

# Environmental monitoring survey of oil and gas fields in Region II, 2003

TL 2003/011 – Sediment survey, Region II, 2003

## Summary report



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## **1 Summary**

Esso Exploration and Production Norway AS commissioned, on behalf of the operators in Region II, UNIFOB AS, Seksjon for anvendt miljøforskning in May 2003 to conduct the regional environmental monitoring survey in Region II in the Norwegian sector of the North Sea. All together, the survey comprised 16 fields. The region has previously been surveyed in 1997 and 2000.

M/V *Highland Eagle* left Bergen on May 20 with the representative for the oil companies and the sampling crew onboard. Sampling in Region II commenced at Varg on May 21 and ceased at Odin on June 2. The vessel returned to Bergen on June 5 after the completion of some additional sampling at Gullfaks. Samples were collected at 194 sampling sites, of which 22 sites were regional or fields specific reference sites which were used for describing the natural conditions.

The sediments in the region consisted mainly of fine sand with varying content of pelite (grain size less than 63  $\mu\text{m}$ ). The lowest pelite content was found in the southern and the northern part of the region, whereas sediments with higher pelite content were found in the central part. Tendencies toward increased pelite content in the sediments were found in 2003 as in 2000.

In general, the highest concentrations of the measured chemical compounds were found in the sediments from the immediate vicinity of the field centres. Faunal disturbances were also found in the immediate vicinity of some field centres.

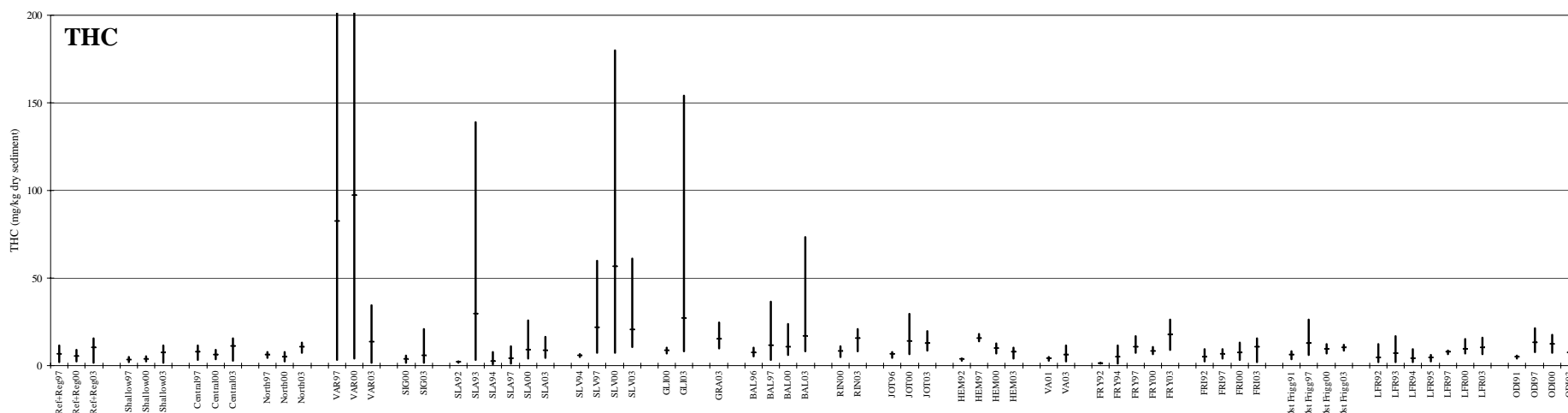
Estimated minimum area ( $\text{km}^2$ ) of THC contamination in the sediments had increased at 7 fields, decreased at 6 fields, and remained at the same level as in 2000 at 2 fields. At one field the area was not estimated in 2003. The total area with THC contaminated sediments increased in Region II from 5.27  $\text{km}^2$  in 2000 to 8.87  $\text{km}^2$  in 2003.

Estimated minimum area ( $\text{km}^2$ ) of Ba contamination in the sediments had decreased at 9 fields, increased at 6 fields, and remained at the same level as in 2000 at 1 field. Since 2000, the total area with barium contaminated sediments decreased from 19.09  $\text{km}^2$  to 14.32  $\text{km}^2$ .

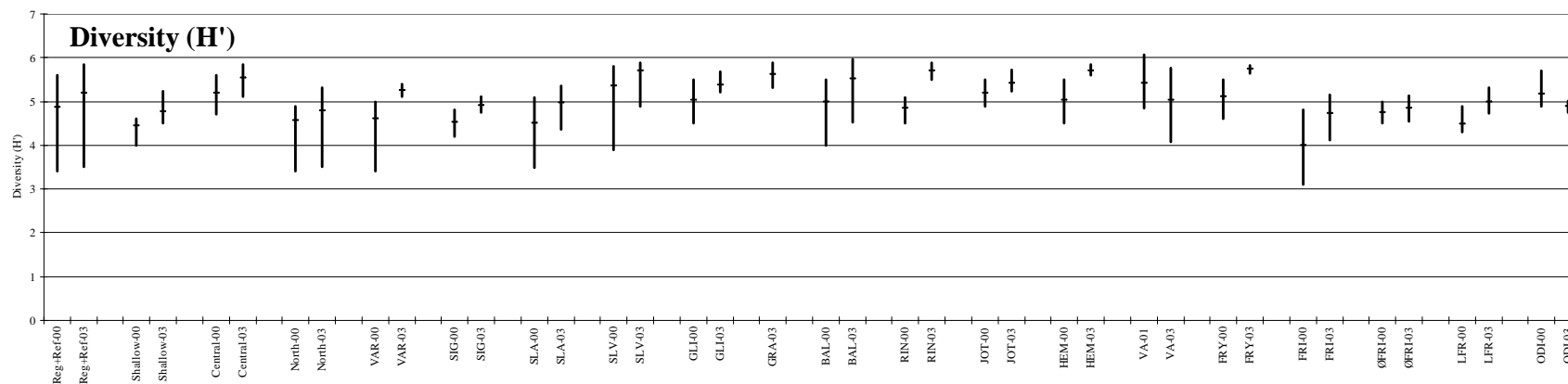
The area ( $\text{km}^2$ ) contaminated with other metals in the sediments increased at 8 fields, and decreased at 4 fields and remained at the same level at 2 fields since 2000. At one field the area was not estimated in 2003. The increase was mainly caused by zinc. Since 2000 the total area contaminated with other metals increased from 2.10  $\text{km}^2$  to 6.50  $\text{km}^2$ .

Faunal disturbance was found at 7 fields, whereas no faunal disturbance was found at the remaining 9 fields. The total area suffering faunal disturbance in the region was reduced from 1.21  $\text{km}^2$  to 0.29  $\text{km}^2$ .

Roughly estimated the total area of Region II is 44 700  $\text{km}^2$ . Approximately 23 000  $\text{km}^2$  are located to the west of the Norwegian trench, where also the surveyed fields are located. Based on these estimates approximately 0.04 % of the area west of the trench was contaminated by THC, 0.06 % was contaminated by Ba and 0.03 % was contaminated by other metals, whereas 0.001 % of the area had some faunal disturbance.



**Figure 1.1.** The average and range of THC at each field in Region II 2003 compared to previous surveys and the THC content at the regional and reference sites. Some values outside ordinate range.



**Figure 1.2.** Average and range of diversity ( $H'$ ) at the reference and regional sampling sites and at the petroleum fields in Region II in 2000 and 2003.

**Table 1.1.** Estimated minimum area (km<sup>2</sup>) of contaminated sediments and disturbed fauna in Region II 1997 – 2003. n.a. = not analyzed.

Field	Year	THC	Ba	Other metals	Fauna
Varg	1997	1.18	0.10	0.00	0.00
Varg	2000	1.33	1.77	0.25	0.15
Varg	2003	0.07	0.20	0.20	0.05
Sigyn	1997	n.a.	n.a.	n.a.	n.a.
Sigyn	2000	0.00	0.00	0.00	0.00
Sigyn	2003	0.02	0.20	0.02	0.00
Sleipner Øst	1997	0.07	13.80	0.07	0.36
Sleipner Øst	2000	0.40	2.21	0.00	0.00
Sleipner Øst. Lok and Sla	2003	0.44	0.83	0.07	0.05
Sleipner Vest	1997	0.88	3.14	3.14	0.00
Sleipner Vest	2000	0.74	3.14	0.74	0.07
Sleipner Vest	2003	0.79	3.53	0.10	0.03
Glitne	1997	n.a.	n.a.	n.a.	n.a.
Glitne	2000	0.00	0.00	0.00	0.00
Glitne	2003	0.88	3.14	0.79	0.00
Hermod (Grane)	1997	0.18	0.37	0.00	0.00
Grane	2000	n.a.	n.a.	n.a.	n.a.
Grane	2003	0.10	0.98	0.05	0.00
Balder	1997	1.09	2.93	0.37	0.48
Balder	2000	0.54	4.21	0.15	0.37
Balder	2003	2.38	0.43	4.13	0.04
Ringhorne	1997	n.a.	n.a.	n.a.	n.a.
Ringhorne	2000	0.00	0.00	0.00	0.00
Ringhorne	2003	3.93	0.74	0.00	0.00
Jotun	1997	0.00	0.00	0.00	0.00
Jotun	2000	1.77	5.30	0.07	0.00
Jotun	2003	n.a.	1.47	n.a.	0.00
Heimdal	1997	0.25	0.25	0.25	0.11
Heimdal	2000	0.12	0.43	0.29	0.18
Heimdal	2003	0.00	0.08	0.15	0.05
Vale	1997	n.a.	n.a.	n.a.	n.a.
Vale	2000	n.a.	n.a.	n.a.	n.a.
Vale	2003	0.00	1.77	0.39	0.00
Frøy	1997	0.29	1.18	0.00	0.29
Frøy	2000	0.07	1.18	0.15	0.29
Frøy	2003	0.20	0.74	0.10	0.02
Frigg	1997	0.00	0.08	0.36	0.13
Frigg	2000	0.06	0.08	0.36	0.12
Frigg	2003	0.06	0.05	0.36	0.05
Øst Frigg	1997	0.11	0.33	0.00	0.07
Øst Frigg	2000	0.07	0.18	0.00	0.00
Øst Frigg	2003	0.00	0.02	0.02	0.00
Lille Frigg	1997	0.00	0.32	0.00	0.00
Lille Frigg	2000	0.15	0.59	0.07	0.00
Lille Frigg	2003	0.00	0.20	0.10	0.00
Odin	1997	0.02	0.01	0.02	0.02
Odin	2000	0.02	0.00	0.02	0.03
Odin	2003	0.00	0.00	0.03	0.00
Total area	1997	4.07	22.51	4.21	1.39
Total area	2000	5.27	19.09	2.10	1.21
Total area	2003	8.87	14.32	6.50	0.29

## 2 Introduction

In May 2003, Statoil ASA, Norsk Hydro Produksjon as, Esso Exploration and Production Norway AS, Total Exploration Norge AS and Pertra AS commissioned Seksjon for anvendt miljøforskning (SAM) to do the 2003 environmental monitoring survey of Region II in the Norwegian sector of the North Sea (Agreement Number 4500149607) (Figure 2.1 and Figure 2.2). This is the third regional survey of Region II. The first took place in 1997 (Mannvik & al. 1998) and the second in 2000 (Mannvik & al. 2001). Prior to the regional surveys, smaller field specific surveys had been carried out.

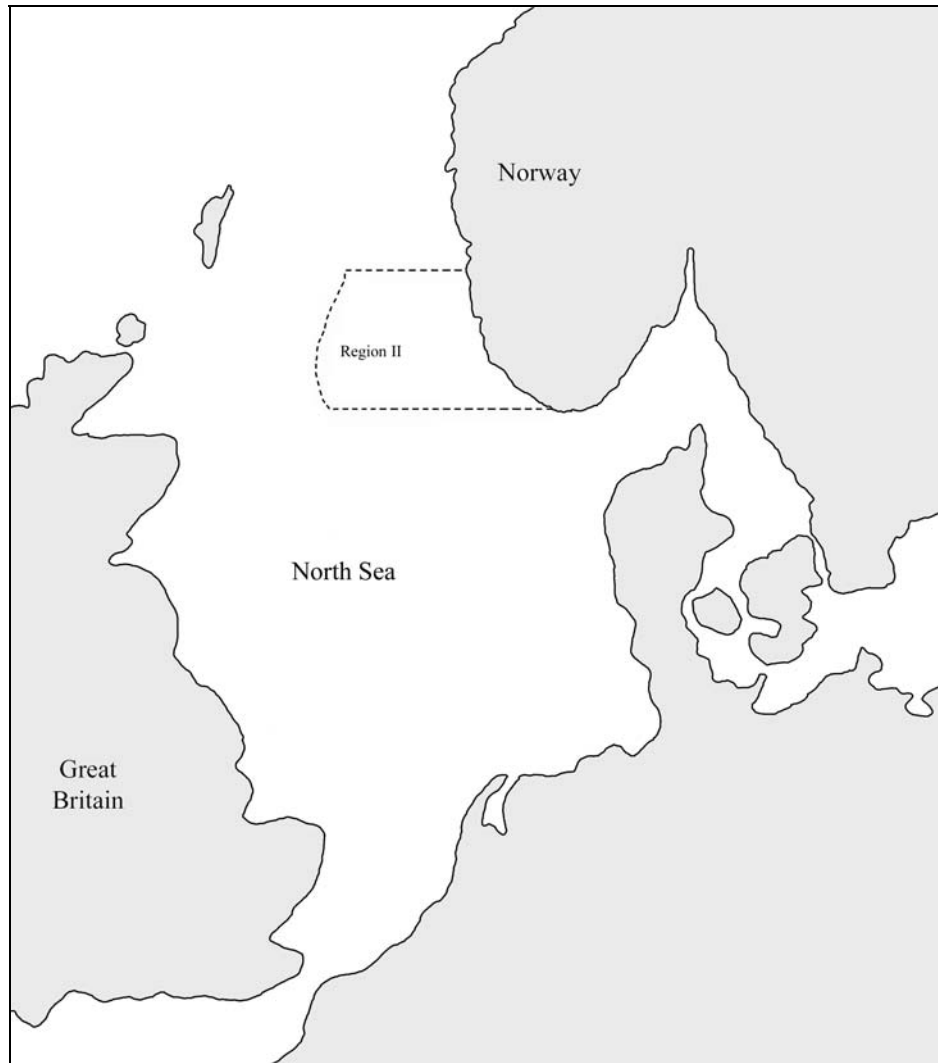
The purpose of this survey was to assess the environmental conditions at regional sampling sites and at 16 different oil and gas fields situated within the region (Table 2.1), and compare the results from the 2003 survey with previous environmental surveys.

**Table 2.1.** Brief summary of operators, fields, and number of sampling sites at each field surveyed in Region II in 2003.

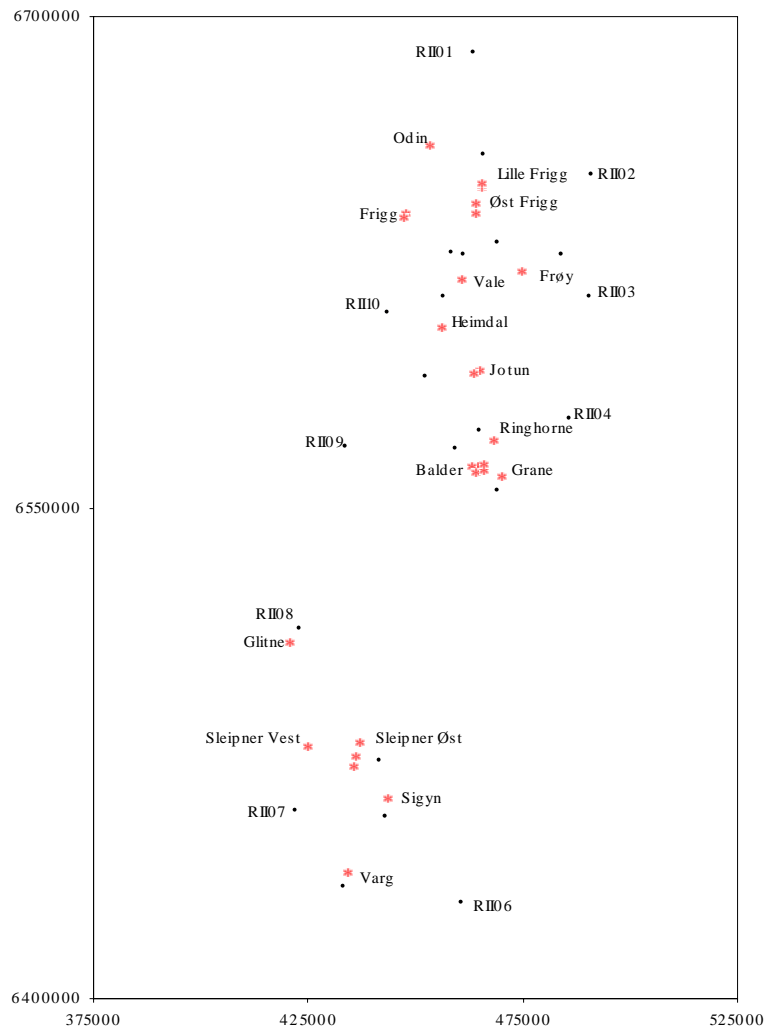
Operator	Field	Number of sampling sites	Status of the field
Statoil	Glitne	11	Active
	Sleipner vest	10	Active
	Sleipner øst (SLE, SLA, Loke)	16	Active
Norsk Hydro	Vale	12	Active
	Grane	13	Under construction
	Heimdal	8	Active
ExxonMobil	Sigyn	14	Active
	Balder	29	Active
	Jotun	14	Active
	Ringhorne	14	Active
	Odin	6	Abandoned August 1994
Total	Frigg	9	Active
	Øst Frigg	5	Abandoned December 1997
	Lille-Frigg	8	Abandoned March 1999
	Frøy	8	Abandoned March 2001
Pertra	Skirne*		Baseline survey in 2002
	Varg	12	Active
	Regional sites	9	Reference

\*A baseline survey was undertaken at the Skirne field in 2002. The drilling at the field comprise one well at Skirne and one well at the nearby Bygve. The wells were drilled from February to ultimo June 2003. Since the final decision on start up date for drilling and duration of drilling was not made when planning the regional survey of 2003 Skirne was not included in this survey. Skirne will be surveyed during 2006.

In addition to the sampling listed above 30 sites at Gullfaks were sampled during the same cruise. The results of that survey are given in a separate report.



**Figure 2.1.** Map showing the location of Region II in the Norwegian sector of the North Sea.



Site	ED50 UTM Zone 31		Depth (m)	Site	ED50 UTM Zone 31		Depth (m)
	E	N			E	N	
RII01	463281	6688937	115	VAR14R	433187	6434316	85
RII02	490795	6651639	118	SIG17R	443211	6455657	80
RII03	490702	6614517	119	SLE41R	441623	6472715	81
RII04	485867	6577412	118	GRA14R	469297	6554935	128
RII06	460684	6429120	77	BAL27R	459203	6567845	126
RII07	421831	6457534	101	RIN29R	465101	6573496	129
RII08	422936	6513198	111	JOT30R	452182	6590203	127
RII09	433551	6568688	119	HEM22R	456430	6614401	121
RII10	443670	6609362	122	VA13R	461199	6627052	114
				FRY18R	483795	6627075	118
				FRI10R	458362	6627966	116
				PSB13R	469290	6630899	116
				LFR01R	465976	6657599	116

**Figure 2.2.** Map showing the internal distribution of petroleum fields and the regional sampling sites in Region II. Positioning according to UTM ED50 zone 31.



### **3 Material and methods**

Region II is located approximately between 58° and 60° N in the North Sea. The total area of the region is estimated to 44 700 km<sup>2</sup>. The water depth in the sampling area varies between 79 and 130 meters, and the sediments consist mainly of sand. Offshore oil and gas production in this part of the North Sea started in September 1977 at Frigg.

Sediment samples were collected from M/V *Highland Eagle* by van Veen grabs with openings of 0.1 m<sup>2</sup>. In total, 189 field sites (including 13 reference sites) and 9 regional sites were sampled. The samples were used for sediment description, and determination of chemical content (THC, copper, chromium, zinc, barium, cadmium and lead, and sometimes mercury, PAH, NPD, decalins and olefins) in the sediments. The bottom fauna was also identified at each sampling site. Sampling commenced at the southernmost regional sampling site RII06 on May 21 and ceased at the northernmost regional sampling site RII01 on June 2, 2003.

#### 4 Regional and reference sites

The results from the regional and field specific reference sites are considered to indicate uncontaminated sediments and undisturbed bottom fauna, as well as describing the natural variation of the sea floor in the region in 2003 (Table 4.1, see also Figure 2.2).

As shown in previous surveys, the sediment in Region II varies from sandy in the shallow (77-85 m) waters in the south to fine sediments in the deeper (101-130 m) central and northern parts of the region. Compared to the survey in 2000, there were no major changes in the sediment characteristics such as grain size and TOM.

Among the regional and field specific reference sites, the total hydrocarbon content (THC) in the sediments varied from <3.0 to 15.5 mg/kg dry sediment. The barium content varied from 4 to 146 mg/kg. Copper, chromium, zinc, lead, cadmium and mercury were found respectively in the ranges 0.3-1.7, 3.7-9.2, 5.5-12.0, 2.1-5.7, <0.03-0.04 and 0.004-0.014 mg/kg dry sediment.

The THC content in the sediments had increased since 2000 at most sites, except at the reference sites at Sigyn and Heimdal where it had decreased, and at the regional site RII04 where it was at the same level.

In general, the content of barium, copper, lead and mercury were lower in 2003 than in 2000, whereas the zinc content was higher. Cadmium was generally below the limit of detection (0.03 mg/kg) in 2003.

A PCA analysis comparing the sampling sites on metal content and THC in the sediments, grouped the sites into three distinct groups. The first group comprised the sites from the shallow waters in the south (RII06, VAR14R, SIG17R, and SLE41R), whereas the second group comprised the sites in the central part of Region II (RII03, RII04, RII07/SLV, RII08/GLI, RII09, GRA14R, BAL27R, RIN29R, JOT30R, HEM22R and FRY18R) and the third group comprised the sites in the northern part of the region (RII01, RII02, VA13R, FRI10R, PSB13R and LFR01R). The sites in the central part generally had higher content of metals and THC than the sites in the shallow and northern parts. Based on this result, values for Least Significant Contamination (LSC) were calculated for the THC and metals for all three parts of Region II, as well as for the whole region and each field specific reference site.

The fauna samples contained 375 taxa and more than 27 000 individuals. The highest numbers of taxa and individuals were found in the central and northern parts of the region. The species diversity was high, but almost the same as in 2000. As in 2000, variation in the species assemblages was found among the sites. Most of the variation in the species data could be explained by the variation in water depth at the sampling sites and the TOM, barium and lead content in the sediments. In the shallow south, the brittle star *Amphiura filiformis*, the polychaeta *Scoloplos armiger* and the crustacean *Eudorellopsis deformis* were common species, whereas the polychaetes *Owenia fusiformis* and *Myriochele oculata*, and the brittle star *Amphiura filiformis* were common species in the northern part. The polychaetes *Myriochele oculata* and *Paramphinome jeffreysi*, the bivalves *Thyasira croluensis* and *Thyasira equalis* were more common in the deeper central part of the region.

**Table 4.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on the regional and reference sites in Region II. Positioning according to UTM ED50 zone 31.

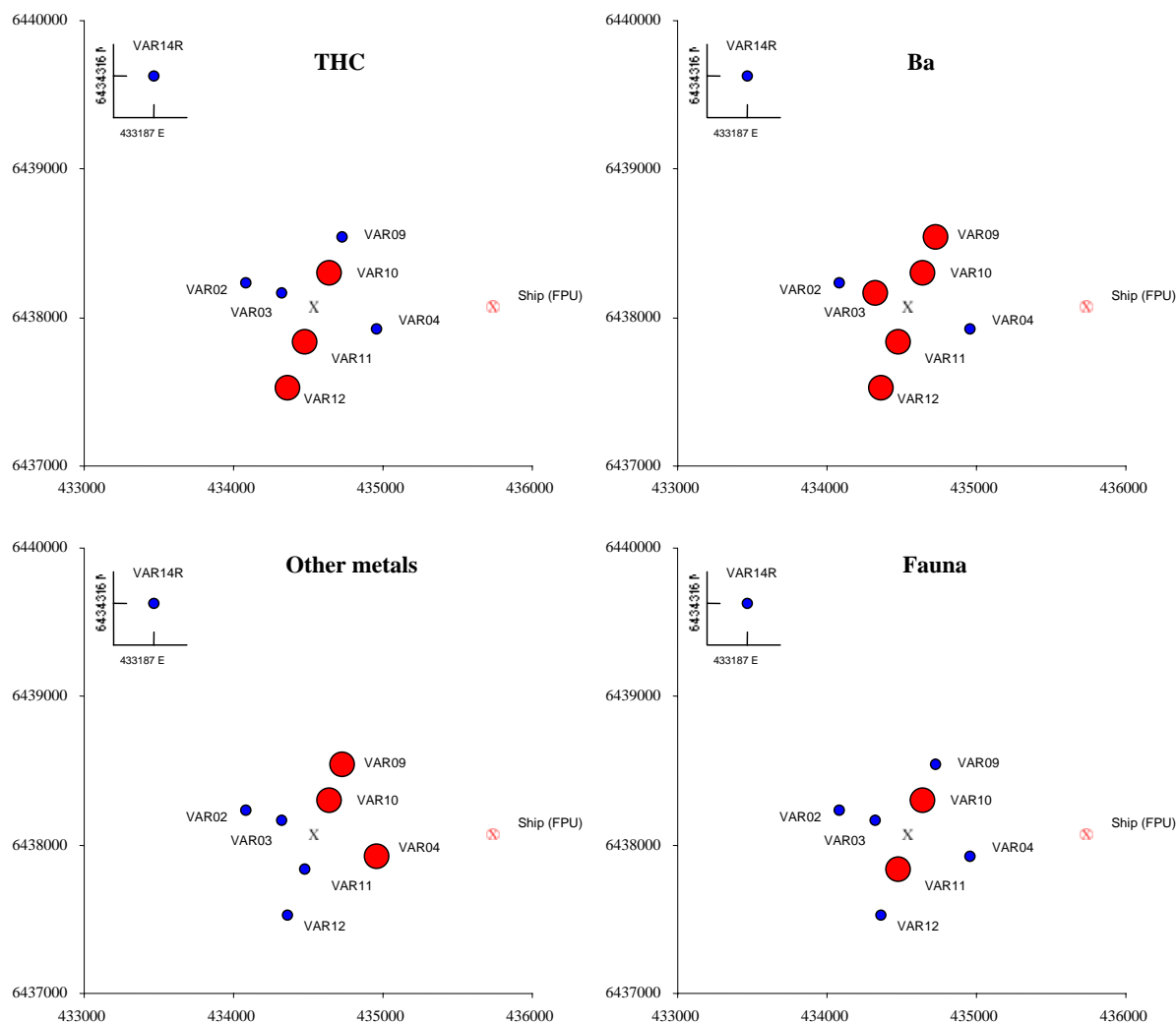
Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
RII01	463281	6688937	1.19	4.17	13.2	0.8	5.4	6.3	18	2.1	574	80	5.16
RII02	490795	6651639	0.93	4.23	9.4	0.5	3.8	6.1	26	2.2	1749	104	3.51
RII03	490702	6614517	1.42	9.97	15.5	1.1	5.6	9.3	63	3.7	1202	136	5.85
RII04	485867	6577412	0.73	3.04	2.9	0.3	4.9	6.8	10	3.6	580	116	5.52
RII06	460684	6429120	0.69	2.05	7.3	0.3	6.3	5.9	4	4.1	268	47	4.50
RII07	421831	6457534	1.16	5.61	13.8	0.6	8.5	9.6	41	4.4	488	94	5.12
RII08	422936	6513198	1.92	12.56	14.2	1.4	8.9	12.0	146	5.1	525	98	5.23
RII09	433551	6568688	1.55	9.60	10.0	1.0	7.0	9.0	53	3.5	692	109	5.61
RII10	443670	6609362	1.89	15.35	10.2	1.3	6.1	9.7	65	3.8	982	141	5.76
VAR14R	433187	6434316	0.90	3.38	11.3	0.4	7.6	7.4	18	5.2	255	65	5.23
SIG17R	443211	6455657	0.57	2.90	1.5	0.3	7.9	5.8	8	4.9	270	53	4.63
SLE41R	441623	6472715	0.51	1.03	5.1	0.3	9.2	7.2	7	5.7	181	49	4.73
GRA14R	469297	6554935	2.05	13.30	12.5	1.3	7.3	9.4	72	4.6	533	104	5.69
BAL27R	459203	6567845	2.16	14.89	15.2	1.4	8.0	9.4	72	4.3	699	116	5.68
RIN29R	465101	6573496	2.18	17.04	12.6	1.7	7.7	10.7	67	5.0	733	102	5.23
JOT30R	452182	6590203	2.19	21.77	12.0	1.7	7.2	10.6	61	4.6	885	109	5.47
HEM22R	456430	6614401	1.66	15.99	6.8	1.4	6.5	8.5	74	3.7	989	125	5.76
VA13R	461199	6627052	0.68	2.85	7.4	0.5	3.7	5.9	18	2.5	643	82	4.81
FRY18R	483795	6627075	1.62	10.74	9.5	1.0	5.6	8.0	67	3.4	986	113	5.66
FRI10R	458362	6627966	1.04	5.77	11.3	0.5	4.5	5.5	37	2.8	932	109	4.89
PSB13R	469290	6630899	0.95	5.95	11.3	0.7	4.4	5.6	41	2.7	870	97	5.02
LFR01R	465976	6657599	1.17	5.98	11.2	0.8	5.6	6.0	34	2.5	750	102	5.31

## 5 Varg

The Varg field is situated in block 15/12. Production started at Varg in December 1998. A baseline survey was carried out in 1997 and was followed by an ordinary monitoring survey in 2000. There has been no drilling or discharges at Varg since 1999. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite (Table 5.1) and decrease in TOM content since 2000. The amounts of THC, barium and most metals, except zinc, have decreased since 2000. More taxa and individuals were found in the bottom fauna in 2003 than in 2000, and the diversity of the fauna was high. Comparisons of fauna assemblage showed that the innermost (250 m distance) sampling sites to the north and to the south were slightly disturbed (Figure 5.1). The measured chemical compounds occurred in highest concentrations at the same two sites. The fauna assemblages were well correlated to the distribution of THC, copper and TOM, which show that the activity at Varg had some environmental influence in the immediate vicinity of the installation. The area of impact was smaller in 2003 than in 2000.

**Table 5.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
VAR02	434090	6438231	0.74	2.70	4.8	0.5	8.2	6.9	22	5.7	241	65	5.22
VAR03	434325	6438160	0.73	2.88	7.3	0.6	8.7	7.2	54	6.7	285	70	5.29
VAR04	434959	6437919	0.60	1.62	1.5	0.3	8.1	7.2	21	7.1	301	69	5.39
VAR09	434733	6438543	0.61	2.48	7.1	0.6	9.1	8.3	88	7.4	242	60	5.15
VAR10	434640	6438300	0.75	3.11	25.8	0.8	9.1	9.8	229	7.2	162	52	5.24
VAR11	434478	6437835	0.72	3.15	34.5	0.8	9.0	8.7	208	6.6	206	56	5.11
VAR12	434367	6437523	0.69	2.55	12.3	0.5	8.3	7.1	69	6.9	355	72	5.33
VAR14R	433187	6434316	0.90	3.38	8.6	0.4	7.6	7.4	18	5.2	255	65	5.23



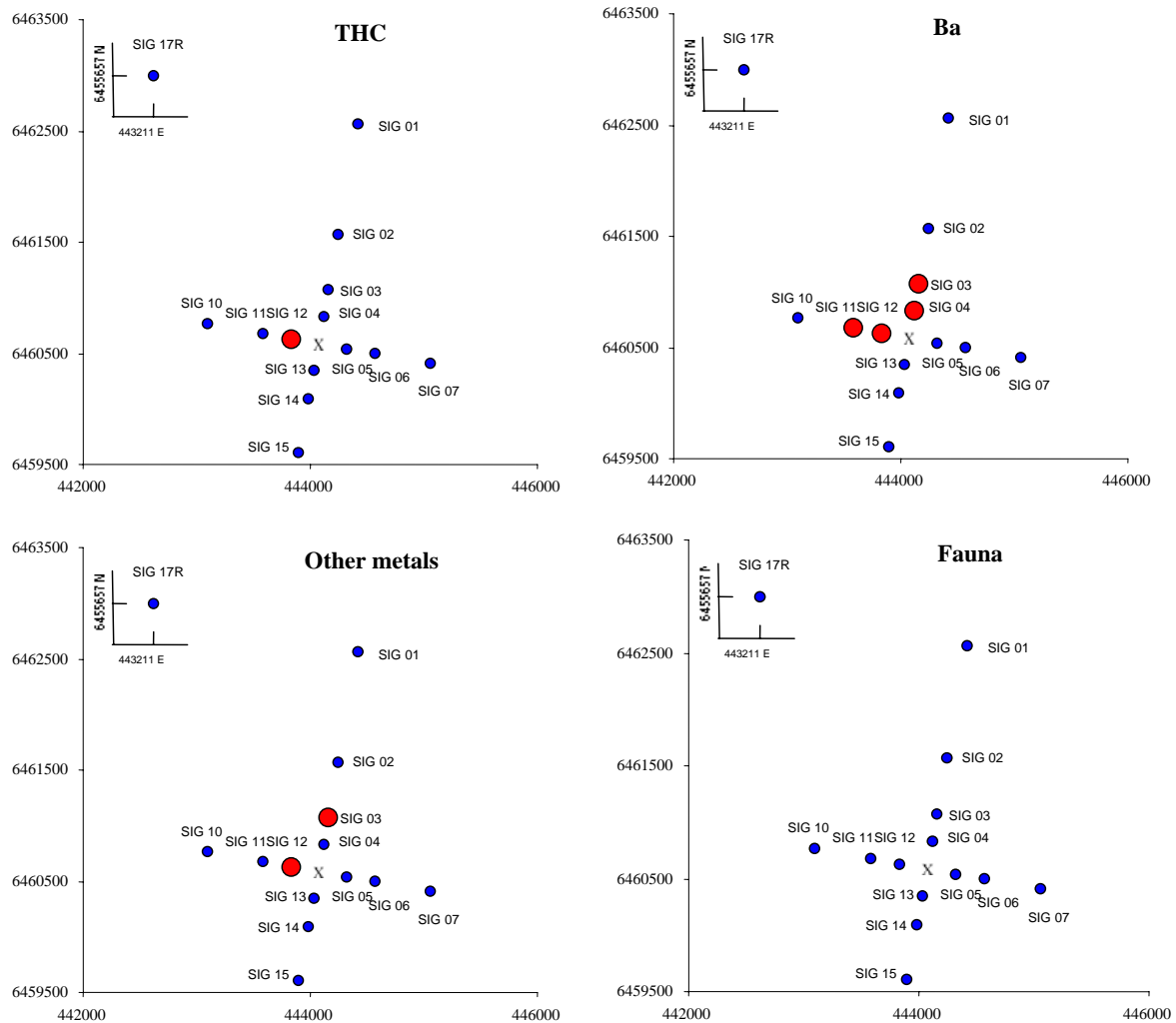
**Figure 5.1.** Faunal disturbance and chemical contamination of the sediments at Varg in 2003, are marked with large red circles. The field centre and ship (FPU) are marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## 6 Sigyn

The Sigyn field is situated in block 16/7, and production started in 2003. A baseline survey was undertaken in 2000. During 2002 three new wells were drilled at Sigyn. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite (Table 6.1) and decrease in TOM content since 2000. The amounts of THC and barium had increased at the sampling sites toward the north and the west (Figure 6.1). The largest increase was found closest to the installation. The other metals were at the same level as in the baseline survey of 2000, except for chromium which occurred above LSC at two sites. Species diversity was at the same levels as in 2000 and the fauna was found to be homogenous at the sampling sites and there was no strong association between the distribution of fauna and chemical compounds at Sigyn. The activity at Sigyn has so far not lead to any faunal disturbance in the sampling area, although the area of contamination was larger in 2003 than in 2000.

**Table 6.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
SIG01	444426	6462551	0.50	2.44	5.2	0.3	9.2	5.9	8	5.2	298	51	4.74
SIG02	444253	6461566	0.49	3.41	3.7	0.3	9.5	6.0	20	5.4	325	59	4.97
SIG03	444166	6461073	0.41	2.20	7.1	0.3	10.3	6.3	43	5.2	229	53	4.84
SIG04	444122	6460827	0.42	2.23	7.0	0.3	9.5	6.3	71	5.6	291	52	4.97
SIG05	444325	6460538	0.79	2.79	2.5	0.3	9.5	6.0	10	5.4	300	57	4.88
SIG06	444571	6460494	0.53	2.01	1.5	0.3	9.5	5.9	8	5.6	340	58	4.87
SIG07	445064	6460407	0.49	2.34	2.3	0.3	9.4	6.1	8	5.5	348	56	4.88
SIG10	443094	6460755	0.47	2.23	2.2	0.3	9.5	7.3	10	5.2	260	67	4.97
SIG11	443587	6460668	0.45	2.25	5.3	0.6	9.6	6.1	43	5.4	251	52	4.85
SIG12	443833	6460624	0.54	2.59	20.9	0.3	11.0	6.9	61	5.9	225	53	5.12
SIG13	444036	6460335	0.43	1.98	5.3	0.3	9.9	6.2	14	5.9	309	60	5.10
SIG14	443992	6460089	0.52	2.54	4.7	0.3	9.0	6.4	18	5.4	325	62	4.92
SIG15	443905	6459596	0.48	2.85	7.0	0.3	9.7	6.2	8	5.7	274	53	4.75
SIG17R	443211	6455657	0.57	2.90	1.5	0.3	7.9	5.8	8	4.9	270	53	4.63



**Figure 6.1.** Faunal disturbance and chemical contamination of the sediments at Sigyn in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

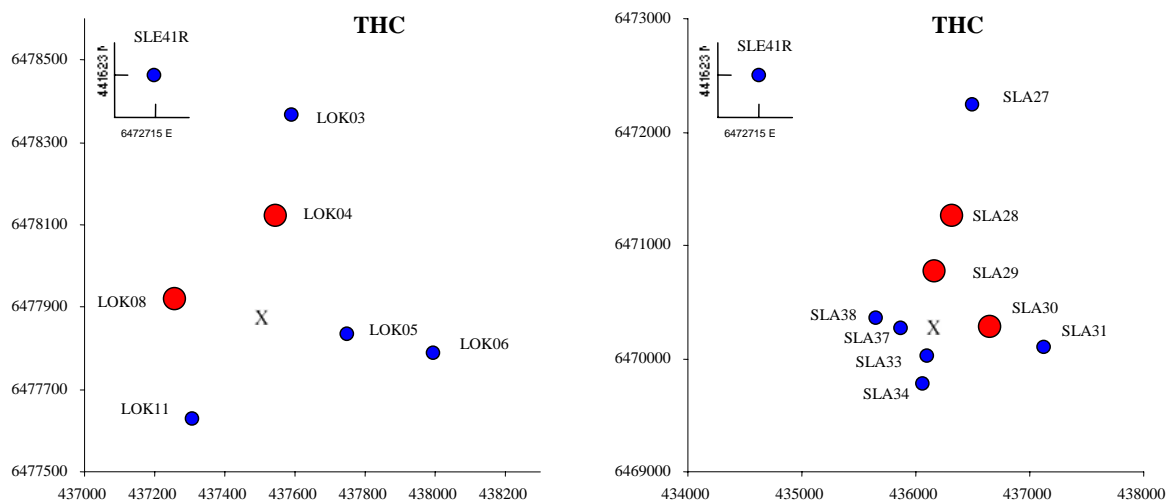
## 7 Sleipner Øst

The Sleipner Øst field which is situated in block 15/9, includes the Sleipner A platform (SLA) and the two templates Loke and Sleipner Øst. Production at Sleipner Øst started in August 1993. Monitoring of the Sleipner Øst was undertaken in 1992, 1993, 1997 and 2000. Since the last survey at Sleipner Øst in 2000 five new wells have been drilled. The sediments are still characterized as fine sand, although there has been a slight decrease in the pelite (Table 7.1) and in TOM content since 2000 except at SLA29 and at SLA38, north of Sleipner A, where the TOM content increased. The amounts of olefins, barium, copper and lead in the sediments had decreased since 2000, whereas the zinc content had increased. The THC content had decreased or was approximately at the same level as in 2000. The species diversity was approximately the same in 2000 and 2003, except at SLA33 and SLA37, 250 m to the south and west of Sleipner A, where it decreased. The measured chemical compounds did not occur in particularly high concentrations at SLA33 and SLA37 although the distribution of fauna was best correlated to the distribution of zinc, barium, lead and chromium (Figure 7.1). Since 2000 there was a slight increase in total area of sediments contaminated by THC and other

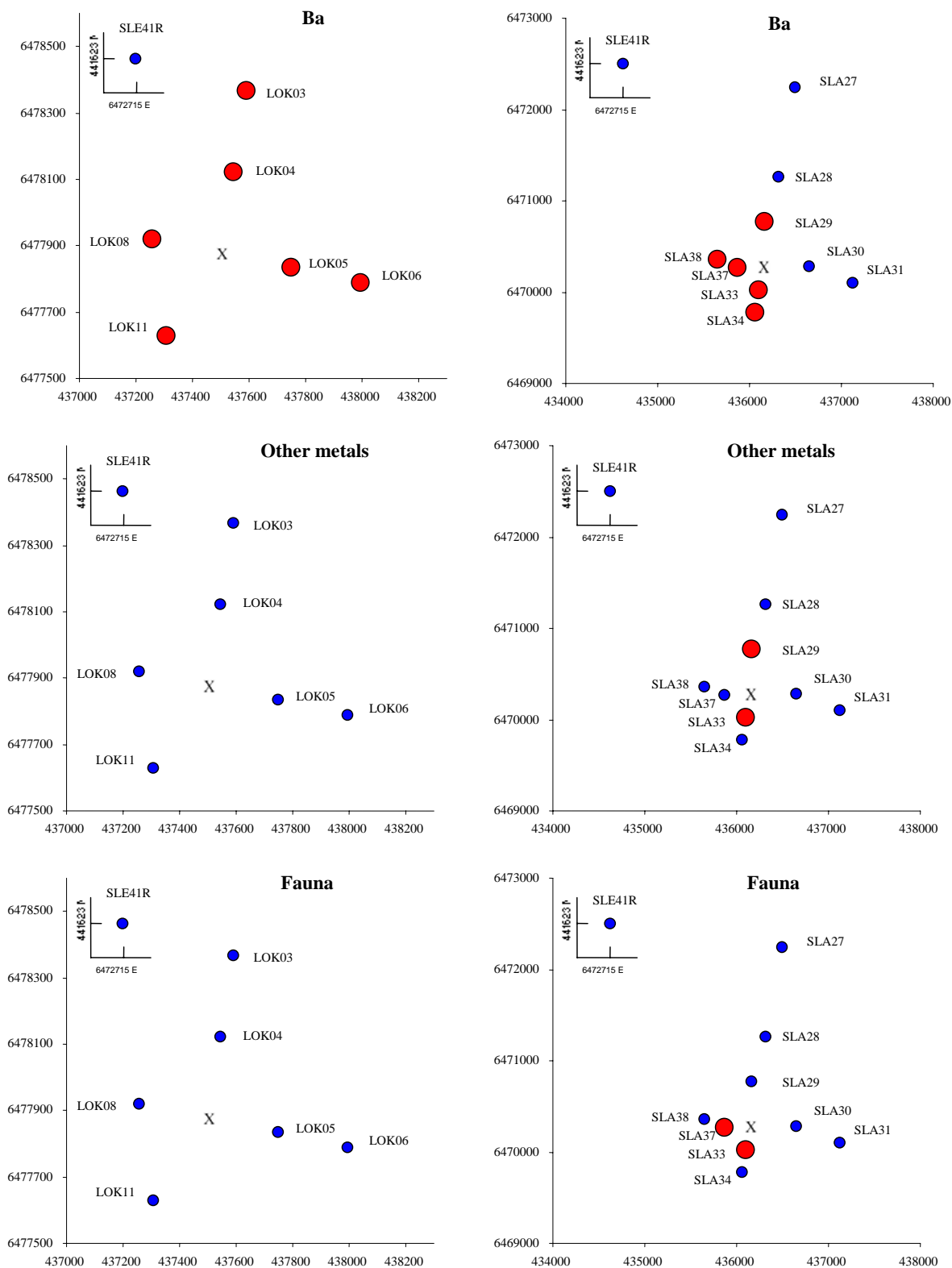
metals as well as in the total area with some faunal disturbance. The total area with barium contaminated sediments was smaller in 2003 than in 2000.

**Table 7.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
LOK03	437590	6478367	0.58	1.70	8.8	0.5	7.2	7.9	173	5.2	296	56	4.90
LOK04	437546	6478121	0.63	2.70	16.3	0.8	7.2	8.5	393	5.7	294	63	5.03
LOK05	437749	6477832	0.68	2.27	7.3	0.5	7.0	6.9	178	5.0	356	59	4.88
LOK06	437995	6477788	0.57	1.54	6.4	0.5	6.8	7.4	61	4.8	307	68	5.11
LOK08	437257	6477918	0.78	2.26	9.2	0.4	6.3	5.9	103	4.8	391	67	5.21
LOK11	437309	6477629	0.61	2.21	4.3	0.3	6.4	6.1	64	4.5	289	59	5.03
SLA27	436497	6472241	0.70	1.80	7.3	0.3	8.3	6.8	28	4.8	273	60	4.98
SLA28	436323	6471256	0.53	1.26	4.2	0.3	7.7	7.9	50	4.2	294	70	5.36
SLA29	436166	6470763	0.83	2.55	6.4	1.0	8.0	12.5	155	5.2	247	49	4.86
SLA30	436650	6470271	0.66	1.40	4.2	0.3	7.5	7.9	37	4.6	326	59	4.96
SLA31	437134	6470097	0.59	1.51	4.0	0.3	8.2	7.7	17	4.7	262	52	4.84
SLA33	436106	6470025	0.66	1.52	6.5	0.8	7.8	9.9	125	5.4	269	45	4.36
SLA34	436063	6469779	0.54	1.06	4.3	0.3	7.2	8.0	62	4.5	297	58	5.03
SLA37	435873	6470264	0.61	1.17	5.2	0.5	8.0	8.6	77	4.6	295	49	4.82
SLA38	435657	6470358	0.85	1.11	4.5	0.4	7.9	7.9	54	4.8	384	65	5.13
SLE41R	441623	6472715	0.51	1.03	5.1	0.3	9.2	7.2	7	5.7	181	49	4.73



**Figure 7.1.** Faunal disturbance and chemical contamination of the sediments at Sleipner Øst in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.



**Figure 7.1.** continue. Faunal disturbance and chemical contamination of the sediments at Sleipner Øst in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

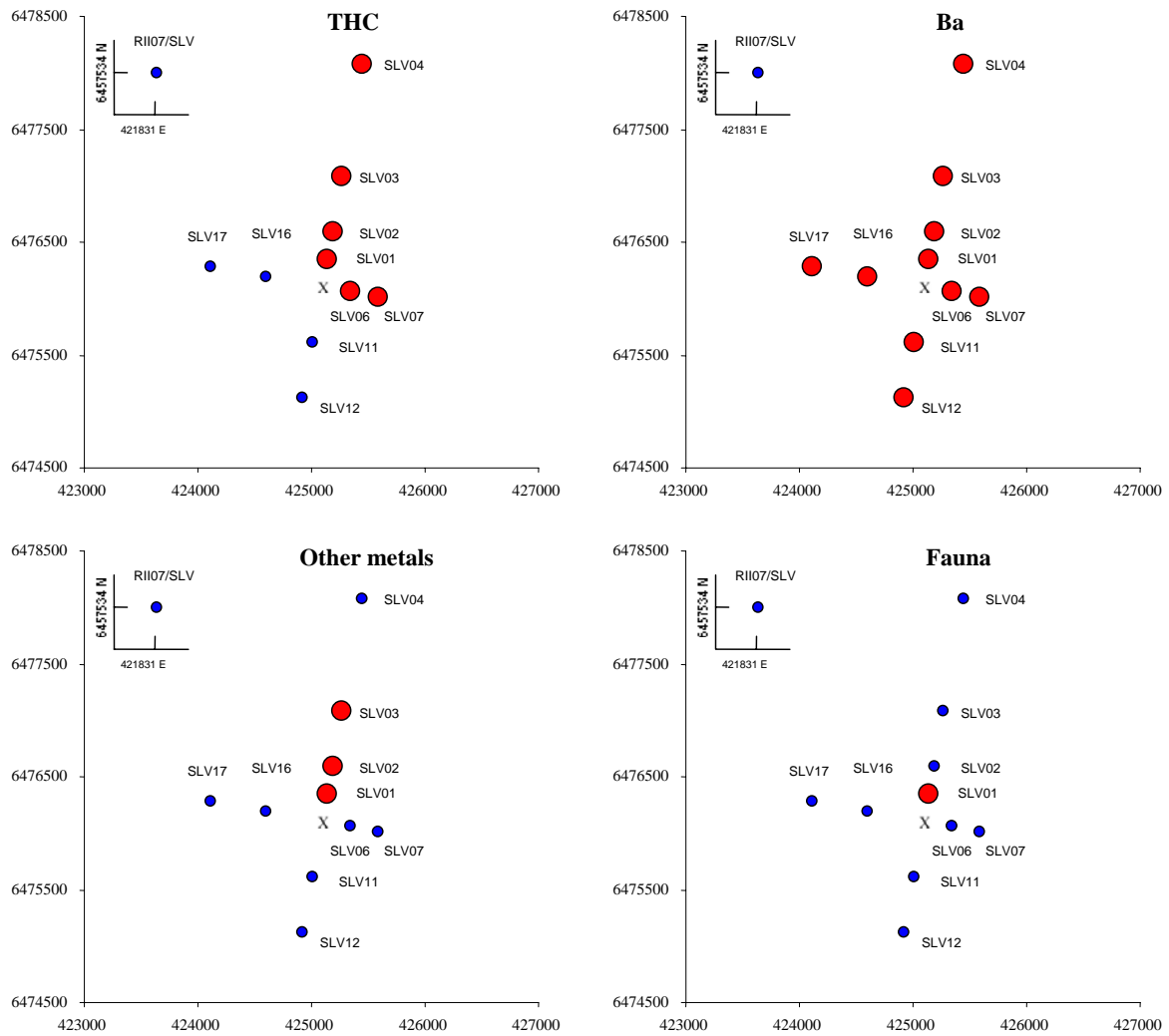


## 8 Sleipner Vest

The Sleipner Vest field is situated in block 15/6, west of the Sleipner Øst field. Production started at Sleipner Vest in August 1996. The baseline survey was carried out in 1994. Monitoring surveys were carried out in 1997 and 2000. There has been no drilling or discharges at Sleipner Vest since 2000. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite (Table 8.1) and decrease in TOM content since 2000. The amounts of THC, barium and metals in the sediments have decreased since 2000. More taxa were found in the bottom fauna in 2003 than in 2000, and the diversity of the fauna was high. Comparisons of fauna assemblage showed that the innermost (250 m distance) sampling site to the north was disturbed (Figure 8.1). The measured chemical compounds occurred in high concentrations at the same site. The fauna assemblage was well associated to the distribution of TOM, THC, copper and sand, which show that the activity at Sleipner Vest have some environmental influence in the immediate vicinity of the installation. The area contaminated by THC and barium was somewhat larger in 2003 than in 2000, whereas the area contaminated by other metals was somewhat smaller. The area with faunal disturbance was also somewhat smaller in 2003 than in 2000.

**Table 8.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
SLV01	425143	6476347	2.5	24.8	61.3	5.4	10.2	28.2	326	8.1	465	78	4.90
SLV02	425186	6476593	2.1	15.2	22.4	2.3	8.5	14.9	328	5.7	716	101	5.60
SLV03	425273	6477086	1.6	12.4	16.1	1.5	8.1	12.9	180	5.0	727	114	5.84
SLV04	425446	6478071	1.9	15.2	15.3	1.3	8.2	11.0	163	5.3	629	106	5.83
SLV06	425345	6476058	2.2	13.9	19.8	1.5	8.7	11.4	288	4.7	711	123	5.88
SLV07	425592	6476014	1.8	13.5	18.6	1.4	8.3	10.4	165	5.0	829	109	5.83
SLV11	425012	6475609	1.8	13.6	14.3	1.5	8.7	10.6	312	4.9	514	102	5.66
SLV012	424926	6475116	1.9	15.9	13.8	1.5	8.9	11.2	193	5.0	608	107	5.78
SLV016	424607	6476188	2.2	14.1	13.6	1.5	8.8	12.1	387	4.8	606	111	5.89
SLV017	424114	6476275	1.7	14.7	10.6	1.1	8.3	10.8	169	4.3	564	106	5.85
RII07/SLV	421831	6457534	1.16	5.61	13.8	0.6	8.5	9.6	40	4.4	489	93.5	5.11



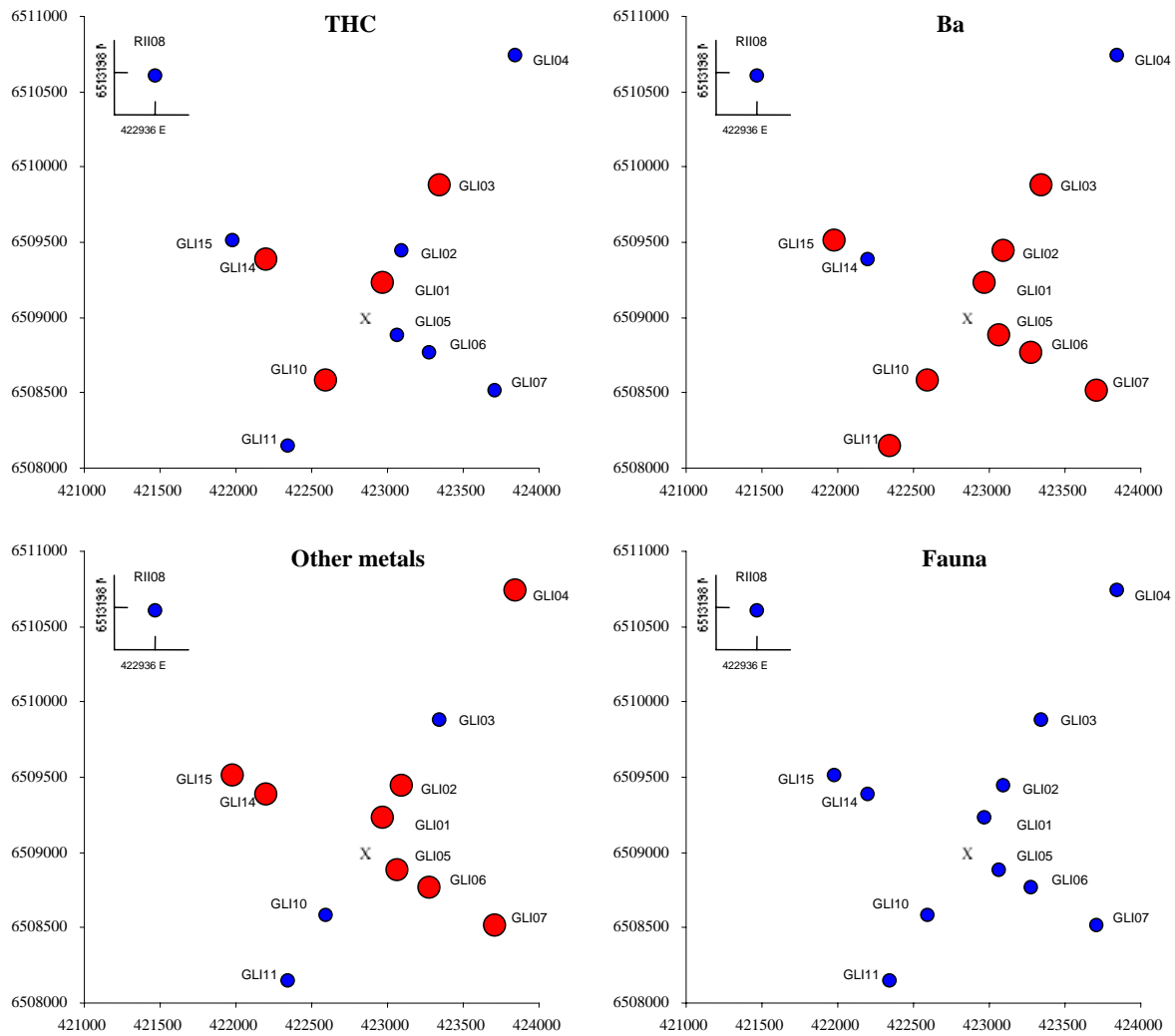
**Figure 8.1.** Faunal disturbance and chemical contamination of the sediments at Sleipner Vest in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## 9 Glitne

The Glitne field is situated in block 15/5. Production started at Glitne in August 2001. During the monitoring survey of Region II in 2000 a baseline survey of Glitne was undertaken. In 2000 and 2001 respectively 3 and 2 wells were drilled at Glitne. The sediments are still characterized as fine sand (Table 9.1 ) as in 2000. Only minor changes in the sediment characteristics were found and they are most likely caused by natural variation. The amounts of THC in the sediments had increased at the sites 250 m to the north and 500 m to the west of the field centre since 2000. And the barium content in the sediments increased at all sites out to 1000 m to the north and at 500 m to the west. An increase of barium was also found at 1000 m to the east. The other metals were at the same levels as in 2000 except for zinc which showed a general tendency of somewhat higher concentrations. The species diversity was high as in 2000. Comparisons of fauna assemblage showed high homogeneity across the Glitne field and there were only weak association between the fauna and the measured environmental variables (Figure 9.1). Due to increased content of THC and barium the area of contamination was larger in 2003, although there was no faunal disturbance.

**Table 9.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
GLI01	422975	6509227	1.31	12.13	154.5	1.8	8.6	15.3	658	6.4	832	116	5.29
GLI02	423100	6509443	1.69	10.25	10.1	1.5	8.3	13.3	285	5.3	689	105	5.39
GLI03	423350	6509876	1.84	11.45	17.7	1.1	8.2	12.2	246	5.1	734	105	5.26
GLI04	423850	6510742	1.70	11.45	12.6	1.0	8.5	22.3	155	5.3	534	94	5.39
GLI05	423067	6508885	1.93	11.69	10.3	0.9	7.8	18.2	169	4.9	622	107	5.68
GLI06	423283	6508760	2.08	12.65	10.8	1.2	9.2	18.4	188	5.4	671	112	5.42
GLI07	423716	6508510	1.94	16.19	13.7	1.1	8.6	17.4	361	5.0	706	107	5.21
GLI10	422600	6508577	1.91	12.12	36.5	1.5	8.7	11.3	396	5.9	858	116	5.55
GLI11	422350	6508144	1.71	11.98	8.3	1.2	8.4	10.2	200	5.0	887	119	5.42
GLI14	422200	6509385	1.70	11.22	15.2	0.8	7.9	16.2	141	5.0	639	104	5.33
GLI15	421984	6509510	1.51	9.97	9.5	1.8	8.6	19.3	164	5.1	480	85	5.26
RII08/GLI	422936	6513198	1.92	12.56	14.2	1.4	8.9	12.0	146	5.1	525	98	5.22



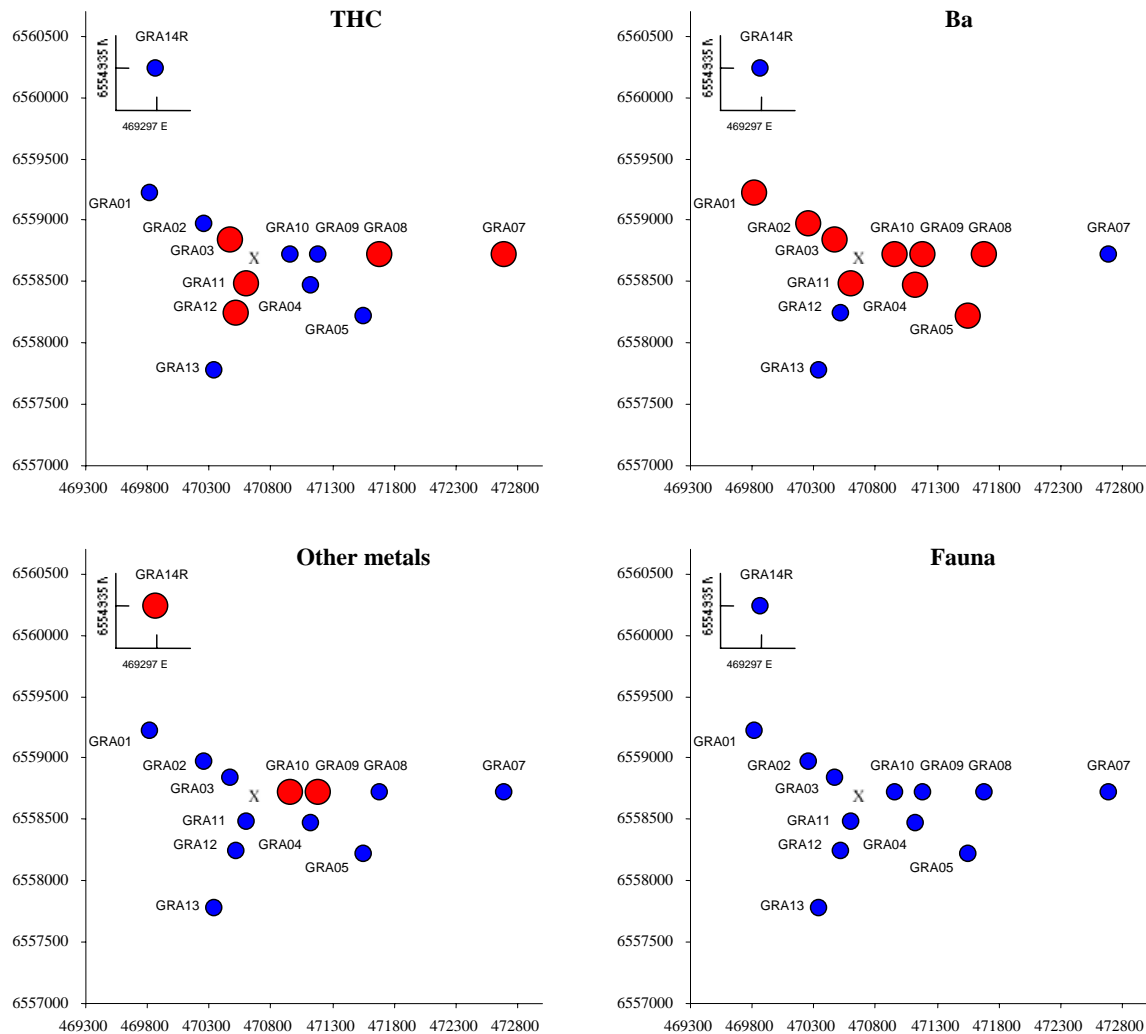
**Figure 9.1.** Faunal disturbance and chemical contamination of the sediments at Glitne in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## 10 Grane

The Grane field is situated in block 25/11. Production started during the fall of 2003, after the sampling cruise was finished. During 2001 two wells were drilled at Grane. The sediments at Grane are characterized as fine sand. THC was relatively evenly distributed in the sediment (Table 10.1), although the THC content was above LSC at 6 out of 12 field sites and the highest THC concentrations were found in sediment to the west of the field centre. The distribution of barium in the sediments was uneven with the highest content in the sediments in the immediate vicinity of the field centre (Figure 10.1). The vertical distribution of barium in the sediments indicates recent supply of barium to the sea floor. The other metals occurred in low and even concentrations at all sites except at 270 m to the east of the field centre where slightly higher levels were found. Fauna diversity was high and the correlation between the distribution of measured chemical compounds and the fauna was weak, showing that there were no signs of faunal disturbance at Grane in 2003.

**Table 10.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
GRA01	469823	6559216	2.10	11.72	13.7	1.3	7.2	9.7	168	4.7	573	117	5.64
GRA02	470256	6558966	1.74	10.38	12.0	1.3	6.6	8.9	197	4.3	459	110	5.65
GRA03	470472	6558841	1.81	11.99	15.3	1.6	6.9	10.8	358	4.2	600	122	5.54
GRA04	471122	6558466	1.75	12.04	13.6	1.6	7.3	9.9	401	5.2	449	94	5.48
GRA05	471555	6558216	1.78	9.52	14.5	1.5	7.2	9.5	173	4.9	420	97	5.59
GRA07	472689	6558716	1.72	9.12	18.2	1.2	6.8	9.9	99	4.5	744	138	5.89
GRA08	471689	6558716	1.92	12.89	15.9	1.4	6.7	9.6	169	5.0	487	105	5.55
GRA09	471189	6558716	2.18	12.85	10.9	1.6	7.9	10.6	329	4.9	428	106	5.83
GRA10	470959	6558716	1.97	14.14	12.2	2.9	9.6	13.4	589	5.5	503	110	5.62
GRA11	470603	6558481	2.01	10.30	21.0	1.8	7.2	9.8	325	4.3	407	103	5.52
GRA12	470518	6558246	1.53	10.08	24.6	1.2	6.8	9.0	114	3.9	310	91	5.31
GRA13	470347	6557776	1.47	11.04	9.8	1.1	6.1	7.9	118	4.3	448	104	5.76
GRA14R	469297	6554935	2.05	13.30	12.5	1.3	7.3	9.4	72	4.6	533	104	5.69



**Figure 10.1.** Faunal disturbance and chemical contamination of the sediments at Grane in 2003, are marked with large red circles. The field centre are marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

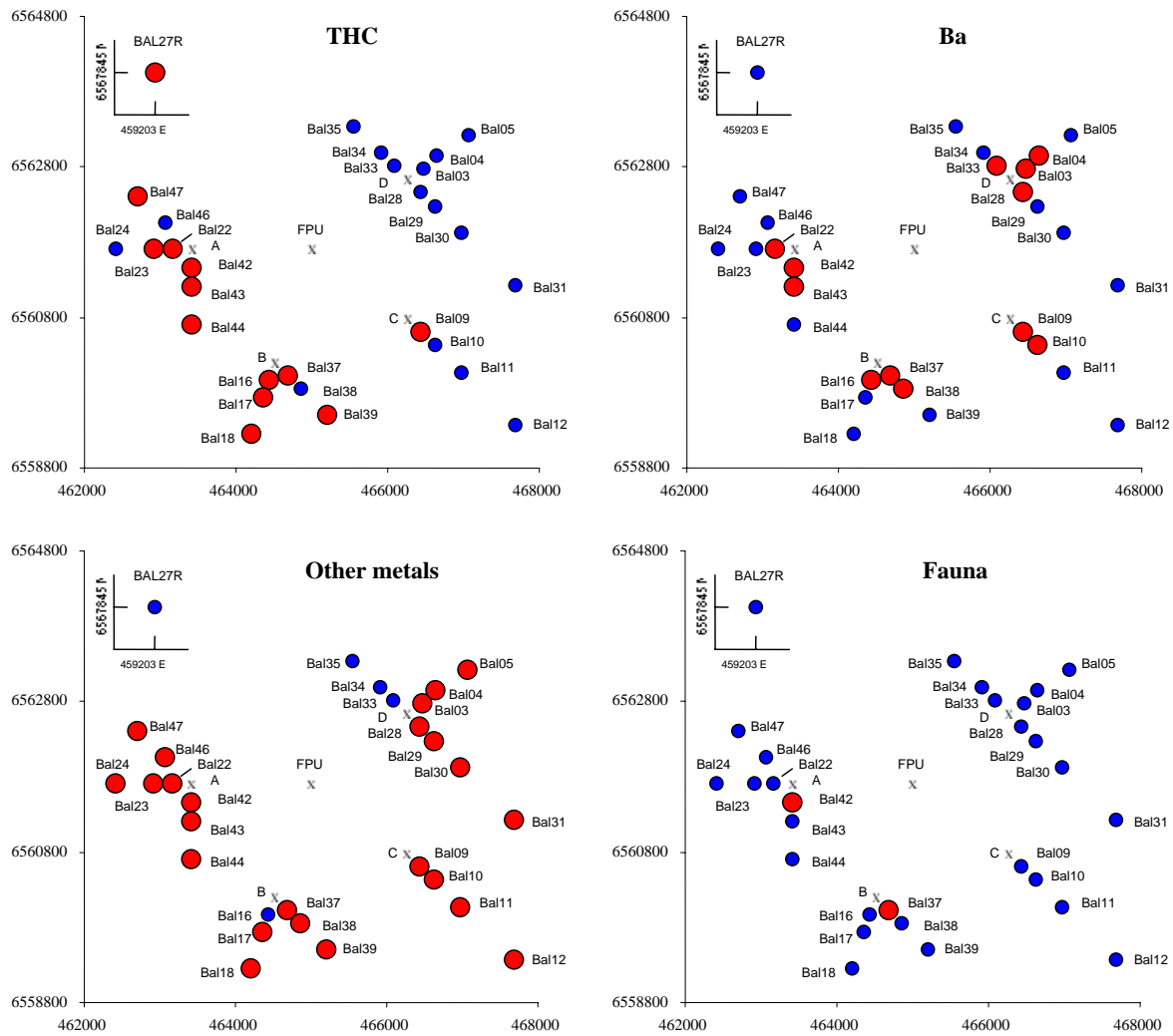
## 11 Balder

The Balder field is situated in block 25/11, and consist of one production ship (Balder FPU) and four sub sea templates (A, B, C and D). Drilling of production wells started in May 1996 and production started at in October 1999. The Balder field consists of four templates (A, B, C and D) and one production vessel. Since the monitoring survey at Balder in 2000 four new wells have been drilled at the field. In addition to this three wells were drilled from Balder to the nearby Ringhorne. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite content (Table 11.1) since 2000. The amounts of THC had increased in the vicinity of template A and B and contamination by THC was revealed at several sites at these templates. A decrease in THC content was found in the vicinity of template C and D, and contamination by THC was only found at 250 m distance to the southeast of template C. At each template olefins occurred in highest concentrations at the innermost sampling site to the south or southeast. The highest concentrations of olefins were found at 250 m distance to the south of template A. At this site the content of olefins was higher in 2003 than in 2000. The barium content in the sediments was in general lower in

2003 than in 2000 although contamination was found in the immediate vicinity of all templates. Due to an increase in the zinc content in the sediments contamination by zinc was found at most sampling sites except the sites to the northwest of template D and at the reference site. The species diversity was in general higher in 2003 than in 2000 although fewer individuals of the bottom fauna were included in the analysis. There was high similarity in the bottom fauna across the field except at 250 m to the south at template A and 250 m to the southeast at template B where some faunal disturbance was found (Figure 11.1). In total the area where faunal disturbance were located was smaller in 2003 than in 2000.

**Table 11.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
BAL03	466476	6562773	2.59	14.61	9.2	1.8	7.8	13.9	277	4.6	601	111	5.73
BAL04	466650	6562947	2.16	17.77	8.2	1.9	8.5	14.5	180	5.0	540	102	5.70
BAL05	467083	6563214	2.85	20.92	13.6	1.7	8.8	10.4	131	4.7	651	99	5.45
BAL09	466451	6560597	1.91	13.36	18.4	1.8	7.6	13.8	240	4.7	1109	113	4.96
BAL10	466628	6560420	1.72	17.64	13.7	1.8	7.8	15.0	174	4.7	733	117	5.43
BAL11	466981	6560067	1.84	12.46	12.8	1.5	7.7	16.0	135	4.7	466	105	5.69
BAL12	467688	6559360	1.65	13.10	11.7	1.3	6.8	15.1	109	4.2	606	106	5.69
BAL16	464436	6559964	1.84	11.98	21.9	1.4	7.4	12.3	206	3.9	722	102	5.37
BAL17	464359	6559726	1.78	13.82	17.9	1.5	7.5	15.6	112	4.6	744	123	5.50
BAL18	464204	6559251	2.17	12.88	16.7	1.4	7.2	14.8	87	4.5	599	107	5.41
BAL22	463175	6561700	1.73	12.14	16.8	1.4	6.8	15.7	173	4.2	745	112	5.56
BAL23	462925	6561700	1.87	13.98	14.6	1.6	7.8	16.4	110	4.5	658	97	5.45
BAL24	462425	6561700	2.05	14.26	11.4	1.2	7.1	14.7	55	3.6	674	110	5.56
BAL28	466451	6562449	2.28	11.84	11.2	2.0	8.1	14.9	310	5.3	715	116	5.67
BAL29	466628	6562272	2.02	23.93	8.3	1.8	8.5	14.4	42	3.3	652	113	5.83
BAL30	466981	6561919	2.55	13.78	14.1	1.6	7.6	13.0	122	4.8	751	117	5.76
BAL31	467688	6561212	1.83	10.94	14.0	1.4	7.5	15.4	112	4.6	557	104	5.71
BAL33	466097	6562803	2.26	13.97	8.3	1.5	7.7	9.3	199	4.4	632	110	5.74
BAL34	465920	6562980	2.06	14.35	8.1	1.8	8.1	10.5	155	4.8	595	115	5.96
BAL35	465567	6563333	1.81	14.50	10.2	1.6	8.1	10.7	101	4.5	722	99	5.63
BAL37	464690	6560025	2.17	13.55	36.6	2.4	9.0	15.7	497	5.8	908	100	5.11
BAL38	464867	6559848	2.24	12.48	14.5	1.7	8.2	22.3	264	4.7	574	109	5.81
BAL39	465220	6559495	2.22	12.10	16.9	1.6	7.8	20.3	133	4.5	757	109	5.68
BAL42	463425	6561450	1.59	11.44	73.4	2.5	8.2	17.2	624	5.6	1077	95	4.52
BAL43	463425	6561200	2.05	14.68	19.7	2.0	8.5	12.7	307	4.9	945	124	5.44
BAL44	463425	6560700	1.95	13.96	17.1	1.4	7.4	15.1	116	4.3	688	101	5.27
BAL46	463071	6562054	2.00	14.09	11.4	1.6	7.8	15.6	128	4.3	609	100	5.54
BAL47	462718	6562407	2.10	15.67	16.3	1.4	6.9	15.0	92	4.0	692	110	5.42
BAL27R	459203	6567845	2.16	14.89	15.2	1.4	8.0	9.4	72	4.3	699	116	5.68



**Figure 11.1.** Faunal disturbance and chemical contamination of the sediments at Balder in 2003, are marked with large red circles. The templates centres and ship (FPU) are marked with a X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

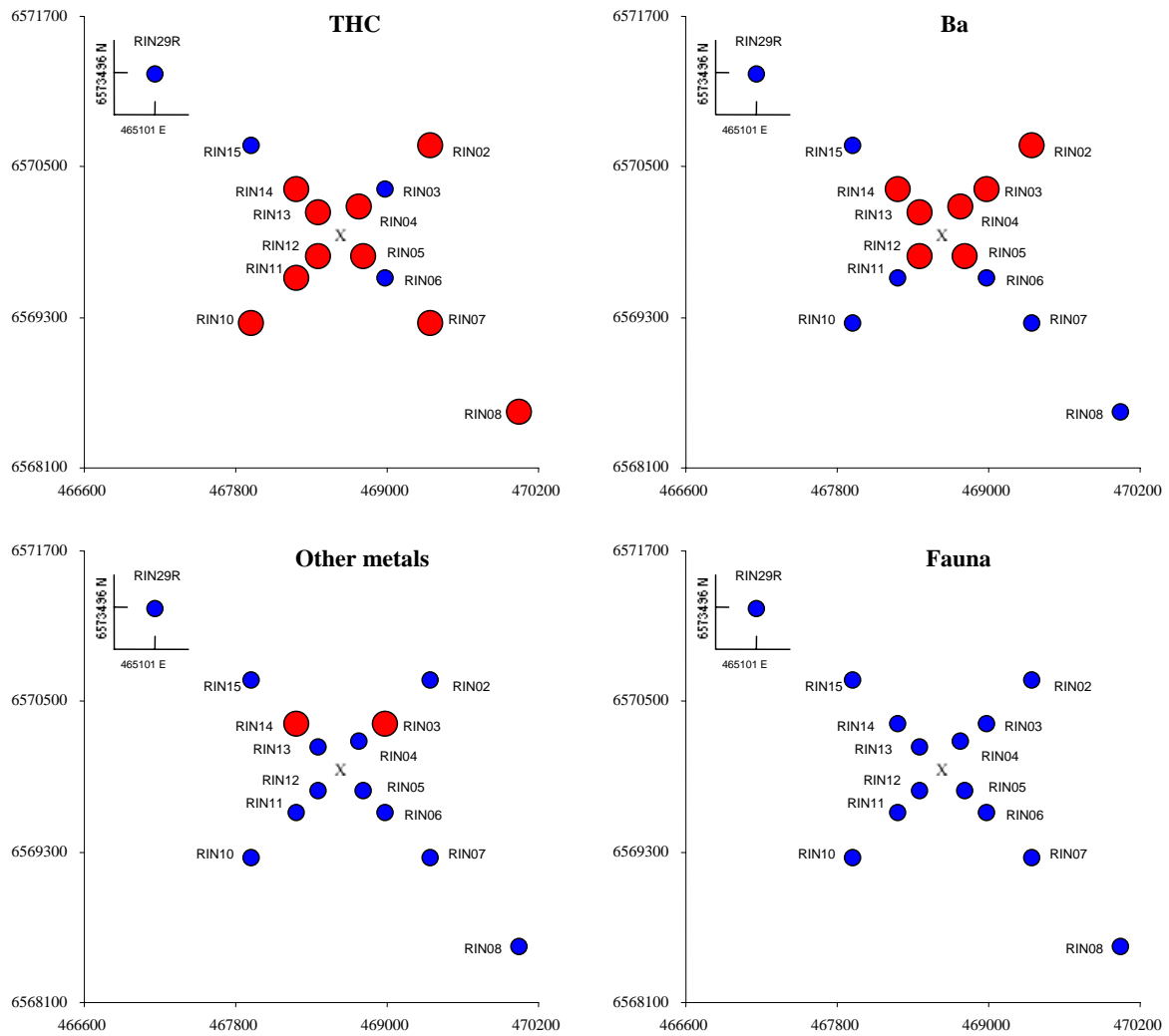


## 12 Ringhorne

The Ringhorne field is situated in block 25/10. Production at Ringhorne started during the spring of 2003. A baseline survey was undertaken at Ringhorne during the monitoring survey in Region II in 2000. During 2001 and 2002 respectively 3 and 2 wells were drilled at Ringhorne. The first environmental survey of the field was in 2000 when a baseline survey was accomplished. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite (Table 12.1) content since 2000. The amounts of THC in the sediments have increased since 2000. Also the barium content in the sediments have increased since 2000, particularly toward the northeast and northwest, but also in the immediate vicinity of the fields centre to southeast and southwest too. Other metals occurred approximately at the same level in 2003 as in 2000. Species diversity remains high at Ringhorne and no fauna effects were found in 2003 (Figure 12.1). Due to the drilling activity and discharges at Ringhorne the area of THC and barium contaminated sediments were larger in 2003 than in 2000.

**Table 12.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
RIN02	469343	6570667	1.58	13.20	14.6	1.8	8.5	12.1	219	5.6	693	113	5.87
RIN03	468990	6570314	2.79	17.50	12.2	1.8	8.2	12.5	315	5.1	621	123	5.89
RIN04	468776	6570180	2.04	12.77	18.8	1.8	7.2	11.2	387	4.2	787	109	5.49
RIN05	468813	6569783	2.22	12.96	17.0	1.7	7.7	11.1	231	4.3	729	119	5.85
RIN06	468990	6569606	1.92	13.72	13.7	1.6	7.7	10.0	99	4.7	768	116	5.68
RIN07	469343	6569253	1.80	14.80	14.8	1.9	7.8	11.1	98	4.7	737	120	5.81
RIN08	470050	6568546	2.10	14.03	16.8	1.7	7.6	10.4	87	5.3	804	121	5.56
RIN10	467929	6569253	2.41	15.78	14.7	1.9	8.3	11.1	84	4.6	541	104	5.67
RIN11	468282	6569606	2.18	14.15	18.3	1.7	7.8	10.5	83	4.4	700	109	5.70
RIN12	468459	6569783	2.10	14.17	16.4	2.0	8.2	11.4	337	4.8	578	104	5.64
RIN13	468459	6570137	1.70	12.47	20.9	2.0	7.9	12.2	299	4.9	604	104	5.54
RIN14	468282	6570314	2.31	16.08	16.1	2.1	9.2	12.7	201	5.2	530	111	5.69
RIN15	467929	6570667	1.96	16.26	8.3	1.8	8.3	11.5	110	5.1	746	116	5.82
RIN29R	465101	6573496	2.18	17.04	12.6	1.7	7.7	10.7	67	5.0	733	102	5.23



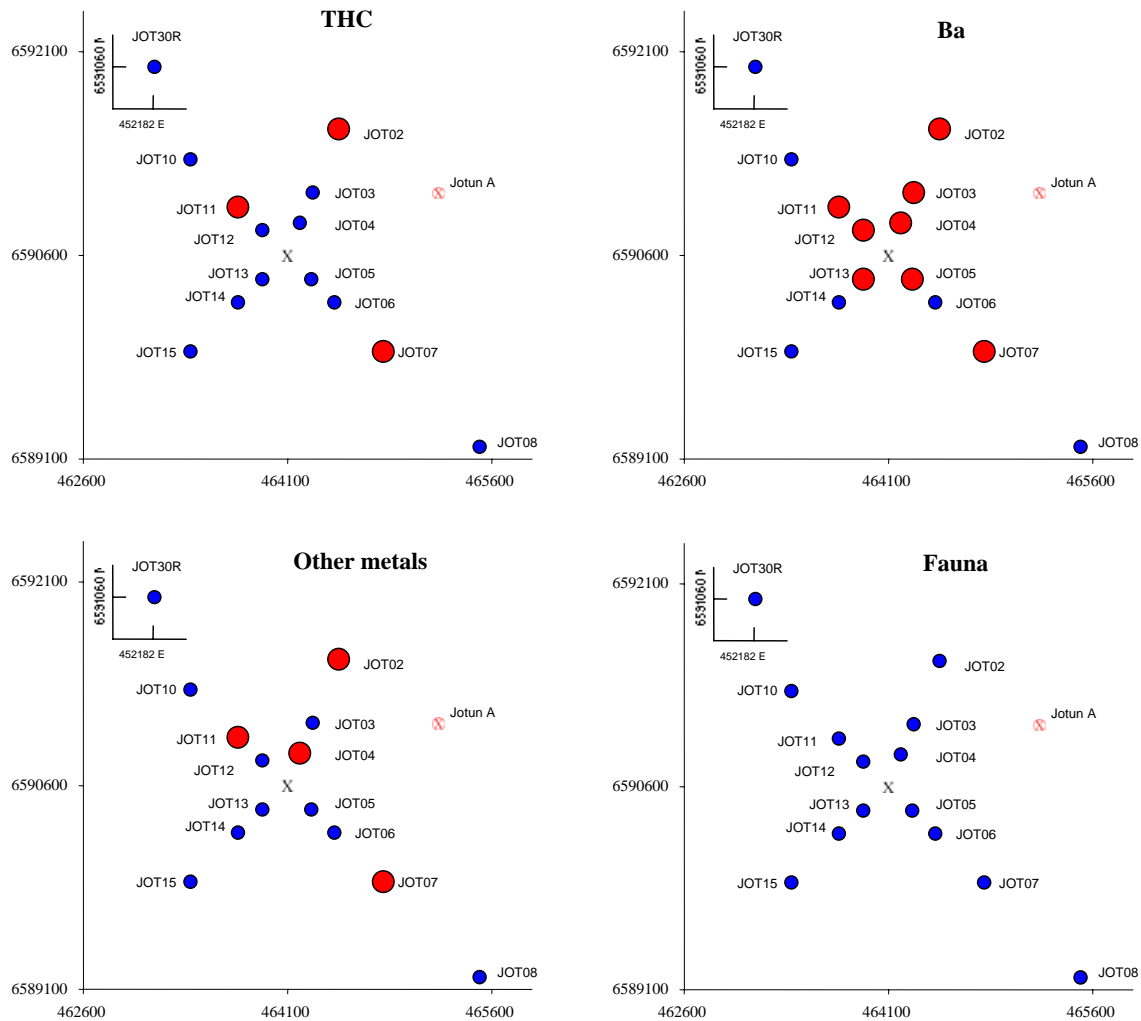
**Figure 12.1.** Faunal disturbance and chemical contamination of the sediments at Ringhorne in 2003, are marked with large red circles. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

### 13 Jotun

The Jotun field is situated in block 25/7 and 25/8. Jotun consist of two units Jotun A (production ship) and Jotun B (well head platform). Production at Jotun started in October 1999. A baseline survey was accomplished in 1997 and a monitoring survey in 2000. Between the baseline survey in 1997 and the monitoring survey in 2000 the field centre was relocated approximately 400 m to north northwest. At least 16 wells have been drilled at Jotun since the last environmental survey at the field. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite content (Table 13.1) since 2000. The amount of THC has decreased at the sites where it occurred in the highest concentrations in 2000 and increased at the other sites. Thus the distribution of THC across the field was more even in 2003 than in 2000 and contamination of THC was only seen at 3 sites of which none where close to the field centre. The concentration of barium and other metals except zinc have decreased since 2000. The area of barium contamination was smaller in 2003 than in 2000. More taxa and individuals were found in the bottom fauna in 2003 than in 2000, and the diversity of the fauna remained high. Comparisons of fauna assemblage showed an even distribution of the fauna and no faunal disturbance (Figure 13.1). The distribution of fauna and environmental variables were not well correlated indicating no linking between fauna and the measured environmental variables.

**Table 13.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
JOT02	464483	6591524	2.53	24.54	19.5	2.2	9.5	12.5	189	5.2	904	115	5.41
JOT03	464291	6591062	2.62	24.94	13.1	1.9	8.3	11.5	227	4.6	1086	122	5.54
JOT04	464196	6590831	2.59	21.94	9.4	2.0	9.2	12.9	412	4.7	959	136	5.73
JOT05	464277	6590423	2.37	21.45	13.0	1.6	7.4	11.0	192	4.0	1144	123	5.60
JOT06	464454	6590246	2.71	22.64	12.2	1.7	8.4	10.4	143	4.3	976	105	5.23
JOT07	464807	6589893	2.72	23.38	15.9	2.2	10.0	12.9	163	5.5	988	110	5.39
JOT08	465514	6589186	2.59	22.89	14.5	2.0	9.2	12.4	121	5.3	921	118	5.39
JOT10	463393	6591307	2.68	23.47	11.4	1.9	8.6	11.7	147	4.8	829	111	5.25
JOT11	463746	6590954	2.36	22.61	15.1	2.1	9.0	12.5	280	5.2	916	115	5.42
JOT12	463923	6590777	2.12	21.47	11.6	1.8	7.7	10.9	439	4.6	1092	124	5.54
JOT13	463923	6590423	2.36	23.42	10.2	1.7	8.1	10.8	268	4.5	1006	110	5.45
JOT14	463746	6590246	2.57	22.79	8.4	1.8	8.2	11.0	143	4.5	794	106	5.37
JOT15	463393	6589893	2.38	25.21	10.0	2.0	8.8	12.1	104	5.1	908	111	5.23
JOT30R	452182	6590203	2.19	21.77	12.0	1.7	7.2	10.6	61	4.6	885	109	5.47



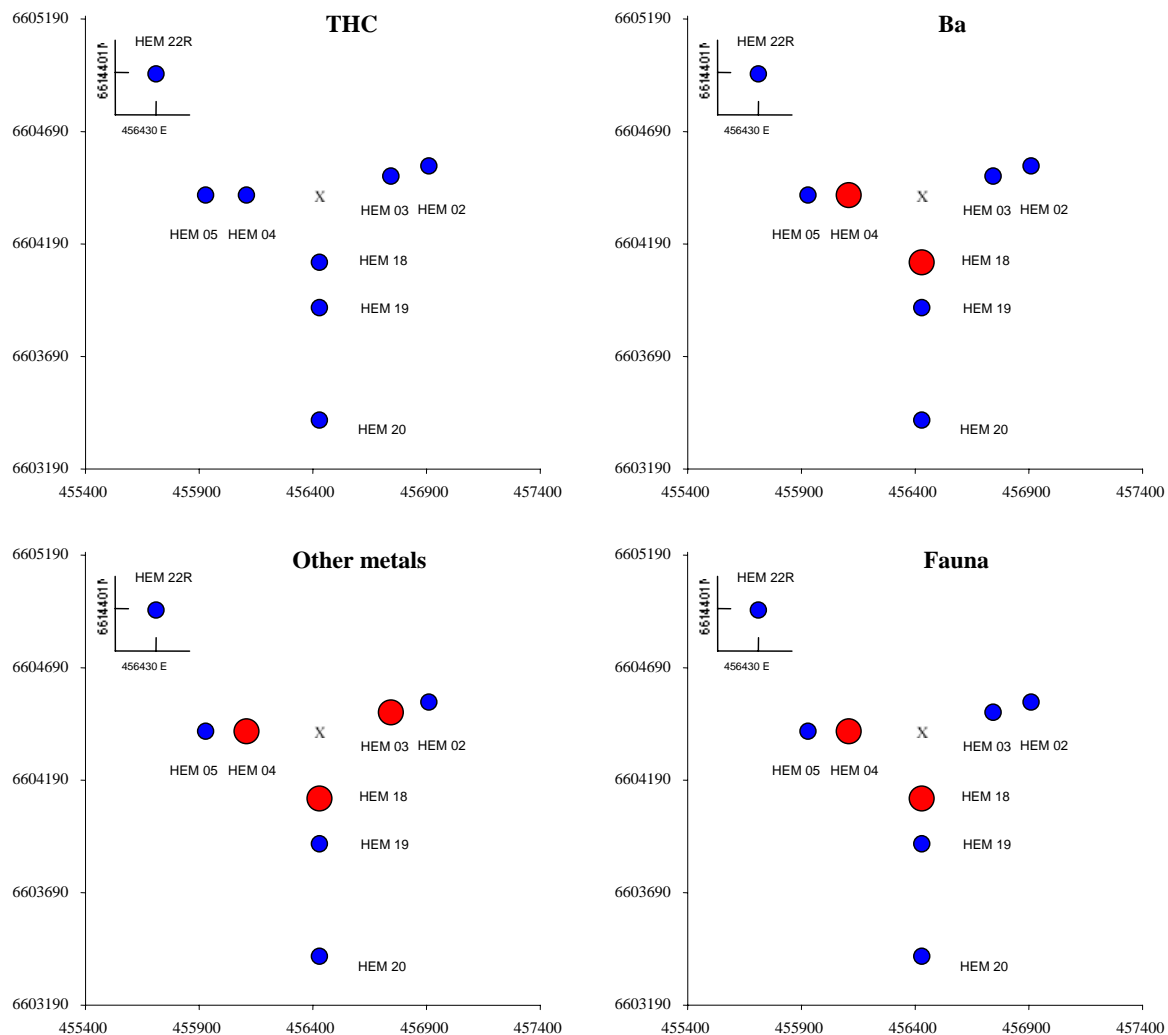
**Figure 13.1.** Faunal disturbance and chemical contamination of the sediments at Jotun in 2003, are marked with large red circles. The field centre and the ship (FPU) are marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## 14 Heimdal

The Heimdal field is situated in block 25/4. Production started at Heimdal in December 1985. The field was surveyed in the regional surveys of both 1997 and 2000. Since the last survey at Heimdal only one well is drilled. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite content (Table 14.1) since 2000. The THC content in the sediments was low and generally lower in 2003 than in 2000. THC contamination was not detected in 2003, although elevated levels of PAH, NPDs and decalins were found in samples taken 300 and 500 m to the south (downstream) of the field centre. Also the levels of metals in the sediments were lower in 2003 than in 2000. The sharpest decrease was seen at sites where metals previously occurred in the highest concentrations. Despite this, sediments were still contaminated by barium out to 500 m to the south and out to 270 m to the west, and contamination by other metals were found out to 300 m to the south, and for copper also out to 330 m to the east and 270 m to the west. Species diversity was slightly higher in 2003 than in 2000. Some faunal disturbances were found out to 500 m to the south (Figure 14.1). The area of contaminated sediments and faunal disturbance was reduced in 2003 compared to the situation in 2000.

**Table 14.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
HEM02	456913	6604531	1.51	11.99	4.2	1.2	5.4	9.2	91	3.8	1279	146	5.6
HEM03	456749	6604487	1.33	12.94	8.1	2.4	5.8	10.2	108	4.4	1270	141	5.8
HEM04	456110	6604401	1.83	15.29	10.1	2.2	6.6	13.1	231	5.6	1398	142	5.7
HEM05	455930	6604401	1.5	12.30	9.8	1.5	5.7	9.1	131	4.4	1281	146	5.8
HEM18	456430	6604101	1.77	13.45	9.9	8.8	8.2	42.3	315	11.2	1258	122	5.6
HEM19	456430	6603901	1.38	13.65	8.5	1.9	6.2	12.4	149	3.8	1143	127	5.7
HEM20	456430	6603401	1.68	15.91	4.4	1.4	5.6	10.1	102	3.8	1067	121	5.7
HEM22R	456430	6614401	1.66	15.99	6.8	1.4	6.5	8.5	74	3.7	989	125	5.8



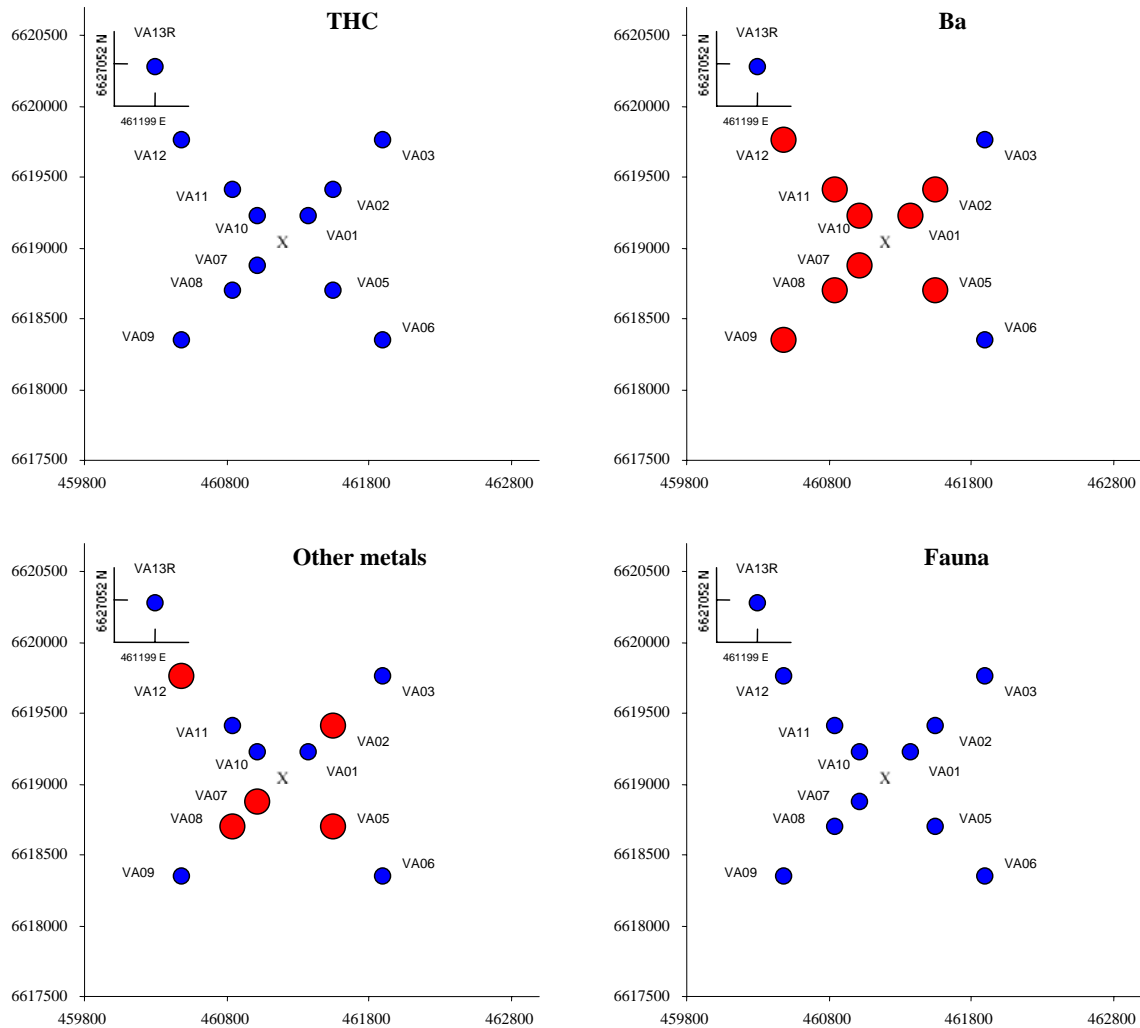
**Figure 14.1.** Faunal disturbance and chemical contamination of the sediments at Varg in 2003, are marked with large red circles. The field centre are marked with a X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## 15 Vale

The Vale field is situated in block 25/4. Production started at Vale in May 2002. A baseline survey was accomplished in 2001. Since the baseline survey at Vale in 2001 one well has been drilled at the field. The sampling sites were relocated in 2003 and the results of this survey can not be directly compared site by site. The sediments at Vale are still characterized as fine sand. The amount of THC (Table 15.1) in the sediments was higher in 2003 than in 2001 although THC contamination was not revealed (Figure 15.1). Contamination by barium was found at most sites except the two sites at 1000 m to the northeast and southeast. None of the other metals occurred in particularly high concentrations although contamination by zinc was revealed at several sites and contamination by copper and lead were revealed 250 m to the southwest of the field centre. Faunal disturbance was not revealed at Vale in 2003.

**Table 15.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
VA01	461376	6619229	1.13	7.24	2.8	0.8	4.1	5.8	89	3.1	1314	112	4.56
VA02	461553	6619406	1.08	7.84	3.1	1.1	4.2	8.4	90	3.9	1262	117	4.74
VA03	461906	6619759	0.98	4.85	10.1	0.7	4.3	5.3	40	2.8	1051	105	4.66
VA05	461553	6618698	1.27	7.57	3.0	1.0	5.2	8.0	84	3.5	1195	126	5.05
VA06	461906	6618345	1.17	6.91	2.3	0.7	4.8	6.6	48	2.9	1135	114	4.63
VA07	461022	6618875	1.28	11.19	10.0	1.9	5.5	8.6	559	4.9	1084	122	5.76
VA08	460845	6618698	1.36	9.96	11.5	1.0	5.3	8.0	179	3.2	1203	116	5.13
VA09	460492	6618345	1.53	10.39	3.6	1.1	4.8	6.5	86	3.2	1021	118	5.66
VA10	461022	6619229	0.91	5.72	5.2	0.7	5.0	6.5	271	3.6	927	89	4.07
VA11	460845	6619406	1.02	9.22	6.4	0.9	4.9	7.2	135	3.0	1116	128	5.69
VA12	460492	6619759	1.17	10.56	9.5	1.1	5.3	8.2	97	3.3	1219	124	5.37
VA13R	461199	6627052	0.68	2.85	7.4	0.5	3.7	5.9	18	2.5	643	82	4.81



**Figure 15.1.** Faunal disturbance and chemical contamination of the sediments at Vale in 2003, are marked with large red circles. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. The field centre is marked with an X. Positioning according to UTM ED50 zone 31.

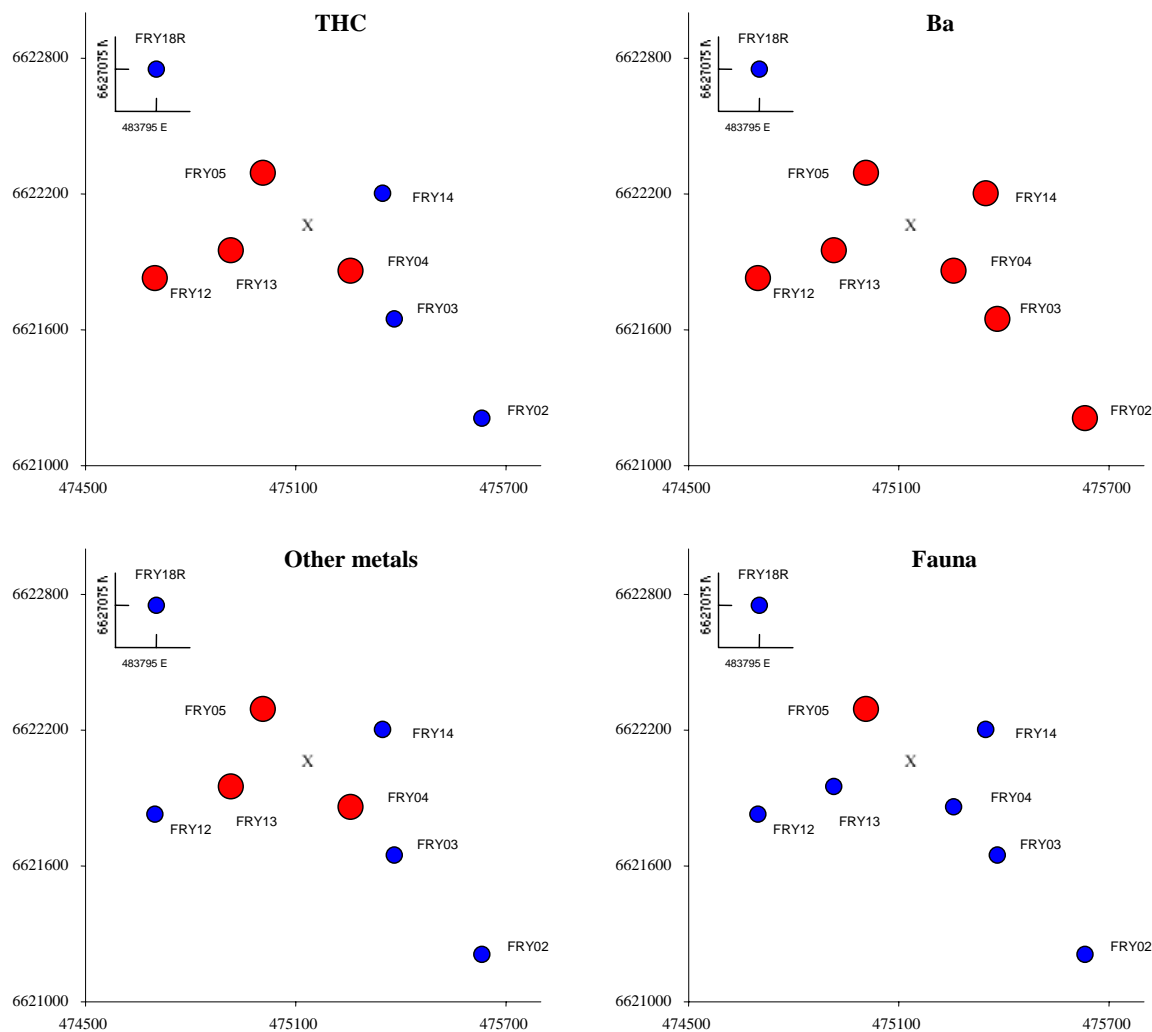
## 16 Frøy

The Frøy field is situated in block 25/2 and 25/5. Production started at Frøy in 1995 and ceased in 2001, when the wells were permanently plugged and abandoned. The jacket was removed in 2002. This is the first post production monitoring survey of the field. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite content (Table 16.1) since 2000. The amount of THC in the sediments has increased since 2000 perhaps due to redistribution of sediments in conjunction with the removal of the jacket, whereas the amounts of olefins, barium and lead have decreased. Highest concentrations of the chemical compounds were found at 250 m distance to the field center to the southeast, southwest and northwest. Fewer individuals and slightly fewer taxa were found among the bottom fauna in 2003 than in 2000. Despite this the diversity of the fauna has increased, indicating improved environmental conditions, although the fauna assemblage showed that the innermost (250 m distance) sampling sites to the northwest were slightly disturbed. The measured chemical compounds occurred in high concentrations at the same site and the fauna assemblage were well associated to the distribution of barium and TOM,

which show that Frøy still have some environmental disturbance in the immediate vicinity of the field centre (Figure 16.1), although the area of disturbance was smaller in 2003 than in 2000.

**Table 16.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
FRY02	475635	6621209	1.32	12.61	9.0	1.0	5.4	7.5	169	3.5	913	124	5.72
FRY03	475385	6621642	0.39	11.31	10.9	1.1	5.1	7.5	217	3.3	926	113	5.77
FRY04	475260	6621859	1.77	13.93	20.3	2.7	7.3	11.0	554	4.6	1276	133	5.70
FRY05	475010	6622292	1.52	11.93	25.2	2.5	7.0	11.4	532	4.6	1549	133	5.63
FRY12	474702	6621825	1.48	11.64	17.4	1.1	5.6	7.6	204	3.1	884	117	5.80
FRY13	474918	6621950	1.92	14.31	26.1	2.3	6.8	9.9	442	4.1	1023	124	5.69
FRY14	475352	6622200	1.83	14.50	13.2	1.4	6.5	8.6	300	3.7	1320	139	5.82
FRY18R	483795	6627075	1.62	10.74	9.5	1.0	5.6	8.0	67	3.4	986	113	5.66



**Figure 16.1.** Faunal disturbance and chemical contamination of the sediments at Frøy in 2003, are marked with large red circles. The field centre is marked with a X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

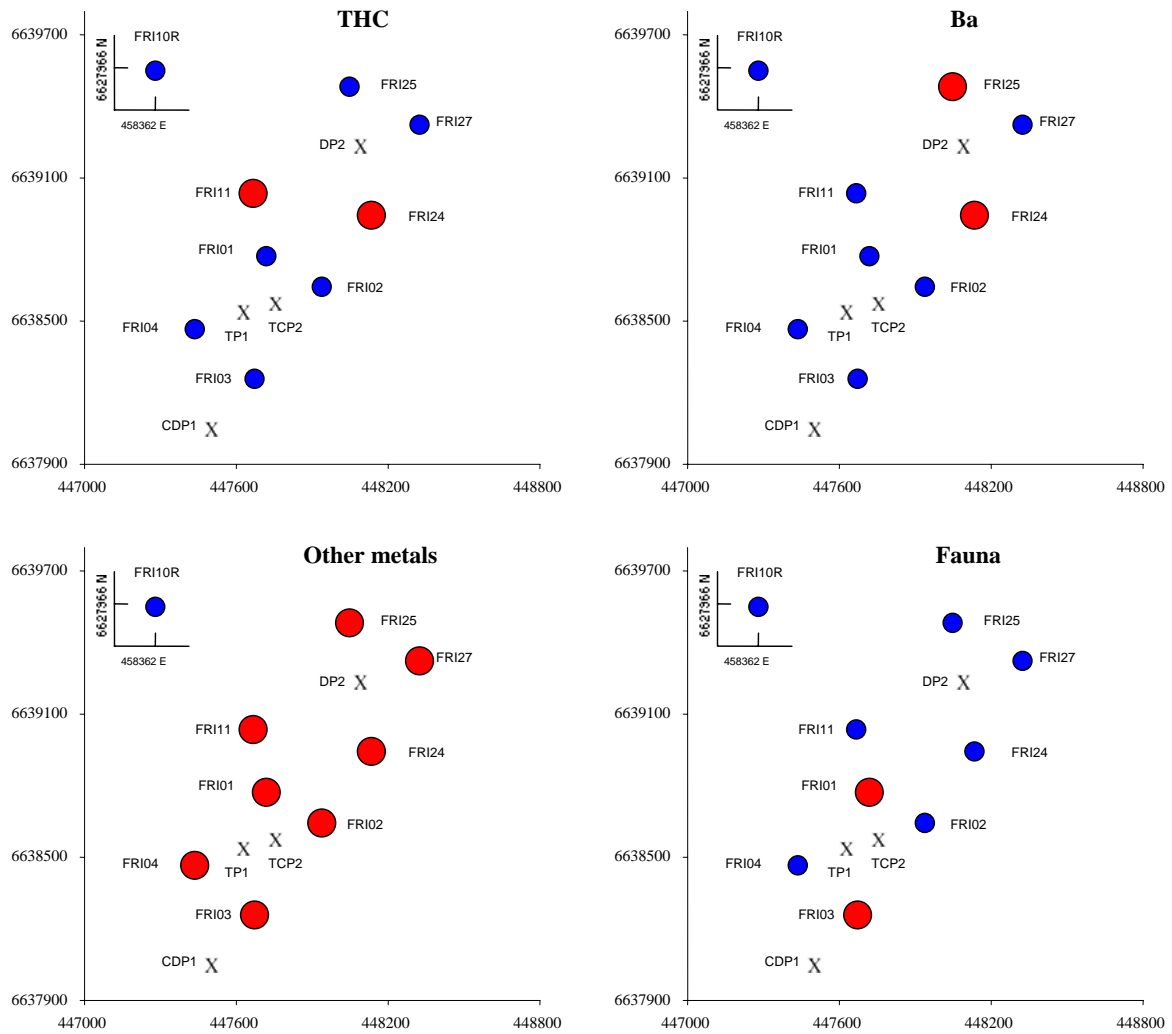


## 17 Frigg

The Frigg field is situated in block 25/1. Production started at Frigg in September 1977 and cessation is planned on July 1, 2004. The only drilling operation at Frigg over the last 6 years was during the permanently plugging and abandonment of 14 wells in the period from March to June 2004, just before the monitoring survey was conducted. The plugging operation was planned as a zero discharge and only minor amounts of water soluble chemicals were discharged. The sediments are still characterized as fine sand. The amounts of THC (Table 17.1) in the sediments were generally low despite an increase in the THC level at five sampling sites since 2000. The barium content had decreased at all sites since 2000, and the content of other metals decreased as well except at one site (FRI01) located 200 m to the north of TCP2 where the content of other metals seems to increase. Despite a general decrease of metals in the sediments all sampling sites were contaminated by metals, except the reference site. The fauna was correlated to some of the measured environmental variables (chromium, TOM and pelite), but no faunal disturbances were revealed (Figure 17.1). The total area contaminated by THC and other metals was the same in 2000 and 2003, whereas the area contaminated by barium was reduced. The area with faunal disturbances was also reduced in 2003 compared to the situation in 2000.

**Table 17.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
FRI01	447719	6638770	0.65	2.14	8.8	17.0	9.8	230.3	72	43.7	1013	89	4.36
FRI02	447942	6638641	0.54	1.83	2.0	3.2	5.3	33.8	28	12.0	819	99	4.72
FRI03	447674	6638253	0.61	1.97	12.2	11.1	8.1	128.0	35	28.8	745	72	4.12
FRI04	447440	6638466	0.86	2.53	8.0	7.0	6.7	67.3	31	16.4	1025	105	4.89
FRI11	447668	6639031	0.74	2.53	15.3	5.3	5.4	36.7	42	13.1	884	96	4.64
FRI24	448135	6638942	0.61	2.55	15.7	4.8	5.1	25.4	102	13.9	722	85	4.92
FRI25	448049	6639480	0.69	2.20	12.5	6.2	6.5	51.5	103	18.9	632	100	5.15
FRI27	448327	6639324	0.59	1.96	9.8	0.9	4.4	7.6	33	4.9	767	102	4.98
FRI10R	458362	6627966	1.04	5.77	11.3	0.5	4.5	5.5	37	2.8	932	109	4.89



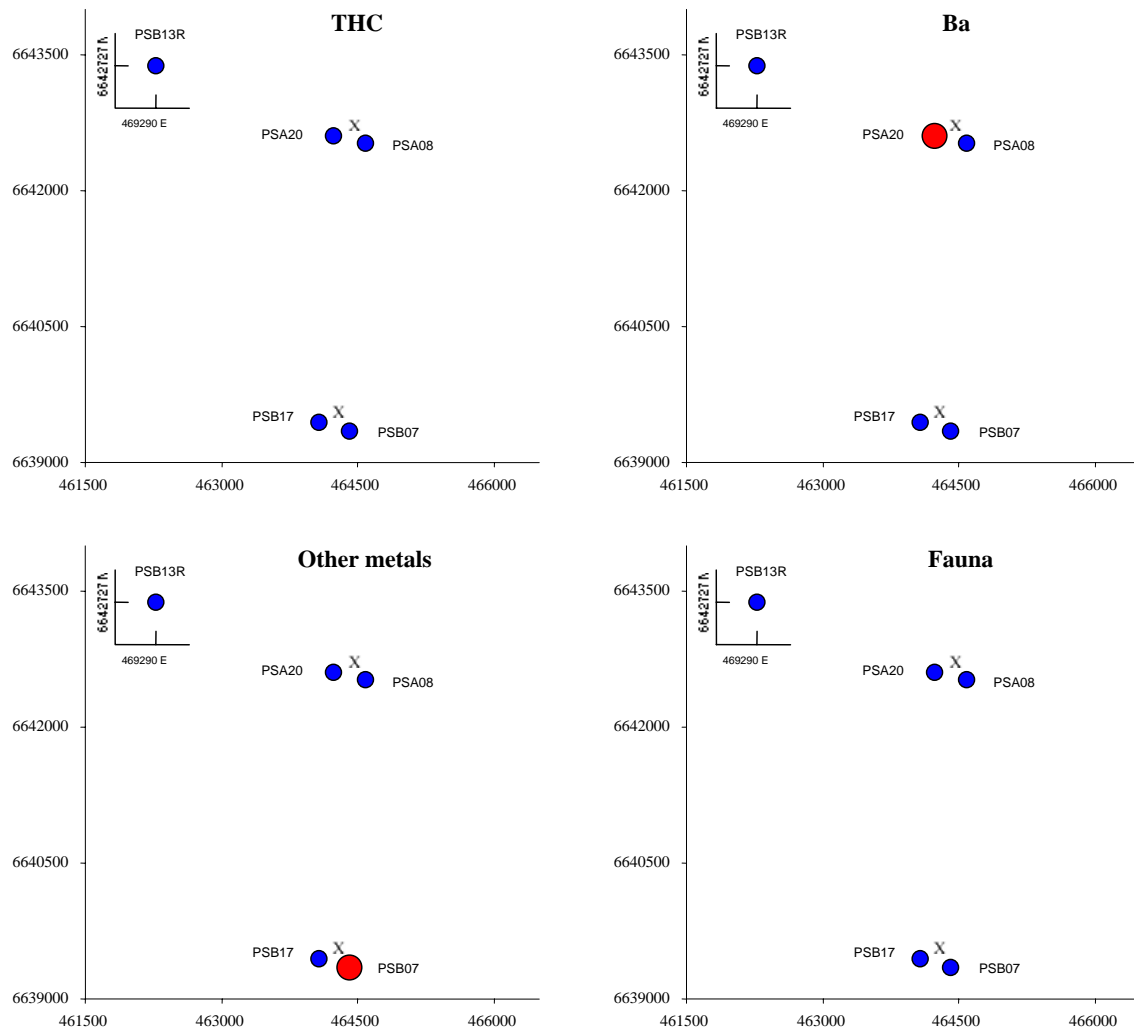
**Figure 17.1.** Faunal disturbance and chemical contamination of the sediments at Frigg in 2003, are marked with large red circles. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. The field centre are marked with a X. Positioning according to UTM ED50 zone 31.

## 18 Øst Frigg

The Øst Frigg field is situated in block 25/4 and 25/2. Production started at Øst Frigg in 1988 and ceased in December 1997. The wells were permanently plugged and abandoned in 1999 and the sub-sea structures were removed in 2002. The field was surveyed during the regional monitoring surveys of both 1997 and 2000. The sediments at Øst Frigg are characterized as fine sand. The THC content (Table 18.1) was low and relatively evenly distributed across the sampling sites. No THC contamination was revealed. Also the metals occurred in low and relatively even concentrations across the field. Contamination by metals was only found at two sites PSA20 (barium) and PSB07 (mercury). Despite lower number of individuals and taxa in the samples in 2003 than in 2000 the species diversity was approximately the same. And despite correlation between the fauna and some of the environmental variables (barium, gravel and lead) no faunal disturbances were found (Figure 18.1), as in 1997 and 2000. The area contaminated with barium was smaller in 2003 than in 2000, whereas the area contaminated by other metals had increased from 0 to 0.2 km<sup>2</sup>.

**Table 18.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
PSA08	464587	6642511	1.15	4.64	10.6	0.6	5.6	5.4	73	2.8	591	81	4.98
PSA20	464245	6642602	0.80	5.10	8.6	0.6	4.9	5.3	77	2.8	642	99	5.13
PSB07	464415	6639343	0.74	4.16	11.8	0.4	4.6	4.9	63	2.7	937	83	4.55
PSB17	464074	6639434	0.90	4.91	9.9	0.6	4.5	5.1	45	2.6	784	85	4.70
PSB13R	469290	6630899	0.95	5.95	11.3	0.7	4.4	5.6	41	2.7	870	97	5.02



**Figure 18.1.** Faunal disturbance and chemical contamination of the sediments at Øst Frigg in 2003, are marked with large red circles. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. The field centre is marked with an X. Positioning according to UTM ED50 zone 31.

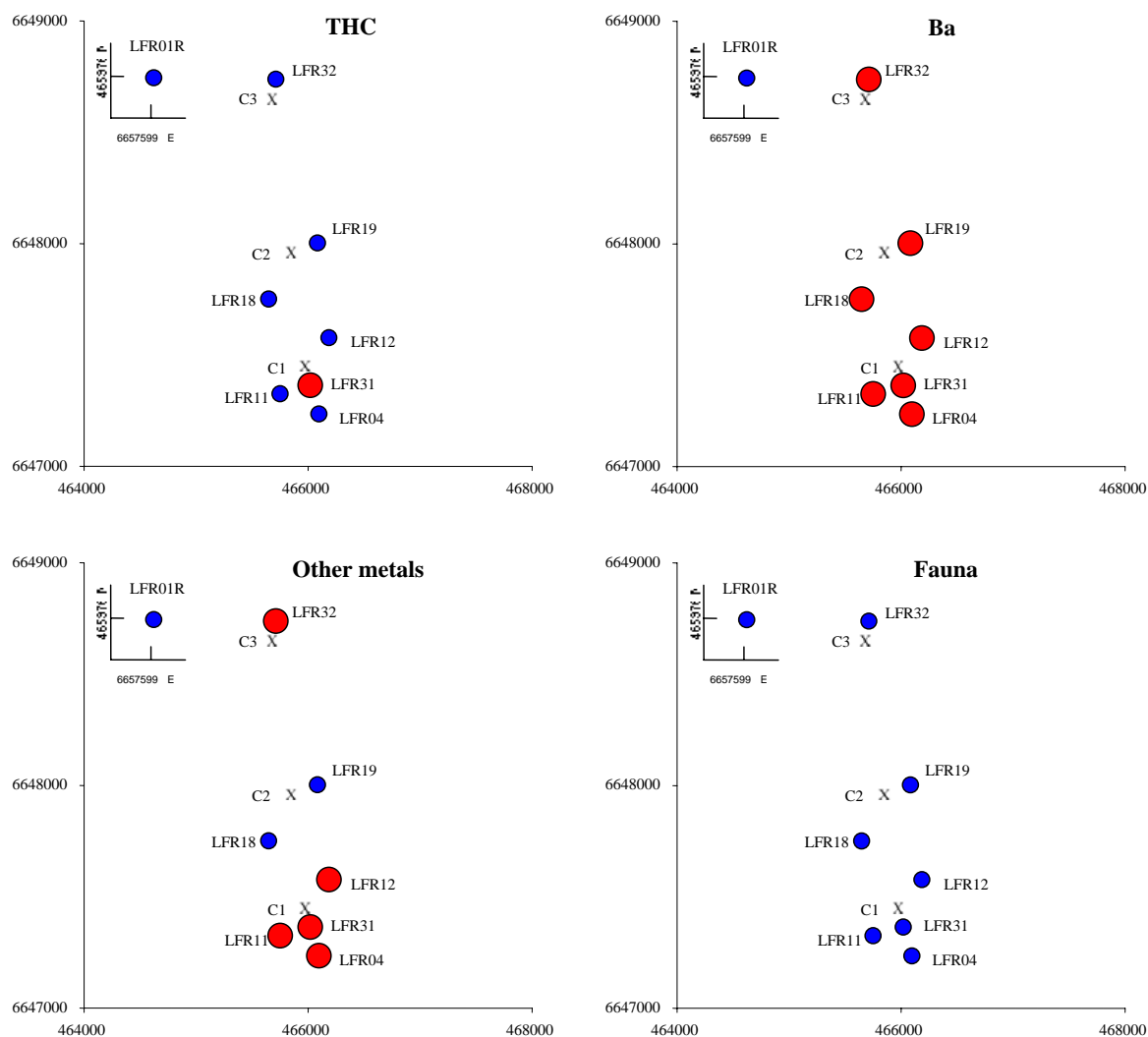
## 19 Lille-Frigg

The Lille-Frigg field is situated in block 25/2, north east of Øst Frigg. Production at Lille-Frigg started in 1994 and ceased in 1999. There have been no drilling activities at Lille-Frigg since 1993/94 and all wells were permanently plugged and abandoned in 2000/2001.

Thus only the sampling sites within 100 m and 250 m was sampled in 2003. The sediments are still characterized as fine sand. The amounts of THC (Table 19.1) were highest 100 m to the south of C1 which also was the only place contamination by THC was revealed. Despite generally lower levels of barium and other metals barium contamination was still present at all sites except the reference site and contamination by other metals were found at most sites except two. More taxa and individuals were found in the bottom fauna in 2003 than in 2000, and the species diversity had increased. Despite high correlation between the fauna and some environmental variables (gravel, chromium, barium and TOM) no faunal disturbance was revealed (Figure 19.1), as in 1997 and 2000. The area contaminated by THC and barium was smaller in 2003 than in 2000, whereas the area contaminated by other metals had increased slightly.

**Table 19.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
LFR04	466101	6647233	0.97	6.53	12.9	0.9	4.9	7.5	369	5.4	808	87	4.87
LFR11	465760	6647324	1.04	5.32	7.6	1.0	4.7	7.0	340	5.3	701	82	4.87
LFR12	466193	6647574	1.46	9.86	8.5	1.9	5.7	8.6	404	7.4	1349	113	5.00
LFR18	465659	6647750	1.20	6.06	7.5	0.7	4.6	7.0	207	3.7	765	89	4.91
LFR19	466092	6648000	1.15	6.48	6.6	0.8	5.0	7.3	319	4.6	1003	97	4.72
LFR31	466026	6647363	1.28	9.87	15.9	2.8	5.5	10.8	709	20.1	877	98	5.20
LFR32	465724	6648738	1.59	7.91	12.3	1.4	5.0	8.8	395	6.4	1233	124	5.32
LFR01R	465976	6657599	1.17	5.98	11.2	0.8	5.6	6.0	34	2.5	750	102	5.31



**Figure 19.1.** Faunal disturbance and chemical contamination of the sediments at Lille-Frigg in 2003, are marked with large red circles. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. The field centre is marked with an X. Positioning according to UTM ED50 zone 31.

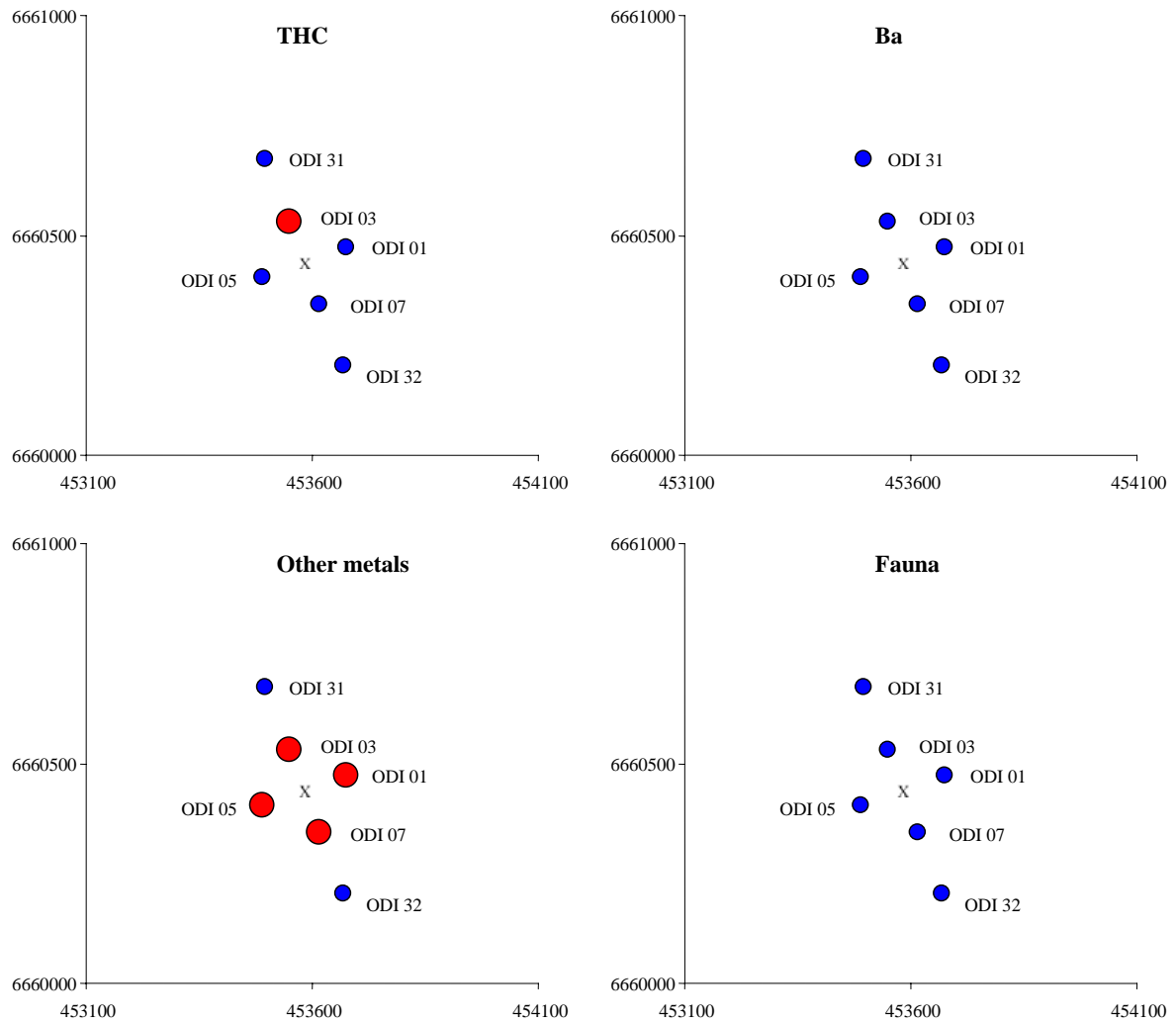
## 20 Odin

The Odin field is situated in block 30/10, about 22 km north east of the Frigg area. Production at Odin started in 1984 and ceased in 1994. The installation was removed in 1997. Monitoring of the field has been carried out in 1991, 1997 and 2000. The sediments are still characterized as fine sand, although there has been a slight increase in the pelite (Table 20.1) and slight decrease in TOM content since 2000. Generally the content of THC, barium and other metals were approximately at the same level in 2003 as in 2000, or slightly lower.

The species diversity in the bottom fauna was high and approximately at the same level as in 2000. The fauna assemblage was well correlated to the distribution of most of the measured environmental variables (lead, TOM, gravel, chromium, barium and copper). Despite this no faunal disturbance was revealed (Figure 20.1). The contaminated area at Odin was negligible.

**Table 20.1.** The table lists the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals in the sediment and number of individuals, number of taxa and diversity index found on each site in the examined field. Positioning according to UTM ED50 zone 31.

Site	E	N	TOM %	Pelite %	THC	Cu	Cr	Zn	Ba	Pb	No. of individ.	No. of taxa	H'
ODI01	453677	6660472	0.75	2.82	4.8	2.2	5.4	13.5	30	6.9	698	89	5.01
ODI03	453549	6660532	0.79	3.05	13.8	3.5	6.2	30.2	23	8.9	643	90	4.92
ODI05	453489	6660404	0.84	2.86	8.1	2.2	5.4	12.5	28	5.7	634	79	4.75
ODI07	453617	6660344	0.74	2.73	9.3	1.7	4.6	12.5	25	6.5	745	97	5.01
ODI31	453497	6660673	0.71	2.56	1.5	1.0	5.1	7.0	34	2.9	541	81	4.79
ODI32	453669	6660203	0.68	3.02	7.6	1.0	4.8	5.2	19	3.0	436	76	4.87



**Figure 20.1.** Faunal disturbance and chemical contamination of the sediments at Odin in 2003, are marked with large red circles. The field centre is marked with an X. Uncontaminated sites and sites with no faunal disturbance are marked with small blue circles. Positioning according to UTM ED50 zone 31.

## **21 Status of Region II in 2003**

Estimated total area contamination by THC has increased by 3.60 km<sup>2</sup> (from 5.27 km<sup>2</sup> in 2000 to 8.87 km<sup>2</sup> in 2003) in Region II. The estimated area contaminated by THC increased at Sigyn, Sleipner Øst, Sleipner Vest, Glitne, Balder, Ringhorne, and Frøy. The estimated area contaminated by THC decreased at Varg, Grane (compared to 1997), Heimdal, Øst-Frigg, Lille-Frigg and Odin, whereas the contaminated area was the same at Vale (no contamination) and Frigg (0.06 km<sup>2</sup>). At Jotun, the area was not estimated. The main contribution to the increase came from Ringhorne where the area increased to 3.93 km<sup>2</sup> from 0.0 km<sup>2</sup>. The main contribution to the decrease came from Varg where the area decreased from 1.33 km<sup>2</sup> to 0.07 km<sup>2</sup>.

Estimated total area contamination by barium has decreased by 4.77 km<sup>2</sup> (from 19.09 km<sup>2</sup> in 2000 to 14.32 km<sup>2</sup> in 2003) in Region II. The estimated area contaminated by barium increased at Sigyn, Sleipner Vest, Glitne, Grane (compared to 1997), Ringhorne, and Vale (not estimated before). The estimated area contaminated by barium decreased at Varg, Sleipner Øst, Balder, Jotun, Heimdal, Frøy, Frigg, Øst-Frigg and Lille-Frigg, whereas the contaminated area was still the same at Odin (0.0 km<sup>2</sup>). The main contribution to the increase came from Glitne where the area increased to 3.14 km<sup>2</sup> from 0.0 km<sup>2</sup>. The main contribution to the decrease came from Jotun where the area decreased by 3.83 km<sup>2</sup> from 5.30 km<sup>2</sup> to 1.47 km<sup>2</sup> and Balder where the area decreased by 3.78 (from 4.21 km<sup>2</sup> to 0.43 km<sup>2</sup>).

Estimated total area contamination by other metals, mainly zinc, has increased by 4.40 km<sup>2</sup> (from 2.10 km<sup>2</sup> in 2000 to 6.50 km<sup>2</sup> in 2003) in Region II. The estimated area contaminated by other metals increased at Sigyn, Sleipner Øst, Glitne, Grane (compared to 1997), Balder, Vale (not estimated before), Øst-Frigg, Lille-Frigg and Odin. The estimated area contaminated by other metals decreased at Varg, Sleipner Vest, Heimdal and Frøy, whereas the contaminated area was the same in 2003 as in 2000 at Ringhorne (0 km<sup>2</sup>) and Frigg (0.36 km<sup>2</sup>). At Jotun, the area was not estimated. The main contribution to the increase came from Balder where the area increased by 3.98 km<sup>2</sup> (from 0.15 km<sup>2</sup> to 4.13 km<sup>2</sup>). The main contribution to the decrease came from Sleipner Vest where the area decreased by 0.64 km<sup>2</sup> (from 0.74 km<sup>2</sup> to 0.10 km<sup>2</sup>).

Estimated total area with faunal disturbance has decreased by 0.92 km<sup>2</sup> (from 1.21 km<sup>2</sup> in 2000 to 0.29 km<sup>2</sup> in 2003) in Region II. Increase in estimated area with faunal disturbance was not found at any field. The estimated area with faunal disturbance increased at Sleipner Øst and decreased at Varg, Sleipner Vest, Balder, Heimdal, Frøy, Frigg and Odin whereas area with faunal disturbance was the same at Sigyn, Glitne, Grane (compared to 1997), Ringhorne, Jotun, Vale (not estimated before), Øst-Frigg and Lille-Frigg. The main contribution to the decrease came from Balder where the area decreased by 0.33 km<sup>2</sup> (from 0.37 km<sup>2</sup> to 0.04 km<sup>2</sup>).

Roughly estimated the total area of Region II is 44 700 km<sup>2</sup>. Approximately 23 000 km<sup>2</sup> are located to the west of the Norwegian trench, where also the surveyed fields are located. Based on these estimates approximately 0.04 % of the area west of the trench was contaminated by THC, 0.06 % was contaminated by Ba and 0.03 % was contaminated by other metals, whereas 0.001 % of the area had some faunal disturbance.