7.5	-	0.93	-	143	-	-	0.297	-	0.119	-	6.110	-
	1-3 cm			-	-	359	-	-	0.631	-	0.127	-	9.850	-
	3-6 cm			-	-	358	-	-	0.301	-	0.136	-	9.890	-
St.19	135°/ 500 m	4.8	3.8	0.89	0.74	24.9	5.0	17.3	0.072	0.020	0.044	0.029	0.713	nd
	1-3 cm			-	-	19.3	6.8	16.5	0.035	0.022	0.080	0.038	0.476	nd
	3-6 cm			-	-	11.7	10.4	11.0	0.042	0.035	0.114	0.065	0.352	0.198
Ref.	315°/6000 m	5.3	3.5	0.86	0.71	3.3	4.1	4.2	0.022	0.022	0.041	0.034	nd	nd
	1-3 cm			-	-	3.31	5.0	2.6	0.029	0.021	0.045	0.040	nd	nd
	3-6 cm			-	-	3.80	4.6	7.1	0.026	0.026	0.063	0.057	nd	nd

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

**Table 4.4.2.** *Ula, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba			Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.4	45°/1000 m	246	135	378	<0.01	<0.02	6.4	5.8	1.4	0.6	-	-	7.0	7.3	6.6	5.5
St.5	45°/ 500 m	1320	-	1200	0.02	-	7.0	-	3.1	-	-	-	11.8	-	14.5	-
St.8	225°/ 500 m	570	-	2440	<0.01	-	6.8	-	1.4		-	-	9.0		8.4	-
St.9	225°/1000 m	245	162	626	0.01	<0.02	6.5	5.9	1.2	0.5	-	-	6.6	5.6	5.9	5.7
St.15	315°/1000 m	134	187	253	<0.01	<0.06	6.6	6.3	1.3	0.7	-	-	6.7	8.1	6.7	17.2
St.16	315°/ 500 m	145	-	540	<0.02	-	5.9	-	1.4	-	-	-	6.3	-	6.2	-

## TECHNICAL REPORT

<b>Table 4.4.2 cont.</b>		Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
Station		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.18	135°/ 250 m	3500	-	-	0.08	-	6.8	-	7.6	-	0.02	-	18.5	-	56.5	-
	1-3 cm	3750	-	-	0.10	-	8.0	-	7.7	-	0.03	-	25.1	-	58.5	-
	3-6 cm	2250	-	-	0.06	-	7.8	-	4.7	-	0.02	-	18.5	-	49.5	-
St.19	135°/ 500 m	979	612	704	0.02	<0.02	6.3	6.2	2.0	0.8	0.01	0.02	8.8	9.2	13.3	8.4
	1-3 cm	1120	1150	-	0.04	<0.02	6.9	5.8	2.4	1.1	<0.01	0.02	8.9	9.6	13.0	9.1
	3-6 cm	1050	1210	-	0.04	<0.02	7.3	6.1	2.0	0.9	0.01	0.01	8.7	8.6	9.5	7.0
Ref.	315°/6000 m	29	33	60	<0.02	<0.02	6.9	6.9	1.3	0.6	<0.01	0.01	6.1	7.3	6.2	5.6
	1-3 cm	33	41	-	<0.01	<0.02	7.0	6.9	1.4	0.6	0.01	0.01	6.4	7.4	7.1	5.9
	3-6 cm	48	160	-	<0.01	<0.02	6.9	7.8	1.5	0.8	<0.01	0.02	6.3	8.4	6.3	7.4

-: not analysed

***The macrobenthic fauna***

The diversity indices are clearly influenced by *M. oculata*, see Table 4.4.3. In general the diversity indices reflect a relatively undisturbed fauna when excluding *M. oculata*, except for station 18 where the fauna is slightly disturbed.

**Table 4.4.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Ula stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
ULA-4	45/1000	70	2249	1084	87	86	3.1	4.4	0.5	0.7	20	29
ULA-5	45/550	71	2251	916	70	69	2.7	4.3	0.4	0.7	18	27
ULA-8	225/500	70	2349	1199	87	86	3.3	4.4	0.5	0.7	22	30
ULA-9	225/1000	70	2605	1165	90	89	3.0	4.4	0.5	0.7	20	31
ULA-15	315/1000	70	1722	927	85	84	3.5	4.7	0.5	0.7	24	33
ULA-16	325/500	70	2271	1081	84	83	3.2	4.6	0.5	0.7	22	31
ULA-18	135/250	70	1827	791	56	55	2.6	3.7	0.4	0.6	15	23
ULA-19	130/500	70	3453	1188	86	85	2.5	4.5	0.4	0.7	18	30
ULA-RefA	315/6000	70	825	615	79	78	4.1	4.4	0.7	0.7	28	32
ULA-RefB	315/6000	70	1012	622	82	81	3.7	4.5	0.6	0.7	26	33

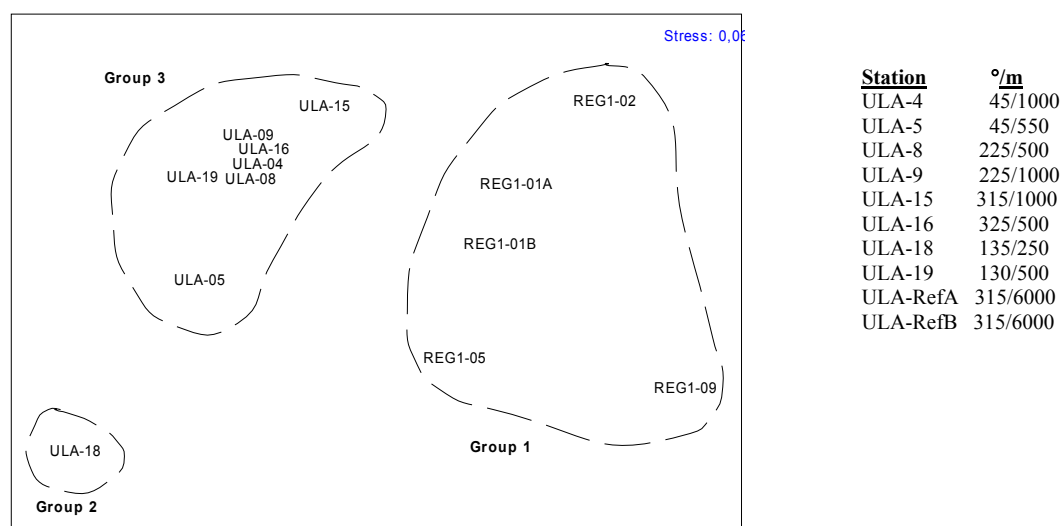
The fauna consists of three main groups, see Figure 4.4.1.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* was, as in 1999, found to dominate the benthic macrofauna at the Ula stations, but in much higher numbers.
- When excluding *M. oculata* from the data the diversity indices were generally high, reflecting an undisturbed fauna community at Ula except for ULA-18 (135°/250m).
- There is a good correlation between fauna and the abiotic factors Ba, Cu and THC. Station 18, located 250m from the installation, had a disturbed fauna and the highest concentration of metals and THC in the sediments.

## TECHNICAL REPORT

- In general there has been an alteration in the fauna community since 1996. This indicates some external influence on the fauna. However, a similar trend is observed at several other fields in the Ekofisk region; an alteration in the fauna composition probably not caused by field activities.



**Figure 4.4.1.** MDS plot, Ula and regional stations 1 (ref.station), 2, 5 and 9 (trans. sq.root, ex. M. oculata and juveniles), Ula 2002.

## 4.5 Gyda

The sediments at Gyda consist mainly of fine sand, and the sand content varies from 93.4 % at station 8, 225°/500m to 99.6 % at station 17, 315°/250m. The gravel content is low, and small amounts are found at three of the stations. The silt and clay content is similar to the previous observations, except for an increase at station 9, 225°/1000m. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.62 % to 0.82 %. The results are similar to the previous surveys in 1999 and 1996.

The THC concentrations are low and similar to those found in 1999. In the top 0-1 cm layer the THC concentrations vary from 3.4 mg/kg at station 21, 135°/2000m to 9.2 mg/kg at station 19, 135°/500m. The highest THC concentration, 22 mg/kg, is found in the 1-3 cm layer at station 19. Only slightly elevated THC concentrations are found at the 500m stations in the 45°, 135° and 225° directions.

The NPD concentrations are slightly elevated at station 19, 135°/500m, and the levels are similar to 1999. The PAH levels are also low, just at the limit of contamination at station 19. The decalin concentrations are still relatively high particularly in the vertical layers, 1.0 mg/kg at 3-6 cm.

The Ba concentrations vary from 40 mg/kg at the reference station to 542 mg/kg at station 19, 135°/500m. The Ba concentrations are similar to the previous surveys. Elevated Ba concentrations are found at all stations except for station 21, 135°/2000m and the reference station. Elevated concentrations are also found in the vertical sections.

The concentrations of the heavy metals are low, and slightly elevated concentrations of Pb and Zn are found at some stations.

## TECHNICAL REPORT

The chemical results are in accordance with the reduced drilling activities at Gyda. No drilling has taken place since the previous survey in 1999, except for top sections drilled with WBM.

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

Station		Silt and clay		TOM		THC			NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	1996	2002	1999	2002	1999	2002	1999
St.4	45°/1000 m	2.8	4.5	0.77	0.62	3.7	3.6	6.6	-	-	-	-	-	-
St.5	45°/ 500 m	3.9	-	0.77	-	6.9	-	-	-	-	-	-	-	-
St.8	225°/ 500 m	5.4	-	0.77	-	7.4	-	-	-	-	-	-	-	-
St.9	225°/1000 m	4.0	1.7	0.80	0.68	5.1	4.4	25.7	-	-	-	-	-	-
St.16	315°/ 500 m	3.9	3.3	0.77	0.78	5.4	4.1	3.0	-	-	-	-	-	-
St.17	315°/ 250 m	0.4	-	0.62	-	4.9	-	-	-	-	-	-	-	-
St.19	135°/ 500 m	2.9	2.5	0.71	0.61	9.2	9.2	7.4	0.052	0.043	0.064	0.028	0.328	0.401
	1-3 cm			-	-	22.0	15.0	2.2	0.039	0.187	0.057	0.155	0.961	0.456
	3-6 cm			-	-	17.5	16.6	9.9	0.026	0.025	0.036	0.010	1.010	0.834
St.20	135°/1000 m	1.6	3.3	0.76	0.72	4.0	7.4	5.5	0.021	-	0.028	-	nd	-
	1-3 cm			-	-	6.5	-	-	0.014	-	0.020	-	0.248	-
	3-6 cm			-	-	6.7	-	-	0.013	-	0.026	-	0.269	-
St.21	135°/2000 m	2.4	4.8	0.76	0.73	3.4	4.3	3.6	-	-	-	-	-	-
Ref.	315°/8000 m	2.6	3.7	0.82	0.74	3.8	3.7	5.6	0.035	0.038	0.035	0.038	nd	nd
	1-3 cm			-	-	3.8	3.0	4.4	0.035	0.031	0.035	0.031	nd	nd
	3-6 cm			-	-	4.6	4.6	7.0	0.049	0.037	0.049	0.037	nd	nd

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

**Table 4.5.2.** *Gyda, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba			Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.4	45°/1000 m	112	60	290	<0.01	<0.02	6.3	5.7	1.2	1.0	-	-	6.0	6.3	5.8	4.1
St.5	45°/ 500 m	280	-	-	0.01	-	6.3	-	1.6	-	-	-	7.8	-	10.8	-
St.8	225°/ 500 m	382	-	-	<0.01	-	6.1	-	1.4	-	-	-	7.1	-	9.0	-
St.9	225°/1000 m	105	105	482	<0.01	<0.02	6.4	6.2	1.3	0.7	-	-	6.1	6.3	5.0	4.7
St.16	315°/ 500 m	106	84	218	<0.01	<0.02	6.2	6.6	1.2	0.6	-	-	6.4	7.4	5.1	5.6
St.17	315°/ 250 m	169	-	-	0.01	-	4.2	-	1.2	-	-	-	4.4	-	4.6	-
St.19	135°/ 500 m	542	379	935	0.01	<0.02	5.9	6.1	1.8	0.7	0.01	<0.02	6.7	6.2	8.1	5.3
	1-3 cm	651	382	-	0.02	<0.02	6.6	6.0	1.8	0.6	0.01	0.01	7.2	5.7	7.8	4.6
	3-6 cm	437	320	-	0.03	0.03	7.4	6.5	1.6	0.5	0.01	0.03	7.1	5.6	9.1	6.8
St.20	135°/1000 m	173	189	219	<0.01	0.03	6.2	6.4	1.3	0.5	0.01	-	5.9	6.5	5.1	4.7
	1-3 cm	367	-	-	0.01	-	6.1	-	1.3	-	<0.01	-	5.9	-	4.9	-
	3-6 cm	323	-	-	0.02	-	6.7	-	1.4	-	0.01	-	6.7	-	6.4	-
St.21	135°/2000 m	74	159	167	0.01	0.02	6.6	7.0	1.3	0.5	-	0.02	6.1	7.1	5.5	4.7
Ref.	315°/8000 m	40	47	63	0.01	<0.02	6.7	7.1	1.3	0.5	0.01	0.02	5.8	6.5	5.7	5.5
	1-3 cm	40	46	-	<0.01	<0.02	6.7	6.9	0.9	0.5	<0.01	0.01	6.1	6.7	5.2	4.5
	3-6 cm	78	112	-	0.01	0.02	6.7	7.7	1.1	0.7	<0.01	0.02	6.3	7.1	6.9	6.7

-: not analysed

***The macrobenthic fauna***

The diversity indices are clearly influenced by *M. oculata*, see Table 4.5.3. When excluding this species, the indices reflect a relatively undisturbed benthic fauna community.

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**Table 4.5.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Gyda stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

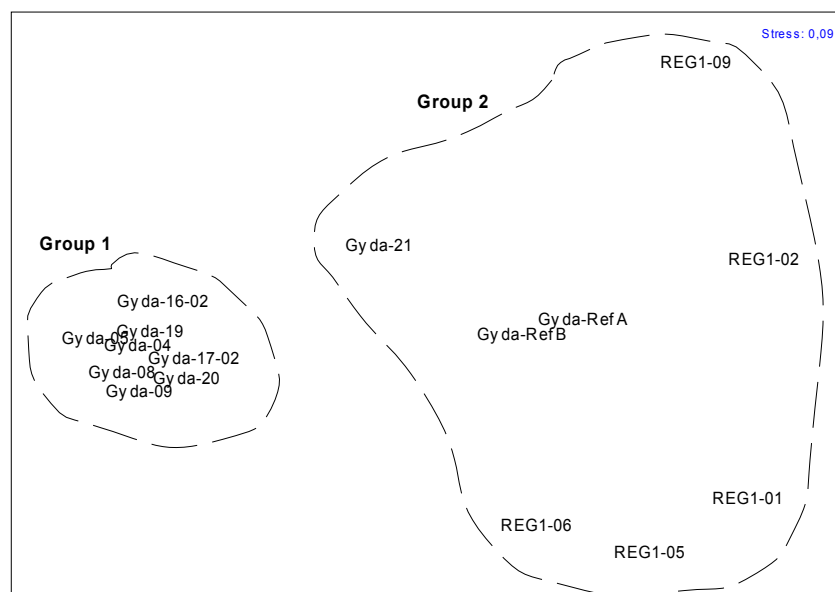
Station	‰/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o	Ex. M. o	Incl. M. o	Ex. M. o	Incl. M. o	Ex. M. o	Incl. M. o	Ex. M. o	Incl. M. o	Ex. M. o
GYDA-4	45/1000	70	7143	1133	86	85	1.3	4.5	0.2	0.7	11	30
GYDA-5	45/500	70	6753	1003	78	77	1.3	4.6	0.2	0.7	11	29
GYDA-8	225/500	70	6426	1286	96	95	1.6	4.5	0.2	0.7	13	29
GYDA-9	225/1000	70	5376	1321	82	81	1.8	4.1	0.3	0.6	13	29
GYDA-16	339/500	70	4569	1034	77	76	1.8	4.6	0.3	0.7	14	29
GYDA-17	330/2500	70	4289	1004	71	70	1.9	4.6	0.3	0.7	15	29
GYDA-19	135/500	70	6153	1293	77	76	1.7	4.4	0.3	0.7	13	28
GYDA-20	135/1000	70	6122	1257	87	86	1.7	4.5	0.3	0.7	13	30
GYDA-21	135/2000	70	2570	650	67	66	2.0	4.7	0.3	0.8	16	31
GYDA-RefA	318/8000	70	1308	528	65	64	2.7	4.4	0.4	0.7	19	30
GYDA-RefB	318/8000	70	1656	571	64	63	2.5	4.6	0.4	0.8	19	32

The MDS plot (Figure 4.5.1) consists of two main groups.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* was, as in 1999, found to dominate the benthic macrofauna at the Gyda stations, but in much higher numbers.
- Excluding *M. oculata* from the data set the diversity indices were high reflecting an undisturbed fauna community at Gyda. Stations Gyda-9, 16 and 21, which were characterised as disturbed in 1999, have higher diversities in 2002, and according to the indices these stations could be characterised as undisturbed in 2002.
- The similarity analyses for the field stations gave a relative poor correlation between fauna and abiotic factors. When nearby regional stations (and *M. oculata*) were included in the analyses the correlation factor increased, giving a good correlation.
- The numbers of *M. oculata* was considerably higher at the Gyda stations than at the regional stations, which could indicate a slight increase of organic matter at the Gyda stations compared to regional stations. Other factors not measured may also contribute to the distribution of the macrobenthic species.
- In general there has been a turn in the fauna community from 1993 when the fauna contained higher numbers of molluscs and crustaceans, to a fauna that contains a higher share of bristle worms. This indicates some external influence on the fauna. However, a similar trend is observed at most of the other fields in the Ekofisk region; an alteration in the fauna composition probably not caused by field activities.

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Station	%m
GYDA-4	45/1000
GYDA-5	45/500
GYDA-8	225/500
GYDA-9	225/1000
GYDA-16	339/500
GYDA-17	330/2500
GYDA-19	135/500
GYDA-20	135/1000
GYDA-21	135/2000
GYDA-RefA	318/8000
GYDA-RefB	318/8000

**Figure 4.5.1.** MDS plot, Gyda and regional stations 1, 2, 5, 6 and 9 (trans. sq.root, ex. *M. oculata* and juveniles), Gyda 2002.

## 4.6 Tambar

The sediments at Tambar consist of fine sand, and the sand content varies from 94 % at station 6, 135°/500m to 97 % at station 11, 225°/1000m. No gravel is found. The average silt and clay content is similar to the previous survey in 1999. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.71 % to 0.91 %. The results are similar to the previous survey in 1999.

The mean THC concentrations vary from 2,9 mg/kg at station 14, 315°/500m to 15.8 mg/kg at station 5, 135°/250m. The THC concentrations are generally low, and elevated concentrations that originate from an incident in 1998, are limited to the 250m and 500m stations in the 135° direction. The THC levels are reduced since 1999.

Elevated levels of NPD and PAH are not found. Elevated levels of decalins are found both at station 5, 135°/250m and station 6, 135°/500m. The concentrations are still relatively high at station 5 with a mean value of 1.05 mg/kg. A reduction is observed in the top 0-1 cm layer since 1999, however the concentrations in the 1-3 cm and 3-6 cm layers are increased.

The Ba concentrations vary from 55 mg/kg at station 7, 135°/1000m to 538 mg/kg at station 1, 45°/250m. The Ba concentrations are reduced since 1999 at most of the stations, except for station 1, 45°/250m where the Ba concentrations are increased from 276 mg/kg in 1999 to 538 mg/kg. This increased level agrees with the discharge of 432 tonnes of barite performed in 2001.

Elevated Ba concentrations are found out to 250m distance in the 315° direction, out to 500m in the 45° and 135° directions and out to 1000 m distance in the 225° direction.

The concentrations of the heavy metals are low, and only slightly elevated levels of Zn are found at some stations.

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



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

Station		Silt and clay		TOM		THC		NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.1	45°/ 250 m	4.0	4.2	0.80	0.76	6.2	5.6	-	-	-	-	-	-
St.2	45°/ 500 m	3.7	4.2	0.81	0.76	3.7	4.1	-	-	-	-	-	-
St.5	135°/ 250 m	4.0	4.9	0.83	0.75	15.8	49.5	0.034	0.032	0.027	0.036	1.050	3.450
	1-3 cm			-	-	27.3	9.6	0.036	0.024	0.032	0.053	2.810	0.363
	3-6 cm			-	-	17.8	11.5	0.036	0.027	0.071	0.062	1.190	0.409
St.6	135°/ 500 m	6.1	3.4	0.79	0.73	5.0	5.3	0.014	-	0.024	-	0.188	-
	1-3 cm			-	-	10.5	-	0.017	-	0.025	-	0.613	-
	3-6 cm			-	-	17.6	-	0.037	-	0.059	-	1.100	-
St.7	135°/1000 m	4.0	2.8	0.79	0.75	3.6	3.6	-	-	-	-	-	-
St.9	225°/ 250 m	5.4	5.3	0.71	0.84	4.5	107	-	-	-	-	-	-
St.10	225°/ 500 m	4.0	2.6	0.75	0.76	3.2	5.3	-	-	-	-	-	-
St.11	225°/1000 m	3.4	4.8	0.91	0.80	3.0	3.9	-	-	-	-	-	-
St.13	315°/ 250 m	4.1	5.2	0.86	0.72	3.0	3.5	-	-	-	-	-	-
St.14	315°/ 500 m	5.0	1.6	0.83	0.80	2.9	4.0	-	-	-	-	-	-

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

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

Station		Ba		Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.1	45°/ 250 m	538	276	<0.02	<0.02	6.5	6.9	1.4	0.7	-	-	6.3	6.2	7.5	5.1
St.2	45°/ 500 m	256	261	<0.01	<0.02	6.4	6.8	2.4	1.8	-	-	5.8	5.9	13.0	6.3
St.5	135°/ 250 m	451	677	<0.01	<0.02	6.6	7.5	1.4	0.8	0.01	<0.01	5.8	6.3	6.3	5.7
	1-3 cm	473	1890	0.01	<0.02	6.8	7.3	1.6	0.9	<0.01	<0.01	6.1	7.6	5.5	5.6
	3-6 cm	431	489	0.03	<0.02	7.6	8.0	1.5	1.2	0.01	<0.01	6.8	6.4	6.8	6.2
St.6	135°/ 500 m	213	107	<0.01	<0.02	7.0	6.9	1.5	0.6	0.01	-	6.3	5.8	8.6	5.3
	1-3 cm	272	-	0.01	-	7.5	-	1.4	-	0.01	-	6.7	-	6.5	-
	3-6 cm	276	-	0.02	-	8.0	-	1.5	-	<0.01	-	7.5	-	7.4	-
St.7	135°/1000 m	55	44	<0.01	<0.02	6.9	7.2	1.3	1.4	-	-	5.9	6.1	5.2	7.0
St.9	225°/ 250 m	232	4040	<0.01	<0.02	6.9	8.0	1.5	3.5	-	-	5.8	8.5	7.7	7.5
St.10	225°/ 500 m	183	1590	<0.01	<0.02	7.0	7.0	1.1	0.8	-	-	6.1	6.8	5.2	5.5
St.11	225°/1000 m	110	253	<0.01	<0.02	7.2	7.3	1.2	1.0	-	-	6.1	6.7	5.3	6.3
St.13	315°/ 250 m	90	280	<0.01	<0.02	6.8	6.9	1.0	2.1	-	-	5.6	5.7	5.1	5.3
St.14	315°/ 500 m	59	118	<0.01	<0.02	6.9	6.9	1.1	0.8	-	-	6.0	6.8	5.1	10.5

-: not analysed

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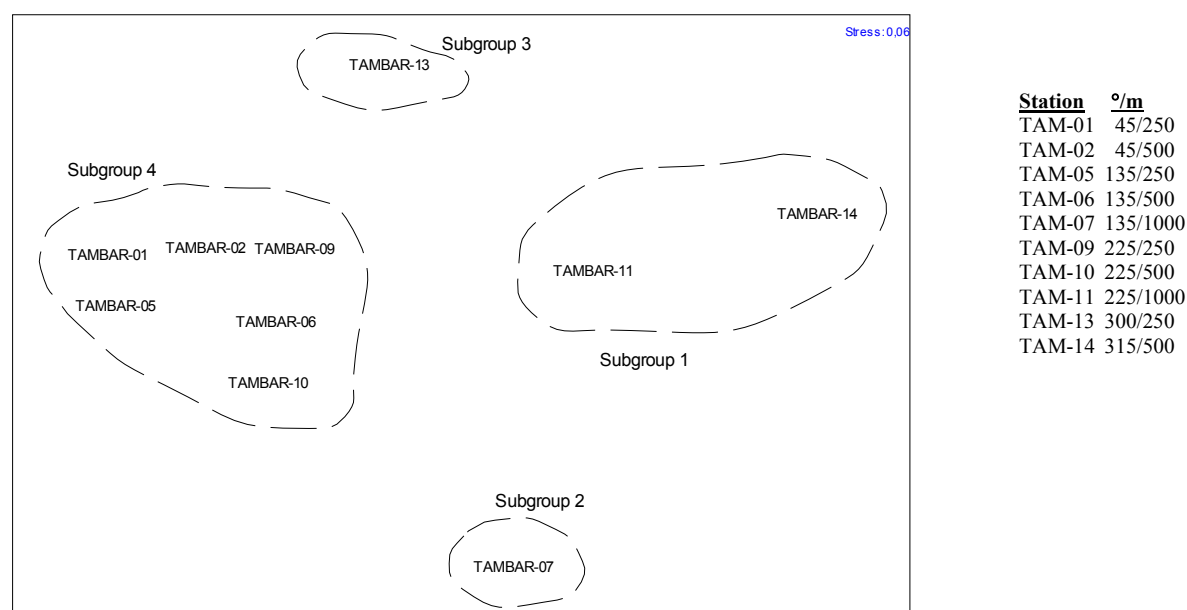
The diversity indices are clearly influenced by *M. oculata*, excluding this species. However, the indices and the fauna composition reflect an undisturbed environment when excluding *M. oculata*, see Table 4.6.3.

The Tambar field stations form a separate group, somewhat different from the nearby regional stations. Although the average similarity is high within the Tambar group, some subgroups (illustrated in the MDS plot in Figure 4.6.1).

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**Table 4.6.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Tambar stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
TAM-01	45°/250	68	2791	781	75	74	2.2	4.7	0.3	0.7	16	32
TAM-02	45°/500	67	2822	752	69	68	2.1	4.6	0.3	0.7	16	30
TAM-05	135°/250	70	2363	823	69	68	2.5	4.6	0.4	0.7	18	29
TAM-06	135°/500	70	3355	800	74	73	1.9	4.7	0.3	0.7	15	31
TAM-07	135°/1000	70	1281	545	72	71	3.0	4.8	0.5	0.8	22	34
TAM-09	225°/250	70	3016	766	65	64	2.0	4.7	0.3	0.8	16	30
TAM-10	225°/500	70	2655	765	83	82	2.3	4.8	0.3	0.8	17	34
TAM-11	225°/1000	70	1304	509	69	68	2.8	4.6	0.4	0.7	20	32
TAM-13	300°/250	69	1793	583	59	58	2.4	4.6	0.4	0.8	18	30
TAM-14	315°/500	69	1015	540	67	66	3.3	4.4	0.5	0.7	23	31



**Figure 4.6.1.** MDS plot, Tambar field stations (trans. sq.root, ex. *M. oculata* and juveniles), Tambar 2002.

The results from the macrobentic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* is, as in 1999, found to dominate the benthic macrofauna.
- The diversity indices reflect an undisturbed fauna at Tambar when excluding *M. oculata* from the data set.
- The Tambar stations have greater abundances of *M. oculata* than the regional stations.

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- There is a high correlation between the fauna incl. *M. oculata* and depth, Ba, Cd and average grain size when including regional stations in the analyses. There is also a weak correlation between the distribution of Ba and the fauna within the Tambar stations. The highest abundances of indicator species are found at stations 250 and 500m from the installation in the 45°, 135° and the 225° direction. This is also the stations with highest concentrations of Ba. However, the high (but somewhat reduced) diversity indices combined with relatively small Ba concentrations and small differences in the fauna community contribute to the conclusion that the fauna in the Tambar area is undisturbed. Like most fields in the region there has been a change in the fauna since 1999, indicating a general external influence of the fauna.

#### 4.7 Ekofisk Centre and 2/4 B&K

The sediments at Ekofisk Centre and 2/4 B&K consist of fine sand, and the sand content varies from 87 % at station 15, 175°/500m to 97 % at the reference station, 90°/15000m. The gravel content is low, however 9.0 % is found at station 19, 200°/1200m. The silt and clay content is increased at most of the stations compared to the previous surveys. The average silt and clay concentration found is 7.2 % compared to 4.9 % in 1999 and 4.8 % in 1996. At the reference station the silt and clay content is similar to the 1996 survey. The total organic matter content in the sediments is low, and the concentrations vary from 0.8 % at the reference station to 2.1 % at station 15, 175°/500m. The concentrations are similar or increased compared to the previous surveys.

The mean THC concentrations (including ether drilling fluid) vary from 5.9 mg/kg at the reference station, 90°/15000m to 601 mg/kg at station 14, 140°/850m. Elevated THC concentrations are found at all stations, except for the reference station. This means out to 4400m in the 144° direction. At most stations the concentrations are similar to the previous surveys. However, a considerable increase is found at station 14, 140°/850m from 52 mg/kg in 1999 to 601 mg/kg in the present survey. The highest concentrations are found in the 1-3 cm and 3-6 cm layers, 1240 mg/kg and 1040 mg/kg respectively. The gas chromatograms show that the major part of the elevated "THC" concentrations found at station 14 results from didecyl ethers in Aquamul B drilling fluid.

Olefins/ethers are found at the five stations analysed, from 2.0 mg/kg at station 33, 180°/1000m to 361 mg/kg at station 14, 140°/850m. The contribution from ethers could not be estimated, since the sediments are not analysed for ether compounds.

The NPD concentrations vary from 0,021 mg/kg at the reference station to 0.392 mg/kg at station 15, 175°/500m. The PAH concentrations vary from 0.048 mg/kg at the reference station to 0.366 mg/kg at station 15. At station 14, 140°/850m the NPD and PAH concentrations are increased since 1999 but similar to 1996. The highest decalin concentrations, 13.6 mg/kg, are found at station 14, and a considerable increase since 1999 is observed. Elevated concentrations of NPD, PAH and decalins are found at all stations except for the reference station. The concentrations in the layer samples are similar to the top 0-1 cm layer.

The mean Ba concentrations vary from 72 mg/kg at the reference station, 90°/15000m to 4680 mg/kg at station 14, 140°/850m. Elevated Ba concentrations are found at all stations, except for the reference station. Mainly the Ba concentrations are similar to the previous surveys, however an increase is observed at station 14, 140°/850m, from 1490 mg/kg in 1999 to 4680 mg/kg in the

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present survey. High concentrations are also found at station 15, 175°/500m, 4180 mg/kg. The Ba concentrations are above 1000 mg/kg at 12 of the 18 stations analysed, and elevated concentrations are observed out to 4400m distance. High Ba concentrations are also found in the 1-3 cm and 3-6 cm layers, similar or slightly higher concentrations than in the top 0-1 cm layer.

The concentrations of the heavy metals are low, however concentrations above the limit of contaminations are found at most of the stations.

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 1999. The ether based drilling fluid Aquamul B was discharged in 1990/1991, and obviously these ether compounds are not breaking down as fast as previously anticipated.

**Table 4.7.1.** *Ekofisk Centre and 2/4 B&K, silt & clay and TOM (%), THC, Olefins, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.8	84°/1800 m	7.5	6.3	1.19	1.03	14.3	12.2	-	-	-	-	-	-	-	-
St.9	94°/1800 m	8.4	-	1.40	-	60.1	-	-	-	0.137	-	0.143	-	2.630	-
St.9a	70°/500 m	8.6	-	1.36	-	40.3	-	3.5	-	-	-	-	-	-	-
St.11	144°/4400 m	5.2	4.1	0.95	1.18	9.6	9.7	-	-	-	-	-	-	-	-
St.12	148°/2500 m	7.5	7.7	1.28	1.17	15.8	16.4	-	-	-	-	-	-	-	-
St.13	146°/1300 m	6.9	5.3	1.32	1.14	18.0	16.0	2.1	-	0.094	-	0.118	-	0.120	-
	1-3 cm			-	-	21.3	-	3.0	-	0.072	-	0.095	-	0.114	-
	3-6 cm			-	-	24.8	-	4.1	-	0.080	-	0.125	-	0.118	-
St.14	140°/ 850 m	9.5	3.2	1.67	0.99	*601	51.6	**361	-	0.352	0.026	0.217	0.055	13.600	0.233
	1-3 cm			-	-	1240	47.4	867	-	0.266	0.058	0.242	0.100	8.050	0.094
	3-6 cm			-	-	1040	100	830	-	0.267	0.168	0.085	0.291	1.420	0.048
St.15	175°/500 m	13.0	-	2.10	-	105	-	-	-	0.392	-	0.366	-	5.300	-
St.18	208°/2500 m	5.6	5.0	0.96	0.94	10.9	12.3	-	-	-	-	-	-	-	-
St.19	200°/1200 m	3.9	-	1.22	-	19.1	-	-	-	-	-	-	-	-	-
St.22	288°/1900 m	5.9	5.9	1.02	1.04	14.6	15.7	-	-	-	-	-	-	-	-
St.23	290°/1000 m	6.6	5.3	1.11	0.93	19.6	13.8	-	-	-	-	-	-	-	-
St.28	360°/1000 m	5.0	3.0	1.07	0.91	34.9	12.0	-	-	-	-	-	-	-	-
St.32	180°/ 500 m	8.4	4.3	1.28	1.07	37.8	19.4	3.9	2.9	0.148	0.060	0.092	0.042	0.385	0.157
	1-3 cm			-	-	39.1	4.0	4.9	-	0.188	0.010	0.081	0.008	0.340	nd
	3-6 cm			-	-	45.5	5.7	5.1	-	0.102	0.043	0.090	0.008	0.500	0.115
St.33	180°/1000 m	8.4	4.3	1.18	0.90	19.6	13.3	2.0	1.5	0.057	-	0.073	-	0.131	-
	1-3 cm			-	-	22.3	-	2.4	-	0.058	-	0.084	-	0.148	-
	3-6 cm			-	-	29.6	-	3.3	-	0.063	-	0.083	-	0.316	-
St.34	270°/1000 m	7.4	4.5	0.96	0.94	11.6	11.9	-	-	-	-	-	-	-	-
St.39	90°/1000 m	7.2	5.0	1.18	1.09	16.2	16.7	-	-	-	-	-	-	-	-
Ref.42	90°/15000m	2.6	5.3	0.82	0.95	5.9	5.5	-	-	0.021	0.010	0.048	0.035	nd	nd
	1-3 cm			-	-	7.92	9.0	-	-	0.028	0.032	0.068	0.094	nd	nd
	3-6 cm			-	-	8.53	5.9	-	-	0.033	0.015	0.081	0.048	nd	nd

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

\*: approx. 60 % Aquamul B (didecyl ethers)      \*\*: mainly Aquamul B (didecyl ethers)

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**Table 4.7.2.** Ekofisk Centre and 2/4 B&K, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station		Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.8	84°/1800 m	840	1030	1510	0.02	<0.02	7.7	8.0	1.6	1.1	-	-	11.5	13.4	10.0	7.1
St.9	94°/1800 m	3750	-	3240	0.05	-	9.6	-	6.1	-	-	-	18.4	-	31	-
St.9a	70°/500 m	3200	-	-	0.08	-	9.4	-	4.9	-	-	-	20.6	-	32	-
St.11	144°/4400 m	277	362	890	0.02	<0.02	7.9	7.8	1.0	0.6	-	0.02	8.5	9.1	7.4	6.9
St.12	148°/2500 m	1330	1430	2150	0.02	0.02	8.5	8.3	1.8	1.5	-	-	13.6	15.4	11.5	11.7
St.13	146°/1300 m	1550	1310	1540	0.02	<0.02	8.4	9.0	1.9	1.4	0.02	-	11.6	16.3	12.2	11.5
	1-3 cm	2590	-	-	0.05	-	9.4	-	3.0	-	0.03	-	15.3	-	17.0	-
	3-6 cm	2620	-	-	0.06	-	9.7	-	2.5	-	0.03	-	16.8	-	20.3	-
St.14	140°/ 850 m	4680	1490	2410	0.14	<0.02	10.1	7.4	70.1	2.0	0.05	0.02	25.3	9.2	65	12.2
	1-3 cm	4708	2740	-	0.12	0.02	9.3	8.0	10.0	2.1	0.05	0.02	36.4	10.6	65	15.0
	3-6 cm	4673	3700	-	0.13	0.04	8.9	6.7	5.4	1.9	0.04	0.02	43.3	14.0	81	17.6
St.15	175°/500 m	4180	-	-	0.16	-	14.4	-	14.1	-	-	-	30.5	-	82	-
St.18	208°/2500 m	941	778	738	<0.01	<0.02	7.9	6.6	1.4	0.9	-	-	11.9	9.0	12	8.1
St.19	200°/1200 m	1980	-	2890	0.03	-	8.9	-	3.1	-	-	-	15.5	-	16.4	-
St.22	288°/1900 m	799	1360	-	0.01	<0.02	7.8	8.3	1.4	1.3	-	-	10.9	14.6	8.5	10.2
St.23	290°/1000 m	1250	1190	2140	0.02	<0.02	7.9	7.6	1.8	1.1	-	-	11.8	11.8	10.1	10.1
St.28	360°/1000 m	1100	1080	-	0.02	<0.02	8.2	8.1	2.4	1.2	-	-	16.7	14.6	12.5	9.8
St.32	180°/ 500 m	2900	1920	3700	0.04	0.02	8.4	7.2	3.4	1.8	0.04	0.02	16.9	11.8	20.9	17.6
	1-3 cm	3830	563	-	0.08	0.02	9.7	4.6	4.5	0.5	0.05	<0.01	29.8	3.3	35.6	5.5
	3-6 cm	2780	357	-	0.07	<0.02	9.5	4.6	3.2	0.4	0.03	<0.01	21.1	3.2	27.5	4.0
St.33	180°/1000 m	2130	1210	1400	-	<0.02	-	5.0	-	1.1	-	-	-	7.2	-	7.5
	1-3 cm	2220	-	-	0.06	-	8.6	-	2.6	-	0.03	-	17.4	-	18.0	-
	3-6 cm	2720	-	-	0.07	-	8.9	-	2.7	-	0.03	-	18.4	-	21.2	-
St.34	270°/1000 m	760	1030	1550	0.02	<0.03	7.8	8.1	1.6	1.2	-	-	10.8	12.7	8.2	11.1
St 39	90°/1000 m	1470	1060	2830	0.03	<0.02	8.2	8.5	1.8	1.4	-	-	12.3	13.5	10.8	11.1
Ref. 42	90°/15000 m	72	41	67	<0.01	<0.02	7.7	7.1	1.0	0.5	<0.01	<0.01	6.3	6.1	5.6	4.7
	1-3 cm	88	50	-	<0.01	<0.02	7.7	7.2	1.1	0.5	0.01	<0.01	6.3	6.0	5.6	5.1
	3-6 cm	331	141	-	0.01	<0.02	8.1	7.8	1.8	0.8	<0.01	<0.01	7.2	7.3	6.9	5.8

-: not analysed

***The macrobenthic fauna***

The diversity indices are clearly influenced by *M. oculata*. The evenness ( $J'$ ) and  $ES_{100}$  was generally high for all stations (ex. *M. oculata*), except at stations EC-9, EC-14 and EC-15 were also the diversity index was below 4. In general the diversity indices reflected a relatively undisturbed fauna in the area, see Table 4.7.3.

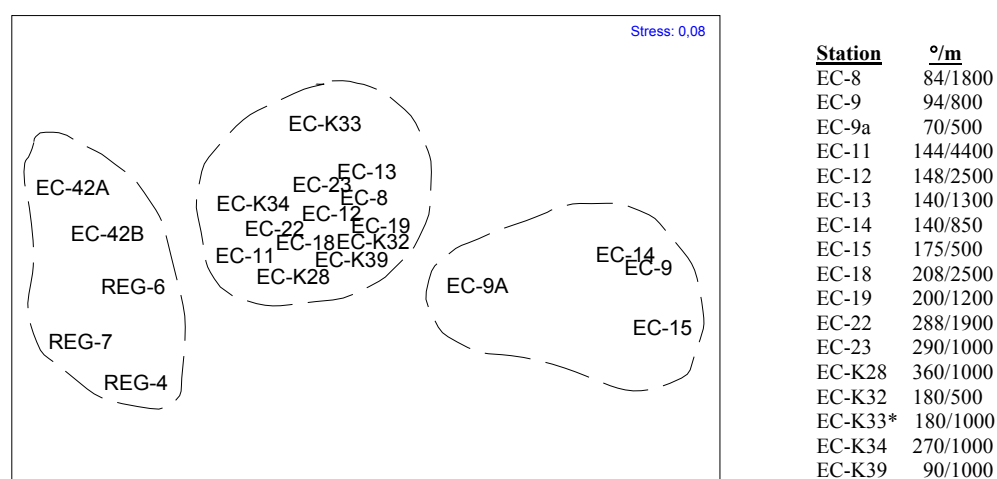
The MDS plot (Figure 4.7.1) shows three distinct groups; the regional stations (group 3) and Ekofisk Centre field stations (group 1 and 2).

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**Table 4.7.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Ekofisk Centre stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
EC-8	84°/1800	74	3116	726	82	81	2.0	5.2	0.3	0.8	17	38
EC-9	94°/800	78	1267	1187	58	57	3.2	3.0	0.5	0.5	19	18
EC-9a	70°/500	77	1189	709	60	59	3.3	3.8	0.5	0.6	20	26
EC-11	144°/4400	71	2167	647	82	81	2.5	5.3	0.4	0.8	21	40
EC-12	148°/2500	75	2099	728	87	86	2.7	5.1	0.4	0.8	21	36
EC-13	140°/1300	78	1878	867	80	79	3.2	4.8	0.5	0.8	24	35
EC-14	140°/850	78	1991	1171	50	49	2.8	3.2	0.5	0.6	16	19
EC-15	175°/500	77	1425	1286	49	48	3.2	3.0	0.6	0.5	19	19
EC-18	208°/2500	73	3732	762	83	82	1.8	5.1	0.3	0.8	15	36
EC-19	200°/1200	78	2078	938	80	79	3.2	5.0	0.5	0.8	24	35
EC-22	288°/1900	70	2269	629	85	84	2.3	5.3	0.4	0.8	20	40
EC-23	290°/1000	78	1834	644	84	83	2.7	5.1	0.4	0.8	22	38
EC-K28	360°/1000	79	1705	665	85	84	3.0	5.3	0.5	0.8	24	39
EC-K32	180°/500	79	2719	839	72	71	2.3	4.7	0.4	0.8	18	32
EC-K33*	180°/1000	79	894	384	55	54	3.0	4.6	0.5	0.8	21	32
EC-K34	270°/1000	78	2359	619	70	69	2.2	5.2	0.4	0.8	19	38
EC-K39	90°/1000	79	2098	718	83	82	2.7	5.1	0.4	0.8	21	37
EC- 42A	90°/15000	70	3734	574	66	65	1.3	4.5	0.2	0.7	11	30
EC- 42B	90°/15000	70	3257	667	71	70	1.7	4.6	0.3	0.7	13	32

\*: Only 3 grab samples were collected because the grab got caught in a wire at the seabed.



**Figure 4.7.1.** MDS plot, Ekofisk centre and regional stations 3 (ref. station), 4, 6 and 7 (trans. 2.root, ex. *M. oculata*, ex. juveniles), Ekofisk centre 2002.

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The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* was, as in 1999, found to dominate the benthic macrofauna. The 2002 results show an even stronger domination than in 1999. The high numbers and the distribution of this species in the Ekofisk region have not been found to correlate well with THC, decalins, organic matters or metals.
- The diversity indices (based on the results exclusive *M. oculata*) show a relatively undisturbed benthic fauna in the Ekofisk Centre area. The exceptions are the fauna at stations EC-9 (94°/800), 9a (70°/500), 14 (140°/850) and 15 (175°/500).
- It was found a strong correlation between the fauna and the concentrations of metals in the Ekofisk Centre area. The sediments of stations EC-9, 9a, 14 and 15 have the highest concentration of Ba, Cd, Cr and Zn.
- On the background of the diversity indices and correlation between fauna and levels of metals stations EC-9 (94°/800), 9a (70°/500), 14 (140°/850) and 15 (175°/500), located closest to the installations with former discharges, are regarded as disturbed.
- EC-14 (140°/850) was characterised as moderately disturbed in 1996, and slightly disturbed in 1999. In the period 1999 to 2002 nearly all measured chemical parameters (incl. ether) have increased considerably at this station and the diversity index has declined significantly. EC-K32 (180°/500) was also characterised as moderately disturbed in 1996, but accompanied by decreasing THC and Ba concentrations the fauna seemed to improve from 1996 to 1999. The 2002 results do not indicate any disturbance at this station. EC-15 (175°/500) was not included in the survey in 1999. However, compared to the 1990-1992 results, the diversity has declined significantly at this station. EC-15 has elevated concentrations of most measured chemical parameters.
- The alterations in the fauna in the period 1990 – 2002 can not be explained by changes in the investigated parameters. A similar trend showing alterations in the fauna over the years, is observed in several of the fields in the Ekofisk region; an alteration probably not caused by field activities.

#### 4.8 Ekofisk 2/4 A

The sediments at Ekofisk 2/4 A consist of fine sand, and the sand content varies from 80.4 % at station 5B, 67°/150m to 94.6 % at station 1, 337°/100m and station 3, 337°/500m. The gravel content is low. The silt and clay content is increased at most of the stations compared to the previous survey, and represents above 10 % at the innermost stations in the 67°, 157° and 247° directions. The total organic matter content in the sediments is low, and the concentrations vary from 0.8 % at station 1, 337°/100m to 2.1 % at station 9, 157°/100m. The concentrations are in general similar to the previous survey, however an increase is observed at station 9, from 1.3 % in 1999 to 2.1 % in the present survey.

The mean THC concentrations vary from 8,2 mg/kg at station 12a, 157°/2000m to 141 mg/kg at station 5, 67°/100m. Elevated THC concentrations are found at all stations, although only slightly elevated at the 2000m station. The THC concentrations are decreased since 1999 at the 100m stations. Vertical layers down to 12 cm depth are taken at four stations, at 150m and 200m in the 157° and 337° directions. A tendency of higher concentrations in the deeper layers compared to

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the top 0-1 cm layer is found. Particularly high THC concentrations are found in the 1-3 cm layer at station 9B, 157°/150m.

Olefins are found at the stations analysed, and the mean value varies from 8,0 mg/kg at station 1, 337°/100m to 54.2 mg/kg at station 5, 67°/100m. Olefins are also found in the 1-3 cm and 3-6 cm layers.

Esters from the drilling fluid Finagreen are found in the sediments at 100m in the 67°, 157° and 247° directions and also at the 150m stations in the 67° and 157° directions. The concentrations are low, approx. 1 mg/kg.

Elevated concentrations of NPD, PAH and decalins are found at all stations analysed, except for no decalins at two stations. The mean NPD concentrations vary from 0.065 mg/kg at station 11, 157°/500m to 0.722 mg/kg at station 9, 157°/100m. The mean PAH concentrations vary from 0.064 mg/kg at station 11 to 0.322 mg/kg at station 9. The mean decalin concentrations vary from 0.073 mg/kg at station 11 to 1.33 mg/kg at station 9. High concentrations of phenanthrene/anthracene and pyrene/fluoranthene are found in the 1-3 cm layer at station 9, 157°/100m.

PCB is found in the samples from the 100m, 150m and 200m stations. The concentrations vary from 0.004 mg/kg at station 1B, 337°/150m to 0.119 mg/kg at station 5C, 67°/200m.

The mean Ba concentrations vary from 268 mg/kg at station 12a, 157°/2000m to 4740 mg/kg at station 5, 67°/100m. Elevated concentrations are found at all stations. Mainly the Ba concentrations are similar to the previous survey. Some changes are observed, a decrease at station 14, 247°/250m and station 15, 247°/500m and an increase at station 10, 157°/250m. High concentrations of Ba are also found in the sediment layers at 1-3 cm and 3-6 cm, and the levels are similar or higher than in the top 0-1 cm layer.

Elevated concentrations of the heavy metals are found at most of the stations. The highest concentrations are found at station 13, 247°/100m.

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

**Table 4.8.1.** *Ekofisk 2/4 A, silt & clay and TOM (%), THC, olefins, esters, PCB, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM		THC		Olefin	Ester	PCB	NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	2002	2002	2002	2002	1999	2002	1999	2002	1999
St.1	337°/ 100 m	5.4	9.1	0.77	1.0	27.8	49.1	8.0	<1	0.009	0.084	-	0.088	-	0.230	-
	1-3 cm			-	-	35.1	-	11.2	<1	-	0.098	-	0.141	-	0.169	-
	3-6 cm			-	-	57.6	-	16.7	<1	-	0.140	-	0.119	-	0.545	-
St.1B	337°/ 150 m	8.4	-	1.09	-	24.1	-	5.5	<1	0.004	0.118	-	0.092	-	nd	-
	1-3 cm			-	-	31.5	-	-	-	-	-	-	-	-	-	-
	3-6 cm			-	-	54.7	-	-	-	-	-	-	-	-	-	-
	6-9 cm			-	-	35.0	-	-	-	-	-	-	-	-	-	-
	9-12 cm			-	-	41.6	-	-	-	-	-	-	-	-	-	-
St.1C	337°/ 200 m	7.2	-	1.01	-	15.1	-	2.5	<1	0.005	0.112	-	0.128	-	nd	-
	1-3 cm			-	-	24.4	-	-	-	-	-	-	-	-	-	-
	3-6 cm			-	-	60.9	-	-	-	-	-	-	-	-	-	-
	6-9 cm			-	-	92.9	-	-	-	-	-	-	-	-	-	-
	9-12 cm			-	-	63.6	-	-	-	-	-	-	-	-	-	-



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<b>Table 4.8.1 cont.</b>		Silt and clay		TOM		THC		Olefin	Ester	PCB	NPD		PAH		Decalins	
Station		2002	1999	2002	1999	2002	1999	2002	2002	2002	2002	1999	2002	1999	2002	1999
St.2	337°/ 250 m	8.2	7.3	1.21	0.9	19.8	11.7	-	-	-	-	-	-	-	-	-
St.3	337°/ 500 m	5.4	5.5	1.05	0.9	12.0	11.1	-	-	-	-	-	-	-	-	-
St.4	337°/1000 m	6.5	7.0	1.26	1.0	15.6	13.8	-	-	-	-	-	-	-	-	-
St.5	67°/ 100 m	14.3	9.9	1.31	1.7	141	384	54.2	1.4	0.014	0.665	-	0.179	-	0.941	-
	1-3 cm			-	-	152	-	60.2	<1	-	0.486	-	0.162	-	1.290	-
	3-6 cm			-	-	91.9	-	11.8	<1	-	0.317	-	0.285	-	0.973	-
St.5B	67°/ 150 m	19.6	-	1.86	-	146	-	51.3	1.1	0.102	0.501	-	0.218	-	1.230	-
St.5C	67°/ 200 m	13.2	-	1.58	-	125	-	44.3	<1	0.119	0.309	-	0.336	-	1.300	-
St.6	67°/ 250 m	11.1	8.3	1.40	1.2	82.6	57.6	-	-	-	-	-	-	-	-	-
St.7	67°/ 500 m	7.2	6.7	1.17	1.0	16.0	8.6	-	-	-	-	-	-	-	-	-
St.8	67°/1000 m	7.2	4.5	1.08	1.1	15.5	12.8	-	-	-	-	-	-	-	-	-
St.9	157°/ 100 m	18.2	7.9	2.06	1.3	119	311	46.2	2.1	0.044	0.722	-	0.322	-	1.330	-
	1-3 cm			-	-	155	-	43.0	<1	-	8.170	-	23.40	-	1.420	-
	3-6 cm			-	-	50.3	-	7.6	<1	-	0.261	-	0.309	-	0.559	-
St.9B	157°/ 150 m	12.1	-	1.90	-	109	-	34.0	1.4	0.021	0.537	-	0.475	-	0.875	-
	1-3 cm			-	-	285	-	-	-	-	-	-	-	-	-	-
	3-6 cm			-	-	104	-	-	-	-	-	-	-	-	-	-
	6-9 cm			-	-	60.0	-	-	-	-	-	-	-	-	-	-
	9-12 cm			-	-	29.6	-	-	-	-	-	-	-	-	-	-
St.9C	157°/ 200 m	13.0	-	1.55	-	87.9	-	21.8	<1	0.113	0.490	-	0.181	-	0.478	-
	1-3 cm			-	-	110	-	-	-	-	-	-	-	-	-	-
	3-6 cm			-	-	52.4	-	-	-	-	-	-	-	-	-	-
	6-9 cm			-	-	22.7	-	-	-	-	-	-	-	-	-	-
	9-12 cm			-	-	9.80	-	-	-	-	-	-	-	-	-	-
St.10	157°/ 250 m	8.8	5.2	1.33	1.3	41.3	59.3	-	-	-	0.214	0.147	0.092	0.065	0.238	0.382
	1-3 cm			-	-	46.0	114	-	-	-	0.183	0.169	0.132	0.067	0.281	1.140
	3-6 cm			-	-	54.0	68.8	-	-	-	0.406	0.197	0.362	0.367	0.423	2.610
St.11	157°/ 500 m	8.8	5.2	0.97	1.0	15.9	15.5	-	-	-	0.065	-	0.064	-	0.073	-
	1-3 cm			-	-	16.4	-	-	-	-	0.063	-	0.074	-	0.072	-
	3-6 cm			-	-	21.0	-	-	-	-	0.081	-	0.106	-	0.135	-
St.12	157°/1000 m	6.2	6.4	0.91	1.4	10.3	13.6	-	-	-	-	-	-	-	-	-
St.12a	157°/2000m	6.4	-	0.91	-	8.2	-	-	-	-	-	-	-	-	-	-
St.13	247°/100 m	14.8	-	1.54	-	93.4	-	35.3	1.2	0.066	0.265	-	0.106	-	0.506	-
	1-3 cm			-	-	205	-	97.4	<1	-	0.544	-	0.137	-	1.620	-
	3-6 cm			-	-	111	-	26.1	<1	-	0.431	-	0.097	-	1.270	-
St.13B	247°/ 150 m	11.9	-	1.40	-	125	-	53.9	<1	0.106	0.320	-	0.150	-	1.540	-
St.13C	247°/ 200 m	10.5	-	1.13	-	35.6	-	12.1	<1	0.023	0.194	-	0.191	-	0.253	-
St.14	247°/ 250 m	8.5	6.9	1.04	1.2	23.7	189	-	-	-	-	-	-	-	-	-
St.15	247°/ 500 m	7.9	5.5	0.95	1.1	12.6	18.2	-	-	-	-	-	-	-	-	-
St.16	247°/1000 m	8.0	2.4	0.91	0.7	11.4	10.2	-	-	-	-	-	-	-	-	-

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg      olefins, esters and PCB not analysed in 1999

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**Table 4.8.2.** *Ekofisk 2/4 A, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba		Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.1	337°/ 100 m	2330	3750	0.06	0.05	7.2	9.4	5.4	2.7	0.07	-	25.2	26.7	29	28.3
	1-3 cm	4500	-	0.19	-	9.1	-	8.0	-	0.11	-	59.0	-	76	-
	3-6 cm	4980	-	0.25	-	10.1	-	11.1	-	0.13	-	65.8	-	103	-
St.1B	337°/ 150 m	1820	-	0.02	-	6.6	-	2.9	-	0.02	-	18.6	-	14	-
St.1C	337°/ 200 m	2290	-	0.02	-	8.1	-	2.3	-	0.03	-	22.4	-	17	-
St.2	337°/ 250 m	1690	2430	0.02	0.02	8.0	7.9	1.8	1.3	-	-	15.9	15.8	11.5	11.8
St.3	337°/ 500 m	945	739	0.02	<0.02	7.8	7.8	1.6	1.0	-	-	11.0	11.9	9.7	9.2
St.4	337°/1000 m	896	1170	0.02	0.02	8.3	9.4	1.7	1.5	-	-	11.7	14.7	10.7	12.5
St.5	67°/ 100 m	4740	5680	0.17	0.33	11.0	13.4	10.4	19.4	0.07	-	46.8	74.7	84	132
	1-3 cm	4950	-	0.42	-	11.3	-	12.9	-	0.12	-	69.4	-	144	-
	3-6 cm	4310	-	0.50	-	13.0	-	19.8	-	0.28	-	106	-	213	-
St.5B	67°/ 150 m	4960	-	0.28	-	11.8	-	12.4	-	0.11	-	53.0	-	100	-
St.5C	67°/ 200 m	4150	-	0.15	-	10.3	-	8.1	-	0.09	-	36.5	-	51	-
St.6	67°/ 250 m	4480	4340	0.15	0.05	12.2	10.4	10.0	3.6	-	-	39.2	36.2	57	29.8
St.7	67°/ 500 m	2290	1860	0.03	<0.02	8.5	6.8	2.3	1.3	-	-	21.2	12.8	13.1	10.5
St.8	67°/1000 m	1190	1310	0.02	<0.02	8.4	8.9	1.7	1.3	-	-	14.6	16.3	11.0	10.9
St.9	157°/ 100 m	4260	4710	0.17	0.24	9.7	10.3	8.3	15.8	0.08	-	41.0	51.5	84	106
	1-3 cm	5620	-	0.46	-	11.8	-	14.2	-	0.13	-	93.6	-	186	-
	3-6 cm	4820	-	0.42	-	12.0	-	11.2	-	0.13	-	83.7	-	117	-
St.9B	157°/ 150 m	5470	-	0.29	-	10.5	-	13.6	-	0.25	-	71.0	-	144	-
St.9C	157°/ 200 m	3400	-	0.10	-	10.0	-	8.1	-	0.12	-	43.9	-	60	-
St.10	157°/ 250 m	4340	2990	0.05	0.03	9.7	8.3	4.2	2.4	0.05	0.05	31.2	27.7	29	23.2
	1-3 cm	6060	5240	0.10	0.10	11.0	8.9	6.5	5.3	0.09	0.22	52.3	45.7	52	49.6
	3-6 cm	5180	4810	0.10	0.12	11.0	10.8	5.6	3.6	0.04	0.08	38.3	45.6	46	53.1
St.11	157°/ 500 m	1350	1670	0.02	<0.02	8.5	8.9	1.9	1.4	0.02	-	16.7	20.1	11.8	14.5
	1-3 cm	2970	-	0.04	-	8.8	-	2.6	-	0.05	-	21.8	-	16.4	-
	3-6 cm	4480	-	0.06	-	9.7	-	2.8	-	0.04	-	22.6	-	22.0	-
St.12	157°/1000 m	476	605	0.01	<0.02	7.4	8.7	1.8	1.3	-	0.03	8.9	11.0	9.1	9.2
St.12a	157°/2000m	268	-	0.02	-	7.9	-	1.5	-	-	-	8.7	-	8.0	-
St.13	247°/100 m	4350	-	0.27	-	11.7	-	13.5	-	0.08	-	57.9	-	150	-
	1-3 cm	5790	-	0.48	-	13.4	-	24.7	-	0.11	-	146	-	234	-
	3-6 cm	4290	-	0.84	-	10.8	-	15.9	-	0.37	-	137	-	341	-
St.13B	247°/ 150 m	4790	-	0.11	-	13.3	-	12.8	-	0.06	-	49.3	-	86	-
St.13C	247°/ 200 m	3460	-	0.08	-	10.2	-	7.3	-	0.05	-	35.9	-	47	-
St.14	247°/ 250 m	2300	4540	0.05	0.17	8.7	9.6	4.1	9.4	-	-	26.5	63.6	28	96.6
St.15	247°/ 500 m	1960	2900	0.02	<0.02	7.7	8.9	2.3	1.5	-	-	17.5	22.7	13.8	14.7
St.16	247°/1000 m	957	567	0.02	<0.02	7.7	6.3	1.8	0.7	-	-	12.4	9.9	9.9	8.6

-: not analysed

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

The sediment varies from fine sand at the top layer, silt and clay in the 10-15 cm layer, coarse sand from 15 to 35 cm and then fine sand again at the bottom. The sand content varies from 34.3 % in the 10-15 cm layer to 92.5 % in the deepest layer at 45-58 cm. Gravel is found, from 0.2 % in the deepest layer to 21,6 % in the 25-30 cm layer. The top 0-5 cm layer contains 6.3 % total organic matter, and then a TOM content of 10.4 % is found in the next layer at 5-10 cm depth.

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Further the TOM content decreases gradually down-wards in the corer, to finally 1.3 % at the bottom 45-58 cm layer.

The THC concentrations including olefins vary from 54.6 mg/kg in the 40-45 cm layer to 71900 mg/kg in the 10-15 cm layer. Extremely high THC concentrations are found in the layers 5-10 cm, 10-15 cm and 15-20 cm. In the two deepest layers that consist mainly of sand, the THC content is low, but still elevated, approx. 50 mg/kg. Hydrocarbons in the drilling mud base oil area dominate in the 35-40 cm layer, a difference from the other layers. The observation of peaks in the drilling mud base oil area could be related to diesel used as additive to water based mud in the 1970-ies or 80-ies.

The Olefin concentrations vary similar to the THC concentrations, from 13 mg/kg in the 40-45 cm layer to 54700 mg/kg in the 10-15 cm layer. A considerable part of the THC content results from olefins, particularly in the most contaminated samples, up to 76 %.

The ester drilling fluid Finagreen decreases gradually downwards in the corer from the top 0-5 cm layer with very high concentrations, 1500 mg/kg, to 1.1 mg/kg in the 40-45 cm layer.

The NPD concentrations vary from 0.30 mg/kg in the bottom layer at 45-58 cm to 40.9 mg/kg in the 35-40 cm layer, the layer with the drilling mud base oil. The PAH concentrations vary from 0.11 mg/kg at the bottom to 1.31 mg/kg in the 5-10 cm layer. The concentrations are low, and no correlation with THC is observed. The decalin concentrations vary from 0.48 mg/kg at the bottom layer to 77.5 mg/kg in the 35-40 cm layer, a clear correspondence with the THC concentrations.

The PCB concentrations (sum PCB 7 dutch) vary from 0.004 mg/kg in the bottom layer to 0.776 mg/kg in the 30-35 cm layer. The PCB concentration is low in the top 0-5 cm layer, and the concentrations are particularly high in the 30-35 cm and 35-40 cm layers.

The Ba concentrations are relatively high and vary from 815 mg/kg in the 45-58 cm layer to 3700 mg/kg in the 40-45 cm layer. The 40-45 cm sediment appears different from the layers above in the mineralogy as the concentrations of the elements Al, Ca, Fe and Mg are very reduced in this sample

High concentrations of the heavy metals are not found in the 40-45 cm layer, but in the 35-40 cm layer, the same layer that shows drilling mud base oil. Particularly high concentrations of Pb and Zn are found, above 1000 mg/kg.

Elevated concentrations of all the chemical parameters analysed are found downwards to 60 cm depth in the drill cuttings pile, except for Cd and Hg in the deepest layer.

The chemical results mainly agree with the drilling history. As no discharges have taken place since 1994, higher concentrations in the layers than in the top 0-5 cm layer could possibly be expected. Olefins and esters have also been discharged. As ester drilling fluids were discharged in 1994, lower concentrations particularly in the top layers could be expected due to the relatively easy decomposition of ester compounds. PCB originates from additives in paint.

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**Table 4.8.3.** Ekofisk 2/4 A, Drill cuttings pile, Core sample VC-2: silt & clay and TOM (%), THC, olefins, esters, PCB, NPD, PAH and decalins (mg/kg dry sediment)

Layer	Silt and clay 2002	TOM 2002	*THC 2002	Olefins 2002	Esters 2002	PCB 2002	NPD 2002	PAH 2002	Decalins 2002
0 - 5 cm	36.6	6.26	5480	3040	1500	0.012	21.50	0.63	22.50
5 - 10 cm	47.7	10.4	35000	24200	1210	**	10.10	1.31	22.50
10 - 15 cm	63.5	9.24	71900	54700	45.2	**	5.54	0.48	29.10
15 - 20 cm	34.5	8.70	19600	14600	32.7	**	11.20	0.84	37.30
20 - 25 cm	14.2	5.17	994	277	12.8	0.064	13.10	0.64	8.08
25 - 30 cm	9.3	4.47	934	200	9.12	0.139	12.70	0.92	18.50
30 - 35 cm	8.0	3.83	883	116	5.76	0.776	14.00	0.75	36.10
35 - 40 cm	47.2	2.71	1360	**nd	3.40	0.711	40.90	1.13	77.50
40 - 45 cm	6.2	1.40	54.6	13.0	1.09	0.078	1.23	0.29	0.88
45 - 58 cm	7.3	1.27	57.6	36.2	2.99	0.004	0.30	0.11	0.48

\*: olefins included

\*\*nd: not detected probably due to high concentrations of drilling mud base oil

**Table 4.8.4.** Ekofisk 2/4 A, Drill cuttings pile, Core sample VC-2: Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Layer	Ba 2002	Cd 2002	Cr 2002	Cu 2002	Hg 2002	Pb 2002	Zn 2002
0 - 5 cm	2280	0.4	36.1	62.4	0.18	56.2	138
5 - 10 cm	1440	0.2	31.8	74.0	0.19	75.6	146
10 - 15 cm	1660	2.8	28.4	73.8	0.61	181	373
15 - 20 cm	2450	0.4	32.1	52.3	0.27	120	354
20 - 25 cm	3010	0.5	52.1	55.7	0.18	123	567
25 - 30 cm	3440	0.6	43.7	65.9	0.18	142	535
30 - 35 cm	2970	1.4	63.1	107	0.47	211	746
35 - 40 cm	1870	12.6	125	136	2.52	1300	2080
40 - 45 cm	3700	0.2	9.8	4.4	0.14	59.9	50
45 - 58 cm	815	< 0.2	10.8	2.3	0.03	8.5	12

**Macrobenthic fauna**

The diversity indices are clearly influenced by *M. oculata*, but reflecting a relatively undisturbed fauna community when excluding this species. The evenness ( $J'$ ) and  $ES_{100}$  was also generally high for all stations (ex. *M. oculata*) except station EKO-A-13, see Table 4.8.5.

Only the Ekofisk A field stations are included in the MDS plot: The stations can be divided into 4 subgroups.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* is, as in 1999, found to dominate the benthic macrofauna at the Ekofisk A stations, but the abundances are higher in 2002.
- The diversity indices (excluding *M. oculata* from the data) are high, reflecting an undisturbed fauna community at most Ekofisk A stations.

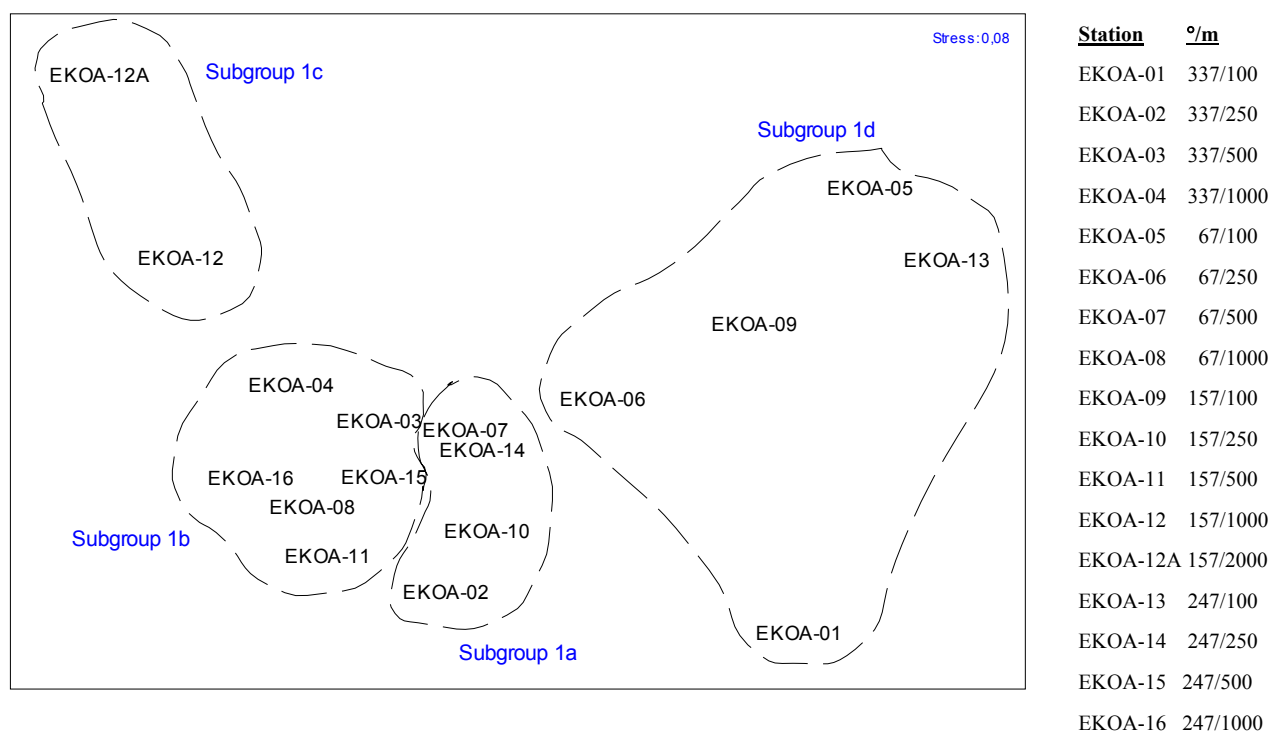
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- There is a relatively good correlation between the fauna and the distribution of Pb, Cd, Zn and THC. The highest concentrations of Pb, Zn, Cd and THC occur at the stations located 100m from the installation centre and one located at 250m in the 67° direction. Thus the fauna at the innermost stations and especially stations 5 (67°/100m) and 13 (247°/100m), seems to be slightly disturbed.
- The diversity indices at station 9 (157°/100m) and 14 (247°/250), both characterised as disturbed in 1999, have increased. The fauna community, however, indicate that station 9 still is slightly disturbed, while station 14, where the THC and Ba have been considerably reduced, seems to have recovered since 1999.
- The changes from 1999 to 2002 are quite similar to a general trend in the region, and are probably not related to Ekofisk A activities.

**Table 4.8.5.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Ekofisk A stations, 2002. Incl. / ex. *M. oculata*, ex. *juv.*

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
EKO-A-01	337/100	74	4649	1089	89	88	1.9	4.8	0.3	0.7	15	33
EKO-A-02	337/250	74	3569	1049	91	90	2.3	5.0	0.4	0.8	18	35
EKO-A-03	337/500	74	2558	838	88	87	2.6	5.2	0.4	0.8	21	38
EKO-A-04	337/1000	76	1648	768	81	80	3.3	4.9	0.5	0.8	24	34
EKO-A-05	67/100	74	2872	1422	76	75	3.1	4.2	0.5	0.7	19	26
EKO-A-06	67/250	73	2243	872	78	77	2.9	4.9	0.5	0.8	22	34
EKO-A-07	67/500	76	3060	829	74	73	2.2	4.9	0.3	0.8	17	33
EKO-A-08	67/1000	75	2595	751	81	80	2.4	5.2	0.4	0.8	19	37
EKO-A-09	157/100	74	2060	1028	82	81	3.3	4.5	0.5	0.7	22	30
EKO-A-10	157/250	75	3044	1044	89	88	2.7	5.1	0.4	0.8	21	36
EKO-A-11	157/500	74	2309	798	86	85	2.7	5.1	0.4	0.8	21	37
EKO-A-12	157/1000	71	1810	599	73	72	2.6	5.1	0.4	0.8	21	38
EKO-A-13	157/2000	71	1650	550	64	63	2.5	4.8	0.4	0.8	20	33
EKO-A-13	247/100	74	2496	1516	78	77	3.5	4.1	0.5	0.6	20	24
EKO-A-14	247/250	74	1972	899	80	79	3.3	5.1	0.5	0.8	25	36
EKO-A-15	247/500	74	3684	924	80	79	2.0	4.9	0.3	0.8	17	33
EKO-A-16	247/1000	72	2077	694	78	77	2.6	5.0	0.4	0.8	20	35

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**Figure 4.8.10.** MDS plot, Ekofisk A and regional stations 3, 4, 6, 7 and 8 (trans. sq.root, ex. *M. oculata* and juveniles), Ekofisk A 2002.

## 4.9 Eldfisk 2/7 A/FTP

The sediments at Eldfisk 2/7 A/FTP consist of fine sand, and the sand content varies from 94 % at station 10, 270°/1000m to 97 % at station 2, 360°/1000m. The gravel content is low. The silt and clay content is similar to the previous surveys. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.76 % to 0.91 %. The concentrations are similar to the previous surveys.

The mean THC concentrations vary from 6.1 mg/kg at station 8, 180°/2000m to 32.5 mg/kg at station 6, 180°/500m. At station 6 an increase is observed since the previous survey. Additional hydrocarbons in the drilling mud base oil area are clearly seen in the gas chromatograms. Crude oil attached to drill cuttings from drilling in the reservoir may also give a contribution to the increased THC concentrations. At most of the other stations a slight decrease is observed. Slightly elevated concentrations are found out to 1000m in the 90° and 360° directions and out to 2000m in the 180° and 270° directions.

Olefins are also detected at the four stations analysed, from 0.9 mg/kg at station 7, 180°/1000m to 1.3 mg/kg at station 14, 90°/500m. The concentrations are similar to the previous survey in 1999.

Elevated levels of NPD and decalins are found at station 6, 180°/500m. The decalin concentrations are increased since 1999, and high levels are found in the 1-3cm and 3-6cm layers.

The Ba concentrations vary from 111 mg/kg at station 8, 180°/2000m to 1540 mg/kg at station 14, 90°/500m. Elevated Ba concentrations are found at all stations. This means out to 1000m in the 90° and 360° directions and out to 2000m in the 180° and 270° directions. The concentrations are similar to the previous survey in 1999.

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The concentrations of the heavy metals are low, and no increases are observed since 1999. Slightly elevated concentrations of Cu, 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 baryte was discharged in 2001 and 2002.

**Table 4.9.1.** *Eldfisk 2/7 A/FTP, silt & clay and TOM (%), THC, olefins, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2	360°/1000 m	3.4	4.0	0.91	0.76	8.5	9.4	-	-	-	-	-	-	-	-
St.3	360°/ 500 m	4.9	-	0.76	-	8.3	-	-	-	-	-	-	-	-	-
St.6	180°/ 500 m	5.1	5.7	0.89	0.81	32.5	16.3	1.3	0.9	0.051	0.062	0.053	0.064	2.49	0.084
	1-3 cm			-	-	47.7	16.0	< 0.6	0.9	0.071	0.043	0.064	0.049	4.20	0.104
	3-6 cm			-	-	52.0	15.9	< 0.6	0.9	0.057	0.042	0.060	0.053	4.62	0.120
St.7	180°/1000 m	4.4	5.9	0.85	0.87	7.6	11.8	0.9	0.4	0.027	-	0.040	-	0.052	-
	1-3 cm			-	-	9.6	-	0.61	-	0.036	-	0.059	-	0.072	-
	3-6 cm			-	-	14.0	-	0.98	-	0.093	-	0.278	-	0.088	-
St.8	180°/2000 m	5.3	4.5	0.80	0.54	6.1	9.8	-	-	-	-	-	-	-	-
St.9	270°/2000 m	4.4	4.6	0.78	0.85	7.2	11.8	-	-	-	-	-	-	-	-
St.10	270°/1000 m	5.6	4.6	0.80	0.87	8.6	11.6	-	-	-	-	-	-	-	-
St.14	90°/ 500 m	5.5	-	0.90	-	16.9	-	1.3	-	-	-	-	-	-	-
St.15	90°/1000 m	4.5	2.6	0.80	0.80	8.4	8.9	1.1	0.4	-	-	-	-	-	-

-: not analysed

**Table 4.9.2.** *Eldfisk 2/7 A/FTP, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba			Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2	360°/1000 m	271	363	561	<0.01	<0.02	7.0	7.5	1.2	0.6	-	-	8.4	9.8	6.9	7.5
St.3	360°/ 500 m	593	-	-	0.01	-	6.7	-	1.5	-	-	-	9.3	-	8.3	-
St.6	180°/ 500 m	1150	1130	2390	0.02	<0.03	7.2	7.8	2.4	1.4	0.02	0.02	10.2	14.5	10.6	13.7
	1-3 cm	2330	1280	-	0.04	<0.02	7.9	7.2	2.7	1.1	0.02	0.04	14.6	14.3	18.8	12.1
	3-6 cm	2600	2740	-	0.04	0.03	7.6	8.0	2.7	1.9	0.03	0.03	15.3	17.5	19.0	20.7
St.7	180°/1000 m	404	455	659	0.01	<0.02	7.6	8.0	1.6	0.8	0.02	-	8.7	10.5	7.9	8.2
	1-3 cm	736	-	-	0.02	-	8.1	-	2.0	-	0.02	-	9.4	-	9.1	-
	3-6 cm	1010	-	-	0.02	-	8.2	-	1.8	-	0.02	-	10.2	-	10.2	-
St.8	180°/2000 m	111	294	397	<0.02	<0.02	6.1	7.9	1.8	0.8	-	<0.02	4.9	9.1	7.7	7.2
St.9	270°/2000 m	352	372	1910	0.01	<0.02	7.3	7.7	1.3	0.8	-	-	9.0	12.3	7.1	7.3
St.10	270°/1000 m	456	549	927	0.01	<0.02	7.0	7.2	1.4	1.0	-	-	9.6	11.7	9.9	8.3
St.14	90°/ 500 m	1540	-	-	0.02	-	7.5	-	2.4	-	-	-	14.0	-	12.5	-
St.15	90°/1000 m	612	772	909	<0.01	<0.02	7.1	7.1	1.4	0.8	-	-	9.6	11.5	8.1	8.2

-: not analysed

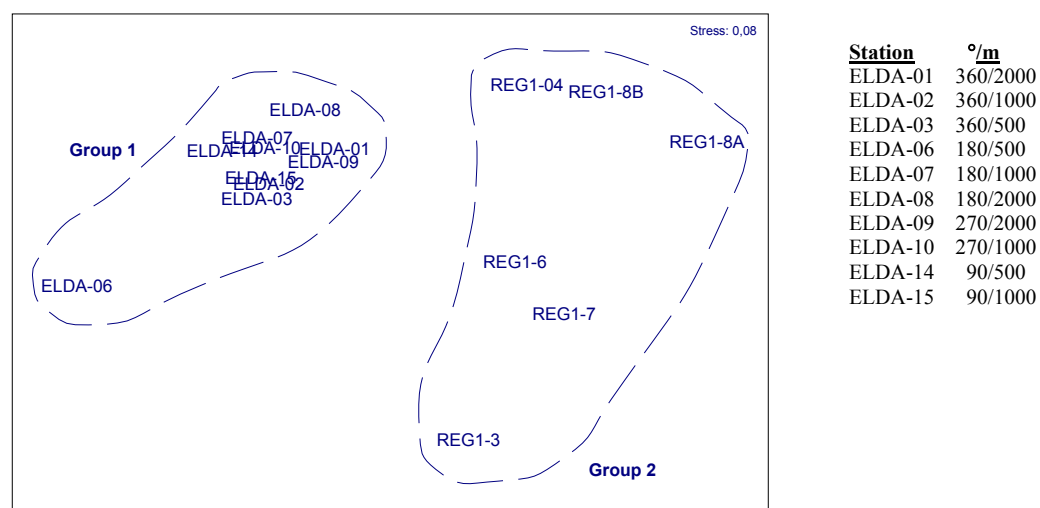
### *The macrobenthic fauna*

The diversity indices are clearly influenced by *M. oculata*, but in general the diversity indices and the fauna composition reflect an undisturbed environment when excluding *M. oculata*. The exception is station ELDA-6(180/500°), which could be characterised as slightly disturbed.

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**Table 4.9.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Eldfisk A stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
ELDA-01	360/2000	71	1770	670	74	73	2.8	4.8	0.4	0.8	21	32
ELDA-02	360/1000	72	2528	778	79	78	2.4	4.9	0.4	0.8	19	35
ELDA-03	360/500	72	2731	840	86	85	2.3	4.6	0.4	0.7	17	33
ELDA-06	180/500	73	2191	1051	68	67	2.9	4.0	0.5	0.6	18	25
ELDA-07	180/1000	72	1936	726	78	77	2.9	5.1	0.5	0.8	22	37
ELDA-08	180/2000	73	1882	622	73	72	2.6	5.0	0.4	0.8	20	35
ELDA-09	270/2000	72	2123	633	75	74	2.4	5.0	0.4	0.8	19	36
ELDA-10	270/1000	73	2818	788	82	81	2.3	5.2	0.4	0.8	19	38
ELDA-14	90/500	73	1908	738	65	64	2.8	4.7	0.5	0.8	20	32
ELDA-15	90/1000	72	2558	838	79	78	2.6	5.0	0.4	0.8	20	35



**Figure 4.9.1.** MDS plot, Eldfisk A incl. regional stations 3, 4, 6, 7 and 8 (trans. sq.root, ex. *M. oculata* and juveniles) (left), ex. regional stations (right) Eldfisk A 2002.

The fauna at Eldfisk A field stations differs somewhat from the regional stations, see Figure 4.9.1.

The results from the macrobenthic analyses show that:

- The diversity indices (based on the results exclusive *M. oculata*) show a relatively undisturbed benthic fauna in the Eldfisk A field. The exception is the fauna at station ELDA-6 (180°/500) where the results show a disturbance on the fauna.
- There is a high correlation between the fauna and THC. The sediments of stations ELDA-6 contain the highest concentration of THC. The fauna composition at this station was somewhat different from the other stations in 1999, but the diversity



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index was still high. Since then the trend has continued, and now a reduction in diversity is observed.

- There are no major changes in diversity (ex. *M. oculata*) through the years, except for a decline at station ELDA-6, which most probably is related to the increased concentration of THC from 1999. The fauna composition seems to have changed slightly during the recent years.

#### 4.10 Eldfisk 2/7 B

The sediments at Eldfisk 2/7 B consist of fine sand, and the sand content varies from 92 % at station 15, 90°/1000m to 97 % at station 2, 360°/1000m and station 10, 270°/1000m. The gravel content is low. The silt and clay content is similar to the previous surveys. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.82 % at station 15, 90°/1000m to 0.99 % at station 8, 180°/2000m. The concentrations are similar to the previous surveys.

The mean THC concentrations vary from 7,8 mg/kg at station 8, 180°/2000m to 16.4 mg/kg at station 14, 90°/500m. The concentrations are similar to the previous survey, and a slight decrease is found at two stations. Slightly elevated THC concentrations are found at all stations analysed, out to 2000m distance in the 180° direction and out to 1000m in the 90°, 270° and 360° directions.

Olefins are detected at the four stations analysed, from 0.8 mg/kg at station 11, 270°/500m to 1.1 mg/kg at station 14, 90°/500m.

Slightly elevated concentrations of NPD are found at station 6, 180°/500m. Elevated PAH concentrations are not found. Decalins are found at the two stations analysed, and the concentrations are increased since the previous surveys. Usually an increase in the decalin concentration is related to an increase in the THC content. In this case an increase in the THC content is not found.

The mean Ba concentrations vary from 213 mg/kg at station 8, 180°/2000m to 1850 mg/kg at station 14, 90°/500m. The Ba concentrations are very similar to the previous survey, and elevated concentrations are found at all stations. Thus elevated levels are found out to 1000m in the 90°, 270° and 360 directions and out to 2000m in the 180° direction. The highest Ba concentrations are found in the 3-6 cm layer at station 6, 180°/500m, 2740 mg/kg.

The concentrations of the heavy metals are low, and no increases are observed since 1999. Slightly elevated concentrations of Cu, 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 B. Pseudo-oil based drilling fluids (olefins) and baryte are discharged since the last survey in 1999.

**Table 4.10.1.** Eldfisk 2/7 B, silt & clay and TOM (%), THC, olefins, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2 360°/1000 m	3.5	4.0	0.90	0.74	8.3	6.7	-	-	-	-	-	-	-	-
St.3 360°/ 500 m	4.5	5.6	0.98	0.75	11.6	8.5	-	-	-	-	-	-	-	-
St.6 180°/ 500 m	5.4	5.1	0.96	1.07	15.0	22.0	0.9	3.8	0.060	0.444	0.056	0.858	0.626	0.091
1-3 cm			-	-	21.3	13.9	1.2	2.2	0.061	0.070	0.061	0.114	0.986	0.058
3-6 cm			-	-	23.2	19.2	2.0	2.6	0.070	0.078	0.102	0.129	0.481	0.111

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Table 4.10.1 cont.		Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
Station		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.7	180°/1000 m	5.1	3.3	0.93	0.89	9.1	11.1	0.9	0.7	0.035	-	0.051	-	0.087	-
	1-3 cm			-	-	12.7	-	1.0	-	0.043	-	0.076	-	0.306	-
	3-6 cm			-	-	15.3	-	1.3	-	0.056	-	0.097	-	0.205	-
St.8	180°/2000 m	6.2	8.0	0.99	1.09	7.8	7.7	-	-	-	-	-	-	-	-
St.10	270°/1000 m	3.5	5.1	0.83	0.84	9.4	10.7	-	-	-	-	-	-	-	-
St.11	270°/ 500 m	6.4	4.5	0.88	0.81	12.2	11.9	0.8	0.7	-	-	-	-	-	-
St.14	90°/ 500 m	6.1	3.6	0.88	0.81	16.4	14.1	1.1	1.2	-	-	-	-	-	-
St.15	90°/1000 m	7.4	3.8	0.82	0.90	8.1	12.0	-	-	-	-	-	-	-	-

-: not analysed

**Table 4.10.2.** Eldfisk 2/7 B, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station		Ba		Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.2	360°/1000 m	405	432	186	0.01	<0.02	6.8	5.7	1.2	0.5	-	-	7.4	7.7	7.2	5.8
St.3	360°/ 500 m	1020	1000	-	0.01	<0.02	6.9	6.2	1.7	0.6	-	-	9.5	8.7	9.3	6.2
St.6	180°/ 500 m	1480	1460	1630	0.02	<0.02	6.1	7.1	1.9	1.2	0.02	0.03	10.3	12.6	13.6	13.1
	1-3 cm	1730	1500	-	0.03	0.02	6.1	6.6	1.9	1.1	0.02	0.02	11.1	12.3	9.7	12.3
	3-6 cm	2740	2930	-	0.03	0.03	7.0	6.9	3.7	1.2	0.03	0.04	15.3	13.5	19.0	12.1
St.7	180°/1000 m	375	389	445	0.01	<0.02	6.8	7.1	1.5	0.8	0.02	-	9.0	10.6	9.4	7.3
	1-3 cm	628	-	-	0.02	-	7.3	-	1.8	-	0.01	-	10.3	-	9.1	-
	3-6 cm	1850	-	-	0.03	-	8.5	-	3.2	-	0.02	-	11.5	-	11.8	-
St.8	180°/2000 m	213	221	404	0.01	0.02	7.5	7.5	1.6	0.8	-	0.03	8.3	9.2	7.7	7.5
St.10	270°/1000 m	532	593	1270	0.01	<0.02	7.1	7.6	1.6	0.8	-	-	9.3	11.7	7.9	7.3
St.11	270°/ 500 m	1210	1450	-	0.01	<0.02	7.0	7.5	1.9	1.1	-	-	10.6	12.8	10.7	9.3
St.14	90°/ 500 m	1850	1740	-	0.02	<0.02	6.8	7.3	2.5	1.4	-	-	15.6	17.3	14.3	11.4
St.15	90°/1000 m	774	986	783	0.01	<0.02	7.3	7.8	1.8	0.9	-	-	10.5	12.4	9.1	8.6

-: not analysed

**The macrobenthic fauna**

The diversity indices are clearly influenced by *M. oculata*, ranging from 4.4 to 5.0 excluding this species, see Table 4.10.3.

**Table 4.10.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Eldfisk B stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

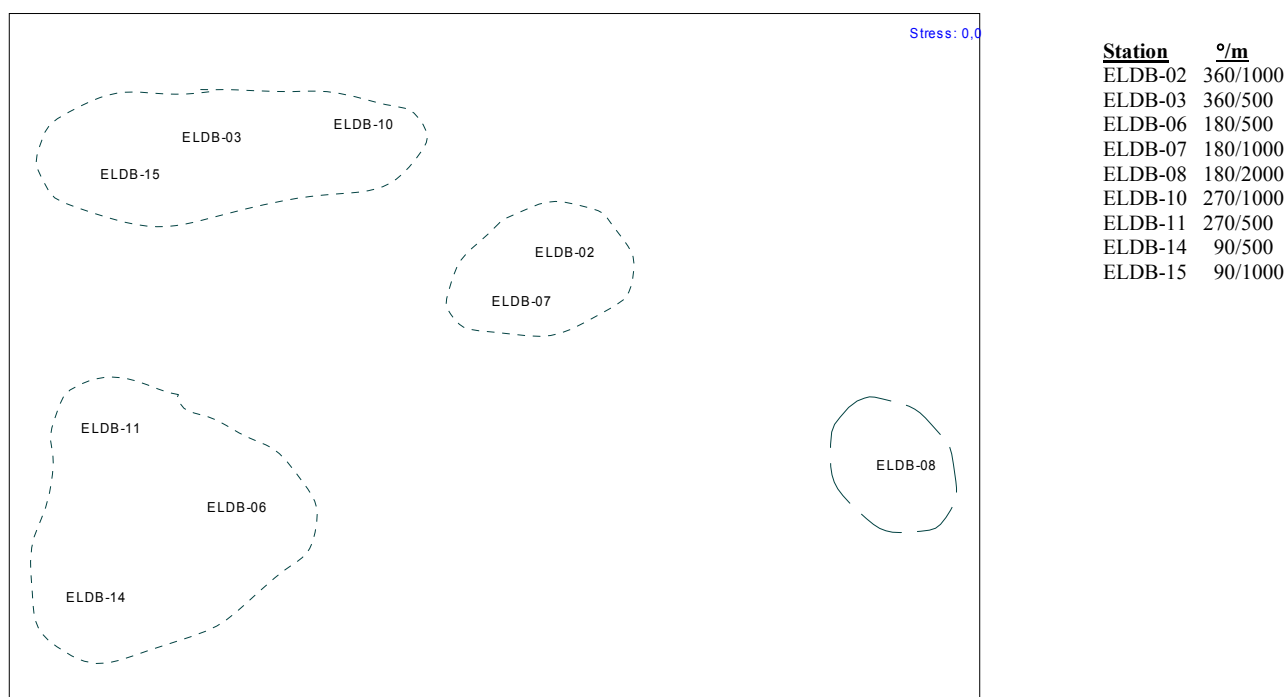
Station	%m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
ELDB-02	360/1000	73	2656	766	73	72	2.3	5.0	0.4	0.8	19	35
ELDB-03	360/500	71	1853	693	69	68	2.8	4.9	0.4	0.8	21	33
ELDB-06	180/500	73	1994	832	66	65	2.8	4.4	0.5	0.7	20	30
ELDB-07	180/1000	73	2210	770	76	75	2.6	4.9	0.4	0.8	20	35
ELDB-08	180/2000	73	2103	733	73	72	2.6	4.7	0.4	0.8	19	31
ELDB-10	270/1000	71	2084	814	78	77	2.9	5.0	0.5	0.8	22	35
ELDB-11	270/500	71	1768	888	65	64	3.3	4.7	0.5	0.8	23	31
ELDB-14	90/500	73	2117	737	62	61	2.5	4.6	0.4	0.8	18	29
ELDB-15	90/1000	74	2269	849	79	78	2.8	4.9	0.4	0.8	21	34

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Two main fauna groups are identified in the multivariate analyses; the Eldfisk B field stations and the regional stations. Although the similarity within the Eldfisk B field stations is high, four subgroups are indicated, see MDS plot in Figure 4.10.1.

The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* is, as in 1999, found to dominate the benthic macrofauna, but in much higher numbers.
- The diversity indices and the community structure reflect an undisturbed fauna at Eldfisk B, excluding *M. oculata* from the data set.
- There is a correlation between fauna and the distribution of Ba. Stations ELDB-3, 6, 11 and 14, all located 500m from the installation centre, have the highest concentrations of Ba. A slight decline in the diversity indices is also observed at these stations. However, the community structure and the diversity indices indicate no disturbance at these stations. The fauna at Eldfisk B is therefore considered to be fairly undisturbed, with a possible weak disturbance related to elevated Ba concentrations at the 500m stations.
- The analyses over the years indicate an alteration in the fauna composition. However, this seems to be of general character in the Ekofisk area, and is considered not to be related to oil activities.



**Figure 4.10.1.** MDS plot, Eldfisk B and regional stations 3, 4, 6, 7 and 8 (trans. sq.root, ex. *M. oculata* and juveniles), Eldfisk B 2002.

#### 4.11 Embla 2/7 D

The sediments at Embla 2/7 D consist of fine sand, and the sand content varies from 93.6 % at station 14, 90°/500m to 97.1 % at station 7, 180°/1000m. The gravel content is low. The silt and

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clay concentration are similar to the previous surveys. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.74 % to 0.91 %. The results are similar to the previous surveys.

The mean THC concentrations vary from 6.7 mg/kg at station 3, 360°/500m and station 15, 90°/1000m to 11.0 mg/kg at station 14, 90°/500m. The concentrations are similar to the 1999 survey. At all stations the concentrations are slightly above the LSC value.

The NPD, PAH and decalin concentrations are slightly higher in the layer samples than in the top 0-1 cm layer. This was also observed in 1999 and 1996. Elevated concentrations of NPD and PAH are not found. Decalins are still present in the vertical layers at station 6, 180°/500m.

The mean Ba concentrations vary from 152 mg/kg at station 7, 180°/1000m to 1170 mg/kg at station 14, 90°/500m. The Ba concentrations are decreased since the previous surveys, however they are still elevated at the stations analysed. This means out to out to 500m in the 270° and 360° directions, and out to 1000m distance in the 90° and 180° directions.

The concentrations of the heavy metals are low, and slightly elevated concentrations are found.

The chemical results agree with the drilling history. No discharges have taken place at Embla 2/7 D since the 1996 survey.

**Table 4.11.1.** *Embla 2/7 D, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM		THC			NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	1996	2002	1999	2002	1999	2002	1999
St.3	360°/ 500 m	4.1	-	0.81	-	6.7	-	5.9	-	-	-	-	-	-
St.6	180°/ 500 m	5.1	4.0	0.84	0.86	7.1	10.9	11.4	0.026	0.040	0.047	0.077	nd	0.129
	1-3 cm			-	-	7.5	18.8	18.5	0.031	0.078	0.041	0.111	0.076	0.209
	3-6 cm			-	-	10.6	9.3	4.9	0.040	0.036	0.067	0.051	0.149	0.071
St.7	180°/1000 m	2.9	4.1	0.91	0.82	6.8	7.2	6.6	0.030	-	0.055	-	nd	-
	1-3 cm			-	-	7.0	-	-	0.031	-	0.056	-	nd	-
	3-6 cm			-	-	8.6	-	-	0.032	-	0.076	-	nd	-
St.11	270°/ 500 m	3.3	-	0.74	-	6.9	-	6.5	-	-	-	-	-	-
St.14	90°/ 500 m	6.1	-	0.81	-	11.0	-	-	-	-	-	-	-	-
St.15	90°/1000 m	4.1	-	0.83	-	6.7	-	8.3	-	-	-	-	-	-

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

**Table 4.11.2.** *Embla 2/7 D, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba			Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.3	360°/ 500 m	408	-	711	<0.01	-	8.0	-	1.3	-	-	-	10.1	-	8.9	-
St.6	180°/ 500 m	341	655	2210	0.01	<0.02	7.2	7.9	1.7	1.2	0.01	0.02	10.0	12.7	9.7	8.3
	1-3 cm	1450	939	-	0.02	<0.02	8.7	7.9	2.0	0.9	0.01	0.03	13.8	13.3	10.8	8.6
	3-6 cm	1170	1680	-	0.03	0.02	8.9	8.1	2.2	1.1	0.01	0.02	12.0	12.6	11.0	8.8
St.7	180°/1000 m	152	144	486	0.01	<0.02	8.0	7.9	1.4	0.6	<0.02	-	8.1	9.6	7.8	6.4
	1-3 cm	206	-	-	0.02	-	8.5	-	1.4	-	<0.01	-	8.5	-	7.7	-
	3-6 cm	624	-	-	0.02	-	8.3	-	1.9	-	0.01	-	9.4	-	18.2	-
St.11	270°/ 500 m	212	-	1770	<0.01	-	7.1	-	1.3	-	-	-	8.2	-	7.3	-
St.14	90°/ 500 m	1170	-	-	0.01	-	7.2	-	1.7	-	-	-	12.0	-	11.8	-
St.15	90°/1000 m	216	-	584	<0.01	-	7.8	-	1.5	-	-	-	10.0	-	9.2	-

-: not analysed

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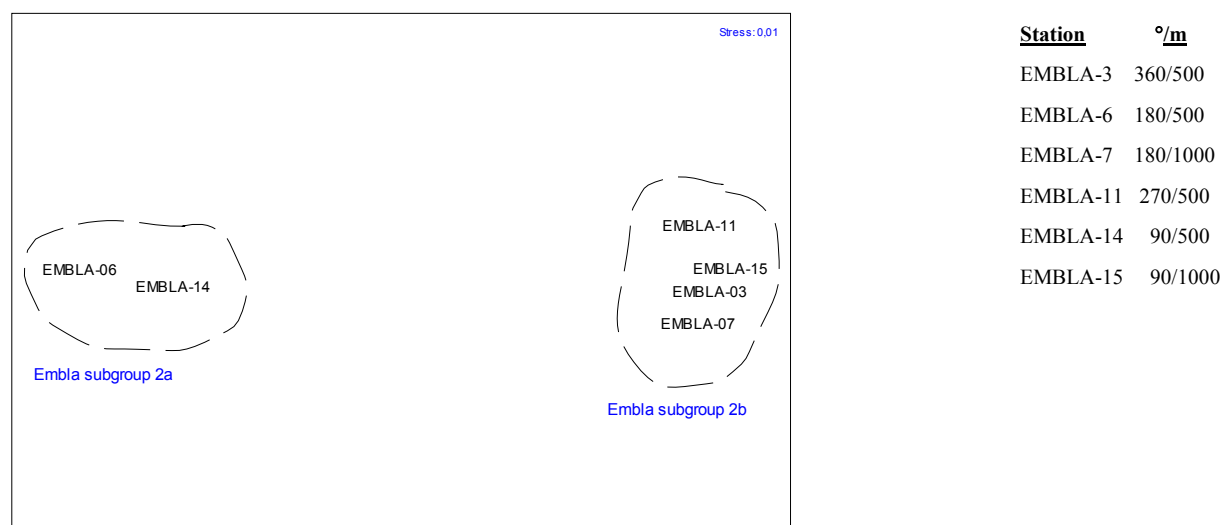
***The macrobenthic fauna***

The diversity indices are clearly influenced by *M. oculata*, but reflecting an undisturbed when excluding this species, see Table 4.11.3.

**Table 4.11.3.** Number of species (*S*) and individuals (*N*) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (*H'*), Pielou's evenness index (*J*), and expected number of species per 100 individuals (*ES*<sub>100</sub>) for each of the Embla stations, 2002. Incl. / ex. *M. oculata*, ex. juv.

Station	°/m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.	Incl. M. o.	Ex. M. o.
EMBLA-3	360°/500	70	1050	630	71	70	3.8	4.7	0.6	0.8	26	33
EMBLA-6	180°/500	72	2272	872	78	77	2.9	5.1	0.5	0.8	23	37
EMBLA-7	180°/1000	71	1272	592	66	65	3.1	4.6	0.5	0.7	22	31
EMBLA-11	270°/500	71	925	645	74	73	4.0	4.5	0.6	0.7	27	32
EMBLA-14	90°/500	71	1247	777	78	77	3.8	4.6	0.6	0.7	26	33
EMBLA-15	90°/1000	71	884	574	68	67	3.9	4.6	0.6	0.7	27	32

The Embla stations form two subgroups, see MDS plot in Figure 4.11.1.



**Figure 4.11.6.** MDS plot, Embla field stations (trans. sq.root, ex. *M. oculata* and juveniles), Embla 2002.

The results from the macrobenthic analyses show that:

- The diversity indices (based on the results exclusive *M. oculata*) and the similarity analyses indicate an undisturbed benthic fauna at the Embla stations. EMBLA-6 and 14 differ somewhat from the other Embla stations in their species composition.
- The number of species has declined at some stations since 1996 and 1999. However, the diversity indices (ex. *M. oculata*) are generally high. At some stations *M. oculata* is more dominating in 2002 than in previous surveys.
- In general there has been a turn in the fauna community from 1990 when the fauna contained higher numbers of molluscs and crustaceans, to a fauna which contain a higher share of bristle worms. This indicates some influence of the fauna, but this trend is general in the region.

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**4.12 Tor 2/4 A**

The sediments at Tor 2/4 E consist of fine sand, and the sand content varies from 96 % to 98 %. No gravel is found. The silt and clay content is similar to the previous survey. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0.90 % to 0.96 %. A slight increase is observed since the previous survey.

The mean THC concentrations vary from 5.5 mg/kg at station 7, 180°/1000m to 30.7 mg/kg at station 5, 180°/250m. The highest concentrations are found in the 1-3 cm and 3-6 cm layers at station 5, 122 mg/kg and 238 mg/kg respectively. The THC concentrations are slightly decreased since 1999, except for the layer samples at station 5, 180°/250m which show similar, relatively high concentrations. Elevated THC concentrations are found at two of the six stations analysed, at 250m and 500m in the 180° direction.

The drilling fluid Aquamul B (didecyl ethers) is seen in the gas chromatograms. These compounds are included in the THC quantification, and they represent a major part of the elevated "THC" concentration found at station 5, 180°/250m.

Elevated NPD concentrations are found at both stations analysed, similar to 1999. Decalins are also found at station 5, a slight decrease in the top layer and similar concentrations as in 1999 in the layers. Elevated concentrations of PAH are not found, a decrease since 1999.

The Ba concentrations vary from 123 mg/kg at station 3, 360°/500m to 1420 mg/kg at station 5, 180°/250m. Elevated Ba concentrations are found at the six stations analysed. This means out to 500m distance in the 90°, 270° and 360° directions and out to 1000m in the 180° direction. The concentrations are similar to the 1999 survey. As for THC high concentrations are found in the 0-1 cm and 3-6 cm layers at station 5, 2110 mg/kg and 2330 mg/kg respectively.

The concentrations of the heavy metals are low, however some elevated concentrations are found, particularly at station 5, 180°/250m and in the layer samples as well. No increases are observed since 1999.

The chemical results agree with the drilling history. No drilling activities has taken place at Tor 2/4 E since 1990. In 1990 the drilling fluid Aquamul B was added as lubricant in the water based mud during drilling.

**Table 4.12.1. Tor 2/4 E, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

Station		Silt and clay		TOM		THC			NPD		PAH		Decalins	
		2002	1999	2002	1999	2002	1999	1996	2002	1999	2002	1999	2002	1999
St.3	360°/ 500 m	4.1	4.8	0.90	0.82	6.2	8.6	8.8	-		-	-	-	-
St.5	180°/ 250 m	4.1	3.5	0.96	0.80	30.7	46.0	35.4	0.120	0.131	0.045	0.166	0.072	0.148
	1-3 cm			-	-	122	174	69.4	0.129	0.158	0.039	0.097	0.208	0.384
	3-6 cm			-	-	238	192	32.6	0.164	0.203	0.046	0.050	0.577	0.462
St.6	180°/ 500 m	4.0	3.6	0.92	0.77	8.5	18.8	12.6	0.048	-	0.043	-	nd	-
	1-3 cm			-	-	9.3	-	-	0.036	-	0.052	-	nd	-
	3-6 cm			-	-	12.8	-	-	0.061	-	0.109	-	0.056	-
St.7	180°/1000 m	3.8	4.6	0.93	0.74	5.5	6.7	7.1	-	0.099	-	0.271	-	nd
St.11	270°/ 500 m	2.1	2.4	0.93	0.82	5.6	9.1	8.0	-	-	-	-	-	-
St.14	90°/ 500 m	3.7	3.5	0.90	0.71	6.5	7.1	5.2	-	-	-	-	-	-

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

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**Table 4.12.2.** *Tor 2/4 E, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba 2002	Ba 1999	Ba 1996	Cd 2002	Cd 1999	Cr 2002	Cr 1999	Cu 2002	Cu 1999	Hg 2002	Hg 1999	Pb 2002	Pb 1999	Zn 2002	Zn 1999
St.3	360°/ 500 m	123	277	308	<0.01	<0.04	7.1	7.4	1.5	0.7	-	-	6.7	8.6	5.8	6.7
St.5	180°/ 250 m	1420	1470	2590	0.04	0.06	7.9	6.6	5.0	2.1	0.04	0.03	24.3	15.3	25.3	26.5
	1-3 cm	2110	2350	-	0.09	0.20	8.4	8.0	5.5	3.1	0.05	0.06	26.6	21.0	40.9	40.2
	3-6 cm	2330	2190	-	0.06	0.22	7.9	8.9	4.6	5.2	0.03	0.04	21.9	31.3	32.1	126
St.6	180°/ 500 m	448	385	1300	0.02	<0.02	8.0	7.2	1.9	0.9	0.02	-	12.6	11.9	9.0	9.5
	1-3 cm	1390	-	-	0.03	-	9.0	-	2.1	-	0.02	-	14.4	-	12.4	-
	3-6 cm	1090	-	-	0.05	-	9.8	-	2.5	-	0.02	-	10.3	-	13.5	-
St.7	180°/1000 m	193	169	269	<0.01	<0.02	7.1	7.2	1.3	0.6	-	<0.01	6.3	6.6	5.7	5.8
St.11	270°/ 500 m	285	269	668	0.01	<0.02	7.6	7.7	1.7	0.9	-	-	7.1	9.0	6.5	9.1
St.14	90°/ 500 m	310	244	301	0.01	<0.02	7.8	7.2	2.5	0.8	-	-	9.2	9.5	7.7	12.6

-: not analysed

**The macrobenthic fauna**

The diversity indices are clearly influenced by *M. oculata*, reflecting a relatively undisturbed fauna excluding this species, see Table 4.12.3.

**Table 4.12.3.** *Number of species (S) and individuals (N) per 0,5m<sup>2</sup>, depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES<sub>100</sub>) Tor, 2002. Incl. / ex. *M. oculata*, ex. juv.*

Station	°/ m	Depth (m)	N		S		H'		J'		ES <sub>100</sub>	
			Incl. M.o	Ex. M.o	Incl. M.o	Ex. M.o	Incl. M.o	Ex. M.o	Incl. M.o	Ex. M.o	Incl. M.o	Ex. M.o
TOR-3	360°/500	66	1222	492	65	64	2.7	4.4	0.5	0.7	20	32
TOR-5	180°/250	66	3889	889	74	73	1.8	4.7	0.3	0.8	15	32
TOR-6	180°/500	68	4209	709	83	82	1.5	4.9	0.2	0.8	13	36
TOR-7	180°/1000	67	2467	927	79	78	2.7	4.7	0.4	0.7	20	32
TOR-11	270°/500	67	822	478	68	67	3.8	4.8	0.6	0.8	28	37
TOR-14	90°/500	66	2769	769	83	82	2.2	5.0	0.4	0.8	18	35

The Tor stations form three subgroups, see Figure 4.12.1

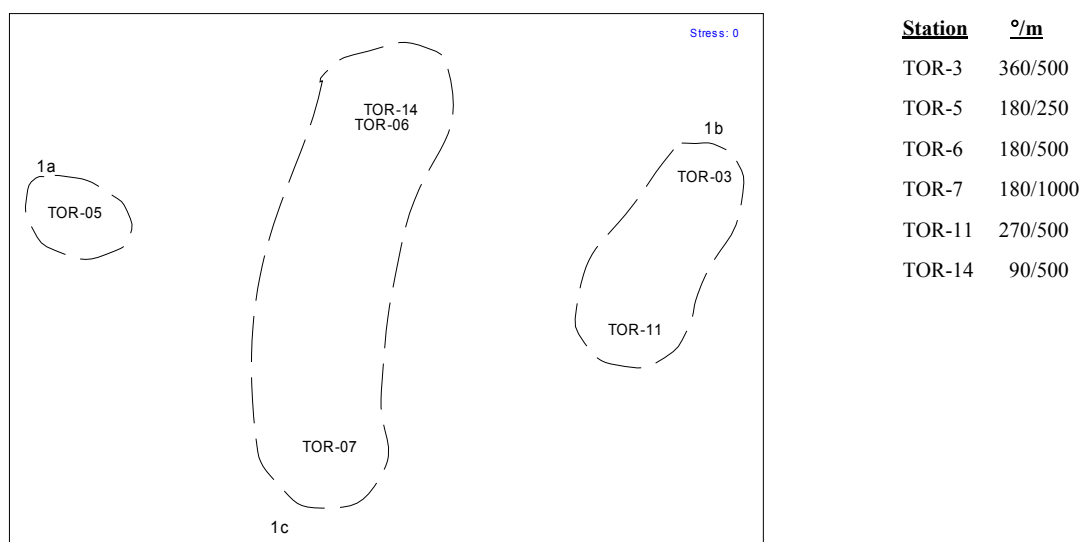
The results from the macrobenthic analyses show that:

- The deposit feeding bristle worm *Myriochele oculata* was, as earlier, found to dominate the benthic macrofauna. The high numbers and the distribution of this species in the area have not been found to correlate well with THC, decalins, organic matters or metals.
- The diversity indices (based on the results exclusive *M. oculata*) show a relatively undisturbed benthic fauna in the Tor area. The similarity analyses show that the fauna to some degree correlates with Ba, Cd, THC and grain size. Station Tor-5 (180°/250) having the highest concentrations of Ba, Cd and THC, was characterised as moderately disturbed in 1996. The 1999 survey concluded that the fauna at this station had improved since 1996. Since 1999 the levels of Ba, Cd and THC have

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declined and the diversity index has increased, thus confirming the positive trend. However, the fauna at Tor-5 still differs somewhat from the other stations and should be regarded as slightly disturbed.

- There seems to have been a gradual alteration in the fauna composition in the period from 1996 to 2002. The change is probably not related to the offshore activities, and should be considered as a part of a general change in the region.



**Figure 4.12.6.** MDS plot, Tor 2002.

### 4.13 Yme Gamma

The sediments at the ordinary stations at Yme Gamma consist of medium sand, and the sand content varies from 94.8 % at station 6, 120°/500m to 99.5 % at the reference station, station 18, 300°/10000m. The gravel content is low. The silt and clay content is mainly similar to the previous surveys. Samples are also taken from the Installation Centre and from stations at 100m distance. At the Centre 0°/0m the sediment consists of 75 % silt and clay. The sediments at the 100m stations consist of medium sand.

The total organic matter content in the sediments outside 100m distance is low. The content vary from 0.53 % at station 10, 210°/250m to 0.93 % at station 5, 120°/250m. The results are similar to the previous surveys. At the Installation Centre 0°/0m the total organic matter content is high, 6.6 %, and the same concentration are also found at station II, 120°/100m.

The mean THC concentrations vary from 1.8 mg/kg at the reference station, 300°/10000m to 86.5 mg/kg at station 5, 120°/250m. Elevated THC concentrations are found at the 250m stations in the 30° and 120° directions. The THC concentrations are decreased or similar to the 1999 survey. Station 1, 30°/250m was not analysed in 1999, however an increase is found since 1996.

At the Installation Centre 0°/0m the THC concentration is extremely high, 13100 mg/kg (1.3 %). Vertical sections to 10 cm depth are taken, and the THC concentrations decrease gradually downwards. High concentrations are also found at the 100m stations in all four directions, and the mean concentrations vary from 537 mg/kg in the 120° direction to 6500 mg/kg in the 300° direction. This high THC content results from extremely high concentrations in one of the grab



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samples. The sediments at the 100m stations also contain high concentrations of olefins. These are not quantified, but included in the THC values.

The mean olefin concentrations vary from not detected (<0.2 mg/kg) to 9.9 mg/kg at station 1, 30°/250m. The concentrations are decreased or similar to the 1999 survey, however an increase is found in the vertical layers at station 5, 120°/250m. Olefins are found out to 250m in the 210° and 300° directions and out to 500m in the 30° and 120° directions. At station 1, 30°/250m the olefins represent 25 % of the THC concentration. This station was not analysed for olefins in 1996, and the development at this innermost station can not be assessed. The olefins found agree with the constituents of the pseudo-oil based drilling fluid Ultidril, C14 and C16 olefins.

The ester based drilling fluid Petrofree is found at two of the three stations analysed, 4.3 mg/kg at station 5, 120°/250m and 0.4 mg/kg at station 6, 120°/500m. The concentrations are reduced since 1999. As in 1999, Finagreen is not detected. The results correspond with the discharge history and with the relatively easy decomposition of ester compounds.

Elevated levels of NPD, PAH and decalins are found at station 5, 120°/250m. The NPD and PAH concentrations are decreased since 1999, and the decalin concentrations are increased. Elevated decalin concentrations are also found at station 6, 120°/500m. At the installation Centre 0°/0m the concentrations are high, 16.4 mg/kg of NPD, 2.5 mg/kg of PAH and 201 mg/kg of decalins. High concentrations are also found at the 100m stations. The decalin concentrations agree with the THC content and represent 2 - 3 %.

The Ba concentrations vary from 6 mg/kg at the reference station, station 18 300°/10000m to 4350 mg/kg at station 5, 120°/250m. High Ba concentrations are also found at station 6, 120°/500m, an increase since 1999 from 994 mg/kg to 2100 mg/kg. At the other stations the Ba concentrations are similar to 1999. Elevated Ba concentrations are found at all stations, except for the reference station. This is out to 1000m in the 120° direction and out to 500m in the other directions.

The concentrations of the heavy metals are low. Elevated concentrations of Cu and Zn are found at some stations, however no increases since 1999 are found.

At the Installation Centre 0°/0m the Ba concentration is high, 6050 mg/kg. High concentrations are also found at the 100m stations in all four directions, ranging from 4080 mg/kg in the 300° direction to 7410 mg/kg in the 120° direction. Elevated levels of all the metals are found both at 0°/0m and at the 100m stations.

Generally the results agree with the drilling history at Yme Gamma. Drilling with waterbased and synthetic drilling fluids has taken place since the last survey. Discharge of oil in water is also reported, 5 tonnes in 2000 and 3.5 tonnes in 2001.

**Table 4.13.1.** *Yme Gamma, silt & clay and TOM (%), THC, olefins, esters, PCB, NPD, PAH and decalins (mg/kg dry sediment)*

Station	Silt & clay		TOM		THC		Olefins		Ester		NPD		PAH		Decalins	
	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.1 30°/ 250m	3.0	-	0.65	-	38.7	-	9.9	-	-	-	-	-	-	-	-	-
St.2 30°/ 500m	2.1	1.9	0.68	0.58	3.6	3.7	0.2	0.3	-	-	-	-	-	-	-	-
St.5 120°/ 250m	4.5	5.6	0.93	0.86	86.5	173	4.8	34.5	4.3	16.4	0.398	1.770	0.124	0.292	2.72	1.870
1-3 cm			-	-	96.6	72.7	15.9	1.6	2.5	12.8	0.241	0.410	0.062	0.120	2.85	0.983
3-6 cm			-	-	68.9	25.8	3.9	<0.1	3.6	4.5	0.224	0.191	0.078	0.068	2.38	0.298
St.6 120°/ 500m	5.2	2.9	0.70	0.64	6.5	18.1	0.7	2.3	0.4	0.9	0.027	-	0.046	-	0.104	-

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<b>Table 4.13.1 cont.</b>		Silt & clay		TOM		THC		Olefins		Ester		NPD		PAH		Decalins	
Station		2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
	1-3 cm			-	-	3.76	-	0.4	-	0.6	-	0.022	-	0.051	-	0.105	-
	3-6 cm			-	-	5.00	-	0.3	-	0.5	-	0.029	-	0.046	-	0.102	-
St.7	120°/1000m	2.5	2.5	0.70	0.62	2.5	3.3	<0.2	<0.2	<0.2	<0.3	-	-	-	-	-	-
St.10	210°/ 250m	2.0	-	0.53	-	4.1	-	0.3	-	-	-	-	-	-	-	-	-
St.11	210°/ 500m	1.7	2.7	0.58	0.46	1.9	3.3	<0.2	0.7	-	-	-	-	-	-	-	-
St.14	300°/ 250m	1.6	-	0.61	-	6.7	-	0.3	-	-	-	-	-	-	-	-	-
St.15	300°/ 500m	2.1	3.4	0.59	0.57	3.0	14.6	<0.2	9.2	-	-	-	-	-	-	-	-
Inst. Centre	0°/0m	75.4	-	6.58	-	13100	-	-	-	-	-	16.4	-	2.51	-	201	-
	1-3 cm			-	-	6180	-	-	-	-	-	12.8	-	1.38	-	163	-
	3-6 cm			-	-	1100	-	-	-	-	-	4.97	-	0.994	-	37.9	-
	6-10 cm			-	-	635	-	-	-	-	-	3.45	-	0.719	-	13.8	-
I	30°/ 100m	11.1	-	1.28	-	567	-	-	-	-	-	1.04	-	0.421	-	16.5	-
II	120°/ 100m	16.2	-	6.58	-	537	-	-	-	-	-	1.83	-	0.469	-	15.1	-
III	210°/ 100m	9.3	-	1.39	-	1257	-	-	-	-	-	1.67	-	0.315	-	32.1	-
IV	300°/ 100m	10.2	-	2.82	-	6500	-	-	-	-	-	7.09	-	1.04	-	128	-
St.18 Ref.	300°/10000m	0.5	2.8	0.63	0.59	1.8	1.9	<0.2	<0.1	<0.2	<0.3	0.006	0.005	0.011	0.015	nd	nd
	1-3 cm			-	-	1.34	1.8	<0.2	<0.1	<0.2	<0.3	0.006	0.004	0.011	0.015	nd	nd
	3-6 cm			-	-	1.36	2.5	<0.2	<0.1	<0.2	<0.3	0.006	0.007	0.010	0.025	nd	nd

-: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

**Table 4.13.2.** Yme Gamma, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station		Ba			Cd		Cr		Cu		Hg		Pb		Zn	
		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St.1	30°/ 250m	1240	-	2420	0.01	-	5.4	-	4.2	-	-	-	8.0	-	14.4	-
St.2	30°/ 500m	326	214	98	<0.01	<0.02	5.0	4.6	1.7	1.0	-	-	6.4	6.4	7.3	6.4
St.5	120°/ 250m	4350	4520	1110	0.03	0.03	7.9	6.9	5.2	7.2	0.01	0.02	10.4	11.9	18.8	19.7
	1-3 cm	5206	4760	-	0.02	0.05	9.5	7.4	4.5	6.6	0.01	0.02	9.9	11.8	17.6	27.6
	3-6 cm	3170	4690	-	0.02	0.02	6.9	7.5	3.9	3.6	0.01	0.02	8.3	9.0	19.0	10.1
St.6	120°/ 500m	2100	994	426	<0.01	<0.02	6.6	5.9	2.7	2.1	0.02	-	6.8	6.7	10.2	10.1
	1-3 cm	2380	-	-	<0.01	-	6.0	-	1.8	-	0.03	-	6.9	-	7.5	-
	3-6 cm	2480	-	-	0.01	-	7.1	-	2.0	-	0.01	-	7.8	-	10.2	-
St.7	120°/1000m	203	149	88	<0.01	<0.02	6.3	5.8	1.1	0.7	-	-	5.8	6.1	6.7	6.3
St.10	210°/ 250m	387	-	662	0.01	-	5.6	-	4.5	-	-	-	7.2	-	17.2	-
St.11	210°/ 500m	45	63	90	<0.01	<0.02	6.1	4.7	0.8	0.5	-	-	5.6	5.0	5.9	4.9
St.14	300°/ 250m	771	-	464	<0.01	-	6.0	-	3.1	-	-	-	7.2	-	11.2	-
St.15	300°/ 500m	108	202	84	<0.01	<0.02	5.5	5.2	0.9	0.5	-	-	5.7	5.9	5.7	5.4
Installation Centre	0°/0m	6050	-	-	0.49	-	38.8	-	75.6	-	0.16	-	94.7	-	136	-
	1-3 cm	497	-	-	0.46	-	40.9	-	58.6	-	0.15	-	62.5	-	115	-
	3-6 cm	474	-	-	0.17	-	38.3	-	38.6	-	0.04	-	31.2	-	77	-
	6-10 cm	8180	-	-	0.10	-	18.1	-	14.2	-	0.04	-	14.4	-	36	-
I	30°/ 100m	5700	-	-	0.09	-	8.9	-	13.4	-	-	-	14.3	-	38	-
II	120°/ 100m	7410	-	-	0.14	-	17.7	-	39.7	-	-	-	43.5	-	85	-
III	210°/ 100m	5790	-	-	0.09	-	11.2	-	26.5	-	-	-	13.4	-	35	-
IV	300°/ 100m	4080	-	-	0.13	-	15.8	-	18.0	-	-	-	22.8	-	52	-
St.18 Ref.	300°/10000m	6	6	6	<0.01	<0.2	6.9	9.8	0.8	0.3	<0.01	0.05	7.5	9.9	5.4	7.4
	1-3 cm	6	9	-	<0.01	<0.02	6.9	9.7	0.8	0.4	<0.01	0.03	7.2	10.1	5.1	7.6
	3-6 cm	9	14	-	0.01	<0.02	6.8	9.2	1.4	0.7	0.01	0.03	7.7	9.2	5.7	7.8

-: not analysed

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***The macrobenthic fauna***

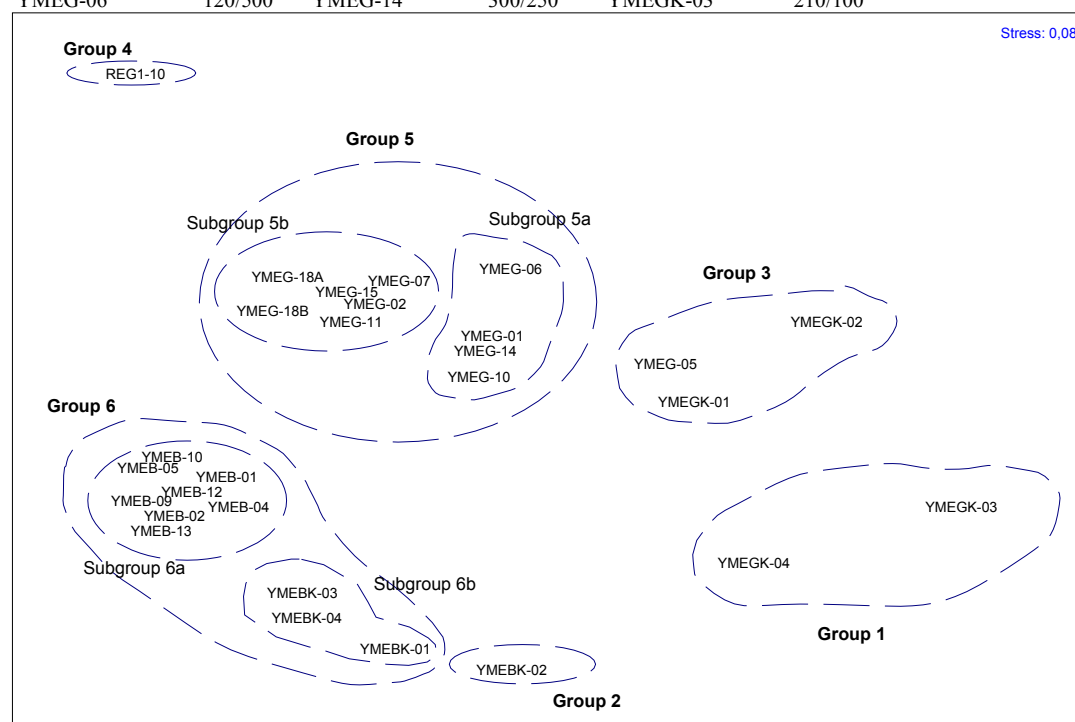
The fauna composition and diversity indices reflect a disturbance at the YGK-stations.

**Table 4.13.1.** Number 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*<sub>100</sub>) for each station at Yme Gamma 2002.

Station	%m	Depth (m)	S		N		H'		J'		ES <sub>100</sub>	
			Incl. juv.	Ex. juv.	Incl. juv.	Ex. juv.	Incl. juv.	Ex. juv.	Incl. juv.	Ex. juv.	Incl. juv.	Ex. juv.
YMEG-01	30/250	91-92	104	99	734	667	5.3	5.1	0.8	0.8	39	38
YMEG-02	30/500	92	104	99	542	490	5.5	5.5	0.8	0.8	45	44
YMEG-05	120/250	94	68	64	687	657	3.9	3.8	0.6	0.8	26	25
YMEG-06	120/500	94	83	78	409	374	5.3	5.2	0.8	0.8	42	40
YMEG-07	120/1000	94	100	94	648	549	5.5	5.4	0.8	0.8	43	43
YMEG-10	210/250	90	92	88	599	545	5.1	4.9	0.8	0.8	38	37
YMEG-11	210/500	90	104	99	711	594	5.6	5.6	0.8	0.8	44	45
YMEG-14	300/250	94	88	84	529	470	5.0	4.8	0.8	0.8	37	37
YMEG-15	300/500	90	106	101	682	606	5.6	5.5	0.8	0.8	44	43
YMEGK-01	30/100	90-92	59	55	565	539	3.9	3.7	0.7	0.6	27	25
YMEGK-02	120/100	92	54	51	1057	1036	3.2	3.1	0.6	0.5	18	17
YMEGK-03	210/100	91	46	43	1274	1256	1.8	1.7	0.3	0.3	13	12
YMEGK-04	300/100	93	64	59	808	757	3.3	3.1	0.6	0.5	23	21
YMEG-18A	300/10000	90	103	100	577	516	5.6	5.6	0.8	0.8	45	45
YMEG-18B	300/10000	90	95	91	574	495	5.6	5.5	0.8	0.9	44	45

The classification of Yme Gamma stations is performed together with the Yme Beta stations and regional station 10, see Figure 4.13.1.

Station	%m	Station	%m	Station	%m	Station	%m
YMEG-01	30/250	YMEG-07	120/1000	YMEG-15	300/500	YMEGK-04	300/100
YMEG-02	30/500	YMEG-10	210/250	YMEGK-01	30/100	YMEG-18A	300/10000
YMEG-05	120/250	YMEG-11	210/500	YMEGK-02	120/100	YMEG-18B	300/10000
YMEG-06	120/500	YMEG-14	300/250	YMEGK-03	210/100		



**Figure 4.13.7.** MDS plot, Yme Beta, Yme Gamma and Regional station 10, Ekofisk 2002.

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The results from the macrobenthic analyses show that:

- The bristle worm *Myriochele oculata* which dominates the fauna in the central part of the Ekofisk region is not dominating the fauna at the Yme field. Yme is situated in the north east corner of the region. The water depth is somewhat deeper and the sediment is coarser (medium sand) than in the central parts of the region.
- The fauna at Yme Gamma is in general very diverse and the fauna composition reflects an undisturbed benthic community with the exception of all the YGK stations (1-4), situated 100m from the field centre and also at YMEG-5 (120/250). Station YGK-3 is clearly influenced of the activity in the area and the fauna composition at YGK-4 also shows an obvious disturbance, but are somewhat less influenced. Stations YGK-1 and 2 and also YMEG-5 is characterised as slightly influenced.
- There is a good correlation between the combination of Ba, Cu, Cr, THC, TOM and grain size parameters (MD and % pelite) and the fauna. The single environmental parameter that correlates best with the variations in the fauna is THC.
- There are only minor changes in the macrofauna compared to 1999.

#### 4.14 Yme Beta

The sediments at the ordinary stations at Yme Beta consist of medium sand, and the sand content varies from 97.4 % at station 2, 60°/500m to 99.1 % at station 13, 330°/500m. The gravel content is low. The silt and clay content is similar to the previous surveys. Samples are also taken from the Installation Centre and from stations at 100m distance. At the centre 0°/0m the sediments consist of 78 % sand. At the 100m stations the sand content is similar to the ordinary Yme Beta stations, and the sand content varies from 95.4 % at station III, 240°/100m to 99.3 % at station IV, 330°/100m. At 0°/0m the gravel content is 2.4 %.

The total organic matter content in the sediments is very low, and only small variations are found at the ordinary stations, from 0.41 % at station 13, 330°/500m to 0.53 % at station 4, 150°/250m. The results are similar to the previous surveys. At the Installation Centre 0°/0m the TOM content is higher, 1.6 %. At the 100m stations the concentrations vary from 0.40 % to 1.02 %. The total organic matter content is considerably lower than at Yme Gamma.

The mean THC concentrations vary from 0.1 mg/kg at station 13, 330°/500m to 4.1 mg/kg at station 4, 150°/250m. Elevated levels are not found. C14-C16 olefins are only found at station 4, 150°/250m (0.3 mg/kg) and in one grab sample at station 5, 150°/500m (4.7 mg/kg).

At the Installation Centre 0°/0m the THC concentration is high, 5000 mg/kg. Elevated THC levels are also found in the vertical sections to 15 cm depth. Elevated concentrations and a patchy distribution are also found at the 100m stations. The mean THC concentrations vary from 1.2 mg/kg at station IV, 330°/100m to 68.5 mg/kg at station III, 240°/100m. The sediments also contain high concentrations of olefins, however these are not quantified.

Elevated levels of NPD, PAH and decalins are not found at the ordinary stations. At the installation Centre 0°/0m the NPD and decalin concentrations are high, 2.44 mg/kg of NPD and 52.1 mg/kg of decalins. High concentrations of decalins are also found at station III, 240°/100m. The same patchy distribution as for THC is observed. Elevated levels are also found in the vertical sections to 15 cm depth, the same concentrations as in the top 0-1 cm layer.

One sample at Yme Beta is analysed for Polychlorinated biphenyls (PCB), the Installation Centre 0°/0m, 6-15 cm depth. PCB is not found

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The Ba concentrations vary from 7 mg/kg at station 10, 240°/500m to 404 mg/kg at station 4, 150°/250m. Elevated Ba concentrations are found out to 500m in the 60° and 150° directions and are limited to the 250m stations in the 240° and 330° directions. At station 4, 150°/250m the Ba concentrations are increased since 1999, from 103 mg/kg to 404 mg/kg. Compared to the Yme Gamma field the Ba levels at Yme Beta are low.

The concentrations of the heavy metals are low, and elevated concentrations are not found.

At the Installation Centre 0°/0m the Ba concentration is high, 6060 mg/kg. High Ba concentrations are also found in the vertical section to 15 cm depth. Elevated concentrations are found at the 100m stations, ranging from 209 mg/kg in the 330° direction to 2540 mg/kg in the 240° direction. A patchy distribution is observed. Elevated levels of the metals are found both at 0°/0m, 0-1 cm and at the deepest layer at 6-15 cm. In addition slightly elevated concentrations of Cu and Zn are found at one of the 100m stations.

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

**Table 4.14.1.** *Yme Beta, silt & clay and TOM (%), THC, olefins, NPD, PAH and decalins (mg/kg dry sediment)*

Station	Silt and clay		TOM		THC		Olefins		NPD		PAH		Decalins	
	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St. 1 0°/ 250 m	1.2	-	0.44	-	0.9	-	< 0.2	-	-	-	-	-	-	-
St. 2 60°/ 500 m	2.6	2.3	0.47	0.41	0.9	1.1	< 0.2	-	-	-	-	-	-	-
St. 4 150°/ 250 m	1.9	2.9	0.53	0.42	4.1	1.6	0.3	0.020	0.003	0.009	0.006	0.103	nd	-
1-3cm			-	-	2.5	1.1	0.3	0.010	0.004	0.005	0.004	nd	nd	-
3-6cm			-	-	2.5	1.5	< 0.2	0.013	0.005	0.005	0.006	nd	nd	-
St. 5 150°/ 500 m	1.5	3.7	0.48	0.40	3.5	1.1	4.7	0.006	-	0.005	-	0.180	-	-
1-3cm			-	-	0.6	-	< 0.2	0.001	-	0.002	-	nd	-	-
3-6cm			-	-	0.9	-	< 0.2	0.003	-	0.005	-	nd	-	-
St. 9 240°/ 250 m	2.4	-	0.40	-	0.4	-	< 0.2	-	-	-	-	-	-	-
St. 10 240°/ 500 m	1.8	1.6	0.42	0.38	0.4	0.8	< 0.2	-	-	-	-	-	-	-
St. 12 330°/ 250 m	1.5	-	0.42	-	0.3	-	< 0.2	-	-	-	-	-	-	-
St. 13 330°/ 500 m	0.9	2.5	0.41	0.41	0.1	0.5	< 0.2	-	-	-	-	-	-	-
Install. Centre 0°/0m	19.2	-	1.56	-	5000	-	-	2.440	-	0.359	-	52.10	-	-
1-3cm			-	-	406	-	-	0.204	-	0.031	-	5.40	-	-
3-6cm			-	-	756	-	-	0.332	-	0.041	-	7.89	-	-
6-8cm			-	-	400	-	-	0.184	-	0.032	-	5.19	-	-
6-15cm			-	-	1440	-	-	3.680	-	0.582	-	13.40	-	-
I 60°/ 100 m	1.1	-	0.53	-	15.1	-	-	-	-	-	-	-	-	-
II 150°/ 100 m	1.4	-	0.54	-	30.5	-	-	-	-	-	-	-	-	-
III 240°/ 100 m	4.6	-	1.02	-	68.5	-	-	0.178	-	0.058	-	2.37	-	-
IV 330°/ 100 m	0.7	-	0.40	-	1.2	-	-	-	-	-	-	-	-	-

: not analysed      nd: not detected, limit of detection for decalins is 50 µg/kg

**Table 4.14.2.** *Yme Beta, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station	Ba			Cd		Cr		Cu		Hg		Pb		Zn	
	2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
St. 1 0°/ 250 m	93	-	1840	<0.01	-	6.5	-	0.5	-	-	-	5.6	-	4.9	-
St. 2 60°/ 500 m	28	18	-	<0.01	<0.02	8.0	8.2	0.5	<0.3	-	-	6.3	7.3	4.9	4.9
St. 4 150°/ 250 m	404	103	87	<0.01	<0.02	8.0	8.6	0.8	<0.3	0.01	<0.01	6.5	7.1	5.1	4.5
1-3cm	183	81	-	<0.01	<0.02	8.1	8.5	0.4	<0.3	0.01	<0.01	6.0	6.9	5.2	4.0

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<b>Table 4.14.2. cont.</b>		Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
Station		2002	1999	1996	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999	2002	1999
	3-6cm	359	94	-	0.02	<0.02	8.0	8.6	0.5	<0.3	0.01	<0.01	6.3	6.9	6.4	4.2
St. 5	150°/ 500 m	57	20	64	0.01	<0.02	8.3	9.0	0.5	<0.3	<0.01	-	6.3	7.8	6.8	5.3
	1-3cm	49	-	-	0.01	-	8.3	-	0.4	-	0.01	-	7.0	-	7.6	-
	3-6cm	58	-	-	<0.01	-	8.5	-	0.3	-	0.01	-	6.4	-	4.1	-
St. 9	240°/ 250 m	20	-	1320	0.01	-	7.5	-	0.4	-	-	-	5.6	-	4.0	-
St. 10	240°/ 500 m	7	14	-	<0.01	<0.02	7.7	8.3	0.4	<0.3	-	-	5.8	7.1	4.1	19.1
St. 12	330°/ 250 m	29	-	691	<0.01	-	6.9	-	0.4	-	-	-	5.7	-	6.8	-
St. 13	330°/ 500 m	8	7	-	<0.01	<0.02	6.8	7.5	0.5	<0.3	-	-	5.7	6.4	9.5	3.9
Install.	Centre 0°/0m	6060	-	-	0.10	-	10.5	-	8.0	-	0.03	-	9.8	-	27	-
	1-3cm	3050	-	-	0.02	-	4.4	-	3.0	-	0.01	-	2.7	-	4.7	-
	3-6cm	3280	-	-	0.02	-	3.4	-	1.6	-	0.01	-	6.7	-	3.3	-
	6-8cm	8010	-	-	0.02	-	6.1	-	4.8	-	0.03	-	6.4	-	6	-
	6-15cm	4230	-	-	0.20	-	29.0	-	30.5	-	1.13	-	33.8	-	71	-
I	60°/ 100 m	631	-	-	<0,01	-	7,3	-	0,8	-	-	-	5,2	-	5,4	-
II	150°/ 100 m	951	-	-	<0,01	-	8,0	-	1,0	-	-	-	6,1	-	6,3	-
III	240°/ 100 m	2540	-	-	<0,1	-	11,5	-	5,1	-	-	-	9,6	-	14	-
IV	330°/ 100 m	209	-	-	<0,01	-	7,1	-	0,5	-	-	-	5,4	-	4,0	-

-: not analysed

***The macrobenthic fauna***

The over all picture shows an undisturbed benthic fauna in the area. However, the fauna at station YBK-1 and 2 reflects a slight disturbance.

**Table 4.14.3.** Number 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<sub>100</sub>) for each station at Yme Beta, 2002.

Station	°/m	Depth (m)	N		S		H'		J		ES <sub>100</sub>	
			Inc. juv.	Ex. Juv.	Inc. juv.	Ex. Juv.	Inc. juv.	Ex. Juv.	Inc. juv.	Ex. Juv.	Inc. juv.	Ex. Juv.
YB-1	60/250	80	606	557	89	86	5.3	5.2	0.8	0.8	40	39
YB-2	60/500	79	604	574	97	92	5.4	5.2	0.8	0.8	42	40
YB-4	150/250	78	717	631	94	90	5.3	5.3	0.8	0.8	39	40
YB-5	150/500	78	531	451	80	78	5.3	5.3	0.8	0.9	40	41
YB-9	240/250	77	569	425	78	73	5.1	5.2	0.8	0.8	37	39
YB-10	240/500	77	730	510	85	80	4.9	5.2	0.8	0.8	36	39
YB-12	330/250	76	613	479	79	74	5.2	5.2	0.8	0.8	39	40
YB-13	330/500	78	702	555	88	83	5.4	5.5	0.8	0.9	42	43
YBK-1	60/100	78	675	610	66	62	4.2	4.1	0.7	0.7	25	24
YBK-2	150/100	77	479	435	56	53	4.2	4.1	0.7	0.7	25	25
YBK-3	240/100	79	684	641	74	71	4.9	4.8	0.8	0.8	33	32
YBK-4	330/100	77	558	458	83	78	4.9	4.8	0.8	0.8	34	35

The Yme Beta MDS plot is shown together with Yme Gamma and regional station 10, see chapter 4.13.

The results from the macrobenthic analyses show that:

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- The bristle worm *Myriochele oculata* which dominates the fauna in the central part of the Ekofisk region is not dominating the fauna at the Yme field. Yme is situated in the north east corner of the region. The water depth is somewhat deeper and the sediment is coarser (medium sand) than in the central parts of the region.
- The fauna at Yme Beta is in general very diverse and the fauna composition reflects an undisturbed benthic community. However, this year's survey included stations located 100m from the former installation centre. The fauna composition at stations YBK-1 and 2, located 100m from the field center in the 60° and 150° direction, indicates a slightly influenced fauna. This is supported by the results from the similarity analyses, showing that the fauna at YBK-2 and 1, and to a certain degree YBK-3 and 4, differ from the rest of the field stations.
- There is a good correlation between the combination of Ba, Cu, Cr, THC, TOM and grain size parameters (MD and % pelite) and the fauna. The YGK stations have the most disturbed fauna and the highest concentrations of Ba, Cr, Cu, TOM and THC in the sediments. The single environmental parameter that correlates best with the variations in the fauna is THC.
- There are only minor changes in the macrofauna compared to 1999.

## 5 RECOMMENDATIONS

### Recommendation from 1999 considered

- Field stations closer to the installations are sampled in the present survey, to better identify the transition zones between contaminated and uncontaminated areas.
- At Tor the sediments contained compounds from synthetic base fluids that could be olefins or ethers. In the present survey the main compounds are identified as ethers from the base oil Aquamul B.

### Limit of Contamination

According to new guidelines a confidence level of 95 % shall be used in the LSC calculations. This will give lower LSC values than in the previous survey in 1999 when a confidence level of 99 % was used.

In the present survey the difference between 95 % and 99 % confidence level for the LSC calculation is modest. However, as the Regional stations are not contaminated, they will show very similar concentrations of the parameter in question and thus low standard deviations. This again will give low LSC values, too low values to include all the natural variations in the sediments when a 95 % confidence level is used. An example: At Regional station 3 THC concentrations > LSC are found in two of the five replicates analysed. No sign of elevated THC concentrations are seen in the gas chromatograms of these samples.

We therefore recommend a confidence level of 99 % in the LSC calculations.

### Sampling stations

The results from the PCA of the results from the chemical analyses suggest that regional stations 2 and 9 could be excluded from the sampling programme. The two stations differed from the other two groups and were omitted in the calculations of the LSC. However, from a biological

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point of view there is no particular reason to exclude the two stations. Regional 2 is relatively similar to the other regional stations in the area, representing an unaffected area east of the Tambar/Gyda area. The fauna at Regional 9, located much closer to Ula than Yme, has a lot in common with the fauna in the Yme area and therefore represents the “outer boundary” of the Ula/Tambar/Gyda fauna. Any future expansion of the Ula/Tambar/Gyda fauna should be reflected in changes in the fauna community at Regional 9.

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