



ENGLISH SUMMARY

STATOIL-SHELL-NORSK HYDRO

ENVIRONMENTAL MONITORING
REGION VI
HALTENBANKEN 2000

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DET NORSKE VERITAS



ENGLISH SUMMARY

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Summary:

This summary presents the results from the environmental monitoring at Region VI, Haltenbanken, 2000.

Sediment and macrofauna were collected around the following offshore installations: Norne, Åsgard, Heidrun, Heidrun Nord, Draugen, Garn West and Njord. A total of 126 stations were investigated. Ten of the stations represent regional stations. The sampling and analysis were conducted in accordance to the STF guideline (99:01) and in accordance to internal DNV procedures for chemical and biological sampling and analysis. The main parameters in the investigation were:

- Macrofauna
- Grain size and organic content
- THC, PAH, NPD
- Metals

The survey is divided into 3 main reports: Main report (DNV, 2001 report no. 2001-0376), Summary report (DNV, 2001 report no. 2001-0378 (NO), 2001-0379 (ENG)), and Appendices report (DNV, 2001 report no. 2001-0377). Foldable maps in A3 format for each of the fields showing station location is given in the Main report.

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PREFACE

The environmental survey at Region VI in 2000 is carried out jointly by Det Norske Veritas and SINTEF Applied Chemistry.

The present report gives the results of the chemical analyses and the grain size distribution of the seabed sediments from Region VI, and the report will be included in the main report given by Det Norske Veritas.

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The main part of the chemical analyses is performed at SINTEF Applied Chemistry, dep. Environmental Technology and Analysis. The hydrocarbon analyses at Draugen and Garn West and the grain size distribution are performed at SINTEF Applied Chemistry, dep. Environmental Engineering.

The biological analysis is performed at DNV's Biological laboratory at department for Environmental Advisory Services.

	<p>The two laboratories - SINTEF Applied chemistry, departments of Environmental Technology & Analyses and Environmental Engineering - are both accredited by Norsk Akkreditering to perform chemical analyses, accreditation numbers P032 and P091. The accreditation is according to NS-EN 45 001 and ISO/IEC Guide25.</p> <p>The accreditation includes methods for determination of total hydrocarbon content (THC), naphthalenes and phenanthrenes (NP), polycyclic aromatic hydrocarbons (PAH), metals and total organic matter (TOM) in sediments. The sediment grain size distribution is also included.</p>
	<p>Biological laboratory (DNV, Dep. Environmental Advisory Services) is accredited by Norsk Akkreditering to conduct sampling of marine sediments and for analysis of soft benthos communities under accreditation number P083. Accredited in accordance ND-ES 45001 and ISO/IEC Guide 25.</p>



1 SUMMARY AND CONCLUSIONS

This summary presents the main results from the environmental survey at Region VI - Haltenbanken in 2000. Det Norske Veritas performed the survey in co-operation with SINTEF-Kjemi on behalf of Statoil, Shell and Norsk Hydro. A separate main report in Norwegian have been issued (DNV, 2001, report no. 2001-0376).

The summary report presents results from regional stations on Haltenbanken and stations around the following installations; Norne, Heidrun, Heidrun Nord, Åsgard, Draugen, Garn West and Njord.

The fieldwork was conducted between 13th of May and 22nd of June 2000 from the geological research vessel *M/V Geograph* (2nd-8th of June was used for field work in Finnmark (Region IX), Sediment was collected from 126 stations. Ten of the stations represented regional stations. The fieldwork was conducted without problems.

The following parameters were investigated:

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 analyses	
• 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 C16H32
• Esters	- Petrofree
• Ethers	- Aquamul B II
• Drilling mud chemical	- DFE-622
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/ boric acid
Biology	
• Soft benthos macrofauna	-Number of individuals and species, diversity, species composition and multivariate analysis



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The 2000 environmental survey at Region VI shows:

- The sediments at Region VI consist mainly of silt and clay (pelite) from 26 % to 98 %. The sediments at Åsgard L, Åsgard Y, Draugen and Garn West contain more sand than the rest of the fields.
- The total organic matter content in the sediments is relatively high, from 2.0 % to 8.2 %.
- The chemical results are in agreement with the drilling history with some exceptions.
- The regional stations and the reference stations are still unaffected by the drilling chemicals - no contamination or elevated concentrations are found in these sediments.
- Relatively high THC levels are found at Norne, Åsgard L and S and Njord. At Åsgard and Njord the concentrations have increased since the previous surveys, while the THC levels at Norne SW are similar to 1997. At these fields, elevated THC concentrations are found out to 1000 - 2000m. At Heidrun and Draugen the THC concentrations are lower, and elevated values are only found at some stations out to 500m. Garn West, Åsgard Y and Heidrun Nord are not contaminated by hydrocarbons.
- The presence of decalins gives indication of drilling mud base oil in the sediments.
- At Heidrun base liquids from pseudo-oil based drilling mud (olefins) are only found at one station. Base liquids from ester based drilling mud (Petrofree) are not found. Low concentrations of the base liquids from ether based drilling mud (Aquamul B II) are found in the sediments, and a decrease is observed since 1997.
- Dispersion of drill cuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found out to 2000m distance at all fields. The levels are higher or similar to the 1997 results.
- The concentrations of the heavy metals are low. Elevated levels of Cu, Pb or Zn are only found at three stations.
- Contamination of Cd and Hg are not found.
- Generally Haltenbanken has a healthy fauna and the contamination level is low. An area between 6 and 12 km² is calculated to be biologic affected (based on measurement on 10 installations). The most contaminated area is found around Njord.
- Depth, grain size and diversity show a strong correlation. Fine sediment is found in deep areas, while coarser sediment is found in the shallower areas. In general lower fauna diversity is found in areas with fine sediment compared to coarser sediment.

The main parameters and the variation at each field:

Regional stations	Variation	Main characteristics
Depth (m)	210 - 432	
THC (mg/kg)	1.2 - 5.9	The concentrations of hydrocarbons, barium and metals are low, and no elevated levels are found.
Ba (mg/kg)	49 - 191	
No. species pr. station	59 - 141	The large variation is due to the large variation in both depth and grain size in the region.
No. individuals pr. station	283 - 880	
Diversity (H')	4.4 - 6.2	



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Norne	Variation	Main characteristics
Depth (m)	371 - 390	
THC (mg/kg)	3.8 - 297	Elevated THC levels out to 1000m (SW) and 1500m (NW). Elevated Ba levels out to 2000m. At SW the THC levels are similar to 1997, while the Ba levels have increased. Elevated THC levels may result from acute discharges of oil-containing drilling mud.
Ba (mg/kg)	191 - 5900	
No. species pr. station	58 - 95	
No. individuals pr. station	420 - 912	
Diversity (H')	3.7 - 5.3	4 of the stations can be regarded as more or less affected.
Åsgard	Variation	Main characteristics
Depth (m)	244 - 390	
THC (mg/kg)	2.8 - 1210	Elevated THC levels out to 1000m at L and S installations, while the Y installation is not contaminated. Elevated Ba levels out to 2000m at L, S and Y. THC and Ba levels at L and S have increased since 1997 and 1999. Elevated THC levels may result from re-injection problems that have caused acute discharges.
Ba (mg/kg)	463 - 2910	
No. species pr. station	47 - 102	
No. individuals pr. station	172 - 501	
Diversity (H')	4.9 - 6.1	The fauna is diverse and healthy.
Heidrun	Variation	Main characteristics
Depth (m)	332 - 352	
THC (mg/kg)	1.4 - 38.4	Elevated THC levels out to 550m, the same levels as in 1997. Olefins are found at <u>one</u> station. Esters are not found, a decrease since 1997. Ethers from Aquamul B II are found at most of the stations, however the levels are decreased since 1997. Elevated Ba levels out to 2000m, levels as in 1997.
Ba (mg/kg)	123 - 7590	
No. species pr. station	67 - 95	
No. individuals pr. station	194 - 1668	
Diversity (H')	4.6 - 5.7	Generally, the fauna is healthy. The fauna on 6 of the stations can be regarded as more or less affected.



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Heidrun Nord	Variation	Main characteristics
Depth (m)	333 - 391	
THC (mg/kg)	3.6 – 7.6	Low THC levels, no contamination. Elevated Ba levels out to 2000m. New stations compared to 1997.
Ba (mg/kg)	428 - 1960	
No. species pr. station	56 - 106	
No. individuals pr. station	205 - 688	
Diversity (H')	5.0 - 5.9	The fauna is diverse and healthy.
Draugen	Variation	Main characteristics
Depth (m)	242 - 270	
THC (mg/kg)	2.7 – 20.3	Elevated THC levels only at <u>one</u> 500m station. Elevated Ba levels out to 2000m, increased concentration since 1997 only at <u>one</u> station. Less discharges of baryte than at the rest of the fields. May result from the drilling activities at Draugen.
Ba (mg/kg)	116 - 5460	
No. species pr. station	87 - 115	
No. individuals pr. station	271 - 1268	
Diversity (H')	4.7 - 5.9	Generally the fauna is healthy; two of the stations can be regarded as affected.
Garn West	Variation	Main characteristics
Depth (m)	259 - 270	
THC (mg/kg)	2.0 - 3.7	Baseline survey. Low THC levels, no contamination. Elevated Ba levels at all stations however lower levels than at the older fields. May result from the drilling activities at Draugen.
Ba (mg/kg)	243 – 781	
No. species pr. station	78 - 102	
No. individuals pr. station	268 - 562	
Diversity (H')	5.3 - 5.9	The fauna is diverse and healthy.
Njord	Variation	Main characteristics
Depth (m)	325 - 330	
THC (mg/kg)	3.4 - 5900	Elevated THC levels out to 2000m, not crude oil but hydrocarbons as the drilling mud base oil. High concentrations at 250m and 500m, low conc. at 1000m and 2000m. Elevated Ba levels out to 2000m. Good correlation between THC and Ba results. No discharges of oil based drilling fluids since 1997.
Ba (mg/kg)	151 – 7470	
No. species pr. station	34 - 106	
No. individuals pr. station	95 - 950	
Diversity (H')	3.4 - 5.9	The fauna on 12 of 17 stations can be regarded as more or less affected.



2 INTRODUCTION

The summary presents results from the regional environmental survey conducted in REGION IV-Haltenbanken in 2000. The intention with the regional investigations is to study the environmental effect from the petroleum activity on a larger scale than the platform (installation) specific surveys conducted earlier. The regional surveys were conducted for the first time in 1996 in the Norwegian sector and in 1997 in REGION IV-Haltenbanken.

Region IV cover the area from Njord in the south to Norne in the north, see figure 2.1.

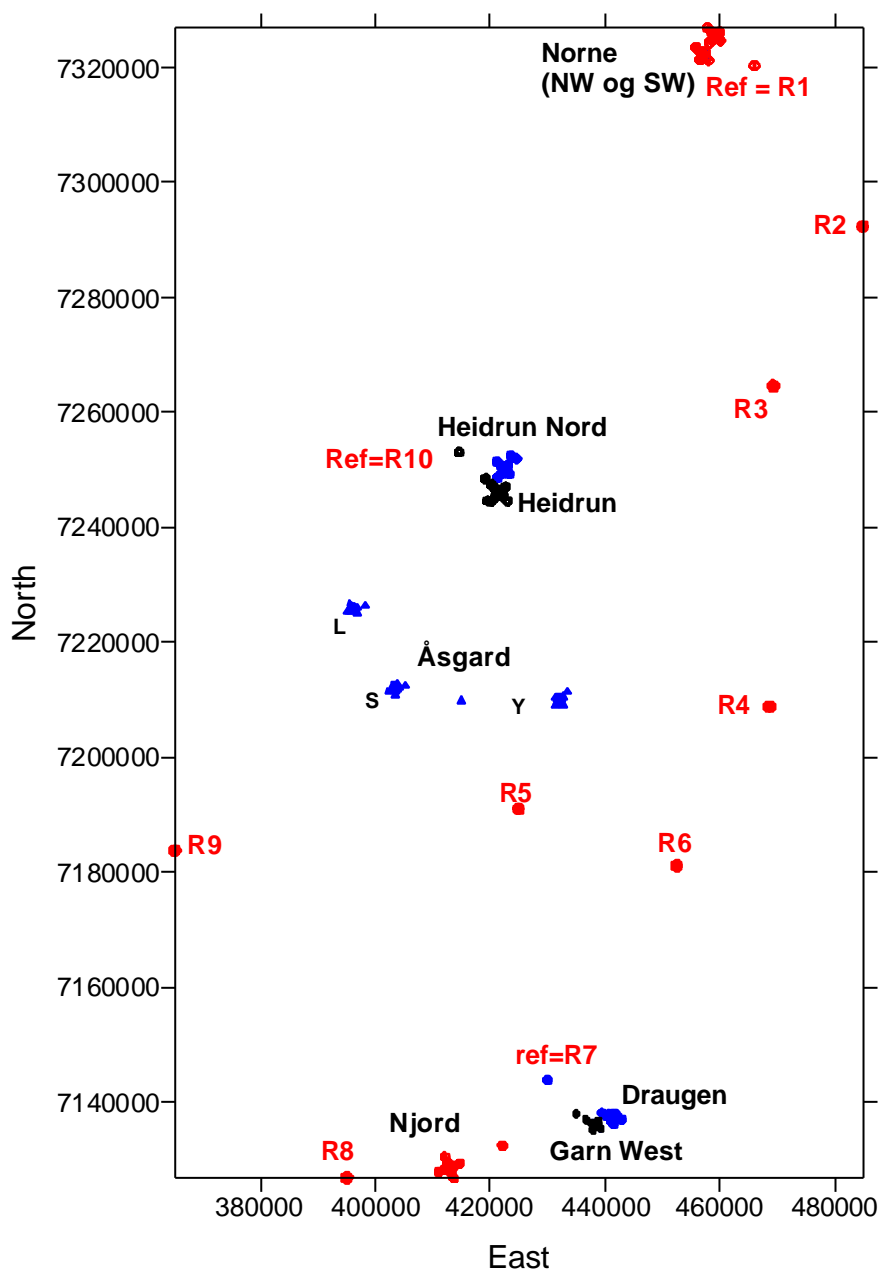


Figure 2.1. Overview of the sampling area on Haltenbanken 2000. Regional stations are marked red from R1-R10. Some of the reference stations function as regional stations.



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The sampling and analysis were conducted in accordance to the STF's guideline (99:01), intention of STF's guideline (97:01) and in accordance to internal DNV procedures for chemical and biological sampling and analysis. Deviations from the above procedures are cited in the main report.

Table 2.1. Field and installations included in the survey conducted in 2000.

Field	Licence holder
Norne	Statoil
Heidrun Nord	Statoil
Heidrun	Statoil
Åsgard	Statoil
Draugen	Shell
Garn West	Shell
Njord	Norsk Hydro

The report is divided into 3 main parts Summary report Appendices (DNV, 2001 report no. 2001-0378 (NO), 2001-0379 (ENG)), Main report (DNV, 2001 report no. 2001-0376) and Appendix report (DNV, 2001 report no. 2001-0377). Foldable maps in A3 format for each of the fields showing station placement is given in the Main report.

3 FIELDWORK AND METHODS

The field work was conducted between 13th of May and 22nd of June 2000 (2nd-8th of June was used for field work in Finnmark (Region IX)) from the geological research vessel *M/V Geograph* by DNV in co-operation with SINTEF-Kjemi, Oslo. The sampling and analysis were conducted in accordance to the STF guideline (99:01) and in accordance to internal DNV procedures for chemical and biological sampling and analysis. There exists a separate cruise report (DNV, 2000, report no. 2000-3312), which can be found in the appendices report (DNV, 2001 report no. 2001-0377). The cruise report contains a complete overview over sampling details. The overview contains station co-ordinates (UTM and geographic), depth, data, time for sampling, sediment volume for biological samples, number of incomplete samples, sediment colour and comments (figure 3.1 shows depth in the region).

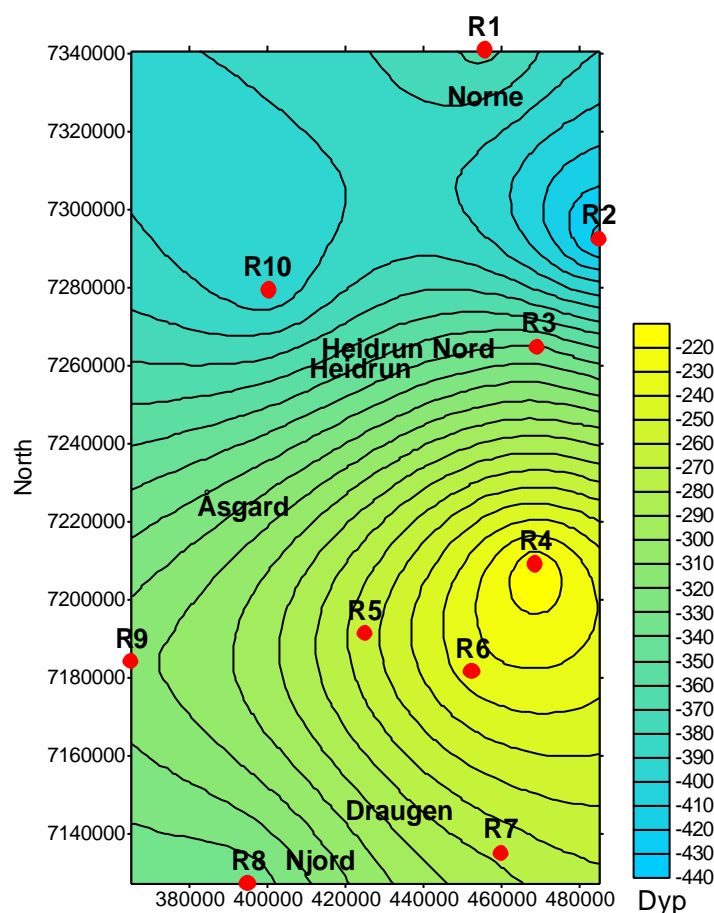


Figure 3.1 : Iso-plot showing depth in Region VI.



The following parameters were investigated

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 analyses	
• 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 C16H32
• Esters	- Petrofree
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• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn, Al and Li digestion by nitric acid and by hydrofluoric acid/aqua regia/ boric acid
Biology	
• Soft benthos macrofauna	- Number of species and individuals, diversity, fauna composition and multivariate analysis



4 RESULTS AND DISCUSSION

Only the most important results and conclusions are given in the Summary report. The complete set of results and conclusions are given in the main report (DNV, 2001, report no. 2001-0376).

4.1 Regional stations

4.1.1 Grain size and chemistry

The sediments at the regional stations consist mainly of silt and clay, however at one station, Regional 4, mainly fine sand is observed. The silt and clay content varies from 25.5 % at Regional 4 to 97.8 % at Regional 2. The same distribution was found in the previous survey in 1997.

A great variation is also observed for total organic matter content. 2.1 % is found at Regional 4, while the highest content of 8.2 % is found at Regional 1. The results are similar to the 1997 results.

The concentrations of hydrocarbons, barium and metals are low, and the sediments are not contaminated. The THC content in the sediments varies from 1.2 mg/kg at Regional 4 to 5.9 mg/kg at Regional 8. The barium concentration varies from 49 mg/kg at Regional 4 to 191 mg/kg at Regional 1.

Regional 4 differs from the other regional stations. At this station, the lowest concentrations of all the parameters are found. Thus Regional 4 is not representative for the area, and we recommend that this station is omitted in the next survey.

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 299 mg/kg at Regional 4 to 507 mg/kg at Regional 8. The concentrations of the heavy metals are similar to digestion by nitric acid.

A limit of contamination (LSC) is calculated for each chemical parameter at Region VI. The LSC values refer to the whole region.

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

Station	Silt and clay		TOM		THC		NPD		PAH	
	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
Regional 1, Norne ref	90.1	92.1	8.2	9.7	3.8	3.6	0.069	0.083	0.123	0.128
Regional 2	97.8	96.0	7.9	10.4	3.2	2.6	0.074	-	0.080	-
Regional 3	79.1	63.7	6.5	6.3	3.0	2.2	0.070	-	0.098	-
Regional 4	25.5	24.7	2.1	2.9	1.2	2.1	0.020	-	0.051	-
Regional 5	74.2	74.0	5.1	6.6	2.5	3.8	0.053	-	0.088	-
Regional 6	62.1	63.9	3.9	4.8	2.4	3.2	0.034	-	0.074	-
Regional 7, Draugen ref	55.9	60.9	5.1	3.9	4.1	2.6	0.074	0.043	0.101	0.090
Regional 8	83.1	79.3	6.1	6.6	5.9	4.8	0.078	-	0.078	-
Regional 9	59.9	43.9	5.6	4.9	5.2	2.9	0.064	-	0.064	-
Regional 10, Heidrun ref	60.2	54.0	5.1	5.3	1.9	1.1	0.062	0.061	0.088	0.144

:- not analysed

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



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

Station	Ba		Cd		Cr		Cu		Hg		Pb		Zn	
	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
Regional 1, Norne ref	191	130	0.10		36.0		10.3	14.1	0.03		21.4	26.2	65.8	65.6
Regional 2	110	89	0.08		39.1		11.2	14.7	0.02		20.8	14.5	70.3	71.6
Regional 3	162	107	0.09		28.7		8.3	8.4	0.02		17.7	12.8	51.4	45.3
Regional 4	49	48	0.04		14.9		3.1	3.1	0.01		10.8	9.2	23.3	22.5
Regional 5	84	150	0.06		23.9		6.7	8.5	0.01		12.8	18.3	39.3	47.3
Regional 6	87	91	0.05		20.7		5.4	6.6	0.02		14.3	13.7	35.2	37.3
Regional 7, Draugen ref	116	113	0.04		22.7		6.7	7.7	0.02		15.2	17.1	37.7	39.0
Regional 8	154	129	0.07		24.8		8.6	9.2	0.02		20.9	19.2	45.6	48.8
Regional 9	123	97	0.07		24.5		8.7	7.4	0.02		20.5	17.2	42.8	41.0
Regional 10, Heidrun ref	123	112	0.08		20.8		7.3	7.2	0.02		15.8	21.2	41.0	41.1

1997: Cd <0,03 to 0,06 mg/kg, Cr not analysed, Hg not analysed at the regional stations

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

Station	Ba		Cd		Cr		Cu		Pb		Zn		Al	Li
	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	2000
Regional 1, Norne ref	483	-	0.13	-	64.6	18.1	-	25.1	-	76.0	-	58510	42.0	
Regional 2	404	365	0.13	<0.20	69.8	17.1	15.3	23.9	28.3	80.6	91.5	61170	45.3	
Regional 3	433	359	0.12	<0.20	53.7	17.2	13.5	22.0	26.2	61.1	71.2	51550	33.8	
Regional 4	299	300	0.09	<0.20	41.2	5.6	6.8	16.7	21.8	31.5	43.4	42120	13.9	
Regional 5	366	424	0.12	<0.20	46.9	10.7	15.7	17.7	33.1	47.2	66.0	48390	26.2	
Regional 6	359	366	0.11	<0.20	45.0	9.3	11.3	20.9	28.0	43.3	60.1	46410	21.6	
Regional 7, Draugen ref	411	-	0.09	-	50.1	11.2	-	21.5	-	47.7	-	49340	23.0	
Regional 8	507	409	0.11	<0.20	50.3	12.8	15.6	24.9	36.9	55.8	66.2	52870	28.7	
Regional 9	423	326	0.11	<0.20	49.4	12.4	12.7	27.7	32.8	51.2	56.7	47820	25.9	
Regional 10, Heidrun ref	405	-	0.10	-	41.9	11.4	-	22.1	-	45.6	-	44740	24.9	

1997: The reference stations are not analysed, Cr is not analysed

Table 4.1.4. Region VI, LSC values at 95 % confidence level, one-tailed t-test (mg/kg dry sediment)

Parameter	x mean	SD	LSC
THC	3.7	1.3	6.0
Ba	138	43	220
Cr	26.3	6.2	38
Cu	8.1	2.2	12
Pb	17.7	3.1	24
Zn	46.7	11.9	69
NPD	0.061	0.015	0.089
PAH	0.091	0.017	0.123

LSC : limit of contamination, $LSC = x_{mean} + t_{0.05, n-1} * SD * (1+1/N)^{1/2}$

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

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

t : t-value, from tables with degree of freedom (N-1) and confidence level (95 %) = 1.81

N : number of measurements/stations = 11



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4.1.2 Biology

The analysis showed a geographical division of the stations. The sediment in the north is relatively homogenous (large content of fine sediment) and has fewer niches for the fauna than heterogeneous sediment (larger content of coarser sediment) further south in the region. This results in a less diverse fauna on the stations in the north (station 1, 2 and 3) than for the fauna further south in the region. Station 4 was different from the rest of the regional stations, with coarser sediment and more shallow depth (see figure 4.1.2).

The sediment in the north reflects calm currents conditions with high sedimentation, which naturally results in a higher content of organic material. The change over time (years) shows an increasing number of individuals in the whole region in addition to an increase in deposit feeders. This can be the result of either increased supply of organic material or natural variation over time

Figure 4.1.1. shows the distribution of deposit feeding species like *Spiophanes* (typical in sediment with a high content of fine particles) versus carnivore species like *Paradiopatra* and *Nephtys* (typical in heterogeneous sediment) for the whole region. *Sphiophanes* is more widespread in the north, where the content of fine particles in the sediment is high, while the carnivore species is more widespread further south, where the sediment has a larger content of coarse material.

Figure 4.1.2 shows the distribution of fine sediment illustrated in an iso-plot, based on the regional stations. They show coarser sediment in the southern part of the region and especially in the middle part (east of Åsgard), which is also the shallowest area.

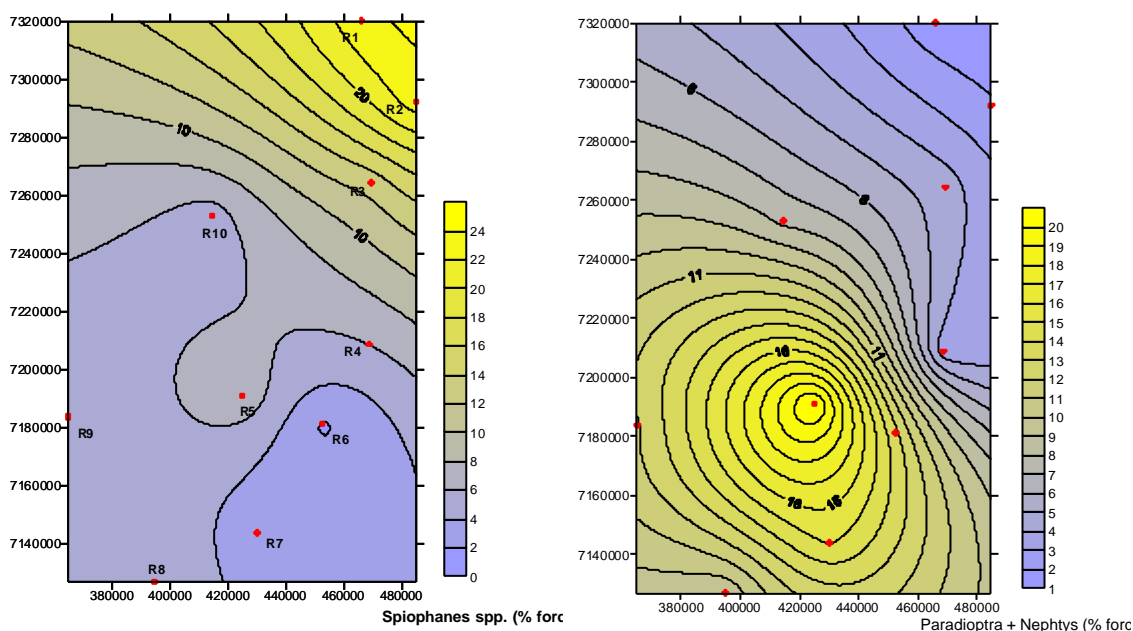


Figure 4.1.1. Distribution (%) of *Sphiophanes* spp. (left) and *Paradiopatra* and *Nephtys* (right).



ENGLISH SUMMARY

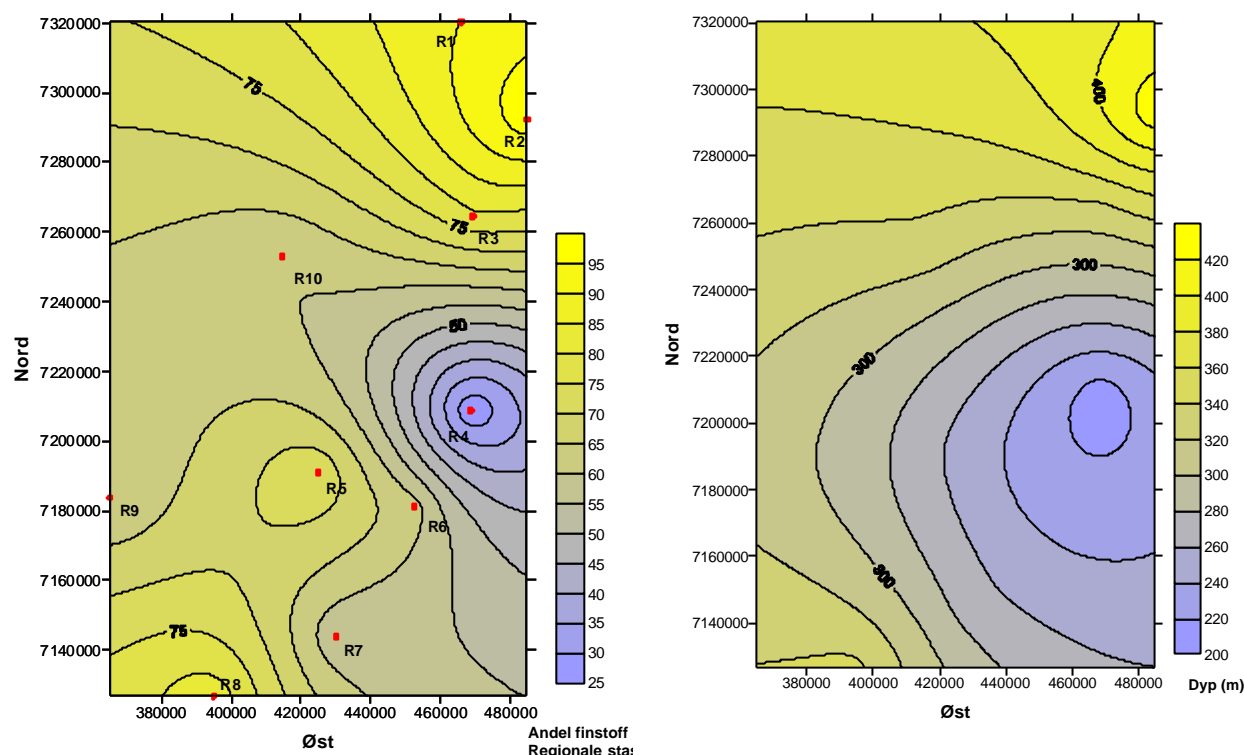


Figure 4.1.2. Distribution of fine sediment (%) and depth (m) based on the 10 regional stations, Region VI 2000.

Shannon-Wieners diversity indices (H') varied from 4.4 (station 1) to 6.2 (station 4), see table 4.1.5. Diversity indices must be viewed in relation to the sediment type. In sediment with a higher content of sand and gravel, the diversity will be higher because of an increased number of niches compared to homogenous sediment.

Table 4.1.5. Depth, number of species (S) and number of individuals (N) per 0.5 m^2 , Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100} .

Station	Depth (m)	S	N	H'	J	ES_{100}
Regional 1	390	74	852	4.4	0.7	31
Regional 2	432	59	376	4.6	0.8	34
Regional 3	336	80	623	5.2	0.8	39
Regional 4	210	141	880	6.2	0.9	52
Regional 5	255	67	283	5.1	0.8	41
Regional 6	230	84	385	5.5	0.9	45
Regional 7	270	93	424	5.8	0.9	49
Regional 8	344	96	593	5.7	0.9	47
Regional 9	310	98	531	5.7	0.9	47
Regional 10	333	86	451	5.7	0.9	47

The similarity analysis showed that the stations divided into 2 groups at 60% similarity, see MDS-plot in figure 4.1.3. Station 4 deviates from the rest of the stations. The division is geographical and follows depth and sediment type to a certain degree.



ENGLISH SUMMARY

The stations in group 2 contain coarser sediment than the stations in group 1. Station 4 is the shallowest station and has the coarsest sediment

The Bioenv analysis, which calculates the correlation between the fauna and the environmental parameters found a high correlation (0.8) between the fauna and depth in combination with sink. Sink itself is not explanatory, but it may correlate with a different not measured parameter.

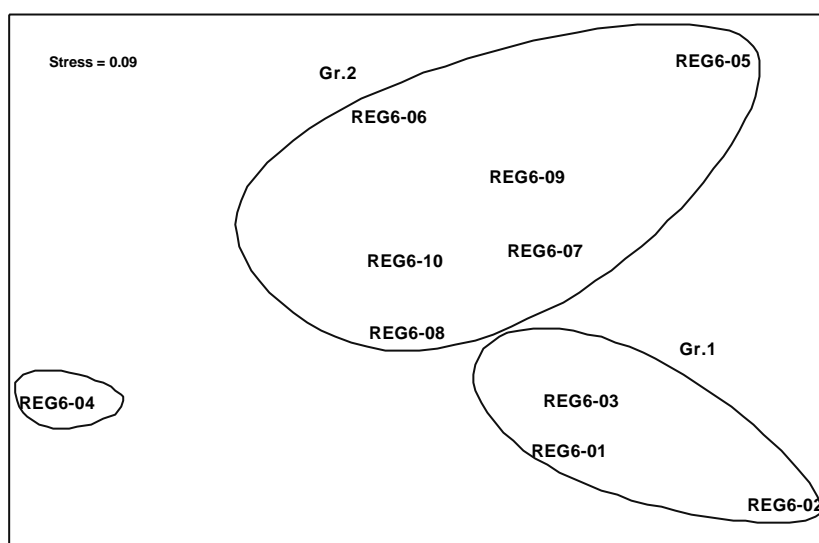


Figure 4.1.3. MDS plot, Regional stations 2000.

The result of a similarity analysis between comparable stations in 1997 and 2000 are shown in the dendrogram in figure 4.1.4. The result showed that station 2 and 4 from both 1997 and 2000 were split into two separate groups (1 and 2), while the rest of the stations were clustered in a third group (large) at 60% similarity. This group subdivides into 2 subgroups (3a and 3b), where the stations were split between years.

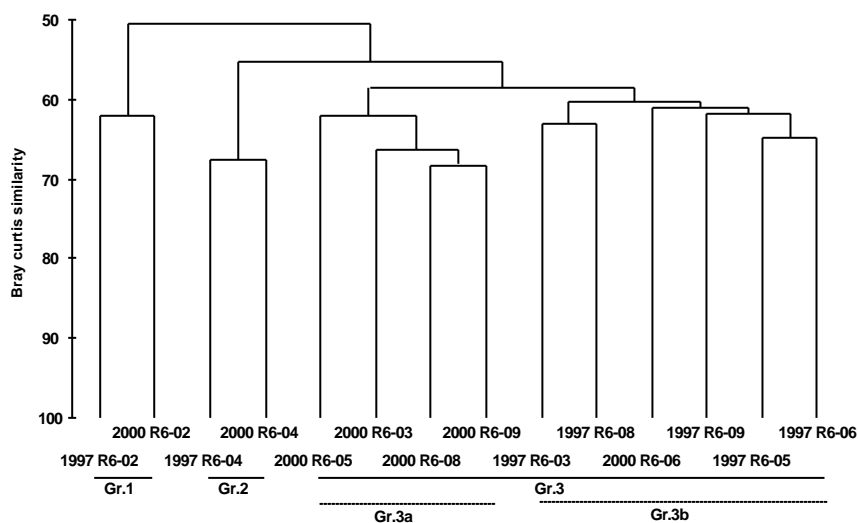


Figure 4.1.4. Dendrogram containing comparable stations from the 1997 and 2000 investigations on Haltenbanken.

ENGLISH SUMMARY

The increase of indicator polychaetes in subgroup 3a and increase of *Spiophanes* spp. in station 2 in 2000 together with a generally increasing number of individuals, may indicate an increased supply of organic material to the region since 1997. The above species are known to tolerate organic load. However, the change could be a result of natural variation over time.

4.2 Norne

4.2.1 Grain size and chemistry

The sediments at Norne consist mainly of silt and clay, which varies from 61 % at station NONW-09, 225°/500m to 94 % at station NONW-12, 315°/250m. The gravel content is low at all stations, and the highest gravel content of 5 % is found at station NOSW-3. The silt and clay content is approximately the same as in the 1997 survey.

The total organic matter content in the sediments varies from 5.1 % at station NONW-09, 225°/500m to 8.2 % at the reference station NOSW-Ref. The results are similar to previous surveys, but at NOSW-03, 135°/500m the content is less than in 1997.

At the SW templates the THC concentrations vary from 3.8 mg/kg at the reference station NOSW-Ref. to 235 mg/kg at station NOSW-10, 315°/250m. The values are mainly at the same level as in 1997. However an increase is observed at the innermost stations in the 315° direction both at the 250m and 500m stations, while a decrease is observed at station NOSW-03, 135°/500m. High THC concentrations, 121 mg/kg, are also found in the 1-3 cm layer at station NOSW-10, 315°/250m. Low THC levels are found at the outermost stations at 1000m and 2000m. At station NOSW-1, 20°/700m a different type of oil with higher boiling point than HDF 200 is observed in one of the samples.

At the NW templates the THC concentrations vary from 5.7 mg/kg at NONW-07, 135°/1000m and NONW-15, 315°/2000m to 297 mg/kg at NONW-09, 225°/500m. The 1-3 cm layer at station NONW-12, 315°/250m also contain slightly elevated THC concentrations, 10.2 mg/kg. Only two stations have elevated concentrations, station NONW-07, 135°/1000m and NONW-15, 315°/2000m.

The NPD and PAH concentrations are low at Norne. Elevated levels are only found at two stations, station NOSW-10 and station NONW-12. However, high decalin concentrations are found, up to 21 mg/kg at stations NOSW-11 and NONW-9. Of the 13 stations analysed, there are only two stations in addition to the reference station where decalins are not found. A clear correspondence is found between the decalin results and the THC results.

The sediments at two stations, NOSW-10 and NONW-12 are also analysed for the drilling mud chemical DFE-622. DFE-622 is not found in these sediments.

Elevated Ba concentrations are found in the sediments out to 2000m at both installations.

At the SW templates the Ba concentrations vary from 191 mg/kg at NOSW-Ref to 5900 mg/kg at station NOSW-10, 315°/250m. The levels have increased since 1997. High Ba concentration, 3370 mg/kg, are also found in the 1-3 cm layer at station NOSW-10.

At the NW templates, the Ba concentrations vary from 327 mg/kg at NONW-03, 45°/1000m to 3420 mg/kg at NONW-12, 315°/250m. The sediment layers at station NONW-12 and the 1-3 cm layer at station NONW-15, 315°/2000m also contain elevated Ba concentrations.



ENGLISH SUMMARY

The concentrations of the heavy metals are low. However, elevated values of Cr, Cu and Zn are found at some stations.

The chemical results are not in full agreement with the discharges. No regular discharges of oil based drilling fluid have taken place at Norne since the previous regional survey. Elevated levels of THC and decalins may probably result from acute discharges of oil-containing drilling mud.

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

Station	Silt and clay		TOM		THC		NPD		PAH		Decalins	
	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
Norne SW												
NOSW-01 20°/ 700 m	82.4	79.2	7.0	7.1	33.6	32.0	0.147	-	0.119	-	0.312	-
NOSW-03 135°/ 500 m	65.0	76.2	5.9	7.9	9.5	42.1	-	-	-	-	-	-
NOSW-04 135°/1000 m	91.3	88.3	7.4	7.7	5.1	4.0	-	-	-	-	-	-
NOSW-07 225°/ 500 m	73.4	71.5	6.1	7.5	10.9	9.2	-	-	-	-	-	-
NOSW-08 225°/1000 m	86.5	82.1	7.7	8.1	6.6	4.7	-	-	-	-	-	-
NOSW-10 315°/ 250 m	66.8	76.1	6.7	6.9	235	84.8	0.827	0.139	0.152	0.111	14.2	17.6
1-3 cm			-	-	121	6.5	0.421	-	0.079	-	6.25	-
3-6 cm			-	-	6.3	3.2	0.050	-	0.041	-	0.38	-
NOSW-11 315°/ 500 m	86.1	78.9	7.8	7.4	202	44.4	0.114	-	0.096	-	21.1	-
NOSW-12 315°/1000 m	80.6	70.7	6.4	6.8	5.7	8.4	-	-	-	-	-	-
NOSW-13 315°/2000 m	80.6	-	7.6	-	4.1	3.3	0.073	0.063	0.084	0.089	nd	nd
1-3 cm			-	-	3.1	2.0	0.068	-	0.081	-	nd	-
3-6 cm			-	-	2.0	1.5	0.058	-	0.081	-	nd	-
NOSW-Ref.	90.1	92.1	8.2	9.7	3.8	3.6	0.069	0.083	0.123	0.128	nd	nd
1-3 cm			-	-	2.4	2.3	0.060		0.106	-	nd	
3-6 cm			-	-	2.0	2.1	0.056		0.105	-	nd	
Norne NW												
NONW-02 45°/ 500 m	92.5	-	6.7	-	14.1	-	0.082	-	0.094	-	0.62	-
NONW-03 45°/1000 m	88.9	-	8.0	-	6.9	-	-	-	-	-	-	-
NONW-06 135°/ 500 m	78.8	-	7.1	-	13.9	-	0.070	-	0.085	-	0.80	-
NONW-07 135°/1000 m	88.1	-	7.7	-	5.7	-	-	-	-	-	-	-
NONW-09 225°/ 500 m	61.2	-	5.1	-	297	-	0.069	-	0.058	-	21.2	-
NONW-10 225°/1000 m	91.7	-	7.8	-	9.9	-	-	-	-	-	-	-
NONW-11 225°/1500 m	93.0	-	8.1	-	12.9	-	0.088	-	0.088	-	0.46	-
NONW-12 315°/ 250 m	93.9	-	7.8	-	98.7	-	0.168	-	0.207	-	4.53	-
1-3 cm			-	-	10.2		0.079	-	0.090	-	0.33	-
3-6 cm			-	-	4.1		0.062	-	0.106	-	nd	-
NONW-13 315°/ 500 m	85.0	-	7.3	-	84.4	-	0.083	-	0.089	-	5.48	-
NONW-14 315°/1000 m	91.4	-	6.9	-	22.9	-	0.077	-	0.089	-	1.15	-
NONW-15 315°/2000 m	78.8	-	6.4	-	5.7	-	0.065	-	0.081	-	nd	-
1-3 cm			-	-	3.8		0.051	-	0.065	-	nd	-
3-6 cm			-	-	3.3		0.049	-	0.064	-	nd	-

-: not analysed

nd: not detected



ENGLISH SUMMARY

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

Station	Ba	Ba	Cd	Cd	Cr	Cu	Cu	Hg	Pb	Pb	Zn	Zn
	2000	1997	2000	1997	2000	2000	1997	2000	2000	1997	2000	1997
Norne SW												
NOSW-01 20°/ 700 m	1010	874	0.07	0.06	32.9	10.0	12.3	-	20.8	24.0	77.2	60.7
NOSW-03 135°/ 500 m	1920	1090	0.07	0.06	29.9	9.3	17.5	-	18.8	22.5	57.3	57.4
NOSW-04 135°/1000 m	732	293	0.08	0.06	36.5	10.9	12.4	-	21.5	21.4	69.4	58.3
NOSW-07 225°/ 500 m	2990	925	0.07	0.07	30.6	10.8	12.0	-	19.5	22.2	60.3	59.4
NOSW-08 225°/1000 m	1520	308	0.07	0.07	33.5	10.4	20.2	-	19.9	21.4	65.0	65.0
NOSW-10 315°/ 250 m	5900	2990	0.09	0.05	31.3	12.4	28.5	0.03	22.3	27.3	64.2	55.2
1-3 cm	3367	-	0.06	-	29.0	9.5	-	0.02	16.8	-	54.5	-
3-6 cm	335	-	0.05	-	31.0	9.2	-	0.01	11.7	-	57.6	-
NOSW-11 315°/ 500 m	1610	841	0.06	0.05	34.4	10.5	12.6	-	19.8	22.9	67.6	59.4
NOSW-12 315°/1000 m	950	260	0.06	0.05	32.4	9.5	11.9	-	17.3	20.5	67.3	57.2
NOSW-13 315°/2000 m	796	161	0.07	0.05	31.5	9.5	10.2	0.03	18.9	20.9	60.2	50.2
1-3 cm	387	-	0.05	-	34.8	10.2	-	0.02	21.8	-	65.5	-
3-6 cm	152	-	0.06	-	34.8	9.6	-	0.02	19.7	-	63.1	-
NOSW-Ref.	191	130	0.10	0.06	36.0	10.3	14.1	0.03	21.4	26.2	65.8	65.6
1-3 cm	114	-	0.09	-	38.0	10.5	-	0.03	22.2	-	70.0	-
3-6 cm	84	-	0.07	-	38.1	10.4	-	0.02	19.9	-	68.7	-
Norne NW												
NONW-02 45°/ 500 m	570	-	0.06	-	36.5	10.9	-	-	22.0	-	71.6	-
NONW-03 45°/1000 m	327	-	0.05	-	37.4	10.6	-	-	20.9	-	68.9	-
NONW-06 135°/ 500 m	726	-	0.05	-	33.9	10.4	-	-	19.9	-	63.9	-
NONW-07 135°/1000 m	556	-	0.06	-	35.6	10.5	-	-	21.5	-	66.7	-
NONW-09 225°/ 500 m	1060	-	0.07	-	29.8	9.0	-	-	16.6	-	56.8	-
NONW-10 225°/1000 m	1290	-	0.09	-	35.9	11.0	-	-	21.3	-	68.7	-
NONW-11 225°/1500 m	1770	-	0.10	-	36.7	11.5	-	-	21.4	-	69.2	-
NONW-12 315°/ 250 m	3420	-	0.10	-	38.5	13.2	-	0.03	20.5	-	75.7	-
1-3 cm	959	-	0.09	-	39.4	11.6	-	0.02	22.3	-	72.6	-
3-6 cm	414	-	0.09	-	38.1	12.3	-	0.02	21.6	-	93.8	-
NONW-13 315°/ 500 m	1240	-	0.09	-	35.3	10.4	-	-	20.0	-	65.0	-
NONW-14 315°/1000 m	852	-	0.10	-	37.6	10.6	-	-	21.9	-	69.7	-
NONW-15 315°/2000 m	786	-	0.09	-	31.0	9.1	-	0.03	18.5	-	63.1	-
1-3 cm	388	-	0.08	-	33.2	9.4	-	0.02	20.1	-	59.6	-
3-6 cm	83	-	0.07	-	33.2	8.5	-	0.02	16.8	-	56.3	-

-: not analysed

1997: Cr is not analysed

ENGLISH SUMMARY

4.2.2 Biology

The fauna at the Norne field is not different from the general features of the region.

The stations NONW-2, 3, 7 and 12 can be regarded as influenced with regard to the fauna composition and diversity. Station 2 and 3 are placed on the 45° transect at 500m and 1000m, station 12 at 250m on the 315° transect and station 7 at 1000m on the 135° transect. However, the NONW-6 station (500 m 135°) does not deviate from the rest of the stations.

Especially station NOSW-10, but also station NOSW-4 and NONW-3, deviates somewhat based on the similarity analysis. On stations NOSW-10 a relatively high content of THC was found in the sediment, which can be related to a slight overweight of *P. jeffreysii*. The sediment is however relatively coarse on the station (>32%) along with varied and diverse fauna. Compared to the rest of the field, the fauna composition on this station cannot be viewed as influenced. Station NOSW-4 deviates from the rest of the stations with its high content of fine sediment (>90 %) and a fauna composition, where one species of crustacean accounts for the largest part of the fauna deviation from the other stations. Compared to the other stations, NONW-4 cannot be characterised as influenced. Station NONW-3 had an excess of deposit feeding indicator species, which causes the station to be classified as influenced. No correlation between the fauna and environmental parameters were found on the Norne field.

The fauna compositions on a number of stations indicate that organic material is available. The stations are however relatively deep with a high content of fine sediment, which generally leads to a higher organic content than coarser sediment. Other factors, which will have an effect and lead to differences, are local current patterns and circulation of the water masses.

A comparison between 1997 and 2000 shows that the numbers of individuals are increasing, especially deposit feeding polychaetes characterised as indicator species (Rygg, 1995; Pearson & Rosenberg, 1978). This pattern is also observed on the regional stations, which can indicate a general, increased supply of organic material in the region. The effect will mainly be measurable in typically sedimentation areas, i.e. areas with a high content of fine sediment.

Shannon-Wieners diversity index (H') varies on NONW stations from 3,7 (NONW-3) to 5.0 (NONW-9). On the NOSW stations the index (H') varied from 4.1 (NOSW-Ref.B) to 5.3 (NOSW-1), see table 4.2.3. The diversity index from each station was compared with the reference stations and this revealed that the fauna diversity on the reference stations was lower than on some of the installation stations. Based on this the location of the reference stations should be considered. If one still takes into account the diversity on the reference station, station NONW-2, 3, 7 and 12 have an index smaller than 4.4.



ENGLISH SUMMARY

Table 4.2.3. Depth, number of species (S) and number of individuals (N) per 0.5 m^2 , Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100}

Station	Depth (m)	S	N	H'	J	ES ₁₀₀
NONW-02	378	58	529	3.9	0.7	28
NONW-03	379	58	454	3.7	0.6	28
NONW-06	382	66	459	4.6	0.8	35
NONW-07	385	77	783	3.9	0.6	29
NONW-09	380	74	524	5.0	0.8	36
NONW-10	380	75	662	4.7	0.8	34
NONW-11	378	73	757	4.5	0.7	31
NONW-12	378	67	912	3.9	0.6	25
NONW-13	375	83	807	4.8	0.8	35
NONW-14	375	78	671	4.6	0.7	32
NONW-15	373	68	445	4.8	0.8	36
NOSW-01	374	95	793	5.3	0.8	41
NOSW-03	375	70	422	5.0	0.8	38
NOSW-04	374	63	420	4.5	0.8	34
NOSW-07	373	87	625	5.1	0.8	39
NOSW-08	373	78	757	4.4	0.7	31
NOSW-10	371	83	539	5.1	0.8	39
NOSW-11	375	72	603	4.7	0.8	34
NOSW-12	373	70	700	4.5	0.7	32
NOSW-13	370	77	602	4.9	0.8	38
NOSW-RefA	390	74	852	4.4	0.7	31
NOSW-RefB	390	60	741	4.1	0.7	28

Especially station NOSW-10, but also station NOSW-4 and NONW-3 separated themselves from the rest of the stations in the similarity analysis, which have a similarity of about 65-70% (see MDS-plot in figure 4.2.1).

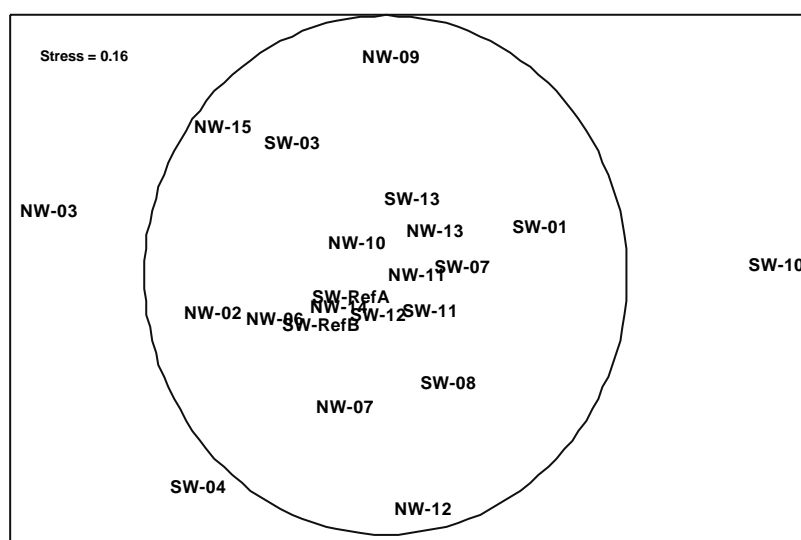


Figure 4.2.1. MDS-plot on station level for Norne 2000.



STATIONS NOSW-10 and NOSW-4 have relatively coarse and relatively fine sediment respectively compared to the rest of the stations. This will contribute to the fauna difference. Even if a relatively high level of Ba and THC were detected in the sediment, there is no evidence in the fauna data that the stations are especially to some extent.

NONW-3 deviates from the rest with a predominance of *Spiophanes* spp. (polychaete). The fauna composition indicates that the fauna on the station is influenced to a certain degree.

The Bioenv analysis showed low correlation between the fauna and the environmental parameters.

Figure 4.2.2. show a dendrogram for 1995, 1997 and 2000. Only the NOSW stations have been sampled every time. The dendrogram shows a division into 3 main groups dependent on which year the sample is taken.

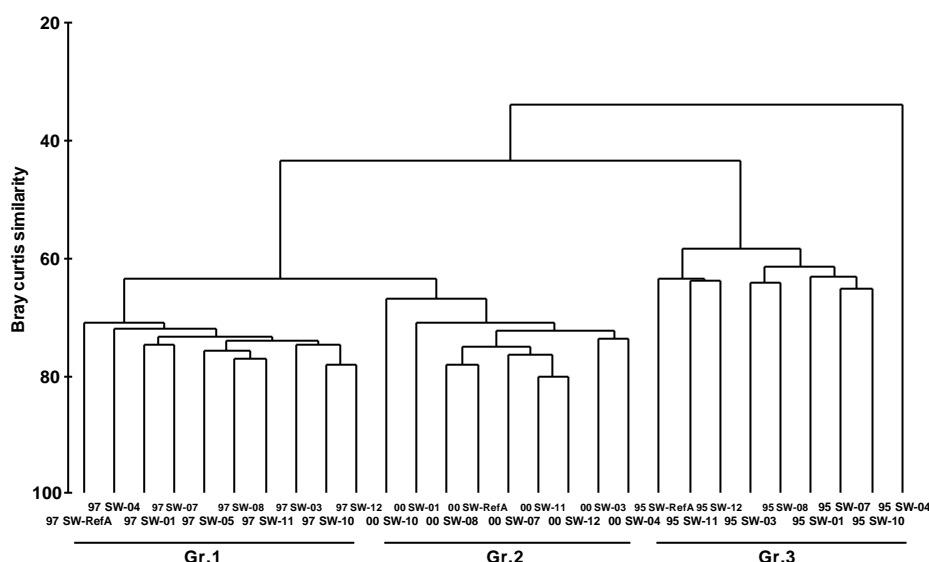


Figure 4.2.2. Dendrogram, Norne NOSW 1995, 1997 and 2000.

The analysis shows that the dissimilarity increases between the years. The fauna found in 1997 and 2000 deviates from the fauna found in 1995. Compared to 1997 the samples from 2000 contain a predominance of indicator polychaetes. The increase of individuals in these species over years suggests a general increase in organic load. Mollusca, especially bivalves constituted a larger fraction of the fauna in 1995. Increasing number of deposit feeders is a trend, which is recorded in the whole region.

The number of species and individuals found in 1997 and 2000 is substantially larger than in 1995. The diversity on station NOSW-1, 3, 7 and 10 in 2000 has not changed much since 1997, but it is higher than in 1995. The rest of the stations show a decline in diversity since 1997.

ENGLISH SUMMARY

4.3 Åsgard

4.3.1 Grain size and chemistry

The sediments at the L and S installations at Åsgard consist mainly of silt and clay, while more sand is observed at the Y installation. The variation of silt and clay at the whole field goes from 40 % at station Y05, 40°/1000m to 86 % at the reference station Åsgard Ref. The gravel content vary to a great degree, from small amounts (0.2 %) at stations L03, 245°/500m and S09, 75°/2000m to 14 % at station Y02, 130°/500m. At the reference station the silt and clay content has increased from 68 % in 1997 to 86 % in the present survey.

The total organic matter content in the sediments varies from 3.4 % at stations Y06, 130°/1000m and Y07, 220°/1000m to 7.0 % at station S09, 75°/2000m. The results at L are similar to the 1997 results.

At the L installation, the THC concentrations vary from 3.3 mg/kg at station L09, 75°/2000m to 62.4 mg/kg at station L01, 75°/500m. At station L01, the THC concentrations have increased since the previous surveys, from 3.8 mg/kg in 1999 to 62.4 mg/kg in 2000.

At the S installation, the THC concentrations vary from 2.8 mg/kg at station S06, 160°/1000m to 1210 mg/kg at station S01, 75°/500m. At most of the stations the THC concentrations have increased since the 1999 survey. Station S01 has very high THC concentrations, and the differences between the replicate samples may indicate a recent discharge.

At the Y installation the THC concentrations are low, and they vary from 3.0 mg/kg at station Y06, 130°/1000m to 6.4 mg/kg at station Y01, 40°/500m.

Elevated THC levels are found out to 1000m both at the L and S installations, while the 2000m stations are uncontaminated. At the Y installation elevated THC concentrations are only found at one of the four 500m stations, scarcely above the limit of contamination. No elevated THC values are found in the sediment layers at 1-3 cm and 3-6 cm.

The NPD and PAH concentrations are low at Åsgard. Slightly elevated values are only found at two stations, station S01, 75°/500m and station S04, 75°/500m. However, the decalin concentrations are high, up to 63 mg/kg at station S01, an increase since 1999. A clear correspondence is found between the decalin results and the THC results.

Elevated Ba concentrations are found in the sediments out to 2000m all over the field.

At the L installation, the Ba concentrations vary from 463 mg/kg at station L09, 75°/2000m to 2800 mg/kg at station L01, 75°/500m. The concentrations have increased since the previous regional survey in 1997.

At the S installation, the Ba concentrations vary from 945 mg/kg at station S02, 160°/500m to 2910 mg/kg at station S03, 250°/500m. At S only station S01, 75°/500m have been analysed previously, and the concentration has increased from 1830 mg/kg in 1999 to 2810 mg/kg in 2000.

At the Y installation, the Ba concentrations vary from 470 mg/kg at station Y09, 40°/2000m to 1170 mg/kg at station Y04, 310°/500m.

The concentrations of the heavy metals are low, and elevated Zn values are only found at one station.

The chemical results are not in full agreement with the discharges. Oil based drilling mud has been used in the drilling of the deepest sections at Åsgard. Some of the oil-containing drilling



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mud has been re-injected and the rest has been taken on shore. Problems with re-injection in 1997/1998 resulted in some major acute discharges that may explain the elevated hydrocarbon levels at some of the stations.

Table 4.3.1. Åsgard silt and clay and TOM (%), THC, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM		THC		NPD		PAH		Decalins	
	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
Installation L												
L01 75°/ 500 m	51.6	47.5	4.1	4.4	62.4	3.4	0.072	-	0.078	-	4.50	-
L02 120°/ 500 m	67.0	54.5	5.6	5.9	5.4	3.4	-	-	-	-	-	-
L03 245°/ 500 m	63.2	46.8	5.5	5.7	12.1	23.7	0.063	-	0.104	-	nd	-
L04 340°/ 500 m	63.9	64.4	5.5	5.0	4.0	2.2	0.053	0.074	0.080	0.113	nd	0.190
1-3 cm			-	-	5.4	2.5	0.056	-	0.094		0.14	-
3-6 cm			-	-	3.5	2.7	0.053	-	0.107		nd	-
L05 75°/1000 m	58.7	-	4.3	-	6.9	4.2	-	-	-	-	-	-
L06 120°/1000 m	50.0	-	4.7	-	6.7	3.1	-	-	-	-	-	-
L07 245°/1000 m	58.8	-	4.6	-	5.4	4.6	-	-	-	-	-	-
L08 340°/1000 m	62.4	-	5.4	-	5.7	2.1	-	-	-	-	-	-
L09 75°/2000 m	45.4	-	4.2	-	3.3	3.2	-	-	-	-	-	-
Installation S												
S01 75°/ 500 m	59.4	-	4.7	-	1210	-	0.202	-	0.084	-	63.00	-
S02 160°/ 500 m	73.9	-	5.6	-	4.3	-	-	-	-	-	-	-
S03 250°/ 500 m	63.7	-	4.7	-	8.7	-	-	-	-	-	-	-
S04 30°/ 500 m	-	-	5.8	-	13.5	-	0.085	-	0.129	-	0.84	-
1-3 cm			-	-	3.3	-	0.052	-	0.081	-	nd	-
3-6 cm			-	-	3.0	-	0.045	-	0.083	-	nd	-
S05 75°/1000 m	65.1	-	5.3	-	10.8	-	-	-	-	-	-	-
S06 160°/1000 m	53.7	-	4.1	-	2.8	-	-	-	-	-	-	-
S07 250°/1000 m	60.0	-	4.7	-	4.8	-	-	-	-	-	-	-
S08 30°/1000 m	81.6	-	6.6	-	8.3	-	-	-	-	-	-	-
S09 75°/2000 m	84.6	-	7.0	-	5.9	-	-	-	-	-	-	-
Installation Y												
Y01 40°/ 500 m	45.1	-	3.8	-	6.4	-	-	-	-	-	-	-
Y02 130°/ 500 m	40.2	-	4.1	-	4.3	-	-	-	-	-	-	-
Y03 220°/ 500 m	48.3	-	4.4	-	4.2	-	-	-	-	-	-	-
Y04 310°/ 500 m	46.5	-	4.0	-	4.0	-	0.054	-	0.070	-	nd	-
1-3 cm			-	-	2.2	-	0.037	-	0.065		nd	-
3-6 cm			-	-	1.8	-	0.029	-	0.072		nd	-
Y05 40°/1000 m	39.6	-	3.9	-	4.2	-	-	-	-	-	-	-
Y06 130°/1000 m	41.2	-	3.4	-	3.0	-	-	-	-	-	-	-
Y07 220°/1000 m	46.2	-	3.4	-	3.8	-	-	-	-	-	-	-
Y08 310°/1000 m	51.2	-	4.2	-	3.8	-	-	-	-	-	-	-
Y09 40°/2000 m	45.0	-	4.0	-	3.1	-	-	-	-	-	-	-
Åsgard Ref.	85.7	67.5	6.0	7.4	4.9	2.9	0.058	0.085	0.110	0.139	nd	nd
1-3 cm			-	-	3.5	1.3	0.050	-	0.099	-	nd	-
3-6 cm			-	-	2.7	1.5	0.043	-	0.091	-	nd	-

-: not analysed

nd: not detected



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

Station	Ba 2000	Ba 1997	Cd 2000	Cd 1997	Cr 2000	Cu 2000	Cu 1997	Hg 2000	Pb 2000	Pb 1997	Zn 2000	Zn 1997
Installation L												
L01 75°/ 500 m	2800	624	0.09	0.07	21.7	8.9	8.0	-	19.6	25.1	40.4	40.2
L02 120°/ 500 m	1080	430	0.11	0.06	23.9	9.0	8.0	-	18.4	23.0	53.2	41.1
L03 245°/ 500 m	1940	861	0.08	0.05	22.7	8.6	8.1	-	17.7	26.5	45.1	40.8
L04 340°/ 500 m	1190	491	0.09	0.06	23.1	8.3	9.7	0.02	18.6	25.0	62.1	46.2
1-3 cm	296	-	0.07	-	23.5	8.2	-	0.02	17.8	-	50.3	-
3-6 cm	89	-	0.07	-	23.9	7.4	-	0.02	15.3	-	41.8	-
L05 75°/1000 m	1570	670	0.08	0.06	22.3	8.1	7.6	-	18.2	22.1	44.0	39.3
L06 120°/1000 m	1050	386	0.08	0.06	22.2	8.2	8.5	-	17.1	24.4	42.8	44.4
L07 245°/1000 m	1080	661	0.08	0.05	20.7	7.1	8.4	-	16.3	25.4	37.3	44.2
L08 340°/1000 m	1250	343	0.09	0.06	23.5	8.5	9.3	-	20.1	26.0	47.1	45.8
L09 75°/2000 m	463	1040	0.08	0.07	20.2	6.6	7.0	-	14.3	21.5	34.9	36.1
Installation S												
S01 75°/ 500 m	2810	-	0.07	-	22.9	8.6	-	-	18.3	-	40.4	-
S02 160°/ 500 m	945	-	0.07	-	24.8	8.7	-	-	16.8	-	44.5	-
S03 250°/ 500 m	2910	-	0.06	-	21.8	7.9	-	-	16.8	-	40.6	-
S04 30°/ 500 m	2400	-	0.07	-	25.9	9.4	-	0.02	19.8	-	54.7	-
1-3 cm	520	-	0.05	-	24.8	8.2	-	0.02	16.3	-	44.4	-
3-6 cm	240	-	0.05	-	24.5	8.1	-	0.02	15.0	-	52.9	-
S05 75°/1000 m	2750	-	0.08	-	24.7	9.4	-	-	21.6	-	56.6	-
S06 160°/1000 m	1090	-	0.06	-	21.0	7.9	-	-	15.3	-	42.8	-
S07 250°/1000 m	1370	-	0.06	-	22.4	8.0	-	-	17.5	-	41.2	-
S08 30°/1000 m	1580	-	0.08	-	28.1	9.9	-	-	18.8	-	59.0	-
S09 75°/2000 m	1380	-	0.09	-	28.4	10.0	-	-	21.7	-	52.9	-
Installation Y												
Y01 40°/ 500 m	895	-	0.07	-	16.7	5.8	-	-	13.5	-	33.7	-
Y02 130°/ 500 m	799	-	0.08	-	19.3	7.4	-	-	15.6	-	34.2	-
Y03 220°/ 500 m	1030	-	0.07	-	18.1	6.1	-	-	17.2	-	32.8	-
Y04 310°/ 500 m	1170	-	0.06	-	19.9	6.4	-	0.02	16.2	-	95.4	-
1-3 cm	293	-	0.04	-	20.3	5.8	-	0.02	14.9	-	35.8	-
3-6 cm	167	-	0.05	-	19.2	5.5	-	0.01	12.1	-	33.9	-
Y05 40°/1000 m	805	-	0.08	-	21.9	6.7	-	-	18.6	-	40.3	-
Y06 130°/1000 m	606	-	0.08	-	22.2	6.3	-	-	17.9	-	38.7	-
Y07 220°/1000 m	845	-	0.07	-	21.6	6.6	-	-	22.3	-	38.7	-
Y08 310°/1000 m	500	-	0.07	-	23.0	6.6	-	-	16.7	-	40.2	-
Y09 40°/2000 m	470	-	0.06	-	18.6	5.0	-	-	13.6	-	33.6	-
Åsgard Ref.	225	220	0.08	0.08	27.9	9.5	9.8	0.02	19.8	28.0	50.1	49.0
1-3 cm	133	-	0.07	-	27.9	8.4	-	0.02	18.6	-	49.9	-
3-6 cm	69	-	0.05	-	27.4	8.0	-	0.02	14.9	-	46.4	-

-: not analysed

1997: Cr is not analysed



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4.3.2 Biology

The fauna on the Åsgard field, which generally can be described as diverse and healthy, does not stand out from the fauna in the region. The fauna composition on the reference station shows some deviation from the rest of the stations. The sediment on the Åsgard field is relatively coarse, which is the result of prevailing water currents and circulation. The field is therefore not a typical sedimentation area, which is reflected in the diverse and generally even fauna composition. A time analysis reveals an increase of indicator species and a decline of molluscs from 1996 to 1997 and 2000. This may indicate an increased input of organic material, which is also the noted in the rest of the region. The pattern, however is not as clear on fields containing typical sedimentation areas as on Åsgard.

Shannon-Wieners diversity index (H') varied from 5 (reference station) to 6.1 (Y-7), see table 4.3.3.

Table 4.3.3. Depth, number of species (S) and number of individuals (N) per 0.5 m^2 , Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100} .

Station	Depth (m)	S	N	H'	J	ES_{100}
L-1	284	94	442	5.8	0.9	49
L-2	283	70	247	5.5	0.9	47
L-3	287	100	491	5.7	0.9	47
L-4	282	77	268	5.6	0.9	48
L-5	285	75	263	5.6	0.9	47
L-6	287	95	359	5.8	0.9	51
L-7	285	86	438	5.5	0.9	44
L-8	283	72	274	5.6	0.9	46
L-9	282	90	289	6.0	0.9	55
S-1	295	81	318	5.3	0.8	46
S-2	300	70	262	5.5	0.9	45
S-3	300	74	348	5.4	0.9	44
S-4	293	68	255	5.3	0.9	43
S-5	295	82	399	5.5	0.9	44
S-6	294	74	261	5.5	0.9	46
S-7	297	79	352	5.4	0.9	43
S-8	297	69	365	5.3	0.9	41
S-9	302	73	375	5.4	0.9	42
Y-1	255	86	311	5.5	0.9	47
Y-2	250	95	308	6.0	0.9	54
Y-3	257	102	501	5.9	0.9	50
Y-4	260	91	425	5.7	0.9	47
Y-5	255	92	376	5.8	0.9	49
Y-6	244	87	308	5.9	0.9	53
Y-7	250	102	376	6.1	0.9	54
Y-8	263	89	347	5.7	0.9	49
Y-9	255	95	498	5.8	0.9	48
RefA	297	47	172	5.0	0.9	38
RefB	297	52	237	4.9	0.9	36



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The similarity analysis show that the stations divide into four main groups with a similarity of about 60% (see MDS-plot figure 4.3.1.). The mean grain size (Md) on the stations seems to have an influence on the group division. The reference station in group 1 have the finest sediment, while the stations in group 2 have the coarsest sediment. The stations in group 3 and 4 cluster themselves independently from Md. Md varies between 3.6 and 5.6 in group 3, and 4.3 and 4.6 in group 4. However when the fauna samples in group 4 were sorted, it was noted that there were gravel and some stones present. The Bioenv analysis gave a correlation value of 0,4 between mean grain size (Md) and fauna, which is not a good correlation.

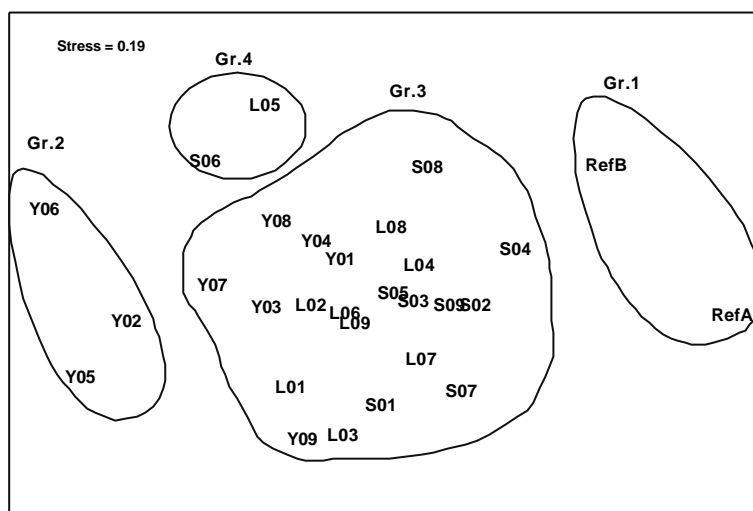


Figure 4.3.1. MDS-plot at station level for Åsgard 20000.

Figure 4.3.2. show a dendrogram for data from 1996, 1997 and 2000. Only the L- stations have been sampled every time. The dendrogram shows a division into 3 main groups dependent on which year the sample is taken.

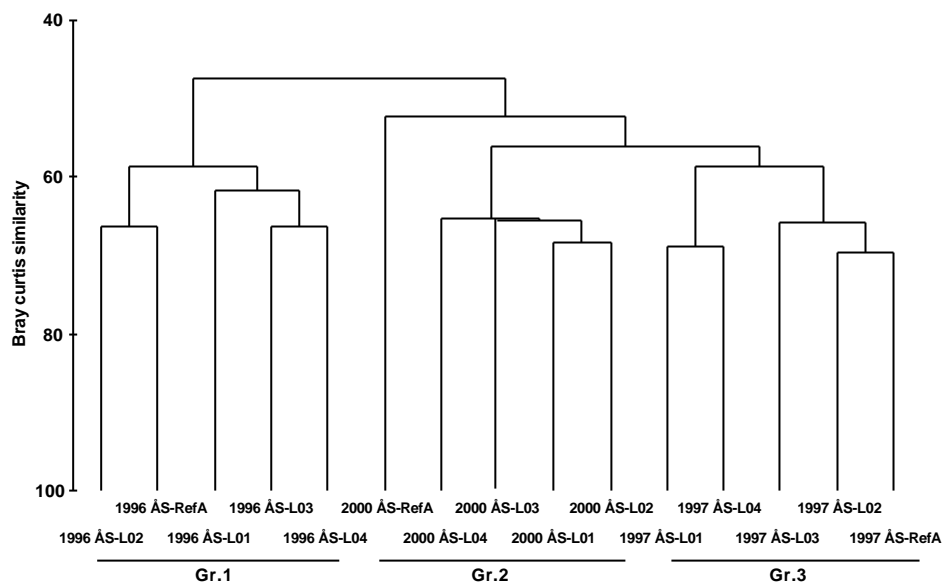


Figure 4.3.2. Dendrogram, Åsgard 1996, 1997 and 2000.

The fauna sampled in 1996 deviates the most from the two other groups (53%). There is no large increase in number of individuals for any particular species from 1997 to 2000 and the difference is only 38%. *P. quadricuspis/fiordica*, *C. setosa* and *Spiophanes* spp accounts for a large part of the increasing share of polychaetes. *C. setosa* and *Spiophanes* spp are indicator species (Rygg, 1995) and typical deposit feeders.



4.4 Heidrun

4.4.1 Grain size and chemistry

The sediments at Heidrun consist mainly of silt and clay, a variation from 58 % at station HEI-19, 315°/3500m to 83 % at station HEI-17, 315°/2000m is found. The gravel content is low at all stations, and the highest gravel content, 3 %, is found at station HEI-6, 50°/550m. The results are similar to the 1997 survey.

The total organic matter content in the sediments varies from 3.3 % at station HEI-06, 50°/550m to 6.2 % at station HEI-17, 315°/2000m. The results are similar to previous surveys, however at HEI-06 the content is lower than in 1997. Since 1997 this station is moved from 45° to 50°.

The THC concentrations vary from 1.4 mg/kg at station HEI-19, 315°/3500m to 38.4 mg/kg at station HEI-06, 50°/500m. The levels are similar to 1997. Elevated THC levels are found at the same three 500m stations as in 1997, HEI-06, HEI-12 and HEI-15. HEI-00 (B), 90°/500m are a separate template, analysed for the first time this year. Contamination of hydrocarbons is not found at this station.

At one station, HEI-06, olefins are also found, and the concentration is 7.2 mg/kg.

The base fluid Petrofree, is not found in the sediments. This is a decrease since 1997, when low concentrations of Petrofree were found at the 500m stations.

The base fluid Aquamul B II is found at most of the stations, and the concentrations vary from 0.3 mg/kg at station HEI-8, 45°/1500m to 119 mg/kg at station HEI-12, 120°/550m. This is a clear decrease since 1997, and the concentration of Aquamul B II is still relatively high at one station only, station HEI-12.

The concentrations of NPD and PAH are low. Slightly elevated values are found at two stations, station HEI-06 and HEI-12. Decalins are found at station HEI-06, the station with the highest THC content.

The Ba concentrations vary from 123 mg/kg at the reference station to 7590 mg/kg at HEI-12, 120°/550m. The levels are mainly similar to 1997. Elevated Ba concentrations are found at all stations except for the reference station, and on the new template HEI-00 (B).

The concentrations of the heavy metals are low, and elevated values of Cu and Pb are only found at a few stations. The levels are similar to the 1997 results.

The chemical results are in agreement with the drilling activities. Except for an acute discharge of oil containing drilling mud at template B, no discharges of oil based drilling fluids or drilling fluids based on olefins, esters or ethers have taken place at Heidrun since the 1997 survey.



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Table 4.4.1. Heidrun silt and clay and TOM (%), THC, olefins, esters, ether, NPD, PAH and decalins (mg/kg dry sediment)

Station	Silt and clay		TOM		THC		Ole-fins	Petrofree		Aquamul B II		NPD		PAH		Decalins
	2000	1997	00	97	00	97		2000	1997	2000	1997	2000	1997	2000	1997	
HEI-00(B) 90°/500 m	74.9	-	5.6	-	3.6	-	-	-	-	-	-	-	-	-	-	-
HEI-01 225°/2000 m	74.3	71.6	5.1	5.7	2.8	2.9	<0.5	-	-	<0.15	-	-	-	-	-	-
HEI-02 225°/1000 m	75.8	-	4.7	-	2.9	-	<0.5	-	-	0.7	-	-	-	-	-	-
HEI-03 225°/ 550 m	76.8	-	4.6	-	4.5	-	<0.5	-	-	1.3	-	-	-	-	-	-
HEI-06 50°/ 550 m	72.1	79.9	3.3	6.0	38.4	28.8	7.2	<0.5	0.37	2.0	216	0.243	-	0.077	-	0,48
HEI-07 45°/1000 m	77.6	75.6	5.1	5.8	6.1	5.0	<0.5	-	-	0.5	1.9	-	-	-	-	-
HEI-08 45°/1500 m	80.4	80.4	5.3	6.6	4.7	3.8	<0.5	-	-	0.3	-	-	-	-	-	-
HEI-10 135°/2000 m	73.8	70.5	4.6	6.1	3.2	2.4	<0.5	-	-	<0.15	-	-	-	-	-	-
HEI-11 135°/1000 m	75.4	71.6	4.2	6.4	5.3	3.2	<0.5	-	-	0.9	5.0	-	-	-	-	-
HEI-12 120°/ 550 m	73.6	75.3	5.1	6.6	13.6	26.0	<0.5	<0.5	0.64	119.0	271	0.111	-	0.195	-	nd
HEI-15 305°/ 550 m	78.5	74.6	5.6	6.1	11.1	10.6	<0.5	<0.5	<0.3	1.4	222	0.077	0.091	0.068	0.084	nd
1-3 cm			-	-	3.9	-		<0.5	-	2.4	-	0.120	-	0.087	-	nd
3-6 cm			-	-	1.3	2.3		<0.5	-	0.2	-	0.071	-	0.056	-	nd
HEI-16 315°/1000 m	59.1	78.4	4.7	6.1	3.8	1.7	<0.5	-	-	<0.15	0.3	-	-	-	-	-
HEI-17 315°/2000 m	83.4	77.4	6.2	6.2	2.6	2.6	<0.5	-	-	<0.15	-	0.068	0.073	0.081	0.092	nd
1-3 cm			-	-	1.1	1.1	-	-	-	-	-	0.046	-	0.051	-	nd
3-6 cm			-	-	1.6	0.3	-	-	-	-	-	0.064	-	0.111	-	nd
HEI-19 315°/3500 m	58.1	60.4	5.1	6.5	1.4	1.2	<0.5	-	-	<0.15	-	-	-	-	-	-
HEI-27 315°/10000m	60.2	54.0	5.1	5.3	1.9	1.1	<0.5	<0.5	<0.3	<0.15	<0.15	0.062	0.061	0.088	0.144	nd
Ref																
1-3 cm			-	-	1.3	0.3	<0.5	<0.5	-	<0.15	-	0.062	-	0.091	-	nd
3-6 cm			-	-	0.7	0.7	<0.5	<0.5	-	<0.15	-	0.077	-	0.107	-	nd

-: not analysed

nd: not detected



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

Station	Ba 2000	Ba 1997	Cd 2000	Cd 1997	Cr 2000	Cu 2000	Cu 1997	Hg 2000	Pb 2000	Pb 1997	Zn 2000	Zn 1997
HEI-00(B) 90°/500 m	1370	-	0.06	-	21.2	7.1	-	-	15.5	-	39.0	-
HEI-01 225°/2000 m	1160	773	0.10	0.06	20.4	6.6	9.2	-	14.3	21.8	37.5	41.1
HEI-02 225°/1000 m	1900	-	0.06	-	22.1	7.9	-	-	16.8	-	42.7	-
HEI-03 225°/ 550 m	4070	-	0.06	-	21.4	8.5	-	-	15.7	-	43.8	-
HEI-06 50°/ 550 m	7060	7270	0.07	0.06	21.5	34.0	29.9	-	46.0	50.3	54.1	68.0
HEI-07 45°/1000 m	6260	5120	0.05	0.09	22.3	10.0	22.5	-	20.1	25.0	43.6	59.8
HEI-08 45°/1500 m	5760	3430	0.04	0.07	22.9	9.1	11.2	-	19.8	21.7	43.7	43.5
HEI-10 135°/2000 m	1970	1300	0.04	0.06	21.6	7.3	11.5	-	16.5	18.9	39.7	44.0
HEI-11 135°/1000 m	3740	3820	0.05	0.07	22.2	8.3	9.2	-	17.2	23.8	41.1	41.2
HEI-12 120°/ 550 m	7590	7800	0.04	0.06	21.9	11.7	15.3	-	28.5	45.6	48.6	53.5
HEI-15 305°/ 550 m	5330	5240	0.04	0.07	24.3	9.7	10.6	0.02	17.5	18.4	44.5	41.8
1-3 cm	5390	-	0.05	-	22.8	8.8	-	0.02	16.5	-	42.7	-
3-6 cm	3674	-	0.05	-	22.4	7.8	-	0.02	13.4	-	39.5	-
HEI-16 315°/1000 m	3720	3270	0.05	0.06	21.5	8.2	11.1	-	16.0	21.4	38.0	47.2
HEI-17 315°/2000 m	1690	856	0.06	0.07	25.3	9.3	10.1	0.03	18.0	21.2	48.1	46.2
1-3 cm	450	-	0.05	-	25.4	8.8	-	0.02	17.6	-	47.0	-
3-6 cm	147	-	0.04	-	25.9	8.4	-	0.02	16.5	-	47.6	-
HEI-19 315°/3500 m	585	247	0.07	0.05	24.4	8.9	10.2	-	18.0	20.4	44.7	46.3
HEI-27 315°/10000m Ref	123	112	0.08	0.05	20.8	7.3	7.2	0.02	15.8	21.2	41.0	41.1
1-3 cm	85	-	0.07	-	21.0	7.5	-	0.02	15.8	-	38.4	-
3-6 cm	54	-	0.06	-	20.2	6.6	-	0.02	13.3	-	36.6	-

-: not analysed

1997: Cr is not analysed

4.4.2 Biology

The fauna on the Heidrun field, which generally can be described as diverse and healthy, are not different from the fauna in the region. Analysis of the fauna composition indicates that station Hei-6, Hei-12 and 15 are influenced, and that station 3, 7, 8 and 11 deviates somewhat from the rest and may therefore be slightly influenced. This indicates effects up to 500m on the 225° transect, 1500m on the 45° transect, 1000m on the 135° transect, 550m on the 120° transect and 550m on the 315° transect.

The species composition for 1995, 1997 and 2000 is similar, but there has been an increase in the number of individuals and polychaetes characterised as indicator species after 1995. There have only been small changes between 1997 and 2000, but generally, the diversity has increased slightly. The increased diversity between 1997 and 2000 may be the result of better conditions for the fauna.

The Shannon-Wieners diversity index (H') varied between 4.6 (Station 6) to 5.7 (Station 27 A+B), see table 4.4.3.

The diversity index on each of the stations was compared with the average fauna diversity of the reference stations (5.7 ± 0.3). The results showed that the following stations had a diversity index lower than 5.4: 3, 6, 7, 8, 11, 12 and 15. These stations were also the ones where few species accounted for a large part of the number of individuals.



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Table 4.4.3. Depth, number of species (*S*) and number of individuals (*N*) per 0.5 m², Shannon-Wieners diversity index (*H'*), Pielous index of evenness (*J*) and *ES*₁₀₀.

Station	Depth (m)	S	N	H'	J	ES ₁₀₀
HEI-00	340	82	384	5.4	0.8	43
HEI-01	340	75	366	5.5	0.9	45
HEI-02	343	70	396	5.4	0.9	41
HEI-03	342	95	794	5.2	0.8	39
HEI-06	346	86	1668	4.6	0.7	30
HEI-07	351	83	361	5.2	0.8	41
HEI-08	352	74	407	5.1	0.8	40
HEI-10	342	85	399	5.6	0.9	46
HEI-11	342	71	525	5.1	0.8	38
HEI-12	343	92	975	5.2	0.8	38
HEI-15	345	75	412	5.1	0.8	39
HEI-16	348	86	378	5.6	0.9	47
HEI-17	348	67	334	5.4	0.9	41
HEI-19	332	69	194	5.5	0.9	48
HEI-27A	333	85	445	5.7	0.9	47
HEI-27B	333	91	521	5.7	0.9	46

The similarity analysis shows that the stations divide into two main groups with a similarity of about 60%. Station 6 and 19 are different from the rest and do not fall into neither group 1 nor 2 (see MDS-plot in figure 4.4.1).

The analysis indicates a very diverse fauna on Hei-19 and an influence on station 6. A brown soft substrate and high content of organic material in the sediment were noticed while working up the samples from station 6. The species composition on station 12 and 15 (group 1) indicates that the stations are influenced.

The Bioenv analysis on the data from Heidrun gave a high correlation (0,8) between the fauna and a combination between grain size (Md), THC and barium.

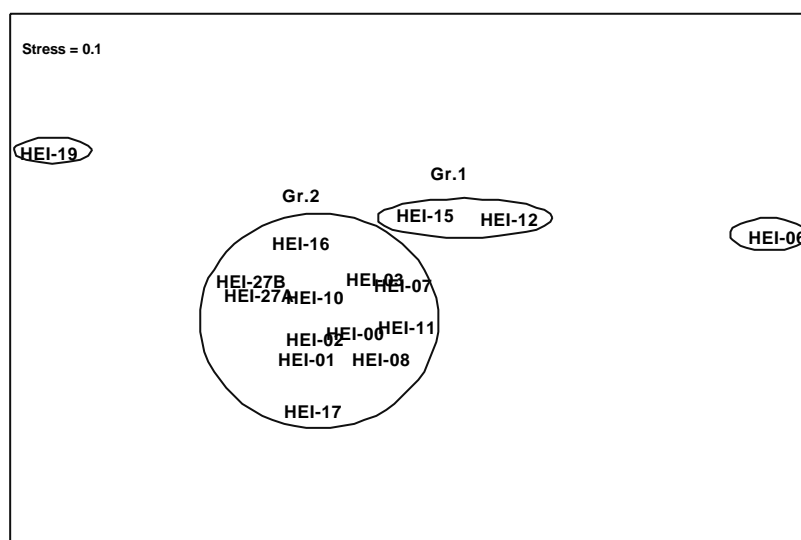


Figure 4.4.1. MDS-plot on station level for Heidrun 2000.



The dendrogram for the years 1995, 1997 and 2000 in figure 4.4.2 show that the stations divide into 3 main groups dependent on the year of the sample. Station Hei-19 from 2000, deviates from the rest.

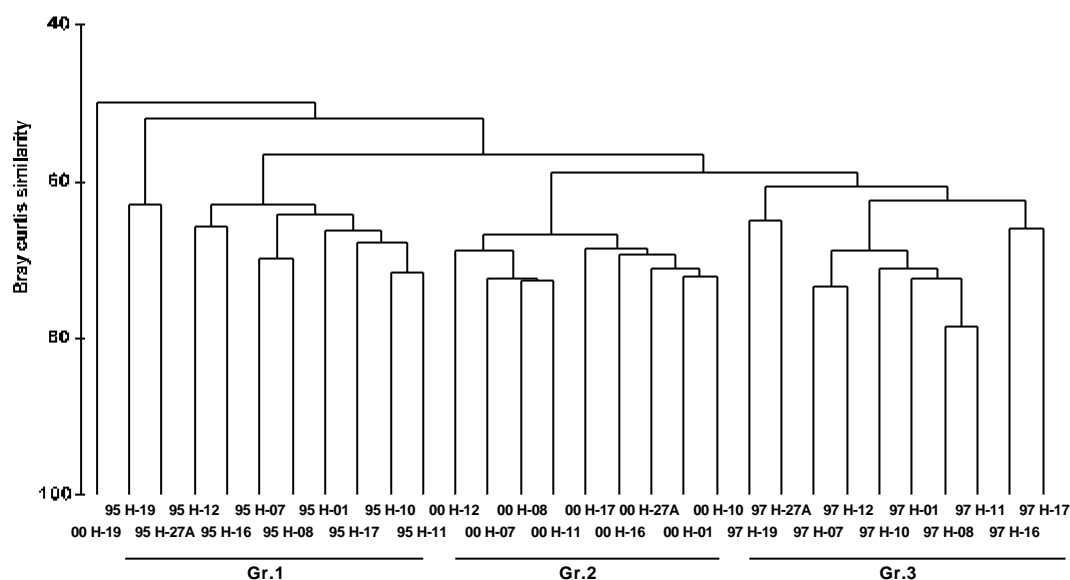


Figure 4.4.2. Dendrogram, Heidrun 1995, 1997 and 2000.

It is mainly the same species that contributed to the similarity within the groups, but there has been an increase in the number of individuals from 1995 through 1997 to 2000, especially for some polychaete species characterised as indicator species. Only small changes have taken place between 1997 and 2000 (some species have increased their number of individuals, while others have had a reduction).

The number of species and individuals is higher for both 1997 and 2000 compared to 1995. The number of species and individuals have increased on some stations and declined on others since 1997. In general the diversity has increased since the previous investigation, this may indicate that the fauna is in better condition in 2000 than in 1997. The diversity in 2000 is comparable to the diversity in 1995.



4.5 Heidrun Nord

4.5.1 Grain size and chemistry

The sediments at Heidrun Nord consist mainly of silt and clay, which vary from 52 % at station HN-9, 315°/1000m to 89 % at station HN-10, 315°/2000m. At two stations the gravel content is above 5 %, station HN-9 Old 270°/1000m and HN-9, 315°/1000m. Only two stations can be compared with the 1997 survey. At one station HN-5 Old, 180°/500m the concentrations are similar to 1997. At the other station HN-9 Old a decrease in the silt and clay content and an increase in the gravel content are observed.

The total organic matter content in the sediments varies from 4.3 % at station HN-09, 315°/1000m to 7.0 % at station HN-9 Old, 270°/1000m. The amounts are approximately the same as in 1997 at the two stations that can be compared.

The THC concentrations vary from 3.6 mg/kg at station HN-9, 315°/1000m to 7.6 mg/kg at station HN-1, 35°/500m. Slightly elevated THC concentrations are found at three stations at 500m and at one station at 1000m, the stations HN-1, HN-2, HN-3 and HN-5. The values are scarcely above the limit of contamination of 6.0 mg/kg. Elevated concentrations are not found in the layer samples.

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

The Ba concentrations varies from 428 mg/kg at station HN-10, 315°/2000m to 1960 mg/kg at station HN-4, 135°/1000m. Elevated Ba levels are found at all stations, and in the layer samples at 1-3 cm at station HN-7, 225°/2000m and station HN-10, 315°/2000m as well.

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

Table 4.5.1. Heidrun Nord silt and clay and TOM (%), THC, NPD and PAH (mg/kg dry sediment)

Station		Silt and clay		TOM		THC		NPD		PAH	
		2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
HN-1	35°/ 500 m	87.8	-	6.1	-	7.6	-	-	-	-	-
HN-2	30°/1000 m	88.3	-	6.3	-	6.2	-	-	-	-	-
HN-3	135°/ 500 m	77.3	-	5.6	-	7.0	-	-	-	-	-
HN-4	135°/1000 m	76.1	-	5.7	-	5.0	-	-	-	-	-
HN-5	225°/ 500 m	67.0	-	5.3	-	6.2	-	-	-	-	-
HN-6	225°/1000 m	56.2	-	5.4	-	5.3	-	-	-	-	-
HN-7	225°/2000 m	70.2	-	5.4	-	5.7	-	-	-	-	-
	1-3 cm					3.6		-	-	-	-
	3-6 cm					3.7		-	-	-	-
HN-8	315°/ 500 m	66.8	-	4.6	-	4.8	-	0.062	-	0.101	-
HN-9	315°/1000 m	51.7	-	4.3	-	3.6	-	-	-	-	-
HN-10	315°/2000 m	88.7	-	6.7	-	4.8	-	0.093	-	0.118	-
	1-3 cm					3.3		0.081	-	0.096	-
	3-6 cm					2.0		0.058	-	0.078	-
HN-5 Old	180°/ 500m	83.1	82.0	6.4	6.4	4.8	3.4	-	-	-	-
HN-9 Old	270°/1000m	78.2	88.8	7.0	7.9	5.8	3.2	-	-	-	-

-: not analysed

Decalins are not found, the detection limit is 50 µg/kg



ENGLISH SUMMARY

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

Station		Ba 2000	Cd 2000	Cr 2000	Cu 2000	Hg 2000	Pb 2000	Zn 2000
HN-1	35°/ 500 m	1380	0.10	28.7	10.8	-	20.2	53.4
HN-2	30°/1000 m	1160	0.09	27.0	9.7	-	19.3	50.5
HN-3	135°/ 500 m	1930	0.08	23.4	8.7	-	18.0	44.4
HN-4	135°/1000 m	1960	0.06	23.5	8.1	-	17.7	42.6
HN-5	225°/ 500 m	853	0.07	20.9	7.3	-	13.5	38.1
HN-6	225°/1000 m	1450	0.08	20.9	7.6	-	17.0	38.7
HN-7	225°/2000 m	1460	0.08	22.9	8.1	-	16.5	42.3
	1-3 cm	353	0.07	24.0	8.0	-	16.5	43.1
	3-6 cm	121	0.07	23.3	8.3	-	14.9	56.1
HN-8	315°/ 500 m	923	0.07	21.8	7.3	0.02	13.6	38.5
HN-9	315°/1000 m	601	0.08	25.8	8.2		17.4	44.0
HN-10	315°/2000 m	428	0.08	27.5	9.2	0.02	19.6	49.9
	1-3 cm	274	0.08	28.5	9.2	0.03	20.5	51.1
	3-6 cm	82	0.06	28.4	8.8	0.02	16.4	49.9
HN-5	Old 180°/ 500m	586	0.08	25.7	8.0	-	14.3	44.2
HN-9	Old 270°/1000m	827	0.10	28.0	9.9	-	20.5	52.0

-: not analysed

4.5.2 Biology

The fauna on "Heidrun Nordflanken", which generally can be described as diverse and healthy, does not deviate from the fauna in the region.

The Shannon-Wieners diversity index (H') varies between 5 (station 3) to 5.8 (station 9(old)), see table 4.5.3. The diversity index on each of the stations was compared to the fauna diversity on undisturbed areas with similar depths and sediment (R1, 2, 3, 8 and 10). Based on the mean diversity (5.5 ± 0.6), none of the stations appears to be influenced.

Table 4.5.3. Depth, number of species (S) and number of individuals (N) per 0.5 m^2 , Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100} .

Station	Depth (m)	S	N	H'	J	ES_{100}
HN-01	362	75	349	5.4	0.9	43
HN-02	360	75	423	5.3	0.8	41
HN-03	355	56	205	5.0	0.9	39
HN-04	354	83	532	5.4	0.9	42
HN-05	357	105	688	5.6	0.8	45
HN-06	342	94	425	5.9	0.9	51
HN-07	333	81	360	5.7	0.9	47
HN-08	374	82	293	5.7	0.9	49
HN-09	370	77	265	5.6	0.9	48
HN-10	391	69	386	5.2	0.8	38
HN-05(old)	350	84	431	5.5	0.9	44
HN-09(old)	360	106	509	5.8	0.9	49



ENGLISH SUMMARY

The results from the similarity analysis (figure 4.5.1) showed that the stations are clustered in one main group with similarity about 65% and two separate stations (station 9 and station 3). Station 9 has clearly the highest content of sand and gravel. This deviation is also reflected in the species composition. The substratum at station 3 is not different from the rest of the station, but the ten dominant species accounts for about 60% of the individuals and the diversity is the lowest on the field. This may indicate that the station is influenced. The Bioenv analysis gave low correlation between the fauna and measured environmental parameters.

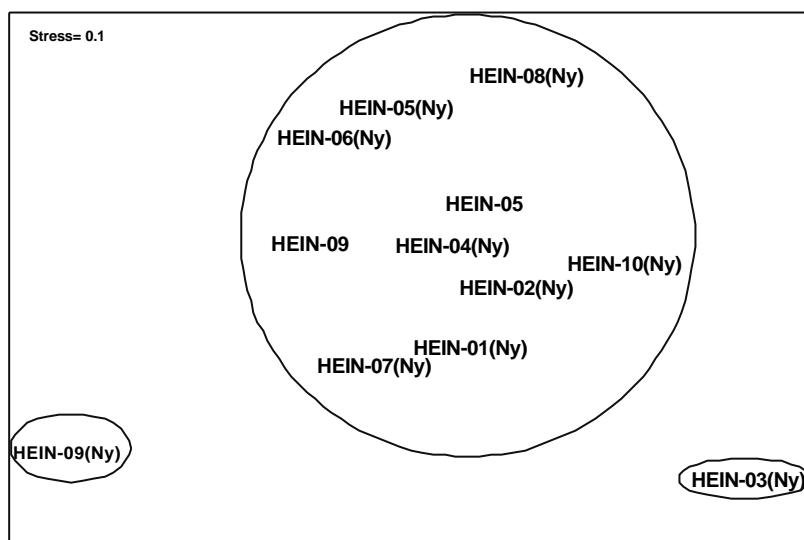


Figure 4.5.1. MDS-plot on station level, Heidrun Nordflanken 2000.

Stations HN-5 and HN-9 are the only ones that were sampled in both 1997 and 2000. The number of species and individuals on both of the stations are lower in 2000 than in 1997. The diversity has increased on station HN-5, while no change has been detected on HN-9 since 1997.

ENGLISH SUMMARY

4.6 Draugen

4.6.1 Grain size and chemistry

The sediments at Draugen vary from a dominance of silt and clay to fine sand. The silt and clay content varies from 37 % at station 24B, 300°/250m to 77 % at station 28A, 45°/1500m. At station 28A the silt and clay fraction has increased considerably since 1997 from 43 % to 77 %. All the stations except for 28A, 45°/1500m contain gravel, and considerable changes have partly occurred since 1997. The stations 24B, 300°/250m and 27A, 45°/750m show the highest gravel content, 14 % and 15 % respectively.

The total organic matter content in the sediments varies from 2.0 % at station 24B, 300°/250m to 5.8 % at station 28A, 45°/1500m. The values are similar to 1997 except for station 28A, 45°/1500m with increased concentrations from 2.8 % to 5.8 %. At this station the silt and clay content has also increased, and the gravel content has decreased since 1997.

The THC concentrations varies from 2.7 mg/kg at station 26B, 162°/500m to 20.3 mg/kg at station 24B, 300°/250m. At one station, station 24B, 300°/250m an increase is observed since 1997, from 5.3 mg/kg to 20.3 mg/kg. This is the only station with elevated THC levels, and slightly elevated concentrations are also found in the 1-3 cm sediment layer.

As in 1997 NPD, PAH and dekalin levels are low, however slightly elevated NPD and dekalin concentrations are found at station 24B, 300°/250m.

The Ba concentrations vary from 116 mg/kg at the reference station 51B to 5460 mg/kg at station 24B, 300°/250m. At one station only, station 24B, 300°/250m, an increase since 1997 is observed, from 3230 mg/kg to 5460 mg/kg. At this station the sediment layers at 1-3 cm and 3-6 cm also show high Ba concentrations. Elevated Ba levels are found at all stations out to 2000m except for 28A, 45°/1500m and the reference station 51B.

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

The chemical results are in agreement with the drilling activities. No discharges of oil based drilling fluids have taken place at Draugen since the last survey in 1997. In addition minor amounts of baryte have been discharged at Draugen since 1997 compared to the other fields at Region VI, approx. 1200 ton.



ENGLISH SUMMARY

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

Station		Silt and clay		TOM		THC		NPD		PAH		Decalins	
		2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
21B	300°/2000 m	57.43	-	3.8	-	2.8	4.3	0.042	0.052	0.072	0.093	nd	nd
	1-3 cm			-	-	1.9	1.5	0.034	-	0.092	-	nd	-
	3-6 cm			-	-	2.2	1.2	0.030	-	0.064	-	nd	-
22B	300°/1000 m	52.68	40.3	4.2	3.2	3.9	4.8	-	-	-	-	-	-
23B	300°/ 500 m	54.22	52.3	3.9	3.2	5.6	5.5	-	-	-	-	-	-
24A	325°/ 900 m	52.14	48.0	3.2	3.4	4.0	3.4	-	-	-	-	-	-
24B	300°/ 250 m	37.32	51.0	2.0	3.2	20.3	5.3	0.144	0.054	0.058	0.059	0.22	nd
	1-3 cm			-	-	9.5	5.2	0.112	-	0.083	-	nd	-
	3-6 cm			-	-	4.9	3.2	0.080	-	0.072	-	nd	-
26B	162°/ 500 m	43.84	54.5	2.7	3.6	2.7	4.7	-	-	-	-	-	-
27A	45°/ 750 m	48.86	47.6	3.9	3.3	3.2	3.8	-	-	-	-	-	-
27B	162°/1000 m	48.73	47.1	4.3	3.6	3.6	3.0	-	-	-	-	-	-
28A	45°/1500 m	77.05	42.8	5.8	2.8	3.1	3.1	-	-	-	-	-	-
30B	325°/ 500 m	45.38	54.8	3.3	3.4	3.7	5.9	-	-	-	-	-	-
31B	35°/1000 m	53.95	50.5	3.4	2.9	4.5	4.1	-	-	-	-	-	-
51B	Ref.	55.89	60.9	3.9	3.9	4.1	2.6	0.074	0.043	0.101	0.090	nd	nd
	1-3 cm			-	-	1.8	2.0	0.055	-	0.079	-	nd	-
	3-6 cm			-	-	2.0	2.0	0.044	-	0.087	-	nd	-

-: not analysed

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

Station		Ba	Ba	Cd	Cd	Cr	Cu	Cu	Hg	Pb	Pb	Zn	Zn
		2000	1997	2000	1997	2000	2000	1997	2000	2000	1997	2000	1997
21B	300°/2000 m	816	802	0.05	<0.03	26.1	7.4	8.3	0.03	17.1	17.8	42.6	32.6
	1-3 cm	261	-	0.03	-	35.7	10.8	-	0.01	12.2	-	47.1	-
	3-6 cm	137	-	0.06	-	41.9	15.6	-	0.01	10.5	-	52.2	-
22B	300°/1000 m	1240	1170	0.05	<0.03	22.0	6.4	8.4	-	16.4	18.0	38.5	34.4
23B	300°/ 500 m	2690	2810	0.05	<0.04	23.3	6.9	9.8	-	15.0	19.1	40.6	59.6
24A	325°/ 900 m	920	734	0.05	0.04	23.9	9.1	6.5	-	17.0	14.8	38.9	31.6
24B	300°/ 250 m	5460	3230	0.05	0.04	20.5	7.8	7.3	0.01	12.9	15.2	52.4	36.3
	1-3 cm	5734	-	0.05	-	20.1	7.5	-	0.02	15.2	-	42.4	40.8
	3-6 cm	3992	-	0.05	-	20.8	6.5	-	0.01	12.3	-	36.0	3.3
26B	162°/ 500 m	457	565	0.06	0.05	22.0	5.7	8.4	-	14.3	19.1	54.3	40.8
27A	45°/ 750 m	337	256	0.06	0.06	27.5	7.4	7.6	-	18.3	17.9	44.3	38.2
27B	162°/1000 m	402	495	0.06	0.05	25.1	6.9	25.6	-	16.9	22.5	40.8	58.7
28A	45°/1500 m	199	156	0.06	0.06	29.6	8.5	9.0	-	20.0	18.6	49.1	45.1
30B	325°/ 500 m	1180	1120	0.05	0.05	24.1	6.3	8.4	-	15.5	20.4	39.8	44.4
31B	35°/1000 m	473	497	0.05	0.05	26.3	6.9	7.4	-	16.8	17.3	42.4	38.0
51B	Ref.	116	113	0.04	0.04	22.7	6.7	7.7	0.02	15.2	17.1	37.7	39.0
	1-3 cm	56	-	0.03	-	22.5	6.4	-	0.02	13.3	-	37.8	-
	3-6 cm	54	-	0.04	-	21.5	6.3	-	0.01	11.2	-	35.7	-

-: not analysed

1997: Cr is not analysed



ENGLISH SUMMARY

4.6.2 Biology

The fauna on Draugen can be characterised as very diverse and healthy. It deviates somewhat from comparable regional stations (5, 6 and 9), but there are 50-60% similarities between the groups. Fauna parameters are shown in figure 4.6.3.

Analysis and the species composition indicate an influence and especially on station 24B, were relatively high content of THC were found in the sediment. Station 30B where the THC content was low did also deviate. This may be caused by an earlier disturbance which can be registered for a longer time in the fauna composition than in the chemical composition or the result of parameters that are not measured.

The Shannon-Wieners diversity index (H') varied between 4.7 (station 24B) to 5.9 (station 21B, 27B, 28A and 31B), see table 4.6.2. The diversity index from each station was compared with the diversity index from the reference stations (5.7 ± 0.3). Based on a diversity index of 5.4, station 24B and 30B are the only ones that have a lower diversity index. These two stations have also a high dominance of indicator species. The results indicate influence to 250m on the 300° transect and 500m 325° transect.

Table 4.6.3. Depth, number of species (S) and number of individuals (N) per 0,5 m², Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100} .

Station	Depth (m)	S	N	H'	J	ES_{100}
21B	249	97	403	5.9	0.9	51
22B	246	92	418	5.8	0.9	49
23B	255	90	395	5.5	0.9	46
24A	245	100	377	5.7	0.9	49
24B	252	115	1268	4.7	0.7	37
26B	254	94	363	5.8	0.9	50
27A	247	92	271	5.8	0.9	53
27B	255	99	395	5.9	0.9	50
28A	248	91	334	5.9	0.9	52
30B	250	91	444	5.0	0.8	42
31B	242	106	382	5.9	0.9	52
51A	270	90	416	5.7	0.9	49
51B	270	87	312	5.7	0.9	49

The similarity analysis show that the stations divide into two main groups with a similarity of about 60% and a third group containing only station 24B (see MDS-plot in figure 4.6.1).

The reference station (51 A and B) in group 1 is the deepest on the field, and this is probably the main reason for the difference between group 1 and 2. A Bioenv analysis was conducted, but no correlation between fauna and measured environmental parameters were found.



ENGLISH SUMMARY

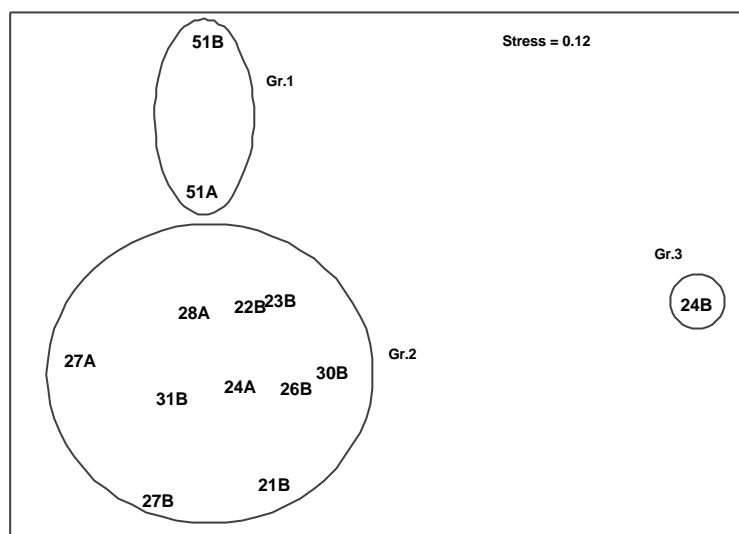


Figure 4.6.1. MDS-plot on station level for Draugen, 2000.

The dendrogram for 1994, 1997 and 2000 is shown in figure 4.6.2 where the stations are grouped into 3 groups dependent on the year the sample was collected.

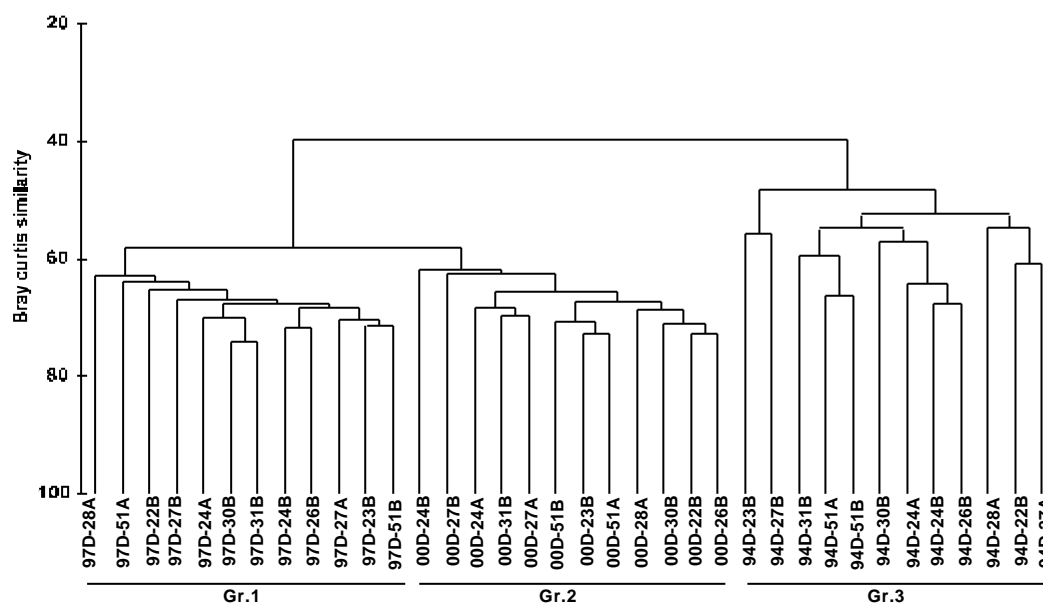


Figure 4.6.2. Dendrogram, Draugen 1994, 1997 and 2000.

There are small changes in the fauna between 1997 and 2000 and no increase in the number of individuals of the indicator species. The fauna diversity on the field as a whole is very high.

The diversity found in 1997 was higher than in 1994 on most of the stations, except 28A. Comparing diversity from 1997 and 2000 shows that the difference is small apart from a decrease on station 24B and 30B and an increase on station 28A.



ENGLISH SUMMARY

4.7 Garn West

4.7.1 Grain size and chemistry

At Garn West a baseline survey is performed. The sediments dominate partly of silt and clay and partly of very fine sand. The silt and clay content varies from 44 % at station GW1, 30°/250m to 78 % at station GW6, 120°/1000m. Station GW12, 300°/1000m has the highest gravel content, 9 %, while station GW2, 30°/500m is the only station with no gravel.

The total organic matter content in the sediments varies from 3.5 % at stations GW1, 30°/250m and GW9, 210°/1000m to 5.6 % at station GW6, 120°/1000m.

The THC concentrations are low throughout the field, and they vary from 2.0 mg/kg at station GW8, 210°/500m to 3.7 mg/kg at stations GW10, 300°/250m and GW14, 300°/4000m. Elevated concentrations are not found.

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

The Ba concentrations vary from 243 mg/kg at station GW13, 300°/2000m to 781 mg/kg at station GW3, 30°/1000m. Elevated values are found at all stations, however the concentrations are low compared with the older fields at the region.

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

The Garn West field is situated south-west of the Draugen field. The highest Ba concentrations are found at the station next to Draugen. In addition, there is a tendency of decreasing concentrations towards the Garn West installation. Based on these observations it is not unlikely that the elevated Ba concentrations found at Garn West, may result from the drilling activities at Draugen.

Table 4.7.1. *Garn West silt and clay and TOM (%), THC, NPD, PAH, Ba, Cd, Cr, Cu, Hg, Pb and Zn (mg/kg dry sediment)*

Station	Silt and clay	TOM	THC	NPD	PAH	Ba	Cd	Cr	Cu	Hg	Pb	Zn
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
GW1 30°/ 250 m	44.1	3.5	2.2	-	-	404	0.05	28.8	5.7	-	15.5	39.7
GW2 30°/ 500 m	58.6	4.5	2.3	-	-	495	0.05	26.2	6.6	-	17.6	41.5
GW3 30°/1000 m	56.6	5.0	3.3	-	-	781	0.05	26.7	7.4	-	19.6	44.1
GW4 120°/ 250 m	62.4	4.7	3.2	-	-	436	0.05	25.7	6.9	-	17.0	41.2
GW5 120°/ 500 m	62.2	4.5	3.2	-	-	407	0.05	25.7	6.8	-	16.2	40.5
GW6 120°/1000 m	78.3	5.6	3.5	-	-	720	0.07	29.3	8.6	-	20.5	49.0
GW7 210°/ 250 m	66.3	4.7	2.2	-	-	415	0.07	27.8	7.6	-	19.9	45.1
GW8 210°/ 500 m	63.4	4.4	2.0	-	-	326	0.05	27.4	7.6	-	19.2	45.0
GW9 210°/1000 m	52.1	3.5	2.9	-	-	346	0.05	28.4	7.4	-	17.3	42.6
GW10 300°/ 250 m	58.5	4.1	3.7	0.078	0.142	423	0.06	25.3	7.7	0.02	17.8	43.5
1-3 cm		-	2.2	0.135	0.146	172	0.06	26.4	7.6	0.02	18.5	44.9
3-6 cm		-	0.5	0.051	0.092	53	0.12	24.1	6.8	0.01	11.6	38.2
GW11 300°/ 500 m	58.3	5.1	3.1	-	-	491	0.07	26.9	8.2	-	20.3	48.6
GW12 300°/1000 m	46.2	3.8	2.2	-	-	331	0.05	26.1	6.6	-	17.0	41.0
GW13 300°/2000 m	49.2	3.6	2.1	0.052	0.090	243	0.04	24.1	6.3	0.01	15.6	38.3
1-3 cm		-	1.6	0.048	0.096	111	0.05	23.8	6.3	0.01	14.0	38.8
3-6 cm		-	1.1	0.034	0.089	54	0.07	26.3	7.9	0.01	12.0	39.0
GW14 300°/4000 m	53.0	4.7	3.7	-	-	298	0.05	21.9	6.8	-	17.8	39.0

:- not analysed

Decalins are not found, the detection limit is 50 µg/kg



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4.7.2 Biology

The fauna on Garn West, can be characterised as very diverse and healthy. There is a uniform distribution between the numbers of individuals on species level, even if some of the stations deviate with a somewhat higher dominance of single species. The fauna at Garn West does however, deviate a bit from the regional stations with similar depth and grain size. The main difference is caused by a dominance of the polychaete *P. quadricuspis/fiordica* on the regional stations (group 2) and a dominance of the polychaete *C. setosa* on Garn West stations. *C. setosa* is a deposit feeding indicator species, but its contribution was not large on any of the stations. The difference cannot be linked to activities on the field, since it is a baseline study.

The Shannon-Wieners diversity index (H') varied between 5.3 (station 5) to 5.9 (station 12), see table 4.7.2. The diversity indices from Garn West were compared with the indices from undisturbed areas in the region and none of the station deviated with low diversity indices.

Table 4.7.2. Depth, number of species (S) and number of individuals (N) per 0.5 m^2 , Shannon-Wieners diversity index (H'), Pielous index of evenness (J) and ES_{100}

Station	Depth (m)	S	N	H'	J	ES_{100}
GW-01	260	85	326	5.8	0.9	49
GW-02	260	88	358	5.5	0.9	46
GW-03	259	85	381	5.8	0.9	49
GW-04	268	90	375	5.6	0.9	46
GW-05	269	82	388	5.3	0.8	42
GW-06	270	94	452	5.6	0.9	46
GW-07	269	96	393	5.8	0.9	49
GW-08	271	93	493	5.6	0.9	45
GW-09	270	88	443	5.6	0.9	45
GW-10	266	86	351	5.7	0.9	49
GW-11	264	96	361	5.6	0.9	48
GW-12	262	102	388	5.9	0.9	53
GW-13	260	78	268	5.6	0.9	48
GW-14	264	89	562	5.4	0.8	42

The similarity analysis shows that the stations divide into 3 main groups, with a similarity of about 60% (see MDS-plot in figure 4.7.1). Station 5 and 13 are not include in any groups and are shown as singletons. The Bioenv analysis gave a low correlation between the fauna and the environmental parameters measured.



ENGLISH SUMMARY

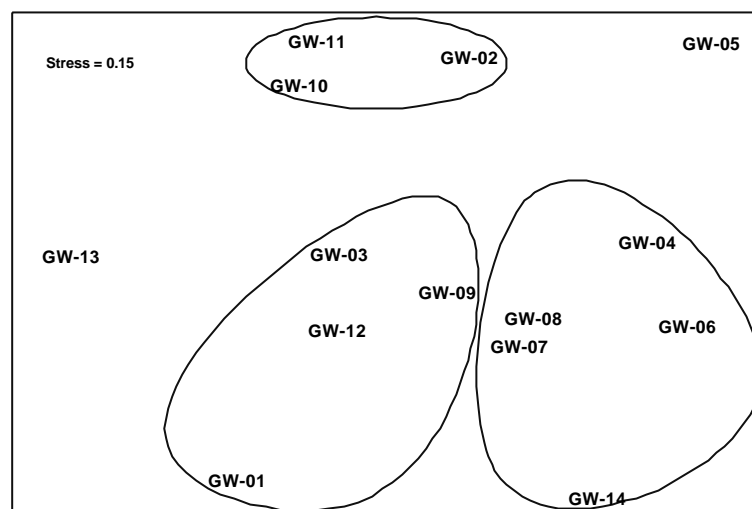


Figure 4.7.1. MDS-plot on station level from Garn West 2000.

4.8 Njord

4.8.1 Grain size and chemistry

The sediments at Njord consist of both silt and clay and very fine sand. The silt and clay content varies from 49 % at station NJ15, 337.5°/1000m to 75 % at station NJ1, 67.5°/250m. The results are similar to 1997. Most of the stations contain some gravel, and the highest content is 13 % at stations NJ5, 157.5°/250m and NJ15, 337.5°/1000m.

The total organic matter content in the sediments varies from 3.5 % at station NJ2, 67.5°/500m to 4.9 % at station NJ12, 247.5°/2000m. The values are similar to the 1997 results. Station NJ1, 67.5°/250m differs from the other stations with 13 % total organic matter. At this station the samples have a quite different consistency than the other sediment samples, and they cannot be characterised as ordinary sediments.

The THC concentrations vary from 3.4 mg/kg at the reference station NJ17, 67.5°/10000m to 900 mg/kg at station NJ13, 337.5°/250m. The THC concentrations at 1000m and 2000m stations are still low, however a slight increase since 1997 is observed. The concentrations at the 250m and 500m stations are on the other hand high. Elevated THC concentrations are found at all stations except for NJ4, 67.5°/2000m and the reference station. Some of these THC values are however just above the limit of contamination. In the layer samples at 1-3 cm and 3-6 cm elevated THC values are found at station NJ5, 157.5°/250m, but not at station NJ8, 157.5°/2000m.

The NPD and PAH concentrations are low, however slightly elevated values are found at some stations. On the other hand high decalin concentrations are found at most of the stations, up to 454 mg/kg at station NJ13, 337.5°/250m. A clear correlation is found between the decalin and the THC results.

The Ba concentrations vary from 151 mg/kg at the reference station NJ17, 67.5°/10000m to 7470 mg/kg at station NJ13, 337.5°/250m. The Ba concentrations at the 1000m and 2000m stations are still relatively low, however a slight increase since 1997 is found. The concentrations at the 250m and 500m stations are high. Elevated Ba levels are found at all stations except for the reference station. As for THC elevated Ba values are found in the layer samples at 1-3 cm and 3-6 cm at station NJ5, but not at station NJ8.



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The concentrations of the heavy metals are low. However, slightly elevated values of Cu, Pb and Zn are found at station NJ13, 337.5°/250m and of Cu at station NJ1 67.5°/250m.

The chemical results are not in agreement with the discharges. Since the previous regional survey less than 1 ton of oil based drilling fluids have been discharged. The elevated THC content found in the sediments does not result from crude oil, but from the same types of hydrocarbons as in the drilling mud base oil HDF 200. A clear correlation is also found between the THC, decalin and Ba results with the highest concentrations at the same stations. This observation may indicate discharges of oil containing drill cuttings together with baryte.

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

Station		Silt and clay		TOM		THC		NPD		PAH		Decalins	
		2000	1997	2000	1997	2000	1997	2000	1997	2000	1997	2000	1997
NJ1	67.5°/ 250 m	74.6	-	12.9	-	266	-	0.095	-	0.027	-	10.8	-
NJ2	67.5°/ 500 m	60.4	-	3.5	-	61.3	-	0.069	-	0.045	-	5.13	-
NJ3	67.5°/1000 m	55.8	57.4	4.0	5.0	6.4	3.8	-	-	-	-	-	-
NJ4	67.5°/2000 m	56.4	-	3.9	-	5.9	-	-	-	-	-	-	-
NJ5	157.5°/ 250 m	54.9	-	4.4	-	397	-	0.056	-	0.162	-	42.5	-
	1-3 cm			-	-	61.6	-	0.068	-	0.106	-	4.82	-
	3-6 cm			-	-	11.8	-	0.051	-	0.108	-	0.73	-
NJ6	157.5°/ 500 m	73.0	-	4.0	-	43.8	-	0.071	-	0.071	-	3.13	-
NJ7	157.5°/1000 m	57.0	54.7	3.8	4.5	7.8	4.1			-	-	-	-
NJ8	157.5°/2000 m	67.9	59.6	3.9	4.7	6.1	4.2	0.069	0.082	0.125	0.149	nd	nd
	1-3 cm			-	-	4.3	1.9	0.060	-	0.109	-	nd	-
	3-6 cm			-	-	3.6	1.8	0.049	-	0.119	-	nd	-
NJ9	247.5°/ 250 m	62.6	-	4.5	-	131	-	0.128	-	0.121	-	8.85	-
NJ10	247.5°/ 500 m	55.0	-	4.4	-	29.3	-	0.069	-	0.113	-	1.74	-
NJ11	247.5°/1000 m	72.8	-	4.5	-	10.0	-	-	-	-	-	-	-
NJ12	247.5°/2000 m	69.7	58.8	4.9	5.4	6.1	3.8	-	-	-	-	-	-
NJ13	337.5°/ 250 m	63.5	-	3.9	-	5900	-	nd*	-	nd*	-	454	-
NJ14	337.5°/ 500 m	65.9	-	4.7	-	125	-	0.093	-	0.112	-	9.94	-
NJ15	337.5°/1000 m	49.4	60.0	4.0	4.7	15.9	5.7	0.063	-	0.125	-	0.74	-
NJ16	337.5°/2000 m	58.1	57.6	4.1	4.7	6.2	3.8	-	-	-	-	-	-
NJ17	67.5°/10000 m	46.5	38.9	3.7	4.0	3.4	3.4	0.035	0.063	0.093	0.126	nd	nd
	1-3 cm			-	-	2.8	2.2	0.033	-	0.100	-	nd	-
	3-6 cm			-	-	2.1	1.8	0.024	-	0.126	-	nd	-

-: not analysed

* NJ 13: The detection limit for NPD is 500 µg/kg and for PAH 50 µg/kg due to large decalin amounts, approx. 400 mg/kg



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

Station		Ba	Ba	Cd	Cd	Cr	Cu	Cu	Hg	Pb	Pb	Zn	Zn
		2000	1997	2000	1997	2000	2000	1997	2000	2000	1997	2000	1997
NJ1	67.5°/ 250 m	2530	-	0.08	-	24.3	20.5	-	-	14.2	-	66.0	-
NJ2	67.5°/ 500 m	1710	-	0.05	-	23.7	7.5	-	-	8.8	-	37.2	-
NJ3	67.5°/1000 m	514	316	0.05	0.06	22.3	7.1	8.1	-	16.9	24.8	39.4	39.2
NJ4	67.5°/2000 m	229	-	0.08	-	20.6	6.7	-	-	16.3	-	36.4	-
NJ5	157.5°/ 250 m	4200	-	0.07	-	24.2	9.7	-	0.02	19.6	-	47.5	-
	1-3 cm	3244	-	0.07	-	23.1	9.0	-	0.02	18.9	-	45.4	-
	3-6 cm	985	-	0.05	-	23.2	7.6	-	0.02	16.7	-	41.8	-
NJ6	157.5°/ 500 m	1050	-	0.03	-	25.6	8.6	-	-	10.1	-	39.2	-
NJ7	157.5°/1000 m	565	225	0.05	0.06	21.7	6.5	8.3	-	15.1	24.3	37.0	39.3
NJ8	157.5°/2000 m	260	141	0.05	0.05	23.9	7.2	6.9	0.02	17.0	21.9	40.5	35.7
	1-3 cm	161	-	0.04	-	22.0	6.9	-	0.02	16.2	-	36.9	-
	3-6 cm	111	-	0.04	-	21.5	6.6	-	0.02	14.9	-	44.4	-
NJ9	247.5°/ 250 m	3900	-	0.04	-	22.8	9.5	-	-	19.3	-	56.4	-
NJ10	247.5°/ 500 m	1440	-	0.04	-	23.6	7.6	-	-	16.3	-	40.2	-
NJ11	247.5°/1000 m	435	-	0.04	-	23.3	7.3	-	-	18.7	-	40.7	-
NJ12	247.5°/2000 m	251	241	0.05	0.05	22.2	6.8	14.9	-	16.5	23.4	38.6	43.6
NJ13	337.5°/ 250 m	7470	-	0.08	-	19.6	43.1	-	-	27.8	-	114	-
NJ14	337.5°/ 500 m	5510	-	0.04	-	20.9	11.2	-	-	19.7	-	47.8	-
NJ15	337.5°/1000 m	1960	321	0.04	0.04	20.9	8.4	8.3	-	16.8	21.3	43.1	35.8
NJ16	337.5°/2000 m	433	248	0.04	0.04	18.7	6.7	9.5	-	15.4	22.6	36.1	40.9
NJ17	67.5°/10000 m	151	113	0.03	0.04	20.2	6.1	7.7	0.02	15.4	19.7	34.5	34.1
	1-3 cm	100	-	0.04	-	21.0	6.8	-	0.01	16.0	-	36.0	-
	3-6 cm	66	-	0.03	-	20.5	5.9	-	0.01	13.3	-	33.9	-

-: not analysed

1997: Cr is not analysed

4.8.2 Biology

The fauna on Njord does not deviate from the rest of the region. The species composition together with multivariate analysis shows that a number of stations are more or less influenced. The fauna on station 13, but also station 1 and 2 are clearly affected and deviate from the rest, while the fauna on station 6, 9 and 14 can be characterised as clearly influenced. On these stations plus station 12, the diversity has declined since the last investigation in 1997.

Comparing the stations with the diversity index of the reference station (5.7 ± 0.2), 12 of 17 stations seems to be influenced to a certain degree (more or less). The exception is the reference station and stations 3, 4, 8 and 16. The fauna is affected out to 2000 m on the 247,5 ° transect, 100 m on 157° transect and to 500 m on both the 247,5 ° and 67,5° transect.

Shannon-Wieners diversity index (H') and Pielous evenness index varied between 3.4 (station 13) to 5.9 (station 3), see table 4.8.3.



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Table 4.8.3. Depth, number of species (*S*) and number of individuals (*N*) per 0.5 m², Shannon-Wieners diversity index (*H'*), Pielous index of evenness (*J*) and *ES*₁₀₀.

Station	Depth (m)	S	N	H'	J	ES ₁₀₀
NJ-01	329	34	95	4.2	0.8	33
NJ-02	328	42	141	4.7	0.9	36
NJ-03	330	101	358	5.9	0.9	53
NJ-04	330	99	346	5.8	0.9	51
NJ-05	325	101	452	5.4	0.8	45
NJ-06	328	73	367	5.0	0.8	39
NJ-07	330	106	590	5.4	0.8	44
NJ-08	320	105	519	5.8	0.9	49
NJ-09	325	93	618	4.8	0.7	36
NJ-10	325	67	275	5.2	0.9	42
NJ-11	330	88	591	5.1	0.8	39
NJ-12	330	90	630	5.4	0.8	41
NJ-13	330	35	418	3.4	0.7	19
NJ-14	330	99	950	4.8	0.7	34
NJ-15	330	97	474	5.5	0.8	45
NJ-16	330	85	359	5.6	0.9	46
NJ-RefA	300	90	286	5.8	0.9	52
NJ-RefB	300	95	375	5.7	0.9	48

In the similarity analysis, station 1, 2 and 13 deviated so strongly from the rest of the stations, that they were removed from further analysis, in order not to mask eventual effects on other stations. Bacterial growths were noted on the sediment surface on both stations 1 and 13 in addition H₂S smell were noted on station 1. Station 2 stood out with fewer individuals and species than the rest of the stations.

An MDS plot for the rest of the stations (not station 1, 2 and 13) is shown in figure 4.8.1. The stations divide into three main groups with about 60% similarity. Station 6 and 10 do not group. The rest of the stations do group in a small degree after transect. Depth and sediment type is relatively similar in the area.

The Bioenv analysis (station 1, 2 and 13 not included) gave a correlation of 0.7 between the fauna distribution and organic material, THC and lead (Pb)

A dendrogram for the years 1996, 1997 and 2000 is shown in figure 4.8.2 and it shows a division into three groups depending on year.



ENGLISH SUMMARY

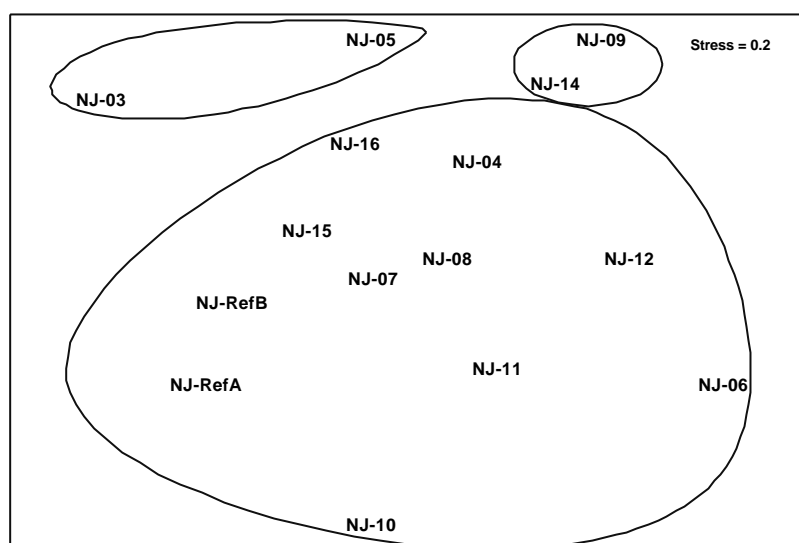


Figure 4.8.1. MDS-plot on station level, Njord 2000.

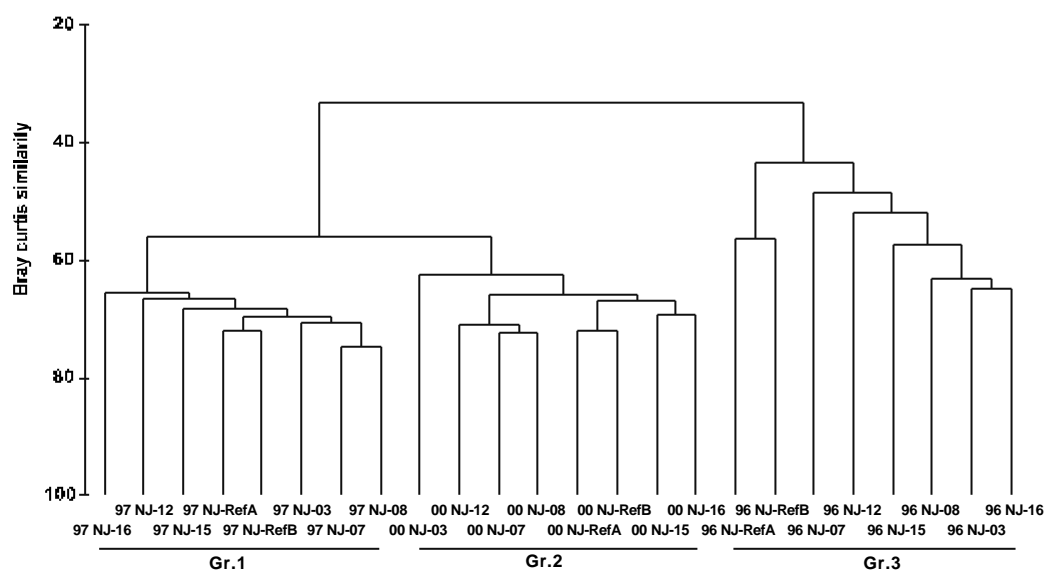


Figure 4.8.2. Dendrogram, for Njord 1996, 1997 and 2000.

The fauna in group 3 (1996 stations) deviate the most from the other two groups. The species that contribute the most to this difference are an overweight of indicator polychaetes. There were found very few individuals from this group in 1996. The number of indicator species has grown in size from 1997 to 2000. The trend shows an increasing organic load on the field as a whole.

Generally, the number of species and individuals are higher in 1997 and 2000 than in 1996. There has been a small increase from 1997 to 2000 in the number of individuals and species on most of the stations. The diversity is generally lower in 1996 than in 1997 and 2000, with the exception of station NJ-1 and 2.



5 EVALUATION AND CONCLUSIONS FOR THE REGION

In this chapter, an overall evaluation (based on all the results) for the region is presented, including estimates of total contaminated area with THC and total biological affected area. Haltenbanken is a region with large variation in both depth and sediment type, which gives a span in natural values (not contaminated) for both chemical and biological parameters. An LCS (limit of significant contamination) value, which indicates if a station has a significant level of contamination, has been calculated for the chemical parameters (more information about LSC can be found in the Main report (DNV, 2001 report no. 2001-0376) chapter 3.2.3). SFT has compiled results from environmental studies conducted in fjords, and proposed an environmental quality classification system. This system is difficult to use offshore, since all stations that are affected on Haltenbanken are classified as not polluted (class #1), we have placed more importance to the regional and reference stations. In this report, the average diversity index with standard deviation is used as indicator for possible impacts together with the multivariate analysis

Maps containing iso-lines are used in this presentation and although they show trends, they can be inaccurate in areas where there are few samples, since the values between measurements are interpolated. In order to calculate the areas that are contaminated / affected, the following approach is used:

- If a station is contaminated and the next station further out on the axis (transect) is not contaminated, it is assumed that the outer edge of the contaminated area is between the two stations.
- If the outer most station on an axis (transect) is contaminated, the calculated area must be regarded as the minimum area.

Depth and sediment variation in the region

Region VI stretches from Garn West in the south to Norne in the north, with depths from 210m to 432m. The sediment varies between 26% and 98% fine sediment (fine sediment = sediment < 63µm). These variations are presented in figure 5.1 as maps with iso-lines. The eastern part of the region is shallower with coarser sediment. The regional station R4 deviates from the rest with much coarser sediment, and as a result different biology. The relationship between depth and fine sediment has been shown in earlier reports (DNV, 1997); the deeper the station is, the higher the content of fine sediment.



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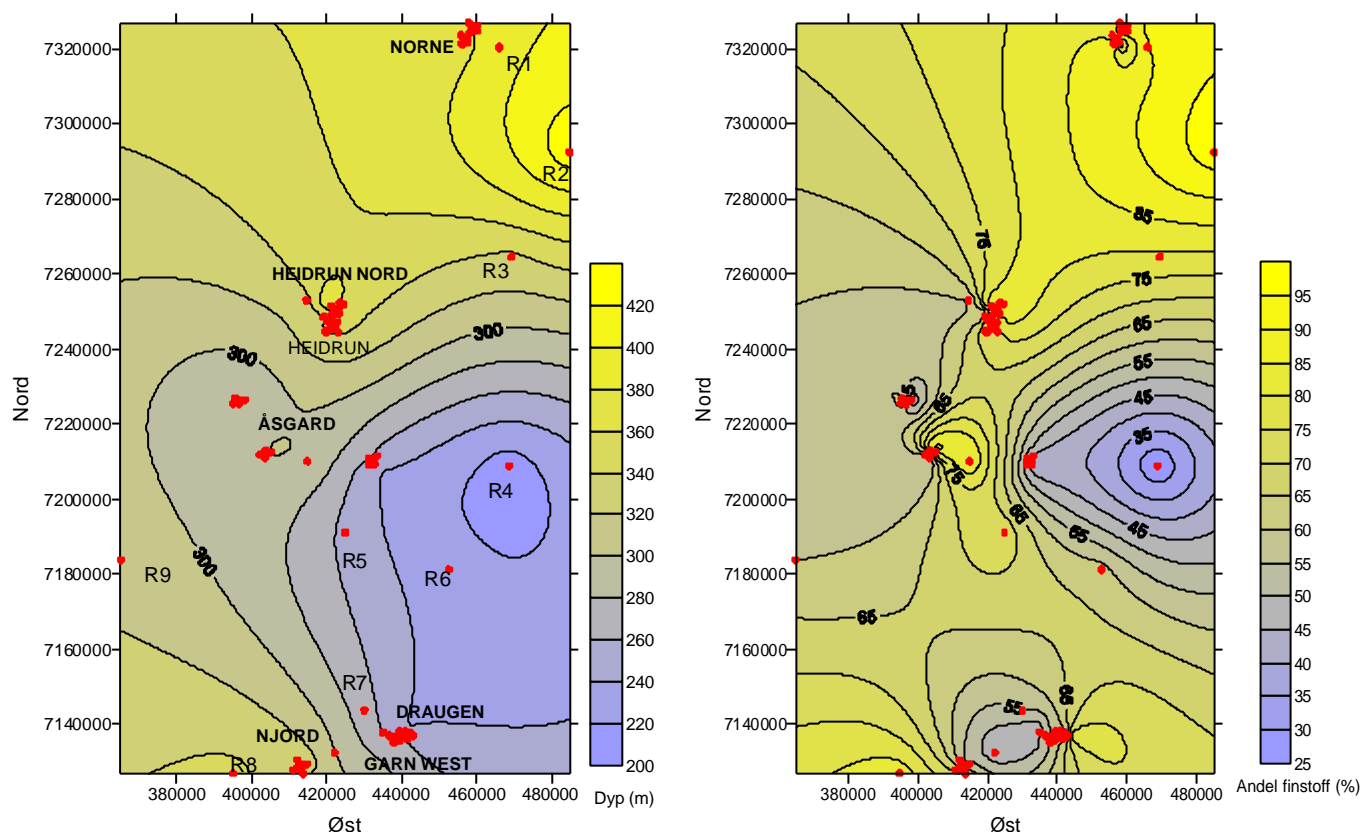


Figure 5.1. Depth contours based on the depth from all the stations (left) and fine sediment content based on the same stations (right).

5.2 Chemical analysis

A summary of the sediment characterisation and the chemical analyses of the sediments at Region VI in 2000 are given table 5.1.

Table 5.1. Results from Region VI 2000

Parameter	Regional stations (10 st.)	Norne SW & NW (21 st.)	Asgard L, S & Y (28 st.)	Heidrun (15 st.)	Heidrun Nord (12 st.)	Draugen (12 st.)	Garn West (14 st.)	Njord (17 st.)
Pelite %	26 - 98	61 - 94	40 - 86	58 - 83	52 - 89	37 - 77	44 - 78	49 - 75
TOM %	2.1 - 8.2	5.1 - 8.2	3.4 - 7.0	3.3 - 6.2	4.3 - 7.0	2.0 - 5.8	3.5 - 5.6	3.5 - 4.9
THC mg/kg	1.2 - 5.9	3.8 - 297	2.8 - 1210	1.4 - 38.4	3.6 - 7.6	2.7 - 20.3	2.0 - 3.7	3.4 - 5900
Olefin mg/kg	na	na	na	nd - 7.2	na	na	na	na
Ester mg/kg	na	na	na	nd	na	na	na	na
Ether mg/kg	na	na	na	nd - 119	na	na	na	na
NPD µg/kg	20 - 78	65 - 827	53 - 202	62 - 243	62 - 93	42 - 144	52 - 78	35 - 128
PAH µg/kg	51 - 123	58 - 207	70 - 129	68 - 195	101 - 118	58 - 101	90 - 142	27 - 162
Decalin mg/kg	nd	nd - 21.2	nd - 63	nd - 0.48	nd	nd - 0.22	nd	nd - 454
Ba mg/kg	49 - 191	191 - 5900	463 - 2910	123 - 7590	428 - 1960	116 - 5460	243 - 781	151 - 7470
Cr mg/kg	15 - 39	30 - 39	17 - 28	20 - 25	21 - 29	21 - 30	22 - 29	19 - 26
Cu mg/kg	3 - 11	9 - 13	5 - 10	7 - 34	7 - 11	6 - 9	6 - 9	6 - 43
Pb mg/kg	11 - 21	17 - 22	14 - 22	14 - 46	14 - 21	13 - 20	16 - 21	9 - 28
Zn mg/kg	23 - 70	57 - 77	33 - 95	38 - 54	38 - 53	38 - 54	38 - 49	35 - 114
Cd mg/kg	0.04 - 0.10	0.05 - 0.10	0.06 - 0.11	0.04 - 0.10	0.06 - 0.10	0.04 - 0.06	0.04 - 0.07	0.03 - 0.08
Hg mg/kg	0.01 - 0.03	0.03	0.02	0.02 - 0.03	0.02	0.01 - 0.03	0.01 - 0.02	0.02

na: not analysed nd: not detected

quantitation limits : olefins 0.5 mg/kg, esters: 0.5 mg/kg, ethers: 0.15 mg/kg, decalins 0.05 mg/kg

NPD, PAH, decalins and Hg are not analysed at all stations

ENGLISH SUMMARY

5.2.1 Grain size distribution

Silt and clay (pelite) dominate in the sediments at Region VI. Åsgard L, Åsgard Y, Draugen and Garn West however, contain more sand than the rest of the fields.

The regional stations show the variation of the silt and clay content at Region VI, from 26 % at Regional 4 to 98 % at Regional 2.

The lowest mean content of silt and clay is found at Åsgard Y (in the middle of the region), 45 %, and the highest content is found at Norne, 79 % at Norne SW and 86 % at Norne NW (north-east in the region). The rest of the fields have a mean content of silt and clay from 52 % to 69 %.

The results from the present survey at Region VI are similar to the previous regional survey in 1997 at most of the fields. However, some changes are observed. At Draugen the content of silt and clay has increased considerably since 1997 at one of the stations (28A, 45°/1500m), from 43 % to 77 %. At this field pronounced variations are also observed in the gravel content compared to 1997. At Åsgard reference station the content of silt and clay has increased since 1997, from 68 % to 86 %.

5.2.2 Total organic matter (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 is found at Draugen, 2,0 % at station 24 B, 300°/250m. The highest content, 8,2 %, is found at Regional 1 and at Norne reference station. The results are mainly similar to the results from the previous regional survey in 1997.

5.2.3 Hydrocarbons

The hydrocarbon content in the sediment origin 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 reference stations the THC concentrations are low, and they vary from 1.2 mg/kg to 5.9 mg/kg. No increase since the previous survey in 1997 is observed.

One base line survey is performed this year, at Garn West. As expected the THC concentrations are low, and the THC values are very similar, from 2.7 to 3.7 mg/kg.

The THC concentrations are also low at the Y installation at Åsgard and at Heidrun Nord. The highest concentration at Åsgard Y is 6.4 mg/kg and at Heidrun Nord 7.6 mg/kg. These values are just above the limit of contamination for THC which is 6.0 mg/kg, and we will consider the sediments at these two fields to be uncontaminated by hydrocarbons.

Slightly higher THC concentrations are found at some stations at Draugen and Heidrun. At Draugen elevated THC levels are found at one station only, 20.3 mg/kg. This station is situated only 250m from the platform, and an increase since 1997 is observed. At Heidrun elevated THC concentrations are found at three of the 500m stations. The highest value is 38.4 mg/kg, and olefins, only found at this station, constitute 7.2 mg/kg.

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At Norne, Åsgard L and S and Njord the THC concentrations are higher. At Norne SW the THC levels are mainly similar to those found in 1997, and elevated levels are found out to 1000m. Norne NW was not investigated in 1997, and at this field elevated THC levels are found out to 1500m. The highest concentrations at Norne are 235 mg/kg at SW and 297 mg/kg at NW. At Åsgard L and S elevated THC concentrations are found out to 1000m. The highest concentration at Åsgard L is 62.4 mg/kg, and at this installation an increase is observed since 1997 and 1999. At Åsgard S the THC concentrations have increased at most of the stations since 1999 (not analysed in 1997). One of the 500m stations has a very high THC value, 1210 mg/kg. At Njord elevated THC concentrations are found at all stations except for one of the 2000m stations and the reference station. An increase is observed since 1997. The innermost stations at 250m and 500m have high THC levels, up to 5900 mg/kg.

The results at Norne, Åsgard L and S and at Njord are not in agreement with the discharges. At Norne and Åsgard no discharges of oil based drilling fluid have taken place since the previous regional survey in 1997. At Njord the discharges have been less than 1 ton. At Njord there is a good correlation between the THC and the Ba results with the highest concentrations at the same stations. This may indicate discharges of oil-containing drillcuttings together with baryte. The elevated THC content found in the sediments does not result from crude oil, but from the same types of hydrocarbons as in the drilling mud base oil HDF 200.

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

The concentrations of the selected hydrocarbons NPD and PAH are low throughout Region VI, however, there is a great variation in the concentrations of C₅ - C₈ alkyl decalins. Decalins are not found at the regional stations, Garn West and Heidrun Nord, while high levels are found at Njord, Åsgard and Norne, up to 454 mg/kg. A good correlation is found between the decalin results and the THC results. The presence of decalins indicates that drilling mud base oil also is present in the sediments. As an information, the base oil HDF 200 contains approx. 2 % of C₅ - C₈ alkyl decalins.

5.2.4 Esters

Esters from the drilling mud base liquids Petrofree are only analysed at Heidrun. Petrofree is not found in the sediments. This is a decrease since 1997, when low concentrations of Petrofree were found at the 500m stations.

5.2.5 Ethers

Ethers from the drilling mud base liquid Aquamul B II are only analysed at Heidrun. Low concentrations of Aquamul B II are found at most of the stations. Only at one of the 550m stations the level is still high, 119 mg/kg. This is a clear decrease since 1997.



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5.2.6 Barium

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

The Ba concentrations vary from background levels to 7600 mg/kg.

As for THC a vertical transport of Ba down in the sediment layers is observed, lower levels than in the top 0-1 cm layer. At the regional stations and the additional reference stations, the Ba concentrations are low and vary from 49 mg/kg to 225 mg/kg. No increase is observed since the last survey in 1997.

Elevated Ba concentrations are found at all stations except for one station at 1500m at Draugen and all the reference stations. This means out to 2000m at all fields. The concentrations are similar to the 1997 results at Heidrun and Draugen, while an increase is found at Norne and Åsgard L. At the rest of the fields the basis for comparison is less due to the fact that only some of the stations are previously analysed. Although a baseline survey, elevated Ba concentrations are found at Garn West. The levels are low compared to the older fields. However, it is not unlikely that the elevated Ba concentrations found at Garn West, may result from the drilling activities at Draugen.

5.2.7 Metals

Generally low concentrations of the heavy metals are found in the sediments. To our opinion, the levels found are mainly within the natural level at Region VI. Only a few elevated levels are found for Cu, Pb and Zn. Cr varies from 15 - 39 mg/kg, the same concentrations at the fields as at the regional stations. Cu varies from 3 - 12 mg/kg, except for three stations with elevated concentrations up to 43 mg/kg, one 550m station at Heidrun and two 250m stations at Njord. Pb varies from 9 - 29 mg/kg, except for 46 mg/kg at one 550m station at Heidrun. Zn varies from 23 - 77 mg/kg, except for one 500m station at Åsgard Y which has 95 mg/kg and one 250m station at Njord which has 114 mg/kg. At Norne the natural Zn level seems to be higher than at the rest of the region, from 57 mg/kg to 77 mg/kg.

Cd and Hg are found at all fields, 0.03 to 0.11 mg/kg for Cd, and 0.01 to 0.03 mg/kg for Hg. The levels are low, and they are considered to be the natural level in the sediments at Region VI.

5.2.8 Contaminated area

Excess level (higher than LSC-value 6 mg/kg) of THC is found on a few stations locally around the installations. The outermost station on the axis (transect) on a few fields are found to be contaminated according to LSC. This makes it difficult to calculate affected area, and the results must be viewed on as a minimum area.

Figure 5.2 show iso-line plot for THC concentrations based on all stations. Iso-lines close together (steep gradients) are found around Åsgard and Njord. The highest concentration was 5897mg/kg, median value 5,1 (38% of the stations had higher than LSC values).

The total area that can be viewed as contaminated according to a LSC value of 6 mg/kg is estimated to be at least 20 km² (calculation based on the 10 installations included in the survey)*. The estimation is based on the calculation shown in table 5.2, which show how far out on each of the axis (transect) higher than 6 mg/kg THC are found. Njord accounts for about 50% of the area.

* On the Åsgard field, 3 out of 16 installations were included in the survey. If one assume that the 3 investigated installations are representative for the whole installation the contaminated area is calculated to be about 34 km².



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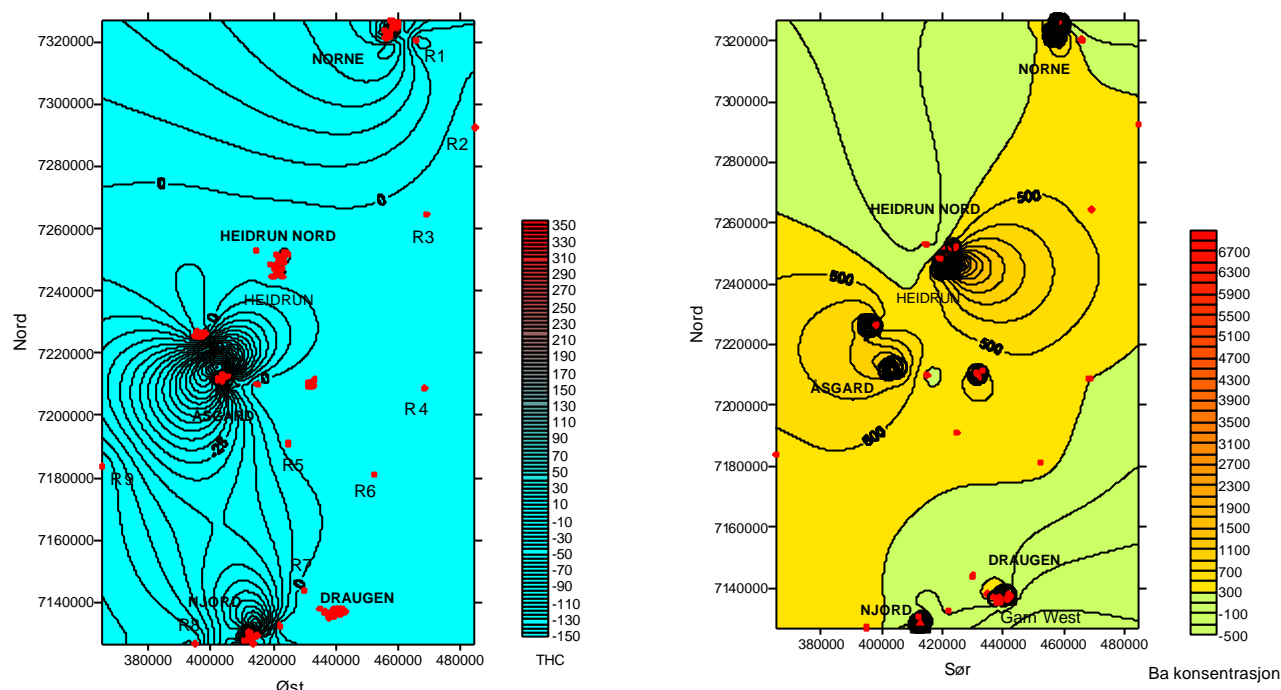


Figure 5.2. Iso-line plot showing the THC concentration (left) and Ba (right). Since excess values for THC only are found locally (some locations have very high levels) the resolution is very hard to present, but a large part of the Haltenbanken area seems not to be contaminated by THC. The area calculated to be contaminated by THC is minimum 20 km². Barium is spread over a much larger area and the total area calculated to be contaminated is a minimum of 67 km².

**Table 5.2.** Basis for calculation of area contaminated with THC, based on 10 installation in the region.

THC	Norne SW:	Norne NW	Åsgard L	Åsgard S	Åsgard Y	Heidrun	Heidrun Nord	Draugen	Garn West	Njord
Transect 1 (m)	700	1000	1000	1000	500	550	1000	250	250	1000
Transect 2 (m)	500	500	1000	1000	250	550	500	250	250	2000
Transect 3 (m)	1000	1500	500	250	250	250	500	250	250	2000
Transect 4 (m)	500	1000	250	500	250	550	250	250	250	2000
¹ Area km ²	1.43	3.14	1.48	1.48	0.31	0.71	0.99	0.20	0.01	9.62
Area > 6,6 mg/kg: 20 km ²	7.4 %	16.2 %	7.7 %	7.7 %	1.6 %	3.7 %	5.1 %	1.0 %	0.0 %	49.7 %

Area contaminated with THC covers about 20 km², and amounts to about 0.02% of the region (area of region is estimated to be 96237 km²). The calculations in 1998 also estimated the contaminated area to be about 20 km² (i.e a minor area of the region is contaminated with THC). Barium is used as an indicator of discharge from the installations and all the stations around the installations are regarded as contaminated. The actual area that is contaminated by Barium is larger than the area calculated, since the outermost stations on the transects also have higher Barium concentration than the LSC-value of 220 mg/kg. At least 68 km² has Barium content higher than 220 mg/kg. The basis for the Barium calculations is shown in figure 5.3.

Table 5.3. Basis for calculation of area contaminated with Barium .Concentration higher than 220 mg/kg, which is the LSC value.

Barium	Norne SW	Norne NW	Åsgard L	Åsgard S	Åsgard Y	Heidrun	Heidrun Nord	Draugen	Garn West	Njord
Transect 1 (m)	700	1000	2000	1000	2000	1500	1000	750	1000	2000
Transect 2 (m)	1000	1000	1000	2000	1000	2000	1000	1000	1000	2000
Transect 3 (m)	1000	1500	1000	1000	1000	2000	2000	2000	1000	2000
Transect 4 (m)	500	2000	1000	1000	1000	3500	2000	1000	2000	2000
¹ Area km ²	2.01	5.94	4.91	4.91	4.91	15.90	7.07	4.43	4.91	12.56
Area > 6,6 mg/kg: 20 km ²	10.4 %	30.7 %	25.3 %	25.3 %	25.3 %	82.1 %	36.5 %	22.9 %	25.3 %	64.8 %

5.3 Biology

Generally the region as a whole is not contaminated, and the fauna is healthy. Figure 5.3 show iso-lines for diversity and content of fine sediment (%) on a map covering the whole region. The figure shows that large areas have very high diversity and that the diversity depends heavily on the content of fine sediment. The diversity is generally lowest in the northern part of the region, where the content of fine sediment is high and it (diversity) increases as the sediment becomes coarser. The diversity in sediment having a higher content of sand and gravel, will naturally be higher because a larger number of niches than in more homogenous sediment (higher content of fine sediment). Even if the diversity generally is high in the region, some have locally affected fauna. This is especially clear on Njord. In some cases faunal composition indicated effects without any evident correlation with the environmental chemical parameters in the sediment.

¹ Calculated as a circle with radius equal the average of the four axis.



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This may be the result of slow fauna response to reduced chemical contamination. Changes in the soft benthos community, which may be interpreted as pollution impacts may be result of variation in natural environmental parameters that are not being measured.

In order to assess the size of the influenced area, an diversity index based on the average values for the reference and the regional stations have been developed minus 1*STD (includes stations that are influenced to moderate - minor extent) and 2*STD (includes stations that are clearly influenced). The results from the above calculation are compared to the multivariate analysis. Diversity index of 5.16 (1*STD) and 4.86 (2*STD) were used for all fields except Norne, which had a fine sediment. For Norne the indices used were 4.0 and 3.8 (STD set to 0.2 because of only one reference station). Stations with lower diversity than these criteria are listed in table 5.4.

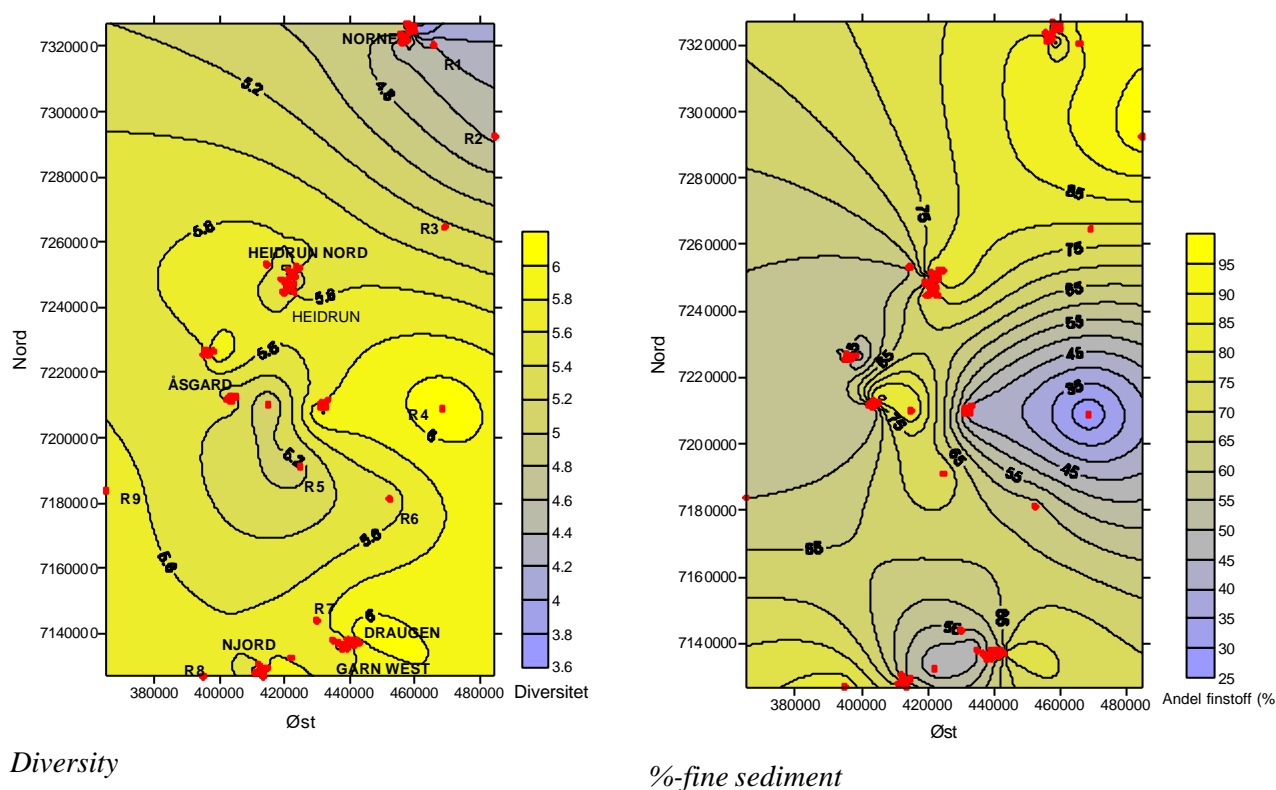


Figure 5.3. Iso-line plot for the diversity and fine sediment content (%) for all the stations in the region.



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Table 5.4. Number of stations that have diversity index lower than the average value for the reference and regional stations minus 1*STD of 2*STD.

Field	Number of stations with diversity < (average-1STD)	Number of stations with diversity < (average-2STD)
Norne	4/21 (NW02, NW03, NW07, NW12)	1/21 (NW03)
Heidrun Nordfl.	0/12	0/12
Heidrun	1/15 (HEI-06)	1/15 (HEI-06)
Åsgard	0/28	0/28
Njord	5/17 (NJ1, NJ2, NJ9, NJ13, NJ14)	3/17 (NJ1, NJ2, NJ13)
Draugen	1/12 (DR24B)	0/12
Garn West	0/14	0/14

Figure 5.4 shows a cluster dendrogram for all the stations. Njord NJ1, NJ2, NJ13 and REG-02 deviates clearly from the rest of the Njord stations. The REG-04, Heidrun stations HEI-06, and Draugen DR24B, deviates from the large group which contain most of the stations. The Norne stations are all in a separate group, but the correlation between the index calculations and the multivariate analysis is not as clear as for the other stations.

From the index calculations and the evaluation of each of the fields based on diversity, species composition and multivariate analysis the minor influenced area is calculated to be less than 6 km² (0.006%), and less than 12 km² (0.012%) of the region can be viewed as moderately influenced.

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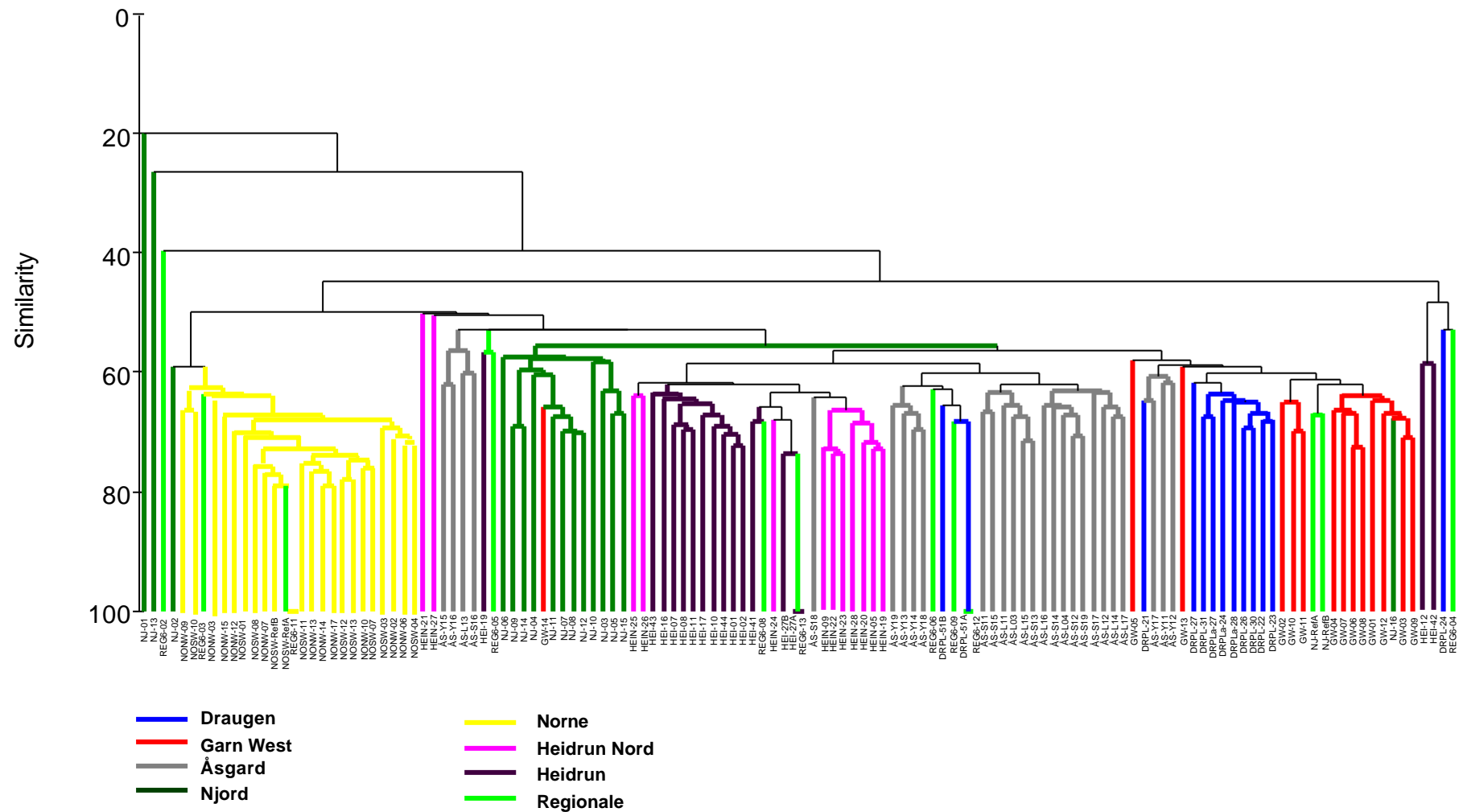


Figure 5.4. Cluster dendrogram were all the stations from the whole region are included.

5.4 Conclusions for Region VI

The 2000 environmental survey at Region VI shows:

- The sediments at Region VI consist mainly of silt and clay (pelite) from 26 % to 98 %. The sediments at Åsgard L, Åsgard Y, Draugen and Garn West contain more sand than the rest of the fields.
- The total organic matter content in the sediments is relatively high, from 2.0 % to 8.2 %.
- The chemical results are in agreement with the drilling history with some exceptions.
- The regional stations and the reference stations are still unaffected by the drilling chemicals - no contamination or elevated concentrations are found in these sediments.
- Relatively high THC levels are found at Norne, Åsgard L and S and Njord. At Åsgard and Njord the concentrations are increased since the previous surveys, while the THC levels at Norne SW are similar to 1997. At these fields elevated THC concentrations are found out to 1000 - 2000m. At Heidrun and Draugen the THC concentrations are lower, and elevated values are only found at some stations out to 500m. Garn West, Åsgard Y and Heidrun Nord are not contaminated by hydrocarbons.
- The presence of decalins gives indication of drilling mud base oil in the sediments.
- At Heidrun base liquids from pseudo-oil based drilling mud (olefins) are only found at one station. Base liquids from ester based drilling mud (Petrofree) are not found. Low concentrations of the base liquids from ether based drilling mud (Aquamul B II) are found in the sediments, and a decrease is observed since 1997.
- Dispersion of drillcuttings and mud is illustrated by the barium results. Elevated Ba concentrations are found out to 2000m distance at all fields. The levels are higher or similar to the 1997 results.
- The concentrations of the heavy metals are low. Elevated levels of Cu, Pb or Zn are only found at three stations.
- Contamination of Cd and Hg are not found.
- Generally Haltenbanken has a healthy fauna and the contamination level is low. An area between 6 and 12 km² is calculated to be biologically affected (based on measurement on 10 installations). The most contaminated area is found around Njord.
- Depth, grain size and diversity show a strong correlation. Fine sediment is found in deep areas, while coarser sediment is found in the shallower areas. Generally lower fauna diversity is found in areas with fine sediment compared to coarser sediment.

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6 RECOMMENDATIONS

Station location

Regional 4 is a station that deviates from the rest of the regional stations, with the lowest value for all the chemical parameters. Regional 4 is not representative for Region VI, and should not be sampled during the next survey.

The reference station at Norne has somewhat lower diversity than other stations at the field, and should be considered before the next survey.

The reference station at Åsgard deviate somewhat from the rest of the stations when it comes to the fauna. The station is therefore not a good reference when investigating influence from the installation on the field.

The reference station at Draugen (regional 7) is not a good reference station for Garn West, since the fauna at regional 7 deviate from the fauna at Garn West.

Calculating LSC values

The LSC value is calculated with a 95% confidence level. In previous surveys, a 99% confidence level have been used, and the results from this survey show that the LSC values becomes too low for some of the parameters. That is, the LSC values are not robust enough to account for the natural variations that occur in the sediment. Based on this conclusion, we suggests that the 99% confidence level is used on a one sided t-test (same as today) when LSC values are calculated.

Unexpected results / discharge

The hydrocarbon (THC and decalins) concentration is found to be elevated on a number of fields without it being possible to trace it to reported discharges. It should be made an effort to find out were the hydrocarbons come from (drilling activity or acute discharge).

Area calculations

A standardised method for calculation the extent of chemical and biological influenced area, should be developed.

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