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# TECHNICAL REPORT

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## BP AMOCO

### ENVIRONMENTAL MONITORING - REGION I, 1999 SUMMARY REPORT

REPORT No. 2000-3241

REVISION No. 01

DET NORSKE VERITAS

## TECHNICAL REPORT

Date of first issue: 19 May 2000	Project No.: 5900060
Approved by:  Christian L. S. Rafn Head of Section	Organisational unit: Environmental Advisory Services
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**Summary:**

The report presents the results from the Environmental Survey in Region I, Ekofisk 1999.

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

A total of 144 stations were sampled for chemical and biological analyses.

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

Report No.: 2000-3241	Subject Group: Marine monitoring	
Report title: Environmental monitoring - Region I, 1999		
Work carried out by: Tor Jensen, Nina Gjør, Sam-Arne Nøland, Frøydis Oreld, Thomas Møskeland, Frøydis Oreld, Siri M. Bakke, Liv Guri Faksness		
Work verified by: Egil Dragsund		
Date of this revision: 19.05.2000	Rev. No.: 01	Number of pages: 65

**Indexing terms**

Sediments  
Macrofauna  
Hydrocarbons  
Environmental Survey

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**PREFACE**

The 1999 environmental survey at Region I has been carried out jointly by Det Norske Veritas and SINTEF Applied Chemistry, on behalf of BP-Amoco, Phillips and Statoil.

Representation from the oil companies have been:

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Phillips: Eimund Garpestad  
Statoil: Arne Myhrvold/Karin Stokke

**Personnel**

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Work up of sediments

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Grain size distribution:

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Bente Vigerust

**Biological analyses:**

Siri Mordal Bakke (analyses and biology)  
Inger Dagny Saanum (Lindesnes Biolab) – polychaetes  
Peter Gibson (hired) – polychaetes  
Tormod Hansen – polychaetes  
Sam-Arne Nøland – echinodermata  
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Tor Jensen, Sam-Arne Nøland, Thomas Møskeland and  
Siri M. Bakke

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The grain size distribution was analysed at SINTEF Applied Chemistry, dep. Environmental Engineering.

The main part of the chemical analyses is performed at SINTEF Applied Chemistry, dep. Environmental Technology and Analysis. The hydrocarbon analyses at Ula, Gyda and Embla are performed at SINTEF Applied Chemistry, dep. Environmental Engineering.

 <p>NORSK AKKREDITERING NR: P032</p>	<p>The two laboratories - SINTEF Applied chemistry, departments of Environmental Technology &amp; Analyses and Environmental Engineering - are both accredited by Norsk Akkreditering to perform chemical analyses, accreditation numbers P032 and P091. The accreditation is according to NS-EN 45 001 and ISO/IEC Guide 25.</p> <p>The accreditation includes methods for determination of total hydrocarbon content (THC), polycyclic aromatic hydrocarbons (PAH), selected hydrocarbons (NPD) and metals in sediments. The sediment grain size distribution is also included</p>
 <p>NORSK AKKREDITERING NR: P083</p>	<p>Biology laboratory (DNV, dep. for Environmental Services) 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 according to ND-ES 45001 and ISO/IEC Guide 25</p>

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## 1 CONCLUSIVE SUMMARY

This report presents results from the environmental survey in the EKOFISK region (Region I) in 1999. Det Norske Veritas and SINTEF Applied Chemistry, on behalf of BP-Amoco, Phillips and Statoil, carried out the survey jointly.

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

The fieldwork was carried out from 2. June to 10. June from the vessel "*Far Spirit*". Ten of the stations were regional stations. The fieldwork was performed without any problems. The following chemical analyses were carried out: total hydrocarbon content (THC), NPD, decalins, 3-6 ring aromatics, metals, and at some stations olefins.

The sediment was also analysed for TOM (total organic matter), grain size distribution and macrofauna composition.

The results from the 1999 survey in Region I show:

- The sediments at Region I consist mainly of fine sand with maximum pelite (silt and clay) content of 4,9 %.
- The total organic matter content in the sediments is low and varies from 0,4 % to 1,7 %.
- The chemical results are in agreement with the drilling history with some exceptions.
- 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 or decreased compared to 1996. This illustrates the low degradation rates for hydrocarbons. The sediments in Region I is still contaminated by hydrocarbons out to 2000m distance from the installations in the Ekofisk area and in the Valhall/Hod area.
- The presence of decalins indicates drilling mud base oil in the sediments.
- Base liquids from pseudo-oil based drilling mud (olefins) are found at all stations at the fields drilled with these systems, except for Valhall.
- Base liquids from ester based drilling mud (Petrofree and Finagreen) were analysed at the Yme fields. A decrease is observed since 1996, and the results agree with the fact that ester compounds are more easily degraded than hydrocarbons.
- Dispersion of drill cuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found at most of the stations and out to 2000m distance at 9 of the 12 fields. Except for the Yme fields, a general decrease in the Ba concentrations since 1996 is observed.
- The concentrations of the heavy metals are low, and elevated levels are only found at some stations.
- Contamination of Cd and Hg are not found.

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- In addition to the ordinary fields in Region I, sediments from old piles of drill cuttings at Ekofisk 2/4 A were analysed. Elevated levels of hydrocarbons, Ba, Pb and Zn are found at all stations. "Olefin peaks" are seen in all the gas chromatograms.

The main parameters and the variation at each field:

Regional stations	Variation	Main characteristics
THC (mg/kg)	1,4 - 5,5	The concentrations of hydrocarbons, barium and metals are low, and no elevated levels are found.
Ba (mg/kg)	5,0 - 67	
Species	53 - 92	The fauna at all regional stations are characterized as undisturbed. The polychaete <i>Myriochele oculata</i> dominated the fauna, especially in the Ula/Gyda area.
Individuals	386 - 1510	
Individuals (excl <i>M. oculata</i> )	371 - 665	
Diversity	2,5 - 5,7	
Diversity (excl. <i>M. oculata</i> )	4,4 - 5,6	

Ula	Variation	Main characteristics
THC (mg/kg)	3,3 - 5,0	No discharges since 1996. Elevated THC levels within 1000m distance, and elevated Ba levels out to 2000m.
Ba (mg/kg)	33 - 612	
Species	65 - 96	Decreased concentrations since 1996. The fauna was dominated by <i>M. oculata</i> , and the investigated stations were characterised as undisturbed.
Individuals	662 - 1241	
Individuals (excl <i>M. oculata</i> )	513 - 832	
Diversity	3,1 - 5,0	
Diversity (excl. <i>M. oculata</i> )	4,4 - 5,2	

Gyda	Variation	Main characteristics
THC (mg/kg)	3,4 - 9,2	Elevated THC levels within 1000m, and elevated Ba levels out to 2000m. The concentrations are decreased or similar to 1996, in accordance with reduced drilling activity.
Ba (mg/kg)	29 - 379	
Species	61 - 87	The fauna was dominated by <i>M. oculata</i> , and three of the investigated stations (out to 2000m) were characterised as disturbed.
Individuals	1037 - 4160	
Individuals (excl <i>M. oculata</i> )	359 - 1387	
Diversity	1,7 - 3,1	
Diversity (excl. <i>M. oculata</i> )	3,2 - 5,0	

Valhall	Variation	Main characteristics
THC (mg/kg)	5,1 - 65	Elevated THC levels out to 2000m, and elevated Ba levels out to 6000m. Olefins are not found, although discharges are reported; this indicates degradation of Novaplus.
Ba (mg/kg)	47 - 2160	
Species	48 - 80	The fauna was dominated by <i>M. oculata</i> , and none of the investigated stations were characterised as disturbed
Individuals	572 - 1684	
Individuals (excl <i>M. oculata</i> )	361 - 663	
Diversity	2,9 - 4,7	
Diversity (excl. <i>M. oculata</i> )	4,4 - 5,1	

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Hod	Variation	Main characteristics
THC (mg/kg)	3,9 - 135	Elevated THC levels out to 2000m, and elevated Ba levels out to 4000m. Olefins are found at all stations, they probably originate from discharges of Novasol in 1994.
Ba (mg/kg)	31 - 1600	
Species	55 - 83	The fauna was dominated by <i>M. oculata</i> , but is regarded as undisturbed.
Individuals	388 - 1438	
Individuals (excl <i>M. oculata</i> )	308 - 677	
Diversity	2,9 - 5,1	
Diversity (excl. <i>M. oculata</i> )	4,5 - 5,3	

Ekofisk Centre and 2/4 B&K	Variation	Main characteristics
THC (mg/kg)	5,5 - 51,6	Elevated THC levels similar to 1996 out to 4400m. Elevated Ba levels out to 5800m, decreased concentrations since 1996. Olefins found at all stations, in accordance with reported discharges.
Ba (mg/kg)	41 - 1920	
Species	66 - 78	The fauna was dominated by <i>M. oculata</i> . Some indications of disturbance at two of the investigated stations.
Individuals	548 - 1507	
Individuals (excl <i>M. oculata</i> )	412 - 765	
Diversity	2,6 - 4,8	
Diversity (excl. <i>M. oculata</i> )	4,7 - 5,2	

Ekofisk 2/4 A	Variation	Main characteristics
THC (mg/kg)	8,6 - 384	Heaps of drillcuttings at the seabed. Elevated levels of hydrocarbons, Ba, Pb and Zn at all stations. "Olefin peaks" in all the chromatograms.
Ba (mg/kg)	567 - 5680	
Species	60 - 84	Many stations dominated by <i>M. oculata</i> . Two stations (100m and 250m) characterised as disturbed.
Individuals	969 - 1946	
Individuals (excl <i>M. oculata</i> )	502 - 922	
Diversity	2,2 - 4,3	
Diversity (excl. <i>M. oculata</i> )	3,3 - 5,2	

Eldfisk 2/7 A/FTP	Variation	Main characteristics
THC (mg/kg)	8,9 - 16,3	Elevated THC levels similar to 1996 out to 2000m. Elevated Ba levels out to 2000m, decreased concentrations since 1996. Olefins found at all stations, in accordance with reported discharges.
Ba (mg/kg)	189 - 1130	
Species	62 - 74	Uniform benthic fauna, undisturbed or slightly disturbed.
Individuals	475 - 743	
Individuals (excl <i>M. oculata</i> )	420 - 632	
Diversity	4,4 - 5,1	
Diversity (excl. <i>M. oculata</i> )	4,8 - 5,0	

Eldfisk 2/7 B	Variation	Main characteristics
THC (mg/kg)	6,7 - 22,0	Elevated THC levels similar to 1996 out to 2000m. Elevated Ba levels similar to 1996 out to 2000m. Olefins found at all stations, in accordance with reported discharges.
Ba (mg/kg)	221 - 1740	
Species	65 - 85	Uniform benthic fauna, regarded as undisturbed. High abundance of <i>M. oculata</i> .
Individuals	721 - 1311	
Individuals (excl <i>M. oculata</i> )	433 - 1104	
Diversity	3,9 - 5,1	
Diversity (excl. <i>M. oculata</i> )	4,8 - 5,3	

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<b>Embla</b>	<b>Variation</b>	<b>Main characteristics</b>
THC (mg/kg)	6,6 - 10,9	Lowest THC concentrations (similar to 1996) at Ekofisk area, and elevated levels at 500m. Elevated Ba levels out to 2000m, decreased concentrations since 1996. No discharges since 1996.  The fauna relatively unchanged since 1996. High densities of <i>Myriochele oculata</i> at some stations.
Ba (mg/kg)	92 - 655	
Species	60 - 79	
Individuals	648 - 1798	
Individuals (excl <i>M. oculata</i> )	408 - 554	
Diversity	2,2 - 4,5	
Diversity (excl. <i>M. oculata</i> )	4,8 - 5,2	
<b>Tor</b>	<b>Variation</b>	<b>Main characteristics</b>
THC (mg/kg)	6,7 - 46,0	Elevated THC levels similar to 1996 out to 1000m. Elevated Ba levels out to 1000m, decreased concentrations since 1996. "Olefin peaks" in all the chromatograms, although no drilling activity is reported.  Fauna dominated by <i>Myriochele oculata</i> . One station (250m) regarded as disturbed.
Ba (mg/kg)	92 - 1470	
Species	67 - 90	
Individuals	975 - 2424	
Individuals (excl <i>M. oculata</i> )	558 - 886	
Diversity	2,4 - 3,9	
Diversity (excl. <i>M. oculata</i> )	4,0 - 5,2	
<b>Yme Gamma</b>	<b>Variation</b>	<b>Main characteristics</b>
THC (mg/kg)	1,9 - 173	Stations at 250m to 2000m sampled. Elevated THC levels out to 500m and elevated Ba levels out to 2000m, increased concentrations since 1996. Olefins at all stations in agreement with discharges. Petrofree found at 250m and 500m distance, decreased concentrations since 1996. Finagreen is not found.  Diverse and undisturbed fauna, except for two stations (250 and 500m).
Ba (mg/kg)	6,0 - 4520	
Species	61 - 105	
Individuals	421 - 601	
Diversity	4,3 - 5,7	
<b>Yme Beta</b>	<b>Variation</b>	<b>Main characteristics</b>
THC (mg/kg)	0,5 - 1,6	Stations at 250m to 1000m sampled. No elevated THC concentrations found. Petrofree and Finagreen are not found. Elevated Ba levels out to 500m. The 250m stations with the highest levels in 1996 are not analysed, and the development cannot be assessed.  Fauna similar to 1996, all sampled stations undisturbed.
Ba (mg/kg)	7,0 - 103	
Species	79 - 97	
Individuals	592 - 839	
Diversity	4,9 - 5,3	
<b>Tambar</b>	<b>Variation</b>	<b>Main characteristics</b>
THC (mg/kg)	3,2 - 107	Baseline survey. Drilling of one exploratory well reported. Elevated THC levels at 250m distance. Elevated Ba levels out to 1000m distance.  Fauna dominated by <i>Myriochele oculata</i> , a possible minor "influence" at three stations (250, 500m).
Ba (mg/kg)	24 - 4040	
Species	59 - 81	
Individuals	806 - 2988	
Individuals (excl <i>M. oculata</i> )	408 - 583	
Diversity	1,5 - 4,1	
Diversity (excl. <i>M. oculata</i> )	4,4 - 5,1	

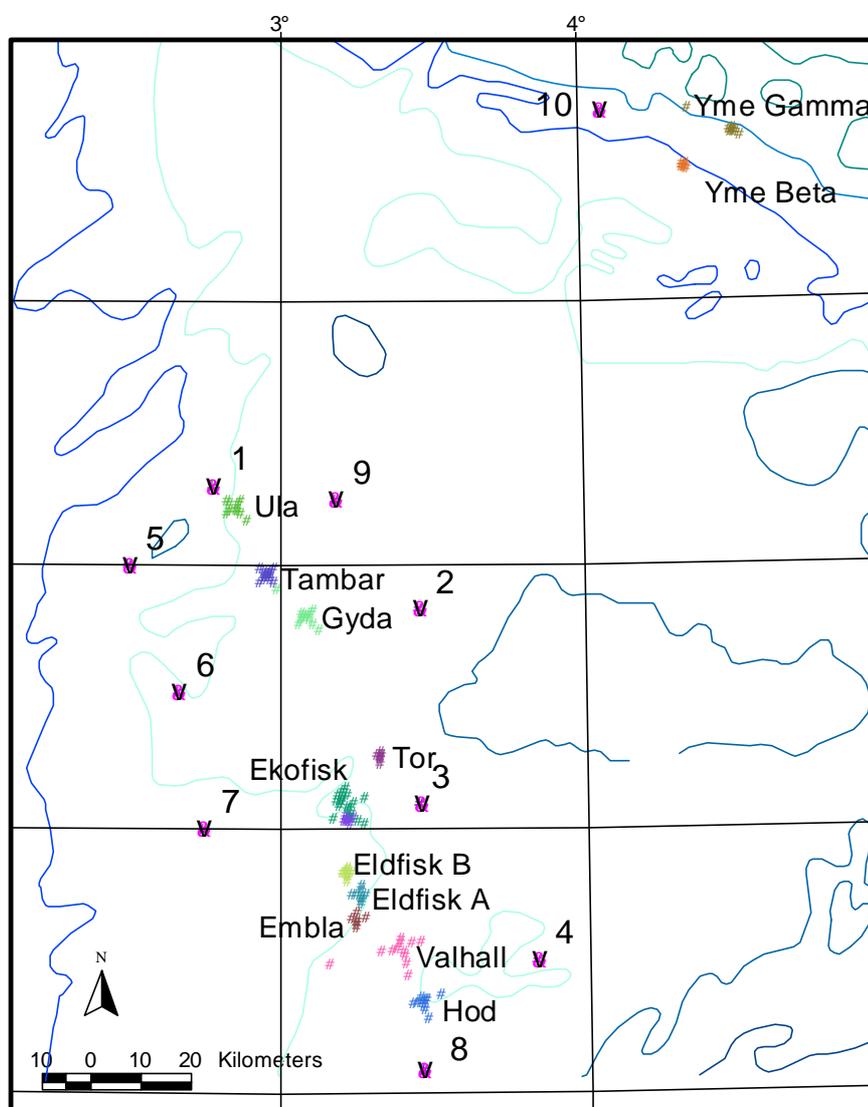
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## 2 INTRODUCTION

### 2.1 The Ekofisk region

This report presents results from the environmental survey in the EKOFISK region in 1999. 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.

This report presents results from 13 different field/installations within the region. An overview of the region including installations is shown in Figure 2.1.



*Figure 2.1. Sampling stations in Region I – Ekofisk area.*

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Fields and installations included in the regional monitoring are shown in Table 2.1.

**Table 2.1.** Fields and installations included in the regional monitoring 1999.

<b>Field/Installation</b>	<b>Operator</b>
Ula	BP-Amoco
Gyda	BP-Amoco
Valhall	BP-Amoco
Hod	BP-Amoco
Ekofisk Centre and 2/4B&K	Phillips
Ekofisk 2/4 A	Phillips
Eldfisk 2/7 A/FTP	Phillips
Eldfisk 2/7 B	Phillips
Embla	Phillips
Tor	Phillips
Yme Gamma	Statoil
Yme Beta	Statoil
Tambar	BP-Amoco

The report is divided into three main sections; the Summary Report (rep. no. 2000-3241), the Main Report (rep. no. 2000-3238) and the Appendix Report (rep. no. 2000-3235). Stations for each field are shown in fold-out maps in the main report.

Region I 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.

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### 3 FIELD WORK/METHODS

The fieldwork in connection with the environmental monitoring in the Ekofisk Region was carried out from 2. - 10. June from the vessel "*Far Spirit*" without any problems. Sampling was carried out in accordance with SFT (99:01) and DNV's internal procedures for this type of work. Details from the fieldwork are described in a separate field report (no. 2000-3236), which is enclosed in the Appendix Report. A complete overview of the sampling is enclosed in the end of this report.

The sediments were analysed according to the method box given below.

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
• Esters	- Petrofree and Finagreen
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/ boric acid
<b>Biological analysis</b>	
• Macrobenthic fauna	- Numbers of species and individuals



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**4 RESULTS AND DISCUSSION****Region I**

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

**Summary table Region I, 1999**

Parameter	Regional stations (10 stations)	Ula (11 stations)	Gyda (10 stations)	Valhall (12 stations)	Hod (10 stations)	Ekofisk Centre 2/4 B&K (18 stations)	Ekofisk 2/4 A (15 stations)
Pelite %	1,4 - 5,3	2,6 - 6,0	1,7 - 4,8	1,3 - 6,1	1,8 - 6,6	3,0 - 7,7	2,4 - 9,9
TOM %	0,7 - 1,1	0,7 - 0,8	0,6 - 0,8	0,4 - 1,1	0,5 - 1,1	0,8 - 1,2	0,7 - 1,7
THC mg/kg	1,4 - 5,5	3,3 - 5,0	3,4 - 9,2	5,1 - 65	3,9 - 135	5,5 - 51,6	8,6 - 384
Olefins mg/kg	na	na	na	nd	1,2 - 7,8	0,9 - 2,9	na
Esters mg/kg	na	na	na	na	na	na	na
NPD* µg/kg	4 - 22	20 - 36	18 - 78	11 - 84	13 - 221	10 - 60	47 - 147
PAH* µg/kg	16 - 51	29 - 34	28 - 40	34 - 80	38 - 74	35 - 60	65 - 90
Decalins*µg/kg	nd	nd	nd - 401	nd - 782	nd - 4710	nd - 233	79 - 382
Ba mg/kg	5,0 - 67	33 - 612	29 - 379	47 - 2160	31 - 1600	41 - 1920	567 - 5680
Cr mg/kg	5,8 - 9,2	5,5 - 6,9	5,7 - 7,1	7,3 - 9,2	6,2 - 8,0	5,0 - 9,0	6,3 - 13,4
Cu mg/kg	0,3 - 0,8	0,5 - 0,8	0,3 - 1,0	0,4 - 1,9	0,4 - 1,1	0,5 - 2,0	0,7 - 19,4
Pb mg/kg	3,9 - 7,3	5,6 - 9,2	6,0 - 7,4	7,2 - 11,6	6,2 - 11,7	6,1 - 16,3	9,9 - 74,7
Zn mg/kg	2,7 - 6,7	4,9 - 17,2	4,1 - 5,6	5,4 - 12,2	5,3 - 11,2	3,4 - 17,6	8,6 - 132
Cd mg/kg	nd	nd	nd - 0,03	nd - 0,03	nd - 0,02	nd - 0,02	nd - 0,33
Hg* mg/kg	nd - 0,02	0,01 - 0,02	nd - 0,02	0,02	0,01- 0,03	nd - 0,02	0,03 - 0,05

\* two to four stations analysed, all regional stations na: not analysed nd: not detected  
 quantitation limits: olefins 0,2 mg/kg, esters: 0,3 mg/kg, decalins 0,050 mg/kg, Cd 0,02 mg/kg, Hg 0,01mg/kg

**Summary table Region I 1999 cont.**

Parameter	Eldfisk 2/7 A / FTP (8 stations)	Eldfisk 2/7 B (9 stations)	Embla (6 stations)	Tor (7 stations)	Yme Gamma (8 stations)	Yme Beta (6 stations)	Tambar (baseline) (16 stations)
Pelite %	2,6 - 5,9	3,3 - 8,0	4,0 - 4,8	2,4 - 4,8	1,9 - 5,6	1,6 - 3,7	1,6 - 5,3
TOM %	0,5 - 0,9	0,7 - 1,1	0,7 - 0,9	0,7 - 0,8	0,5 - 0,9	0,4 - 0,5	0,7 - 0,8
THC mg/kg	8,9 - 16,3	6,7 - 22,0	6,6 - 10,9	6,7 - 46,0	1,9 - 173	0,5 - 1,6	3,2 - 107
Olefins* mg/kg	0,4 - 0,9	0,7 - 3,8	na	na	nd - 34,5	na	na
Esters mg/kg	na	na	na	na	nd - 16,4	nd	na
NPD* µg/kg	26 - 62	22 - 444	31 - 40	99 - 131	5 - 1770	3 - 7	11 - 32
PAH µg/kg	64 - 69	55 - 858	41 - 77	166 - 271	15 - 292	6 - 10	25 - 36
Decalins*µg/kg	nd - 84	nd - 91	nd - 129	nd - 148	nd - 1870	nd	nd - 3450
Ba mg/kg	189 - 1130	221 - 1740	92 - 655	92 - 1470	6,0 - 4520	7,0 - 103	24 - 4040
Cr mg/kg	7,1 - 8,0	5,7 - 7,6	7,2 - 8,3	6,6 - 7,7	4,6 - 9,8	7,5 - 9,2	6,5 - 8,0
Cu mg/kg	0,6 - 1,4	0,5 - 1,4	0,5 - 1,2	0,5 - 2,1	0,3 - 7,2	<0,3	0,4 - 3,5
Pb mg/kg	9,1 - 14,5	7,7 - 17,3	7,6 - 12,7	6,6 - 15,3	5,0 - 11,9	6,4 - 8,2	5,6 - 8,5
Zn mg/kg	6,5 - 13,7	5,8 - 13,1	5,4 - 8,3	5,5 - 26,5	4,9 - 19,7	3,9 - 19,1	5,1 - 12,8
Cd mg/kg	nd	nd - 0,02	nd	nd - 0,06	nd - 0,03	nd	nd
Hg* mg/kg	nd - 0,02	0,03	0,02	nd - 0,03	0,02 - 0,05	nd - 0,02	nd

\* two to four stations analysed na: not analysed nd: not detected  
 quantitation limits: olefins 0,2 mg/kg, esters: 0,3 mg/kg, decalins 0,050 mg/kg, Cd 0,02 mg/kg, Hg 0,01mg/kg

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***Grain size distribution***

The sediments from most of the fields in Region I consist of olive grey fine sand. The stations at Yme Beta and Yme Gamma have a more yellowish brown colour, and the sediments at the Yme Beta field are coarser than at Yme Gamma.

The sand content in the sediment dominates at all stations. At the regional stations the average sand content is 96,4 %, and the average pelite content (silt and clay) is 3,6 %. This mean value are representative for the region.

The pelite content varies from 1,3 % (Valhall station 5, 74°/4000m ) to 9.9 % (Ekofisk 2/4 A station 5, 67°/100m). The lowest average pelite content is found at Yme Beta and Yme Gamma, 2,5 % and 3,2 % respectively (north-east in the region). At Ula, Gyda, Tambar and Tor the average pelite value is about 3,6 %. The highest content is found at Valhall, Hod and the Ekofisk area, the average value ranging from 4,1 % to 4,9 %.

Generally only slight differences are observed in the average pelite content compared to the previous survey in 1996. In addition a decrease is observed at Hod, from 6,8 % to 4,4 %, and an increase is observed at Yme Beta, from 0,4 % to 2,5 %.

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

The total organic matter content in the sediments is low. Only small variations are found, from 0,4 % (Yme Beta) to 1,7 % (Ekofisk 2/4 A). The results are similar to the previous survey in 1996.

***Hydrocarbons***

The content in the sediment of hydrocarbons 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 1,4 mg/kg to 5,5 mg/kg. No increase is observed since the last survey in 1996.

At Ula and Gyda most of the stations sampled are outside 500m distance from the platforms. The THC concentrations are low, 3,3 mg/kg to 9,2 mg/kg, and the concentrations are similar or decreased compared to the 1996 survey. No elevated THC concentrations are found at and outside 1000m distance. At Embla the situation is similar, no elevated THC concentrations are found at the 1000m stations, and the results are similar to 1996.

At Valhall and Hod most of the stations are also outside 500m distance, however the THC concentrations are higher, up to 65 mg/kg at Valhall and up to 135 mg/kg at Hod. Elevated THC concentrations are found out to 2000m distance. Decrease/increase compared to 1996 are found. Olefins from pseudo-oil based drilling mud base liquids are found at all stations at Hod, except for the reference station, but at none of the Valhall stations. Compared to 1996 this is a reduction at Valhall and status quo at Hod.

In the Ekofisk area (Ekofisk Centre, Eldfisk 2/7 A/FTP, Eldfisk 2/7 B, Tor) the THC concentrations are similar to the 1996 results, up to 52 mg/kg. Elevated THC concentrations are found out to 4400m at Ekofisk Centre, out to 2000m at Eldfisk 2/7 A and B, and out to 1000m at Tor. Olefins are observed at all stations, except for the reference station.

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The Yme fields are located north-east in Region I. The fields are more recently established, with baseline surveys in 1994. Stations closer to the platforms are sampled compared to the other fields. At Yme Gamma elevated THC concentrations are found out to 500m distance, and an increase is observed since 1996. Olefins are found at all stations, except for the reference station. At Yme Beta no elevated THC concentrations are found. Due to lack of samples from the 250m stations contaminated in 1996, the development close to the platform can not be assessed. However, the dispersal area at Yme Beta will be within 500m distance and has not increased since 1996.

A baseline investigation at Tambar is included in the 1999 survey. The THC concentrations vary from 3,2 mg/kg to 107 mg/kg. Elevated THC levels are found at two of the four 250m stations due to drilling of one exploratory well. Generally the sediments at Tambar appear to be "undisturbed" with low background levels. Thus additional THC "humps" in the chromatograms could be observed at 500m distance.

Sediments close to Ekofisk 2/4 A, from 100m to 1000m distance, are included in the survey. The aim is to investigate the contamination level in old heaps of drill cuttings at the seabed. As expected the THC levels are relatively high, ranging from 8,6 mg/kg to 384 mg/kg, and the olefin contribution is considerable.

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.

### ***Esters***

Esters from the drilling mud base liquids Petrofree and Finagreen are only analysed at the Yme fields. At Yme Gamma Petrofree is found at 250m and 500m distance, and a decrease is observed since 1996. Finagreen is not found in the sediments, and this is also a decrease since 1996. At Yme Beta Petrofree and Finagreen are not found in the present survey. These compounds were not analysed in 1996.

### ***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 5,0 mg/kg to 67 mg/kg. No increase is observed since the last survey in 1996.

The Ba concentrations vary from background levels to 4500 mg/kg (exclusive Ekofisk 2/4 A). 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. 6000m at Valhall and Ekofisk Centre, out to 4000m at Hod, out to 2000m at Ula, Gyda, Eldfisk 2/7 A/FTP, Eldfisk B, Embla and Yme Gamma, out to 1000m at Tor and Tambar and out to 500m at Yme Beta. A decrease or a slight decrease in the Ba concentrations since 1996 is

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observed, except for the Yme fields. At Yme Gamma the Ba concentrations are increased since 1996, and at Yme Beta the development can not be assessed.

At Tambar the Ba concentrations vary from 24 mg/kg to 4040 mg/kg in this baseline survey. Elevated Ba levels are found out to 1000m due to drilling of one exploratory well.

At Ekofisk 2/4 A the Ba concentration is high. All the stations analysed, out to 1000m, have elevated Ba concentrations, with a maximum level of 5700 mg/kg at one of the 100m stations.

**Metals**

Generally low concentrations of the heavy metals are found in the sediments. Only some of the stations have elevated levels. The maximum concentrations found are 9,8 mg/kg Cr, 7,2 mg/kg Cu, 17,3 mg/kg Pb, and 26,5 mg/kg Zn. Cd and Hg are detected at some stations, however the concentrations are just above the detection limit.

Ekofisk 2/4 A is an exception. All stations have elevated concentrations of Pb and Zn. Elevated concentrations of Cd, Cr, and Cu are found at several stations, and Hg is also detected at the two stations analysed. Metal transport down in the sediment is also observed, and the concentrations are mostly higher than in the top 0-1 cm layer.

**Biology**

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

*Biological results (excl. M. oculata), Region I 1999.*

Parameter	Regional stations (10 stations)	Ula (11 stations)	Gyda (10 stations)	Valhall (12 stations)	Hod (10 stations)	Ekofisk Centre 2/4 B&K (18 stations)	Ekofisk 2/4 A (15 stations)
Species	53 – 92	65 - 96	61 – 87	48 - 80	55 – 83	66 – 78	60 – 84
Individuals	371 – 665	513 – 832	359 – 1387	361 – 663	308 – 677	412 – 765	502 – 922
Diversity	4,4 – 5,6	4,4 – 5,2	3,2 – 5,0	4,4 – 5,1	4,5 – 5,3	4,7 – 5,2	3,3 – 5,2
Evenness	0,7 – 0,9	0,7 – 0,8	0,6 – 0,8	0,8 all st.	0,7 – 0,9	0,8 – 0,9	0,7 – 0,8
ES <sub>100</sub>	28,1 – 47,8	29,6 – 37,9	22,8 – 36,1	28,3 – 38,9	32,7 – 39,4	31,5 – 39,2	23,1 – 38,4
	<b>Eldfisk 2/7 A / FTP (8 stations)</b>	<b>Eldfisk 2/7 B (9 stations)</b>	<b>Embla (6 stations)</b>	<b>Tor (7 stations)</b>	<b>Yme Gamma (8 stations)</b>	<b>Yme Beta (6 stations)</b>	<b>Tambar (baseline) (16 stations)</b>
Species	62 – 74	65 – 85	60 – 79	67 – 90	61 – 105	79 – 97	59 – 81
Individuals	420 – 632	433 – 1104	408 – 554	558 – 886	421 – 601	592 – 839	408 – 583
Diversity	4,8 – 5,0	4,8 – 5,3	4,8 – 5,2	4,0 – 5,2	4,3 – 5,7	4,9 – 5,3	4,4 – 5,1
Evenness	0,8 all st.	0,8 all st.	0,8 all st.	0,7 – 0,8	0,7 – 0,9	0,8 all st.	0,8 all st.
ES <sub>100</sub>	33,6 – 36,1	32,4 – 39,0	33,5 – 39,7	28,1 – 37,8	30,4 – 46,6	35,0 – 39,4	31,2 – 37,7

The polychaete *Myriochele oculata* dominated the fauna in the Ekofisk Region (except at Yme) in 1999. This species can be found in high numbers everywhere. When excluding this species from the data the diversity indices in the Ekofisk Region are high, and only small areas can be regarded as affected. More than 73% of the stations have higher diversity than the mean diversity (4.7) at the regional stations (and more than 85% have higher than 4.5 that is the range for the

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regional stations  $4.7 \pm 0.2$ ). The diversity was at the lowest close to the installation at Ekofisk A and at Gyda, see Figure 5.2.1

#### 4.1 Regional stations

The sediments at the Regional stations consist in average of 3,6 % pelite ( $< 63 \mu\text{m}$ ) and 96,4 % sand ( $> 63 \mu\text{m}$ ). The same average distribution was found in the previous survey in 1996. Some changes are observed, an increase from 2,9 % to 5,3 % at Regional 3 and a decreased from 5,8 % to 2,8 % at Regional 8. The total organic matter content in the sediments is low, and only small variations are found, from 0,7 % to 1,1 %.

The concentrations of hydrocarbons, barium and heavy metals are low, and the sediments are not contaminated. The THC content in the sediments vary from 1,4 mg/kg to 5,5 mg/kg. The concentration of Ba varies from 5 mg/kg to 67 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 digestion, and they vary from 162 mg/kg to 235 mg/kg. The concentrations of the heavy metals are similar to digestion by nitric acid.

The limit of contamination (LSC) is calculated for each chemical parameter at Region I. Data from regional stations and reference stations back to 1993 are used. For all parameters, except Ba, the LSC value refers to the whole region. For Ba the region is divided into two subregions, and two different LSC values are calculated.

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

Station	Pelite		TOM		THC		NPD		PAH	
	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
Regional 1, Ula ref	3,5	2,5	1,06	0,82	4,1	3,9	0,022	0,012	0,034	0,054
Regional 2	3,5	3,6	0,94	0,95	2,6	4,3	0,008	-	0,023	-
Regional 3, Ekofisk ref	5,3	2,9	0,95	0,86	5,5	5,4	0,010	0,026	0,035	0,045
Regional 4	2,9	3,8	0,93	0,95	5,3	6,3	0,016	-	0,041	-
Regional 5	4,4	3,4	1,14	0,94	3,6	6,8	0,016	-	0,051	-
Regional 6	3,7	4,7	1,13	0,95	4,1	6,5	0,012	-	0,047	-
Regional 7	3,3	3,1	1,11	0,93	4,3	4,2	0,012	-	0,043	-
Regional 8, Hod ref	2,8	5,8	0,71	0,92	3,9	5,3	0,013	0,020	0,038	0,081
Regional 9	1,4	na	0,78	-	1,4	-	0,004	-	0,016	-
Regional 10	3,2	na	0,85	-	1,9	-	0,005	-	0,018	-

-: not analysed      Decalins are not detected, limit of detection is 50 $\mu\text{g}/\text{kg}$

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

Station	Ba		Cr		Cu		Hg		Pb		Zn	
	1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996	
Regional 1, Ula ref	33	52	6,9	0,6	0,7	0,01	7,3	6,6	5,6	5,9		
Regional 2	13	23	6,1	0,4	0,6	0,01	4,5	4,5	3,6	2,6		
Regional 3, Ekofisk ref	41	68	7,1	0,8	<0,6	nd	5,8	6,2	4,7	3,0		
Regional 4	67	102	7,5	0,6	0,7	0,02	7,2	7,6	6,7	5,2		

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

Regional 5	28	42	6,2	0,5	<0,6	0,02	6,8	7,3	5,3	4,3
Regional 6	31	35	7,0	0,6	<0,6	0,02	6,9	6,4	5,9	4,1
Regional 7	31	58	7,4	0,5	<0,6	0,02	7,3	7,2	5,4	4,2
Regional 8, Hod ref	31	51	6,6	0,4	0,8	0,01	6,2	6,4	5,3	3,7
Regional 9	6	-	5,8	<0,3	-	nd	3,9	-	2,7	-
Regional 10	5	-	9,2	0,5	-	nd	6,4	-	6,7	-

-: not analysed      Cd is not detected      Cr not analysed in 1996

**Table 4.1.3. Regional stations, Metals - digestion by HF /aqua regia/boric acid 1999 (mg/kg dry sediment)**

Station	Ba	Cd	Cr	Cu	Pb	Zn	Al	Li
Regional 1, Ula ref	223	<0,02	12,6	1,4	10,1	9,6	15810	3,7
Regional 2	208	<0,02	10,3	1,3	7,7	10,7	15350	3,0
Regional 3, Ekofisk ref	218	<0,02	10,7	1,2	9,5	8,0	14410	3,4
Regional 4	235	<0,03	12,3	1,9	9,8	18,6	15320	4,6
Regional 5	231	<0,02	13,2	1,5	10,8	11,8	17290	4,1
Regional 6	221	<0,02	11,9	1,2	9,8	23,0	15120	3,9
Regional 7	229	<0,02	10,9	1,1	10,7	8,4	14230	3,7
Regional 8, Hod ref	198	<0,02	9,8	1,2	9,6	7,8	12970	3,5
Regional 9	206	<0,02	9,3	1,3	7,1	5,7	15100	2,4
Regional 10	162	<0,03	11,3	1,0	9,6	8,9	11380	2,8

**Table 4.1.4. Region I, LSC values at 99 % confidence level, one-tailed t-test (mg/kg dry sediment)**

Parameter	Number of stations	Number of measurements	t value	x mean	SD	LSC
THC	13	129	2,36	4,0	1,9	<b>9</b>
Ba, Region I except Yme	10	113	2,36	53	24	<b>110</b>
Ba, Yme fields	3	21	2,52	5,5	1,3	<b>10</b>
Cr	13	74	2,38	8,0	1,6	<b>12</b>
Cu	13	129	2,36	0,6	0,3	<b>2</b>
Pb	13	129	2,36	6,8	1,3	<b>10</b>
Zn	13	129	2,36	5,7	2,1	<b>11</b>
NPD	13	108	2,36	0,014	0,009	<b>0,040</b>
PAH	13	109	2,36	0,038	0,019	<b>0,090</b>

LSC : limit of contamination,  $LSC = x_{\text{mean}} + SD \times t_{0,01, n-1}$

$x_{\text{mean}}$  : mean of regional stations and reference stations (uncontaminated stations)

SD : standard deviation,  $SD^2 = \Sigma (x - x_{\text{mean}})^2 / (n-1)$

t : t-value, from tables with degree of freedom (n-1) and confidence level (99 %)

n : number of samples

## Biology

A total of 191 species and 7321 individuals were sampled at 10 regional stations. Greatest abundance (47 %) was found among the polychaetes. The deposit feeder *Myriochele oculata* dominated at most of the stations (16-68%). The 10 most abundant species made up from 45 to 84%, see table below.

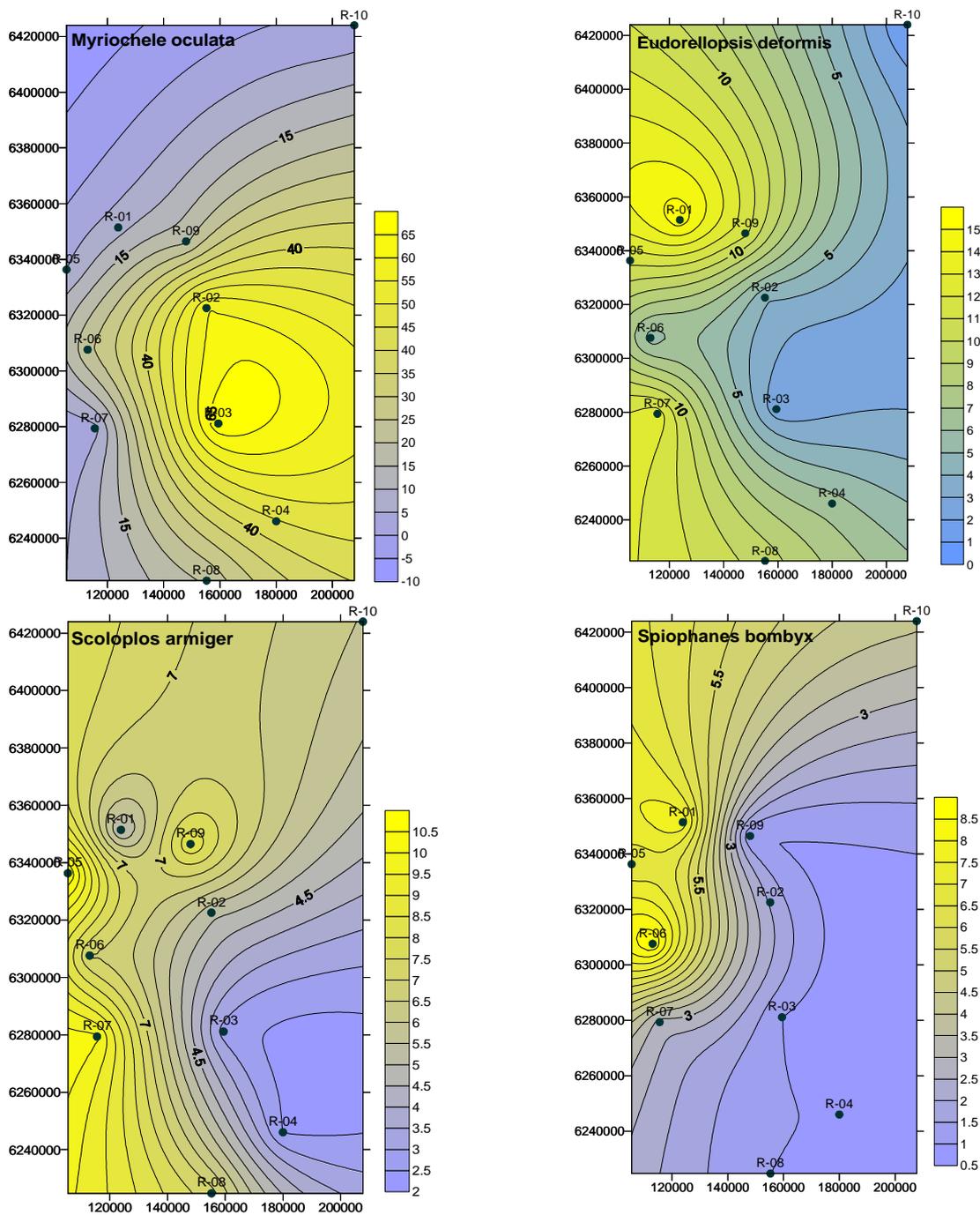
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*The 10 most abundant species at each station, Regional stations, Ekofisk 1999.*

St.1	Number	%	Cum.%	St.2	Number	%	Cum.%
1. Eudorellopsis deformis	113	15.61	15.61	1. Myriochele oculata	901	59.67	59.67
2. Amphipura filiformis	78	10.77	26.38	2. Amphipura filiformis	82	5.43	65.10
3. Paramphionome jeffreysii	68	9.39	35.77	3. Scoloplos armiger	78	5.17	70.26
4. Myriochele oculata	59	8.15	43.92	4. Eudorellopsis deformis	63	4.17	74.44
5. Spiophanes bombyx	57	7.87	51.80	5. Goniada maculata	35	2.32	76.75
6. Ophiuroidea spp. juv	41	5.66	57.46	6. Spiophanes bombyx	29	1.92	78.68
7. Scoloplos armiger	35	4.83	62.29	7. Nephtys longosetosa	23	1.52	80.20
8. Owenia fusiiformis	29	4.01	66.30	8. Owenia fusiiformis	22	1.46	81.66
9. Goniada maculata	24	3.31	69.61	9. Pholoe inornata	16	1.06	82.72
10. Echinoida spp. juv	19	2.62	72.24	10. Ophelia borealis	14	0.93	83.64
St.3	Number	%	Cum.%	St.4	Number	%	Cum.%
1. Myriochele oculata	1037	68.81	68.81	1. Myriochele oculata	379	44.59	44.59
2. Amphipura filiformis	66	4.38	73.19	2. Amphipura filiformis	81	9.53	54.12
3. Scoloplos armiger	42	2.79	75.98	3. Eudorellopsis deformis	55	6.47	60.59
4. Eudorellopsis deformis	36	2.39	78.37	4. Edwardsia sp.	41	4.82	65.41
5. Goniada maculata	33	2.19	80.56	5. Goniada maculata	32	3.76	69.18
6. Ampelisca macrocephala	22	1.46	82.02	6. Scoloplos armiger	21	2.47	71.65
7. Ophiura affinis	19	1.26	83.28	7. Cerianthus lloydii	19	2.24	73.88
8. Pholoe inornata	18	1.19	84.47	8. Nephtys longosetosa	14	1.65	75.53
9. Sphaerodorum gracilis	17	1.13	85.60	9. Owenia fusiiformis	13	1.53	77.06
10. Nephtys longosetosa	14	0.93	86.53	10. Diplocirrus glaucus	12	1.41	78.47
St.5	Number	%	Cum.%	St.6	Number	%	Cum.%
1. Amphipura filiformis	74	16.05	16.05	1. Myriochele oculata	116	23.82	23.82
2. Eudorellopsis deformis	52	11.28	27.33	2. Amphipura filiformis	58	11.91	35.73
3. Scoloplos armiger	51	11.06	38.39	3. Spiophanes bombyx	44	9.03	44.76
4. Spiophanes bombyx	30	6.51	44.90	4. Scoloplos armiger	34	6.98	51.75
5. Goniada maculata	23	4.99	49.89	5. Eudorellopsis deformis	27	5.54	57.29
6. Myriochele oculata	23	4.99	54.88	6. Nephtys longosetosa	22	4.52	61.81
7. Nephtys longosetosa	20	4.34	59.22	7. Goniada maculata	15	3.08	64.89
8. Chaetoderma spp.	18	3.90	63.12	8. Paradothis lyra	14	2.87	67.76
9. Spiophanes kroeyeri	12	2.60	65.73	9. Phoronis muelleri	11	2.26	70.02
10. Owenia fusiiformis	12	2.60	68.33	10. Nemertea spp.	8	1.64	71.66
St.7	Number	%	Cum.%	St.8	Number	%	Cum.%
1. Amphipura filiformis	70	17.68	17.68	1. Myriochele oculata	80	20.62	20.62
2. Goniada maculata	57	14.39	32.07	2. Eudorellopsis deformis	37	9.54	30.15
3. Eudorellopsis deformis	50	12.63	44.70	3. Echinoida spp. juv	34	8.76	38.92
4. Scoloplos armiger	40	10.10	54.80	4. Scoloplos armiger	28	7.22	46.13
5. Myriochele oculata	13	3.28	58.08	5. Amphipura filiformis	28	7.22	53.35
6. Nemertea spp.	11	2.78	60.86	6. Goniada maculata	26	6.70	60.05
7. Spiophanes bombyx	11	2.78	63.64	7. Phaxas pellucidus	12	3.09	63.14
8. Phoronis muelleri	10	2.53	66.16	8. Phoronis muelleri	11	2.84	65.98
9. Levisenia gracilis	9	2.27	68.43	9. Nephtys longosetosa	10	2.58	68.56
10. Chaetozona setosa	7	1.77	70.20	10. Chaetoderma nitidulum	10	2.58	71.13
St.9	Number	%	Cum.%	St.10	Number	%	Cum.%
1. Myriochele oculata	116	18.95	18.95	1. Amphipura filiformis	40	10.36	10.36
2. Eudorellopsis deformis	69	11.27	30.23	2. Paramphionome jeffreysii	27	6.99	17.36
3. Amphipura filiformis	54	8.82	39.05	3. Scoloplos armiger	23	5.96	23.32
4. Goniada maculata	52	8.50	47.55	4. Spiophanes bombyx	16	4.15	27.46
5. Scoloplos armiger	52	8.50	56.05	5. Nemertea spp.	13	3.37	30.83
6. Paramphionome jeffreysii	39	6.37	62.42	6. Nephtys longosetosa	13	3.37	34.20
7. Bathyporeia sp.	26	4.25	66.67	7. Goniada maculata	12	3.11	37.31
8. Edwardsia sp.	25	4.08	70.75	8. Aonides paucibranchiata	12	3.11	40.41
9. Mysella bidentata	18	2.94	73.69	9. Edwardsia sp.	10	2.59	43.01
10. Nephtys longosetosa	16	2.61	76.31	10. Tunica spp.	10	2.59	45.60

The distribution (as %) of six of the most abundant species in the region is shown in Figure 4.1.1. *M. oculata* was found in high numbers in the central parts of the investigated areas. Highest numbers were observed at regional station 3 and 2, which are situated nearby Tor and Gyda respectively (which are also dominated by *M. oculata*). *Eudorellopsis deformis*, *Scoloplos armiger*, *Spiophanes bombyx*, *Amphipura filiformis* and *Goniada maculata*, all typical for this region, were all more evenly distributed in the region and also found in smaller numbers in areas where *M. oculata* dominated.

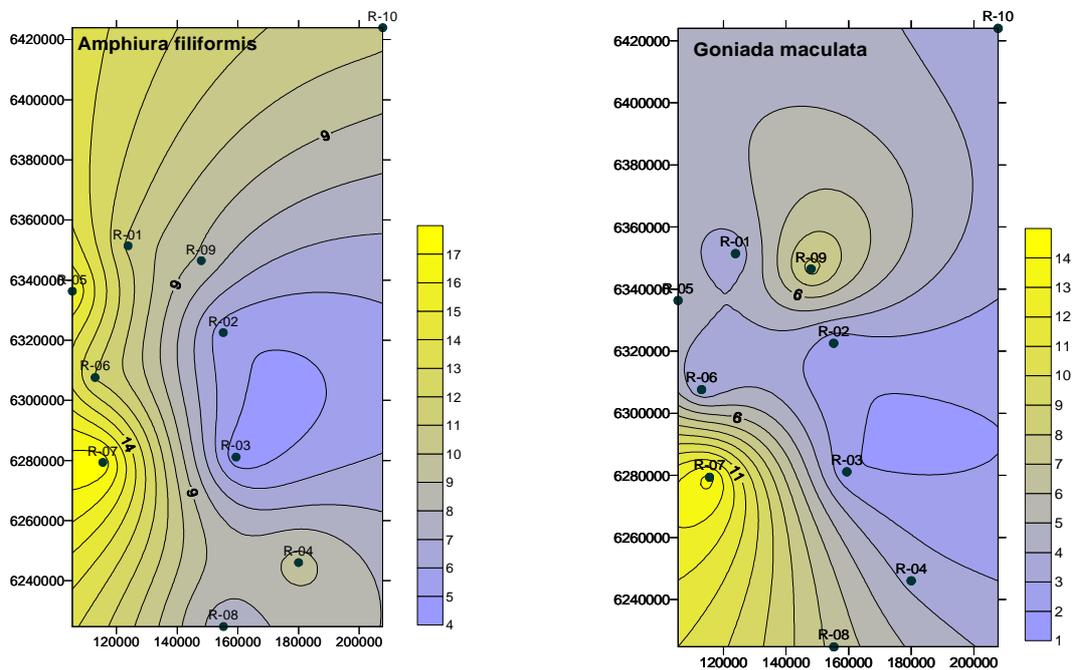
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**Figure 4.1.1.** Distribution of *Myriochele oculata*, *Eudorellopsis deformis*, *Scoloplos armiger* and *Spiophanes bombyx* (numbers of ind./0.5 m<sup>2</sup>) at regional stations, Region I 1999.

Figures 4.1.1 and 4.1.2 shows isoline-plots based on numbers of individuals per 0.5m<sup>2</sup>. It should be emphasised that in these plots some adjustments and assumptions are made, dependent on numbers of sampling stations. This means that in areas with few stations the uncertainty is greater than in areas with many stations. However, the plots show an overview of the distribution of selected species in the Ekofisk area.

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**Figure 4.1.2.** Distribution of *Amphiura filiformis* and *Goniada maculata* (numbers of ind./0.5 m<sup>2</sup>) at Regional stations, Region I 1999.

In this region, which is dominated by sand, the available amounts of organic matter is less than in areas where pelite dominates the sediment. This is because most of the organic matter in the water column is transported out of the area with the water current (sand reflects higher water movements). Though deposit feeders dominate the fauna (i.e. *M. oculata* and *S. bombyx*) 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.

*M. oculata* has pelagic larvae and the larvae swarm of this species is probably capable of finding temporary free niches with low predation and competition. Once established, they can create temporary populations with very high number of specimen. There has not been found any correlation between numbers of individuals at each station and the levels of hydrocarbons, metals, decalins or organic matter in the sediments. The high numbers of this species is therefore assumed to be occasional temporary. In areas/fields where *M. oculata* dominates, the calculations of various indices and different types of other analyses have been performed on data with and without *M. oculata*. In Figure 4.1.3 the distribution of *M. oculata* for all fields in the region is shown (except Yme, where *M. oculata* is rare), and there is no clear correlation between the distance from a field centre and the abundance of *M. oculata*.

TECHNICAL REPORT

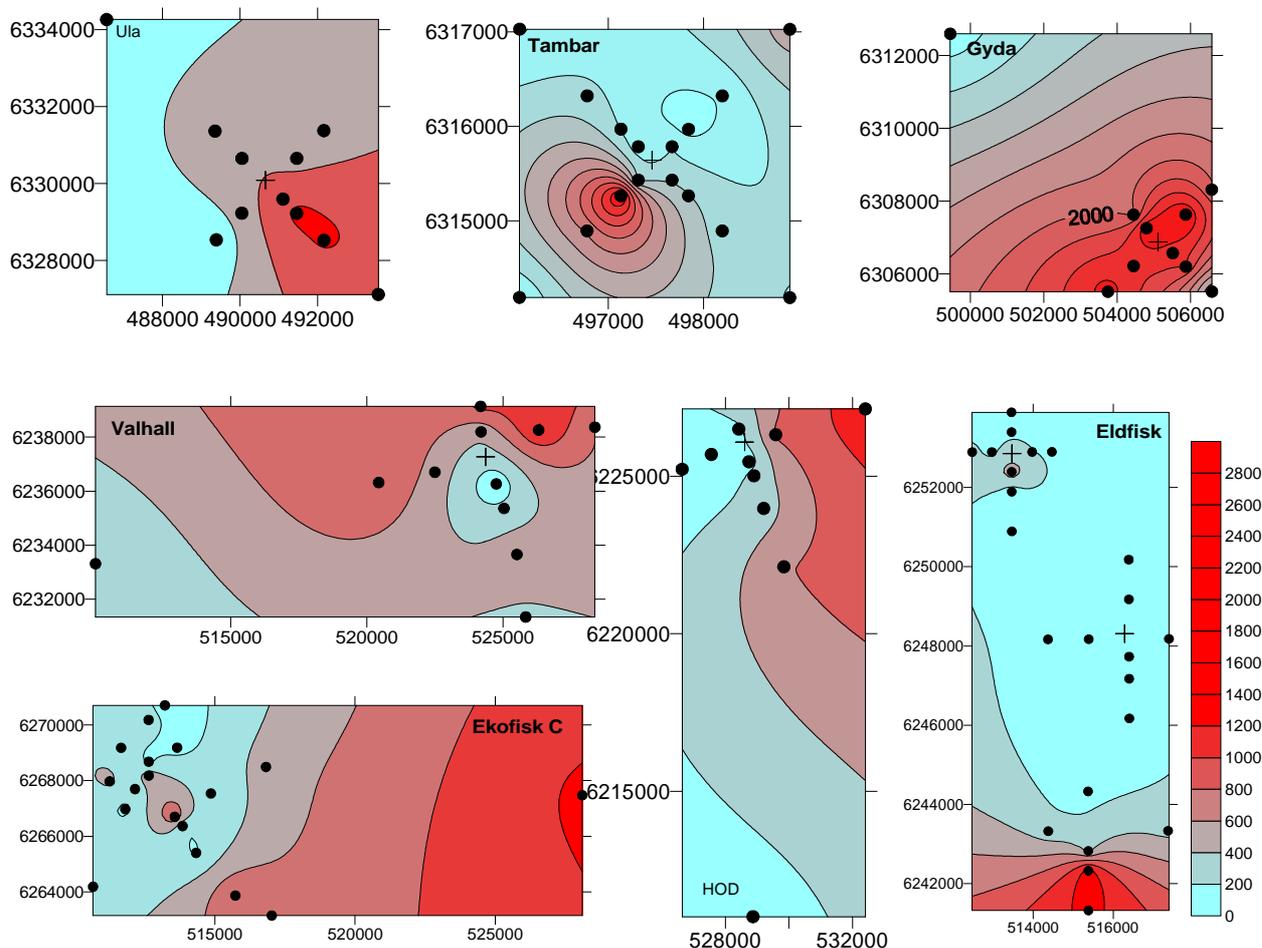


Figure 4.1.3. Distribution of *M. oculata* (number of ind./0.5 m<sup>2</sup>) at different fields in Region I, Ekofisk 1999.

The macrobenthic indices from the regional stations are listed in the table below.

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 Regional stations, 1999. Incl. / excl. *M. oculata*.

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
1	71	725/665	83	4.6/4.6	0.7/0.7	30.2/30.6
2	65	1510/609	85	3.0/5.0	0.5/0.8	22.6/37.4
3	69	1507/470	70	2.5/5.0	0.4/0.8	19.6/35.9
4	70	850/471	76	3.7/4.9	0.6/0.8	26.6/36.1
5	72	461/438	65	4.7/4.7	0.8/0.8	32.9/32.8
6	72	487/371	65	4.4/4.8	0.7/0.8	31.1/34.9
7	72	396/383	58	4.7/4.4	0.8/0.8	31.8/32.1
8	71	388/308	55	4.5/4.7	0.8/0.8	30.4/33.1
9	66	612/496	53	4.3/4.5	0.8/0.8	26.5/28.1
10	86	386/376	92	5.7/5.6	0.9/0.9	48.0/47.8

TECHNICAL REPORT

Compared with the 1996 survey the diversity index is quite similar (excl. *M. oculata*), but somewhat higher in 1999 at regional stations 5 and 8, but no clear trends can be seen.

Figure 4.1.4 and 4.1.5 shows the dendrogram from the cluster analyses and the MDS plot. The results are very similar when performing the same analyses excluding the dominant species *M. oculata* (not shown).

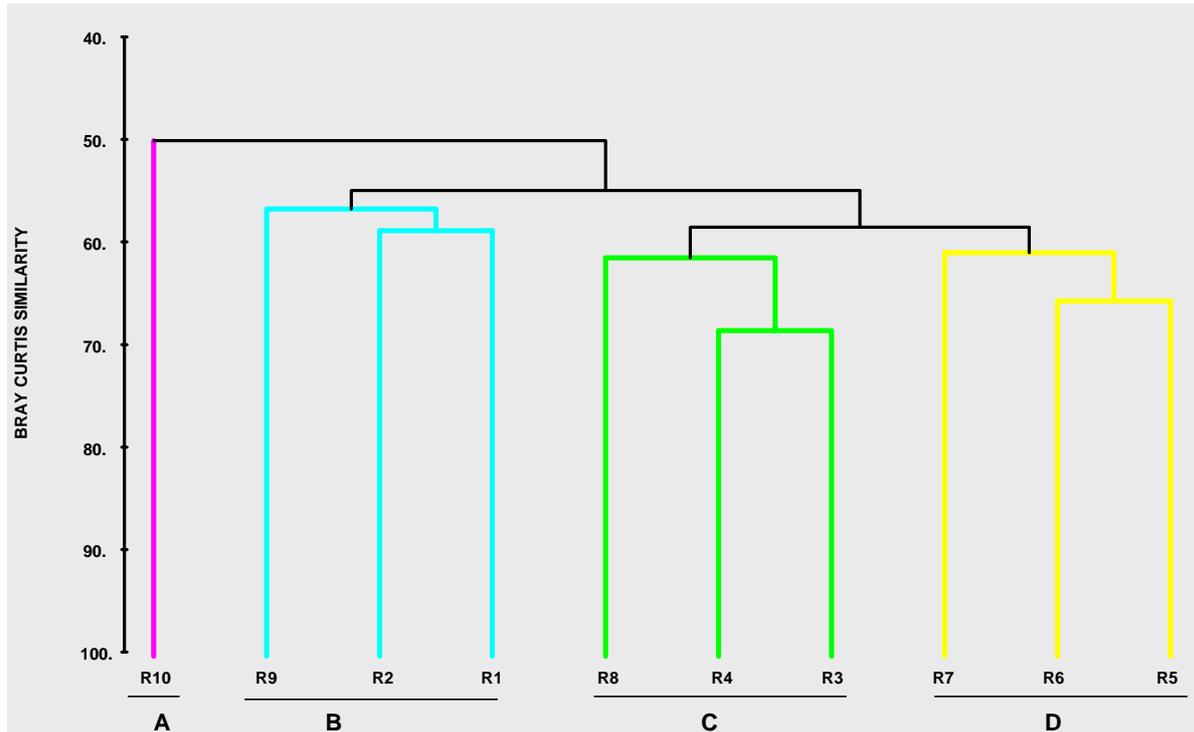


Figure 4.1.4. Dendrogram at station level, Regional stations 1999. 4<sup>th</sup> root transformation.

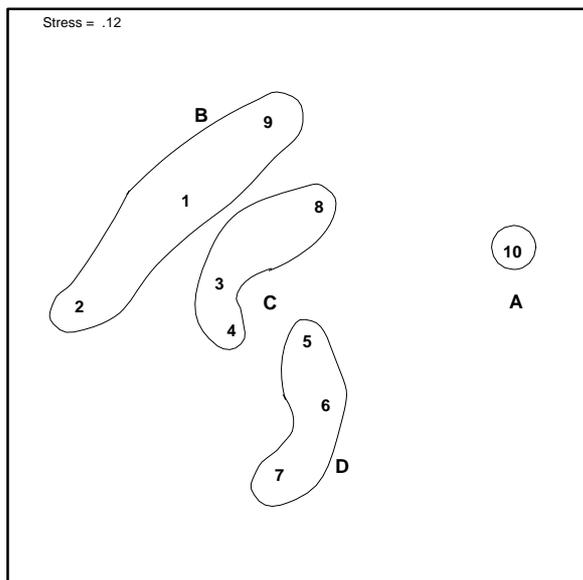
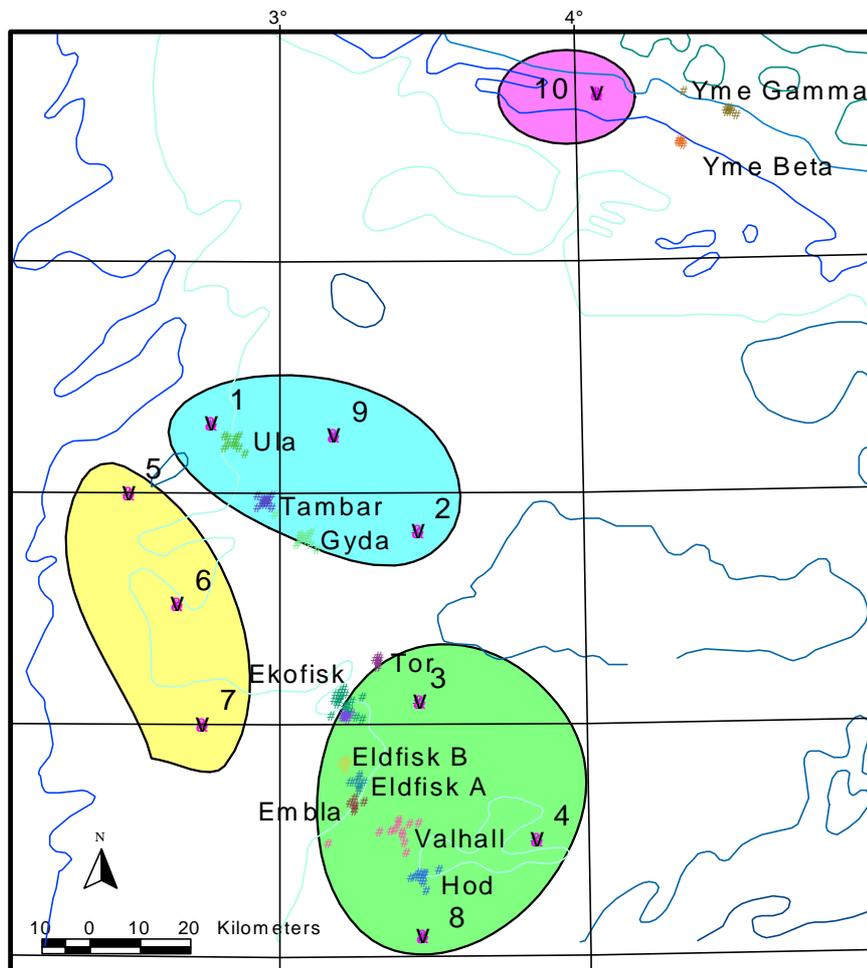


Figure 4.1.5. MDS-plot at station level, Regional stations, 1999.

## TECHNICAL REPORT

The similarities between groups B, C and D are high. The abundance of *M. oculata*, together with some other species that are absent in one group and found in relative low numbers in others, is the main reason for the separation between these groups.



**Figure 4.1.6.** Regional stations separated according to the classification analyses.

A comparison between the 1996 and 1999 macrofauna revealed that the main difference is high abundance of *M. oculata* in 1999 and *Cheatozone setosa* in 1996.

The fauna in the Yme area is quite different from the rest of the Ekofisk region, where the polychaete *M. oculata* was found in high numbers and dominated the fauna in some areas, e.g. the Ula/Gyda area. However, this species is not suitable as an indicator species, and due to an apparently patchy distribution, the presence of *M. oculata* might disturb other patterns in the fauna data.

All regional stations can be regarded as undisturbed with a species composition that is typical for sediment types that are found in the region.

## TECHNICAL REPORT

## 4.2 Ula

The sediments at Ula consist in average of 3,6 % pelite. The average pelite concentration is approximately the same as in the previous survey in 1996. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0,65 % to 0,81 %. The results are similar to 1996.

The THC levels are low, and the mean concentrations vary from 3,3 mg/kg to 5,0 mg/kg. Only one station at 500 m distance is analysed, station 19, 135°/500m. This station is still considered contaminated by hydrocarbons, as slightly elevated THC levels are found down in the sediments at the 3-6 cm layer. Elevated levels of decalins are also found in this sediment sample. The THC concentrations from 1000 m distance are low, and elevated THC levels are not found. Thus the area contaminated by hydrocarbons around Ula is within 1000m distance from the platform. The THC levels have decreased since 1996. The NPD and PAH levels are low at the three stations analysed, and elevated concentrations are not observed.

The Ba concentrations vary from 36 mg/kg at the reference station to 612 mg/kg at station 19, 135°/500m. The stations with the highest levels in 1996 are not analysed in the present survey. Elevated Ba concentrations are found at the 1000m stations in all four directions, and also at the 2000m station in the 135° and 225° directions. The Ba levels at the 1000m stations have decreased since 1996. A vertical transport of Ba down in the sediment is observed. The concentrations of the heavy metals are low, and only slightly elevated levels of Zn are found at one station.

The chemical results agree with the drilling history. No discharges have taken place at Ula since the 1996 survey.

**Table 4.2.1.** Ula, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Pelite		TOM		THC		NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.3 45°/2000 m	3,8	-	0,67	-	3,5	-	-	-	-	-	-	-
St.4 45°/1000 m	2,6	3,0	0,71	0,81	4,4	10,2	-	-	-	-	-	-
St.9 225°/1000 m	2,7	3,2	0,70	0,89	3,3	9,2	-	-	-	-	-	-
St.10 225°/2000 m	3,4	-	0,78	-	4,3	-	-	-	-	-	-	-
St.14 315°/2000 m	2,9	-	0,75	-	4,7	-	-	-	-	-	-	-
St.15 315°/1000 m	6,0	3,3	0,65	0,84	4,6	9,8	-	-	-	-	-	-
St.19 135°/ 500 m	3,8	3,0	0,74	0,88	5,0	17,3	0,020	0,125	0,029	0,080	nd	0,629
1-3 cm					6,8	16,5	0,022	0,047	0,038	0,040	nd	0,198
3-6 cm					10,4	11,0	0,035	0,030	0,065	0,217	0,198	0,192
St.20 135°/1000 m	3,8	2,1	0,81	1,16	4,7	11,0	-	-	-	-	-	-
St.21 135°/2000 m	3,4	2,7	0,70	0,80	4,4	4,7	0,036	0,013	0,033	0,036	nd	0,064
1-3 cm					4,8	7,1	0,019	0,026	0,032	0,067	nd	0,206
3-6 cm					4,6	9,6	0,022	0,047	0,038	0,154	nd	0,156
St.22 135°/4000 m	3,3	-	0,71	-	4,1	-	-	-	-	-	-	-
Ref. 315°/6000 m	3,5	2,5	0,71	0,82	4,1	4,2	0,022	0,012	0,034	0,054	nd	nd
1-3 cm					5,0	2,6	0,021	0,021	0,040	0,080	nd	0,082
3-6 cm					4,6	7,1	0,026	0,028	0,057	0,157	nd	0,077

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

## TECHNICAL REPORT

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

Station		Ba		Cr		Cu		Hg		Pb		Zn	
		1999	1996	1999	1999	1996	1999	1999	1996	1999	1996	1999	1996
St.3	45°/2000 m	55	-	5,7	0,5	-	-	6,3	-	5,2	-		
St.4	45°/1000 m	135	378	5,8	0,6	0,9	-	7,3	8,7	5,5	6,6		
St.9	225°/1000 m	162	626	5,9	0,5	0,6	-	5,6	8,3	5,7	7,5		
St.10	225°/2000 m	130	-	6,2	0,5	-	-	7,4	-	5,7	-		
St.14	315°/2000 m	56	-	6,2	0,7	-	-	7,0	-	6,1	-		
St.15	315°/1000 m	187	253	6,3	0,7	0,3	-	8,1	7,7	17,2	6,7		
St.19	135°/ 500 m	612	704	6,2	0,8	1,4	0,02	9,2	10,8	8,4	10,9		
	1-3 cm	1150	-	5,8	1,1	-	0,02	9,6	-	9,1	-		
	3-6 cm	1210	-	6,1	0,9	-	0,01	8,6	-	7,0	-		
St.20	135°/1000 m	279	417	5,8	0,6	1,2	-	6,7	8,3	5,7	7,3		
St.21	135°/2000 m	50	131	5,5	0,6	1,4	0,02	6,2	6,8	4,9	5,9		
	1-3 cm	117	-	5,8	0,7	-	nd	6,7	-	5,4	-		
	3-6 cm	338	-	6,5	1,0	-	0,04	7,6	-	7,0	-		
St.22	135°/4000 m	36	-	6,7	0,6	-	-	7,0	-	5,3	-		
Ref.	315°/6000 m	33	60	6,9	0,6	0,5	0,01	7,3	6,9	5,6	6,0		
	1-3 cm	41	-	6,9	0,6	-	0,01	7,4	-	5,9	-		
	3-6 cm	160	-	7,8	0,8	-	0,02	8,4	-	7,4	-		

-: not analysed      Cd is not detected      Cr not analysed in 1996

## Biology

The water depth and sediment structure in the investigated area is reflected in a relatively uniform fauna. The polychaete *M. oculata* dominated at most of the stations (6-51%), while *E. deformis*, *D. arietina* and *A. filiformis* were found from 3 to 16% at some stations.

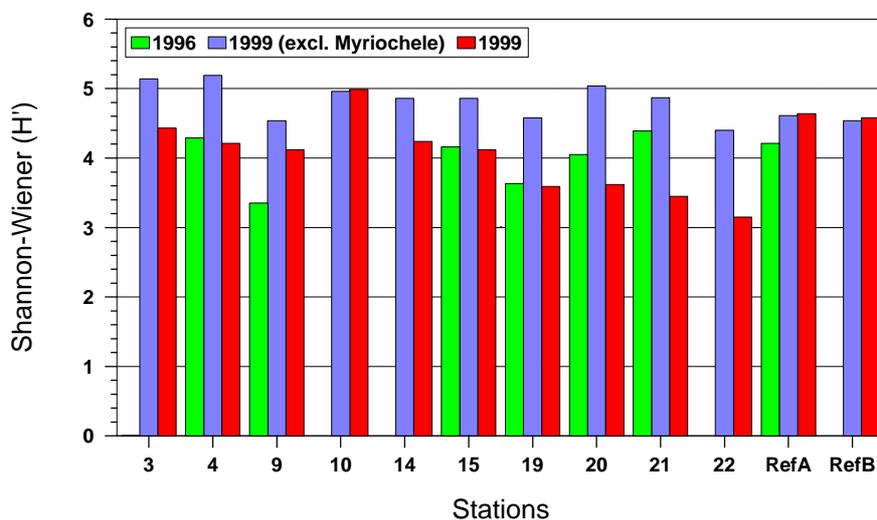
The abundance of *M. oculata* was highest in the 135° direction at 1000, 2000 and 4000m stations. This species clearly affects the diversity, as shown in the table below.

*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 stations at Ula 1999. Incl / excl. M. oculata.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
3 - 45°/2000m	72	876/603	80	4.4/5.1	0.7/0.8	31.8/37.5
4 - 45°/1000m	70	872/548	83	4.2/5.2	0.6/0.8	30.6/37.9
9 - 225°/1000m	69	1046/753	82	4.1/4.5	0.6/0.7	27.2/31.1
10 - 225°/2000m	72	884/832	85	5.0/5.0	0.8/0.8	34.2/34.2
14 - 315°/1000m	69	1089/748	90	4.2/4.9	0.6/0.7	29.0/34.2
15 - 315°/2000m	70	1091/714	84	4.1/4.9	0.6/0.8	27.9/33.7
19 - 135°/500m	72	1202/682	80	3.6/4.6	0.6/0.7	23.1/29.6
20 - 135°/1000m	72	1326/691	96	3.6/5.0	0.5/0.8	26.2/36.6
21 - 135°/2000m	70	1241/625	77	3.4/4.9	0.5/0.8	24.3/33.4
22 - 135°/4000m	70	1047/513	65	3.1/4.4	0.5/0.7	21.0/30.3
RefA- 315°/6000m	71	725/665	83	4.6/4.6	0.7/0.7	30.2/30.6
RefB	71	662/655	78	4.6/4.5	0.7/0.7	30.8/30.3

TECHNICAL REPORT

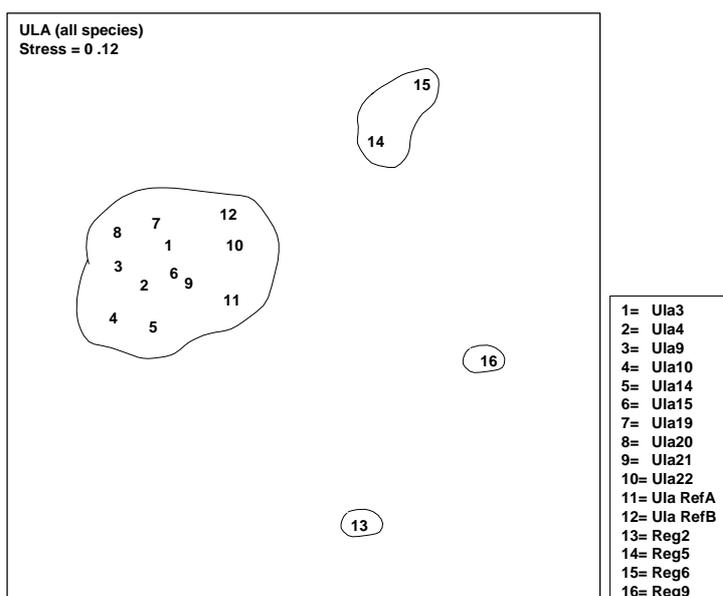
The number of species has increased at all stations since 1996 and the diversity (excl. *M. oculata*) is generally higher in 1999 than in 1996.



Shannon-Wiener diversity index ( $H'$ ) at Ula, 1996 and 1999.

No regular discharges have been reported since 1996, and the only station that has elevated THC and Ba level was station 19 (135/500m). Biologically this station did not differ from the others.

The polychaete *Myriochele oculata* dominates the fauna at Ula and hence “controls” the diversity. The distribution of this species seems not to follow any gradient from any centre of installation at Ekofisk, and can dominate close to an installation as well as 2000 or 4000m from a centre. Disregarding *Myriochele oculata*, the fauna in the investigated area (only one station closer than 1000m from the installation) is regarded as undisturbed. The multivariate analyses support the impression of an unaffected macrobenthic community.



MDS-plot at station level, Ula 1999. 4<sup>th</sup> root transformation.

## TECHNICAL REPORT

### 4.3 Gyda

The sediments at Gyda consist in average of 3,5 % pelite. The pelite concentration has slightly increased since the previous survey in 1996, but is similar to the average at the Regional stations. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0,61 % to 0,78 %. The results are similar to 1996.

The THC levels are low, and the mean concentrations vary from 3,4 mg/kg to 9,2 mg/kg. Only one station has elevated THC concentrations, station 19, 135°/500m. At this station the vertical transport of hydrocarbons has increased since 1996. 15,0 mg/kg and 16,6 mg/kg are found in the 1-3 cm layer and the 3-6 cm layer respectively. No elevated levels are observed at station 9, 225°/1000m, the most contaminated station in 1996. Apart from the decrease in the THC concentration at station 9 and the vertical transport at station 19, only minor changes since 1996 are observed. The NPD concentrations are slightly elevated at both stations analysed, station 19 and station 21, and an increase is observed since 1996. Elevated NPD and PAH concentrations are also found in the 1-3 cm sediment layer at station 19. Decalins are also found at station 19, with the highest concentrations in the 3-6 cm layer. This result is similar to 1996.

The Ba concentrations vary from 29 mg/kg at station 3, 45°/2000m to 379 mg/kg at station 19, 135°/500m. Elevated Ba concentrations are found at three stations in the 135° direction, at 500m, 1000m and 2000m. The Ba levels have decreased since 1996. A vertical transport of Ba down in the sediment is observed. The concentrations of the heavy metals are low, and elevated concentrations are not found.

The chemical results are in accordance with the reduced drilling activities at Gyda since the last survey. However, the NPD and decalin concentrations are still relatively high.

**Table 4.3.1.** Gyda, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Pelite		TOM		THC		NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.3 45°/2000 m	4,0	1,3	0,65	0,68	3,4	3,9	-	-	-	-	-	-
St.4 45°/1000 m	4,5	1,9	0,62	0,68	3,6	6,6	-	-	-	-	-	-
St.9 225°/1000 m	1,7	2,9	0,68	0,80	4,4	25,7	-	-	-	-	-	-
St.10 225°/2000 m	3,7	2,8	0,67	0,80	3,4	7,3	-	-	-	-	-	-
St.15 315°/1000 m	3,3	3,2	0,69	0,75	4,0	8,5	-	-	-	-	-	-
St.16 315°/ 500 m	3,3	2,1	0,78	0,71	4,1	3,0	-	-	-	-	-	-
St.19 135°/ 500 m	2,5	2,8	0,61	0,65	9,2	7,4	0,043	0,012	0,028	0,028	0,401	0,304
1-3 cm					15,0	2,2	0,187	0,010	0,155	0,023	0,456	0,504
3-6 cm					16,6	9,9	0,025	0,035	0,010	0,174	0,834	1,720
St.20 135°/1000 m	3,3	2,4	0,72	0,70	7,4	5,5	-	-	-	-	-	-
St.21 135°/2000 m	4,8	1,4	0,73	0,84	4,3	3,6	0,078	0,007	0,040	0,044	nd	0,091
1-3 cm					4,8	3,8	0,021	0,006	0,040	0,047	nd	0,133
3-6 cm					5,5	8,4	0,026	0,033	0,040	0,158	0,060	0,249
Ref. 315°/8000 m	3,7	3,0	0,74	0,97	3,7	5,6	0,018	0,015	0,038	0,056	nd	0,075
1-3 cm					3,0	4,4	0,016	0,026	0,031	0,093	nd	0,136
3-6 cm					4,6	7,0	0,018	0,019	0,037	0,078	nd	0,074

-: not analysed      nd: not detected

## TECHNICAL REPORT

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

Station		Ba		Cd	Cr		Cu		Hg	Pb		Zn	
		1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996	
St.3	45°/2000 m	29	111	nd	6,0	<0,3	<0,6	-	6,2	6,4	4,4	4,9	
St.4	45°/1000 m	60	290	nd	5,7	1,0	<0,6	-	6,3	6,1	4,1	8,1	
St.9	225°/1000 m	105	482	nd	6,2	0,7	1,2	-	6,3	5,6	4,7	11,7	
St.10	225°/2000 m	42	226	nd	6,5	0,4	0,9	-	6,0	6,3	4,3	7,1	
St.15	315°/1000 m	60	215	nd	6,5	0,8	<0,6	-	7,0	6,6	4,6	5,3	
St.16	315°/ 500 m	84	218	nd	6,6	0,6	1,1	-	7,4	6,5	5,6	6,2	
St.19	135°/ 500 m	379	935	nd	6,1	0,7	1,0	nd	6,2	5,7	5,3	5,7	
	1-3 cm	382	-	nd	6,0	0,6	-	0,01	5,7	-	4,6	-	
	3-6 cm	320	-	0,03	6,5	0,5	-	0,03	5,6	-	6,8	-	
St.20	135°/1000 m	189	219	0,03	6,4	0,5	<0,6	-	6,5	5,9	4,7	5,0	
St.21	135°/2000 m	159	167	0,02	7,0	0,5	<0,6	0,02	7,1	6,2	4,7	5,0	
	1-3 cm	103	-	0,02	7,2	0,5	-	0,02	6,9	-	4,6	-	
	3-6 cm	276	-	0,02	7,4	0,7	-	0,02	8,5	-	7,2	-	
Ref.	315°/8000 m	47	63	nd	7,1	0,5	0,6	0,02	6,5	6,0	5,5	5,8	
	1-3 cm	46	-	nd	6,9	0,5	-	0,01	6,7	-	4,5	-	
	3-6 cm	112	-	0,02	7,7	0,7	-	0,02	7,1	-	6,7	-	

-: not analysed    nd: not detected    Cr not analysed in 1996

**Biology**

The 10 most abundant species make up from 52% to 79,6%. The polychaete *Myriochele oculata* was extremely dominating at all stations, while *Eudorellopsis deformis*, *Ditrupea arietina* and *Amphiura filiformis* were found to be common at most of the stations. The number of *M. oculata* was extremely high and more than 2000 individuals were collected at each station except for the reference stations where the density was some lower. *M. oculata* clearly affects the diversity (see table below).

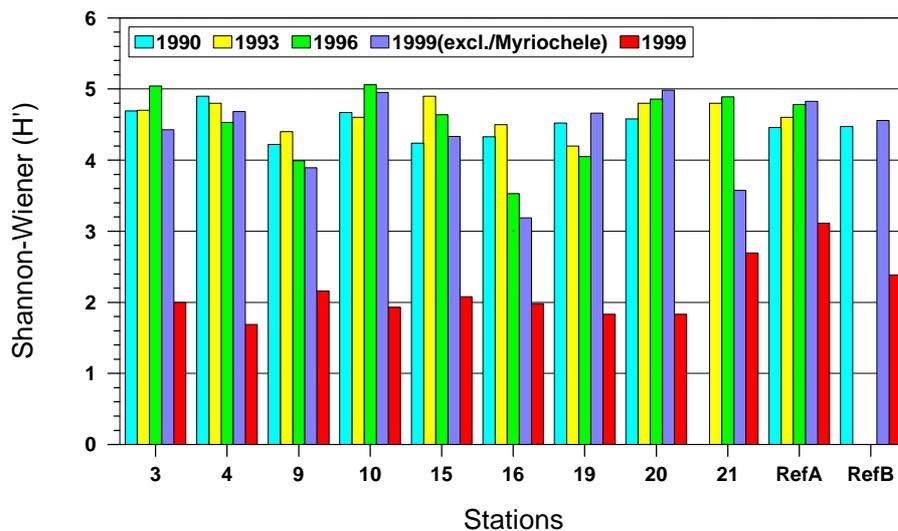
*Number of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J) and expected number of species per 100 individuals (ES<sub>100</sub>) for each stations at Gyda 1999.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
3 - 45° /2000	66	2762/727	69	2.0/4.4	0.3/0.7	15.3/31.5
4 - 45° /1000	67	3535/723	77	1.7/4.7	0.3/0.8	13.7/31.5
9 - 225°/ 1000	65	3579/1154	81	2.2/3.9	0.3/0.6	14.9/26.7
10 - 225°/ 2000	67	3516/817	83	1.9/5.0	0.3/0.8	15.9/34.2
15 - 315° /1000	67	2750/775	73	2.1/4.3	0.3/0.7	15.4/30.4
16 - 315° /500	67	4160/1387	76	2.0/3.2	0.3/0.5	12.7/22.8
19 - 135° /500	67	3194/726	70	1.8/4.7	0.3/0.8	14.7/31.1
20 - 135° /1000	67	3077/665	82	1.8/5.0	0.3/0.8	15.3/35.3
21 - 135° /2000	67	2244/1064	87	2.7/3.6	0.4/0.6	17.6/26.9
RefA - 315°/8000	67	1037/456	74	3.1/4.8	0.5/0.8	23.0/36.1
RefB - 315°/8000	67	1108/359	61	2.4/4.6	0.4/0.8	17.8/33.0

## TECHNICAL REPORT

The diversity indices (incl. *M. oculata*) were very low at all stations, even at the reference station. However, when excluding *M. oculata* from the data the diversity indices varied from 3.2 to 5.0.

The number of species has increased from previous surveys. The diversity indices (excl. *M. oculata*) did not follow the same trend. At some stations the diversity has increased, while at other the diversity has declined. The decline was considerable at stations 16 and 21.



Shannon-Wiener diversity index ( $H'$ ) at Gyda, 1990, 1993, 1996 and 1999.

The multivariate analyses support the impression of a uniform macrobenthic community, and stations 16, 21 and 9 (where the diversity was somewhat lower) did not differ from the others in the analyses.

The THC and metal levels are generally low with elevated THC and Ba concentrations at station 19. However, biologically this station does not differ from the others.

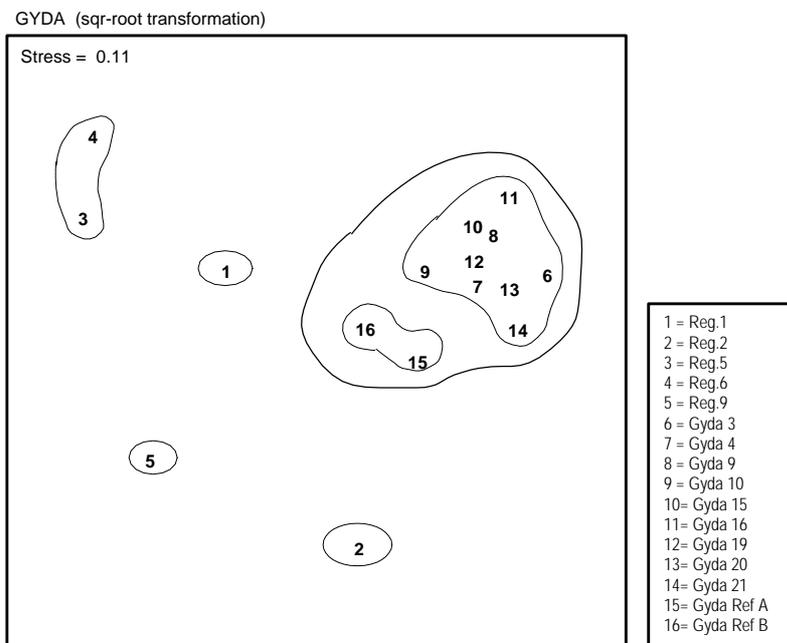
The dendrogram and MDS plot were similar when carrying out the same analyses excluding the dominant species *M. oculata*, and when using a more gentle transformation as square root-transformation. The results are in accordance with the 1996 survey, where a CCA-analysis shows a gradient that was unlikely to be related to field effects (Mannvik et. al.1997).

Since 1996 the discharges have been reduced, and the concentrations of THC and metals have decreased. The three innermost stations were regarded as moderately disturbed in 1996, and two of these stations that are investigated in the present survey (stations 9 and 16) can still be regarded as disturbed.

All in all the macrofauna at Gyda field is dominated by the polychaete *M. oculata*. This species “controls” the diversity. Excluding this species from the analyses results in relatively high diversity indices at most stations. Stations 16 (315°/500m), 21 (135°/2000m) and 9 (225°/1000m), however, have all somewhat reduced diversity, but only station 21 have an

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elevated concentration of NPD. The conclusion from the survey is that the macrofauna can be regarded as undisturbed, except for three stations where reduced diversity indicates disturbance.



MDS-plot at station level, Gyda 1999. 4<sup>th</sup> root transformation.

#### 4.4 Valhall

The sediments at Valhall consist in average of 4,1 % pelite. The average pelite concentration is the same as in the previous survey in 1996, but a slight decrease is observed at the reference station. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,4 % to 1,1 %. The results are similar to 1996.

The mean THC concentrations vary from 5,1 mg/kg at the reference station to 65 mg/kg at station 9, 164°/1000m. Elevated THC concentrations are found out to 2000 m distance.

Olefins are not detected in any of the samples. This is a reduction since 1996, when the highest concentrations found were 88 mg/kg at station 16\*, 254°/1000m.

Compared to the 1996 survey, a pronounced reduction in the THC concentration is observed at station 16\*, 254°/1000m, from 137 mg/kg in 1996 to 34 mg/kg in 1999. This is probably due to the reduction in the olefin concentration, as olefins are included in the THC results. A slight increase in the THC content is observed at station 9, 164°/1000m, from 42 mg/kg in 1996 to 65 mg/kg in 1999. At the other stations the THC concentrations are similar to 1996. THC contamination is also found in the vertical sediment layers at station 9, 164°/1000m, and the concentrations have increased since 1996.

Elevated levels of NPD, PAH and decalins are found at station 9, 164°/1000m, in the top 0-1 cm layer and in the 1-3 cm and 3-6 cm layers as well. The concentrations are generally similar to 1996.

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The Ba concentrations vary from 47 mg/kg at the reference station to 2160 mg/kg at station 9, 164°/1000m. Elevated Ba concentrations are found at all stations, except for the reference station. This means out to 2000m in the 344° direction, out to 4000m in the 74° and 254° directions and out to 6000m in the 164° direction. A slight decrease is observed since 1996, however, the Ba concentrations are still relatively high. A vertical transport of Ba down in the sediment is observed. The concentrations of the heavy metals are low, and slightly elevated concentrations of Zn and Pb are found at some stations.

The chemical results are not quite in correspondence with the drilling history at Valhall. Olefins are not found in the sediments, although discharges are reported. This may indicate that the olefins used, Novaplus, have been degraded.

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

Station	Pelite		TOM		THC		Olefins		NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.4 74°/2000 m	5,5	4,0	0,41	0,87	10,8	14,9	nd	1,7	-	-	-	-	-	-
St.5 74°/4000 m	1,3	4,5	0,74	0,86	7,9	7,6	-	-	-	-	-	-	-	-
St.9 164°/1000 m	4,1	4,7	0,90	1,09	65,0	41,8	nd	3,0	0,084	0,078	0,080	0,074	0,782	0,476
1-3 cm					80,5	50,7	nd		0,105	0,141	0,156	0,096	2,040	1,310
3-6 cm					48,7	11,4	nd		0,090	0,054	0,165	0,122	1,320	0,192
St.10 164°/2000 m	3,4	3,6	0,76	0,89	11,0	13,2	nd	0,3	-	-	-	-	-	-
St.11 164°/4000 m	4,5	5,3	0,79	0,87	8,5	7,3	-	-	-	-	-	-	-	-
St.12 164°/6000 m	2,4	3,6	0,71	0,81	5,7	5,7	-	-	0,011	0,020	0,034	0,035	nd	nd
1-3 cm					6,2	6,1			0,012	0,024	0,036	0,139	nd	nd
3-6 cm					8,7	8,2			0,026	0,029	0,064	0,054	nd	nd
St.16* 254°/1000 m	4,5	3,6	0,90	1,15	34,0	137	nd	88,2	-	-	-	-	-	-
St.16 254°/2000 m	4,7	-	0,69	-	10,2	-	nd	-	-	-	-	-	-	-
St.17 254°/4000 m	4,2	4,3	0,71	0,84	6,7	6,8	nd	-	-	-	-	-	-	-
St.22 344°/1000 m	4,8	5,4	0,84	0,99	14,9	22,4	-	1,4	-	-	-	-	-	-
St.23 344°/2000 m	6,1	4,1	1,13	0,95	8,2	8,7	-	-	-	-	-	-	-	-
Ref. 254°/15000 m	3,2	4,7	0,74	0,81	5,1	6,1	-	-	0,015	0,028	0,048	0,049	nd	0,055
1-3 cm					6,4	3,7			0,020	0,054	0,063	0,059	nd	0,119
3-6 cm					7,2	5,5			0,026	0,051	0,085	0,085	nd	0,056

-: not analysed      nd: not detected

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

Station	Ba		Cd	Cr	Cu		Hg	Pb		Zn	
	1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.4 74°/2000 m	578	1040	nd	7,5	0,8	0,8	-	9,8	8,9	7,6	3,7
St.5 74°/4000 m	139	182	nd	7,7	0,6	0,7	-	9,0	7,6	6,2	3,4
St.9 164°/1000 m	2160	2420	nd	7,8	1,2	1,2	0,02	10,8	10,3	8,7	6,1
1-3 cm	1910	-	nd	8,0	1,1	-	0,02	11,3	-	10,0	-
3-6 cm	989	-	0,02	9,6	1,2	-	0,03	11,4	-	11,7	-
St.10 164°/2000 m	533	756	nd	7,5	0,7	<0,6	-	11,5	11,5	7,0	3,5
St.11 164°/4000 m	129	159	nd	8,1	0,6	<0,6	-	9,5	8,0	6,6	2,9
St.12 164°/6000 m	52	94	nd	7,3	0,4	<0,6	0,02	7,2	6,4	5,4	2,5
1-3 cm	90	-	nd	7,6	0,5	-	0,08	7,7	-	6,2	-
3-6 cm	201	-	nd	8,0	0,6	-	0,02	8,0	-	6,8	-

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

St.16* 254°/1000 m	1050	2070	nd	9,2	1,9	1,6	-	11,5	10,9	12,2	7,8
St.16 254°/2000 m	405	-	nd	7,3	0,6	-	-	9,3	-	7,0	-
St.17 254°/4000 m	102	179	nd	7,8	0,5	0,6	-	9,3	7,8	6,4	3,0
St.22 344°/1000 m	1150	774	nd	8,3	1,2	0,9	-	11,6	11,0	10,7	5,5
St.23 344°/2000 m	220	452	0,03	8,7	1,2	0,8	-	8,5	10,0	10,4	3,6
Ref. 254°/15000 m	47	67	nd	8,1	0,5	0,6	0,02	8,1	7,0	6,1	3,3
1-3 cm	68	-	nd	8,1	0,5	-	0,02	8,3	-	6,4	-
3-6 cm	139	-	nd	8,8	1,0	-	0,02	9,3	-	8,1	-

-: not analysed    nd: not detected    Cr not analysed in 1996

**Biology**

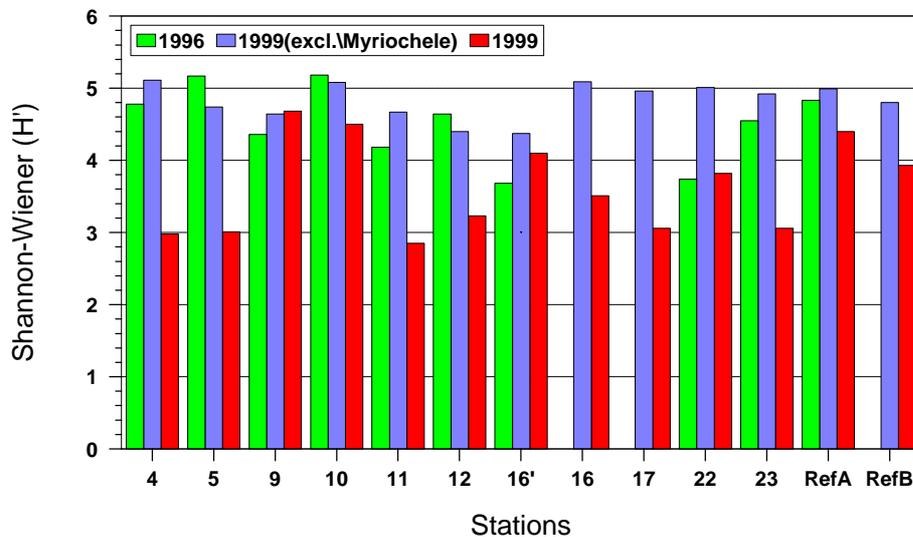
The 10 most abundant species made up from 65% to 85%. The polychaete *Myriochele oculata* dominated at nearly all stations, while *Eudorellopsis deformis*, *Ditrupa arietina* and *Amphiura filiformis* were found to be common on most of the stations. This species clearly affects the diversity, see table below.

Depth, number of individuals (N) and species (S), 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, VALHALL 1999. incl./ excl. *M. oculata*.

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
4 – 74°/2000m	69	1684/663	71	3.0/5.1	0.5/0.8	23.3/35.4
5 – 74°/4000m	68	1046/447	60	3.0/4.7	0.5/0.8	22.1/32.7
9 – 164°/1000m	71	679/632	66	4.7/4.6	0.8/0.8	32.7/32.8
10 – 164°/2000m	72	879/630	67	4.5/5.1	0.7/0.8	32.2/36.5
11 – 164°/4000m	71	900/361	57	2.9/4.7	0.5/0.8	20.9/32.4
12 – 164°/6000m	71	726/367	49	3.2/4.4	0.6/0.8	21.8/29.0
16* - 254°/1000m	70	861/651	58	4.1/4.4	0.7/0.8	25.8/28.3
16 – 254°/2000m	69	1042/514	68	3.5/5.1	0.6/0.8	26.5/36.9
17 – 254°/4000m	69	1341/562	71	3.1/5.0	0.5/0.8	23.6/35.9
22 – 344°/1000m	72	1036/586	67	3.8/5.0	0.6/0.8	27.5/35.1
23 – 344°/2000m	72	1470/620	80	3.1/4.9	0.5/0.8	23.1/36.2
RefA – 254°/15000m	70	572/404	75	4.4/5.0	0.7/0.8	32.7/38.9
RefB – 254°/15000m	70	700/433	69	3.9/4.8	0.6/0.8	26.9/33.6

The diversity index (incl. *M. oculata*) varied from 2.9 to 4.7. However, when removing *M. oculata* from the data the diversity index ranged from 4.4 to 5.1. Numbers of species and individuals have decreased at nearly all stations since 1996, but the diversity index (exclusive *M. oculata*) is quite similar to previous surveys.

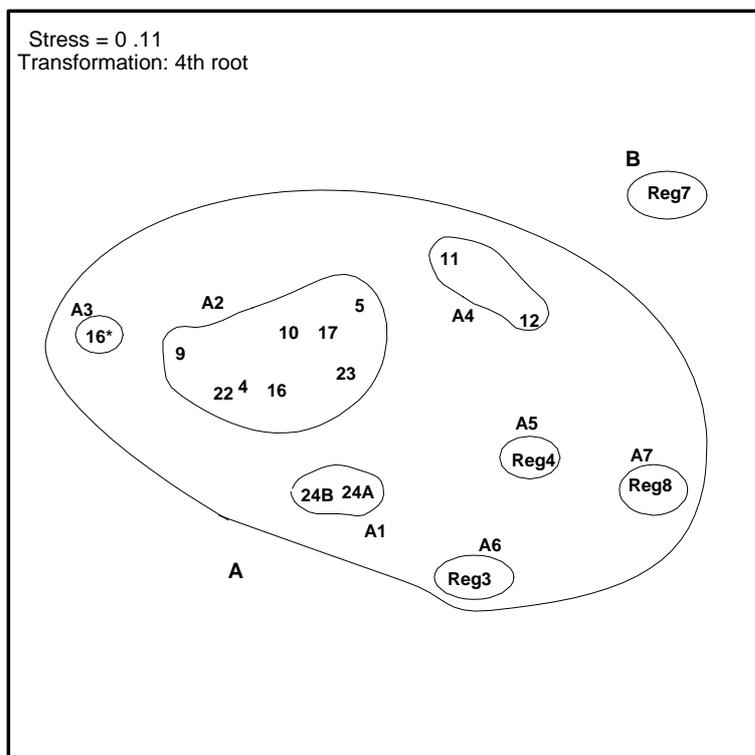
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Shannon-Wiener diversity index ( $H'$ ) at Valhall, 1996 and 1999.

Several stations have elevated levels of THC and Ba. However, no clear correlation can be seen between elevated concentrations of Ba and THC and the diversity indices.

The results indicate a quite uniform macrobenthic community in the 1000 and 2000m distances from the platform. Despite elevated Ba and THC concentrations at stations 16\*, 9 and 22, the fauna differ only slightly from the other stations, and a significant environmental affect has not been possible to detect at Valhall.



MDS-plot at station level, Valhall 1999.

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## 4.5 Hod

The sediments at Hod consist in average of 4,4 % pelite. The pelite concentration has decreased on all stations, except station 8, 164°/500m since 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,5 % to 1,1 %. The results are similar to 1996.

The mean THC concentrations vary from 3,9 mg/kg at the reference station to 135 mg/kg at station 8, 164°/500m. Elevated THC concentrations are found out to 2000 m distance in one of the directions. At the two other 2000m stations and at a 4000m station elevated THC levels are not found, however, olefins are clearly seen in the chromatograms. The sediments at all stations are thus affected by hydrocarbons. Compared to the 1996 survey an increase in the THC concentration is observed at station 8, 164°/500, from 65 mg/kg in 1996 to 135 mg/kg in 1999. A decrease in the THC concentration is observed at station 9, 164°/1000m, from 39 mg/kg in 1996 to 13 mg/kg in 1999. Elevated THC concentrations are found in the vertical sediment layers at station 8, 164°/500m, at the same level as in 1996.

Olefins are found at the four stations analysed, from 1,2 mg/kg to 7,8 mg/kg. This is generally the same level as in 1996. Olefins are also found in the sediment layers at station 8, 164°/500m.

Elevated levels of NPD, PAH and decalins are found at station 8, 164°/500m, down to 6 cm in the sediment layer. The decalin concentrations are high, and thus confirm the presence of drilling mud base oil in the sediments. The concentrations are generally similar to 1996. At the reference station, 180°/15000m elevated NPD and PAH levels are found in the 3-6 cm layer due to the presence of phenanthrene/anthracene. In this sample elevated PAH levels were also found in 1996.

The Ba concentrations vary from 31 mg/kg at the reference station 180°/15000m to 1600 mg/kg at station 8, 164°/500m. Elevated Ba concentrations are found at all stations, except for station 16, 254°/2000m and the reference station. This means out to 1000m in the 254° direction, out to 2000m in the 74° direction and out to 4000m in the 164° direction. A slight decrease is observed since 1996. A vertical transport of Ba down in the sediment is observed. The concentrations of the heavy metals are low, and slightly elevated concentrations of Pb and Zn are found at one station.

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

**Table 4.5.1. Hod, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

Station	Pelite		TOM		THC		Olefins		NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.3 74°/1000 m	6,5	7,6	0,94	1,29	13,2	7,6	1,2	0,3	-	-	-	-	-	-
St.4 74°/2000 m	4,8	-	0,84	-	9,1	-	-	-	-	-	-	-	-	-
St.8 164°/ 500 m	6,6	6,2	1,05	1,18	135,1	64,7	7,8	2,2	0,221	0,329	0,074	0,089	4,710	3,390
1-3 cm					58,5	54,0	2,37	-	0,130	0,427	0,160	0,085	2,110	4,340
3-6 cm					46,5	88,7	1,61	-	0,141	0,470	0,201	0,139	1,480	2,110
St.9 164°/1000 m	4,7	9,7	0,95	1,02	12,6	39,0	1,5	3,6	-	-	-	-	-	-
St.10 164°/2000 m	4,3	7,9	0,88	0,94	8,6	7,4	-	0,2	-	-	-	-	-	-
St.11 164°/4000 m	4,1	4,9	0,89	0,91	6,6	6,1	-	0,1	0,018	0,026	0,056	0,054	nd	0,072
1-3 cm					5,8	8,3			0,016	0,035	0,043	0,220	nd	0,089
3-6 cm					7,7	10,7			0,022	0,042	0,056	0,173	nd	0,094

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**Table 4.5.1 cont. Hod, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

St.15 254°/1000 m	2,4	4,7	0,76	0,89	9,2	7,3	1,3	0,3	-	-	-	-	-	-
St.16 254°/2000 m	1,8	-	0,47	-	7,5	-	-	-	-	-	-	-	-	-
St.20 344°/ 500 m	4,6	6,5	0,51	1,17	10,3	12,7	-	0,6	-	-	-	-	-	-
Ref. 180°/15000 m	3,6	5,8	0,71	0,92	3,9	5,3	-	-	0,013	0,020	0,038	0,081	nd	nd
1-3 cm					3,8	6,2	-	-	0,014	0,024	0,040	0,104	nd	0,061
3-6 cm					6,2	7,2	-	-	0,245	0,029	0,323	0,114	nd	0,075

-: not analysed      nd: not detected

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

Station	Ba		Cd	Cr	Cu		Hg	Pb		Zn	
	1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.3 74°/1000 m	318	400	nd	7,7	0,7	0,6	-	7,8	9,2	8,0	5,6
St.4 74°/2000 m	117	-	nd	7,3	0,5	-	-	6,3	-	7,2	-
St.8 164°/ 500 m	1600	1990	0,02	7,8	1,1	1,2	0,03	11,7	14,9	11,2	7,9
1-3 cm	1680	-	0,03	8,8	1,3	-	0,03	12,9	-	13,1	-
3-6 cm	1780	-	0,04	9,9	1,4	-	0,04	13,3	-	17,4	-
St.9 164°/1000 m	332	515	nd	7,8	0,6	0,8	-	7,3	8,7	7,5	4,3
St.10 164°/2000 m	152	356	nd	8,0	0,6	0,8	-	7,4	9,0	7,7	4,9
St.11 164°/4000 m	106	298	nd	8,0	0,6	0,6	0,02	6,3	7,2	7,3	3,9
1-3 cm	150	-	nd	8,2	0,6	-	0,02	6,5	-	7,7	-
3-6 cm	147	-	nd	7,9	0,6	-	0,02	6,2	-	7,1	-
St.15 254°/1000 m	200	376	nd	6,8	0,6	0,7	-	6,7	8,3	6,6	3,8
St.16 254°/2000 m	82	-	nd	6,2	0,5	-	-	7,8	-	5,8	-
St.20 344°/ 500 m	321	284	nd	6,8	0,7	0,7	-	9,1	8,9	6,5	3,5
Ref. 180°/15000 m	31	48	nd	6,6	0,4	0,7	0,01	6,2	6,4	5,3	3,6
1-3 cm	29	-	nd	6,8	0,4	-	0,01	6,3	-	5,3	-
3-6 cm	53	-	nd	7,2	0,5	-	0,02	6,7	-	5,9	-

-: not analysed      nd: not detected      Cr not analysed in 1996

**Biology**

The number of species per station varied from 55 to 83, while the number of individuals per station varied from 388 to 1438. A total of 9074 individuals were identified to 181 taxa. The polychaete *Myriochele oculata* dominated at most of the stations (12 to 63%), while *Eudorellopsis deformis*, *Ditrupa arietina* and *Amphiura filiformis* were found from 3 to 21% at some stations.

The number of *M. oculata* was highest in the 74°-direction at 1000 and 2000m, and in the 164°-direction at 1000, 2000 and 4000m. The high abundance of this species clearly affects the diversity, see table below.

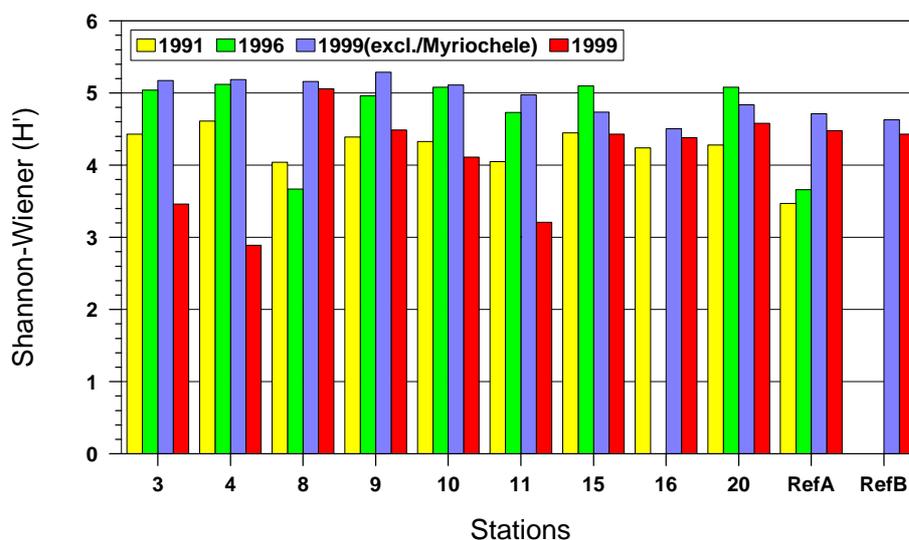
The diversity index (incl. *M. oculata*) varied from 2.9 to 5.1, and from 4.5 to 5.3 excluding the same species.

The numbers of species have increased at some stations compared to the survey in 1996 and at all stations (except RefA), compared to the investigation in 1991. The diversity (excl. *M. oculata*) is generally higher in 1999 than in 1991 and 1996.

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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 ( $ES_{100}$ ) for each station at Hod 1999.

Station	Depth	N	S	$H'$	$J'$	$ES_{100}$
3 – 74°/1000m	72	1211/576	77	3.5/5.2	0.6/0.8	26.2/37.4
4 – 74°/2000m	71	1438/538	76	2.9/5.2	0.5/0.8	23.1/39.0
8 – 164°/500m	71	771/677	82	5.1/5.2	0.8/0.8	36.1/37.5
9 – 164°/1000m	72	845/572	83	4.5/5.3	0.7/0.8	33.2/39.4
10 – 164°/2000m	72	766/472	80	4.1/5.1	0.7/0.8	30.1/38.6
11 – 164°/4000m	70	1061/473	72	3.2/5.0	0.5/0.9	23.9/35.4
15 – 254°/1000m	72	701/540	74	4.4/4.7	0.7/0.8	31.2/35.1
16 – 254°/2000m	72	567/465	69	4.4/4.5	0.7/0.7	30.3/32.7
20 – 344°/500m	72	802/639	83	4.6/4.8	0.7/0.8	32.1/35.3
RefA – 180°/15000m	71	388/308	55	4.5/4.7	0.8/0.8	30.4/33.1
RefB – 180°/15000m	71	524/420	67	4.4/4.6	0.7/0.8	30.4/33.3



Shannon-Wiener diversity index ( $H'$ ) at Hod, 1996 and 1999.

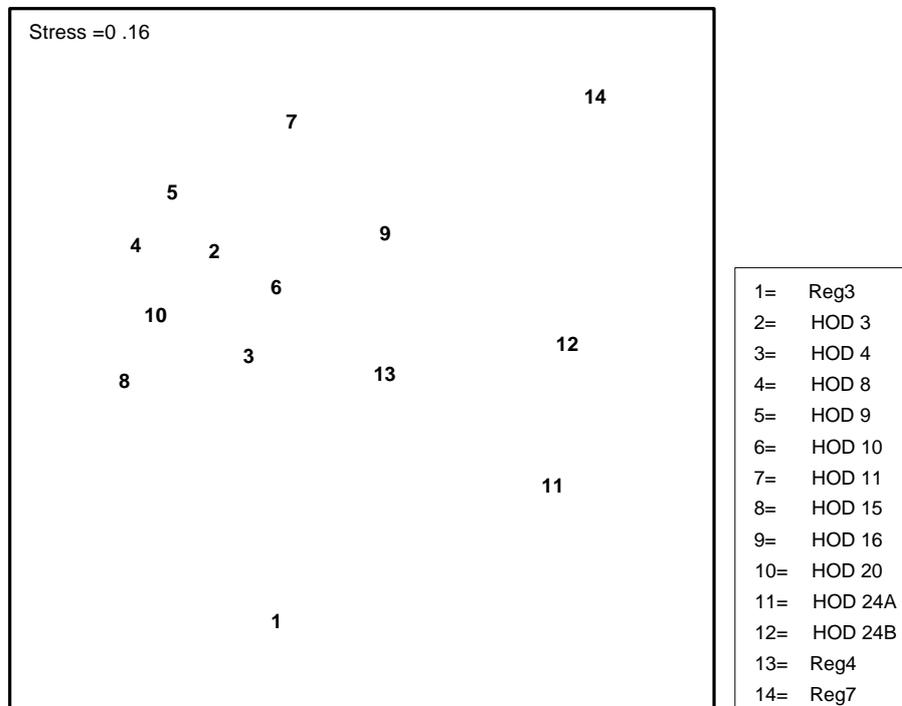
When excluding *M. oculata* from the data set the diversity indices indicates a healthy soft bottom community in the Hod area. Elevated levels of THC and Ba were seen at station 8 (164°/500m). However, biologically this station did not differ from the others. The diversity index was one of the highest in the Ekofisk survey.

The multivariate analyses did not reveal any major differences among the Hod stations, and there were no strong correlations between the fauna composition and environmental variables such as sediment chemistry (THC, metals), depth, grain size and organic content.

In the 1996 survey station 8 was characterized as moderately disturbed and all others as slightly disturbed. None of the stations in the 1999 survey can be characterized as moderate disturbed. Stations 3, 8, 9 and 20 are grouped together as a subgroup (similarity about 75%) and are situated around the centre of the installation, but neither the diversity nor the species composition indicate any disturbance at these stations. The diversity indices are even higher at these stations than the reference stations.

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HOD, 4th root transformation



MDS-plot at station level, Hod 1999. 4th root transformation.

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

The sediments at Ekofisk Centre 2/4 B&K consist in average of 4,9 % pelite. The average pelite concentration is the same in 1999 as in 1996, but the amount of pelite at the reference station has increased since the 1996 survey. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,8 % to 1,2 %. The results are similar to 1996.

The mean THC concentrations vary from 5,5 mg/kg at the reference station, Ref. 42 90°/15000m to 51,6 mg/kg at station 14, 140°/850m. Elevated THC concentrations are found at all stations, except for the two stations at 3900m and 5800m respectively, however, olefins are clearly seen in the gas chromatograms. The sediments at all stations are thus affected by hydrocarbons. The THC levels are similar to the 1996 results. A tendency of higher THC concentrations in the layer samples than in the top 0-1 cm layer is observed.

Olefins are found at the four stations analysed, from 0,9 mg/kg to 2,9 mg/kg.

The tendency of higher concentrations in the layer samples is also observed for NPD, PAH and decalins. Some of the concentrations are elevated at station 11, 144°/4400m, station 14, 140°/850m and station 32, 180°/500m.

The mean Ba concentrations vary from 41 mg/kg at the reference station, Ref 42 90°/15000m to 1920 mg/kg at station 32, 180°/500m. Elevated Ba concentrations are found at all stations, except for the reference station. A decrease is observed since 1996, however the concentrations

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are still high. At 11 of the 18 stations sampled the Ba concentrations are above 1000 mg/kg, and elevated concentrations are observed out to 5800m distance. The highest Ba concentrations are found in the 1-3 cm layer and 3-6 cm layer at station 14, 140°/850m, 2740 mg/kg and 3700 mg/kg respectively. The concentrations of the heavy metals are low, however some elevated concentrations are found at several stations.

The chemical results agree with the drilling history at Ekofisk Centre 2/4 B&K. Pseudo-oil based drilling fluids (olefins) and baryte are discharged since the last survey in 1996. The discharge of baryte is reduced in 1999 compared to the previous years.

**Table 4.6.1.** Ekofisk Centre and 2/4 B&K, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Pelite		TOM		THC		Olefin	NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996		1999	1996	1999	1996	1999	1996
St.2 3°/3300 m 2/4 T	4,1	-	0,91	-	12,2	-	-	-	-	-	-	-	-
St.7 74°/3900 m 2/4 T	4,9	-	0,77	-	6,9	-	-	-	-	-	-	-	-
St.8 84°/1800 m 2/4 T	6,3	4,6	1,03	1,06	12,2	10,4	-	-	-	-	-	-	-
St.10 137°/5800 m 2/4 T	4,4	-	0,85	-	7,5	-	-	-	-	-	-	-	-
St.11 144°/4400 m 2/4 T	4,1	3,5	1,18	0,86	9,7	8,3	-	0,017	0,019	0,060	0,042	nd	0,065
1-3 cm					10,8	17,8	-	0,022	0,051	0,070	0,111	nd	0,131
3-6 cm					15,9	21,6	-	0,040	0,055	0,158	0,142	0,082	0,174
St.12 148°/2500 m 2/4 T	7,7	5,7	1,17	1,11	16,4	15,9	-	-	-	-	-	-	-
St.13 146°/1300 m 2/4 T	5,3	5,1	1,14	1,11	16,0	15,3	-	-	-	-	-	-	-
St.14 140°/ 850 m 2/4 T	3,2	5,6	0,99	1,31	51,6	25,8	-	0,026	0,252	0,055	0,500	0,233	0,172
1-3 cm					47,4	204	-	0,058	0,123	0,100	0,163	0,871	0,204
3-6 cm					100,0	246	-	0,168	0,072	0,291	0,335	0,642	0,246
St.17 217°/4000 m 2/4 T	4,3	-	0,84	-	9,0	-	-	-	-	-	-	-	-
St.18 208°/2500 m 2/4 T	5,0	4,7	0,94	1,04	12,3	18,3	-	-	-	-	-	-	-
St.22 288°/1900 m 2/4 T	5,9	-	1,04	-	15,7	-	-	-	-	-	-	-	-
St.23 290°/1000 m 2/4 T	5,3	4,9	0,93	1,16	13,8	20,9	-	-	-	-	-	-	-
St.28 360°/1000 m 2/4 K	3,0	-	0,91	-	12,0	-	-	-	-	-	-	-	-
St.32 180°/ 500 m 2/4 K	4,3	5,2	1,07	1,29	19,4	37,8	2,9	0,060	0,153	0,042	0,124	0,157	0,454
1-3 cm					4,0	54,2	-	0,010	0,173	0,008	0,098	nd	1,120
3-6 cm					5,7	30,2	-	0,043	0,068	0,008	0,117	0,115	0,541
St.33 180°/1000 m 2/4 K	6,0	3,2	0,90	1,45	13,3	43,8	1,5	-	-	-	-	-	-
St.34 270°/1000 m 2/4 K	4,5	4,7	0,94	0,98	11,9	12,3	0,9	-	-	-	-	-	-
St 39 90°/1000 m 2/4 K	5,0	5,5	1,09	1,15	16,7	16,7	1,2	-	-	-	-	-	-
Ref.42 90°/15000 m 2/4 T	5,3	2,9	0,95	0,86	5,5	6,4	-	0,010	0,026	0,035	0,045	nd	0,053
1-3 cm					9,0	10,0	-	0,032	0,079	0,094	0,091	nd	0,075
3-6 cm					5,9	8,7	-	0,015	0,049	0,048	0,187	nd	0,088

-: not analysed    nd: not detected    Olefins not analysed in 1996

## TECHNICAL REPORT

**Table 4.6.2.** Ekofisk Centre and 2/4 B&K, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba		Cd	Cr	Cu		Hg	Pb		Zn	
	1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.2 3°/3300 m 2/4 T	568	-	nd	8,1	0,9	-	-	11,8	-	6,2	-
St.7 74°/3900 m 2/4 T	168	-	nd	7,7	0,6	-	-	7,7	-	3,4	-
St.8 84°/1800 m 2/4 T	1030	1510	nd	8,0	1,1	1,1	-	13,4	13,2	7,1	8,9
St.10 137°/5800 m 2/4 T	196	-	nd	7,4	0,7	-	-	8,7	-	6,2	-
St.11 144°/4400 m 2/4 T	362	890	nd	7,8	0,6	1,1	0,02	9,1	10,3	6,9	5,4
1-3 cm	920	-	nd	8,4	0,7	-	0,02	11,0	-	8,1	-
3-6 cm	906	-	0,03	9,1	1,1	-	0,02	10,4	-	11,0	-
St.12 148°/2500 m 2/4 T	1430	2150	0,02	8,3	1,5	3,2	-	15,4	13,9	11,7	9,0
St.13 146°/1300 m 2/4 T	1310	1540	nd	9,0	1,4	1,4	-	16,3	12,5	11,5	8,2
St.14 140°/ 850 m 2/4 T	1490	2410	nd	7,4	2,0	1,9	0,02	9,2	14,9	12,2	11,0
1-3 cm	2740	-	0,02	8,0	2,1	-	0,02	10,6	-	15,0	-
3-6 cm	3700	-	0,04	6,7	1,9	-	0,02	14,0	-	17,6	-
St.17 217°/4000 m 2/4 T	304	-	nd	7,0	1,4	-	-	9,0	-	6,7	-
St.18 208°/2500 m 2/4 T	778	738	nd	6,6	0,9	1,4	-	9,0	15,3	8,1	8,0
St.22 288°/1900 m 2/4 T	1360	-	nd	8,3	1,3	-	-	14,6	-	10,2	-
St.23 290°/1000 m 2/4 T	1190	2140	nd	7,6	1,1	1,4	-	11,8	14,4	10,1	9,3
St.28 360°/1000 m 2/4 K	1080	-	nd	8,1	1,2	-	-	14,6	-	9,8	-
St.32 180°/ 500 m 2/4 K	1920	3700	0,02	7,2	1,8	3,2	0,02	11,8	25,0	17,6	24,3
1-3 cm	563	-	0,02	4,6	0,5	-	<0,01	3,3	-	5,5	-
3-6 cm	357	-	nd	4,6	0,4	-	<0,01	3,2	-	4,0	-
St.33 180°/1000 m 2/4 K	1210	1400	nd	5,0	1,1	1,0	-	7,2	8,4	7,5	6,6
St.34 270°/1000 m 2/4 K	1030	1550	nd	8,1	1,2	1,2	-	12,7	12,3	11,1	7,3
St 39 90°/1000 m 2/4 K	1060	2830	nd	8,5	1,4	1,3	-	13,5	16,5	11,1	8,5
Ref.42 90°/15000 m 2/4 T	41	67	nd	7,1	0,5	<0,6	<0,01	6,1	6,2	4,7	3,0
1-3 cm	50	-	nd	7,2	0,5	-	<0,01	6,0	-	5,1	-
3-6 cm	141	-	nd	7,8	0,8	-	<0,01	7,3	-	5,8	-

-: not analysed    nd: not detected    Cr not analysed in 1996

## Biology

The number of species per station varied from 66 to 78, and the number of individuals varied from 548 to 1507. A total of 18931 individuals were identified to 184 taxa. The 10 most abundant species made up from 62% to 87%.

The polychaete *Myriochele oculata* dominated on all stations (18-69%), while *Eudorellopsis deformis*, *Levinsenia gracilis* and *Amphiura filiformis* were found up to 11% at some stations.

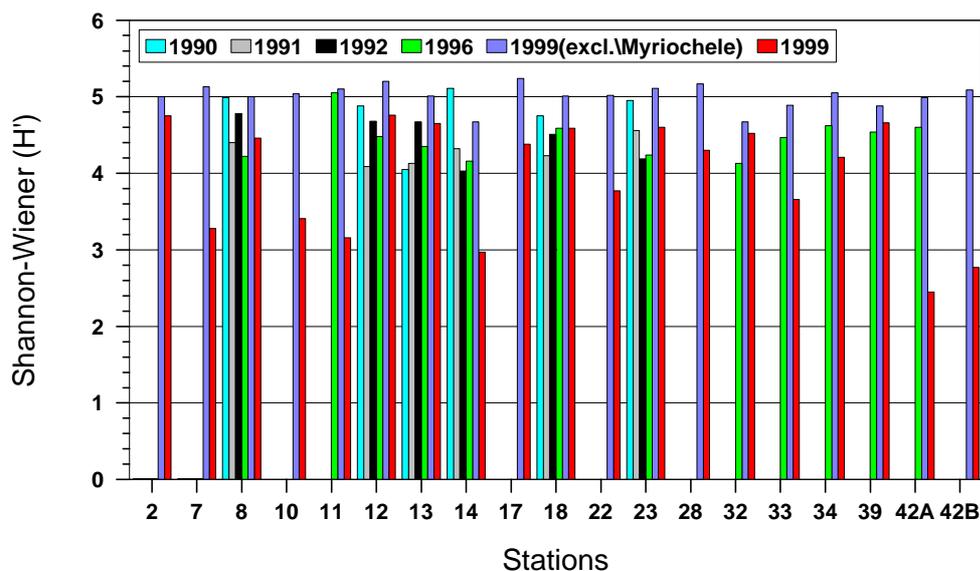
The number of *M. oculata* was highest in the 90° direction at 15000m, and in the 144° direction at 4400m. The high abundance of this species clearly affects the diversity index, see table below. When excluding *M. oculata* from the data, the diversity indices at all Ekofisk Centre stations are quite uniform; i.e. no stations stands out as obviously disturbed.

In general the number of individuals was higher in 1996 than in the 1999 survey. The diversity indices (excl. *M. oculata*) are generally higher in 1999 than in the other years.

## TECHNICAL REPORT

**Table 4.6.8.** Depth, number of individuals (*N*) and species (*S*), 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 Ekofisk Centre 1999. Incl. / excl. *M. oculata*.

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
2 – 3°/3300m	69	548/443	70	4.8/5.0	0.8/0.8	32.9/35.7
7 – 74°/3900m	69	922/412	66	3.3/5.1	0.5/0.9	25.5/37.2
8 – 84°/1800m	75	871/625	75	4.5/5.0	0.7/0.8	31.4/35.9
10 – 137°/5800m	70	1170/561	76	3.4/5.0	0.6/0.8	25.0/34.7
11 – 144°/4400m	70	1411/602	74	3.2/5.1	0.5/0.8	24.3/35.8
12 – 148°/2500m	74	804/614	73	4.8/5.2	0.8/0.8	34.0/37.3
13 – 146°/1300m	75	988/765	74	4.7/5.0	0.8/0.8	31.8/35.0
14 – 140°/850m	74	1376/585	66	3.0/4.7	0.5/0.8	21.1/31.5
17 – 217°/4000m	71	811/535	78	4.4/5.2	0.7/0.8	32.5/39.2
18 – 208°/2500m	74	666/503	72	4.6/5.0	0.7/0.8	31.7/35.4
22 – 288°/1900m	74	983/544	70	3.8/5.0	0.6/0.8	27.7/36.5
23 – 290°/1000m	72	874/644	76	4.6/5.1	0.7/0.8	32.6/36.7
28 – 0°/1000m	72	880/574	77	4.3/5.2	0.7/0.8	31.0/37.2
32 – 180°/500m	75	873/718	71	4.5/4.7	0.7/0.8	29.5/31.5
33 – 180°/1000m	72	1152/627	76	3.7/4.9	0.6/0.8	25.5/33.9
34 – 270°/1000m	73	921/596	70	4.2/5.1	0.7/0.8	29.7/35.6
39 – 90°/1000m	72	802/652	69	4.7/4.9	0.8/0.8	31.3/33.4
42A – 90°/15000m		1507/470	70	2.6/5.0	0.4/0.8	19.6/35.9
42B – 90°/15000m		1372/492	78	2.8/5.1	0.4/0.8	21.7/38.1

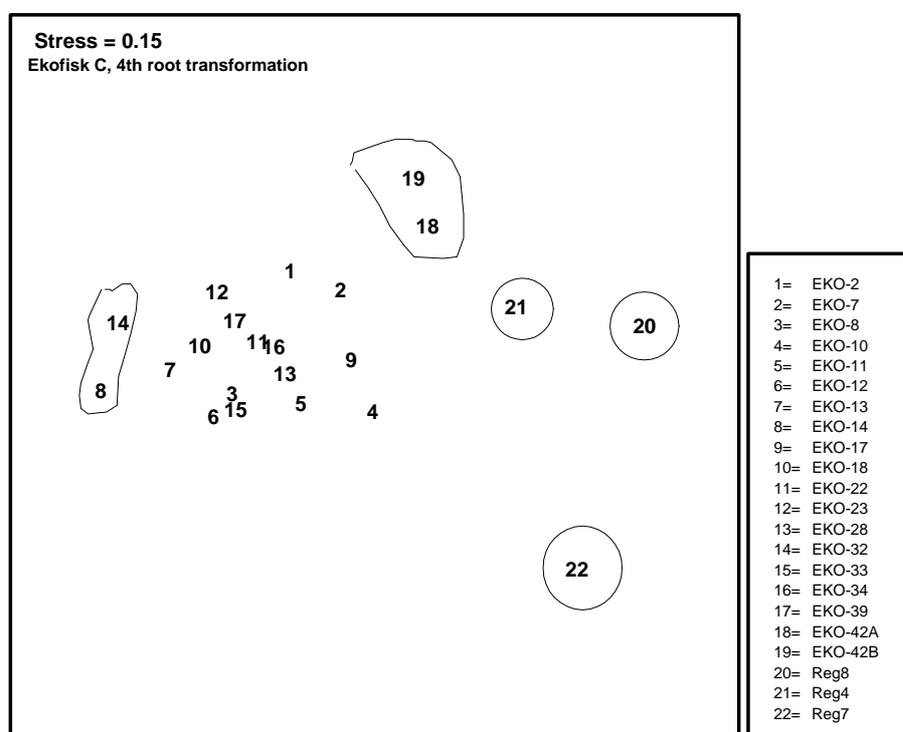


Shannon-Wiener diversity index (*H'*) at Ekofisk Centre, 1990, 1991, 1992, 1996 and 1999.

## TECHNICAL REPORT

The results indicate some disturbance at stations 14 and 32 (Ekofisk Centre T-140°/850m and K-180°/500m respectively), where the highest levels of THC and Ba were found. Station 14 was characterised as moderately disturbed in 1996. Since then the THC level has increased and the barium level declined. Station 32 was characterised as moderately disturbed in 1996, but the conditions seems to have improved at this location. This is also in accordance with reduced levels of both THC and barium in the sediments.

1999.



MDS-plot at station level, Ekofisk Centre 1999.

#### 4.7 Ekofisk 2/4 A

The sediments at Ekofisk 2/4 A consist of more than 90 % sand. The pelite content varies from 2.4 % to 9.9 % with a mean value of 6,8 %. The total organic matter content in the sediments is low, and only small variations are found at the field, from 0,7 % to 1,7 %.

All stations, from 100m distance to 1000m distance in four directions, are contaminated by THC, and the olefin contribution is considerable. The THC levels are relatively high, and the mean concentrations vary from 8,6 mg/kg to 384 mg/kg. The highest concentrations are found at the innermost stations in all directions, at 100 m distance in the 67°, 157° and 337° direction (stations 5, 9 and 1), and at 250 m distance in the 247° direction (station14).

A vertical transport of hydrocarbons in the sediment layer is observed. At station 10, 157°/250m higher THC levels are found down in the sediment than in the top 0-1 cm layer. This is also observed for NPD, PAH and decalins.

## TECHNICAL REPORT

Olefin peaks are clearly seen in all the chromatograms from the field.

All stations have elevated concentrations of Ba, Pb and Zn. The Ba levels are high, and the mean concentrations vary from 567 mg/kg to 5680 mg/kg. As for THC, the highest concentrations are found at the innermost stations in all directions.

Elevated levels of Cd, Cr, and Cu are found at several stations, and Hg is also detected at the two stations analysed. Metal transport down in the sediment is also observed, and the concentrations are mostly higher than in the top 0-1 cm layer.

**Table 4.7.1.** Ekofisk 2/4 A 1999, Total organic matter (%), total hydrocarbon content, NPD, PAH, decalins and metals (mg/kg dry sediment).

Station	Pelite	TOM	THC	NPD	PAH	Decalins	Ba	Cd	Cr	Cu	Hg	Pb	Zn
St.1 337°/ 100 m	9,1	1,0	49,1	-	-	-	3750	0,05	9,4	2,7	-	26,7	28,3
St.2 337°/ 250 m	7,3	0,9	11,7	-	-	-	2430	0,02	7,9	1,3	-	15,8	11,8
St.3 337°/ 500 m	5,5	0,9	11,1	-	-	-	739	<0,02	7,8	1,0	-	11,9	9,2
St.4 337°/1000 m	7,0	1,0	13,8	-	-	-	1170	0,02	9,4	1,5	-	14,7	12,5
St.5 67°/ 100 m	9,9	1,7	384	-	-	-	5680	0,33	13,4	19,4	-	74,7	132
St.6 67°/ 250 m	8,3	1,2	57,6	-	-	-	4340	0,05	10,4	3,6	-	36,2	29,8
St.7 67°/ 500 m	6,7	1,0	8,6	-	-	-	1860	<0,02	6,8	1,3	-	12,8	10,5
St.8 67°/1000 m	4,5	1,1	12,8	-	-	-	1310	<0,02	8,9	1,3	-	16,3	10,9
St.9 157°/ 100 m	7,9	1,3	311	-	-	-	4710	0,24	10,3	15,8	-	51,5	106
St.10 157°/ 250 m	5,2	1,3	59,3	0,147	0,065	0,382	2990	0,03	8,3	2,4	0,05	27,7	23,2
1-3 cm			114	0,169	0,067	1,140	5240	0,10	8,9	5,3	0,22	45,7	49,6
3-6 cm			68,8	0,197	0,367	2,610	4810	0,12	10,8	3,6	0,08	45,6	53,1
St.11 157°/ 500 m	5,0	1,0	15,5	-	-	-	1670	<0,02	8,9	1,4	-	20,1	14,5
St.12 157°/1000 m	6,4	1,4	13,6	0,047	0,090	0,079	605	<0,02	8,7	1,3	0,03	11,0	9,2
1-3 cm			13,1	0,041	0,109	0,083	901	nd	8,8	1,2	0,03	11,9	10,3
3-6 cm			16,1	0,042	0,139	0,073	1220	0,03	9,8	1,4	0,03	13,1	12,0
St.14 247°/ 250 m	6,9	1,2	189	-	-	-	4540	0,17	9,6	9,4	-	63,6	96,6
St.15 247°/ 500 m	5,5	1,1	18,2	-	-	-	2900	<0,02	8,9	1,5	-	22,7	14,7
St.16 247°/1000 m	2,4	0,7	10,2	-	-	-	567	<0,02	6,3	0,7	-	9,9	8,6
Ref. 42 Ekofisk Centre	5,3	1,0	5,5	0,010	0,035	nd	41	<0,02	7,1	0,8	<0,01	5,8	4,7
1-3 cm			9,0	0,032	0,094	nd	50	nd	7,2	0,7	nd	5,7	5,1
3-6 cm			5,9	0,015	0,048	nd	141	nd	7,8	1,0	nd	6,8	5,8

-: not analysed      nd: not detected

**Table 4.7.2.** Ekofisk 2/4A, Variation in the mean concentrations at the 0-1 cm sediment layer.

Parameter	Ekofisk 2/4 A 1999	Ekofisk Centre reference station 1999
Pelite	% 2,4 - 9,9	5,3
TOM	% 0,7 - 1,7	1,0
THC	mg/kg 8,6 - 384	5,5
NPD*	mg/kg 0,047 - 0,147	0,010
PAH*	mg/kg 0,065 - 0,090	0,035
Decalins*	mg/kg 0,079 - 0,382	nd (<0,05)
Ba	mg/kg 567 - 5680	41
Cd	mg/kg <0,02 - 0,33	nd (<0,02)
Cr	mg/kg 6,3 - 13,4	7,1
Cu	mg/kg 1,0 - 19,4	0,8
Hg*	mg/kg 0,03 - 0,05	nd (< 0,01)
Pb	mg/kg 9,9 - 74,7	5,8
Zn	mg/kg 8,6 - 132	4,7

\* two stations analysed      nd: not detected

## TECHNICAL REPORT

**Biology**

The number of species varied from 60 to 84, and the number of individuals varied from 969 to 1946. The polychaete *Myriochele oculata* dominated on all stations (27 to 73%), while *Scoloplos armiger*, *Levinsenia gracilis* and *Nemertea* spp. were found in abundance more than 10% at some stations.

The number of *M. oculata* was high in all directions with maximum abundance at 500m and 1000m from the Ekofisk A installation. The high numbers of this species clearly affect the diversity indices, see table below. The species composition at stations 1, 9 and 14 are indicates disturbance. Several of the remaining stations also show signs of disturbance.

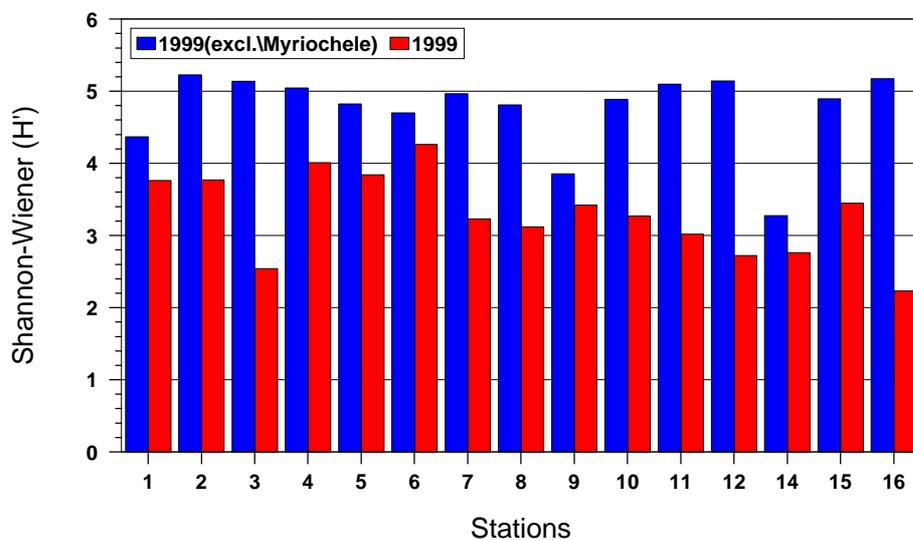
*Depth, number of individuals (N) and species (S), Shannon-Wiener diversity index (H'), Pielou's evenness index (J) and expected number of species per 100 individuals (ES<sub>100</sub>) for each station at Ekofisk A 1999. Incl. / excl. M. oculata.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
1 – 337°/100m	74	992/642	68	3.8/4.4	0.6/0.7	24.0/29.1
2 – 337°/250m	75	1130/600	77	3.8/5.2	0.6/0.8	28.5/38.4
3 – 337°/500m	74	1572/502	69	2.5/5.1	0.4/0.8	20.9/36.7
4 – 337°/1000m	75	1001/604	72	4.0/5.1	0.7/0.8	28.5/35.3
5 – 67°/100m	74	1117/663	73	3.8/4.8	0.6/0.8	26.0/32.8
6 – 67°/250m	75	1109/805	84	4.3/4.7	0.7/0.7	28.2/32.4
7 – 67°/500m	74	1734/780	82	3.2/5.0	0.5/0.8	23.9/35.7
8 – 67°/1000m	72	1409/623	60	3.1/4.8	0.5/0.8	22.8/32.7
9 – 157°/100m	72	969/624	63	3.4/3.9	0.6/0.7	23.5/28.5
10 – 157°/250m	74	1418/660	76	3.3/4.9	0.5/0.8	23.6/34.5
11 – 157°/500m	71	1816/730	81	3.0/5.1	0.5/0.8	23.1/36.7
12 – 157°/1000m	74	1946/675	81	2.7/5.1	0.4/0.8	21.5/37.4
14 – 247°/250m	73	1713/922	67	2.8/3.3	0.6/0.5	16.7/23.1
15 – 247°/500m	74	1757/879	83	3.5/4.9	0.5/0.8	24.9/34.9
16 – 247°/1000m	75	1835/494	73	2.2/5.2	0.4/0.8	18.8/38.2

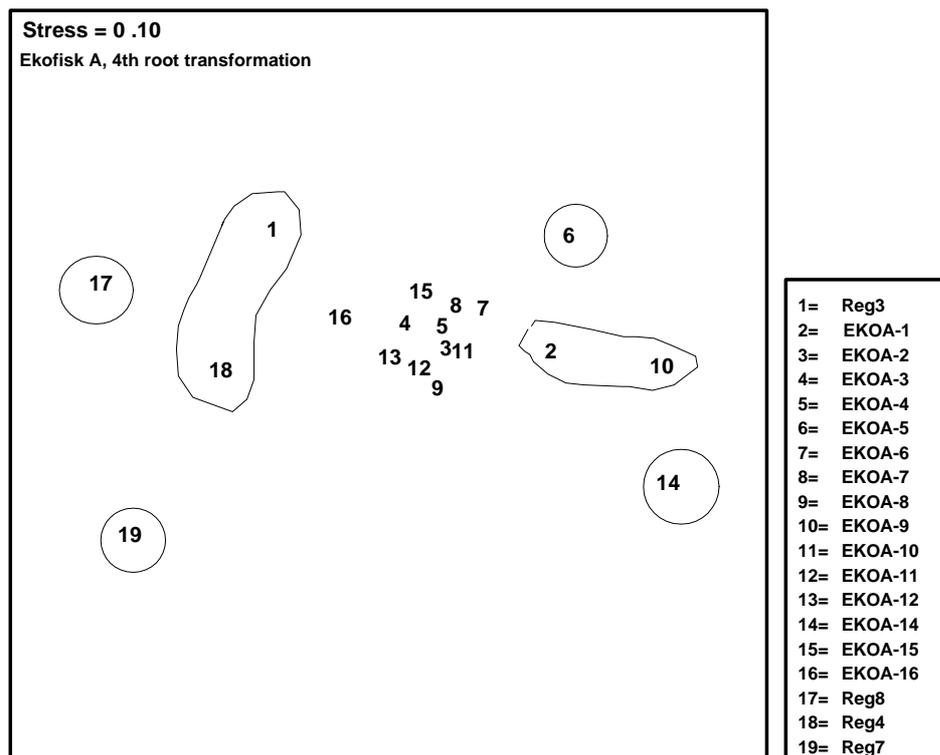
The diversity index (incl. *M. oculata*) varied from 2.2 to 4.3, and from 3.3 to 5.2 when *M. oculata* was removed from the data.

The results from the biological analyses indicate disturbance at station 14 and 9 (247°/250m and 157°/100m). The fauna at station 5 (67°/100m) is more diverse but still has a lot in common with station 9.

TECHNICAL REPORT



Shannon-Wiener diversity index ( $H'$ ) at Ekofisk A, 1999.



MDS-plot at station level, Ekofisk A 1999.

## TECHNICAL REPORT

**4.8 Eldfisk 2/7 A/FTP**

The sediments at Eldfisk 2/7 A/FTP consist in average of 4,6 % pelite. The average pelite concentration is the same in 1999 as in 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,5 % to 1,0 %. Compared to the previous survey in 1996 a slight decrease is observed at station 8.

The mean THC concentrations vary from 8,9 mg/kg at station 15, 90°/1000m to 16,3 mg/kg at station 6, 180°/500m. All three stations at 2000m distance have elevated THC concentrations, and the levels are similar to 1996.

Olefins are also found at the three stations analysed, from 0,4 mg/kg at station 7, 180°/1000m and station 15, 90°/1000m to 0,9 mg/kg at station 6, 180°/500m. Olefin concentrations as low as 0,24 mg/kg are clearly detected in the sediments.

Elevated levels of NPD and decalins are found at station 6, 180°/500m. At station 8, 180°/2000m elevated NPD, PAH and decalin concentrations are only found in the 1-3 cm and 3-6 cm layers, at the same level as in 1996.

The Ba concentrations vary from 189 mg/kg at station 1, 360°/2000m to 1130 mg/kg at station 6, 180°/500m. Elevated Ba concentrations are found at all stations. This means out to 1000m in the 90° direction and out to 2000m in the 180°, 270° and 360° directions. A decrease is observed since 1996. The highest Ba concentrations are found in the 1-3 cm layer and 3-6 cm layer at station 6, 180°/500m, 1280 mg/kg and 2740 mg/kg respectively. The concentrations of the heavy metals are low, however elevated concentrations are found at some stations.

The chemical results agree with the drilling history at Eldfisk 2/7 A/FTP. Pseudo-oil based drilling fluids (olefins) and baryte were discharged just after the 1996 survey.

**Table 4.8.1. Eldfisk 2/7 A/FTP, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

Station	Pelite		TOM		THC		Olefin	NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996		1999	1996	1999	1996	1999	1996
St.1 360°/2000 m	4,9	5,2	0,85	1,01	9,6	9,3	-	-	-	-	-	-	-
St.2 360°/1000 m	4,0	4,9	0,76	0,84	9,4	9,0	-	-	-	-	-	-	-
St.6 180°/ 500 m	5,7	4,2	0,81	0,86	16,3	18,8	0,9	0,062	0,076	0,064	0,042	0,084	0,165
1-3 cm					16,0	10,3	0,9	0,043	0,080	0,049	0,083	0,104	0,121
3-6 cm					15,9	33,9	0,9	0,042	0,144	0,053	0,076	0,120	0,202
St.7 180°/1000 m	5,9	4,1	0,87	0,87	11,8	10,2	0,4	-	-	-	-	-	-
St.8 180°/2000 m	4,5	5,0	0,54	0,79	9,8	10,8	-	0,026	0,034	0,069	0,180	nd	0,089
1-3 cm					14,0	13,3	-	0,043	0,068	0,120	0,109	0,060	0,124
3-6 cm					16,7	13,8	-	0,049	0,064	0,141	0,128	0,088	0,126
St.9 270°/2000 m	4,6	3,8	0,85	1,13	11,8	9,7	-	-	-	-	-	-	-
St.10 270°/1000 m	4,6	4,5	0,87	0,86	11,6	11,4	-	-	-	-	-	-	-
St.15 90°/1000 m	2,6	3,8	0,80	0,87	8,9	12,0	0,4	-	-	-	-	-	-

-: not analysed      nd: not detected      Olefins not analysed in 1996

## TECHNICAL REPORT

**Table 4.8.2.** 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	
	1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.1 360°/2000 m	189	567	nd	7,8	0,7	0,8	-	9,4	9,9	6,5	9,2
St.2 360°/1000 m	363	561	nd	7,5	0,6	0,9	-	9,8	10,0	7,5	9,2
St.6 180°/ 500 m	1130	2390	nd	7,8	1,4	2,1	0,02	14,5	14,2	13,7	13,2
1-3 cm	1280	-	nd	7,2	1,1	-	0,04	14,3	-	12,1	-
3-6 cm	2740	-	0,03	8,0	1,9	-	0,03	17,5	-	20,7	-
St.7 180°/1000 m	455	659	nd	8,0	0,8	0,8	-	10,5	9,9	8,2	6,9
St.8 180°/2000 m	294	397	nd	7,9	0,8	1,4	<0,02	9,1	8,2	7,2	6,9
1-3 cm	535	-	nd	8,3	0,9	-	0,02	9,6	-	8,0	-
3-6 cm	1018	-	0,02	8,6	1,0	-	0,02	10,8	-	9,2	-
St.9 270°/2000 m	372	1910	nd	7,7	0,8	1,0	-	12,3	15,2	7,3	7,7
St.10 270°/1000 m	549	927	nd	7,2	1,0	0,9	-	11,7	12,4	8,3	7,6
St.15 90°/1000 m	772	909	nd	7,1	0,8	0,9	-	11,5	12,6	8,2	8,0

-: analysed      nd: not detected      Cr not analysed in 1996

## Biology

The number of species per station varied from 62 to 76, while the number of individuals varied from 475 to 743. A total of 4826 individuals were identified to 138 taxa. The 10 most abundant species made up from 60% to 71%.

The polychaete *Myriochele oculata* dominated at most of the stations (6-27%), while *Eudorellopsis deformis*, *Ditrupa arietina*, *Scoloplos armiger* and *Amphiura filiformis* were found from 4 to 11% at some stations.

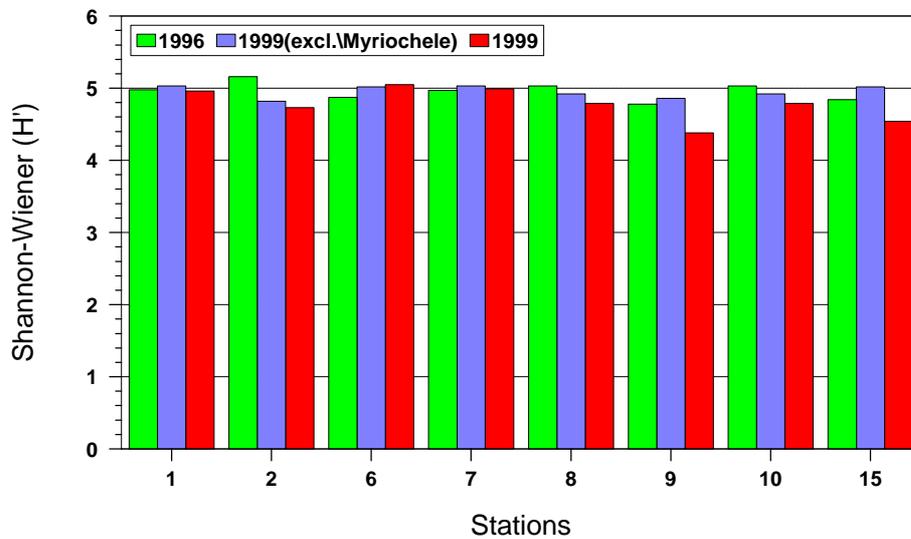
The abundance of *M. oculata* was highest in the 90° direction at 1000m and in 270° at 1000m and 2000m stations. At these stations *M. oculata* obviously affects the diversity index (4.5/5.0 and 4.4/4.9 respectively), while on the other stations the effect was quite small, see table below.

*Depth, number of individuals (N) and species (S), Shannon-Wiener diversity index (H'), Pielou's evenness index (J) and expected number of species per 100 individuals (ES<sub>100</sub>), Eldfisk A 1999. Incl. / excl. M. oculata.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
1 – 0°/2000m	71	475/420	71	5.0/5.0	0.8/0.8	34.9/36.1
2 – 0°/1000m	70	498/428	64	4.7/4.8	0.8/0.8	32.3/33.8
6 – 180/500m	72	669/632	76	5.1/5.0	0.8/0.8	35.0/34.9
7 – 180°/1000m	72	569/511	73	5.0/5.0	0.8/0.8	34.6/35.4
8 – 180°/2000m	70	621/526	66	4.8/4.9	0.8/0.8	32.1/33.6
9 – 270°/2000m	72	606/441	62	4.4/4.9	0.7/0.8	30.0/33.9
10 – 270°/1000m	71	645/548	71	4.8/4.9	0.8/0.8	32.6/34.1
15 – 90°/1000m	71	743/548	74	4.5/5.0	0.7/0.8	31.2/35.0

The number of species and individuals (excl. *M. oculata*) are generally somewhat lower in 1999 than in 1996, but the diversity index is relatively unchanged. However, at station 9 and 15 there have been a slight reduction in diversity due to the abundance of *M. oculata*.

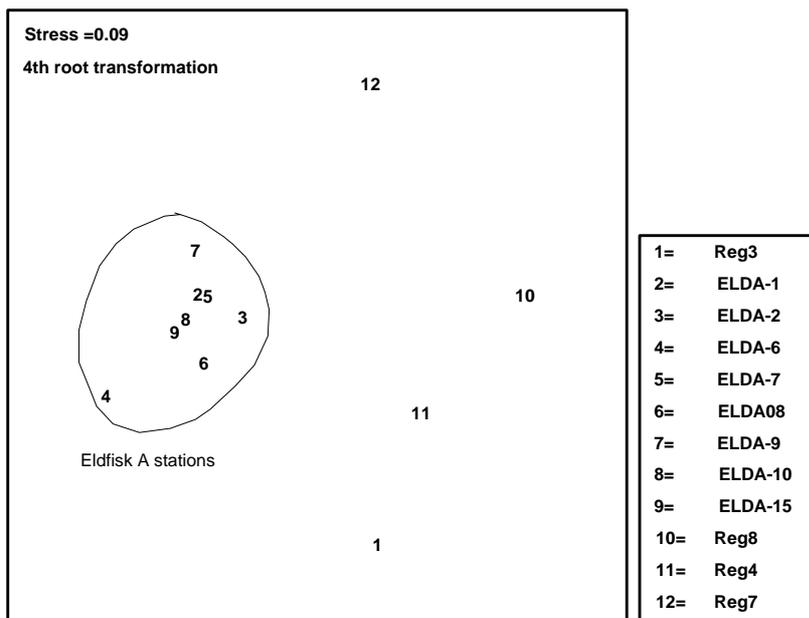
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Shannon-Wiener diversity index ( $H'$ ) at Eldfisk A, 1996 and 1999.

The community composition within the field stations is quite similar, and the overall picture is that the Eldfisk stations seem to be undisturbed or only slightly disturbed. Station 6 differs somewhat from the other stations, but the community composition does not indicate disturbance.

Nearly all the Eldfisk A stations have elevated levels of THC and Ba. The distribution of THC and Ba seems to be quite uniform, and differences in the benthic community caused by (the lack of) variations in the chemical parameters are not expected. The question whether all the investigated stations are slightly disturbed therefore arises.



MDS-plot at station level, Eldfisk A 1999.

## TECHNICAL REPORT

**4.9 Eldfisk 2/7 B**

The sediments at Eldfisk 2/7 B consist in average of 4,8 % pelite. The average pelite concentration is the same in 1999 as in 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,7 % to 1,1 %. Compared to the previous survey in 1996 a slight increase is observed at station 2 and station 6.

The mean THC concentrations vary from 6,7 mg/kg at station 2, 360°/1000m to 22,0 mg/kg at station 6, 180°/500m, and the levels are similar to 1996. Elevated THC concentrations are found at most of the stations analysed, out to 2000m distance in the 180° direction and out to 1000m in the 90° and 270° directions. The lowest THC concentrations are found in the 360° direction at 500m and 1000 m distance. At these stations the THC levels are not elevated, however, olefins are clearly seen in the chromatograms. All the sediments samples are thus affected by hydrocarbons.

The olefin concentrations at the four stations analysed, vary from 0,7 mg/kg at station 7, 180°/1000m and station 11, 270°/500m to 3,8 mg/kg at station 6, 180°/500m.

Elevated levels of NPD, PAH and decalins are found at station 6, 180°/500m. In one replicate particularly high concentrations of NPD and PAH are found, 1,2 mg/kg and 2,3 mg/kg respectively, and these compounds represent approx. 10% of the THC content. For the other replicates and the layer samples the concentrations are similar to the 1996 results. At station 8, 180°/2000m slightly elevated NPD, PAH and decalin concentrations are only found in the 3-6 cm layer.

The Ba concentrations vary from 432 mg/kg at station 2, 360°/1000m to 1740 mg/kg at station 14, 90°/500m. Elevated Ba 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 Ba levels are generally similar to the previous surveys. The highest Ba concentrations are found in the 3-6 cm layer at station 6, 180°/500m, 2930 mg/kg. The concentrations of the heavy metals are low, however elevated concentrations are found at some stations.

The chemical results agree with the drilling history at Eldfisk 2/7 B. Pseudo-oil based drilling fluids (olefins) and baryte are discharged since the last survey in 1996.

**Table 4.9.1. Eldfisk 2/7 B, pelite and TOM (%), THC, NPD, PAH and decalins(mg/kg dry sediment)**

Station		Pelite		TOM		THC		Olefin	NPD		PAH		Decalins	
		1999	1996	1999	1996	1999	1996		1999	1996	1999	1996	1999	1996
St.2	360°/1000 m	4,0	2,8	0,74	0,56	6,7	4,9	-	-	-	-	-	-	-
St.3	360°/ 500 m	5,6	-	0,75	-	8,5	-	-	-	-	-	-	-	-
St.6	180°/ 500 m	5,1	4,7	1,07	0,78	22,0	12,7	3,8	0,444	0,062	0,858	0,058	0,091	0,088
	1-3 cm					13,9	18,9	2,2	0,070	0,095	0,114	0,068	0,058	0,161
	3-6 cm					19,2	26,3	2,6	0,078	0,093	0,129	0,095	0,111	0,533
St.7	180°/1000 m	3,3	6,1	0,89	0,87	11,1	13,4	0,7	-	-	-	-	-	-
St.8	180°/2000 m	8,0	4,4	1,09	0,94	7,7	14,8	-	0,022	0,038	0,055	0,068	nd	0,108
	1-3 cm					8,1	23,0	-	0,028	0,054	0,069	0,084	nd	0,216
	3-6 cm					11,6	13,6	-	0,042	0,064	0,116	0,099	0,052	0,154
St.10	270°/1000 m	5,1	4,7	0,84	0,86	10,7	8,8	-	-	-	-	-	-	-
St.11	270°/ 500 m	4,5	-	0,81	-	11,9	-	0,7	-	-	-	-	-	-
St.14	90°/ 500 m	3,6	-	0,81	-	14,1	-	1,2	-	-	-	-	-	-
St.15	90°/1000 m	3,8	4,9	0,90	0,99	12,0	12,7	-	-	-	-	-	-	-

-: not analysed      nd: not detected      Olefins not analysed in 1996

## TECHNICAL REPORT

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

Station		Ba		Cd	Cr		Cu		Hg	Pb		Zn	
		1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996	
St.2	360°/1000 m	432	186	nd	5,7	0,5	<0,6	-	7,7	7,2	5,8	4,4	
St.3	360°/ 500 m	1000	-	nd	6,2	0,6	-	-	8,7	-	6,2	-	
St.6	180°/ 500 m	1460	1630	nd	7,1	1,2	1,2	0,03	12,6	13,5	13,1	8,6	
	1-3 cm	1500	-	0,02	6,6	1,1	-	0,02	12,3	-	12,3	-	
	3-6 cm	2930	-	0,03	6,9	1,2	-	0,04	13,5	-	12,1	-	
St.7	180°/1000 m	389	445	nd	7,1	0,8	1,2	-	10,6	10,1	7,3	6,1	
St.8	180°/2000 m	221	404	0,02	7,5	0,8	1,0	0,03	9,2	9,4	7,5	5,7	
	1-3 cm	468	-	nd	7,7	0,7	-	0,02	9,8	-	7,4	-	
	3-6 cm	709	-	nd	8,2	0,8	-	0,02	11,1	-	8,2	-	
St.10	270°/1000 m	593	1270	nd	7,6	0,8	0,8	-	11,7	11,9	7,3	8,1	
St.11	270°/ 500 m	1450	-	nd	7,5	1,1	-	-	12,8	-	9,3	-	
St.14	90°/ 500 m	1740	-	nd	7,3	1,4	-	-	17,3	-	11,4	-	
St.15	90°/1000 m	986	783	nd	7,8	0,9	0,8	-	12,4	13,4	8,6	8,3	

-: not analysed      nd: not detected      Cr not analysed in 1996

**Biology**

The number of species per station varied from 71 to 85, and the number of individuals varied from 581 to 1311. A total of 8460 individuals were identified to 159 taxa. The 10 most abundant species made up from 57% to 74%.

The polychaete *Myriochele oculata* dominated at most of the stations (12-63%), while *Eudorellopsis deformis*, *Scoloplos armiger* and *Amphiura filiformis* were found from 4 to 12% at some stations.

The number of *M. oculata* was highest in the 180° direction at 500m, in the 270° direction at 1000m, and in the 90° direction at 500m. The high abundance of this species clearly affects the diversity at some stations, see table below.

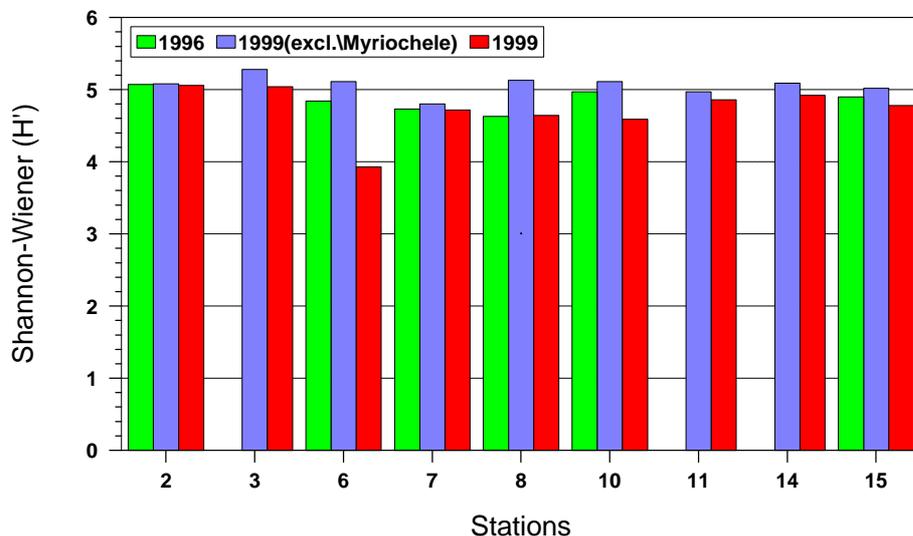
*Depth, number of individuals (N) and species (S), Shannon-Wiener diversity index (H'), Pielou's evenness index (J) and expected number of species per 100 individuals (ES<sub>100</sub>), Eldfisk B 1999. Incl. / excl. M. oculata.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
2 – 0°/1000m	73	721/654	72	5.1/5.1	0.8/0.8	35.1/35.6
3 – 0°/500m	74	1016/845	85	5.0/5.3	0.8/0.8	35.4/37.5
6 – 180°/500m	71	1239/716	82	3.9/5.1	0.6/0.8	28.1/36.0
7 – 180°/1000m	73	726/629	65	4.7/4.8	0.8/0.8	31.4/32.5
8 – 180°/2000m	72	581/433	77	4.6/5.1	0.7/0.8	34.1/39.0
10 – 270°/1000m	70	907/667	80	4.6/5.1	0.7/0.8	33.2/37.7
11 – 270°/500m	72	1106/951	71	4.9/5.0	0.8/0.8	31.4/32.4
14 – 90°/500m	73	1311/1104	78	4.9/5.1	0.8/0.8	34.1/36.0
15 – 90°/1000m	73	853/694	79	4.8/5.0	0.8/0.8	33.0/35.6

The diversity index (incl. *M. oculata*) varied from 3.9 to 5.1, and from 4.8 to 5.3 excl. *M. oculata*.

TECHNICAL REPORT

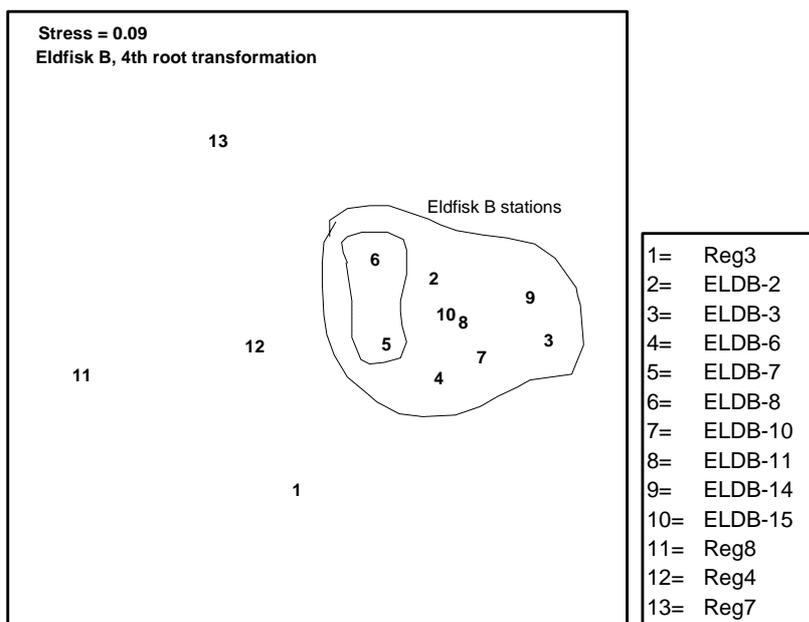
The numbers of species and individuals have generally increased compared to the survey in 1996. There are only minor changes in the diversity (excl. *M. oculata*) between 1996 and 1999.



Shannon-Wiener diversity index ( $H'$ ) at Eldfisk B, 1996 and 1999.

In 1996 station 6 (180°/500m) was the only station described as slightly disturbed, presumably because of high numbers of *M. oculata* (?). In 1999 this polychaete was abundant in high numbers at all field stations. It is unlikely that all stations have changed negatively during the last three years considering no discharges in 1998 and 1999 and a decrease of THC and Ba at several stations.

The benthic community within the Eldfisk B area show no significant indications of differences between stations due to drilling activities. Disregarding the high abundance of *M. oculata* at station 6, the fauna at Eldfisk B is regarded as undisturbed.



MDS-plot at station level, Eldfisk B 1999.

## TECHNICAL REPORT

**4.10 Embla**

The sediments at Embla consist in average of 4,4 % pelite. The pelite concentration has slightly increased at all stations compared to the previous survey in 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,7 % to 0,9 %. The results are similar to the 1996 results.

The mean THC concentrations vary from 6,6 mg/kg at station 8, 180°/2000m to 10,9 mg/kg at station 6, 180°/500m. The mean levels are above the limit of contamination for only one of the six stations analysed, station 6, 180°/500m. However, slightly elevated THC concentrations are also found in some of the samples from other stations. The highest concentration, 18,8 mg/kg is found in the 1-3 cm layer at station 6. The THC levels are similar to the 1996 results.

The NPD, PAH and decalin concentrations are higher in the layer samples than in the top 0-1 cm layer. This was also observed in 1996. Elevated levels are only observed at station 6, 180°/500m, in the layer samples.

The Ba concentrations vary from 92 mg/kg at station 2, 360°/1000m to 655 mg/kg at station 6, 180°/500m. Elevated Ba concentrations are found at five of the six stations analysed. This means out to 1000m distance in the 270° direction and out to 2000m in the 90° and 180° direction. A decrease is observed since 1996. A vertical transport of Ba down in the sediment is observed, and the concentrations are higher than in the top sediment layer. The concentrations of the heavy metals are low, and slightly elevated concentrations of Pb are found at one station.

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

**Table 4.10.1. Embla, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

Station		Pelite		TOM		THC		NPD		PAH		Decalins	
		1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.2	360°/1000 m	4,8	3,1	0,68	0,83	6,8	7,2	-	-	-	-	-	-
St.6	180°/ 500 m	4,0	3,0	0,86	0,87	10,9	11,4	0,040	0,037	0,077	0,046	0,129	0,169
	1-3 cm					18,8	18,5	0,078	0,075	0,111	0,145	0,209	0,934
	3-6 cm					9,3	4,9	0,036	0,082	0,051	0,265	0,071	0,114
St.7	180°/1000 m	4,1	3,5	0,82	0,90	7,2	6,6	-	-	-	-	-	-
St.8	180°/2000 m	4,0	3,3	0,79	0,93	6,6	7,5	0,031	0,048	0,041	0,072	nd	0,074
	1-3 cm					7,8	4,5	0,036	0,047	0,032	0,099	nd	0,107
	3-6 cm					9,9	19,8	0,051	0,059	0,111	0,116	nd	0,133
St.10	270°/1000 m	4,6	3,7	0,85	0,85	7,2	6,6	-	-	-	-	-	-
St.16	90°/2000 m	4,7	2,4	0,85	1,07	8,7	7,8	-	-	-	-	-	-

-: not analysed      nd: not detected

## TECHNICAL REPORT

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

Station		Ba		Cd	Cr	Cu		Hg	Pb		Zn	
		1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.2	360°/1000 m	92	254	nd	7,2	0,5	0,7	-	7,6	7,8	5,4	6,0
St.6	180°/ 500 m	655	2210	nd	7,9	1,2	1,2	0,02	12,7	12,7	8,3	8,5
	1-3 cm	939	-	nd	7,9	0,9	-	0,03	13,3	-	8,6	-
	3-6 cm	1681	-	0,02	8,1	1,1	-	0,02	12,6	-	8,8	-
St.7	180°/1000 m	144	486	nd	7,9	0,6	0,9	-	9,6	8,9	6,4	5,5
St.8	180°/2000 m	108	339	nd	8,3	0,6	0,9	0,02	8,8	7,6	6,3	6,1
	1-3 cm	192	-	nd	8,5	0,7	-	0,03	8,9	-	6,8	-
	3-6 cm	294	-	0,02	8,3	0,8	-	0,02	9,5	-	7,4	-
St.10	270°/1000 m	227	487	nd	7,5	0,7	0,7	-	9,2	9,0	6,3	5,8
St.16	90°/2000 m	197	247	nd	7,7	0,7	0,7	-	8,8	7,5	6,4	5,7

-: not analysed      nd: not detected      Cr not analysed in 1996

## Biology

The number of species varied from 60 to, and the number of individuals varied from 648 to 1798. A total of 6525 individuals were identified to 141 taxa. The 10 most abundant species made up from 68% to 89%.

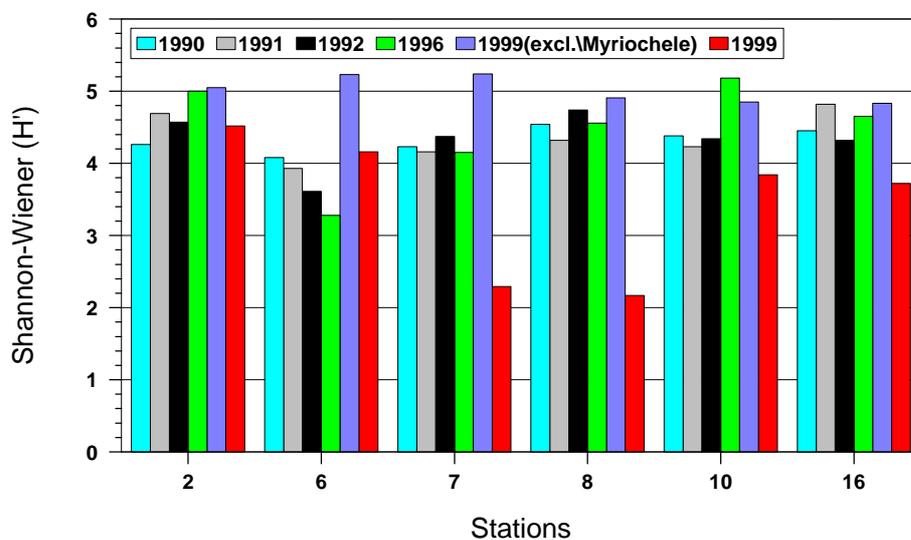
The polychaete *M. oculata* dominated at most of the stations (27-73%) and clearly affected the diversity indices, see table below. The number was highest in the 180° direction at the 1000m and 2000m stations.

*Depth, number of individuals (N) and species (S), 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 (incl. / excl. M. oculata), Embla 1999.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
2 – 0°/1000m	72	648/472	75	4.5/5.1	0.7/0.8	33.4/38.5
6 – 180°/500m	71	908/554	75	4.2/5.2	0.7/0.8	31.2/38.8
7 – 180°/1000m	72	1798/493	79	2.3/5.2	0.4/0.8	19.2/39.7
8 – 180°/2000m	72	1684/456	70	2.2/4.9	0.4/0.8	17.5/34.8
10 – 270°/1000m	70	691/408	65	3.8/4.9	0.6/0.8	27.7/35.6
16 – 90°/2000m	69	796/449	60	3.7/4.8	0.6/0.8	26.4/33.5

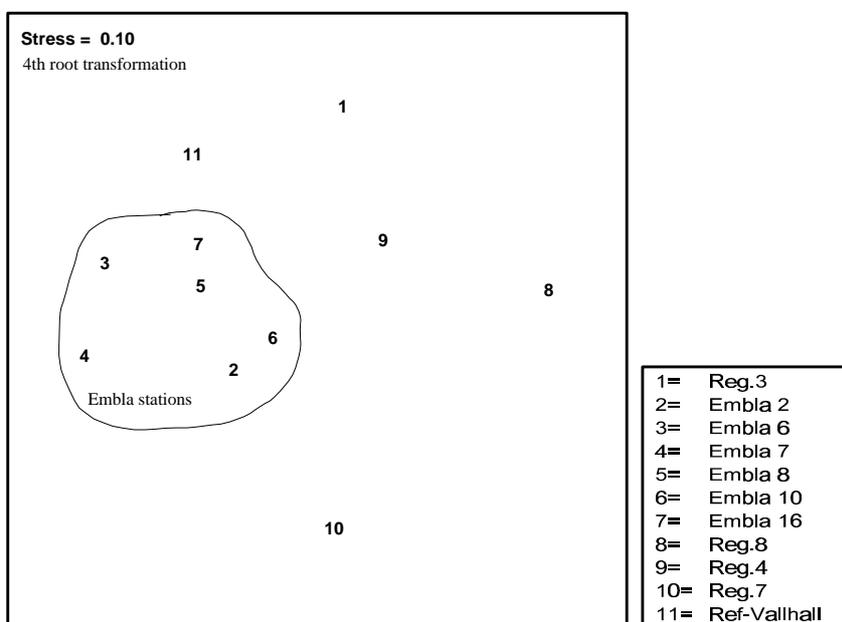
The Shannon-Wiener diversity index (incl. *M. oculata*) varied from 2.2 to 4.5. Removing *M. oculata* from the data resulted in higher diversity indices at all stations; from 4.8 to 5.2. When *M. oculata* is removed from the data, the diversity indices are generally higher in 1999 than in previous surveys.

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Shannon-Wiener diversity index ( $H'$ ), Embla, 1990, 1991, 1992, 1996 and 1999.

There is no pattern in the data that would suggest a correlation between the presence of *M. oculata* and elevated concentrations of hydrocarbons/metals in the sediments. Except for a translocation of *M. oculata* within the field, the fauna composition is quite similar to the 1996 fauna.



MDS-plot at station level, Embla 1999.

## TECHNICAL REPORT

**4.11 Tor**

The sediments at Tor consist in average of 3,6 % pelite. The pelite concentration has slightly increased at most of the stations compared to 1996. The total organic matter content in the sediments is low and similar throughout the field, from 0,71 % to 0,82 %, and similar to 1996.

The mean THC concentrations vary from 6,7 mg/kg at station 7, 180°/1000m to 46,0 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, 174 mg/kg and 192 mg/kg respectively. Elevated THC concentrations are found out to 1000m distance in the 180° direction. The mean THC levels are similar to the 1996 results, however an increase is observed in the 1-3 cm and 3-6 cm layers at station 5, 180°/250m.

Olefins are not analysed in the sediment samples at Tor. However, the gas chromatograms show the same "olefin peaks" that are found at Ekofisk Centre 2/4 B&K, Eldfisk 2/7 A/FTP and Eldfisk 2/7 B where pseudo-oil based drilling fluids Novaplus (olefins) are discharged.

Elevated NPD and PAH concentrations are found at both stations analysed, and in the 1-3 cm and 3-6 cm layers as well. Elevated decalin concentrations are found at station 5, 180°/250m and in the 3-6 cm layer at station 7, 180°/1000m. Great differences are observed between the replicates. The levels are similar or somewhat higher than in 1996.

The Ba concentrations vary from 92 mg/kg at station 8, 180°/2000m to 1470 mg/kg at station 5, 180°/250m. Elevated Ba concentrations are found at six of the seven stations analysed. This means out to 500m distance in the 90°, 270° and 360° directions and out to 1000m in the 180° direction. A decrease is observed since 1996. Elevated Ba concentrations are found in the vertical sections at station 5, 180°/250m and station 7, 180°/1000m. The concentrations are higher than in the top 0-1 cm layer, and the highest Ba concentration at the field, 2350 mg/kg, is found in the 1-3 cm layer at station 5. The concentrations of the heavy metals are low, however some elevated concentrations are found, particularly at station 5, 180°/250m. The highest concentrations are found in the 1-3 cm and 3-6 cm layers at this station.

No drilling activities are reported at Tor since the last survey in 1996, nor in the period 1993 to 1996. However, compounds are observed in the gas chromatograms that are similar to those found at other fields in the Ekofisk area where discharges of drilling fluids are reported.

**Table 4.11.1. Tor, pelite and TOM (%), THC, NPD, PAH and decalins mg/kg dry sediment)**

Station		Pelite		TOM		THC		NPD		PAH		Decalins	
		1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996
St.3	360°/ 500 m	4,8	3,3	0,82	0,94	8,6	8,8	-	-	-	-	-	-
St.5	180°/ 250 m	3,5	1,9	0,80	0,80	46,0	35,4	0,131	0,285	0,166	0,303	0,148	0,186
	1-3 cm					174	69,4	0,158	0,189	0,097	0,029	0,384	0,391
	3-6 cm					192	32,6	0,203	0,112	0,050	0,042	0,462	0,244
St.6	180°/ 500 m	3,6	3,7	0,77	0,84	18,8	12,6	-	-	-	-	-	-
St.7	180°/1000 m	4,6	2,9	0,74	0,92	6,7	7,1	0,099	0,030	0,271	0,064	nd	0,061
	1-3 cm					10,7	7,4	0,029	0,028	0,093	0,063	nd	0,083
	3-6 cm					12,7	13,0	0,058	0,055	0,210	0,157	0,121	0,193
St.8	180°/2000 m	2,8	-	0,80	-	7,8	-	-	-	-	-	-	-
St.11	270°/ 500 m	2,4	2,1	0,82	1,07	9,1	8,0	-	-	-	-	-	-
St.14	90°/ 500 m	3,5	2,0	0,71	0,77	7,1	5,2	-	-	-	-	-	-

-: not analysed      nd: not detected

## TECHNICAL REPORT

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

Station		Ba		Cd	Cr		Cu		Hg	Pb		Zn	
		1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996	
St.3	360°/ 500 m	277	308	nd	7,4	0,7	0,7	-	8,6	7,8	6,7	5,4	
St.5	180°/ 250 m	1470	2590	0,06	6,6	2,1	2,2	0,03	15,3	14,9	26,5	21,6	
	1-3 cm	2350	-	0,20	8,0	3,1	-	0,06	21,0	-	40,2	-	
	3-6 cm	2190	-	0,22	8,9	5,2	-	0,04	31,3	-	125,9	-	
St.6	180°/ 500 m	385	1300	nd	7,2	0,9	1,2	-	11,9	14,6	9,5	11,5	
St.7	180°/1000 m	169	269	nd	7,2	0,6	0,8	nd	6,6	8,5	5,8	7,2	
	1-3 cm	778	-	0,02	7,8	0,8	-	nd	8,5	-	8,3	-	
	3-6 cm	1350	-	0,04	9,9	1,3	-	0,05	11,2	-	12,7	-	
St.8	180°/2000 m	92	-	nd	7,5	0,5	-	-	6,7	-	5,5	-	
St.11	270°/ 500 m	269	668	nd	7,7	0,9	0,9	-	9,0	8,9	9,1	6,6	
St.14	90°/ 500 m	244	301	nd	7,2	0,8	0,8	-	9,5	9,4	12,6	7,2	

-: not analysed      nd: not detected      Cr not analysed in 1996

## Biology

The number of species varied from 67 to 90, and the number of individuals varied from 975 to 2424. A total of 9147 individuals were identified to 148 taxa. The 10 most abundant species made up from 76% to 90%.

The polychaete *Myriochele oculata* dominated at most of the stations (38 to 64%), while *Eudorellopsis deformis*, *Ditrupa arietina* and *Amphiura filiformis* were common.

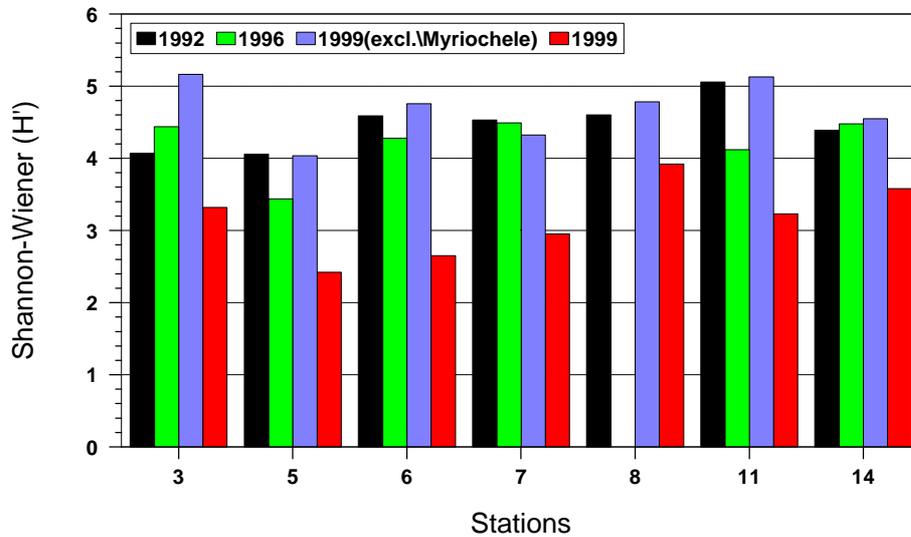
The number of *M. oculata* was highest at station 5 (180°/250m) and 6 (180°/500m). The high abundance of this species clearly affects the diversity, see table below.

*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 Tor 1999.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
3 – 0°/500m	67	1366/615	81	3,3/5.2	0,5/0.8	25,3/37.8
5 – 180°/250m	66	2424/886	67	2,4/4.0	0,4/0.7	16,9/28.1
6 – 180°/500m	67	2117/759	77	2,7/4.8	0,4/0.8	19,9/33.7
7 – 180°/1000m	67	1477/668	73	3,0/4.3	0,5/0.7	20,9/31.9
8 – 180°/2000m	68	975/603	76	3,9/4.8	0,6/0.8	27,8/35.1
11 – 270°/500m	67	1278/558	76	3,2/5.1	0,5/0.8	24,8/37.0
14 – 90°/500m	67	1265/720	90	3,6/4.6	0,6/0.7	24,8/33.3

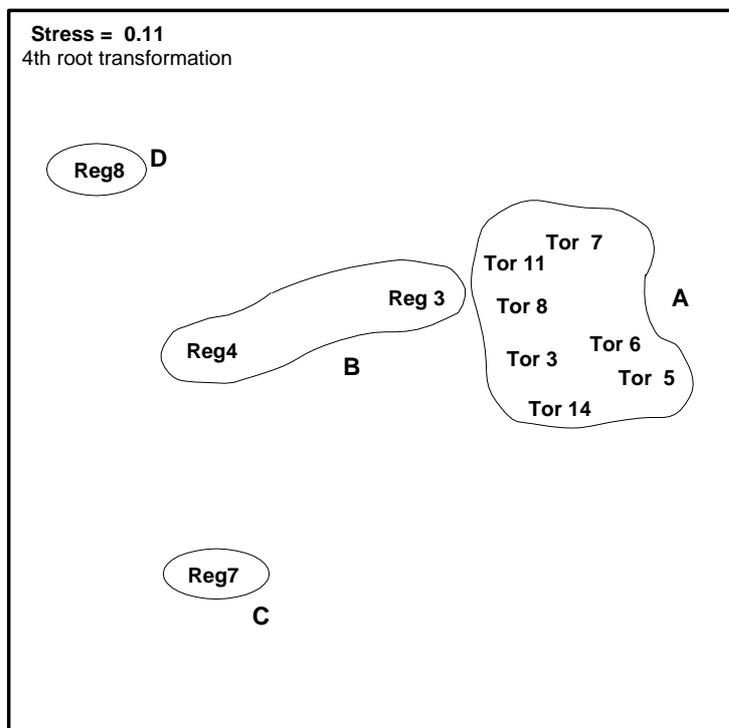
The diversity index varied from 2.4 to 3.9 including *M. oculata*, and from 4.0 to 5.2 excluding the same species. The number of species have increased at all stations but one (station 5) compared to the survey in 1992 and 1996. The diversity index (excl. *M. oculata*) is generally slightly higher or equal compared to the results from 1992, 1996 and 1999.

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Shannon-Wiener diversity index ( $H'$ ) at Tor, 1996 and 1999.

When excluding *M. oculata* from the data the diversity indices were generally high, but still reduced at station 5. The fauna at station 5 is regarded as disturbed.



MDS-plot at station level, Tor 1999. 4<sup>th</sup> root transformation.

## TECHNICAL REPORT

## 4.12 Yme Gamma

The sediments at Yme Gamma consist in average of 3,2 % pelite. The average pelite concentration and the amount of pelite at the reference station have slightly increased since 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,5 % to 0,9 %. Compared to the previous survey, a slight decrease is observed at some stations.

The mean THC concentrations vary from 1,9 mg/kg at the reference station to 173 mg/kg at station 5, 120°/250m. Elevated THC concentrations are found at three of the innermost stations, station 5, 120°/250m, station 6, 120°/500m and station 15, 300°/500m. An increase is observed since 1996.

Olefins are detected at all stations except for the reference station. The highest concentrations, 34,5 mg/kg, are found at station 5, 120°/250m. Olefins are also found in the 1-3 cm layer at station 5, but not in the 3-6 cm layer. At the two stations at 1000m and 2000m distance olefins are only found in one of the replicates at each station. The olefins found agree with the constituents of the pseudo-oil based drilling fluid Ultidril, C14 and C16 olefins. Since olefins are found, the sediments at all stations are affected by hydrocarbons.

Elevated levels of NPD, PAH and decalins are found at station 5, 120°/250m. The mean concentrations of NPD and decalins are high, 1,77 mg/kg and 1,87 mg/kg respectively, mainly due to high concentrations in one replicate. The concentrations in the vertical sections are also relatively high. The levels are increased compared to 1996.

The ester compounds in Petrofree are found at three stations, the same stations that show the highest THC concentrations. The results are 16,4 mg/kg at station 5, 120°/250m, 0,9 mg/kg at station 6, 120°/500m and 0,4 mg/kg at station 15, 300°/500m. A decrease is observed since 1996. Petrofree is also detected in the 1-3 cm layer and 3-6 cm layer at station 5. The ester compounds in Finagreen are not detected at any station, and this is a decrease since 1996.

The Ba concentrations vary from 6 mg/kg at the reference station, station 18 300°/10000m to 4520 mg/kg at station 5, 120°/250m. High Ba concentrations, 994 mg/kg, are also found at station 6, 120°/500m. Compared to 1996 the Ba concentrations are increased at most stations, particularly at station 5, 120°/250m. Elevated Ba concentrations are found at all stations, except for the reference station. This is out to 2000m in the 120° direction and out to 500m in the other directions. The concentrations of the heavy metals are low. Elevated concentrations of Cu, Pb and Zn are found at station 5, and Cd and Hg are also detected at this station.

Generally the results agree with the drilling history at Yme Gamma. Drilling with waterbased, esterbased and pseudo-oil based drilling fluids has taken place since the last survey. This explain the content of Ba, esters (Petrofree) and olefins (Ultidril) in the sediments. However, the increase of THC, NPD, PAH and decalins indicate additional discharges. Discharge of oil in produced water is reported, 3 tons in 1997 and 9 tons in 1998.

## TECHNICAL REPORT

**Table 4.12.1. Yme Gamma, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)**

Station		Pelite		TOM		THC		Olefin	Petrofree		Finagreen		NPD		PAH		Decalins	
		99	96	99	96	99	96	99	99	96	99	96	99	96	99	96	1999	1996
St.2	30°/ 500 m	1,9	2,5	0,58	0,63	3,7	4,2	0,3	nd	-	nd	-	-	-	-	-	-	-
St.5	120°/ 250 m	5,6	2,0	0,86	0,96	173	24,6	34,5	16,4	312	nd	17,8	1,770	0,192	0,292	0,066	1,870	0,366
	1-3 cm					72,7	7,2	1,60	12,8	-	nd	-	0,410	0,047	0,120	0,059	0,983	0,118
	3-6 cm					25,8	6,5	nd	4,5	-	nd	-	0,191	0,086	0,068	0,033	0,298	0,094
St.6	120°/ 500 m	2,9	2,2	0,64	0,90	18,1	8,4	2,3	0,9	9,0	nd	0,4	-	-	-	-	-	-
St.7	120°/1000 m	2,5	2,7	0,62	0,72	3,3	4,9	nd	nd	1,2	nd	nd	-	-	-	-	-	-
St.8	120°/2000 m	3,2	2,2	0,58	0,72	2,7	4,2	nd	nd	0,3	nd	0,1	0,009	0,011	0,020	0,041	nd	0,058
	1-3 cm					2,01	2,7	nd	nd	-	nd	-	0,008	0,009	0,015	0,033	nd	0,043
	3-6 cm					1,84	4,2	nd	nd	-	nd	-	0,007	0,011	0,018	0,034	nd	0,053
St.11	210°/ 500 m	2,7	2,0	0,46	0,71	3,3	4,0	0,7	nd	-	nd	-	-	-	-	-	-	-
St.15	300°/ 500 m	3,4	2,3	0,57	0,70	14,6	3,9	9,2	0,4	-	nd	-	-	-	-	-	-	-
St.18 Ref.	300°/10000m	2,8	0,9	0,59	0,67	1,9	3,6	nd	nd	nd	nd	0,02	0,005	0,018	0,015	0,039	nd	0,039
	1-3 cm					1,78	4,0	nd	nd	-	nd	-	0,004	0,005	0,015	0,020	nd	0,034
	3-6 cm					2,45	1,4	nd	nd	-	nd	-	0,007	0,005	0,025	0,018	nd	0,039

-: not analysed    nd: not detected    Olefins not analysed in 1996

**Table 4.12.2. Yme Gamma, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)**

Station		Ba		Cd	Cr	Cu		Hg	Pb		Zn	
		1999	1996	1999	1999	1999	1996	1999	1999	1996	1999	1996
St.2	30°/ 500 m	214	98	nd	4,6	1,0	<0,6	-	6,4	5,7	6,4	4,8
St.5	120°/ 250 m	4520	1110	0,03	6,9	7,2	1,4	0,02	11,9	5,0	19,7	5,9
	1-3 cm	4760	-	0,05	7,4	6,6	-	0,02	11,8	-	27,6	-
	3-6 cm	4690	-	0,02	7,5	3,6	-	0,02	9,0	-	10,1	-
St.6	120°/ 500 m	994	426	nd	5,9	2,1	0,9	-	6,7	6,8	10,1	5,6
St.7	120°/1000 m	149	88	nd	5,8	0,7	0,8	-	6,1	5,9	6,3	5,5
St.8	120°/2000 m	39	46	nd	5,4	0,5	0,8	0,02	6,2	6,7	5,9	5,6
	1-3 cm	52	-	nd	5,1	0,4	-	0,02	5,8	-	4,8	-
	3-6 cm	51	-	0,02	5,5	0,4	-	0,02	6,2	-	5,3	-
St.11	210°/ 500 m	63	90	nd	4,7	0,5	0,9	-	5,0	5,7	4,9	5,6
St.15	300°/ 500 m	202	84	nd	5,2	0,5	0,7	-	5,9	5,7	5,4	5,9
St.18 Ref.	300°/10000m	6	6	nd	9,8	0,3	0,9	0,05	9,9	9,1	7,4	6,7
	1-3 cm	9	-	nd	9,7	0,4	-	0,03	10,1	-	7,6	-
	3-6 cm	14	-	nd	9,2	0,7	-	0,03	9,2	-	7,8	-

-: not analysed    nd: not detected    Cr not analysed in 1996

## Biology

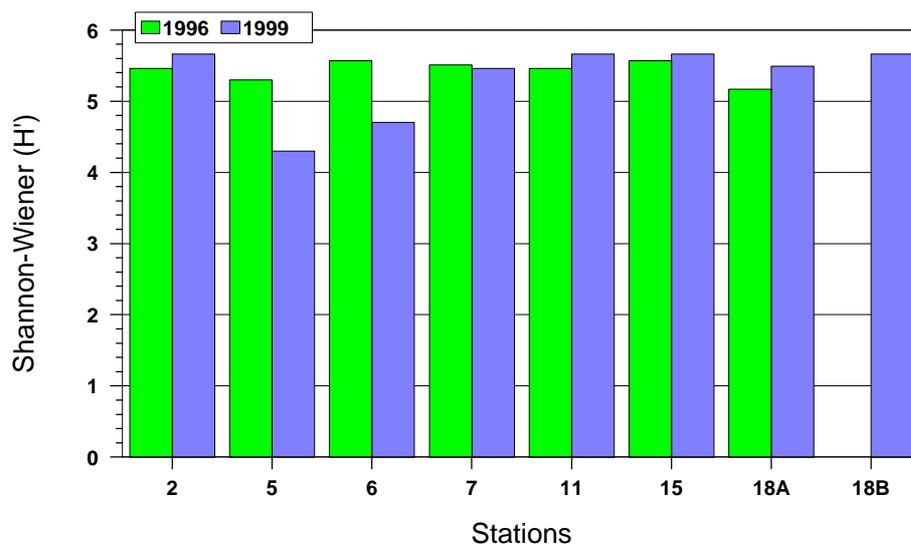
The number of species per station varied from 61 to 105, and the number of individuals varied from 421 to 601. A total of 4316 individuals were identified to 182 taxa. The 10 most abundant species made up from 47% to 73%. At Yme Gamma *Myriochele oculata* is not a dominant species as seen at most of other fields in the Ekofisk region.

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Depth, number of individuals ( $N$ ) and species ( $S$ ), Shannon-Wiener diversity index ( $H'$ ), Pielou's evenness index ( $J$ ) and expected number of species per 100 individuals ( $ES_{100}$ ) for each station, Yme Gamma 1999.

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
2 – 30°/500m	92	550	105	5.7	0.8	46.6
5 – 120°/250m	90	421	61	4.3	0.7	30.4
6 – 120°/500m	92	459	78	4.7	0.8	37.9
7 – 120°/1000m	91	593	96	5.5	0.8	43.5
11 – 210°/500m	91	556	104	5.7	0.9	46.1
15 – 300°/500m	92	557	93	5.7	0.9	45.8
18A – 300°/10000m	90	601	97	5.5	0.8	43.2
18B – 300°/10000m	90	579	91	5.7	0.9	45.9

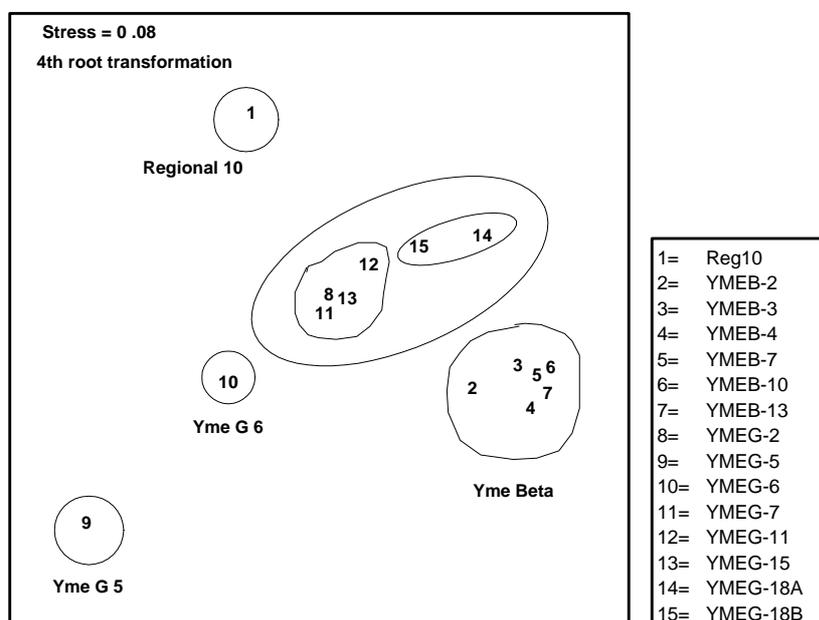
At station 5 (120°/250m) and 6 (120°/500m) the number of species and individuals and diversity indices are reduced in 1999 compared to 1996. The species composition at the same stations indicates an influenced fauna at these two stations.



Shannon-Wiener diversity index ( $H'$ ) at Yme Gamma, 1996 and 1999.

The macrofauna at Yme Gamma is diverse and undisturbed. Two exceptions were found. Oil drilling and discharges have slightly disturbed the macrofauna at station 5. Station 6 can also be regarded as disturbed, but not to the same extent as station 5.

## TECHNICAL REPORT



MDS-plot at station level, Yme Gamma and Beta 1999

### 4.13 Yme Beta

The sediments at Yme Beta consist in average of 2,5 % pelite. The pelite concentrations have increased since 1996. The total organic matter content in the sediments is low and only small variations are found at the field, from 0,38 % to 0,47 %. This is the lowest TOM concentrations found at Region I in 1999. The content is similar to the results from the previous survey in 1996 and to the baseline survey in 1994.

The mean THC concentrations vary from 0,5 mg/kg at station B13, 330°/500m to 1,6 mg/kg at station B4, 150°/250m. Obviously the THC content at Yme Beta is very low, and no elevated levels are found. However, the two stations at 250m distance that showed elevated THC concentrations in 1996, are not sampled this year. Thus the development since 1996 close to the platform can not be assessed. The conclusion is that the dispersal area has not increased since 1996, this area will be within 500m distance, but the THC levels close to the platform are unknown. Elevated levels of NPD, PAH and decalins are not found.

Compounds from the esterbased drilling fluids Finagreen and Petrofree are not found in the sediments at Yme Beta. The detection limit is 0,3 mg/kg.

The Ba concentrations vary from 7 mg/kg at stations B6, 150°/1000m and B13, 330°/500m to 103 mg/kg at station B4, 150°/250m. Slightly elevated Ba concentrations are found out to 500m distance in the 60°, 150° and the 240° directions. No elevated Ba concentrations are found at 500m distance in the 330° direction and at 1000m distance in the 150° direction. The two stations at 250m distance that showed the highest concentrations in 1996, more than 1000 mg/kg, are not sampled this year. Thus the development since 1996 close to the platform can not be assessed. The concentrations of the heavy metals are low, and only slightly elevated levels of Zn are found at one station.

## TECHNICAL REPORT

The results so far do not indicate that the dispersal area for the chemicals has increased since 1996. Generally the results agree with the drilling history at Yme Beta.

**Table 4.13.1.** *Yme Beta, pelite and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station	Pelite		TOM		THC		Esters	NPD		PAH		Decalins	
	1999	1996	1999	1996	1999	1996		1999	1996	1999	1996	1999	1996
B 2 60°/ 500 m	2,3	-	0,41	-	1,1	-	nd	-	-	-	-	-	-
B 4 150°/ 250 m	2,9	0,4	0,42	0,41	1,6	4,5	nd	0,003	0,012	0,006	0,013	nd	0,099
1-3 cm					1,1	<1,2	nd	0,004	0,008	0,004	0,028	nd	nd
3-6 cm					1,5	<1,2	nd	0,005	0,008	0,006	0,032	nd	nd
B 5 150°/ 500 m	3,7	0,4	0,40	0,47	1,1	1,9	nd	-	-	-	-	-	-
B 6 150°/ 1000 m	2,2	0,3	0,47	0,43	1,1	1,2	nd	0,007	-	0,010	-	nd	-
1-3 cm					2,6	-	nd	0,006	-	0,010	-	nd	-
3-6 cm					1,6	-	nd	0,006	-	0,010	-	nd	-
B 10 240°/ 500 m	1,6	-	0,38	-	0,8	-	nd	-	-	-	-	-	-
B 13 330°/ 500 m	2,5	-	0,41	-	0,5	-	nd	-	-	-	-	-	-

-: not analysed      nd: not detected      Esters (Petrofree and Finagreen) not analysed in 1996

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

Station	Ba		Cd	Cr	Cu		Hg	Pb		Zn	
	1999	1996			1999	1996		1999	1996	1999	1996
B 2 60°/ 500 m	18	-	nd	8,2	nd	-	-	7,3	-	4,9	-
B 4 150°/ 250 m	103	87	nd	8,6	nd	<0,6	<0,01	7,1	5,7	4,5	4,5
1-3 cm	81	-	nd	8,5	nd	-	<0,01	6,9	-	4,0	-
3-6 cm	94	-	nd	8,6	nd	-	<0,01	6,9	-	4,2	-
B 5 150°/ 500 m	20	64	nd	9,0	nd	<0,6	-	7,8	6,3	5,3	4,8
B 6 150°/ 1000 m	7	41	nd	9,2	nd	0,9	0,02	8,2	6,4	5,0	5,2
1-3 cm	18	-	nd	9,7	nd	-	0,03	8,5	-	5,1	-
3-6 cm	46	-	nd	9,9	nd	-	<0,01	8,7	-	5,1	-
B 10 240°/ 500 m	14	-	nd	8,3	nd	-	-	7,1	-	19,1	-
B 13 330°/ 500 m	7	-	nd	7,5	nd	-	-	6,4	-	3,9	-

-: not analysed      nd: not detected      Cr not analysed in 1996

## Biology

The number of species per station varied from 79 to 97, and the number of individuals varied from 592 to 839. A total of 4156 individuals were identified to 148 taxa. The 10 most abundant species made up from 56% to 63%.

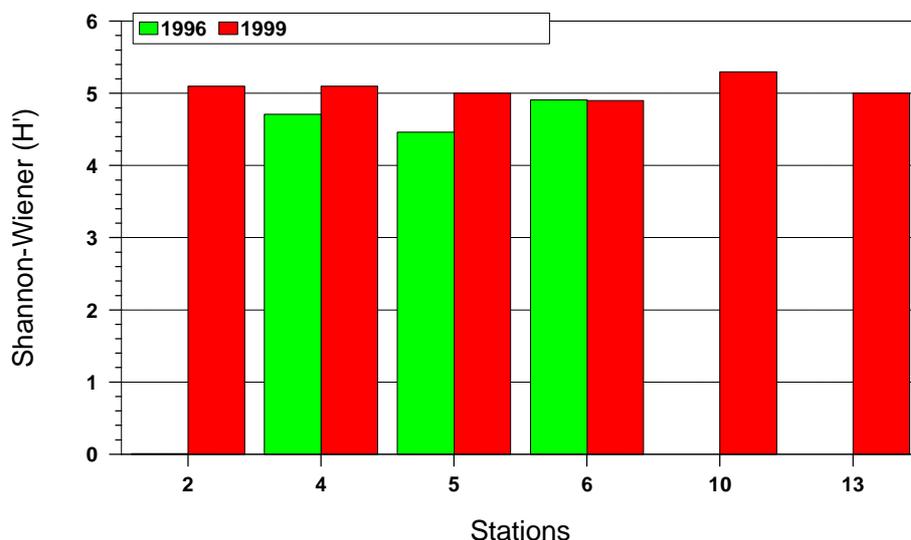
The polychaete *Spiophanes bombyx* and *Aricidea simonae/cerrutii* dominated at most of the stations (14 to 17%), while *Spiophanes kroeyeri* and *Myriochele oculata* were found up to 18% at some stations. *M. oculata* was not a dominating species at Yme Beta, and this species does hardly influence the diversity index.

## TECHNICAL REPORT

Depth, number of individuals ( $N$ ) and species ( $S$ ), Shannon-Wiener diversity index ( $H'$ ), Pielou's evenness index ( $J$ ) and expected number of species per 100 individuals ( $ES_{100}$ ) for each station at Yme Beta 1999.

Station	Depth	N	S	$H'$	$J'$	$ES_{100}$
2 – 60°/500m	76	666	86	5.1	0.8	38.6
4 – 150°/250m	76	656	88	5.0	0.8	37.9
5 – 150°/500m	78	592	81	5.0	0.8	37.1
6 – 150°/1000m	79	834	84	4.9	0.8	35.0
10 – 240°/500m	76	759	97	5.3	0.8	40.8
13 – 330°/500m	78	540	79	5.2	0.8	39.4

The diversity index varied from 4.9 to 5.3. The numbers of species and individuals and diversity indices were generally higher in 1999 than in 1996.



Shannon-Wiener diversity index ( $H'$ ) at Yme Beta, 1996 and 1999.

Similar to the results from the 1996 survey, the macrofauna at the stations sampled at Yme Beta are characterised as typical for undisturbed sediments (see Yme Gamma for MDS plot).

#### 4.14 Tambar

At this base line survey at Tambar samples are taken out to 2000m distance in four directions, 45°, 135°, 225° and 315°.

At Tambar the content of fine sand is dominating at all stations. The sediments consist in average of 3,7 % pelite (< 63  $\mu\text{m}$ ) and 96,3 % sand (> 63 $\mu\text{m}$ ).

The total organic matter content in the sediments is low, and only small variations are found at the field, from 0,71 % to 0,84 %.

## TECHNICAL REPORT

In general the sediments around Tambar appear to be "undisturbed" with low background levels of THC. Additional input of mineral oil is therefore easy to recognize in the gas chromatograms, and traces as low as 4,1 mg/kg could be detected. The mean THC concentrations vary from 3,2 mg/kg at station 8, 135°/2000m to 107 mg/kg at station 9, 225°/250m. Elevated THC concentrations are found at the 250m in the 135° and 225° directions. Additional THC "humps" are also found at the 500m stations in these directions. No elevated THC concentrations or additional THC "humps" are observed at and outside 1000m distance. The results indicate that discharges of drillcuttings have taken place. One exploratory well has been drilled by use of HDF 200 base oil in the lowest section, however, no discharges are reported.

Elevated levels of NPD and PAH are not found. Elevated levels of decalins are found at station 5, 135°/250m. The concentrations are high with a mean value of 3,45 mg/kg. The decalin results confirm the THC results, and the indication of discharges of drillcuttings.

The Ba concentrations vary from 24 mg/kg at station 8, 135°/2000m to 4040 mg/kg at station 9, 225°/250m. High Ba concentrations, 1590 mg/kg, are also found at station 10, 225°/500m. Elevated Ba concentrations are found out to 250m distance in the 135° direction, out to 500m in the 315° direction and out to 1000 m distance in the 45° and 225° directions. The Ba results agree with the fact that baryte has been discharged during exploration.

The concentrations of the heavy metals are low, and only slightly elevated levels of Cu and Zn are only found in a few samples.

**Table 4.14.1. Tambar, pelite and TOM (%), THC, NPD, PAH, decalins, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)**

Station		Pelite	TOM	THC	NPD	PAH	Decal ins	Ba	Cd	Cr	Cu	Hg	Pb	Zn
		1999	1999	1999	1999	1999	1999	1999	1999	1999	1999	1999	1999	1999
St.1	45°/ 250 m	4,2	0,76	5,6	-	-	-	276	nd	6,9	0,7	-	6,2	5,1
St.2	45°/ 500 m	4,2	0,76	4,1	-	-	-	261	nd	6,8	1,8	-	5,9	6,3
St.3	45°/1000 m	4,7	0,75	3,8	-	-	-	132	nd	6,8	2,3	-	5,9	5,6
St.4	45°/2000 m	3,5	0,74	3,3	-	-	-	50	nd	6,5	2,6	-	5,9	12,8
St.5	135°/ 250 m	4,9	0,75	49,5	0,032	0,036	3,450	677	nd	7,5	0,8	nd	6,3	5,7
	1-3 cm			9,6	0,024	0,053	0,363	1894	nd	7,3	0,9	nd	7,6	5,6
	3-6 cm			11,5	0,027	0,062	0,409	489	nd	8,0	1,2	nd	6,4	6,2
St.6	135°/ 500 m	3,4	0,73	5,3	-	-	-	107	nd	6,9	0,6	-	5,8	5,3
St.7	135°/1000 m	2,8	0,75	3,6	-	-	-	44	nd	7,2	1,4	-	6,1	7,0
St.8	135°/2000 m	3,1	0,71	3,2	0,011	0,025	nd	24	nd	6,9	0,5	nd	5,8	5,2
	1-3 cm			3,1	0,009	0,028	nd	48	nd	6,8	0,4	nd	5,6	5,3
	3-6 cm			4,6	0,020	0,061	nd	123	nd	8,0	0,8	nd	6,8	8,0
St.9	225°/ 250 m	5,3	0,84	107	-	-	-	4040	nd	8,0	3,5	-	8,5	7,5
St.10	225°/ 500 m	2,6	0,76	5,3	-	-	-	1590	nd	7,0	0,8	-	6,8	5,5
St.11	225°/1000 m	4,8	0,80	3,9	-	-	-	253	nd	7,3	1,0	-	6,7	6,3
St.12	225°/2000 m	2,8	0,79	3,9	-	-	-	66	nd	7,3	0,7	-	6,4	5,9
St.13	315°/ 250 m	5,2	0,72	3,5	-	-	-	280	nd	6,9	2,1	-	5,7	5,3
St.14	315°/ 500 m	1,6	0,80	4,0	-	-	-	118	nd	6,9	0,8	-	6,8	10,5
St.15	315°/1000 m	2,6	0,72	3,3	-	-	-	88	nd	6,5	0,5	-	5,6	5,8
St.16	315°/2000 m	4,0	0,74	3,4	-	-	-	32	nd	6,8	0,4	-	6,1	6,5

## TECHNICAL REPORT

**Biology**

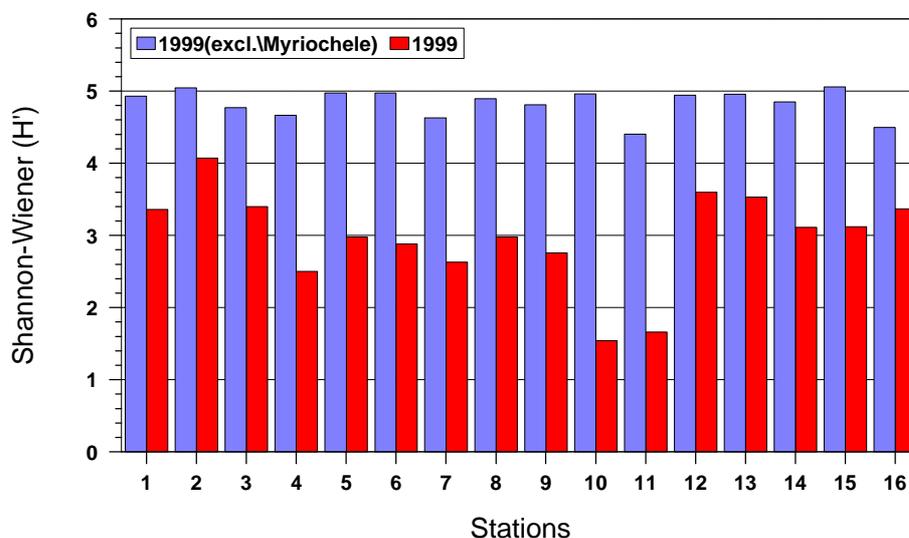
The number of species per station varied from 59 to 81, and the number of individuals varied from 806 to 2988. A total of 20158 individuals were identified to 162 taxa. The 10 most abundant species made up from 72% to 93%.

The polychaete *Myriochele oculata* dominated at all stations (38 to 82%), while *Eudorellopsis deformis* and *Amphiura filiformis* were found in abundance from 2 to 10% at some stations. The numbers were highest in the 225° direction at the 250, 500 and 1000m stations. This species clearly affects the diversity, see table below.

*Number of individuals (N), 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 stations at Tambar 1999.*

Station	Depth	N	S	H'	J'	ES <sub>100</sub>
1 – 45°/250m	69	1160/556	70	3.4/4.9	0.6/0.8	24.5/34.2
2 – 45°/500m	68	863/532	74	4.1/5.1	0.7/0.8	29.4/36.2
3 – 45°/1000m	68	852/428	68	3.4/4.8	0.6/0.8	24.5/34.4
4 – 45°/2000m	68	1727/583	74	2.5/4.7	0.4/0.8	18.2/31.2
5 – 135°/250m	67	1292/521	76	3.0/5.0	0.5/0.8	22.6/35.5
6 – 135°/500m	66	1322/510	75	2.9/5.0	0.5/0.8	21.9/35.1
7 – 135°/1000m	67	1087/396	60	2.6/4.6	0.5/0.8	19.7/33.0
8 – 135°/2000m	68	998/408	66	3.0/4.9	0.5/0.8	22.6/35.7
9 – 225°/250m	67	1229/461	65	2.8/4.8	0.5/0.8	20.9/34.9
10 – 225°/500m	69	2988/526	68	1.5/5.0	0.3/0.8	13.5/35.0
11 – 225°/1000m	69	1798/377	59	1.7/4.4	0.3/0.8	13.2/31.2
12 – 225°/2000m	70	841/443	81	3.6/4.9	0.6/0.8	26.6/37.7
13 – 315°/250m	67	979/500	75	3.5/5.0	0.6/0.8	26.1/36.7
14 – 315°/500m	68	1044/456	75	3.1/4.9	0.5/0.8	22.9/35.9
15 – 315°/1000m	68	1172/496	76	3.1/5.1	0.5/0.8	23.9/37.5
16 – 315°/2000m	69	806/425	60	3.4/4.5	0.6/0.8	22.7/31.2

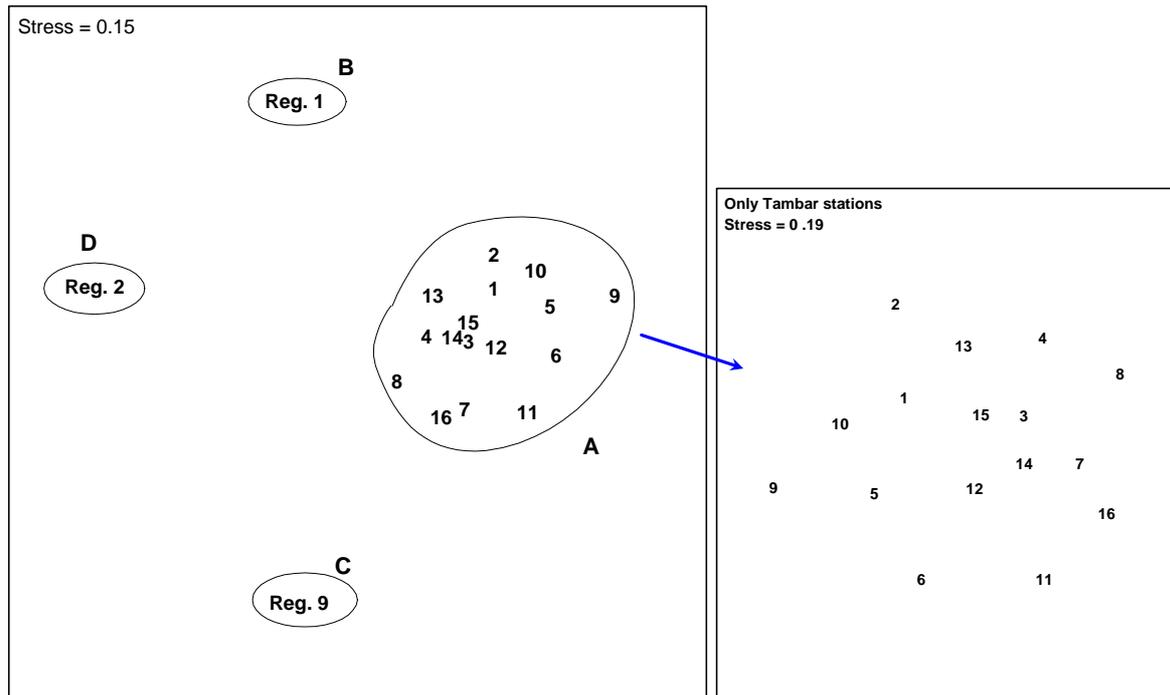
The diversity index, including *M. oculata* varied from 1.5 to 4.1, and from 4.4 to 5.1 excluding the same species.



*Shannon-Wiener diversity index (H') at Tambar, 1999. With and without M. oculata.*

TECHNICAL REPORT

The polychaete *Myriochele oculata* dominated at all stations with highest abundance at station 10 (225°/500m). The diversity was low at stations where *M. oculata* was found in high numbers, but the diversity index, evenness and ES<sub>100</sub> were all high when excluding *M. oculata* from the data. The multivariate analyses support the impression of an unaffected macrobenthic fauna, with a possible minor “influence” at the three chemical contaminated stations 5, 9 and 10.



MDS-plot at station level, Tambar 1999. The MDS plot to the right shows only Tambar stations.

## 5 RECOMMENDATIONS

### Field stations

When planning the stations for the 1999 survey, the results from the 1996 survey were assessed and the intention was to identify the transition zones between the contaminated and uncontaminated area around the installations. This objective has been achieved, but for some fields the area of contamination is closer to the installation than the stations sampled. It is therefore recommended that samples are taken closer to the installations during the next survey in Region 1.

### Representative analyses

According to the SFT Guidelines (99:01) all stations shall be analysed for the main compounds in the synthetic base liquids used during drilling (however, the 1999 monitoring program was worked out prior to the release of SFT 99:01). The objective was to assess the change in the concentrations and dispersal area of these compounds. During the next survey in Region 1, all stations where synthetic drilling fluids have been used should be analysed for the relevant synthetic base liquids.

### Unexplained results

In the present survey the sediments at Tor contain compounds that are not in accordance with the drilling history. The gas chromatographic profiles tentatively indicate that these compounds are similar to the pseudo-oil base fluids used at the other fields in the Ekofisk area. However, synthetic base fluids of ether type (Aquamul B) have very similar GC profile. Additional work to identify the discharged compound is recommended.

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