

ENVIRONMENTAL MONITORING

STATOIL/SHELL/HYDRO

ENVIRONMENTAL MONITORING REGION VI -
HALTENBANKEN 2003

ENGLISH SUMMARY REPORT

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ENGLISH SUMMARY

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Summary:

This summary presents the results from the environmental monitoring at Region VI, Haltenbanken, 2003.

A total of 10 fields and 8 regional stations were included in the survey.

Sediments have been sampled from the following fields: Norne, Åsgard, Njord, Heidrun, Draugen, Garn Vest, Garn Central, Rogn Sør, Mikkel and Kristin. A total of 199 stations were investigated.

The main parameters in the investigation were:

- Macrofauna
- Grain size and organic content
- THC/ PAH/NPD/decalins
- Metals

The report is divided into 3 main reports: Main report (DNV-report no. 2004-0218), Norwegian Summary report (DNV-report no. 2004-0316, English Summary report 2004-0317), and Appendices report (DNV-report no. 2004-0312). Foldable maps for each of the fields showing station location are given in the Main report.

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PREFACE

The environmental survey at Region VI in 2003 was carried out jointly by Det Norske Veritas and SINTEF.

The report presents the results of the chemical/physical and macrobenthic analysis of the seabed sediments from Region VI.

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The main part of the chemical analysis was performed at SINTEF Material and Chemistry. dep. Environmental Technology and Analysis.

The biological analysis were performed at DNV's Biological laboratory at Høvik.

	<p>The laboratories - SINTEF SINTEF Material and Chemistry. dep. Environmental Technology and Analysis. – are accredited by Norsk Akkreditering to perform chemical analysis, accreditation no. Test 032 og Test 091. The accreditation is in accordance with NS-EN ISO/IEC 17025.</p> <p>The accreditation includes methods for determination of total hydrocarbon content (THC), naphtalensr, phenanthrenes and dibenzotiofenes (NPD), polycyclic aromatic hydrocarbones (PAH), metals, total organic matter (TOM) and grain size distribution in sediments.</p>
	<p>The biological analyses were carried out at DNV's Biology Laboratory, Høvik. The laboratory is accredited by Norsk Akkreditering to perform sampling of marine sediments and analysis of macrobenthic fauna in accordance with the Activity Regulations, accreditation no. TEST 083. The accreditation is in accordance with NS-EN ISO/IEC 17025.</p>



1 SUMMARY AND CONCLUSIONS

This summary presents the main results from the environmental monitoring in Region VI, Haltenbanken, 2003. Det Norske Veritas performed the survey in co-operation with SINTEF.

The report presents the results from the chemical/physical analysis of seabed sediments and from the analysis of macrobenthic fauna.

The field work was conducted in two periods from the vessel S/V *Geobay* in the period 20th of May to the 8th of June and from the vessel *Viking Poseidon* in the period 26th to 27th of June in 2003.

The sediments are analysed for the following analytical parameters.

Analysis	Parameter
Sediment characterization	
• 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
Chemical analysis	
• 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
• Ethers	- Aquamul B II
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/boric acid

**The 2003 survey at Region VI shows:**

- The sediments at Region VI are partly dominated by silt & clay and partly of very fine sand.
- The total organic matter content in the sediments is relative high and varies from 1,7 % to 8,1 %.
- The chemical results are in agreement with the drilling history.
- The regional stations and the reference stations are still unaffected by the drilling chemicals - no contamination or elevated concentrations are found in these sediments.
- Relative high THC levels (>50 mg/kg) are found at Åsgard M, Heidrun, Njord and Mikkel. The THC concentrations are lower at Norne, Åsgard N, S and X, Garn Vest and Rogn Sør, and elevated THC levels are not found at Draugen, Garn Central and Kristin. The dispersal area varies, out to 250m from the installation at new fields to 2000m at Njord. The THC concentrations have increased at Heidrun, Mikkel and partly at Njord. At Njord one station still contains very high THC concentrations due to leakage of oil based drilling mud from *slipjoint* in 2000.
- Decalins are found in the sediments when drilling mud base oil is found.
- Olefins and esters from drilling fluids are not found in the sediments at Heidrun.
- Ethers from the drilling fluid Aquamul B II are found in the sediments at Heidrun, the same low concentrations as in 2000. The results indicate a slow degradation rate.
- Dispersion of drill cuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found out to 500m at Rogn Sør, out to 1000m at Garn Vest and out to 2000m at the other fields. Generally the Ba concentrations are similar to previous surveys, however a decrease is found at Draugen and an increase is found at Norne, Heidrun, Garn Vest, Mikkel and partly at Njord.
- The concentrations of the heavy metals are low, and elevated levels are only found at some stations.
- The macro benthic fauna community in the region are in general healthy and undisturbed. The species composition at the Regional station 1 and 3 differ somewhat from the other Regional stations. At these stations there are relative fine sediment compared to the others. Analyses over year show that there have not been any considerable changes in the region in the period 1997 – 2003.



- Following stations are considered as disturbed:
 - Station Heidrun-6 (50°/550m) together with Heidrun-7 (45°/1000m) and Heidrun-12 (120°/550m). There was a good correlation between fauna and a combination of the factors Ba, Cd, Pb og THC.
 - Station DR24B (300°/250m) at Draugen was characterised as disturbed in 2000, and the analysis reveals that this is still the case. But the levels of Ba and THC are reduced since 2000.
 - At Njord the stations NJ-6 (157,5°/500m) and NJ-13 (337,5°/250m) are disturbed. In addition the analysis indicate slightly disturbance in the fauna at the stations NJ-9 (247,5°/250m), 14 (337,5°/500m), NJ-1 (67,5°/250m), NJ-2 (67,5°/500m) and NJ-5 (157,5°/250m).
- At several fields in the region, changes in the species composition gives indications of an increased supply of organic material.
- The results from the present survey in 2003 are in agreement with the 2000 survey.

The main parameters and the variation at each field:

Regional stations	Variation	Main characteristics
THC (mg/kg)	2,6 – 4,7	The concentrations of hydrocarbons, barium and metals are low, and no elevated levels are found. Undisturbed fauna
Ba (mg/kg)	88 - 182	
Diversity (H')	5,2 – 6,0	

Norne	Variation	Main characteristics
THC (mg/kg)	4,0 - 25,7	Elevated THC levels out to 500m (NW) and 1000m (SW). Elevated Ba levels out to 2000m. Lower THC levels than in 2000, and similar Ba levels.
Ba (mg/kg)	500 – 3000	
Diversity (H')	4,4 – 5,2	In general a healthy and undisturbed fauna, a possible slightly organic influence at some stations.

Åsgard	Variation	Main characteristics
THC (mg/kg)	2,8 - 75,5	Elevated THC levels out to 500 - 1000m. Elevated Ba levels out to 500m at installations N, X and M and out to 2000m at S. At S the THC levels are decreased, and the Ba levels are similar to 2000.
Ba (mg/kg)	441 - 2310	
Diversity (H')	4,9 – 6,0	In general a healthy and undisturbed fauna, a possible slightly organic influence around S and X.



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Heidrun	Variation	Main characteristics
THC (mg/kg)	2,7 - 76,9	Elevated THC levels out to 1000m, an increase since 2000. Olefins and esters are not found. Ethers from Aquamul B II are found, same concentrations as in 2000. Elevated Ba levels out to 2000m, an increase since 2000. 1500 tonnes of baryte are discharged in the period 2000 - 2002
Ba (mg/kg)	182 - 8140	
Diversity (H')	4,5 - 5,8	Disturbance in the fauna at station Hei-6 (50°/550m), but also at Hei-7 (45°/1000m) and Heidrun-12 (120°/550m).
Draugen	Variation	Main characteristics
THC (mg/kg)	2,6 - 5,1	Elevated THC levels are not found, but only one 250m station is analysed. Elevated Ba levels out to 2000m, and a tendency of a decrease since 2000.
Ba (mg/kg)	125 - 2710	
Diversity (H')	5,4 - 6,3	In general a healthy and undisturbed fauna. Station DR24B (300°/250m) are characterised as disturbed.
Garn Vest	Variation	Main characteristics
THC (mg/kg)	3,1 - 8,2	Low, but elevated THC levels out to 250m. Elevated Ba levels out to 1000m. A slight decrease of THC and Ba since the baseline survey in 2000.
Ba (mg/kg)	191 - 1090	
Diversity (H')	5,7 - 6,0	In general a healthy and undisturbed fauna. Some indications of supply of organic material in 500 and 1000m.
Garn Central	Variation	Main characteristics
THC (mg/kg)	3,1 - 5,6	Baseline survey. Elevated THC levels are not found. Low, but elevated Ba levels at all stations out to 2000m.
Ba (mg/kg)	400 - 702	
Diversity (H')	5,6 - 6,0	In general a healthy and undisturbed fauna
Njord	Variation	Main characteristics
THC (mg/kg)	3,0 - 3660	Elevated THC levels out to 2000m. Fresh drilling mud base oil at station NJ6, 157,5°/500m. Elevated Ba levels out to 2000m. Some increases and some decreases of THC and Ba since 2000. The leakage from <i>slipjoint</i> in 2000 still causes very high THC levels. Discharges of baryte in 2000, and some during the first six months of 2003 as well.
Ba (mg/kg)	109 - 6840	
Diversity (H')	2,8 - 6,1	NJ-6 (157,5°/500m) and 13 (337,5°/250m) is disturbed. Slight disturbance at NJ-9 (247,5°/250m), 14 (337,5°/500m), NJ-1 (67,5°/250m), NJ-2 (67,5°/500m) and NJ-5 (157,5°/250m).



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Mikkel	Variation	Main characteristics
THC (mg/kg)	2,4 - 112	Elevated THC levels out to 500m. Elevated Ba levels out to 2000m. An increase of THC and Ba since the baseline survey in 2001. Drilling started in 2002, and 700 tones of baryte are discharged. High Cu concentrations are found at <u>one</u> station.
Ba (mg/kg)	150 – 3260	
Diversity (H')	5,4 – 5,9	Species rich and undisturbed fauna.
Rogn Sør	Variation	Main characteristics
THC (mg/kg)	2,1 - 11,1	Slightly elevated concentrations at a few stations, THC out to 250m and Ba out to 500m. A slight increase since the baseline survey in 2001. Drilling started in 2002, and baryte has not been discharged.
Ba (mg/kg)	99 - 314	
Diversity (H')	5,6 – 6,1	Species rich and undisturbed fauna. Possible some organic enrichment.
Kristin	Variation	Main characteristics
THC (mg/kg)	1,6 - 6,9	Baseline survey. Low THC concentrations, no contamination. Low, but elevated Ba concentrations out to 1000m.
Ba (mg/kg)	89 - 1370	
Diversity (H')	5,3 – 6,1	Species rich and undisturbed fauna.



2 INTRODUCTION

This report presents the results from the regional survey at Haltenbanken 2003. The purpose of the regional survey is to study the environmental effects from the petroleum activity for a greater area than the earlier platform specific surveys. The regional survey at Haltenbanken was first performed in 1997.

The report is divided in three parts. In the summary report (this) is the most important results presented, and in the main report (DNV-report nr. 2004 – 0218) the results are commented and discussed.

The appendix report (DNV – report nr. 2004 – 0312) contains:

- Appendix A – Survey report
- Appendix B – Test report – sampling/biology
- Appendix C – Chemical results
- Appendix E – Survey program

In the region the following fields are included:

Table 2.1. *Fields and installations included in the regional survey 2003.*

Field	Operator
Norne	Statoil
Heidrun	Statoil
Åsgard	Statoil
Mikkel	Statoil
Kristin	Statoil
Draugen	Shell
Garn Central	Shell
Garn Vest	Shell
Rogn Sør	Shell
Njord	Hydro

The area included in the regional survey is shown in figure 2.1.

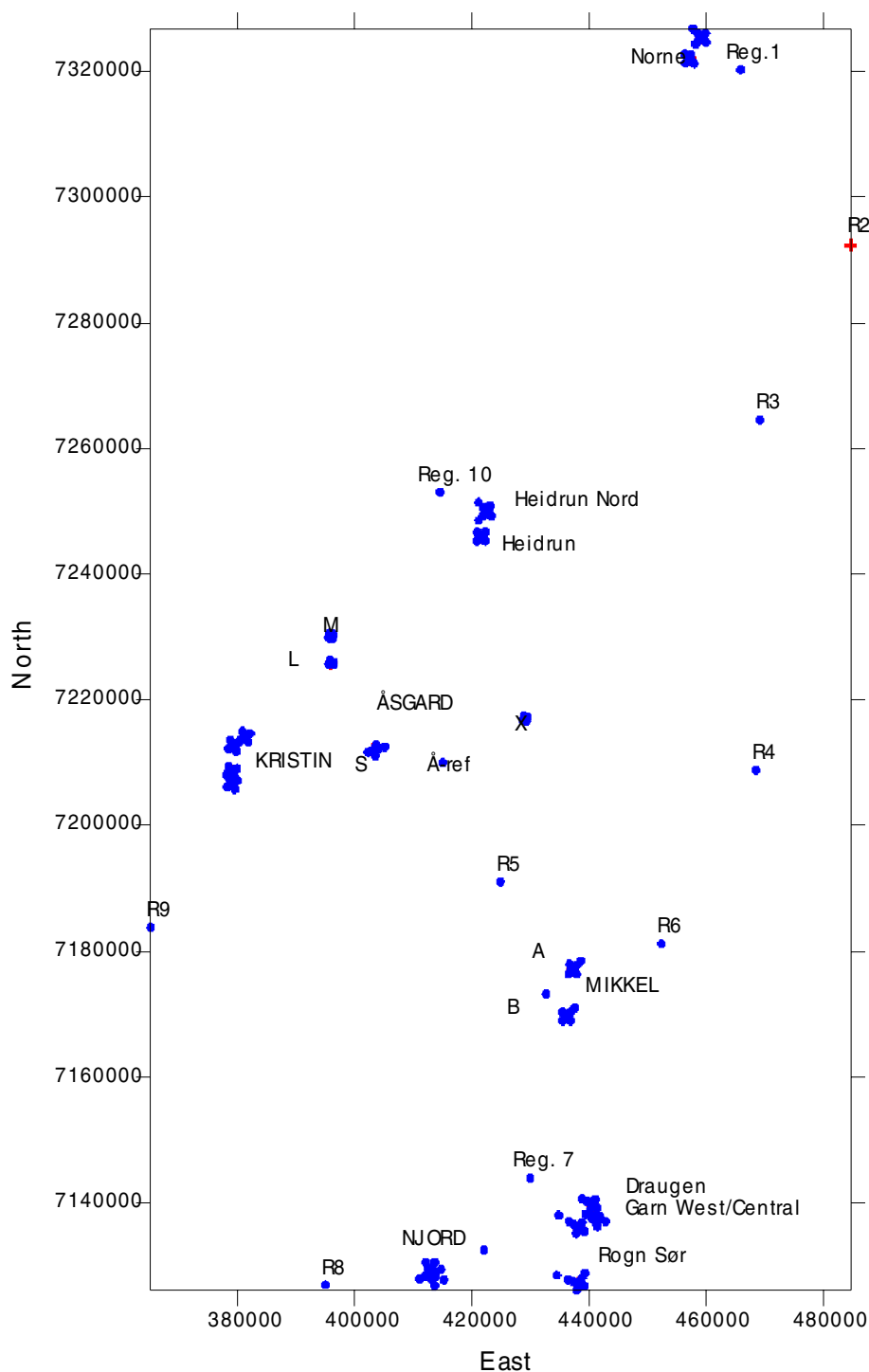


Figure 2.1. Overview of the fields included in his regional survey. Regional stations are marked R1 to R10. Some reference stations also functions as regional stations. Regional station R2 is excluded from the programme in 2003.



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Table 2.2. gives an overview of the number of stations at each field where biological and chemical sampling was performed.

Table 2.2. Total number of stations and analysis included in the regional survey at Haltenbanken 2003.

	Draugen	Garn Central	Garn Vest	Rogn Sør	Njord	Heidrun	Åsgard	Norne	Mikkel	Kristin	Reg.	Sum
Grain	11	13	13	14	22	19	22	20	21	39	5	199
TOM	11	13	13	14	22	19	22	20	21	39	5	199
Metals	41	43	43	50	76	69	78	72	75	137	15	699
Hg	17	10	10	17	22	27	27	27	27	47	15	246
HF	3	-	-	-	-	3	-	3	-	-	15	24
THC	41	43	43	50	76	69	78	72	75	137	15	699
NPD	17	10	10	17	22+12	27+4	27	27	27+3	47	15	265
Olefin	-	-	-	-	-	33	-	-	-	-	-	33
Ester	-	-	-	-	-	18	-	-	-	-	-	18
Ether	-	-	-	-	-	33	-	-	-	-	-	33
Biology	60	65	65	75	115	100	115	105	110	200	25	1035

3 FIELD WORK AND METHODS

The field work was performed by DNV in cooperation with SINTEF using the vessel S/V Geobay in the period 20th of May to 8th of June and the vessel Viking Poseidon from 26th of June to 27th of June. Sampling and analysis are done with reference to activity regulation (OD, SFT, Hi, 2001), appendix 1, *requirement to environmental monitoring of the petroleum activity on the Norwegian continental shelf – technical appendix 2, Sediment monitoring* and DNV procedures for this kind of work. Deviation from the regulations is described in chapter 3.4. It is prepared a separate survey report, see appendix A in the Appendix report (DNV report 2004 – 0312). The survey report contains a complete overview of the sampling programme, included stations coordinates (UTM and degrees/minutes), water depth, date and time for the sampling, volume of sediment used in the soft bottom analysis, the number of unsuccessful shot, colour and some comments.



The sediments are analysed for the following analytical parameters.

Analysis	Parameter
Sediment characterization	
• Grain size distribution	<ul style="list-style-type: none"> - 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	<ul style="list-style-type: none"> - % TOM in the sediment
Chemical analysis	
• Hydrocarbons	<ul style="list-style-type: none"> - 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
• Ethers	- Aquamul B II
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/boric acid



4 RESULTS AND DISCUSSION

In the summary report are only the most important results and conclusions presented. More detailed results and discussions are presented in the main report (DNV, 2004, report nr. 2004 – 0218).

4.1 Regional stations

4.1.1 Grain size and chemical analysis

The sediments at the regional stations consist mainly of silt and clay, and the content varies from 57 % at Regional 9 to 92 % at Regional 1. Similar distribution was found in the previous survey in 2000.

The total organic matter content is relative high and varies from 3,9 % at Regional 5 and Regional 7 to 6,3 % at Regional 1. The results can not be compared directly with previous years as deeper sediment layers are analysed in 2003. The tendency is slightly lower values in the present survey.

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

The THC content in the sediments varies from 2,6 mg/kg at Regional 6 to 4,7 mg/kg at Regional 8. The barium concentration varies from 88 mg/kg at Regional 6 to 182 mg/kg at Regional 10.

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 375 mg/kg at Regional 6 to 504 mg/kg at Regional 8. The concentrations of the heavy metals are similar to digestion by nitric acid.

A limit of significant contamination (LSC value) at Region VI is calculated for each chemical parameter at a confidence level of 95 %. The LSC values cover the total region.

Table 4.1. Regional stations, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM			THC			NPD			PAH		
	2003	2000	2003	2000	1997	2003	2000	1999	2003	2000	1997	2003	2000	1997
Regional 1, Norne ref	91,6	90,1	6,3	8,2	9,7	4,0	3,8	3,6	0,089	0,069	0,083	0,130	0,123	0,128
Regional 3	83,1	79,1	4,9	6,5	6,3	3,3	3,0	2,2	0,088	0,070	-	0,095	0,098	-
Regional 5	75,7	74,2	3,9	5,1	6,6	3,5	2,5	3,8	0,078	0,053	-	0,098	0,088	-
Regional 6	69,6	62,1	5,1	3,9	4,8	2,6	2,4	3,2	0,058	0,034	-	0,074	0,074	-
Regional 7, Draugen ref	66,9	55,9	3,9	5,1	3,9	4,6	4,1	2,6	0,076	0,074	0,043	0,125	0,101	0,090
Regional 8	83,5	83,1	5,3	6,1	6,6	4,7	5,9	4,8	0,103	0,078	-	0,149	0,078	-
Regional 9	57,3	59,9	4,3	5,6	4,9	4,0	5,2	2,9	0,077	0,064	-	0,116	0,064	-
Regional 10, Heidrun ref	59,4	60,2	4,3	5,1	5,3	3,4	1,9	1,1	0,065	0,062	0,061	0,095	0,081	0,144

-: not analysed Decalins are not found, detection limit 50µg/kg



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Table 4.2. Regional stations, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Cu	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
	2003	2000	1997	2003	2000	2003	2000	2003	2000	1997	2003	2000	2003	2000	1997	2003	2000	1997
Regional 1	147	191	130	0,10	0,10	35,9	36,0	12,3	10,3	14,1	0,06	0,03	20,3	21,4	26,2	64	65,8	65,6
Regional 3	164	162	107	0,11	0,09	28,8	28,7	10,5	8,3	8,4	0,04	0,02	19,4	17,7	12,8	53	51,4	45,3
Regional 5	121	84	150	0,12	0,06	24,7	23,9	9,2	6,7	8,5	0,03	0,01	18,5	12,8	18,3	44	39,3	47,3
Regional 6	88	87	91	0,05	0,05	20,4	20,7	6,8	5,4	6,6	0,03	0,02	14,7	14,3	13,7	35	35,2	37,3
Regional 7	125	116	113	0,06	0,04	22,2	22,7	7,9	6,7	7,7	0,05	0,02	17,6	15,2	17,1	38	37,7	39,0
Regional 8	129	154	129	0,06	0,07	24,7	24,8	9,8	8,6	9,2	0,03	0,02	20,4	20,9	19,2	45	45,6	48,8
Regional 9	119	123	97	0,07	0,07	23,5	24,5	8,8	8,7	7,4	0,04	0,02	20,1	20,5	17,2	41	42,8	41,0
Regional 10	182	123	112	0,09	0,08	20,7	20,8	8,1	7,3	7,2	0,06	0,02	17,7	15,8	21,2	37	41,0	41,1

Table 4.3. Regional stations, Metals - digestion with fluoric acid/aqua regia/boric acid (mg/kg dry sed.)

Station	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Pb	Pb	Zn	Zn	Al	Al	Li	Li
	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000
Regional 1	425	483	0,10	0,13	61,1	64,6	13,4	18,1	26,6	25,1	77,2	76,0	56170	58510	45,0	42,0
Regional 3	441	433	0,12	0,12	51,4	53,7	13,0	17,2	15,6	22,0	66,0	61,1	48830	51550	37,4	33,8
Regional 5	419	366	0,11	0,12	48,2	46,9	11,7	10,7	24,9	17,7	57,2	47,2	47880	48390	30,9	26,2
Regional 6	375	359	0,08	0,11	42,1	45,0	9,2	9,3	18,2	20,9	46,6	43,3	44400	46410	23,7	21,6
Regional 7	447	411	0,10	0,09	44,1	50,1	10,9	11,2	25,3	21,5	46,8	47,7	45970	49340	23,9	23,0
Regional 8	504	507	0,10	0,11	47,2	50,3	12,4	12,8	29,3	24,9	57,9	55,8	50330	52870	30,0	28,7
Regional 9	439	423	0,12	0,11	45,8	49,4	11,2	12,4	27,4	27,7	52,5	51,2	45620	47820	26,2	25,9
Regional 10	479	405	0,11	0,10	39,0	41,9	11,2	11,4	25,0	22,1	42,3	45,6	43190	44740	26,1	24,9

**Table 4.4. LSC values Region VI 2003 (mg/kg dry sediment)
95% confidence level, one-tailed t-test**

Parameter	LSC value	Parameter	LSC value
THC	5,3	Cr	33
NPD	0,101	Cu	12
PAH	0,143	Pb	25
Ba	198	Zn	60



4.1.2 Biology

The benthic fauna community in the region could be characterised as healthy and divers.

The Shannon-Wieners diversity index (H') range from 5,2 (Reg-01) to 6,0 (Reg-09). Pielou's index of evenness was in general high with a range from 0,8 to 0,9.

Different fauna parameters are given in table 4.5.

Table 4.5. Depth, number of species (S) and number of individuals (N) per $0,5 m^2$, Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Regional stations 2003.

Station	Depth (m)	S	N	H'	J	ES100
REG-01 (Norne Ref.A)	388	78	625	5,2	0,8	38
REG-03	336	95	563	5,4	0,8	42
REG-05	263	86	338	5,6	0,9	47
REG-06	232	91	467	5,6	0,9	45
REG-07 (DR51Bref.A)	270	99	520	5,8	0,9	47
REG-08	335	89	497	5,7	0,9	46
REG-09	312	108	563	6,0	0,9	51
REG-10 (HEI-27ref.A)	332	109	590	5,8	0,9	48

The MDS plot from the similarity analysis at station level is shown in figure 4.1. At about 60 % similarity the stations divide in 3 groups. The distribution of the stations in group 2 and 3 are in little degree dependent of the depth and geography.

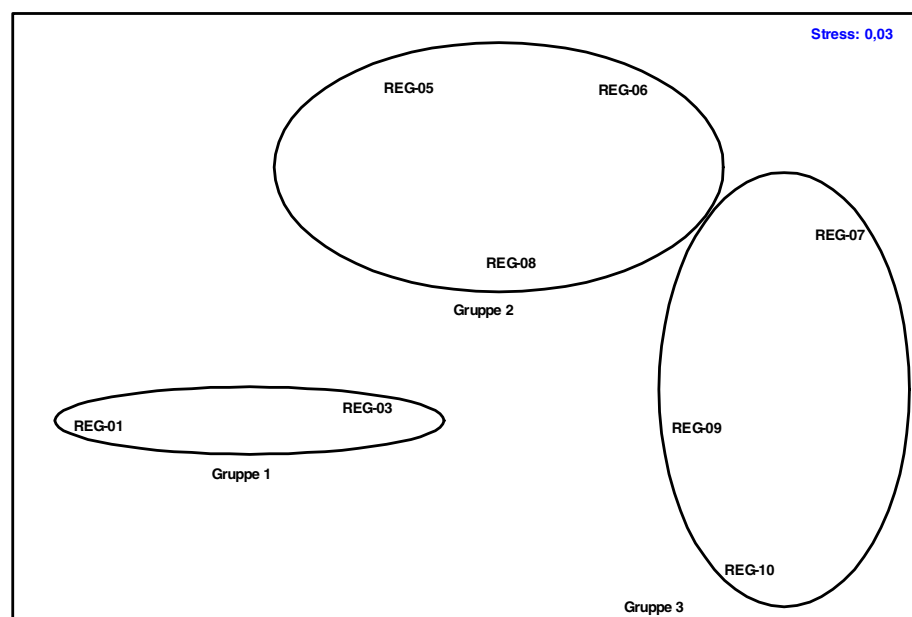


Figure 4.1. MDS-plot station level, Regional stations 2003



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A bioenv analysis gave a high correlation (0,8) between fauna and a combination of the factors depth and grain size. The single factor which correlated best with fauna was the clay and silt fraction (0,6), followed by sand (0,5).

In particular station Reg-01, but also station Reg-03 separates from the others with a somewhat different species composition. However, these two stations have relative fine sediment compared to the others.

The dendrogram for the years 1994 - 2003, is shown in figure 4.2. Stations sampled in 1997, 2000 and 2003 separate in a main group at a similarity of about 60 %. The regional station sampled in 1994 separates most, while the station sampled in 1995 separates less from the others.

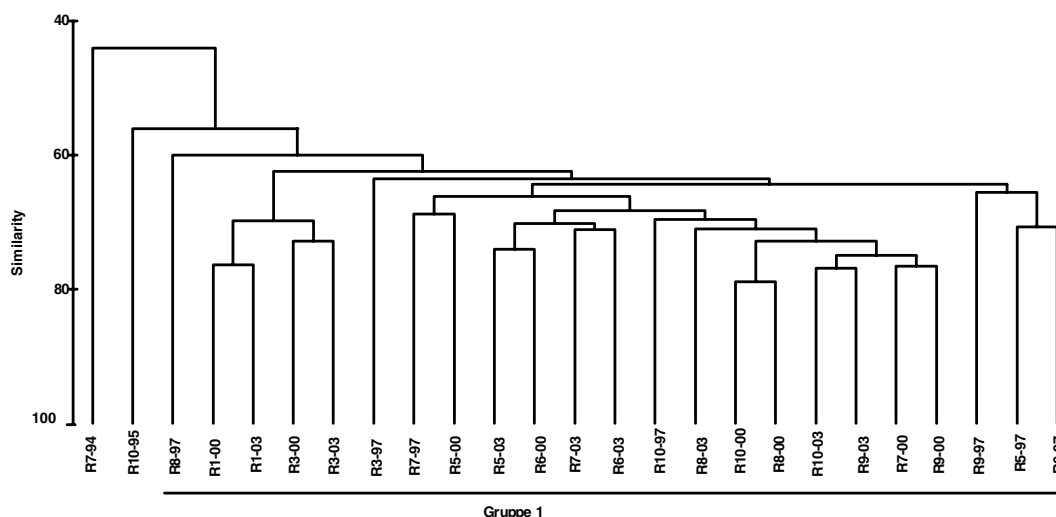


Figure 4.2. Dendrogram, Regional stations 1994 – 2003.

The results from the analysis over the years indicate very small changes since 1997.



4.2 Norne

4.2.1 Grain size and chemical analysis

The sediments at Norne consist mainly of silt and clay, from 73 % at station NOSW-07, 225°/500m to 96 % at station NONW-09, 225°/500m. The gravel content is low at all stations, up to 5 %. The results are similar to the 2000 results, except for station NONW-09, 225°/500m where the silt and clay content has increased from 61 % in 2000 to 96 % in 2003.

The total organic matter content varies from 4,7 % at station NOSW-12, 315°/1000m to 8,1 % at station NONW-02, 45°/500m and NONW-10, 225°/1000m. The results can not be compared directly with previous years as different sediment layers are analysed, 0-5cm in 2003 and 0-1cm previously. A tendency of same values at NW and slightly lower values at SW is observed.

At the NW templates the THC concentrations vary from 4,4 mg/kg at NONW-06, 135°/500m and NONW-10, 225°/1000m to 25,7 mg/kg at NONW-12, 315°/250m. The values are considerably lower than in 2000. The greatest difference is found at station NONW-09, 225°/500m where the THC concentration is reduced from 297 mg/kg in 2000 to 17,1 mg/kg in 2003. The 1-3 cm layer at station NONW-12 also contains slightly elevated THC values. Elevated concentrations are found out to 500m in the 225° direction and traces of elevated THC values are found out to 500m in the 45° and 315° directions. In the 135° direction no elevated THC concentrations are found at the innermost station at 500m.

At the SW templates the THC concentrations vary from 4,0 mg/kg at the reference station NOSW-ref. to 18,5 mg/kg at station NOSW-10, 315°/250m. The concentrations are decreased or they are at the same level as in 2000. At station NOSW-10 a THC concentration of 235 mg/kg was found in 2000. Elevated THC concentrations are found out to 500m in the 135° and 315° directions, out to 700m in the 20° direction and out to 1000 m in the 225° direction. However, the THC concentrations are low at these stations, below 10 mg/kg.

As previously low NPD and PAH concentrations are found at Norne. However, the concentrations are increased at station NOSW-10, 315°/250m where elevated levels are found. Previously high decalin concentrations are found at Norne. The decalin content is decreased since 2000, but the values are still high as 2,15 mg/kg is found at station NONW-12, 315°/250m. At this station the highest THC concentrations are found as well.

Elevated Ba concentrations are found in the sediments out to 2000m at both installations, and the concentrations are similar to the previous survey at most stations. At the NW template the Ba concentrations vary from 500 mg/kg at NONW-07, 135°/1000m to 2440 mg/kg at station NONW-12, 315°/250m. An increase is found at station NONW-09, 225°/500m, from 1060 mg/kg in 2000 to 2350 mg/kg in 2003. At station NONW-12, 315°/250m the Ba concentration is decreased in the top 0-1 cm layer and increased in the 1-3cm and 3-6cm layers.

At the SW templates the Ba concentrations vary from 147 mg/kg at the reference station NOSW-ref. to 3000 mg/kg at station NOSW-10, 315°/250m. At station NOSW-10 a decrease is found in the top layer, from 5900 mg/kg in 2000 to 3000 mg/kg in 2003. However, the concentration is increased in the 3-6 cm layer, from 335 mg/kg in 2000 to 1010 mg/kg in 2003.



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The concentrations of the heavy metals are low. Slightly elevated concentrations of Zn and Cr are found at all stations and of Cu at some stations. Values > LSC were also found at some stations in 2000.

The chemical results are in agreement with the drilling history. No discharges of oil containing drilling fluid have taken place at Norne since the previous regional survey. Previously large quantities of baryte have been discharged, and the discharges are now reduced, 362 tonnes in 2000, 78 tonnes in 2001 and 122 tonnes in 2002.

Table 4.6. *Norne, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station	Silt & clay		TOM			THC			NPD			PAH			Decalins		
	2003	2000	2003	2000	1997	2003	2000	1999	2003	2000	1997	2003	2000	1997	2003	2000	1997
Norne NW																	
NONW-02 45°/ 500m	94,3	92,5	8,1	6,7	-	7,6	14,1	-	-	-	-	-	-	-	-	-	-
NONW-03 45°/1000m	90,2	88,9	7,8	8,0	-	4,6	6,9	-	-	-	-	-	-	-	-	-	-
NONW-06 135°/ 500m	87,5	78,8	5,8	7,1	-	4,4	13,9	-	-	-	-	-	-	-	-	-	-
NONW-07 135°/1000m	89,1	88,1	7,0	7,7	-	5,2	5,7	-	-	-	-	-	-	-	-	-	-
NONW-09 225°/ 500m	96,1	61,2	8,0	5,1	-	17,1	297	-	-	-	-	-	-	-	-	-	-
NONW-10 225°/1000m	94,9	91,4	8,1	7,8	-	4,4	9,9	-	-	-	-	-	-	-	-	-	-
NONW-11 225°/1500m	90,1	93,0	7,7	8,1	-	7,1	12,9	-	-	-	-	-	-	-	-	-	-
NONW-12 315°/ 250m	82,6	93,9	6,8	7,8	-	25,7	98,7	-	0,076	0,168	-	0,087	0,207	-	2,15	4,53	-
NONW-13 315°/ 500m	88,9	85,0	6,7	7,3	-	7,3	84,4	-	0,081	0,083	-	0,110	0,089	-	nd	5,48	-
NONW-14 315°/1000m	89,1	91,4	7,3	6,9	-	5,2	22,9	-	-	-	-	-	-	-	-	-	-
NONW-15 315°/2000m	90,4	78,8	7,3	6,4	-	5,0	5,7	-	-	-	-	-	-	-	-	-	-
Norne SW																	
NOSW-01 20°/ 700m	74,3	82,4	6,1	7,0	7,1	8,8	33,6	32,0	-	-	-	-	-	-	-	-	-
NOSW-03 135°/ 500m	77,7	65,0	6,2	5,9	7,9	8,2	9,5	42,1	-	-	-	-	-	-	-	-	-
NOSW-04 135°/1000m	87,2	91,3	7,4	7,4	7,7	4,5	5,1	4,0	-	-	-	-	-	-	-	-	-
NOSW-07 225°/ 500m	73,3	73,4	4,8	6,1	7,5	9,5	10,9	9,2	-	-	-	-	-	-	-	-	-
NOSW-08 225°/1000m	77,4	86,5	5,4	7,7	8,1	6,2	6,6	4,7	-	-	-	-	-	-	-	-	-
NOSW-10 315°/ 250m	73,9	66,8	5,4	6,7	6,9	18,5	235	84,8	1,390	0,827	0,139	0,657	0,152	0,111	0,60	14,2	17,6
NOSW-11 315°/ 500m	92,1	86,1	7,3	7,8	7,4	8,8	202	44,4	0,188	0,114	-	0,140	0,096	-	0,15	21,1	-
NOSW-12 315°/1000m	84,2	80,6	4,7	6,4	6,8	5,3	5,7	8,4	-	-	-	-	-	-	-	-	-
NOSW-ref	91,6	90,1	6,3	8,2	9,7	4,0	3,8	3,6	0,089	0,069	0,083	0,130	0,123	0,128	nd	nd	nd

-: not analysed nd: not found



ENGLISH SUMMARY

Table 4.7. *Norne, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station	Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Cu	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
	2003	2000	1997	2003	2000	2003	2000	2003	2000	1997	2003	2000	2003	2000	1997	2003	2000	1997
Norne NW																		
NONW-02 45°/ 500m	885	570	-	0,10	0,06	43,6	36,5	12,4	10,9	-	-	-	22,1	22,0	-	83	71,6	-
NONW-03 45°/1000m	518	327	-	0,10	0,05	41,4	37,4	12,2	10,6	-	-	-	21,5	20,9	-	79	68,9	-
NONW-06 135°/ 500m	814	726	-	0,09	0,05	41,3	33,9	11,6	10,4	-	-	-	19,8	19,9	-	81	63,9	-
NONW-07 135°/1000m	500	556	-	0,09	0,06	40,4	35,6	11,2	10,5	-	-	-	19,7	21,5	-	75	66,7	-
NONW-09 225°/ 500m	2350	1060	-	0,09	0,07	43,3	29,8	13,1	9,0	-	-	-	21,8	16,6	-	82	56,8	-
NONW-10 225°/1000m	715	1290	-	0,08	0,09	43,6	35,9	11,9	11,0	-	-	-	21,0	21,3	-	82	68,7	-
NONW-11 225°/1500m	1390	1770	-	0,09	0,10	39,5	36,7	12,6	11,5	-	-	-	21,4	21,4	-	76	69,2	-
NONW-12 315°/ 250m	2440	3420	-	0,08	0,10	41,1	38,5	13,6	13,2	-	0,05	0,03	18,6	20,5	-	99	75,7	-
NONW-13 315°/ 500m	1370	1240	-	0,09	0,09	41,5	35,3	11,6	10,4	-	0,06	-	18,1	20,0	-	76	65,0	-
NONW-14 315°/1000m	818	852	-	0,10	0,10	41,8	37,6	11,7	10,6	-	-	-	20,7	21,9	-	78	69,7	-
NONW-15 315°/2000m	763	786	-	0,11	0,09	41,8	31,0	11,6	9,1	-	-	0,03	21,6	18,5	-	78	63,1	-
Norne SW																		
NOSW-01 20°/ 700m	939	1010	874	0,08	0,07	34,4	32,9	8,9	10,0	12,3	-	-	14,9	20,8	24,0	72	77,2	60,7
NOSW-03 135°/ 500m	996	1920	1090	0,09	0,07	38,4	29,9	10,1	9,3	17,5	-	-	19,5	18,8	22,5	69	57,3	57,4
NOSW-04 135°/1000m	661	732	293	0,09	0,08	39,9	36,5	11,1	10,9	12,4	-	-	19,7	21,5	21,4	74	69,4	58,3
NOSW-07 225°/ 500m	2750	2990	925	0,09	0,07	35,3	30,6	11,0	10,8	12,0	-	-	18,5	19,5	22,2	66	60,3	59,4
NOSW-08 225°/1000m	1010	1520	308	0,08	0,07	35,5	33,5	9,8	10,4	20,2	-	-	16,3	19,9	21,4	67	65,0	65,0
NOSW-10 315°/ 250m	3000	5900	2990	0,08	0,09	34,9	31,3	12,8	12,4	28,5	0,06	0,03	17,9	22,3	27,3	68	64,2	55,2
NOSW-11 315°/ 500m	2200	1610	841	0,09	0,06	38,5	34,4	11,4	10,5	12,6	0,06	-	21,0	19,8	22,9	78	67,6	59,4
NOSW-12 315°/1000m	987	950	260	0,08	0,06	36,9	32,4	10,4	9,5	11,9	-	-	19,2	17,3	20,5	71	67,3	57,2
NOSW-ref	147	191	130	0,10	0,10	35,9	36,0	12,3	10,3	14,1	0,06	0,03	20,3	21,4	26,2	64	65,8	65,6

-: not analysed

4.2.2 Biology

The fauna community at Norne is in general healthy and undisturbed.

The fauna at Norne differ somewhat from the fauna at fairly comparable regional stations. The difference is mainly due to a finer sediment type and a greater depth at Norne compared with the regional stations.

The Shannon-Wieners diversity index (H') range from 4,4 (NONW-12) to 5,1 (NONW-3, 6, and 15) at the NONW stations. Pielou's index of evenness was in general high with a range from 0,7 to 0,8.

At the NOSW stations the diversity index (H') range from 4,6 (NOSW-10) to 5,2 (NOSW-3). Pielou's index of evenness was in general high and range from 0,7 to 0,8.

Different fauna parameters are given in table 4.8.



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Table 4.8. Depth, number of species (*S*) and number of individuals (*N*) per 0,5 m², Shannon-Wieners diversity index (*H'*), Pielou's index of evenness (*J*) and *ES*₁₀₀, Norne stations 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
NONW-02	45	500	376	85	876	4,8	0,7	36
NONW-03	45	1 000	380	88	870	5,1	0,8	37
NONW-06	135	500	382	87	791	5,1	0,8	37
NONW-07	135	1 000	382	68	483	5,0	0,8	37
NONW-09	225	500	378	85	913	4,7	0,8	35
NONW-10	225	1 000	377	79	716	4,9	0,7	36
NONW-11	225	1 500	374	87	827	4,8	0,8	36
NONW-12	315	250	378	72	820	4,4	0,8	30
NONW-13	315	500	376	83	951	4,7	0,8	34
NONW-14	315	1 000	376	82	761	4,8	0,8	35
NONW-15	315	2 000	373	75	598	5,1	0,8	38
NOSW-01	20	700	372	95	949	4,8	0,8	36
NOSW-03	135	500	375	95	770	5,2	0,8	39
NOSW-04	135	1 000	375	82	634	5,1	0,8	38
NOSW-07	225	500	372	97	839	5,1	0,7	38
NOSW-08	225	1 000	372	72	570	4,7	0,8	34
NOSW-10	315	250	372	82	793	4,6	0,8	34
NOSW-11	315	500	374	89	849	4,9	0,7	36
NOSW-12	315	1 000	372	78	776	4,7	0,7	35
RefA (Reg. 1)			388	78	625	5,2	0,8	38
RefB			388	76	652	5,0	0,8	35

The MDS plot, figure 4.3, from the similarity analysis at station level shows that the fauna was relative similar at the Norne field. At 70 % similarity only one station, NOSW-8, separates from the main group (group 1). A division at about 70 - 75 % similarity separates the other stations in 4 sub groups.

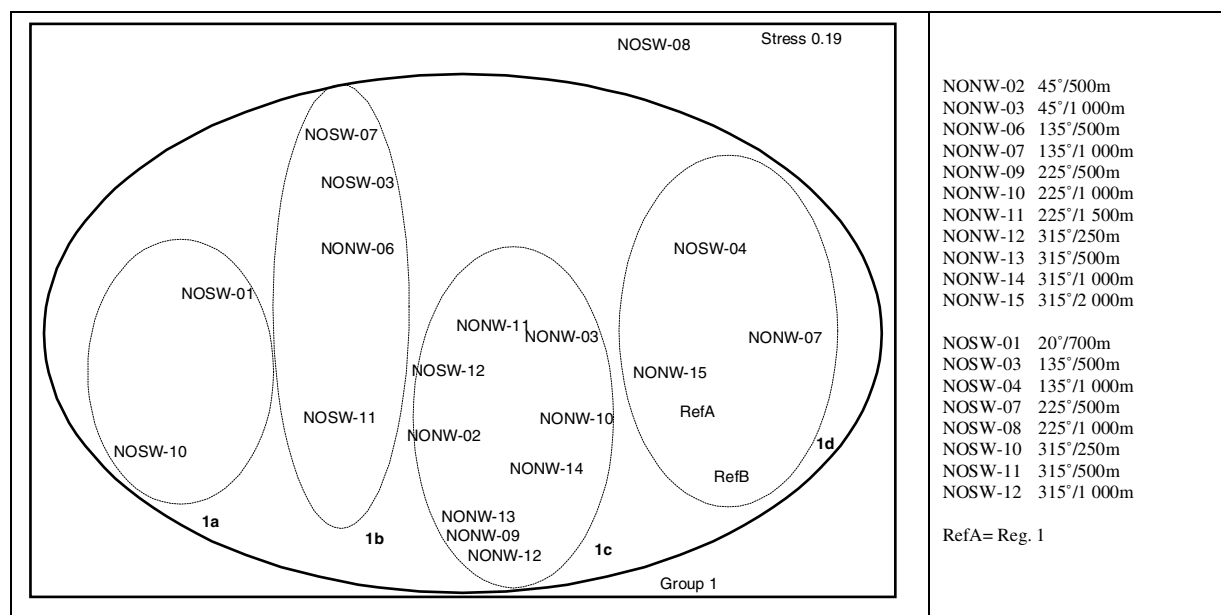


Figure 4.3. MDS-plot station level, Norne 2003.

The species composition and similarity analysis indicate a possible organic load at the NOSW stations close to the field centre in the 20° and 315° directions. NOSW-1 (20°/700m) and 10 (315°/250m). There were not found any correlation between fauna and environmental factors.

Figure 4.4 gives the dendrogram for the years 1995, 1997, 2000 and 2003. Only the NOSW stations are sampled all the years. The 1995 stations separate in group 2. Group 1 contains the other stations and could be divided in 4 sub groups, after years.

The trend analysis shows a general increase in the number of individuals within the most families. It was the increase of indicator species forward to 2003 which contributed most to the differences between the years. This indicates an increasing supply of organic materials in the area.



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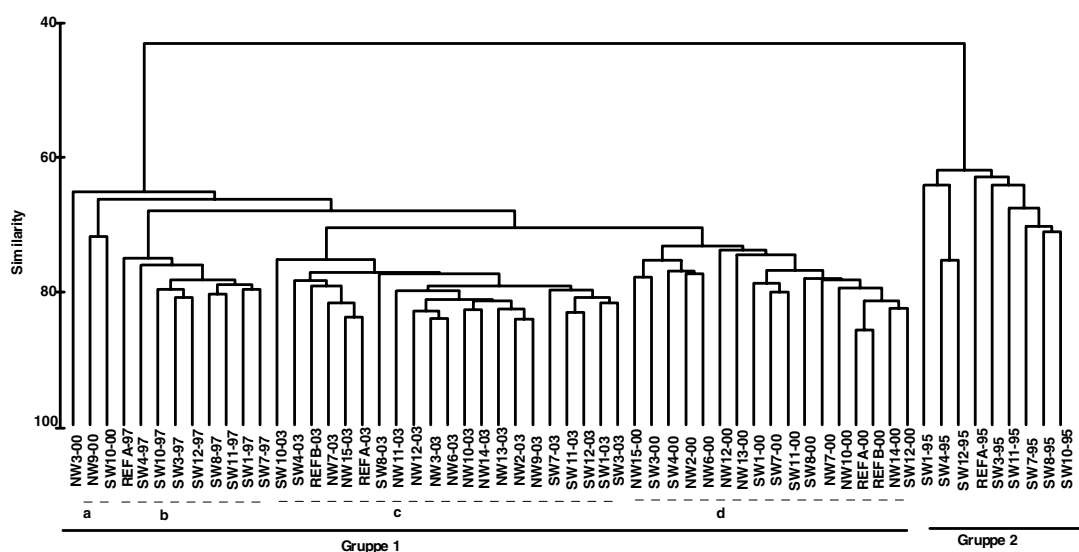


Figure 4.4. Dendrogram, Norne 1997-2003.

4.3 Åsgard

4.3.1 Grain size and chemical analysis

At Åsgard the installations N, S, X and M are included, and except for the baseline survey only the sediments at installation S are previously analysed.

The sediments at installations N and M at Åsgard are dominated of very fine sand, while the sediments at Åsgard S and Åsgard X are dominated of silt and clay. The silt and clay content at the field varies from 33 % at station N03, 240°/500m to 85 % at station S02, 160°/500m. The gravel content varies to a great extent, from no gravel at several stations to 13 % at station N01, 60°/500m. The variation is similar to the observations in 2000.

The total organic matter content in the sediments varies from 2,3 % at station N03, 240°/500m to 6,7 % at station S09, 75°/2000m. The lowest content is found at the N template (mean value 2,8 % at 500m) and the highest content is found at the S template (mean value 5,4 % at 500m). The results are similar to the 2000 results.

At installation N the THC concentrations vary from 2,8 mg/kg at station N04, 330°/500m to 14,9 mg/kg at station N03, 240°/500m. Only one of the five stations has elevated THC concentrations.

At installation S the THC concentrations vary from 3,4 mg/kg at station S07, 250°/1000m to 40,2 mg/kg at station S01, 75°/500m. The concentrations are decreased since 2000, and at station S01 a considerably reduction from 1210 mg/kg in 2000 to 40,2 mg/kg in 2003 is found. Only station S01 shows elevated THC concentrations.

At installation X the THC concentrations are low, and they vary from 3,7 mg/kg at station X03, 225°/500m to 9,8 mg/kg at station X01, 45°/500m. Only one station has slightly elevated THC values.



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At installation M the THC concentrations vary from 3,0 mg/kg at station M04, 325°/500m to 75,5 mg/kg at station M01, 60°/500m. In addition to station M01, slightly elevated THC concentrations are found at station M03, 240°/500m (7,0 mg/kg).

Elevated THC concentrations are found out to 500m in one direction at the installations N (240°), S (75°) and X (45°), and out to 500m in two directions at installation M (60° and 240°).

The NPD and PAH concentrations are low. Slightly elevated values are only found in two of the samples. However, high decalin concentrations are found at station M01, 60°/500m, and decalins are also found at station X01, 45°/500m. A clear correspondence between the decalin and the THC results is observed.

Elevated Ba concentrations are found in the sediments at all stations except for the reference station. This means out to 2000m at template S and out to 500m at templates N, X and M. The Ba concentrations are relative similar across the survey area, although the lowest concentrations are found at template X. The Ba concentrations vary from 180 mg/kg to 2310 mg/kg.

The concentrations of the heavy metals are low at all four templates. Values slightly above the limit of significant contamination are only found at one station for Cu and two stations for Zn.

The chemical results are in agreement with the drilling history. No discharges of oil containing drilling fluid have taken place at Åsgard since the previous regional survey. The drilling includes one to five wells at each of the four templates, and minor acute discharges of oil based mud have occurred. Baryte has been discharged, less quantities in 2002 than in previous years.

Table 4.9. Åsgard, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM			THC			NPD		PAH		Decalins	
	2003	2000	2003	2000	1999	2003	2000	1999	2003	2000	2003	2000	2003	2000
Installation N														
N01 60°/ 500 m	34,5	-	2,4	-	-	4,3	-	-	0,059	-	0,067	-	nd	-
N02 150°/ 500 m	42,9	-	3,0	-	-	4,2	-	-	-	-	-	-	-	-
N03 240°/ 500 m	32,5	-	2,3	-	-	14,9	-	-	-	-	-	-	-	-
N04 330°/ 500 m	45,5	-	3,5	-	-	2,8	-	-	-	-	-	-	-	-
Installation S														
S01 75°/ 500 m	55,9	59,4	4,4	4,7	5,8	40,2	1210	17,4	-	-	-	-	-	-
S02 160°/ 500 m	84,7	73,9	6,3	5,6	-	3,8	4,3	2,9	-	-	-	-	-	-
S03 250°/ 500 m	55,9	63,7	4,6	4,7	-	4,5	8,7	<0,7	-	-	-	-	-	-
S04 30°/ 500 m	78,2	75,1	6,1	5,8	-	6,0	13,5	<0,7	0,096	0,085	0,113	0,129	nd	nd
S05 75°/1000 m	69,4	65,1	5,8	5,3	-	5,7	10,8	0,6	-	-	-	-	-	-
S06 160°/1000 m	65,8	53,7	4,9	4,1	-	3,8	2,8	<0,7	-	-	-	-	-	-
S07 250°/1000 m	70,0	60,0	5,1	4,7	-	3,4	4,8	2,0	-	-	-	-	-	-
S08 30°/1000 m	79,4	81,6	6,3	6,6	-	4,3	8,3	2,4	-	-	-	-	-	-
S09 75°/2000 m	83,5	84,6	6,7	7,0	-	5,0	5,9	1,1	-	-	-	-	-	-
Installation X														
X01 45°/ 500 m	67,5	-	4,0	-	-	9,8	-	-	0,488	-	0,162	-	0,19	-
X02 90°/ 500 m	74,0	-	3,9	-	-	4,3	-	-	-	-	-	-	-	-
X03 225°/ 500 m	84,4	-	5,8	-	-	3,7	-	-	-	-	-	-	-	-
X04 315°/ 500 m	62,8	-	4,6	-	-	4,5	-	-	-	-	-	-	-	cont.



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Table 4.9. cont.

Station	Silt and clay		TOM			THC			NPD		PAH		Decalins	
	2003	2000	2003	2000	1999	2003	2000	1999	2003	2000	2003	2000	2003	2000
Installation M														
M01 60°/ 500 m	37,8	-	3,0	-	-	75,5	-	-	0,086	-	0,082	-	5,70	-
M02 145°/ 500 m	46,1	-	3,4	-	-	3,9	-	-	-	-	-	-	-	-
M03 240°/ 500 m	41,3	-	3,2	-	-	7,0	-	-	-	-	-	-	-	-
M04 325°/ 500 m	38,2	-	3,4	-	-	3,0	-	-	-	-	-	-	-	-
Åsgard Ref.	83,0	85,7	6,1	6,0	6,4	4,3	4,9	2,2	0,071	0,058	0,101	0,110	nd	nd

-: not analysed nd: not found

Table 4.10. Åsgard, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba			Cd		Cr		Cu			Hg		Pb			Zn		
	2003	2000	1999	2003	2000	2003	2000	2003	2000	1999	2003	2000	2003	2000	1999	2003	2000	1999
Installation N																		
N01 60°/ 500 m	2150	-	-	0,08	-	23,5	-	7,7	-	-	0,07	-	18,0	-	-	42	-	-
N02 150°/ 500 m	1390	-	-	0,08	-	21,4	-	6,4	-	-	-	-	17,7	-	-	38	-	-
N03 240°/ 500 m	1960	-	-	0,08	-	22,6	-	7,0	-	-	-	-	16,8	-	-	40	-	-
N04 330°/ 500 m	1170	-	-	0,07	-	19,1	-	5,8	-	-	-	-	14,6	-	-	36	-	-
Installation S																		
S01 75°/ 500 m	2310	2810	1830	0,08	0,07	29,6	22,9	9,9	8,6	8,8	-	-	17,8	18,3	20,8	53	40,4	45,3
S02 160°/ 500 m	836	945	-	0,08	0,07	32,1	24,8	12,2	8,7	-	-	-	21,4	16,8	-	62	44,5	-
S03 250°/ 500 m	1780	2910	-	0,07	0,06	28,1	21,8	9,3	7,9	-	-	-	17,5	16,8	-	51	40,6	-
S04 30°/ 500 m	1540	2400	-	0,08	0,07	30,0	25,9	9,3	9,4	-	0,05	0,02	19,3	19,8	-	56	54,7	-
S05 75°/1000 m	2310	2750	-	0,09	0,08	29,6	24,7	9,9	9,4	-	-	-	23,2	21,6	-	56	56,6	-
S06 160°/1000 m	1090	1090	-	0,08	0,06	26,8	21,0	8,3	7,9	-	-	-	19,7	15,3	-	51	42,8	-
S07 250°/1000 m	565	1370	-	0,07	0,06	26,8	22,4	7,5	8,0	-	-	-	14,9	17,5	-	48	41,2	-
S08 30°/1000 m	2040	1580	-	0,09	0,08	32,3	28,1	11,5	9,9	-	-	-	21,7	18,8	-	61	59,0	-
S09 75°/2000 m	1310	1380	-	0,09	0,09	32,5	28,4	10,1	10,0	-	-	-	21,9	21,7	-	59	52,9	-
Installation X																		
X01 45°/ 500 m	1460	-	-	0,07	-	26,4	-	8,1	-	-	0,03	-	18,1	-	-	48	-	-
X02 90°/ 500 m	694	-	-	0,08	-	26,1	-	8,0	-	-	-	-	17,5	-	-	52	-	-
X03 225°/ 500 m	441	-	-	0,08	-	28,5	-	9,1	-	-	-	-	18,1	-	-	54	-	-
X04 315°/ 500 m	765	-	-	0,08	-	25,8	-	8,7	-	-	-	-	17,9	-	-	51	-	-
Installation M																		
M01 60°/ 500 m	2210	-	-	0,08	-	20,0	-	6,8	-	-	0,03	-	17,2	-	-	38	-	-
M02 145°/ 500 m	1570	-	-	0,08	-	22,1	-	7,0	-	-	-	-	19,2	-	-	40	-	-
M03 240°/ 500 m	1310	-	-	0,07	-	17,8	-	5,0	-	-	-	-	15,1	-	-	30	-	-
M04 325°/ 500 m	1530	-	-	0,08	-	20,6	-	5,0	-	-	-	-	18,8	-	-	36	-	-
Åsgard Ref.	180	225	236	0,08	0,08	25,7	27,9	6,8	9,5	8,2	0,03	0,02	18,5	19,8	21,7	47	50,1	44,4

-: not analysed



4.3.2 Biology

The fauna community at Åsgard is in general healthy and undisturbed, and the regional stations do not separate from the Åsgard stations.

Shannon-Wieners diversity index (H') range from 4,9 (ÅS-X02) to 6,0 (ÅS-M01, 02, 04 and ÅS-N01). Pielou's index of evenness was high (0,8 and 0,9) at all stations.

Different fauna parameters are given in table 4.11.

Table 4.11. Depth, number of species (S) and number of individuals (N) per 0,5 m², Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Åsgard stations 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
ÅS-M01	60	500	376	129	746	6,0	0,8	51
ÅS-M02	145	500	276	112	588	6,0	0,9	52
ÅS-M03	240	501	278	127	828	5,9	0,8	48
ÅS-M04	325	500	270	123	652	6,0	0,9	50
ÅS-N01	70	500	272	121	744	6,0	0,9	51
ÅS-N02	155	500	268	119	724	5,8	0,8	48
ÅS-N03	256	500	277	130	910	5,8	0,8	49
ÅS-N04	335	500	278	138	1042	5,8	0,8	46
ÅS-RefA			295	72	349	5,4	0,9	44
ÅS-RefB			295	71	288	5,1	0,8	42
ÅS-S01	75	500	298	106	837	5,3	0,8	41
ÅS-S02	160	500	304	78	388	5,6	0,9	46
ÅS-S03	235	502	300	85	372	5,6	0,9	46
ÅS-S04	20	500	305	90	702	5,4	0,8	41
ÅS-S05	75	1000	302	79	385	5,4	0,9	43
ÅS-S06	160	1000	297	102	661	5,6	0,8	45
ÅS-S07	244	1000	301	95	546	5,6	0,9	45
ÅS-S08	32	1021	303	104	610	5,7	0,8	46
ÅS-S09	75	2000	300	95	626	5,5	0,8	43
ÅS-X01	45	500	299	96	761	5,3	0,8	42
ÅS-X02	90	500	301	88	580	4,9	0,8	41
ÅS-X03	225	500	301	86	531	5,2	0,8	40
ÅS-X04	315	500	292	95	667	5,6	0,8	44

The MDS plot from the similarity analysis at station level is given in figure 4.5. At a similarity of about 65 % the stations separates in 3 groups.

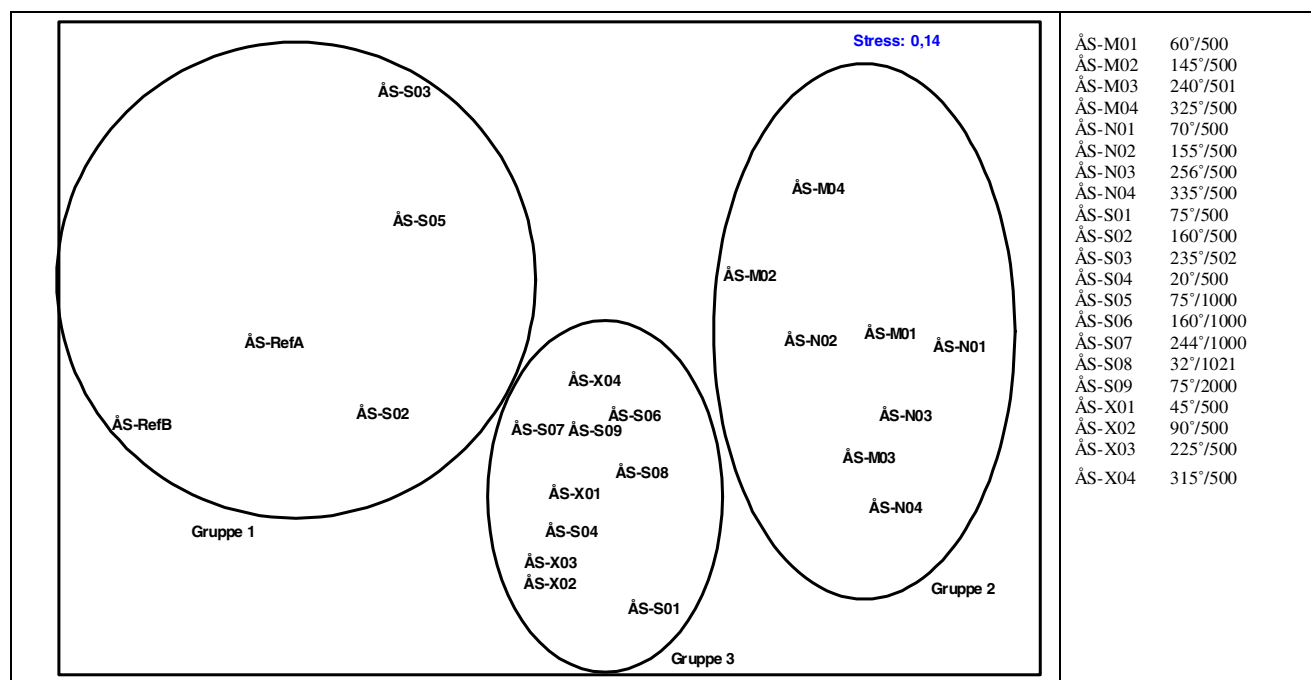


Figure 4.5 MDS-plot station levels, Åsgard 2003

The results from the similarity analysis indicate an organic load at the base frame S and X.

The bioenv analysis gave a correlation of 0,6 between fauna and a combination of the factors Ba, Cr and grain size. The single factor which correlated best was grain size (0,6). The correlations indicate some relations.

The dendrogram for the years 1996, 1997, 2000 and 2003 is given in figure 4.6. The dendrogram gives a separation into 5 main groups at about 60 % similarity.

The analysis indicates an increased supply of organic material in the area, with an increasing number of individuals.

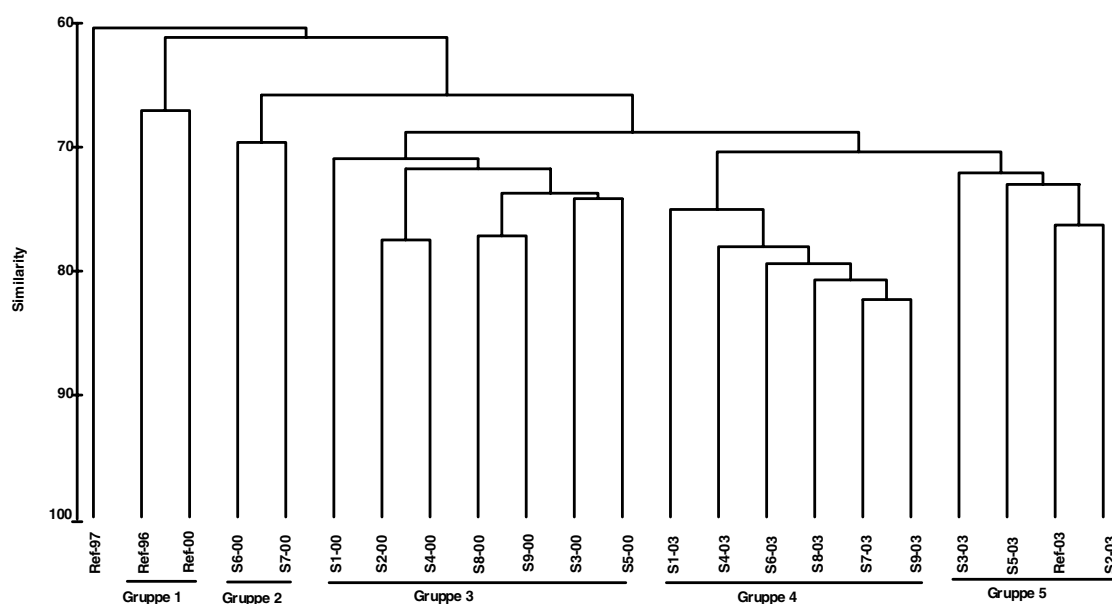


Figure 4.6. Dendrogram Åsgard, 1997 – 2003.

4.4 Heidrun

4.4.1 Grain size and chemical analysis

The sediments at Heidrun consist mainly of silt and clay that varies from 51 % at station HN-6, 225°/1000m to 86 % at station HN-1, 35°/500m. The gravel content is low, and the highest gravel content found is 2,7 %. The results are in agreement with the 2000 results.

The total organic matter content in the sediments varies from 3,3 % at station HN-9, 315°/1000m to 6,5 % at station HN-1, 35°/500m. Generally the results are similar to the 2000 results, but at some stations the content is decreased.

The THC concentrations vary from 2,7 mg/kg at station HEI-16, 315°/1000m to 76,9 mg/kg at station HEI-06, 50°/550m. An increase is found at several stations at 500m. Elevated THC concentrations are found at most of the stations at the main field, and this means out to 550m in the 225° and 305°/315° directions and out to 1000m in the 45°/50° and 120°/135° directions. Stations further out than 1000m are not analysed. At the templates further north only slightly elevated THC concentrations are found at two stations at 500m, station HN-1, 35°/500m and station HN-5, 225°/500m. At these templates stations out to 2000m are also included. It is likely that some of the elevated THC level results from drilling mud base oil, and that the main part of the THC contamination results from other discharges. Similar hydrocarbon profiles were also found in the 2000 survey.

Olefins are not found in the sediments, a further reduction since the 2000 survey when low concentrations were found at one station. The drilling fluid Petrofree, is not found in the sediments, and was not found in the 2000 survey either.

The drilling fluid Aquamul B II is found at all stations at the main field (TLP). The mean values vary from 0,3 mg/kg at station HEI-16, 315°/1000m to 65,4 mg/kg at station HEI-06, 50°/550m.



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At station HEI-12, 120°/550m a decrease is found, from 271 mg/kg in 1997, 119 mg/kg in 2000 to 17,9 mg/kg in 2003. A very uneven distribution and relative high concentrations in the sediments are observed. In the 3-6cm layer at station HEI-15, 305°/550m surprisingly high values are found (125 mg/kg). In general the conclusion is status quo, and the results confirm the slow degradation rate of the drilling fluid Aquamul B II.

The concentrations of NPD and PAH are low. Slightly elevated values are found at two stations, station HEI-06 and HEI-15. Decalins are found at station HEI-06, which also has the highest THC concentrations. One sample is analysed at station HEI-03, 225°/500m, and decalins and alkylated NPD compounds are found. This confirms that hydrocarbons from drilling mud base oil and also from other hydrocarbon sources are present.

High concentrations of Ba are found at Heidrun, and the values vary from 182 mg/kg at the reference station to 8140 mg/kg at HEI-06, 50°/550m. Elevated Ba levels are found at all stations except for the reference station, and this means out to 1000m and 2000m. At the templates an increase is found since the previous survey at all 500m stations. Otherwise a slight increase or similar levels as previously are found.

The concentrations of the heavy metals are low. At three stations slightly elevated concentrations of Cu and Pb are found, and elevated Hg concentrations, 0,30 mg/kg, are found at one station.

Generally the chemical results are in agreement with the drilling history. No discharges of oil containing drilling fluid have taken place at Heidrun since the previous survey in 2000. The main part of the THC concentrations found, results from other "hydrocarbons" than drilling mud base oil. In the period 2000-2002 more than 15000 tonnes of baryte have been discharged, 11 wells have been drilled at the templates and 1 well in the TLP area.

Table 4.12. Heidrun, silt & clay and TOM (%), THC, Aquamul B II, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt & clay		TOM			THC			Aquamul B II			NPD		PAH		Decalins	
	2003	2000	2003	2000	1997	2003	2000	1999	2003	2000	1997	2003	2000	2003	2000	2003	2000
HEI-02 225°/1000 m	76,0	75,8	4,5	4,7	-	7,1	2,9	-	0,8	0,7	-	-	-	-	-	-	-
HEI-03 225°/ 550 m	76,1	76,8	4,0	4,6	-	36,1	4,5	-	1,8	1,3	-	1,060	-	0,136	-	2,35	-
HEI-06 50°/ 550 m	74,5	72,1	3,4	3,3	6,0	76,9	38,4	28,8	65,4	2,0	216	0,601	0,243	0,182	0,077	0,78	0,48
HEI-07 45°/1000 m	79,1	77,6	5,5	5,1	5,8	9,2	6,1	5,0	0,4	0,5	1,9	-	-	-	-	-	-
HEI-11 135°/1000 m	75,4	75,4	5,3	4,2	6,4	9,1	5,3	3,2	2,8	0,9	5,0	-	-	-	-	-	-
HEI-12 120°/ 550 m	72,6	73,6	4,6	5,1	6,6	37,0	13,6	26,0	17,9	119	271	-	-	-	-	-	-
HEI-15 305°/ 550 m	74,9	78,5	4,4	5,6	6,1	12,5	11,1	10,6	3,8	1,4	222	0,202	0,077	0,136	0,068	nd	nd
HEI-16 315°/1000 m	53,9	59,1	4,1	4,7	6,1	2,7	3,8	1,7	0,27	<0,15	0,3	-	-	-	-	-	-
HN-1 35°/500m	86,3	87,8	6,5	6,1	-	15,0	7,6	-	-	-	-	-	-	-	-	-	-
HN-2 30°/1000m	85,7	88,3	6,1	6,3	-	3,4	6,2	-	-	-	-	-	-	-	-	-	-
HN-3 135°/500m	69,6	77,3	4,2	5,6	-	6,0	7,0	-	-	-	-	-	-	-	-	-	-
HN-4 135°/1000m	74,0	76,1	5,5	5,7	-	3,9	5,0	-	-	-	-	-	-	-	-	-	-
HN-5 225°/500m	67,2	67,0	5,0	5,3	-	8,3	6,2	-	-	-	-	0,078	-	0,106	0,106	nd	nd
HN-6 225°/1000m	51,1	56,2	4,1	5,4	-	3,3	5,3	-	-	-	-	0,055	-	0,075	-	-	-
HN-7 255°/2000m	80,9	70,2	5,6	5,4	-	5,1	5,7	-	-	-	-	-	-	-	-	-	-
HN-8 315°/500m	66,7	66,8	3,5	4,6	-	4,7	4,8	-	-	-	-	-	-	-	-	-	-
HN-9 315°/1000m	60,2	51,7	3,3	4,3	-	2,8	3,6	-	-	-	-	-	-	-	-	-	-
HN-10 315°/2000m	83,2	88,7	5,3	6,7	-	3,7	1,4	1,2	-	-	-	0,082	0,093	0,118	0,118	nd	nd
HEI-27 315°/1000m	59,4	60,2	4,3	5,1	5,3	3,4	1,9	1,1	<0,15	<0,15	<0,15	0,065	0,062	0,095	0,081	nd	nd
ref																	

-: not analysed nd: not found



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Table 4.13. Heidrun, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Cu	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
	2003	2000	1997	2003	2000	2003	2000	2003	2000	1997	2003	2000	2003	2000	1997	2003	2000	1997
HEI-02 225°/1000 m	3520	1900	-	0,08	0,06	24,6	22,1	7,5	7,9	-	-	-	18,5	16,8	-	50	42,7	-
HEI-03 225°/ 550 m	4780	4070	-	0,07	0,06	26,8	21,4	10,7	8,5	-	-	-	19,0	15,7	-	55	43,8	-
HEI-06 50°/ 550 m	8140	7060	7270	0,08	0,07	27,9	21,5	35,1	34,0	29,9	-	-	66,1	46,0	50,3	58	54,1	68,0
HEI-07 45°/1000 m	7140	6260	5120	0,07	0,05	27,9	22,3	15,5	10,0	22,5	-	-	30,4	20,1	25,0	55	43,6	59,8
HEI-11 135°/1000 m	4750	3740	3820	0,07	0,05	25,6	22,2	10,0	8,3	9,2	-	-	21,1	17,2	23,8	50	41,1	41,2
HEI-12 120°/ 550 m	6280	7590	7800	0,07	0,04	25,9	21,9	16,1	11,7	15,3	-	-	32,9	28,5	45,6	60	48,6	53,5
HEI-15 305°/ 550 m	4920	5330	5240	0,06	0,04	25,4	24,3	10,0	9,7	10,6	0,07	0,02	20,0	17,5	18,4	48	44,5	41,8
HEI-16 315°/1000 m	3630	3720	3270	0,06	0,05	20,9	21,5	6,7	8,2	11,1	-	-	13,2	16,0	21,4	36	38,0	47,2
HN-1 35°/500m	2530	1380	-	0,10	0,10	31,1	28,7	11,1	10,8	-	-	-	18,9	20,2	-	60	53,4	-
HN-2 30°/1000m	1100	1160	-	0,08	0,09	30,1	27,0	8,9	9,7	-	-	-	15,9	19,3	-	62	50,5	-
HN-3 135°/500m	2710	1930	-	0,08	0,08	30,1	23,4	11,1	8,7	-	-	-	16,0	18,0	-	54	44,4	-
HN-4 135°/1000m	2250	1960	-	0,09	0,06	25,2	23,5	8,7	8,1	-	-	-	16,6	17,7	-	49	42,6	-
HN-5 225°/500m	2330	853	-	0,09	0,07	25,0	20,9	8,6	7,3	-	0,30	-	19,5	13,5	-	48	38,1	-
HN-6 225°/1000m	2030	1450	-	0,09	0,08	23,9	20,9	8,3	7,6	-	0,08	-	17,9	17,0	-	44	38,7	-
HN-7 255°/2000m	1920	1460	-	0,11	0,08	28,5	22,9	8,9	8,1	-	-	-	20,1	16,5	-	52	42,3	-
HN-8 315°/500m	2080	923	-	0,08	0,07	25,5	21,8	7,7	7,3	-	-	0,02	16,4	13,6	-	45	38,5	-
HN-9 315°/1000m	1050	601	-	0,10	0,08	26,4	25,8	8,0	8,2	-	-	-	19,1	17,4	-	51	44,0	-
HN-10 315°/2000m	786	428	-	0,09	0,08	27,7	27,5	8,5	9,2	-	0,08	0,02	19,4	19,6	-	53	49,9	-
HEI-27 315°/10000m ref	182	123	112	0,09	0,08	20,7	20,8	8,1	7,3	7,2	0,06	0,02	17,7	15,8	21,2	37	41,0	41,1

-: not analysed

4.4.2 Biology

The fauna community at Heidrun is in general healthy and undisturbed and the fauna do not differ from comparable regional stations.

The Shannon-Wieners diversity index (H') range from 4,5 (HEI-06) to 5,8 (HEI-27A and 27B, HN-05, 06 and 09). Pielou's index of evenness was in general high and range from 0,7 to 0,9, with the lowest value at stations HEI-06 and 12.

Different fauna parameters are given in table 4.14.

The MDS plot, figure 4.7, from the similarity analysis shows in general a relative diverse and healthy fauna community at Heidrun. However the analysis indicates disturbance in the fauna particular at station Heidrun-6 (50°/550m), but also at station Heidrun-7 (45°/1000m) and Heidrun-12 (120°/550m).

It was found a high correlation between fauna and a combination of the factors Ba, Cd, Pb and THC.

In figure 4.8 the dendrogram for the years 1995, 1997, 2000 and 2003 is given. The stations divide into 4 main groups relative independent of year at a similarity of about 55 %. The numbers of species and individuals have increased since 2000, but the diversity is relative unaltered in the same period. The changes are small and could be random and natural.



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Table 4.14. Depth, number of species (*S*) and number of individuals (*N*) per 0,5 m², Shannon-Wieners diversity index (*H'*), Pielou's index of evenness (*J*) and *ES*₁₀₀, Heidrun 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
HEI-02	225	1 000	348	84	564	5,4	0,8	42
HEI-03	225	550	347	82	619	5,1	0,8	38
HEI-06	50	550	350	102	1754	4,5	0,7	29
HEI-07	45	1 000	357	103	1129	5,2	0,8	39
HEI-11	135	1 000	344	103	710	5,3	0,8	41
HEI-12	120	550	343	122	1632	5,1	0,7	36
HEI-15	305	550	352	84	517	5,1	0,8	38
HEI-16	315	1 000	354	85	502	5,4	0,8	43
HEI-27A	315	10 000	332	109	590	5,8	0,9	48
HEI-27B	315	10 000	332	107	559	5,8	0,9	49
HN-01	35	500	365	90	665	5,0	0,8	39
HN-02	30	1000	362	95	567	5,3	0,8	42
HN-03	135	500	355	98	747	5,2	0,8	41
HN-04	135	1000	353	89	512	5,6	0,9	45
HN-05	225	500	358	112	633	5,8	0,9	50
HN-06	225	1000	345	95	514	5,8	0,9	47
HN-07	225	2000	334	93	447	5,6	0,9	46
HN-08	315	500	379	94	513	5,5	0,8	45
HN-09	315	1000	375	109	599	5,8	0,9	49
HN-10	315	2000	390	95	409	5,4	0,8	46

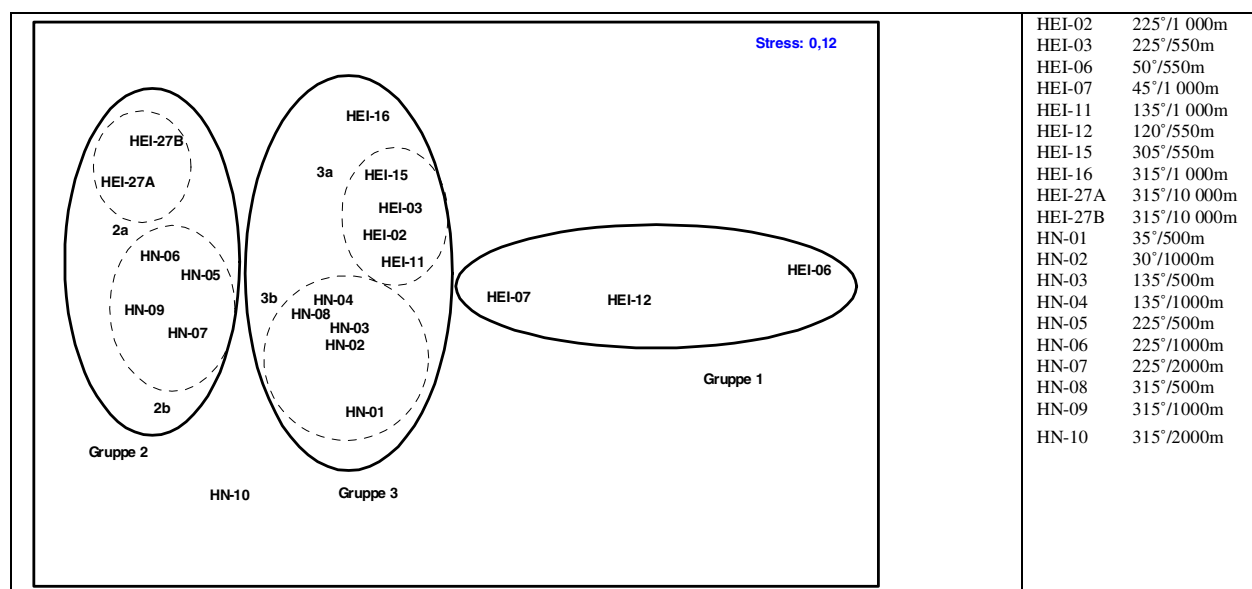


Figure 4.7. MDS-plot station level, Heidrun 2003.

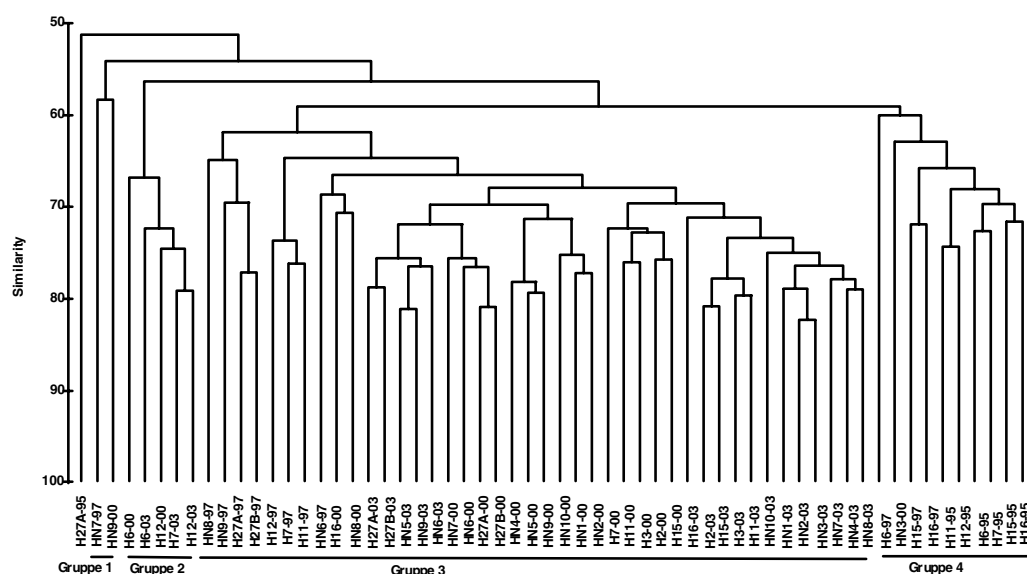


Figure 4.8. Dendrogram Heidrun, 1995-2003.

4.5 Draugen

4.5.1 Grain size and chemical analysis

The sediments at Draugen vary from silt and clay to fine sand. The silt and clay fraction varies from 36 % at station 24A, 325°/900m to 70 % at station 28A, 45°/1500m. The silt and clay fraction is increased at some stations and decreased at others. Gravel is found at all stations, and 13 % gravel is found at stations 24A, 325°/900m and 26B, 162°/500m. Compared to 2000, the gravel content is increased at some stations and decreased at other stations. As in 2000 the field is classified as very fine sand.

The total organic matter content in the sediments varies from 2,7 % at station 24A, 325°/900m to 4,9 % at station 27B, 162°/1000m. The values are similar to the 2000 results.

The THC concentrations vary from 2,6 mg/kg at station 24A, 325°/900m to 5,1 mg/kg at three of the stations. No elevated THC concentrations are found. At station 24B, 300°/250m the THC content is reduced from 20,3 mg/kg in 2000 to 4,9 mg/kg in 2003.

As in previous surveys the NPD, PAH and decalin concentrations are low, and elevated values are not found. This means that the decalin content at station 24B is decreased since 2000, in the same way as for THC.

The Ba concentrations vary from 125 mg/kg at the reference station 51B to 2710 mg/kg at station 24B, 300°/250m. A tendency of slightly decreased Ba concentrations is found at several stations. At station 24B, 300°/250m, a decrease from 5460 mg/kg in 2000 to 2710 mg/kg in 2003 is found. The layer samples at 1-3 cm and 3-6 cm also contain lower Ba concentrations compared to 2000. All stations show elevated Ba values except for the reference station 51B. Elevated Ba concentrations are found out to 2000m.

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



ENGLISH SUMMARY

The chemical results are in agreement with the drilling history. No discharges of oil containing drilling fluid have taken place at Draugen since the previous survey in 2000. Baryte was discharged in the first six months of 2003, but no discharges in 2002. Probably the discharges in 2003 will not be found in the sediments across the field until future surveys.

Table 4.15. Draugen, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station		Silt & clay		TOM			THC			NPD			PAH			Decalins		
		2003	2000	2003	2000	1997	2003	2000	1999	2003	2000	1997	2003	2000	1997	2003	2000	1997
21B	300°/2000 m	59,4	57,4	4,0	3,8	-	3,8	2,8	4,3	-	-	-	-	-	-	-	-	-
22B	300°/1000 m	53,4	52,7	3,8	4,2	3,2	3,4	3,9	4,8	-	-	-	-	-	-	-	-	-
24A	325°/ 900 m	35,8	52,1	2,7	3,2	3,4	2,6	4,0	3,4	0,053	-	-	0,074	-	-	nd	-	-
24B	300°/ 250 m	37,1	37,3	2,9	2,0	3,2	5,1	20,3	5,3	0,058	0,144	0,054	0,058	0,058	0,059	nd	0,217	nd
26B	162°/ 500 m	42,9	43,8	3,5	2,7	3,6	2,7	2,7	4,7	-	-	-	-	-	-	-	-	-
27A	45°/ 750 m	45,5	48,9	3,3	3,9	3,3	5,1	3,2	3,8	-	-	-	-	-	-	-	-	-
27B	162°/1000 m	68,7	48,7	4,9	4,3	3,6	4,8	3,6	3,0	-	-	-	-	-	-	-	-	-
28A	45°/1500 m	69,8	77,1	4,5	5,8	2,8	4,7	3,1	3,1	-	-	-	-	-	-	-	-	-
30B	325°/ 500 m	62,0	45,4	3,8	3,3	3,4	4,0	3,7	5,9	-	-	-	-	-	-	-	-	-
31B	35°/1000 m	53,0	54,0	3,0	3,4	2,9	5,1	4,5	4,1	-	-	-	-	-	-	-	-	-
51B	Ref.	66,9	56,0	4,3	3,9	3,9	4,6	4,1	2,6	0,076	0,074	0,043	0,125	0,101	0,090	nd	nd	nd

-: not analysed nd: not found

Table 4.16. Draugen, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station		Ba		Ba	Cd	Cd	Cr	Cr	Cu	Cu	Cu	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
		2003	2000	1997	2003	2000	2003	2000	2003	2000	1997	2003	2000	2003	2000	1997	2003	2000	1997
21B	300°/2000 m	771	816	802	0,07	0,05	23,8	26,1	7,5	7,4	8,3	-	0,03	17,9	17,1	17,8	44	42,6	32,6
22B	300°/1000 m	762	1240	1170	0,06	0,05	23,1	22,0	7,4	6,4	8,4	-	-	15,8	16,4	18,0	42	38,5	34,4
24A	325°/ 900 m	542	920	734	0,07	0,05	22,8	23,9	7,1	9,1	6,5	0,05	-	15,4	17,0	14,8	41	38,9	31,6
24B	300°/ 250 m	2710	5460	3230	0,04	0,05	17,1	20,5	6,5	7,8	7,3	0,03	0,01	10,3	12,9	15,2	35	52,4	36,3
26B	162°/ 500 m	311	457	565	0,05	0,06	23,4	22,0	6,8	5,7	8,4	-	-	12,0	14,3	19,1	40	54,3	40,8
27A	45°/ 750 m	299	337	256	0,06	0,06	23,7	27,5	7,0	7,4	7,6	-	-	14,3	18,3	17,9	42	44,3	38,2
27B	162°/1000 m	425	402	495	0,07	0,06	28,4	25,1	8,8	6,9	25,6	-	-	22,1	16,9	22,5	52	40,8	58,7
28A	45°/1500 m	222	199	156	0,07	0,06	27,9	29,6	8,8	8,5	9,0	-	-	21,2	20,0	18,6	51	49,1	45,1
30B	325°/ 500 m	924	1180	1120	0,06	0,05	25,5	24,1	8,2	6,3	8,4	-	-	17,4	15,5	20,4	47	39,8	44,4
31B	35°/1000 m	698	473	497	0,07	0,05	28,1	26,3	8,4	6,9	7,4	-	-	18,4	16,8	17,3	55	42,4	38,0
51B	Ref.	125	116	113	0,06	0,04	22,2	22,7	7,9	6,7	7,7	0,05	0,02	17,6	15,2	17,1	38	37,7	39,0

-: not analysed

4.5.2 Biology

The fauna community at Draugen is in general healthy and undisturbed. However, the fauna at Draugen separates somewhat from comparable regional stations, but it is still 60 % similarity between the groups.

The Shannon-Wieners diversity index (H') range from 5,4 (DR24B) to 6,3 (DR24A).

The species composition indicates a relative coarse sediment, with amongst others echinoderms among the dominant species at several stations.



ENGLISH SUMMARY

Different fauna parameters are given in table 4.17

Table 4.17. Depth, number of species (*S*) and number of individuals (*N*) per 0,5 m², Shannon-Wieners diversity index (*H'*), Pielou's index of evenness (*J*) and *ES*₁₀₀, Draugen stations 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
DR21B	300	2 000	250	92	500	5,7	0,9	45
DR22B	300	1 000	245	111	427	5,9	0,9	51
DR24A	325	900	242	128	514	6,3	0,9	57
DR24B	300	250	253	143	1371	5,4	0,8	43
DR26B	162	500	256	106	542	6,0	0,9	51
DR27A	45	750	251	107	479	6,1	0,9	53
DR27B	162	1 000	264	109	559	5,9	0,9	51
DR28A	45	1 500	248	114	624	6,0	0,9	51
DR30B	325	500	250	113	783	5,6	0,8	44
DR31B	35	1 000	241	104	381	6,0	0,9	53
DR51BrefA (Reg 7)			270	99	520	5,8	0,9	47
DR51BrefB			270	93	503	5,7	0,9	47

In figure 4.9 the MDS plot from the similarity analysis is shown.

- The station DR24B separates somewhat in the analysis. At this station the indicator species *C. setosa* dominates in a high degree, the highest Ba concentration and a relative high fraction of sand in the sediment was also found at this station. The bioenv analysis gave a correlation of 0,6 between fauna and barium at the field.
- Indices and species composition indicate a healthy and divers fauna at the other stations.

Station DR24 B was also characterised as disturbed in 2000. Since then the levels of Ba and THC have decreased considerable.

Figure 4.10 gives the dendrogram for the years 1994, 1997, 2000 and 2003. The stations separate in two main groups. Group 1 contains stations sampled in 1997, 2000 and 2003 which further can be divided into sub groups after years. The exception is station 24B in 1997, 2000 and 2003 which separates into an own sub group.

The difference between the years is about 34-35 %. The stations sampled in 1997 differ most because of high individual numbers within the family Capitellidae (it was found a high number of the indicator species *Capitella capitata* at station 28A in 1997). Except from this, the differences are due to, in a high degree, variations within the bristle worms families *Amphinomidae*, *Ampharetidae*, *Sabellidae*, *Cirratulidae* and *Tricobranchidae* where the individual numbers varies between years, without any pattern. This is expected to be due to natural variations between years.

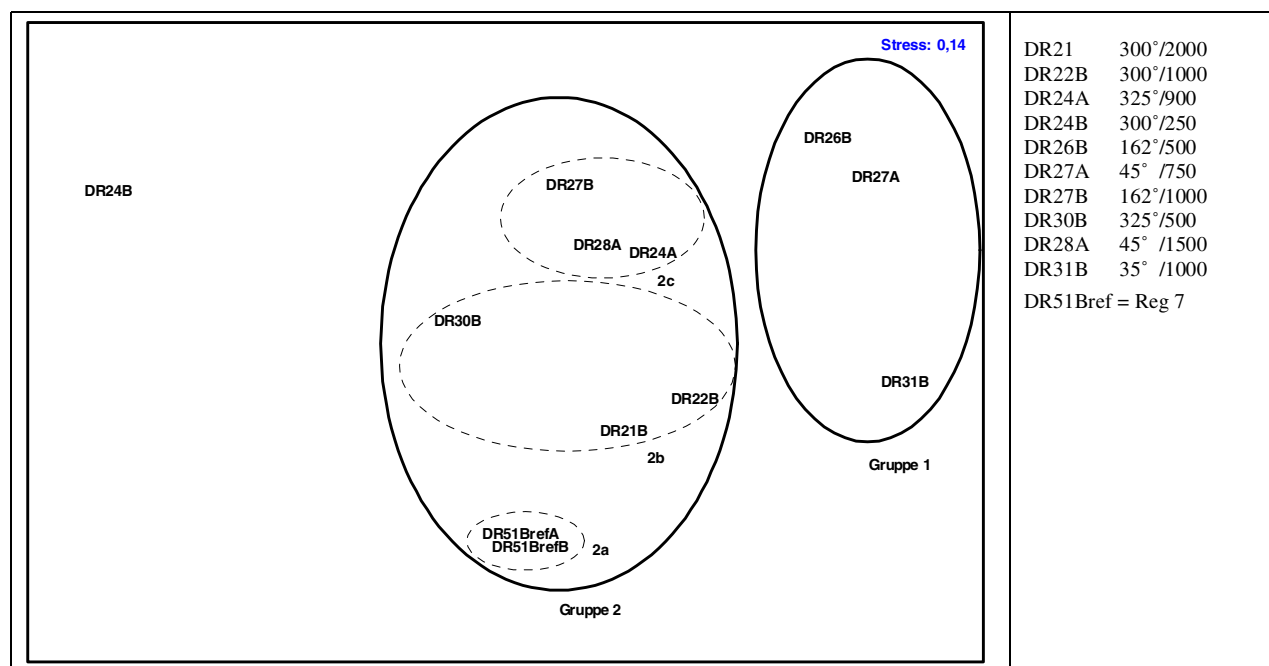


Figure 4.9. MDS-plot station level, Draugen 2003.

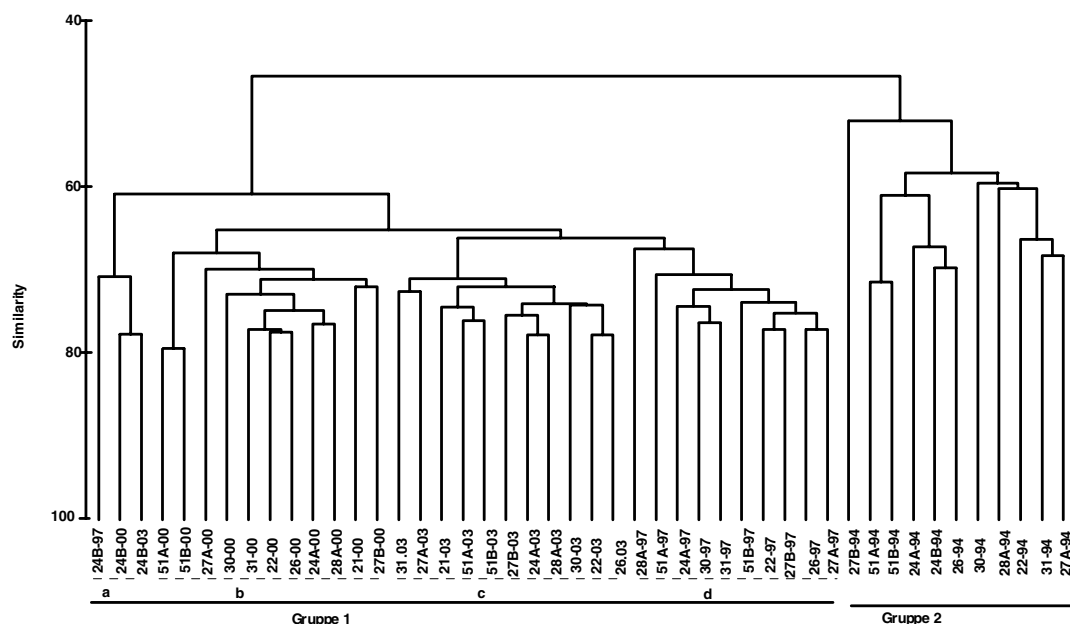


Figure 4.10. Dendrogram Draugen, 1994-2003.



4.6 Garn Vest

4.6.1 Grain size and chemical analysis

The sediments at Garn Vest vary from silt and clay to fine sand. The silt and clay fraction varies from 32 % at station GV13, 300°/2000m to 70 % at station GV7, 210°/250m. Gravel is found at all stations except for station GV7, an increase since 2000. The highest gravel content, 23 %, is found at station GV13, 300°/2000m. As in the baseline survey in 2000 the field is classified as very fine sand.

The total organic matter content in the sediments varies from 2,4 % at station GV12, 300°/1000m to 4,5 % at station GV10, 300°/250m. Compared to 2000 (0-1cm layer) the total organic matter content is lower at several stations in 2003 (0-5 cm layer).

The THC concentrations are low across the field, and they vary from 3,1 mg/kg at station GV13, 300°/2000m and station GV14, 300°/4000m to 8,2 mg/kg at station GV4, 120°/250m. A slight increase is found since the baseline survey in 2000. Although values above the LSC value are found at all the 250m stations and at two of the 500m stations, slightly elevated concentrations are only found at the 250m station in the 120° direction, station GV4.

The concentrations of NPD and PAH are low, and decalins are not found.

The Ba concentrations vary from 191 mg/kg at station GV13, 300°/2000m to 1090 mg/kg at station GV4, 120°/250m. A slight increase is found at some of the innermost stations. Slightly elevated Ba concentrations are found out to 1000m in three directions.

The concentrations of the heavy metals are low, and only a few elevated values are found.

The chemical results are in agreement with the drilling history. Two wells have been drilled at Garn Vest in 2001. Approx. 1 m³ of the base oil EDC 95-11 and 100 tonnes of baryte have been discharged in 2001.

Table 4.18. Garn Vest, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station		Silt and clay		TOM		THC		NPD		PAH		Decalins	
		2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000
GV1	30°/ 250 m	51,8	44,07	3,1	3,5	6,3	2,2	-	-	-	-	-	-
GV2	30°/ 500 m	56,5	58,62	3,6	4,5	4,9	2,3	-	-	-	-	-	-
GV3	30°/1000 m	49,6	56,59	3,3	5,0	4,8	3,3	-	-	-	-	-	-
GV4	120°/ 250 m	65,7	62,36	4,2	4,7	8,2	3,2	-	-	-	-	-	-
GV5	120°/ 500 m	46,6	62,15	3,0	4,5	4,8	3,2	-	-	-	-	-	-
GV7	210°/ 250 m	70,2	66,33	4,4	4,7	6,8	2,2	-	-	-	-	-	-
GV8	210°/ 500 m	61,3	63,36	3,8	4,4	6,1	2,0	-	-	-	-	-	-
GV9	210°/1000 m	51,5	52,14	3,6	3,5	4,4	2,9	-	-	-	-	-	-
GV10	300°/ 250 m	63,1	58,54	4,5	4,1	7,5	3,7	0,128	0,078	0,316	0,142	nd	nd
GV11	300°/ 500 m	62,6	58,30	3,6	5,1	7,0	3,1	-	-	-	-	-	-
GV12	300°/1000 m	41,6	46,18	2,4	3,8	4,9	2,2	-	-	-	-	-	-
GV13	300°/2000 m	31,7	49,18	3,1	3,6	3,1	2,1	0,050	0,052	0,099	0,090	nd	nd
GV14	300°/4000 m	50,4	52,96	3,3	4,7	3,1	3,7	-	-	-	-	-	-

-: not analysed nd: not found



ENGLISH SUMMARY

Table 4.19. *Garn Vest, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station		Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Hg	Hg	Pb	Pb	Zn	Zn
		2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000
GV1	30°/ 250 m	787	404	0,07	0,05	31,8	28,8	7,3	5,7	-	-	20,0	15,5	54	39,7
GV2	30°/ 500 m	531	495	0,07	0,05	28,1	26,2	7,4	6,6	-	-	18,0	17,6	48	41,5
GV3	30°/1000 m	684	781	0,07	0,05	26,1	26,7	6,5	7,4	-	-	17,8	19,6	48	44,1
GV4	120°/ 250 m	1090	436	0,07	0,05	33,7	25,7	9,2	6,9	-	-	19,9	17,0	64	41,2
GV5	120°/ 500 m	595	407	0,07	0,05	30,1	25,7	7,7	6,8	-	-	18,3	16,2	50	40,5
GV7	210°/ 250 m	1070	415	0,07	0,07	40,5	27,8	11,7	7,6	-	-	16,0	19,9	87	45,1
GV8	210°/ 500 m	790	326	0,07	0,05	36,4	27,4	10,7	7,6	-	-	19,2	19,2	70	45,0
GV9	210°/1000 m	376	346	0,06	0,05	29,1	28,4	6,5	7,4	-	-	18,8	17,3	49	42,6
GV10	300°/ 250 m	623	423	0,08	0,06	30,7	25,3	8,0	7,7	0,05	0,02	20,9	17,8	53	43,5
GV11	300°/ 500 m	512	491	0,08	0,07	32,1	26,9	8,2	8,2	-	-	20,8	20,3	52	48,6
GV12	300°/1000 m	388	331	0,07	0,05	31,2	26,1	6,4	6,6	-	-	18,4	17,0	47	41,0
GV13	300°/2000 m	191	243	0,04	0,04	29,2	24,1	5,7	6,3	0,04	0,01	16,7	15,6	42	38,3
GV14	300°/4000 m	205	298	0,04	0,05	24,3	21,9	5,8	6,8	-	-	15,9	17,8	39	39,0

-: not analysed

4.6.2 Biology

The fauna community at Garn Vest is healthy and undisturbed with high diversity indices. In general there are relative high similarities between the Garn Vest stations and the regional stations.

The Shannon-Wieners diversity index (H') was high for all the stations and range from 5,7 (GW-08 and 11) to 6,0 (GW-03 and 12). Pielou's index of evenness was high at all stations (0,8 and 0,9).

Different fauna parameters are given in table 4.20.

Table 4.20. *Depth, number of species (S) and number of individuals (N) per 0,5 m², Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Garn Vest 2003.*

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
GW-01	30	250	260	97	452	5,8	0,9	48
GW-02	30	500	260	92	432	5,8	0,9	48
GW-03	30	1000	260	105	422	6,0	0,9	53
GW-04	120	250	268	115	672	5,9	0,9	51
GW-05	120	500	270	98	395	5,8	0,9	50
GW-07	210	250	270	106	509	5,9	0,9	50
GW-08	210	500	270	99	470	5,7	0,9	47
GW-09	210	1000	268	101	502	5,9	0,9	50
GW-10	300	250	277	107	641	5,8	0,9	47
GW-11	300	500	258	107	554	5,7	0,8	47
GW-12	300	1000	266	112	533	6,0	0,9	51
GW-13	300	2000	260	98	338	5,9	0,9	53
GW-14	300	4000	265	88	357	5,8	0,9	50



ENGLISH SUMMARY

The results from the similarity analysis, see MDS plot in figure 4.11, implies in general a healthy and divers fauna community.

A bioenv analysis gave a correlation of 0,6 between the fauna and a combination of the factors Cd and grain size. The best single factor was Cd and THC. The correlation coefficient indicates some relation.

In figure 4.12 the dendrogram for the years 2000 and 2003 is given. The analysis gives a trend with an increase of strong indicators as the bristle worm's *C. setosa* and *P. kefersteini* in addition to an increase of more sensitive suspension feeders from 2000 to 2003. The numbers of *C. setosa* and *P. kefersteini* at the individual stations are not very high, but this together with a general increase in the number of individuals could indicate an increasing supply of organic materials in the area.

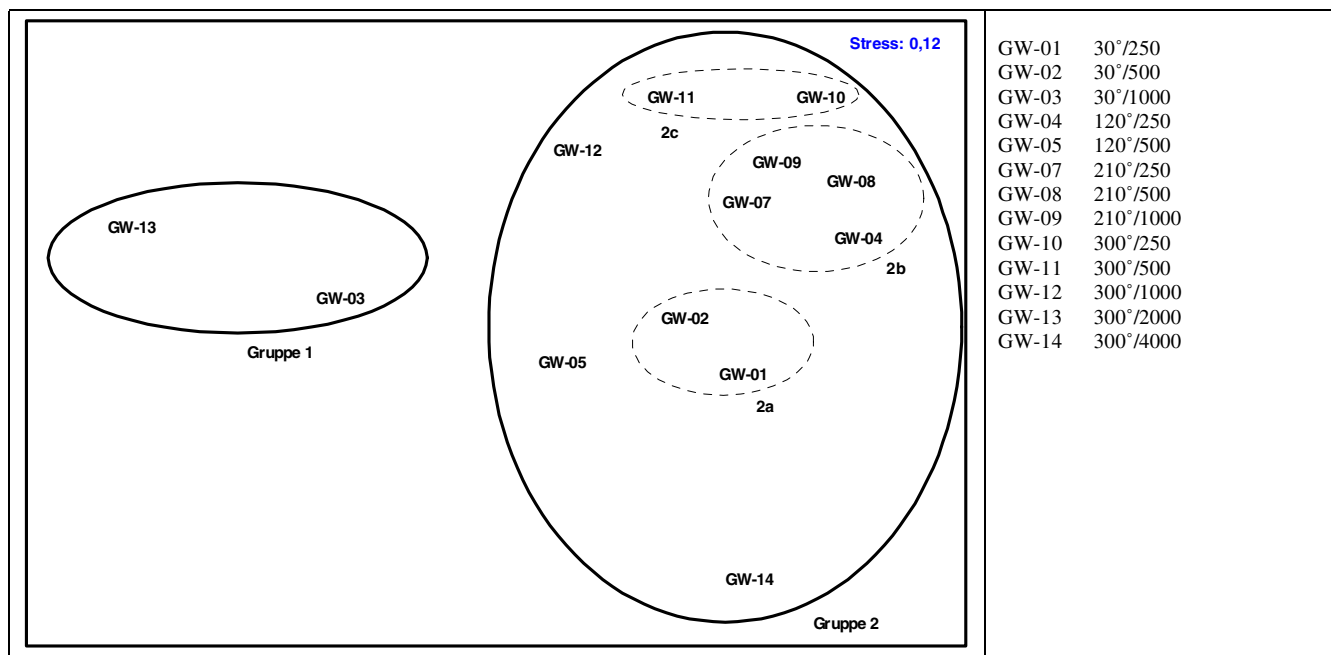


Figure 4.11. MDS-plot station level, Garn Vest 2003.

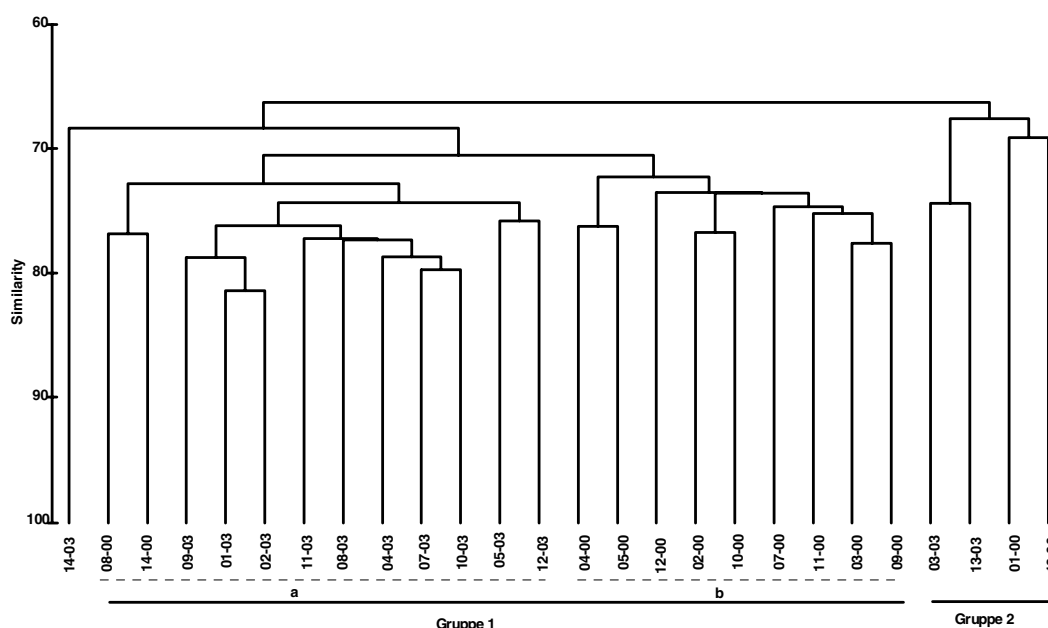


Figure 4.12. Dendrogram, Garn Vest 2000-2003.

4.7 Garn central

4.7.1 Grain size and chemical analysis

At Garn Central a baseline survey is performed. The silt and clay content varies from 43 % at station GC11, 300°/500m to 74 % at station GC10, 300°/250m. Gravel is found in the sediments at all stations. The highest content, 34 %, is found at station GC13, 300°/2000m.

The total organic matter content in the sediments varies from 3,1 % at station GC5, 120°/500m to 4,9 % at station GC10, 300°/250m.

The THC concentrations are low across the field, and they vary from 3,1 mg/kg at stations GC3, 30°/1000m and GC7, 210°/250m to 5,6 mg/kg at station GC13, 3000°/2000m. Elevated values are not found.

The concentrations of NPD and PAH are low, and decalins are not found.

The Ba concentrations vary from 400 mg/kg at station GC1, 30°/250m to 702 mg/kg at station GC9, 210°/1000m. Elevated values are found at all stations, but the concentrations are low compared to older fields in the region.

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

Garn Central is situated north of Draugen. The highest Ba concentrations are found at the station nearest Draugen. It is not unlikely that the elevated Ba concentrations found at Garn Central may result from drilling performed at Draugen.



ENGLISH SUMMARY

Table 4.21. *Garn Central, silt & clay and TOM (%), THC, NPD, PAH and metals (mg/kg dry sediment)*

Station		Silt and clay	TOM	THC	NPD	PAH	Ba	Cd	Cr	Cu	Hg	Pb	Zn
		2003	2003	2003	2003	2003	2003	2003	2003	2003	2003	2003	2003
GC1	30°/ 250 m	62,7	3,9	3,4	-	-	400	0,07	24,7	7,4	-	19,3	50
GC2	30°/ 500 m	70,1	4,3	4,3	-	-	408	0,07	24,4	7,1	-	18,4	48
GC3	30°/1000 m	56,3	3,4	3,1	-	-	418	0,08	24,9	6,6	-	19,4	47
GC4	120°/ 250 m	61,2	4,0	3,9	-	-	414	0,07	25,2	6,3	-	17,7	42
GC5	120°/ 500 m	45,5	3,1	3,4	-	-	438	0,07	25,5	6,2	-	16,9	43
GC6	120°/1000 m	50,8	3,6	3,3	-	-	492	0,06	23,8	6,4	-	17,2	41
GC7	210°/ 250 m	56,5	3,7	3,1	-	-	478	0,07	24,1	6,4	-	19,0	43
GC8	210°/ 500 m	57,8	3,6	3,6	-	-	567	0,07	25,0	7,0	-	18,8	44
GC9	210°/1000 m	54,5	3,6	4,3	-	-	702	0,06	20,7	5,9	-	15,2	37
GC10	300°/ 250 m	74,2	4,9	4,7	0,095	0,149	499	0,07	26,0	7,7	0,05	20,4	48
GC11	300°/ 500 m	42,6	3,6	3,8	0,062	0,119	453	0,07	26,3	7,1	0,05	19,4	49
GC12	300°/1000 m	66,0	4,3	4,3	-	-	521	0,07	24,4	7,1	-	19,0	44
GC13	300°/2000 m	43,5	4,3	5,6	-	-	426	0,07	26,8	7,8	-	21,3	49

-: not analysed

nd: not found

Decalins are not found

4.7.2 Biology

The fauna community at Garn Central is healthy and undisturbed and do not differ much from comparable regional stations.

The Shannon-Wieners diversity index (H') range from 5,6 (GC-02) to 6,0 (GC-06). Pielou's index of evenness was high (0,9) at all stations.

The fauna community is according to the indices very healthy. The species composition is typical for relative coarse sediment.

Different fauna parameters are given in table 4.22.

The results from the similarity analysis imply an undisturbed fauna in the whole area. However, the species composition could indicate a greater supply of organic material in group 1. The differences are however small and could be random and natural. It was not found any correlation between fauna and environmental factors. See MDS plot, in figure 4.13.



ENGLISH SUMMARY

Table 4.22. Depth, number of species (S) and number of individuals (N) per $0,5 \text{ m}^2$, Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Garn Central 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
GC-01	30	250	249	91	329	5,8	0,9	50
GC-02	30	500	250	82	301	5,6	0,9	48
GC-03	30	1000	242	84	282	5,8	0,9	50
GC-04	120	250	249	98	550	5,8	0,9	48
GC-05	120	500	248	82	289	5,8	0,9	51
GC-06	120	1000	246	104	384	6,0	0,9	53
GC-07	210	250	247	83	320	5,7	0,9	48
GC-08	210	500	245	94	415	5,8	0,9	49
GC-09	210	1000	246	99	509	5,9	0,9	50
GC-10	300	250	250	89	409	5,7	0,9	47
GC-11	300	500	241	100	541	5,8	0,9	48
GC-12	300	1000	251	95	524	5,7	0,9	46
GC-13	300	2000	241	91	390	5,8	0,9	50

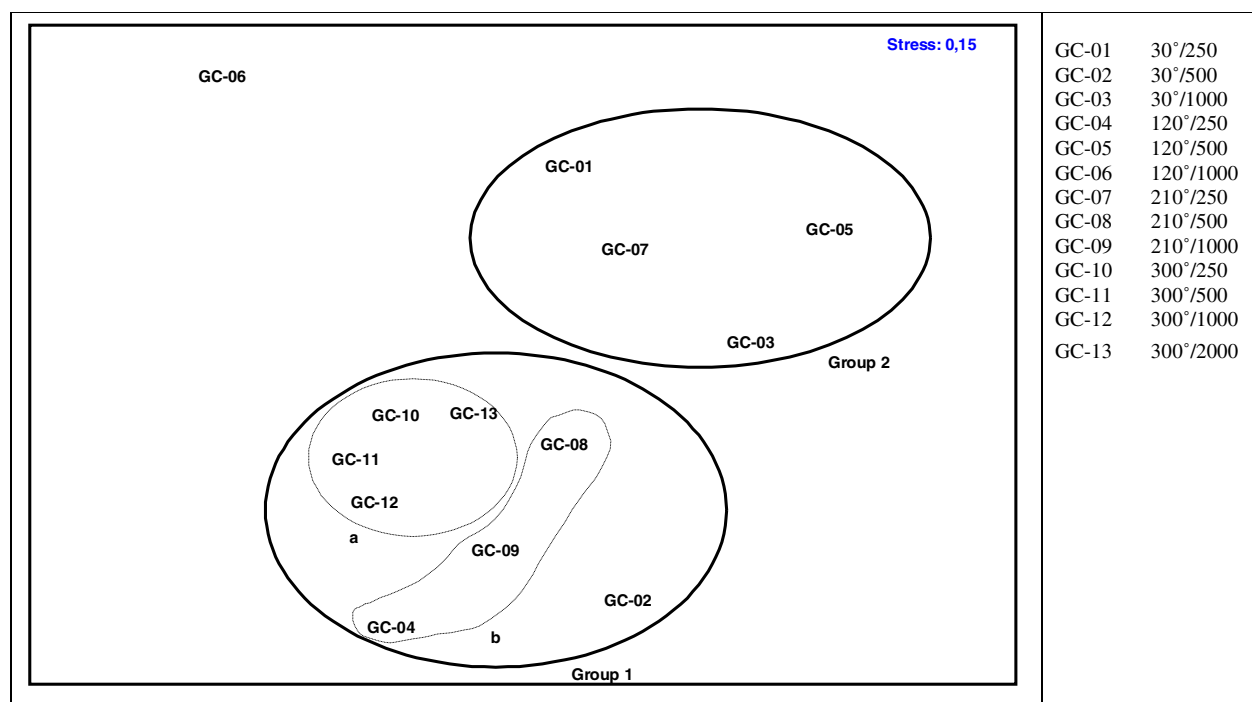


Figure 4.13. MDS-plot station level, Garn Central 2003



4.8 Njord

4.8.1 Grain size and chemical analysis

At Njord samples from 21 stations out to 2000m in 6 directions from the platform are analysed. The reference station is situated at 10 000m.

The sediments at Njord consist of silt and clay and also of very fine sand. The silt and clay content varies from 42 % at the reference station NJ17, 67,5°/10000m to 75 % at station NJ6, 157,5°/500m. Gravel is found at most of the stations, up to 8 %. The results are similar to the 2000 results.

The total organic matter content in the sediments varies from 2,8 % at station NJ2, 67,5°/500m to 4,4 % at station NJ11, 247,5°/1000m. The values are similar to the 2000 results.

The THC concentrations vary from 3,0 mg/kg at the reference station NJ17, 67,5°/10000m to 3660 mg/kg at station NJ13, 337,5°/250m. The THC values are similar or they are reduced since the 2000 survey. The exception is the two innermost stations in the 67,5° direction where an increase is found. Elevated THC concentrations are not found in the layer samples at 1-3cm and 3-6cm, a decrease at station NJ5, 157,5°/250m since 2000.

Station NJ6, 157,5°/500m differs from the other stations as a more fresh "drilling mud base oil" is found in the sediments. The station inside, NJ5, 157,5°/250m, does not show the same hydrocarbon profile, but has a more common profile of degraded "drilling mud base oil". The results indicate acute discharges in the neighbourhood of NJ6.

The THC concentrations at the 1000m and 2000m stations are still low. However, drilling mud base oil is detected in the gas chromatograms from all stations except for three stations at 2000m.

As in previous surveys the concentrations of NPD and PAH are low. On the other hand, high concentrations of decalins are found at most of the stations, up to 265 mg/kg at station NJ13, 337,5°/250m. A clear correspondence is found between the decalin and the THC results. The concentration of decalins are also increased at stations NJ1, 67,5°/250m and NJ2, 67,5°/500m.

The Ba concentrations vary from 109 mg/kg at the reference station NJ17, 67,5°/10000m to 6840 mg/kg at station NJ1, 67,5°/250m. Elevated Ba levels are found at most of the stations. High concentrations are found out to 1000m from the platform. At 2000m the concentrations are decreasing, but only the station in the 112° direction shows no elevated values. Compared to the 2000 survey an increase is found in the 67,5° direction and a decrease in the 157,5° direction.

The concentrations of the heavy metals are low. However, slightly elevated concentrations of Cu, Pb and Zn are found at station NJ13, 337,5°/250m.

The chemical results seem to be in agreement with the drilling history. Oil based drilling fluid has been used at Njord in the first six months of 2003, and an acute discharge of oil based mud has occurred, 94 m³ in February 2003. The leakage from *slipjoint* in 2000 resulted in very high THC concentrations in the sediments, and degradation of this oil will takes time. Large quantities of baryte have been discharged in 2000 and somewhat less in 2003.



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Table 4.23. *Njord, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)*

Station		Silt and clay		TOM			THC			NPD		PAH		Decalins	
		2003	2000	2003	2000	1997	2003	2000	1999	2003	2000	2003	2000	2003	2000
NJ1	67.5°/ 250 m	68,4	74,6	3,7	12,9	-	878	515	266	*	0,095	0,089	0,027	46,9	10,8
NJ2	67.5°/ 500 m	67,3	60,4	2,8	3,5	-	260	30,9	61,3	*	0,069	0,068	0,045	15,3	5,13
NJ3	67.5°/1000 m	61,4	55,8	3,1	4,0	5,0	6,3	-	6,4	-	-	-	-	-	-
NJ4	67.5°/2000 m	58,7	56,4	3,4	3,9	-	7,7	-	5,9	-	-	-	-	-	-
NJ5	157.5°/ 250 m	65,2	54,9	3,3	4,4	-	36,7	690	397	0,069	0,056	0,089	0,162	2,30	42,5
NJ6	157.5°/ 500 m	74,9	73,0	3,3	4,0	-	16,8	59,9	43,8	0,100	0,071	0,049	0,071	1,06	3,13
NJ7	157.5°/1000 m	56,3	57,0	3,0	3,8	4,5	8,2	7,0	7,8	-	-	-	-	-	-
NJ8	157.5°/2000 m	59,5	67,9	3,5	3,9	4,7	7,2	-	6,1	-	-	-	-	-	-
NJ9	247.5°/ 250 m	68,4	62,6	3,8	4,5	-	94,5	294	131	-	-	-	-	-	-
NJ10	247.5°/ 500 m	60,6	55,0	3,5	4,4	-	39,5	37,6	29,3	-	-	-	-	-	-
NJ11	247.5°/1000 m	68,6	72,8	4,4	4,5	-	8,9	-	10,0	-	-	-	-	-	-
NJ12	247.5°/2000 m	72,5	69,7	3,9	4,9	5,4	6,1	-	6,1	-	-	-	-	-	-
NJ13	337.5°/ 250 m	65,5	63,5	4,1	3,9	-	3660	5580	5900	*	*	0,102	*	265	454
NJ14	337.5°/ 500 m	66,5	65,9	4,1	4,7	-	61,9	210	125	0,092	0,093	0,127	0,112	3,39	9,94
NJ15	337.5°/1000 m	65,1	49,4	4,2	4,0	4,7	11,1	-	15,9	-	-	-	-	-	-
NJ16	337.5°/2000 m	54,3	58,1	3,1	4,1	4,7	6,4	-	6,2	-	-	-	-	-	-
NJ19	112°/ 500 m	58,6	-	3,6	-	-	485	-	-	0,133	-	0,114	-	33,9	-
NJ20	112°/1000 m	53,4	-	3,6	-	-	28,0	-	-	-	-	-	-	-	-
NJ21	112°/2000 m	63,0	-	4,0	-	-	4,8	-	-	-	-	-	-	-	-
NJ24	22.5°/1000 m	62,9	-	3,6	-	-	11,1	-	-	-	-	-	-	-	-
NJ25	22.5°/2000 m	58,5	-	4,1	-	-	5,2	-	-	-	-	-	-	-	-
NJ17	67.5°/10000 m	42,4	46,5	3,2	3,7	4,0	3,0	3,6	3,4	0,054	0,035	0,105	0,093	nd	nd

-: not analysed nd: not found *: not determined due to interferences, e.g. from decalins

Table 4.24. *Njord, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station			Ba	Ba	Ba	Cd	Cd	Cr	Cr	Cu	Cu	Cu	Hg	Hg	Pb	Pb	Pb	Zn	Zn	Zn
			2003	2000	1997	2003	2000	2003	2000	2003	2000	2003	2000	1997	2003	2000	2003	2000	1997	2003
NJ1	67.5°/ 250 m		6840	2530	-	0,05	0,08	23,4	24,3	10,3	20,5	-	-	-	14,2	14,2	-	42	66,0	-
NJ2	67.5°/ 500 m		1970	1710	-	0,04	0,05	25,9	23,7	7,4	7,5	-	-	-	11,5	8,8	-	46	37,2	-
NJ3	67.5°/1000 m		1060	514	316	0,06	0,05	22,1	22,3	7,3	7,1	8,1	-	-	17,9	16,9	24,8	42	39,4	39,2
NJ4	67.5°/2000 m		392	229	-	0,06	0,08	22,4	20,6	6,9	6,7	-	-	-	17,3	16,3	-	41	36,4	-
NJ5	157.5°/ 250 m		824	4200	-	0,05	0,07	25,5	24,2	7,8	9,7	-	0,04	0,02	14,9	19,6	-	44	47,5	-
NJ6	157.5°/ 500 m		161	1050	-	0,07	0,03	31,5	25,6	9,0	8,6	-	0,03	-	10,3	10,1	-	52	39,2	-
NJ7	157.5°/1000 m		496	565	225	0,05	0,05	23,5	21,7	7,2	6,5	8,3	-	-	16,6	15,1	24,3	43	37,0	39,3
NJ8	157.5°/2000 m		239	260	141	0,05	0,05	23,8	23,9	6,9	7,2	6,9	-	0,02	16,0	17,0	21,9	42	40,5	35,7
NJ9	247.5°/ 250 m		2940	3900	-	0,04	0,04	23,2	22,8	9,0	9,5	-	-	-	18,3	19,3	-	55	56,4	-
NJ10	247.5°/ 500 m		2580	1440	-	0,04	0,04	25,9	23,6	9,3	7,6	-	-	-	15,8	16,3	-	47	40,2	-
NJ11	247.5°/1000 m		837	435	-	0,05	0,04	23,5	23,3	7,5	7,3	-	-	-	17,6	18,7	-	45	40,7	-
NJ12	247.5°/2000 m		306	251	241	0,04	0,05	23,0	22,2	6,7	6,8	14,9	-	-	17,2	16,5	23,4	43	38,6	43,6
NJ13	337.5°/ 250 m		5640	7470	-	0,12	0,08	33,0	19,6	39,6	43,1	-	-	-	32,4	27,8	-	149	114	-
NJ14	337.5°/ 500 m		5450	5510	-	0,04	0,04	23,4	20,9	10,1	11,2	-	-	-	20,4	19,7	-	53	47,8	-
NJ15	337.5°/1000 m		1760	1960	321	0,04	0,04	22,5	20,9	7,8	8,4	8,3	-	-	18,0	16,8	21,3	51	43,1	35,8
NJ16	337.5°/2000 m		438	433	248	0,04	0,04	24,4	18,7	7,1	6,7	9,5	-	-	16,7	15,4	22,6	45	36,1	40,9

cont.



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Table 4.24 *cont.*

Station		Ba 2003	Ba 2000	Ba 1997	Cd 2003	Cd 2000	Cr 2003	Cr 2000	Cu 2003	Cu 2000	Cu 1997	Hg 2003	Hg 2000	Pb 2003	Pb 2000	Pb 1997	Zn 2003	Zn 2000	Zn 1997
NJ19	112°/ 500 m	2000	-	-	0,04	-	20,8	-	9,4	-	-	0,04	-	16,0	-	-	43	-	-
NJ20	112°/1000 m	1160	-	-	0,05	-	21,8	-	7,5	-	-	-	-	17,9	-	-	41	-	-
NJ21	112°/2000 m	153	-	-	0,04	-	19,3	-	5,4	-	-	-	-	13,8	-	-	35	-	-
NJ24	22,5°/1000 m	1280	-	-	0,05	-	21,6	-	7,1	-	-	-	-	16,1	-	-	41	-	-
NJ25	22,5°/2000 m	282	-	-	0,04	-	22,1	-	6,7	-	-	-	-	17,4	-	-	41	-	-
NJ17	67,5°/10000 m	109	151	113	0,05	0,03	18,9	20,2	4,1	6,1	7,7	0,02	0,02	16,6	15,4	19,7	35	34,5	34,1

-: not analysed

4.8.2 Biology

The fauna community at Njord is in general healthy and undisturbed and do not differ from comparable regional stations.

- However, analysis and the species composition show that the fauna at station NJ-6 (157,5°/500m) and NJ-13 (337,5°/250m) is disturbed. In addition there are indications that the fauna at stations NJ-1 (67,5°/250m), NJ-2 (67,5°/500m), NJ-5 (157,5°/250m), NJ-9 (247,5°/250m) and NJ-14 (337,5°/500m) is slightly disturbed.

The Shannon-Wieners diversity index (H') was below 4 at station NJ-13 (337,5°/250 m) and NJ-6 (157,5°/ 500 m). At the other stations the diversity index H' range from 4,6 to 6,1. Pielou's index of evenness was high at the most stations and range from 0,5 to 0,9, with the lowest value at station NJ-13 (337,5°/ 250 m).

Different fauna parameters are given in table 4.25.

The MDS plot from the similarity analysis is shown in figure 4.14. Station NJ-6 and NJ-13 differed considerable from the other stations. The remaining stations divides into 2 main group at about 45 % similarity, of which group 2 consist of stations NJ-1, 2 and 5.

The similarity analysis indicates:

- The fauna at station NJ-6 (157,5°/500m) and 13 (337,5°/250m) is disturbed.
- A slight disturbance in the fauna at the stations in sub group 1a; NJ-9 and 14 (247,5°/250m and 337,5°/500m) and at station NJ-1 (67,5°/250m), NJ-2 (67,5°/500m) and NJ-5 (157,5°/250m) in group 2.
- The fauna at the other stations could be characterised as healthy and undisturbed.

It was found a relative good correlation between fauna and a combination of the factors Cr, Pb and THC. The single factor which correlated best (0,6) was Pb.



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In figure 4.15. the dendrogram for the years 1996, 2000 and 2003 is given. The stations divide into 4 groups at a similarity of about 30 %. Group 1 contains the 1996 stations, while group 2 contains most of the Njord stations from 2000 and 2003 which group at a similarity of about 70 %. The analysis shows that station NJ6-03 separates into the same group as station NJ13-00 and NJ13-03. This indicates an increased disturbance in the fauna at station NJ-6 since 2000.

Table 4.25. Depth, number of species (*S*) and number of individuals (*N*) per 0,5 m², Shannon-Wieners diversity index (*H'*), Pielou's index of evenness (*J*) and *ES*₁₀₀, Njord 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
NJ-1	67,5	250	332	57	270	4,6	0,8	35
NJ-2	67,5	500	334	69	233	5,2	0,8	44
NJ-3	67,5	1 000	332	130	705	6,0	0,8	50
NJ-4	67,5	2 000	332	115	467	6,1	0,9	54
NJ-5	157,5	250	325	48	139	5,0	0,9	41
NJ-6	157,5	500	331	18	48	3,2	0,9	18
NJ-7	157,5	1 000	327	104	341	6,0	0,9	55
NJ-8	157,5	2 000	328	95	433	5,7	0,9	48
NJ-9	247,5	250	336	77	511	5,0	0,8	37
NJ-10	247,5	500	335	84	350	5,4	0,8	44
NJ-11	247,5	1 000	335	115	748	5,5	0,8	43
NJ-12	247,5	2 000	338	88	382	5,8	0,9	49
NJ-13	337,5	250	331	41	1077	2,8	0,5	15
NJ-14	337,5	500	334	95	823	5,0	0,8	36
NJ-15	337,5	1 000	332	92	489	5,5	0,8	45
NJ-16	337,5	2 000	333	104	421	5,8	0,9	50
Ref.A	67,5	10 000	312	98	488	5,8	0,9	48
Ref.B	67,5	10 000	312	109	439	6,0	0,9	53
NJ-19	112	500	336	122	1058	5,3	0,8	41
NJ-20	112	1 000	337	108	609	5,8	0,9	47
NJ-21	112	2 000	331	100	669	5,7	0,9	46
NJ-24	22,5	1000	334	110	507	5,9	0,9	49
NJ-25	22,5	2000	332	91	339	5,8	0,9	51

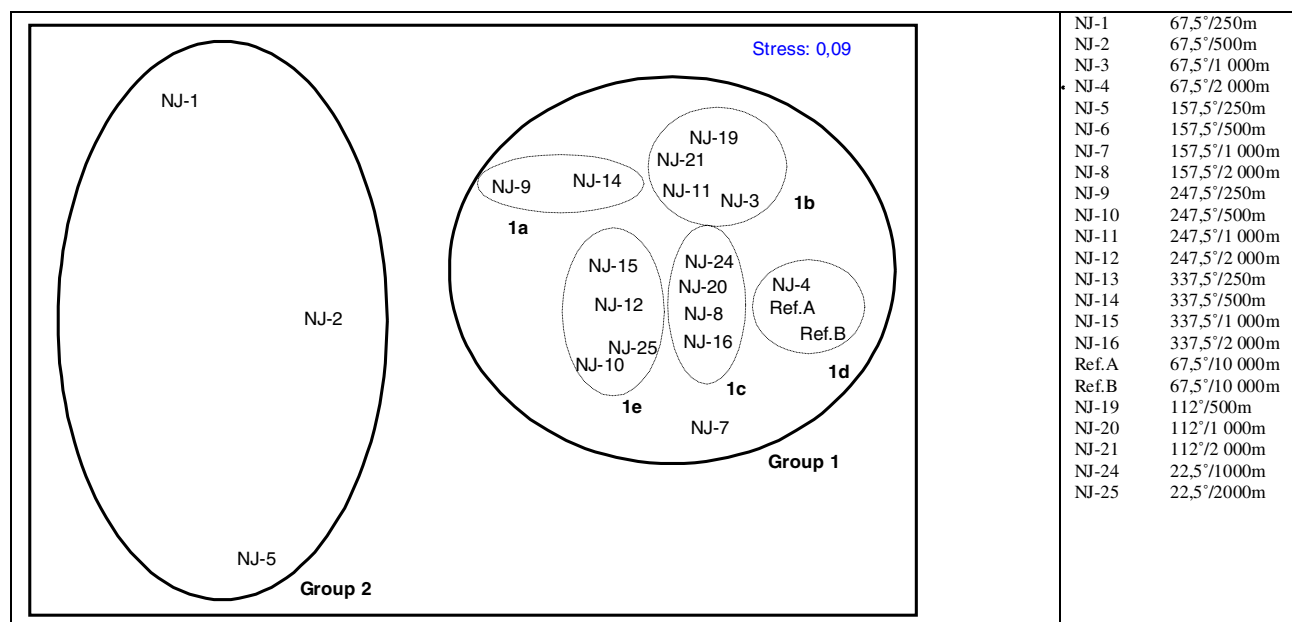


Figure 4.14. MDS-plot station level, without NJ-6 and 13, Njord 2003.

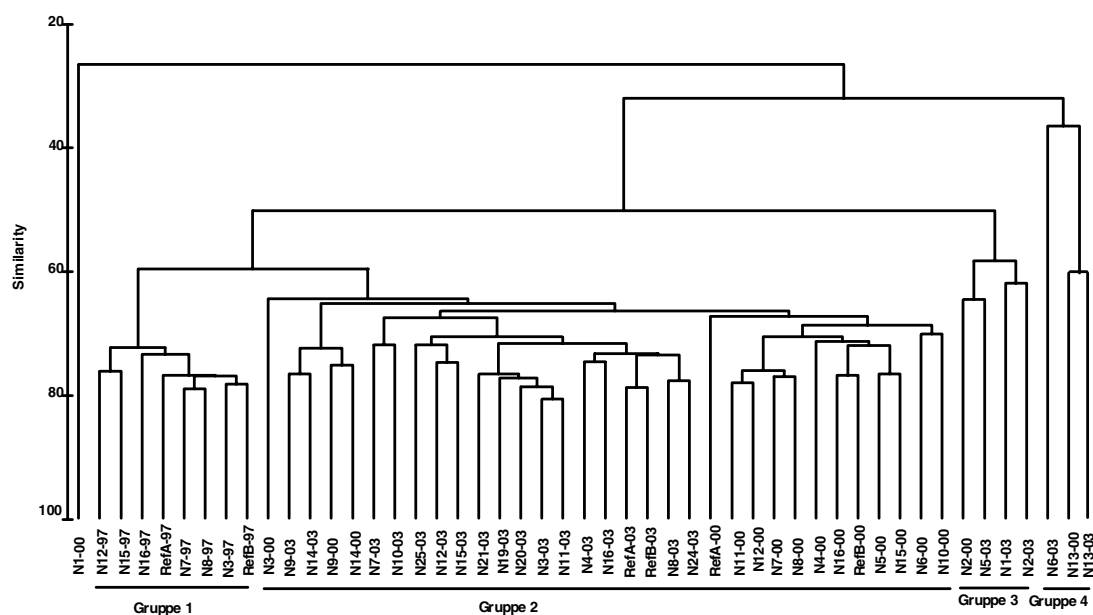


Figure 4.15. Dendrogram Njord, 1996 -2003.



4.9 Mikkel

4.9.1 Grain size and chemical analysis

The sediments at Mikkel show a great variation, from silt and clay to coarse sand. The sediments are somewhat finer at template B than at template A. At template A the silt and clay content varies from 20 % at station MIKA, 07 225°/500m to 64 % at station MIKA 10, 330°/1000m. At template B the silt and clay content varies from 32 % at station MIKB 10, 315°/1000m to 61 % at station MIKB 06, 135°/1000m. Gravel is found at all stations, up to 29 %. Some differences are observed since the baseline survey in 2001, however, the mean values are similar.

The total organic matter content is quite similar at the two templates. At template A the concentrations vary from 1,7 % at station MIKA 07, 225°/500m to 3,6 % at station MIKA 06, 135°/1000m and station MIKA 10, 330°/1000m. At template B the concentrations vary from 2,4 % at station MIKB 01, 45°/250m to 4,1 % at station MIKB 06, 135°/1000m. The highest content, 5,0 %, is found at the reference station MIKB 11A, 315°/5000m.

The THC concentrations are increased at some of the innermost stations at 250m and 500m since the baseline survey in 2001. At template A the concentrations vary from 2,4 mg/kg at station MIKA-04, 45°/2000m to 112 mg/kg at station MIKA-01, 45°/250m. Elevated THC concentrations that result from drilling mud base oil are found out to 500m in the 45° direction.

In addition elevated THC values are found at the 500m stations in the 225° and 330° directions, however, these hydrocarbons are compounds with higher bp. than the drilling mud base oil HDF 200.

At template B the THC concentrations vary 3,1 mg/kg at station MIKB-02 45°/500m to 52,7 mg/kg at station MIKB-05, 135°/500m. Elevated THC values are only found at station MIKB-05.

The NPD and PAH concentrations are low, and no values are considered as elevated. Decalins are found at four stations, up to 7,89 mg/kg at station MIKA-01, 45°/250m, the station with the highest THC values. The finding of decalins confirms the THC results and that drilling mud base oil is present in the sediments.

The Ba concentrations are increased at several stations out to 1000m, and elevated values are found at all stations except for the reference station. At template A the Ba values vary from 223 mg/kg at station MIKA-04, 45°/2000m to 2710 mg/kg at station MIKA-07, 225°/500m. An increase is found out to 500m in the 45° direction, in the 225° direction and in the 330° direction. At template B the Ba values vary from 150 mg/kg at the reference station MIKB-11A, 315°/5000m to 3260 mg/kg at station MIKB-05, 135°/500m. The Ba values are increased at the 500m station in the 135° direction and at the 1000m station in the 225° direction, but not in the 45° direction.

The concentrations of the heavy metals are low, but at one station, station MIKA-07, 225°/500m relative high Cu concentrations are found.

Generally the chemical results are in agreement with the drilling history. The drilling at Mikkel started in 2002, and 2 wells are drilled at template A and 1 well at template B by use of water based drilling mud. However, the results indicate that oil based drilling fluid has been used as well. 700 tonnes of baryte were discharged in 2002.



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Table 4.26. Mikkell, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM		THC		NPD		PAH		Decalins	
	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001
Installation A												
MIKA 01 45°/ 250m	43,1	45,3	3,3	3,9	112	3,0	0,051	0,050	0,085	0,090	7,89	-
MIKA 02 45°/ 500m	36,6	39,0	3,1	3,4	6,4	2,3	0,037	-	0,066	-	0,20	-
MIKA 03 45°/1000m	40,2	38,2	2,9	3,6	2,8	2,3	-	-	-	-	-	-
MIKA 04 45°/2000m	33,8	33,6	2,9	3,5	2,4	2,5	-	-	-	-	-	-
MIKA 05 135°/ 500m	42,2	46,3	3,3	3,9	3,7	2,8	-	-	-	-	-	-
MIKA 06 135°/1000m	45,2	49,1	3,6	4,3	3,2	3,2	-	-	-	-	-	-
MIKA 07 225°/ 500m	20,3	38,2	1,7	2,1	7,4	1,9	-	-	-	-	-	-
MIKA 08 225°/1000m	41,0	39,0	2,6	3,2	3,0	2,6	-	-	-	-	-	-
MIKA 09 330°/ 500m	42,8	46,8	2,8	3,4	6,5	2,4	-	-	-	-	-	-
MIKA 10 330°/1000m	63,9	58,8	3,6	4,7	3,7	3,5	-	-	-	-	-	-
Installation B												
MIKB 01 45°/ 250m	46,8	52,2	2,4	4,4	3,6	3,6	0,047	0,055	0,069	0,101	nd	-
MIKB 02 45°/ 500m	50,2	54,3	3,1	4,3	3,1	4,1	0,055	-	0,080	-	nd	-
MIKB 03 45°/1000m	47,9	52,2	3,0	4,2	3,6	3,5	-	-	-	-	-	-
MIKB 04 45°/2000m	49,3	57,7	2,5	4,4	3,5	3,4	-	-	-	-	-	-
MIKB 05 135°/ 500m	44,8	61,9	3,7	4,4	52,7	5,0	0,147	-	0,096	-	4,86	-
MIKB 06 135°/1000m	61,4	49,7	4,1	4,6	4,1	3,7	-	-	-	-	-	-
MIKB 07 225°/ 500m	49,3	72,7	3,5	3,1	3,5	2,9	-	-	-	-	-	-
MIKB 08 225°/1000m	46,1	54,3	2,8	3,8	3,5	3,3	-	-	-	-	-	-
MIKB 09 315°/ 500m	46,7	44,8	3,6	3,7	4,8	2,5	-	-	-	-	-	-
MIKB 10 315°/1000m	32,0	48,7	2,9	4,0	3,8	2,5	-	-	-	-	-	-
MIKB 11A 315°/5000m	53,5	45,6	5,0	4,7	4,2	3,3	0,061	0,060	0,123	0,122	nd	nd

-: not analysed nd: not found

Table 4.27. Mikkell, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba		Cd		Cr		Cu		Hg		Pb		Zn	
	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001
Installation A														
MIKA 01 45°/ 250m	1010	188	0,07	0,06	18,7	17,4	6,4	6,6	0,07	0,03	15,9	15,7	35	32
MIKA 02 45°/ 500m	516	203	0,07	0,06	19,0	17,7	6,1	6,7	0,05	-	16,5	15,9	35	32
MIKA 03 45°/1000m	292	210	0,06	0,05	18,0	17,4	5,3	6,7	-	-	15,7	15,1	33	31
MIKA 04 45°/2000m	223	204	0,06	0,06	17,4	18,5	5,2	7,0	-	0,03	15,2	16,3	32	33
MIKA 05 135°/ 500m	423	339	0,08	0,06	18,3	19,9	6,4	9,4	-	-	17,7	17,3	37	36
MIKA 06 135°/1000m	525	354	0,07	0,05	18,3	19,5	6,9	7,9	-	-	17,0	16,7	36	35
MIKA 07 225°/ 500m	2710	1840	0,06	0,06	22,1	24,5	*154	10,6	-	-	22,8	18,6	51	44
MIKA 08 225°/1000m	407	177	0,07	0,05	19,6	17,7	6,0	6,6	-	-	17,0	14,9	38	31
MIKA 09 330°/ 500m	1450	1080	0,06	0,05	20,9	17,8	5,9	7,0	-	-	14,0	15,8	36	33
MIKA 10 330°/1000m	230	169	0,07	0,05	23,6	19,5	6,6	7,8	-	-	16,8	15,8	43	36

Cont.



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Table 4.27. cont.

Station	Ba 2003	Ba 2001	Cd 2003	Cd 2001	Cr 2003	Cr 2001	Cu 2003	Cu 2001	Hg 2003	Hg 2001	Pb 2003	Pb 2001	Zn 2003	Zn 2001
Installation B														
MIKB 01 45°/ 250m	788	539	0,06	0,04	24,8	20,0	7,0	7,9	0,05	0,03	14,2	18,9	43	37
MIKB 02 45°/ 500m	686	526	0,06	0,05	23,2	19,2	6,4	8,0	0,05	-	17,2	18,1	41	37
MIKB 03 45°/1000m	436	269	0,06	0,04	21,4	20,1	6,0	7,9	-	-	16,9	18,2	39	38
MIKB 04 45°/2000m	345	216	0,07	0,04	22,8	19,5	7,2	7,7	-	0,03	20,0	18,3	44	37
MIKB 05 135°/ 500m	3260	720	0,09	0,05	23,2	27,8	7,7	11,2	-	-	19,5	22,3	42	47
MIKB 06 135°/1000m	461	342	0,07	0,05	24,3	21,2	7,6	8,5	-	-	21,5	19,8	46	41
MIKB 07 225°/ 500m	402	379	0,05	0,06	20,0	31,7	5,8	12,3	-	-	14,8	16,4	36	47
MIKB 08 225°/1000m	1060	670	0,07	0,06	21,7	20,7	6,9	8,6	-	-	19,1	20,2	40	40
MIKB 09 315°/ 500m	515	215	0,08	0,05	23,0	19,9	7,0	7,6	-	-	18,3	17,3	43	36
MIKB 10 315°/1000m	348	172	0,07	0,05	20,7	20,3	5,7	7,5	-	-	16,3	16,4	37	36
MIKB 11A 315°/5000m	150	134	0,08	0,05	23,6	22,6	6,7	9,1	0,03	0,03	24,3	21,6	47	43

-: not analysed

4.9.2 Biology

The fauna at Mikkell is very divers and healthy and the stations at Mikkell do not differ much from comparable regional stations.

The Shannon-Wieners diversity index (H') range from 5,4 (MIKA-10 and MIKB-11B) to 5,9 (MIKB-10). Pielou's index of evenness was relative high (0,8 and 0,9) at all stations.

Different fauna parameters are given in table 4.28.

The MDS plot from the similarity analysis at station level is shown in figure 4.16. Most of the stations divide into 2 groups at a similarity of about 65 %. Station MIKA-07 (217°/565m) and the second half of the reference station, MIKB-11B (315°/5000m), did not group.

The results from the similarity analysis could indicate an incipient slight disturbance in the fauna. However the diversity indices are high and the differences could be random and natural or be due to slight differences in the sediment structure.

A bioenv analysis gave a correlation of 0,5 between fauna and a combination of the factors Cu and gravel. The single factor that correlated best (0,5) was gravel. This is not any good correlation, but could indicate some relation.

In figure 4.17 the dendrogram for the years 2001 and 2003 is given. The stations divide into 2 main groups at a similarity of about 70 %, independent of years. It has been an increase in the number of individuals at some stations since 2001.



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Table 4.28. Depth, number of species (S) and number of individuals (N) per $0,5 \text{ m}^2$, Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Mikkelsen 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES_{100}
MIKA-01	94	267	226	113	826	5,5	0,8	43
MIKA-02	70	468	226	98	568	5,6	0,8	45
MIKA-03	58	950	222	100	487	5,7	0,9	47
MIKA-04	51	1928	219	96	589	5,6	0,8	44
MIKA-05B	135	500	223	95	474	5,5	0,8	45
MIKA-06B	135	1000	226	116	777	5,7	0,8	45
MIKA-07	217	565	221	103	616	5,3	0,8	41
MIKA-08	214	1094	220	109	580	5,7	0,8	46
MIKA-09	324	284	230	101	561	5,7	0,9	45
MIKA-10	328	780	235	102	975	5,4	0,8	41
MIKB-01	128	283	227	100	508	5,7	0,9	47
MIKB-02	89	397	227	90	389	5,6	0,9	46
MIKB-03	65	830	227	122	764	5,8	0,8	47
MIKB-04	54	1800	231	93	458	5,7	0,9	47
MIKB-05B	144	500	222	96	594	5,5	0,8	43
MIKB-06	145	1300	220	94	557	5,5	0,8	44
MIKB-07B	225	500	225	91	484	5,7	0,9	46
MIKB-08	212	1250	227	104	652	5,7	0,8	46
MIKB-09	269	309	228	103	516	5,8	0,9	49
MIKB-10	298	750	225	116	630	5,9	0,9	50
MIKB-11A	315	5000	220	117	801	5,7	0,8	45
MIKB-11B	315	5000	220	85	457	5,4	0,8	43

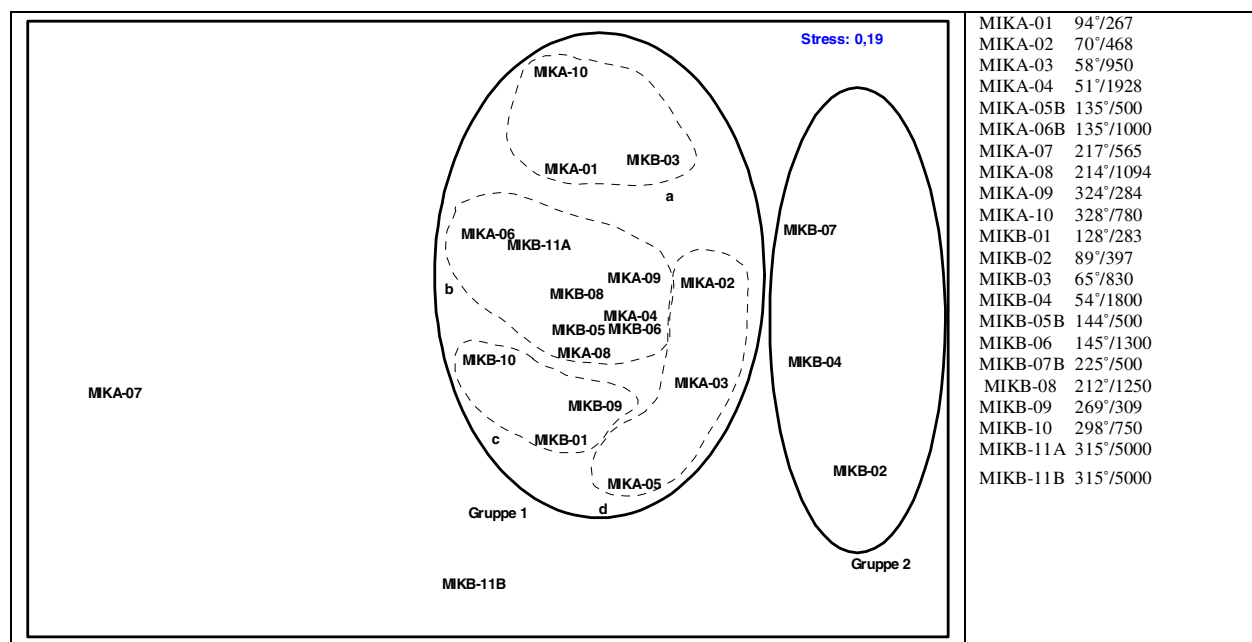


Figure 4.16. MDS-plot station level, Mikkel 2003

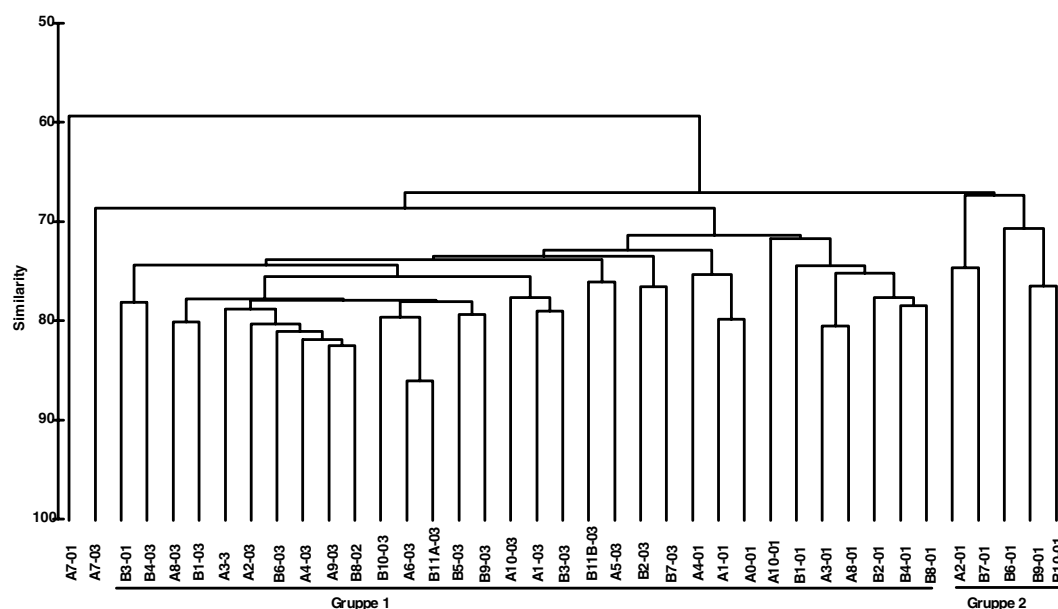


Figure 4.17. Dendrogram, Mikkel 2001- 2003.



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4.10 Rogn south

4.10.1 Grain size and chemical analysis

The sediments at Rogn Sør consist of very fine sand to fine sand. The content of silt and clay varies from 33,4 % at station ROGNS-08, 200°/250m to 60,4 % at station ROGNS-04, 30°/2000m. Gravel is found at all stations, except one, up to 23 %. Only small differences from the baseline survey in 2001 are observed.

The total organic matter content in the sediments varies from 2,3 % at the reference station ROGNS-15, 290°/4000m to 4,0 % at station ROGNS-10, 200°/1000m. The values are similar to the 2001 results.

The THC concentrations are low and vary from 2,1 mg/kg at the reference station ROGNS 15A, 290°/4000m to 11,1 mg/kg at station ROGNS 11, 290°/250m. Slightly elevated values are only found at one station at 250m in 290° direction, an increase since 2001.

The concentrations of NPD and PAH are low, and elevated values are not found. Decalins are not found either.

The Ba concentrations are low and vary from 99 mg/kg at station ROGNS 04, 30°/2000m to 314 mg/kg at station ROGNS 11, 290°/250m. Slightly elevated values are found at three stations, an increase since 2001. These are stations ROGNS 08, 200°/250m, ROGNS 11, 290°/250m and ROGNS 12, 290°/500m.

The concentrations of the heavy metals are low, and only some elevated values are found.

The chemical results are in agreement with the drilling history. The drilling at Rogn Sør started in 2002 with drilling of 2 wells with water based drilling mud. 1 m³ of the base oil EDC 95-11 has been discharged. Baryte has not been discharged.

Table 4.29. Rogn Sør, silt & clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station			Silt and clay		TOM		THC		NPD		PAH		Decalins	
			2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001
ROGNS-01	30°/ 250m		41,8	44,0	2,9	4,2	3,5	3,9	0,016	0,050	0,039	0,124	nd	nd
ROGNS-02	30°/ 500m		54,1	51,6	3,0	3,9	4,7	3,7	0,039	-	0,065	-	-	-
ROGNS-03	30°/1000m		51,1	52,3	3,1	4,1	3,6	4,3	-	-	-	-	-	-
ROGNS-04	30°/2000m		60,4	59,8	3,7	4,2	3,1	4,6	-	-	-	-	-	-
ROGNS-06	110°/ 500m		51,5	47,6	3,7	3,3	4,1	4,2	-	-	-	-	-	-
ROGNS-07	110°/1000m		44,3	52,1	3,5	4,4	3,1	5,2	-	-	-	-	-	-
ROGNS-08	200°/ 250m		33,4	36,8	3,4	3,7	3,6	3,7	-	-	-	-	-	-
ROGNS-09	200°/ 500m		38,2	41,1	3,3	3,7	3,6	3,8	-	-	-	-	-	-
ROGNS-10	200°/1000m		50,6	35,5	4,0	4,3	3,5	3,9	-	-	-	-	-	-
ROGNS-11	290°/ 250m		43,4	39,9	3,7	3,7	11,1	3,5	-	-	-	-	-	-
ROGNS-12	290°/ 500m		49,2	44,9	3,7	3,4	3,4	3,3	-	-	-	-	-	-
ROGNS-13	290°/1000m		42,9	45,4	3,4	3,6	2,6	3,7	-	-	-	-	-	-
ROGNS-14	290°/2000m		42,2	46,6	2,6	3,4	2,3	2,9	-	-	-	-	-	-
ROGNS-15A	290°/4000m		35,1	30,2	2,3	3,3	2,1	3,6	3,5	3,9	0,095	0,122	nd	nd

-: not analysed nd: not found



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Table 4.30. Rogn Sør, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)

Station	Ba		Cd		Cr		Cu		Hg		Pb		Zn	
	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001
ROGNS-01 30°/ 250m	127	89	0,07	0,05	36,7	27,4	7,2	7,5	0,02	0,02	7,0	16,3	86	40
ROGNS-02 30°/ 500m	143	123	0,07	0,05	33,5	22,6	7,8	7,3	0,03	-	11,2	15,1	81	36
ROGNS-03 30°/1000m	124	151	0,05	0,05	28,6	21,7	5,9	7,5	-	-	13,0	15,3	43	36
ROGNS-04 30°/2000m	99	147	0,04	0,05	26,5	23,8	5,8	8,3	-	0,02	13,0	15,7	42	41
ROGNS-06 110°/ 500m	174	118	0,07	0,05	31,3	24,9	5,8	7,9	-	-	17,6	16,4	47	39
ROGNS-07 110°/1000m	124	155	0,06	0,05	28,5	27,6	5,5	8,4	-	-	16,1	18,5	43	43
ROGNS-08 200°/ 250m	206	127	0,06	0,05	25,0	24,3	5,1	7,1	-	-	15,7	15,7	38	37
ROGNS-09 200°/ 500m	158	129	0,06	0,06	29,1	27,3	6,2	8,6	-	-	19,7	18,4	47	43
ROGNS-10 200°/1000m	106	111	0,06	0,05	30,7	35,7	6,7	8,0	-	-	17,8	19,7	49	48
ROGNS-11 290°/ 250m	314	144	0,06	0,05	33,6	31,2	5,5	8,2	-	-	18,6	18,2	50	43
ROGNS-12 290°/ 500m	221	136	0,06	0,05	27,3	26,5	6,6	8,0	-	-	16,4	16,6	45	40
ROGNS-13 290°/1000m	147	155	0,05	0,05	25,8	24,7	5,5	7,5	-	-	16,4	15,3	41	37
ROGNS-14 290°/2000m	103	107	0,05	0,04	21,7	21,1	5,1	6,8	-	-	13,7	13,6	36	33
ROGNS-15A 290°/4000m	109	100	0,04	0,04	18,6	20,4	4,0	6,7	0,02	0,02	15,2	14,4	31	32

-: not analysed

4.10.2 Biology

The fauna at Rogn Sør could be characterised as very diverse and undisturbed. Comparable regional stations do not differ from the Rogn Sør stations.

The Shannon-Wieners diversity index (H') range from 5,6 (ROGNS-03 and 04 in direction 30°/1000–2000m and ROGNS-11 (290°/250m) to 6,1 (ROGNS-15A, 290°/4000m). Pielou's index of evenness was high (0,9) at all stations.

Different fauna parameters are given in table 4.31.

The MDS plot from the similarity analysis at station level is given in figure 4.18. The stations divide into 4 main groups at about 60 % similarity. The stations in group 3 are further divided into 2 sub groups at a similarity of about 70 %. Station ROGNS-03 in group 4 differs somewhat from the rest of the stations in the group.

The analysis could indicate a somewhat greater supply of organic material at the stations in 250–550 m distance from the field centre. In addition the stations ROGNS-7 and 14, which are localised respectively 110°/1000m and 290°/2000m in direction and distance from the field centre, grouped together with these stations. However the diversity indices are very high and the fauna must be characterised as undisturbed. A bioenv analysis gave a correlation of 0,5 between fauna and grain size, which indicate some relation.

In figure 4.19 the dendrogram for the years 2001 and 2003 is given. The analysis shows a great resemblance between the years 2001 and 2003 (about 70 %). It is mainly a higher numbers of individuals in group 2 (2003) within the family Ampharetidae (mainly *A. macroglossus*) which contributes most to the difference. There are small differences within other families between the years. *A. macroglossus* is a suspension feeder and is relative sensitive. The difference between the years is small and is probably random and natural.



Table 4.31. Depth, number of species (*S*) and number of individuals (*N*) per 0,5 m², Shannon-Wieners diversity index (*H'*), Pielou's index of evenness (*J*) and *ES*₁₀₀, Rogn Sør 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
ROGNS-01	30	250	290	100	498	5,8	0,9	49
ROGNS-02	30	550	290	114	635	6,0	0,9	51
ROGNS-03	30	1000	290	71	202	5,6	0,9	49
ROGNS-04	30	2000	290	81	327	5,6	0,9	47
ROGNS-06	110	500	295	118	740	5,9	0,9	49
ROGNS-07	110	1000	289	110	528	6,0	0,9	51
ROGNS-08	200	250	289	93	383	5,9	0,9	51
ROGNS-09	200	500	294	98	419	5,8	0,9	50
ROGNS-10	200	1000	299	94	428	5,8	0,9	49
ROGNS-11	290	250	290	86	435	5,6	0,9	45
ROGNS-12	290	500	292	100	387	5,9	0,9	52
ROGNS-13	290	1000	293	102	475	5,9	0,9	51
ROGNS-14	290	2000	297	100	416	5,9	0,9	51
ROGNS-15A	290	4000	310	110	399	6,1	0,9	55
ROGNS-15B	290	4000	310	97	340	6,0	0,9	54

*: New position

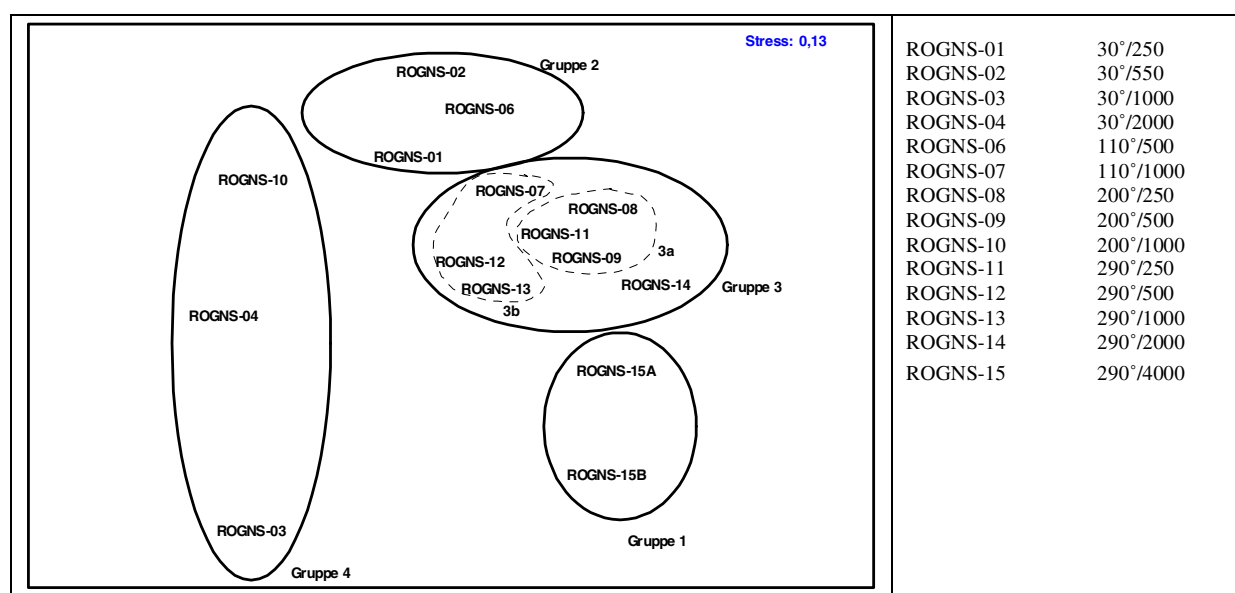


Figure 4.18. MDS-plot station level, Rogn Sør 2003.

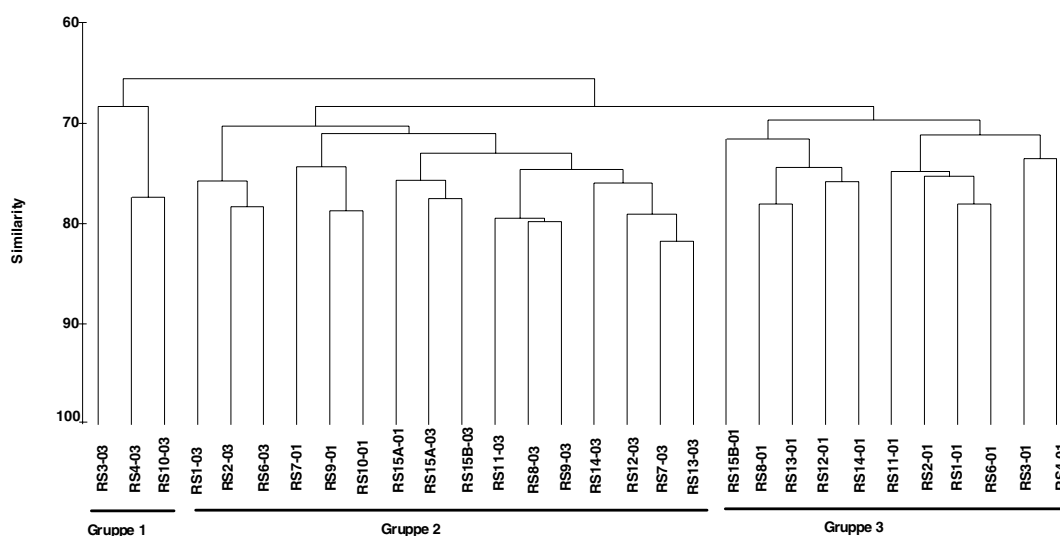


Figure 4.19. Dendrogram, Rogn Sør, 2001 and 2003.

4.11 Kristin

4.11.1 Grain size and chemical analysis

A baseline survey at Kristin is performed which includes 39 stations arranged on four templates. The sediments consist of very fine sand. The silt and clay content varies from 38 % at station KR7, 240°/500m to 52 % at station KN7, 240°/1000m. Gravel is found at most of the stations, up to 6 % at station KR7.

The total organic matter content is very similar over the field, and the concentrations vary from 2,3 % to 3,6 %.

The THC concentrations are low across the field, the lowest THC concentrations found at Region VI. Slightly elevated values are, however, found at one station, station KP9, 330°/1000m with 6,9 mg/kg and hydrocarbons similar to drilling mud base oil. At the other stations the THC concentrations vary from 1,6 mg/kg at station KN1, 150°/500m to 2,9 mg/kg at station KS5, 60°/1000m.

The concentrations of NPD and PAH are low, and elevated values are not found. Decalins are not found.

The Ba concentrations are low across the field except for one station, KS10, 330°/1000m with 1370 mg/kg. The Ba concentrations vary from 89 mg/kg to 1370 mg/kg. Slightly elevated Ba values are found at 9 stations out to 1000m from the templates, two at template P, two at template R and five at template S. The concentrations of the heavy metals are low, and elevated values are not found.



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Table 4.32. Kristin, silt & clay and TOM (%), THC, NPD, PAH and metals (mg/kg dry sediment)

Station	Silt and clay 2003	TOM 2003	THC 2003	NPD 2003	PAH 2003	Ba 2003	Cd 2003	Cr 2003	Cu 2003	Hg 2003	Pb 2003	Zn 2003
Installation N												
Kristin KN1 150°/ 500m	47,7	2,7	1,6	-	-	145	0,05	16,4	4,3	-	13,4	29
Kristin KN2 150°/1000m	48,4	3,0	1,9	-	-	146	0,06	17,0	4,6	-	13,6	31
Kristin KN3 60°/ 250m	49,9	3,3	2,0	0,040	0,071	135	0,05	18,8	5,4	0,03	13,8	34
Kristin KN4 60°/ 500m	51,8	3,5	2,0	0,035	0,054	108	0,05	17,4	4,7	0,03	12,3	31
Kristin KN5 60°/1000m	49,4	3,3	2,5	-	-	127	0,05	17,5	4,6	-	12,9	31
Kristin KN6 240°/ 500m	50,8	3,0	2,1	-	-	132	0,05	17,4	4,6	-	13,1	30
Kristin KN7 240°/1000m	52,2	3,4	2,3	-	-	115	0,05	18,4	4,8	-	14,5	32
Kristin KN8 330°/ 500m	51,5	3,1	1,8	-	-	132	0,05	17,5	4,4	-	11,8	30
Kristin KN9 330°/1000m	52,5	3,4	1,9	-	-	144	0,06	19,1	5,2	-	15,3	34
Kristin KN10 330°/5000m ref	44,1	2,8	1,8	0,035	0,069	117	0,04	14,6	3,4	0,02	12,2	26
Installation P												
Kristin KP1 150°/ 500m	49,9	2,8	2,0	-	-	132	0,06	18,2	5,2	-	13,0	30
Kristin KP2 150°/1000m	46,8	2,8	1,7	-	-	134	0,06	18,6	5,0	-	13,0	31
Kristin KP3 60°/ 250m	49,7	3,0	2,3	0,043	0,064	259	0,06	19,0	5,2	0,04	14,4	32
Kristin KP4 60°/ 500m	47,8	3,2	2,2	0,041	0,064	137	0,06	19,2	5,1	0,03	12,1	32
Kristin KP5 60°/1000m	49,1	3,1	2,3	-	-	152	0,06	18,6	4,8	-	13,2	31
Kristin KP6 240°/ 500m	48,6	3,3	2,2	-	-	177	0,05	18,7	5,2	-	12,2	30
Kristin KP7 240°/1000m	51,5	3,6	2,6	-	-	178	0,06	20,4	5,7	-	14,7	35
Kristin KP8 330°/ 500m	47,9	3,3	1,9	-	-	170	0,06	17,9	4,2	-	11,8	30
Kristin KP9 330°/1000m	47,1	3,2	6,9	-	-	978	0,06	19,0	5,1	-	13,8	32
Installation R												
Kristin KR1 150°/ 500m	45,5	3,3	2,4	-	-	170	0,06	17,1	5,0	-	12,8	30
Kristin KR2 150°/1000m	41,1	3,1	2,3	-	-	250	0,05	16,5	4,6	-	10,5	29
Kristin KR3 60°/ 250m	47,9	3,4	2,7	0,043	0,067	196	0,07	18,7	5,7	0,04	16,3	34
Kristin KR4 60°/ 500m	44,3	2,3	1,9	0,047	0,066	141	0,06	16,3	4,4	0,03	13,1	29
Kristin KR5 60°/1000m	44,9	2,4	2,2	-	-	181	0,06	16,5	4,9	-	13,1	29
Kristin KR6 60°/2000m	41,3	2,8	2,6	-	-	245	0,06	16,6	5,0	-	14,0	30
Kristin KR7 240°/ 500m	38,0	2,6	1,8	-	-	125	0,05	16,1	4,4	-	12,5	27
Kristin KR8 240°/1000m	41,9	2,6	2,0	-	-	169	0,05	16,1	4,3	-	11,8	26
Kristin KR9 330°/ 500m	42,5	2,8	1,9	-	-	127	0,06	17,9	4,0	-	13,6	28
Kristin KR10 330°/1000m	46,1	3,2	2,6	-	-	101	0,06	17,4	4,3	-	12,5	28
Installation S												
Kristin KS1 150°/ 500m	45,3	3,0	2,0	-	-	136	0,05	15,9	4,2	-	11,2	24
Kristin KS2 150°/1000m	49,4	3,2	2,1	-	-	89	0,05	17,7	3,8	-	12,2	27
Kristin KS3 60°/ 250m	47,2	3,1	2,6	0,048	0,075	265	0,06	18,8	3,5	0,05	14,6	32
Kristin KS4 60°/ 500m	45,7	3,1	2,4	0,040	0,069	129	0,05	17,2	3,0	0,04	11,5	27
Kristin KS5 60°/1000m	47,4	3,2	2,9	-	-	191	0,05	17,9	3,4	-	14,3	30
Kristin KS6 60°/2000m	44,6	2,8	1,9	-	-	120	0,04	16,8	3,6	-	11,4	27
Kristin KS7 240°/ 500m	43,8	3,1	2,3	-	-	237	0,05	17,9	5,1	-	11,5	29
Kristin KS8 240°/1000m	43,9	3,3	2,7	-	-	237	0,06	19,2	6,0	-	13,3	33
Kristin KS9 330°/ 500m	44,5	3,2	2,3	-	-	306	0,05	18,1	4,6	-	12,2	30
Kristin KS10 330°/1000m	49,9	3,1	2,4	-	-	1370	0,05	18,3	4,9	-	13,0	32

-: not analysed nd: not found Decalins are not found



4.11.2 Biology

The diversity indices indicate a very healthy fauna community in the area.

The Shannon-Wieners diversity index (H') range from 5,3 (KR-01) to 6,1 (KSRefB). Pielou's index of evenness was in general high and range from 0,8 to 0,9.

Different fauna parameters are given in table 4.33.

The similarity analysis, see MDS plot in figure 4.20, divided the stations into 2 main groups at about 65 - 70 % similarity. Most of the stations group in group 1 at a similarity of 70 %. The bioenv analysis gave a correlation of 0,5 between fauna and a combination of the factors depth, Cd, organic material and grain size. The correlation factor suggests some relation.

The results from the similarity analysis of Kristin with comparable regional stations, show a higher numbers of indicator species at Kristin.

Table 4.33. Depth, number of species (S) and number of individuals (N) per 0,5 m², Shannon-Wieners diversity index (H'), Pielou's index of evenness (J) and ES_{100} , Kristin 2003.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
KN-01	150	500	364	109	677	5,8	0,9	47
KN-02	150	1000	360	105	733	5,7	0,8	46
KN-03	60	250	370	108	681	5,7	0,8	45
KN-04	60	500	367	100	641	5,7	0,9	47
KN-05	60	1000	362	104	629	5,8	0,9	48
KN-06	240	500	372	100	604	5,7	0,8	46
KN-07	240	1000	378	112	1082	5,5	0,8	43
KN-08	330	500	370	107	800	5,6	0,8	44
KN-09	330	1000	372	89	661	5,4	0,8	41
KP-01	150	500	374	119	1018	5,5	0,8	43
KP-02	150	1000	369	103	671	5,7	0,8	46
KP-03	60	250	378	109	936	5,5	0,8	43
KP-04	60	500	375	98	710	5,4	0,8	42
KP-05	60	1000	370	102	588	5,7	0,9	47
KP-06	240	500	381	97	540	5,7	0,9	46
KP-07	240	1000	381	106	762	5,5	0,8	44
KP-08	330	500	378	99	774	5,6	0,8	44
KP-09	330	1000	380	113	824	5,6	0,8	44
KR-01	150	500	354	113	691	5,3	0,8	44
KR-02	150	1000	349	106	693	5,4	0,8	45
KR-03	60	250	357	105	607	5,7	0,8	46
KR-04	60	500	357	95	568	5,4	0,8	43
KR-05	60	1000	350	121	755	5,8	0,8	47
KR-06	60	2000	347	108	621	5,8	0,9	49
KR-07	240	500	357	106	570	5,8	0,9	49
KR-08	240	1000	360	117	628	5,8	0,8	49

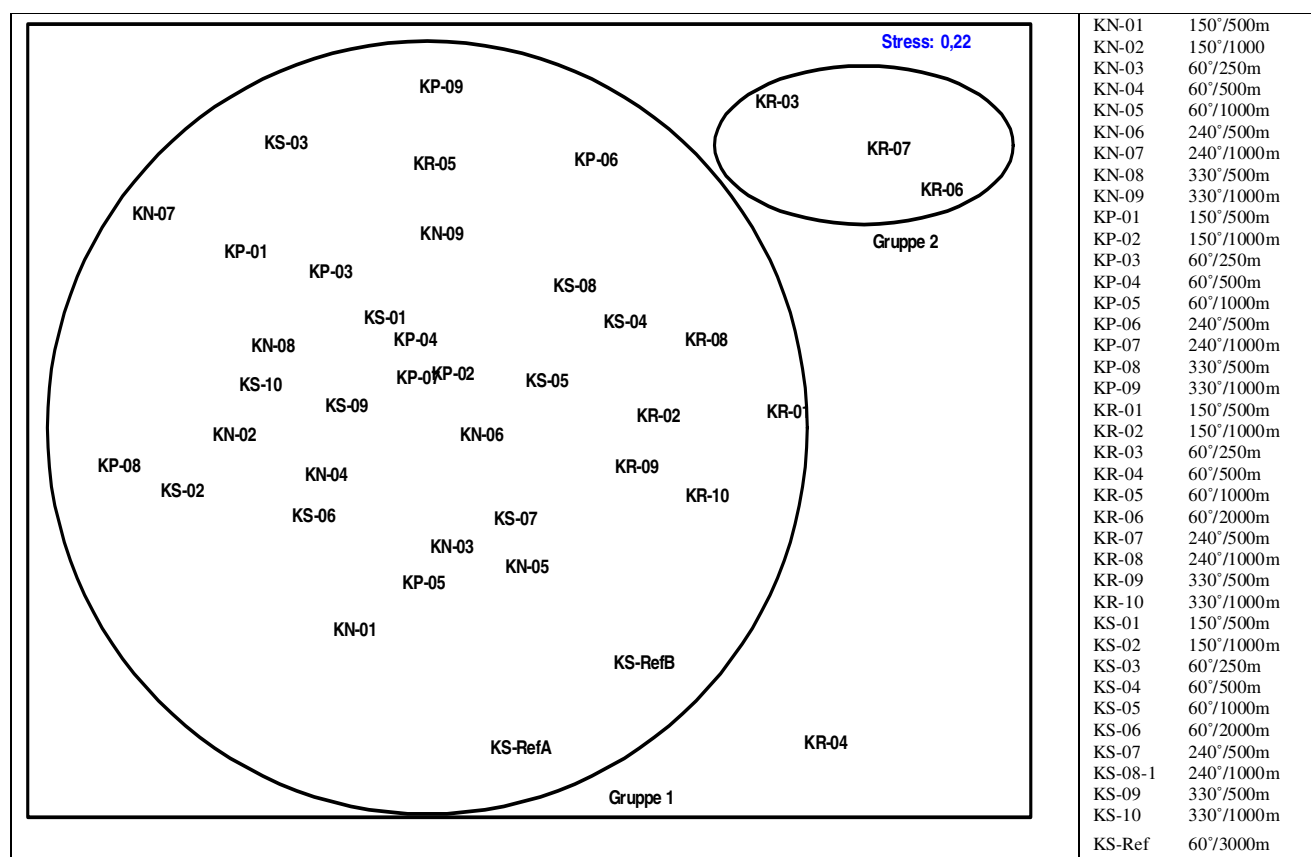
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ENGLISH SUMMARY

Table 4.33 cont.

Station	Direction	Distance (m)	Depth (m)	S	N	H'	J	ES ₁₀₀
KR-09	330	500	361	117	761	5,8	0,8	48
KR-10	330	1000	363	97	613	5,8	0,9	47
KS-01	150	500	362	117	919	5,6	0,8	45
KS-02	150	1000	362	103	883	5,6	0,8	43
KS-03	60	250	365	130	1110	5,7	0,8	46
KS-04	60	500	367	112	758	5,4	0,8	43
KS-05	60	1000	363	103	844	5,5	0,8	43
KS-06	60	2000	359	97	753	5,6	0,8	44
KS-07	240	500	371	103	627	5,8	0,9	48
KS-08-1	240	1000	370	112	815	5,7	0,8	45
KS-09	330	500	369	108	777	5,6	0,8	44
KS-10	330	1000	370	98	846	5,4	0,8	42
KS-RefA	60	3000	353	119	814	5,9	0,9	50
KS-RefB	60	3000	353	123	631	6,1	0,9	53





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5 EVALUATION AND CONCLUSIONS

5.1 Chemical analysis

An overview of the characterisation and the chemical analysis of the sediments from Region VI are shown in the table below.

Summary table Region VI 2003

Parameter	Regional st. (8 st.)	Norne (20 st.)	Åsgard (22 st.)	Heidrun (19 st.)	Draugen (11 st.)	Garn West (13 st.)
Silt og clay %	57 - 92	73 - 96	33 - 85	51 - 86	36 - 70	32 - 70
TOM %	3,9 - 6,3	4,7 - 8,1	2,3 - 6,7	3,3 - 6,5	2,7 - 4,9	2,4 - 4,5
THC mg/kg	2,6 - 4,7	4,0 - 25,7	2,8 - 75,5	2,7 - 76,9	2,6 - 5,1	3,1 - 8,2
Olefin mg/kg	na	na	na	nd	na	na
Ester mg/kg	na	na	na	nd	na	na
Ether mg/kg	na	na	na	0,3 - 65	na	na
NPD µg/kg	58 - 103	76 - 1390	59 - 488	55 - 601	53 - 76	50 - 128
PAH µg/kg	74 - 149	87 - 657	67 - 162	75 - 182	58 - 125	99 - 316
Decalins mg/kg	nd	nd - 2,15	nd - 5,7	nd - 0,78	nd	nd
Ba mg/kg	88 - 182	147 - 3000	180 - 2310	182 - 8140	125 - 2710	191 - 1090
Cr mg/kg	20 - 36	34 - 44	18 - 33	21 - 31	17 - 28	24 - 41
Cu mg/kg	7 - 12	9 - 14	5 - 12	7 - 35	7 - 9	6 - 12
Pb mg/kg	15 - 20	15 - 22	15 - 23	13 - 66	10 - 22	16 - 21
Zn mg/kg	35 - 64	64 - 99	30 - 62	36 - 62	35 - 55	39 - 87
Cd mg/kg	0,05 - 0,12	0,08 - 0,10	0,07 - 0,09	0,06 - 0,11	0,04 - 0,07	0,04 - 0,08
Hg mg/kg	0,03 - 0,06	0,05 - 0,06	0,03 - 0,07	0,06 - 0,30	0,03 - 0,05	0,04 - 0,05

na: not analysed nd: not detected

Quantification limit: olefins 0,5-1,0 mg/kg, esters: 0,5-1,0 mg/kg, ethers: 0,15 mg/kg, decalins 0,05 mg/kg

NPD, PAH, decalins og Hg are not analysed on all stations

Summary table Region VI 2003 continue.

Parameter	Garn Central (13 st.)	Njord (22 st.)	Mikkel (21 st.)	Rogn Sør (14 st.)	Kristin (39 st.)
Silt og clay %	43 - 74	42 - 75	20 - 64	33 - 60	38 - 52
TOM %	3,1 - 4,9	2,8 - 4,4	1,7 - 4,1	2,3 - 4,0	2,3 - 3,6
THC mg/kg	3,1 - 5,6	3,0 - 3660	2,4 - 112	2,1 - 11,1	1,6 - 6,9
Olefin mg/kg	na	na	na	na	na
Ester mg/kg	na	na	na	na	na
Ether mg/kg	na	na	na	na	na
NPD µg/kg	62 - 95	54 - 133	37 - 147	16 - 40	35 - 48
PAH µg/kg	119 - 149	68 - 127	66 - 132	39 - 95	54 - 75
Decalins mg/kg	nd	nd - 265	nd - 7,89	nd	nd
Ba mg/kg	400 - 702	109 - 6840	150 - 3260	99 - 314	89 - 1370
Cr mg/kg	21 - 27	19 - 33	17 - 25	19 - 37	15 - 20
Cu mg/kg	6 - 8	4 - 40	5 - 154	4 - 8	3 - 6
Pb mg/kg	15 - 21	10 - 32	14 - 24	7 - 20	11 - 16
Zn mg/kg	37 - 50	35 - 149	32 - 51	31 - 86	24 - 35
Cd mg/kg	0,06 - 0,08	0,03 - 0,12	0,05 - 0,09	0,04 - 0,07	0,04 - 0,07
Hg mg/kg	0,05	0,02 - 0,04	0,03 - 0,07	0,02 - 0,03	0,02 - 0,05

na: not analysed nd: not detected

Quantification limit decalins: 0,05 mg/kg

NPD, PAH, decalines and Hg are not analysed on all stations

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5.1.1 Grain size distribution

The sediments at Region VI are partly dominated by silt & clay and partly of very fine sand. Mikkel differs from the other fields and show a great variation, from silt and clay to coarse sand. At the regional stations the silt and clay content varies from 57 % at Regional 9 (in the western part of Region VI) to 92 % at Regional 1 (north in Region VI close to Norne). The lowest mean content is found in the middle of the region at Åsgard N, 39 %, and the highest content is found at Norne, 90 % at Norne NW and 80 % at Norne SW. The remaining fields have a mean content of silt and clay from 41 % to 73 %. Gravel is found at most of the stations.

At most of the fields the results from the present survey at Region VI are similar to the results from the previous survey in 2000. However, some changes are observed. At Norne a considerable increase is found in the silt and clay content at one of the 250m stations, from 61 % to 96 %. At Draugen an increase at some stations and a decrease at other stations are observed.

5.1.2 Total organic material (TOM)

The total organic matter content in the sediments is relatively high. The variation at the region is in accordance with the grain size distribution. The lowest content, 1,7 %, is found at one of the 500m stations at template A at Mikkel. The highest content, 8,1 %, is found at one 500m station and one 1000m station at the Norne NW template. The results correspond to the results from the previous environmental survey in 2000.

5.1.3 Hydrocarbons

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

At the regional stations and the additional reference stations the THC concentrations are low, and they vary from 2,6 mg/kg to 4,7 mg/kg. No increase is observed since the last survey in 2000.

Two baseline surveys are performed in 2003, at Garn Central in the Draugen area and at Kristin situated west of Åsgard. As expected the THC concentrations in the sediments are low. The THC concentrations at Garn Central vary from 3,1 mg/kg to 5,6 mg/kg and at Kristin from 1,6 mg/kg to 6,9 mg/kg.

The THC concentrations are also low at Draugen, Garn Vest, Rogn Sør and Åsgard installations N and X. At Draugen the THC values vary from 2,6 mg/kg to 5,1 mg/kg, a decrease since 2000, and elevated concentrations are not found. At Garn Vest and Rogn Sør a slight increase is found since the baseline surveys, and only one 250m station at each field shows slightly elevated concentrations, 8,2 mg/kg and 11,1 mg/kg respectively. At Åsgard N and X slightly elevated THC concentrations are also found at one station at each template, 14,9 mg/kg and 9,8 mg/kg respectively.

The THC concentrations are somewhat higher at Norne and Åsgard S, although all values are below 50 mg/kg. The concentrations are decreased since 2000, and the highest concentrations found are 18,5 mg/kg at Norne SW, 25,7 mg/kg at Norne NW and 40,2 mg/kg at Åsgard S.

At Åsgard M, Heidrun and Mikkel A and B the highest THC concentrations are between 52 mg/kg and 112 mg/kg. Template M at Åsgard has not been included in the previous surveys, and elevated THC concentrations are found at two of the four 500m stations.

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At Heidrun an increase is found at several stations at 500m, and elevated concentrations are found at most of the stations at the main field, that is out to 1000m. It is likely that some of the elevated THC level at Heidrun results from drilling mud base oil, and that the main part of the THC contamination results from other discharges. At Mikkjel the THC concentrations are increased since the baseline survey in 2001, however, THC concentrations above 10 mg/kg are only found at two stations, one at 250m (template A) and one at 500m (template B).

High THC concentrations are found at Njord, up to 3660 mg/kg. This very high THC level, more than 3000 mg/kg, results from leakage of oil based mud from *slipjoint* in 2000, and degradation of this oil will take time. The THC values are increased at the two innermost stations in the 67,5° direction since 2000, otherwise the levels are the same or they are decreased. Station NJ6, 157,5°/500m differs from the other stations as a more fresh "drilling mud base oil" is found in the sediments. The station inside, NJ5, 157,5°/250m, does not show the same hydrocarbon profile, but has a more common profile of degraded "drilling mud base oil". The results indicate acute discharges in the neighborhood of NJ6. Drilling mud base oil is found out to 2000m.

A vertical transport of hydrocarbons in the sediment layers is observed. The concentrations are lower than in the top 0-1 cm layer.

The concentrations of the selected hydrocarbons NPD and PAH are low at Region VI, while a great variation in the concentrations of C₅ - C₈ alkyl decalins is observed. Decalins are not found at the regional stations, Draugen, Garn Vest, Garn Central, Rogn Sør and Kristin. At Norne, Åsgard, Heidrun and Mikkjel decalins at mg level are found, while up to 265 mg/kg is found at Njord. A good correlation between the decalin results and the THC results is obtained. The presence of decalins gives indication of drilling mud base oil in the sediments. The base oils HDF 200 and EDC 95-11 both contain a few % of C₅ - C₈ alkyl decalins.

Generally the THC results are in agreement with the drilling history.

5.1.4 Esters

Esters from the drilling fluid Petrofree are only analyzed at Heidrun. Petrofree is not found in the sediments, and esters were not found in the 2000 survey either.

5.1.5 Ethers

Ethers from the drilling fluid Aquamul B II are only analyzed at Heidrun in the TLP area. Aquamul B II is found at all stations, up to 65 mg/kg at one of the 550m stations. At another 550m station a gradual decrease is found, from 271 mg/kg in 1997, 119 mg/kg in 2000 to 17,9 mg/kg in 2003. Generally the conclusion is status quo, and the results confirm the slow degradation rate of the drilling fluid Aquamul B II.

5.1.6 Barium

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

The Ba concentrations vary from background levels to 8100 mg/kg, and the results are in agreement with the previous survey in 2000.



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As for THC a vertical transport of Ba in the sediment layer is observed, lower concentrations than in the upper 0-1 cm layer.

At the regional stations and the reference stations the Ba concentrations are low, and they vary from 88 mg/kg to 182 mg/kg.

Elevated Ba concentrations are found at most of the stations at the older fields. This means out to 1000m at Garn Vest and out to 2000m at the other fields. At Rogn Sør elevated Ba concentrations are only found at three stations, out to 500m. At Kristin, a baseline survey, elevated Ba concentrations are found at 9 of 39 stations, out to 2000m as well.

The Ba level is generally as previously. However, some decreases are found at Draugen, and some increases are found at Norne, Heidrun, Garn Vest, Mikkell and also at Njord.

5.1.7 Metals

Generally low concentrations of the heavy metals are found in the sediments. To our opinion, the concentrations found are mainly within the natural levels at Region VI. Only a few elevated levels are found for Cr, Cu, Pb and Zn. Cr varies from 15 - 44 mg/kg, Cu varies from 3 - 40 mg/kg, Pb varies from 7 - 66 mg/kg and Zn varies from 24 - 149 mg/kg. In addition high Cu concentrations, 154 mg/kg, are found at one of the 500m stations at Mikkell template A.

Cd and Hg are found at all fields, 0,04 to 0,11 mg/kg for Cd, and 0,01 to 0,07 mg/kg for Hg. The levels are low and correspond to the results from 2000. A relatively high Hg concentration, 0,30 mg/kg, is found at one of the 500m stations at Heidrun.

5.1.8 Limit of significant contamination

Based on the content of THC, NPD, PAH, Ba, Cr, Cu, Pb and Zn in the sediment there is calculated a limit of significant contamination, a LSC value (limit of significant contamination). Concentrations above this limit can be viewed as higher than background levels or a pollution of the sediments.

The LSC value is calculated by using a one tailed t-test with confidence limits of 95 %. Data from the regional and reference stations from the period 1996 – 2003 are used. The calculations of THC and Ba are based on 155 measurements.

LSC values for this year investigation are presented in table 5.2. The values are for the whole region and are mg/kg dry sediment.

Table 5.2. LSC values (limit of significant contamination), Region VI 2003.

Parameter	LSC 2003 mg/kg 95 % confidence level
THC	5,3
Ba	198
Cr	33
Cu	12
Pb	25
Zn	60
NPD	0,101
PAH	0,143



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5.1.9 Polluted/contaminated area

When evaluating which stations have increased THC values and thereby are polluted by hydrocarbons, both the THC content and the gas chromatogram that shows the hydrocarbon profile are used. Especially we look at the retention area for the drilling mud oil HDF 200, and if there is any extra "peaks" compared to the sample from the reference station

Base on stations with increased values, the extent of the polluted area is decided. In those cases where there is not enough data to decide the extent of the THC pollution, we have to make an estimate.

In table 5.3 an overview of the basis for the calculations at each field are presented.

Table 5.3. THC pollution, Region VI i 2003.

Field	Direction	Distance	Comments and THC concentrations in mg/kg
Norne NW	135°	< 500m	250m station is not analysed
	45° og 315°	250 - 500m	Only the 500m station show traces of THC. Probably limit between 250m and 500m
Norne SW	225°	some > 500m	17,1 at 500m, no THC at 1000m
	135° og 315°	500m	8,2 and 8,8 at 500m, no THC at 1000m
	20°	700m	8,8 at 700m, no stations further out
	225°	1000m	6,2 at 1000m, clear THC "peak" in one grabb. No stations further out.
Åsgard N	60°, 150°, 330°	< 500m	Only 500m stations are analysed at N
	240°	some > 500m	14,9 at 500m
Åsgard S	30°, 160°, 250°	< 500m	250m station is not analysed
	75°	500m - 1000m	40,2 at 500m, no THC at 1000m.
Åsgard X	90°, 225°, 315°	< 500m	Only 500m stations are analysed at X
	45°	500m	9,8 at 500m
Åsgard M	145°, 325°	< 500m	Only 500m stations are analysed at M
	60°	> 500m	75,5 at 500m
	240°	500m	7,0 at 500m
Heidrun TLP	225°	550m - 1000m	36,1 at 550m; no THC at 1000m
	305°/315°	some > 550m	12,5 at 550m; no THC at 1000m
	45°/50° og 120°/135°	1000m	9,2 and 9,1 at 1000m; no stations further out.
Bunnrammer	135° og 315°	< 500m	250m station is not analysed.
	30°/35°	some > 500m	15,0 at 500m, no THC at 1000m
	225°	500m	8,3 at 500m; no THC at 1000m
Draugen	300°	< 250m	Boundary is difficult to understand because there is only <u>one</u> 250m station (300°).
	162° og 325°	< 500m	
	45°	< 750m	
Garn Vest	30° og 210°	0 - 250m	Only traces of THC at 250m station, 6,3 and 6,8
	120°	250m	8,2 at 250m, no THC at 500m
Garn Central	30°, 120°, 210° og 300°	< 250m	No stations have increased THC values. The field is not polluted by THC
Njord	22,5° og 247,5°	1000m	11,1 and 8,9 at 1000m, not THC at 2000m
	112°	1000m - 2000m	28,0 at 1000m, no THC at 2000m
	67,5°, 157,5° og	2000m	7,7; 7,2; 6,4 at 2000m
	337,5°		2000m is the outermost station in all directions

Cont.



ENGLISH SUMMARY

Table 5.3. cont.

Field	Direction	Distance	Comments and THC concentrations in mg/kg
Mikkel A	135°	< 500m	250m station is not analysed.
	45°	500m	6,4 at 500m, not THC at 1000m
	225° og 330°	500m	7,4 og 6,5 at 500m; no drilling mud oil, higher kp, not THC at 1000m.
Mikkel B	45°	< 250m	Clear evidence of drilling mud oil in the 3-6 cm layer at 250m, 9,3 mg/kg, but no oil in the 0-1 cm and 1-3 cm layer – station regarded as not polluted.
	225° og 315°	< 500m	250m station is not analysed.
	135°	500m - 1000m	52,7 at 500m, no THC at 1000m
Rogn Sør	30° og 200°	< 250m	250m station is not analysed.
	110°	< 500m	11,1 at 250m, no THC at 500m
	290°	250m	Increased values of drilling mud oil is found at one station, KP9 330°/1000m (6,9 mg/kg), no increased values inside. The field is not polluted by THC.
Kristin	60°, 150°, 240°	< 250m	
N, P, R og S	og 330°		

The area contaminated by THC (higher than LSC value on 5.3 mg/kg) is calculated to be greater than 25 km². For some fields the outermost station in one of the axis is contaminated in accordance with the LSC value, something that makes it difficult to exactly estimate the contaminated area. In those cases where the 500m station is contaminated and not the 1000m station, the area of contamination is set to the average distance of 750m. The area calculations are based on the calculations shown in table 5.4, which show the distance out from four axes where increased concentrations of THC is found (> LSC values).

In figure 5.1 an isoline plot for THC and Ba concentrations for all stations shown.

ENGLISH SUMMARY

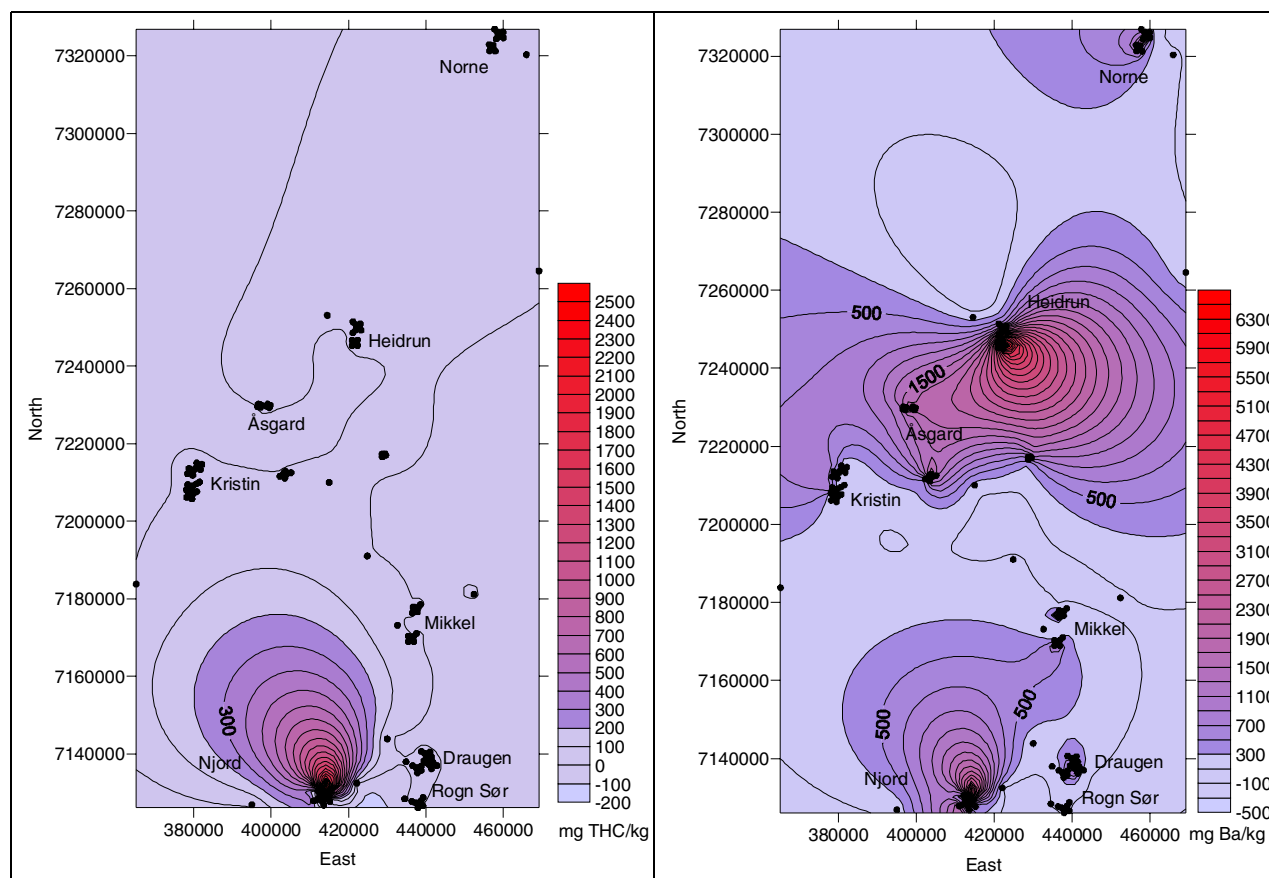


Figure 5.1. Iso plot for the THC concentrations to left and the Ba concentrations to the right. Due to locally heightened concentrations of THC, the resolution in the plot is difficult to illustrate. In total the THC contaminated area is calculated to be over 25 km². Barium is dispersed over a larger area and the total area with concentrations above 198 mg/kg is calculated to be over 100 km².



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Table 5.4. Basis of calculation for THC contaminated area, Region VI Haltenbanken 2003.

Installasjon	Akse 1 (m)	Akse 2 (m)	Akse 3 (m)	Akse 4 (m)	Radius	Areal (km ²) > 5,3 mg THC/kg	Andel
Njord	2000	2000	2000	2000	2,000	12,57	50 %
Heidrun	1000	1000	1500	550	1,013	3,22	13 %
Heidr. N	750	750	750	375	0,656	1,35	5 %
Norne W	750	250	1500	750	0,813	2,07	8 %
Norne S	700	750	1000	1000	0,863	2,34	9 %
Rogn S	250	250	250	378	0,282	0,25	1 %
Mikkel A	750	500	750	500	0,6250	1,23	5 %
Mikkel B	400	1000	500	300	0,5500	0,95	4 %
Åsgard-N	500	500	750	500	0,5625	0,99	4 %
Åsgard-S	1000	500	500		0,6667	1,40	6 %
Åsgard-X	500	500	500	500	0,5000	0,79	3 %
Åsgard-M	500	500	500	500	0,5000	0,79	3 %
Draugen	750	500	250		0,5000	0,79	3 %
Garn V	375	375	750	750	0,5625	0,99	4 %
Garn C	250	250	250	250	0,2500	0,20	1 %
Kristin N	250	250	250	250	0,2500	0,20	1 %
Kristin P	250	250	250	250	0,2500	0,20	1 %
Kristin R	250	250	250	250	0,2500	0,20	1 %
Kristin S	250	250	250	250	0,2500	0,20	1 %
						24,97	

The area is calculated in accordance with an LSC value on 5,3 mg/kg corresponds to 25 km², which is some higher than in 2000, where the contaminated area was calculated to 20 km². In 2000 the LSC value was 6,0 mg THC/kg.

Barium is used as an indicator of discharge and all stations around the installations is regarded as polluted. The actual area is greater than estimated here because the outermost stations have higher concentrations than the LSC value of 196 mg Ba/kg. A minimum of 100 km² is contaminated by barium. In 2000 the area was minimum 68 km², calculated from a LSC value of 220 mg Ba/kg. This means that the area has increased some since 2000.

In table 5.5 an overview of the area contaminated by Ba is shown.



Table 5.5. Basis of calculation for the estimation of Ba contaminated area, Region VI Haltenbanken 2003.

Fields	Axis 1 (m)	Axis 2 (m)	Axis 3 (m)	Axis 4 (m)	Radius	Area (km ²) > 198 mg Ba/kg	Portion
Njord	2000	2000	2000	2000	2,000	12,57	12 %
Heidrun	2000	2000	2000	2000	2,000	12,57	12 %
Heidr. N	2000	2000	2000	2000	2,000	12,57	12 %
Norne W	2000	2000	2000	2000	2,000	12,57	12 %
Norne S	2000	2000	2000	2000	2,000	12,57	12 %
Rogn S	250	250	325	250	0,269	0,23	0 %
Mikkel A	2000	2000	2000	2000	2,0000	12,57	12 %
Mikkel B	2000	2000	2000	2000	2,0000	12,57	12 %
Åsgard-N	2000	2000	2000	2000	2,0000	12,57	12 %
Åsgard-S	2000	2000	2000	2000	2,0000	12,57	12 %
Åsgard-X	2000	2000	2000	2000	2,0000	12,57	12 %
Åsgard-M	2000	2000	2000	2000	2,0000	12,57	12 %
Draugen	2000	2000	2000	2000	2,0000	12,57	12 %
Garn V	2000	2000	2000	2000	2,0000	12,57	12 %
Garn C	2000	2000	2000	2000	2,0000	12,57	12 %
Kristin N	250	250	250	250	0,2500	0,20	0 %
Kristin P	325	250	250	1000	0,4563	0,65	1 %
Kristin R	375	1000	500	500	0,5938	1,11	1 %
Kristin S	375	1000	1000	1000	0,8438	2,24	2 %
						100,76	

5.1.10 The influence on the bottom fauna

The dendrogram shown in figure 5.3 shows that some of the stations at Njord is most different from the other stations in the region. Some stations at Heidrun and one station at Draugen are also different from the other stations in the region. The remainder of the stations in the region separates at approximately 55 % similarity. The stations are generally separated according to field, and the most homogeneous fields were Norne, Kristin, Mikkel and Draugen.

The calculations of how great area which is influenced is performed as follow:

An index based on the average values from the reference and regional stations minus 2 * standard deviation is worked out (intercept stations which are low/moderate polluted). This index is compared to the results from the multivariate analysis. If there is not shown any influence on the innermost station the "area contaminated" is still regarded limited by the innermost station (in most cases 500m, but 250m at some fields). This means that the calculations have to be interpreted as less than the given area. In those cases where there is shown increased levels at 500m but not at 1000m, the area is calculated from an average distance at 750m.

Average diversity index for the regional and reference stations was 5,7. The limit value then become 5,2 when subtracting 2 * standard deviation. Based on this, 6 out of 22 stations at Njord are disturbed, 5 out of 19 at Heidrun and 1 station at Åsgard. At Norne we can not use the same reference value because of the special bottom type.



ENGLISH SUMMARY

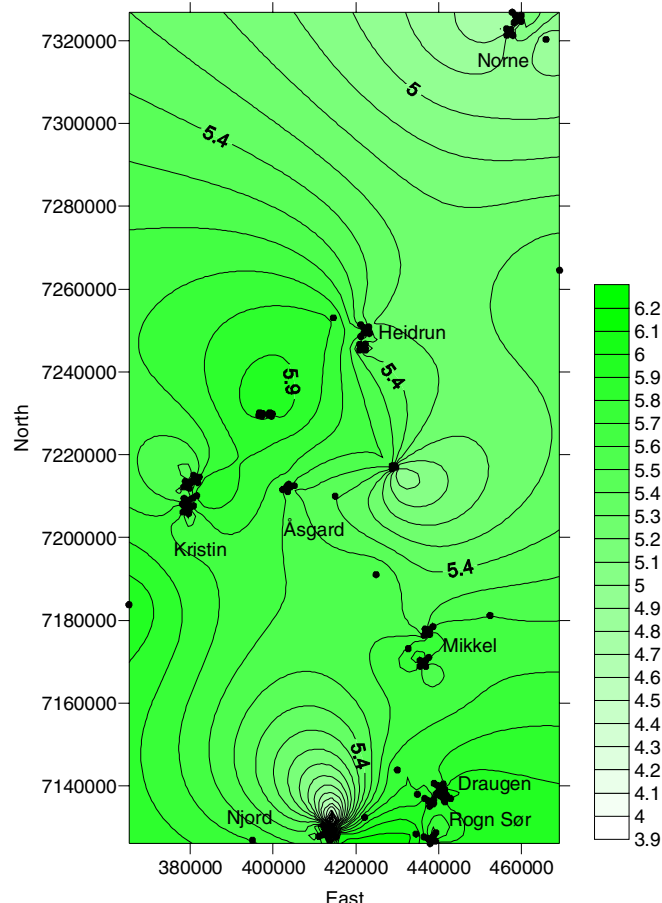
Estimated area becomes almost the same. In table 5.6 is the calculations shown. Influenced area is less than 10 km² for the whole region.

Table 5.6. Calculations of influenced area a) based on diversity b) based on multivariate methods.

A) Field	Axis 1 (m)	Axis 2 (m)	Axis 3 (m)	Axis 4 (m)	Radius	Area (diversity)
Njord	325	750	325	750	0,538	0,91
Heidrun	750	750	750	750	0,750	1,77
Heidr. N	750	500	500	500	0,563	0,99
Norne W	250	250	250	250	0,250	0,20
Norne S	1000	500	500	325	0,581	1,06
Rogn S	250	250	250	250	0,250	0,20
Mikkel A	250	250	250	250	0,2500	0,20
Mikkel B	250	250	250	250	0,2500	0,20
Åsgard-N	500	500	500	500	0,5000	0,79
Åsgard-S	500	500	500	500	0,5000	0,79
Åsgard-X	500	500	500	500	0,5000	0,79
Åsgard-M	500	500	500	500	0,5000	0,79
Draugen	250	250	250	250	0,2500	0,20
Garn V	250	250	250	250	0,2500	0,20
Garn C	250	250	250	250	0,2500	0,20
Kristin N	250	250	250	250	0,2500	0,20
Kristin P	250	250	250	250	0,2500	0,20
Kristin R	250	250	250	250	0,2500	0,20
Kristin S	250	250	250	250	0,2500	0,20
TOTALT						10,0 km2
B) Felt	Akse 1 (m)	Akse 2 (m)	Akse 3 (m)	Akse 4 (m)	Radius	Areal (multivariate)
Njord	750	750	325	750	0,644	1,30
Heidrun	2000	750	750	550	1,013	3,22
Heidr. N	500	500	500	500	0,500	0,79
Norne W	250	250	250	250	0,250	0,20
Norne S	1000	500	500	325	0,581	1,06
Rogn S	250	250	250	250	0,250	0,20
Mikkel A	250	250	250	250	0,2500	0,20
Mikkel B	250	250	250	250	0,2500	0,20
Åsgard-N	500	500	500	500	0,5000	0,79
Åsgard-S	500	500	500	500	0,5000	0,79
Åsgard-X	500	500	500	500	0,5000	0,79
Åsgard-M	500	500	500	500	0,5000	0,79
Draugen	250	250	250	250	0,2500	0,20
Garn V	250	250	250	250	0,2500	0,20
Garn C	250	250	250	250	0,2500	0,20
Kristin N	250	250	250	250	0,2500	0,20
Kristin P	250	250	250	250	0,2500	0,20
Kristin R	250	250	250	250	0,2500	0,20
Kristin S	250	250	250	250	0,2500	0,20
TOTALT						11,7 km2

ENGLISH SUMMARY

Figure 5.2 shows that the diversity is high in the whole region. The area which is slightly disturbed or influenced is limited to less than 10 km².

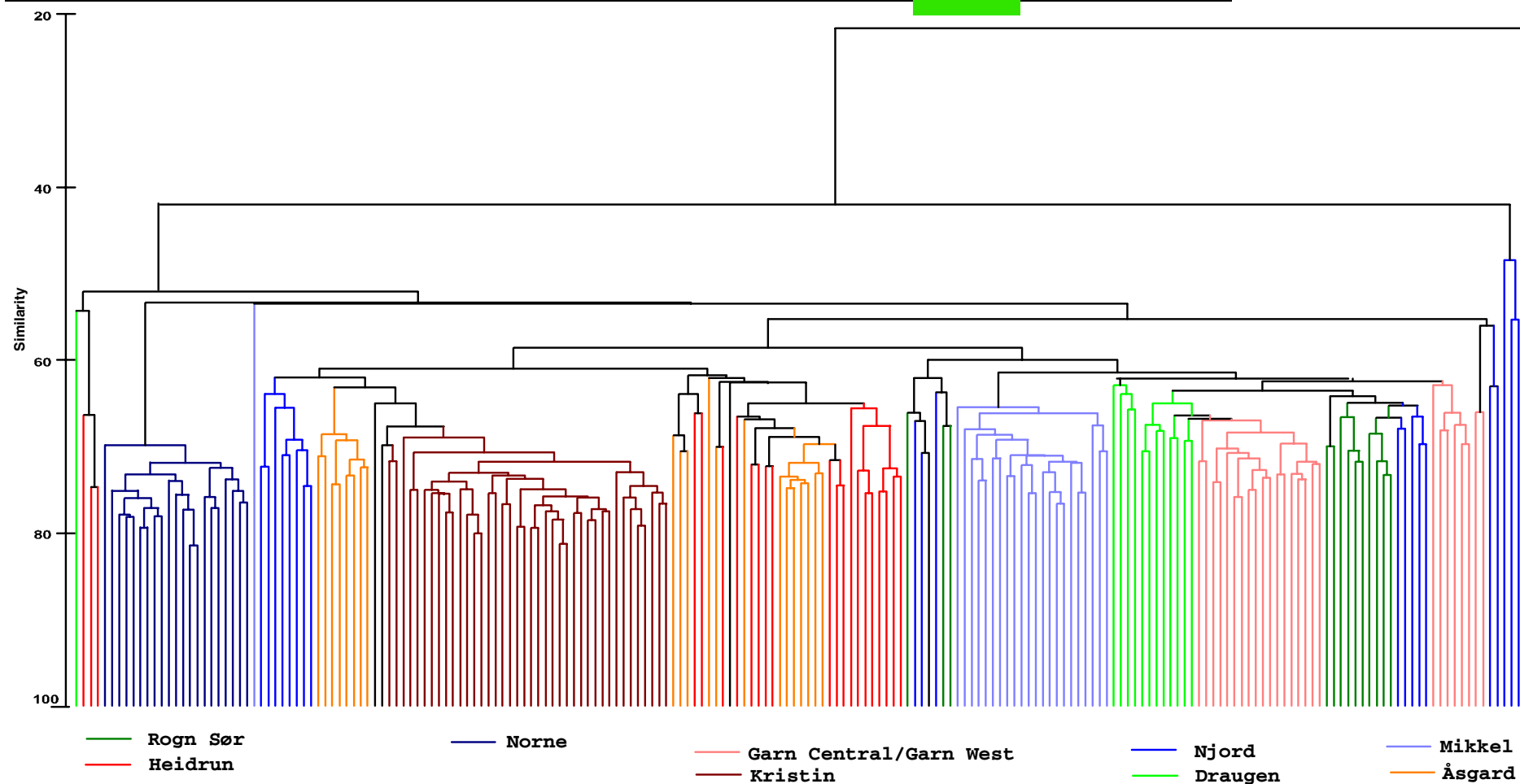


Figur 5.2. Isoline plot - diversity in the region.

For several fields the analysis and species composition indicated an increased supply of organic material, both between areas and over years, which in several cases can not be related to the activity in the area. Compared to last investigation the results generally show an increase the number of individuals. This could be random changes in time and space but may also imply a general increase of organic material to the region.



ENGLISH SUMMARY



Figur 5.3. Dendrogram for all stations in Region VI – Haltenbanken 2003



5.2 Conclusions – Region VI

The environmental investigation in 2003 at Region VI has given these results:

The 2003 survey at Region VI shows:

- The sediments at Region VI are partly dominated by silt & clay and partly of very fine sand.
- The total organic matter content in the sediments is relatively high and varies from 1,7 % to 8,1 %.
- The chemical results are in agreement with the drilling history.
- The regional stations and the reference stations are still unaffected by the drilling chemicals - no contamination or elevated concentrations are found in these sediments.
- Relatively high THC levels (>50 mg/kg) are found at Åsgard M, Heidrun, Njord and Mikkel. The THC concentrations are lower at Norne, Åsgard N, S and X, Garn Vest and Rogn Sør, and elevated THC levels are not found at Draugen, Garn Central and Kristin. The dispersal area varies, out to 250m from the installation at new fields to 2000m at Njord. The THC concentrations have increased at Heidrun, Mikkel and partly at Njord. At Njord one station still contains very high THC concentrations due to leakage of oil based drilling mud from *slipjoint* in 2000.
- Decalins are found in the sediments when drilling mud base oil is found.
- Olefins and esters from drilling fluids are not found in the sediments at Heidrun.
- Ethers from the drilling fluid Aquamul B II are found in the sediments at Heidrun, the same low concentrations as in 2000. The results indicate a slow degradation rate.
- Dispersion of drillcuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found out to 500m at Rogn Sør, out to 1000m at Garn Vest and out to 2000m at the other fields. Generally the Ba concentrations are similar to previous surveys, however a decrease is found at Draugen and an increase is found at Norne, Heidrun, Garn Vest, Mikkel and partly at Njord.
- The concentrations of the heavy metals are low, and elevated levels are only found at some stations.
- The results from the present survey in 2003 are in agreement with the 2000 survey.
- The macro benthic fauna community in the region are in general healthy and undisturbed. The species composition at the Regional station 1 and 3 differ somewhat from the other Regional stations. At these stations there are a relative fine sediment compared to the others. Analyses over year show that there have not been any considerable changes in the region in the periode 1997 – 2003.



- Following stations are considered as disturbed:
 - Station Heidrun-6 (50°/550m) together with Heidrun-7 (45°/1000m) and Heidrun-12 (120°/550m). There was a good correlation between fauna and a combination of the factors Ba, Cd, Pb og THC.
 - Station DR24B (300°/250m) at Draugen was characterised as disturbed in 2000, and the analysis reveals that this is still the case. But the levels of Ba and THC are reduced since 2000.
 - At Njord the stations NJ-6 (157,5°/500m) and NJ-13 (337,5°/250m) are disturbed. In addition the analysis indicate slightly disturbance in the fauna at the stations NJ-9 (247,5°/250m), 14 (337,5°/500m), NJ-1 (67,5°/250m), NJ-2 (67,5°/500m) and NJ-5 (157,5°/250m).
- At several fields in the region, changes in the species composition gives indications of an increased supply of organic material.
- The results from the present survey in 2003 are in agreement with the 2000 survey.

6 RECOMMENDATIONS

New stations

It is recommended to consider including new stations in the survey, particularly close to the installations (250m). At region VI several 500m stations have no elevated THC concentrations, and this may lead to uncertainty in the calculation of the contaminated area.

Establishment of LSC values (limit of significant contamination)

At Region VI environmental surveys have been performed in 1997, 2000 and in 2003. This means that a great many data exist for the different parameters. In the present calculation of LSC values, the numbers are based on 155 data for THC and for Ba as well.

It is recommended to consider if sufficient data now are available to establish fixed LSC values for the chemical parameters at Region VI.

It is also recommended to consider to use a confidence level of 99 % in the calculations instead of 95 %, to get realistic LSC values. The LSC value should not be lower than the natural backgroundlevel at the region.



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