

# Environmental monitoring of oil and gas fields in Region II, 2006

Agreement: 4501108894

## Summary report



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## **1. Summary**

The operators in Region II, Statoil ASA Norsk Hydro Produksjon as, Esso Exploration and Production Norway AS, Total Exploration Norge AS, Talisman Energy Norge AS og Marathon Petroleum Company (Norway), commissioned UNIFOB AS, Seksjon for anvendt miljøforskning to undertake an environmental survey in the region in May 2006. The survey comprises 16 fields in addition to the region its self. Corresponding surveys have previously been undertaken in 1997, 2000 and 2003.

*S/V Geograph*, was hired by Total E&P Norge from Geoconsult, too function as a cruise vessel. Sampling commenced on May 19 and ceased on June 4, interrupted only by crew replacement between May 29 and June 1, and minor interruptions due to bad weather or other ongoing operations at the installations.

In total 235 sites were sampled. On deck sample colour, sample odour, visible fauna, sediment type or special conditions of the sample were recorded. In addition samples for measurement of sediments grain size, organic content, oil hydrocarbons and heavy metal were taken. Samples for bottom fauna identifications and enumerations were also collected. Most samples were taken in the immediate vicinity of the installations as to describe the conditions at the seafloor around the installations (212 sampling sites). In an attempt to describe the natural condition in the region samples were collected from 23 sites far off the installations.

Based on the results Region II was divided into three sub-regions. One relatively shallow sub-region in the southern part, one relatively deep sub-region in the central part and one relatively deep sub-region in the northern part. In the shallow sub-region sediments contains slightly more sand and less fine material than in the central and northern sub-regions.

Compared to the previous survey the content of oil hydrocarbons, barium and chrome were lower, whereas copper, zinc, lead and cadmium remained at the same level. The bottom fauna were in general less disturbed in 2006 than previously.

Compared to 2003 estimated minimums area of THC contaminated sediments were reduced at 10 fields and remained unchanged at 3 fields. The total area with THC contaminated sediments decreased in Region II to 0.56 km<sup>2</sup> in 2006 from 8.87 km<sup>2</sup> in 2003.

Compared to 2003 estimated minimums area of barium contaminated sediments were reduced at 12 fields. The total area with barium contaminated sediments decreased in Region II to 2.79 km<sup>2</sup> in 2006 from 14.32 km<sup>2</sup> in 2003.

Compared to 2003 estimated minimums area of metal contaminated sediments were reduced at 7 fields, and increased at 4 fields. The total area with metal contaminated sediments decreased in Region II to 2.86 km<sup>2</sup> in 2006 from 6.59 km<sup>2</sup> in 2003.

Compared to 2003 estimated minimums area of disturbed bottom fauna were reduced at 6 fields, and remained unchanged at 6 fields. Disturbed bottom fauna was only identified at one sampling site close to the former field centre at Frøy. The total area with fauna disturbance decreased in Region II to 0.001 km<sup>2</sup> in 2006 from 0.29 km<sup>2</sup> in 2003.

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 the surveyed fields are located. Based on these estimates approximately 0.002 % of the area west of the trench was contaminated by THC, compared to 0.04 % in 2003. Approximately 0.01 % was contaminated by barium, compared to 0.06 % in 2003, and approximately 0.01 % was contaminated by other metals, compared to 0.03 % in 2003. Estimated area of fauna disturbance was 0.000 % in 2006 compared to 0.001 % in 2003.

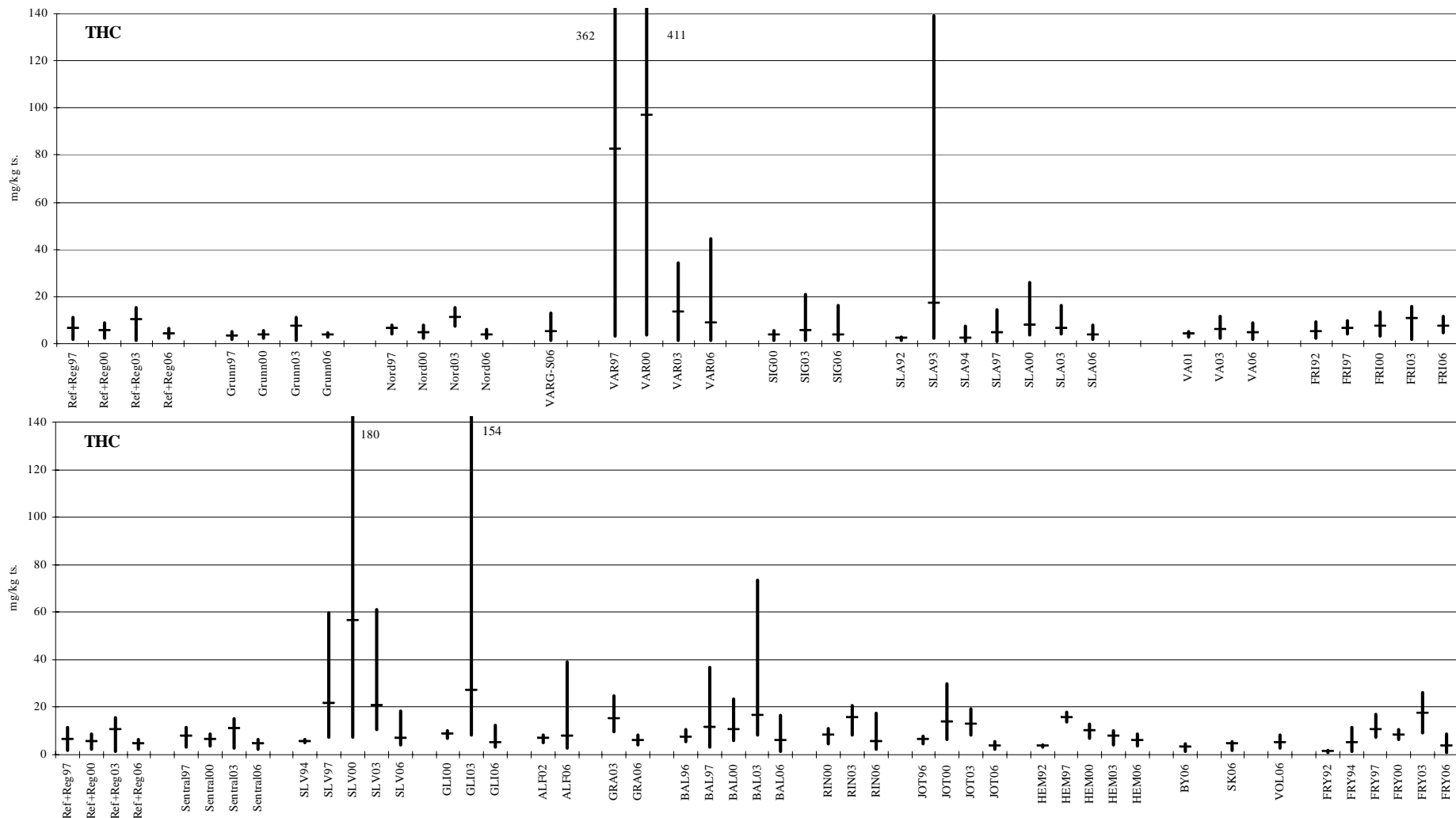
**Table 1.1.** Estimated minimum area (km<sup>2</sup>) of contaminated sediments and disturbed fauna in Region II 1997 – 2006. n.e. = not estimated.

Felt	Region and sub-region	Year	THC	Ba	Other metal	Fauna
<b>Total areal</b>	<b>Region II</b>	<b>1997</b>	<b>4.07</b>	<b>22.51</b>	<b>4.21</b>	<b>1.39</b>
<b>Total areal</b>	<b>Region II</b>	<b>2000</b>	<b>5.27</b>	<b>19.09</b>	<b>2.10</b>	<b>1.21</b>
<b>Total areal</b>	<b>Region II</b>	<b>2003</b>	<b>8.87</b>	<b>14.32</b>	<b>6.50</b>	<b>0.29</b>
<b>Total areal</b>	<b>Region II</b>	<b>2006</b>	<b>0.56</b>	<b>2.79</b>	<b>2.91</b>	<b>0.00</b>
Varg sør (VARS)	Shallow	2006	0.14	0.95	0.20	0.00
Varg (VAR)	Shallow	1997	1.18	0.1	0.00	0.00
Varg (VAR)	Shallow	2000	1.33	1.77	0.25	0.15
Varg (VAR)	Shallow	2003	0.07	0.2	0.20	0.05
Varg (VAR)	Shallow	2006	0.05	0.1	0.49	0.00
Sigyn (SIG)	Shallow	2000	0.00	0.00	0.00	0.00
Sigyn (SIG)	Shallow	2003	0.02	0.20	0.02	0.00
Sigyn (SIG)	Shallow	2006	0.02	0.00	0.00	0.00
Sleipner Øst (SLA)	Shallow	1997	0.07	13.8	0.07	0.36
Sleipner Øst (SLA)	Shallow	2000	0.40	2.21	0.00	0.00
Sleipner Øst (SLA)	Shallow	2003	0.44	0.83	0.07	0.05
Sleipner Øst (SLA)	Shallow	2006	0.00	0.20	0.15	0.00
Vale (VA)	Northern	2001	0.00	0.00	0.00	0.00
Vale (VA)	Northern	2003	0.00	1.77	0.39	0.00
Vale (VA)	Northern	2006	0.00	0.05	0.10	0.00
Frigg (FRI)	Northern	1997	0.00	0.08	0.36	0.13
Frigg (FRI)	Northern	2000	0.06	0.08	0.36	0.12
Frigg (FRI)	Northern	2003	0.06	0.05	0.36	0.05
Frigg (FRI)	Northern	2006	0.02	n.e.	0.01 (Hg)	n.e.

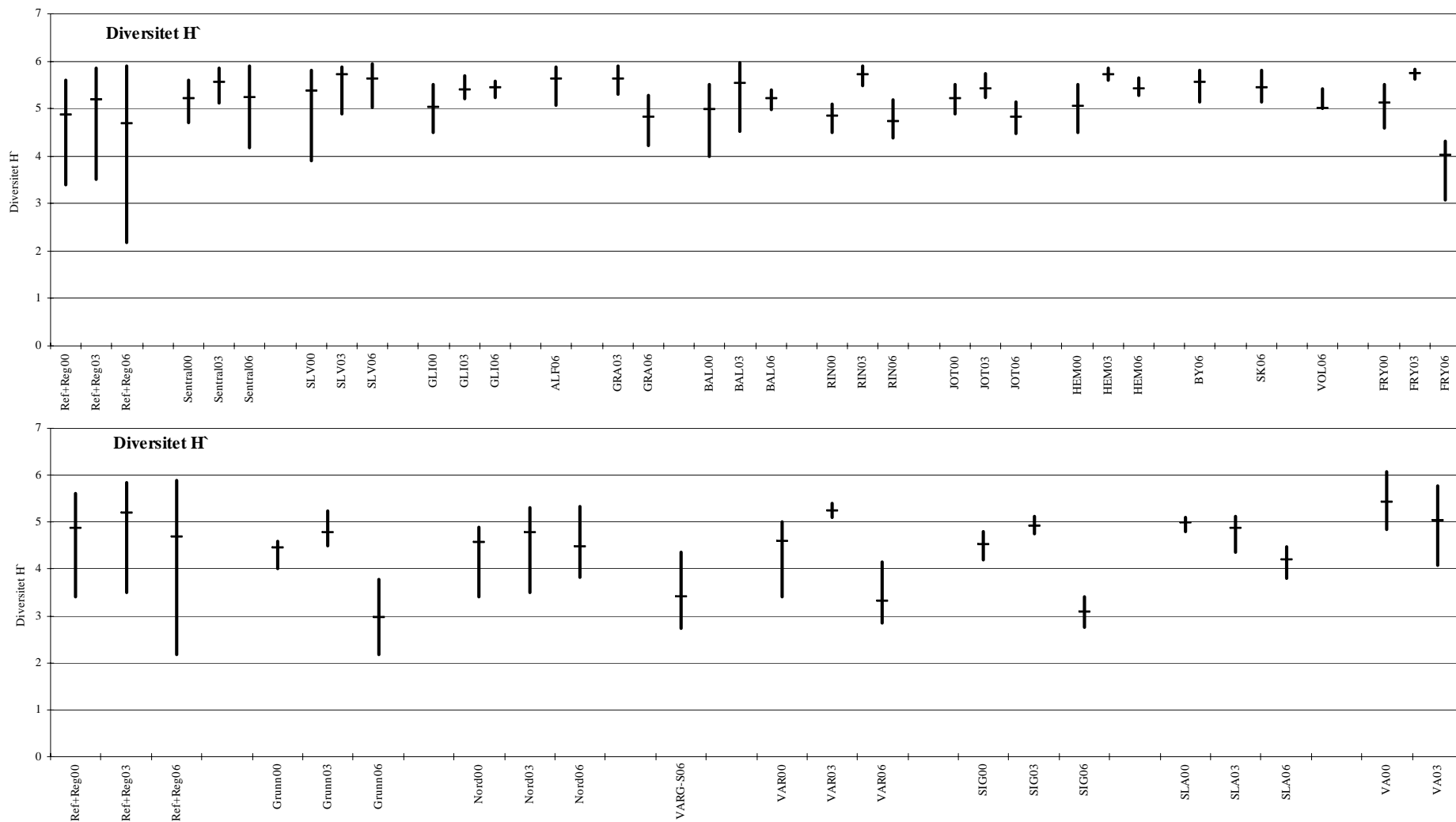
**Table 1.1. continue.** Estimated minimum area (km<sup>2</sup>) of contaminated sediments and disturbed fauna in Region II 1997 – 2006. n.e. = not estimated.

Felt	Region and sub-region	Year	THC	Ba	Other metal	Fauna
Sleipner Vest (SLV)	Central	1997	0.88	3.14	3.14	0.00
Sleipner Vest (SLV)	Central	2000	0.74	3.14	0.74	0.07
Sleipner Vest (SLV)	Central	2003	0.79	3.53	0.10	0.03
Sleipner Vest (SLV)	Central	2006	0.02	0.02	0.05	0.00
Alfa nord (ALF)	Central	2006	0.03	0.00	0.00	0.00
Glitne (GLI)	Central	1997				
Glitne (GLI)	Central	2000	0.00	0.00	0.00	0.00
Glitne (GLI)	Central	2003	0.88	3.14	0.79	0.00
Glitne (GLI)	Central	2006	0.00	0.04	0.04	0.00
Hermod (Grane) (GRA)	Central	1997	0.18	0.37	0.00	0.00
Hermod (Grane) (GRA)	Central	2003	0.10	0.98	0.05	0.00
Hermod (Grane) (GRA)	Central	2006	0.00	0.59	0.00	0.00
Balder (BAL)	Central	1997	1.09	2.93	0.37	0.48
Balder (BAL)	Central	2000	0.54	4.21	0.15	0.37
Balder (BAL)	Central	2003	2.38	0.43	4.13	0.04
Balder (BAL)	Central	2006	0.25	0.25	0.25	0.00
Ringhorne (RIN)	Central	1997				
Ringhorne (RIN)	Central	2000	0.00	0.00	0.00	0.00
Ringhorne (RIN)	Central	2003	3.93	0.74	0.00	0.00
Ringhorne (RIN)	Central	2006	0.03	0.30	0.03	0.00
Jotun (JOT)	Central	1997	0.00	0.00	0.00	0.00
Jotun (JOT)	Central	2000	1.77	5.30	0.07	0.00
Jotun (JOT)	Central	2003	n.e.	1.47	n.e.	0.00
Jotun (JOT)	Central	2006	0.00	0.20	0.10	0.00
Volund (VOL)	Central	2006	0.00	0.00	0.79	0.00
Heimdal (HEM)	Central	1997	0.25	0.25	0.25	0.11
Heimdal (HEM)	Central	2000	0.12	0.43	0.29	0.18
Heimdal (HEM)	Central	2003	0.00	0.08	0.15	0.05
Heimdal (HEM)	Central	2006	0.00	0.06	0.63	0.00
Skirne (SK)	Central	2006	0.00	0.00	0.02	0.00
Byggve (BY)	Central	2006	0.00	0.02	0.02	0.00
Frøy (FRY)	Central	1997	0.29	1.18	0.00	0.29
Frøy (FRY)	Central	2000	0.07	1.18	0.15	0.29
Frøy (FRY)	Central	2003	0.20	0.74	0.10	0.02
Frøy (FRY)	Central	2006	0.001	0.009	0.001	0.001

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**Figure 1.1.** The average and range (maximum and minimum) of THC at each field in Region II in 2006 compared to previous surveys and the THC content at the regional sites. (All regional sampling sites = Reg+Ref, shallow sub-region = grunn, northern sub-region = nord, central sub-region = sentral).



**Figure 1.2.** Average and range (maximum and minimum) of species diversity (H') at each field in 2006, 2003 and 2000, and at the regional sampling sites (All regional sampling sites = Reg+Ref, shallow sub-region = grunn, northern sub-region = nord, central sub-region = sentral).

## 2. Introduction

In May 2006, Statoil ASA, Norsk Hydro Produksjon as, Esso Exploration and Production Norway AS, Total Exploration Norge AS, Talisman Energy Norge AS and Marathon Petroleum Company (Norway) commissioned Unifob AS, Seksjon for anvendt miljøforskning, to do the 2006 environmental monitoring survey of Region II in the Norwegian sector of the North Sea (agreement: 4501108894).

Previously have three similar surveys been undertaken in this region. The first one of these was undertaken in 1997 (Mannvik & al. 1998), the second one was undertaken in 2000 (Mannvik & al. 2001), and the third one in 2003 (Botnen & al. 2004). Prior the regional surveys were smaller field specific surveys undertaken.

The purpose of the survey was to describe the environmental conditions in the region as well as at area surrounding the offshore gas and oil installations within this region of the North Sea, and compare the results with comparable surveys undertaken previously. In total, bottom samples were taken at 235 field specific sampling sites, including associated regional sampling sites and 7 regional sampling sites without any association to a specific installation. The samples were examined for physical conditions and chemical content, and bottom fauna.

**Table 2.1.** Brief summary of operators of the fields in Region II as it was in May 2006. Type of survey and number of sampling sites and status of the field is also indicated.

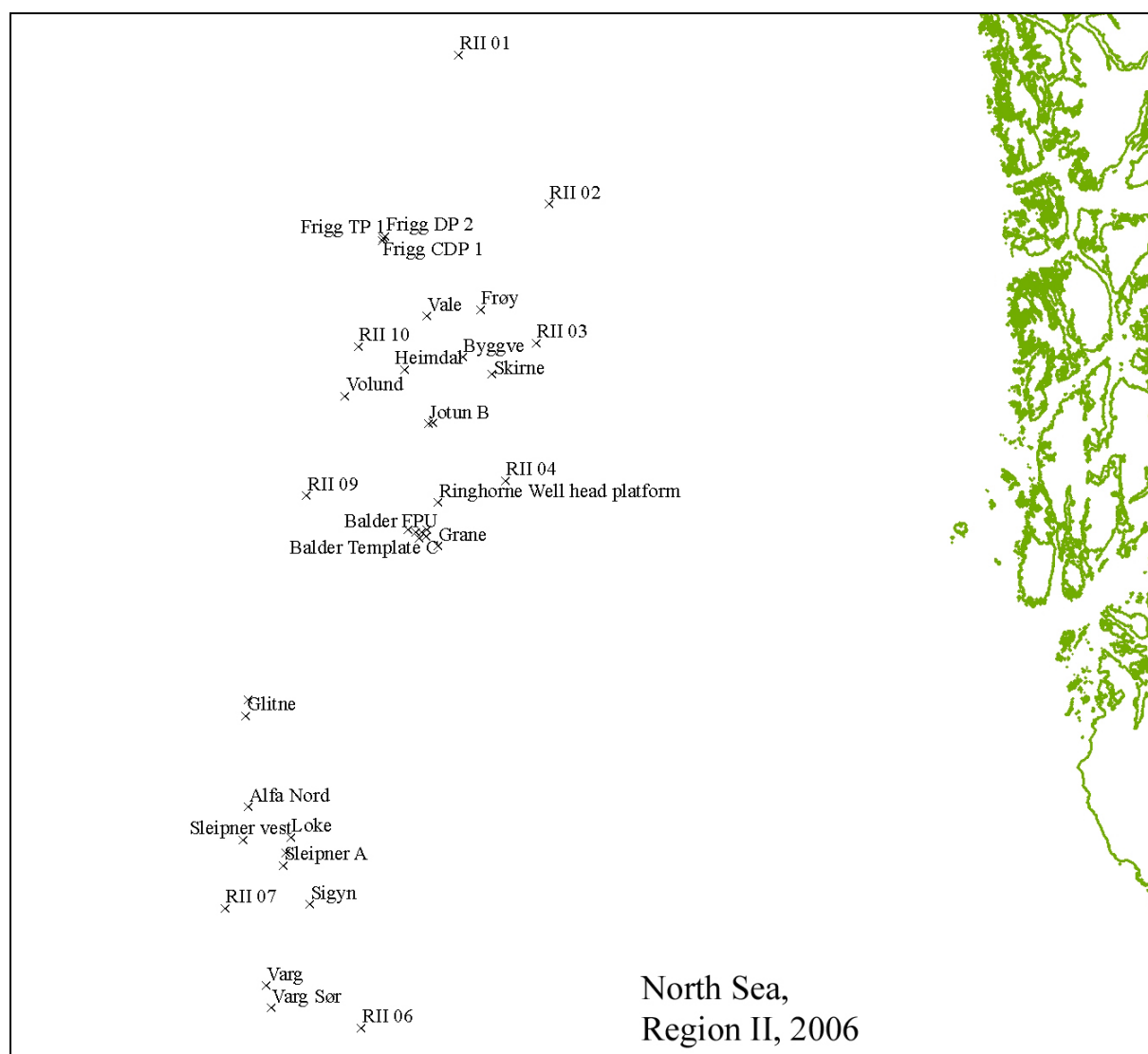
Operator	Field	Type of survey	Number of sampling sites	Current status of the field
Talisman	Varg	Monitoring	10	Active
	Varg Sør	Baseline	12	Under construction
Norsk Hydro	Heimdal	Monitoring	8	Active
	Vale	Monitoring	12	Active
	Grane	Monitoring	13	Active
	Skirne and Byggve	Monitoring	27	Active
ExxonMobil	Balder	Monitoring	21	Active
	Jotun	Monitoring	12	Active
	Ringhorne	Monitoring	15	Active
	Sigyn	Monitoring	11	Active
Statoil	Sleipner øst and Loke	Monitoring	15 <sup>1</sup>	Active
	Sleipner vest and Alfa Nord	Monitoring	25	Active
	Glitne	Monitoring	12 <sup>2</sup>	Active
Total	Frigg	Monitoring	11	Closed October 2004
	Frøy	Monitoring	9	Closed March 1997
Marathon	Volund	Baseline	15	Under construction
All	Regional sites		7 <sup>3</sup>	Reference material

<sup>1</sup> inclusive RII07

<sup>2</sup> inclusive RII08

<sup>3</sup> only regional sampling sites without associated field





**Figure 2.1.** Map showing the position of the surveyed fields in the North Sea, and the Norwegian south-western shoreline.

### 3. Material and methods

Region II is located approximately between 58° and 60° N on the Norwegian shelf 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 S/V *Geograph*. The vessel left Bergen on May 19 with a sampling crew from Unifob AS and AnalyCen AS. Sampling commenced in the southern part of Region II and continued northwards, including Heimdal, until May 29 when the vessel returned to Bergen. On June 1 the vessel was back in Region II with a new sampling crew from Det norske Veritas (DnV) and Molab AS. This crew continued sampling until June 4 when the sampling in Region II was completed. Thereafter the vessel sailed north to Region

VI for further sampling. The samples collected in Region II by Det norske Veritas and Molab AS were handed over to Unifob during demobilisation of the vessel at Ågotnes on June 29.

Sediment samples were collected by van Veen grabs with openings of 0.1 m<sup>2</sup>. In total samples were taken at 235 sampling sites including field specific regional sampling sites and 7 regional sampling sites without any associate field. According to the sampling programme were totally 885 fauna samples taken, 776 samples for THC analysis, 573 samples for metal analysis (Cu, Cr, Zn, Ba, Pb og Cd), 213 samples for Hg analysis, 201 samples for NPD/PAH analysis and 177 samples for sediment geological analysis.

#### **4. Regional sampling sites**

The results from the regional sampling sites are considered to indicate uncontaminated sediments and undisturbed bottom fauna, as well as describing the natural variation of the sea floor in Region II in 2006 (Table 4.1).

The sediments in Region II varied from sand in the shallow and northern sub-region to finer sediments in the central sub-region. Except for increased content of pelitt at JOT30R only minor changes had taken place since the 2003 survey.

Among the regional sampling sites the total amount of oil hydrocarbons (THC) varied from 2.3 to 6.4 mg/kg dry sediment. The content of barium varied from 5 to 75 mg/kg. The content of copper, chromium, zinc, lead, cadmium and mercury were, respectively, found in these ranges 0.4-2.6, 2.0-8.3, 3.3-11.2, 1.7-5.1, <0.03-0.04 and 0.002-0.007 mg/kg dry sediment.

Compared to 2003, the THC content was lower at all sites except at SIG17R where it had increased slightly and at RII04 where it remained at the same level.

The content of metals was generally at the same level as in 2003, or lower. The content of cadmium was generally lower than the limit of detection (0.003 mg/kg) in 2006.

A PCA analysis comparing the sampling sites on metal content and THC in the sediments, grouped the sites into three distinct groups (sub-regions). 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, RII07, RII08, RII09, RII10, GRA14R, BAL27R, RIN29R, JOT30R, HEM22R, FRY18R, VOL15R, ALF15R and BY14R) and the third group comprised the sites in the northern part of the region (RII01, RII02, RII04, VA13R and FRI10R). 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 Limit of 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 (Table 4.2).

The fauna samples from the regional sampling sites contained in total 367 taxa and 28755 individuals. The highest numbers of taxa was found in the central part of the region. The species diversity was high at most sampling sites, but at several sites in the northern and the shallow sub-region had the species diversity decreased due to high numbers of the polychetes *Owenia borealis* (in the north) and *Spiophanes bombyx* (in the shallow). The increased density of these species is supposed to be within the natural variation of occurrence in the

species and thus have natural causes. Multivariate analysis showed that the bottom fauna was divided into the same sub-regions as the chemical parameters. Water depth and type of sediments explain some of this sub division, although there is remaining variation in the data that is not explained by the measured chemical parameters.

**Table 4.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at the regional sites in Region II in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
RII01	463281	6688937	0.97	3.90	2.8	0.9	4.0	4.5	15.1	1.7	1739	98	3.83
RII02	490795	6651639	0.76	4.16	6.0	0.7	2.6	4.1	18.5	1.7	1377	87	4.05
RII03	490702	6614517	1.14	10.17	6.4	1.2	3.5	6.5	34.1	2.9	2194	125	4.26
RII04	485867	6577412	0.63	3.86	2.5	0.6	4.0	3.9	10.7	3.1	668	97	5.32
RII06	460684	6429120	0.67	2.08	2.8	0.9	5.1	3.9	5.5	3.6	1328	68	2.73
RII07	421831	6457534	1.26	8.24	5.5	1.1	6.9	8.7	29.0	4.8	1011	123	5.33
RII08	422936	6513198	1.28	12.28	4.9	1.4	5.9	8.9	52.0	4.3	714	122	5.60
RII09	433551	6568688	1.26	10.64	4.5	2.0	5.1	8.1	51.5	3.6	1407	123	5.19
RII10	443670	6609362	1.54	15.67	4.0	1.7	4.5	8.0	49.0	3.4	1212	128	5.70
VAR14R	433187	6434316	0.88	3.37	4.8	0.7	6.3	7.9	16.0	4.7	1218	96	3.20
SIG17R	443211	6455657	0.61	2.51	3.5	0.5	6.8	5.3	6.8	4.5	1645	72	2.18
SLE41R	441623	6472715	0.48	2.18	3.4	0.4	8.3	5.1	4.9	5.1	451	50	3.78
ALF15R	430394	6484057	1.39	12.11	6.0	1.6	6.5	9.9	55.3	4.8	905	135	5.90
GRA14R	469297	6554935	1.69	14.73	2.3	2.2	5.7	10.1	75.4	4.6	1213	128	5.03
BAL27R	459203	6567845	1.56	15.87	4.2	1.5	3.8	7.1	26.6	3.6	1292	117	5.22
RIN29R	465101	6573496	1.68	16.74	5.8	2.0	5.7	9.7	56.2	4.3	1200	107	5.09
JOT30R	452182	6590203	2.32	29.73	4.1	2.6	6.0	11.2	52.9	4.7	1052	109	5.24
VOL15R	438571	6598728	1.11	13.20	3.5	1.4	3.3	6.1	25.7	2.8	1799	146	5.49
BY14R	461684	6610833	0.85	8.81	3.5	1.2	3.3	6.0	68.4	3.0	1794	141	5.51
HEM22R	456430	6614401	1.43	15.95	5.1	2.2	4.5	8.2	74.1	3.3	1439	140	5.58
VA13R	461199	6627052	0.60	96.10	3.4	0.6	2.0	3.3	12.0	1.9	798	102	4.69
FRI10R	458362	6627966	4.87	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
FRY18R	483795	6627075	1.62	10.91	6.4	1.3	3.7	6.4	40.4	2.7	2299	128	4.18

**Table 4.2.** "Limit of significant contamination" (LSC) for Region II in 2006. All values in mg/kg dry sediment. n.c. = not calculated.

LSC	THC	PAH	NPD	Cu	Cr	Zn	Ba	Pb	Cd	Hg	Olefiner
Subregion <sub>grunn 97-06</sub>	7,9	n.c.	n.c.	1,0	9,8	8,8	28,6	6,7	<0,03	0,01	n.c.
Subregion <sub>sentral 96-06</sub>	13,7	n.c.	n.c.	2,3	9,9	12,2	152,6	6,7	0,04	0,02	n.c.
Subregion <sub>nord 97-06</sub>	11,3	n.c.	n.c.	1,2	6,3	7,2	59,4	4,4	<0,03	0,01	n.c.

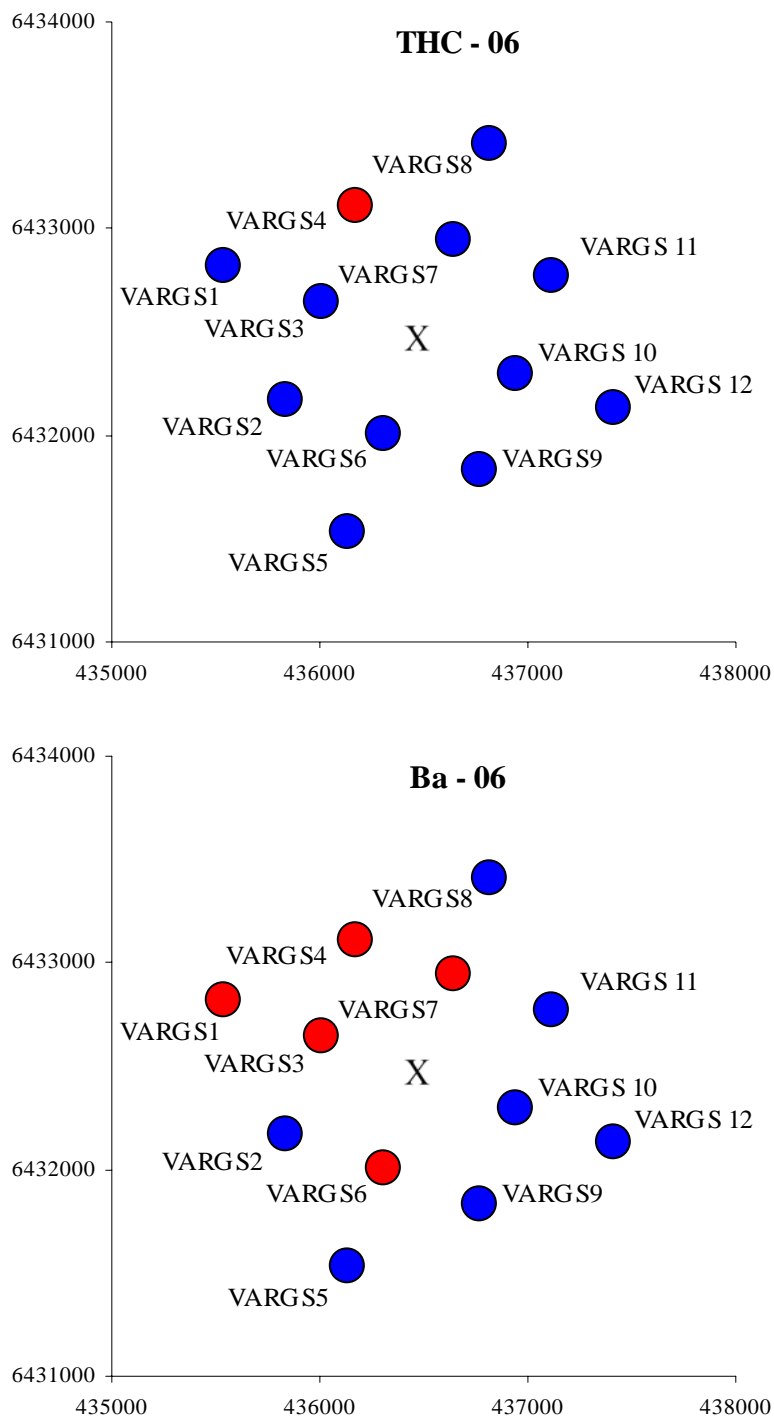
## 5. Varg Sør

Varg sør is situated in block 25/12 approximately 6 km south of Varg. Varg sør was the southern most field in the 2006 survey. This was the first survey at Varg sør and the results are considered as an environmental baseline survey of the field.

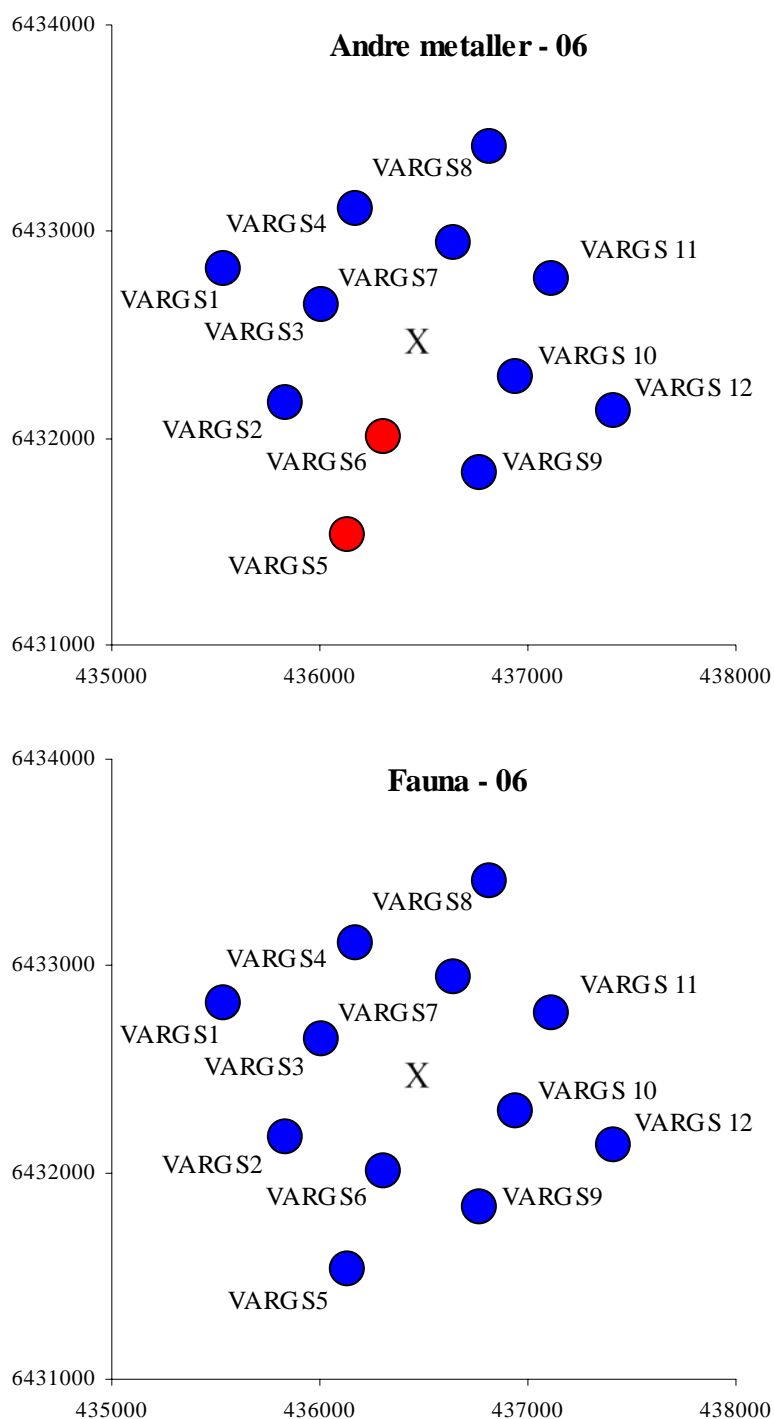
The survey revealed THC contamination at one sampling site about 700 m to the north northwest of the field centre. Contamination of barium was revealed out to about 700 m to the north northeast, 500 m to the south and 1000 m to the west. Contamination of copper was revealed out to 1000 m to the south. There was no disturbed fauna.

**Table 5.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Varg sør in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
VARG S1	435535	6432815	0.67	3.16	5.2	0.7	7.4	7.7	61.3	5.6	1256	95	3.37
VARG S2	435834	6432174	0.68	2.17	2.8	0.7	7.2	7.1	26.4	5.6	1080	88	3.35
VARG S3	436005	6432644	0.56	3.12	3.4	0.7	7.3	7.2	69.0	5.3	1456	91	3.31
VARG S4	436176	6433113	0.72	2.91	12.9	0.9	7.3	7.8	54.6	5.7	1501	95	3.08
VARG S5	436132	6431533	0.72	3.56	5.8	1.2	7.0	7.3	28.2	5.4	1108	90	3.49
VARG S6	436303	6432003	0.62	2.78	6.5	1.1	6.8	6.9	41.2	5.6	780	90	4.35
VARG S7	436646	6432942	0.71	3.24	3.8	0.6	6.8	6.7	50.9	5.3	1212	75	2.73
VARG S8	436817	6433412	0.83	3.04	4.2	0.6	6.9	6.7	23.6	5.4	953	83	3.64
VARG S9	436773	6431832	0.73	3.45	1.5	0.9	7.7	7.1	16.8	5.7	1093	77	3.15
VARG S10	436944	6432301	0.80	3.66	4.7	0.7	7.7	7.1	13.1	5.7	1081	88	3.38
VARG S11	437115	6432771	0.57	2.97	3.0	0.6	7.1	6.8	12.1	5.4	751	71	3.63
VARG S12	437414	6432130	0.60	3.21	5.9	0.6	7.7	6.9	11.8	5.6	1013	79	3.42



**Figure 5.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region <sub>shallow 97-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region <sub>shallow 97-06</sub> are marked with blue circles.



**Figure 5.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region <sub>shallow 97-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region <sub>shallow 97-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.

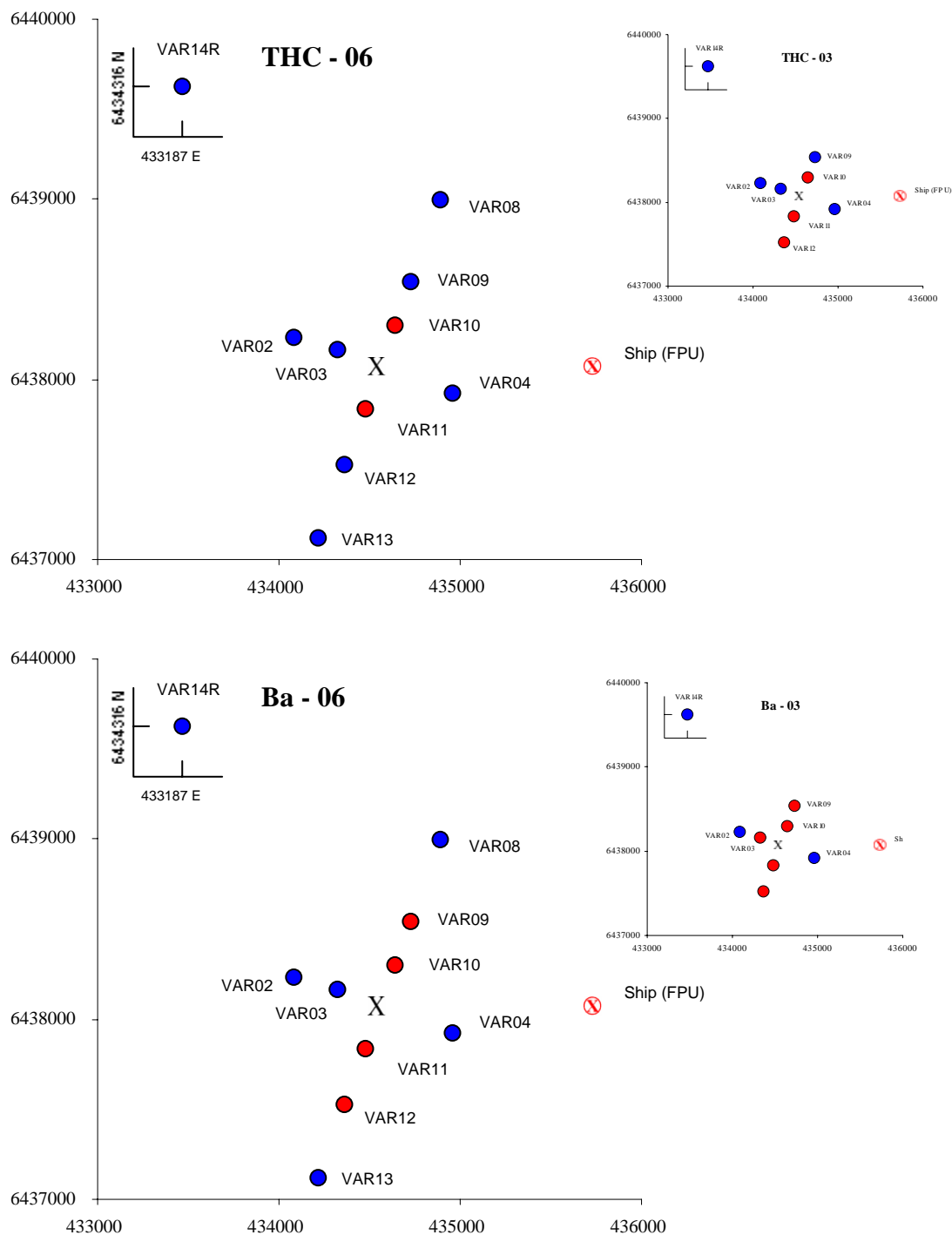
## 6. Varg

Varg is situated in block 15/12. Production started at Varg in December 1998. A baseline survey was undertaken in 1997 and was followed by ordinary monitoring surveys in 2000 and in 2003.

From 2003 to 2006 nine new wells have been drilled at Varg. The sediments consist of fine sand with slightly reduced content of pelitt and TOM. In the sediments the content of THC, chromium and barium were reduced, whereas the content of copper, zinc, lead and cadmium were at the same level as before. The number of specimens in the fauna had increased in 2006, compared to previous surveys. This was mainly due to natural variation in the population size of the two polychetes *Spiophanes bombyx* and *Spiophanes kroyeri*, and has no relation to the activity at Varg. The bottom fauna was in general more similar across the field in 2006 than in 2003, and the fauna assemblage indicate good and improved environmental conditions compared to 2003. The area contaminated by THC and barium, and the area with disturbed fauna was smaller in 2006 than in 2003. The area contaminated by other metals was larger in 2006 than in 2003. The northerly transect was too short (1000 m) to include sediment uncontaminated with lead.

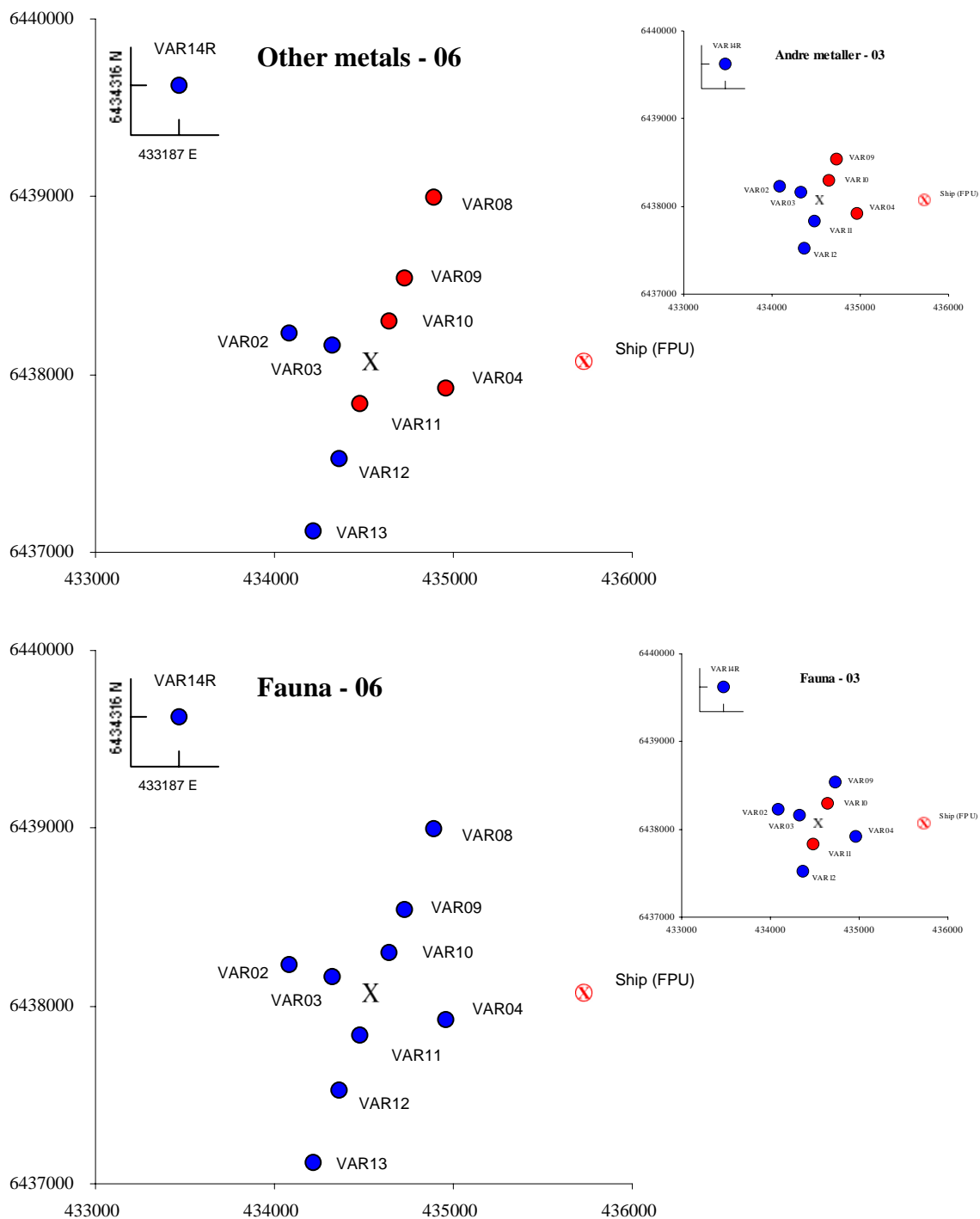
**Table 6.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index ( $H'$ ) at Varg in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	$H'$
VAR02	434090	6438231	0.63	2.68	3.5	0.6	7.5	5.8	15.4	5.1	903	67	3.14
VAR03	434325	6438160	0.52	2.07	1.8	0.6	6.2	4.7	13.2	2.9	1005	79	3.73
VAR04	434959	6437919	0.47	0.78	1.7	0.5	7.6	6.9	12.0	7.0	1429	86	2.94
VAR08	434899	6438997	0.53	1.04	3.6	0.5	8.7	7.6	14.3	8.5	944	75	3.47
VAR09	434733	6438543	0.60	1.49	3.9	0.7	8.2	8.2	51.7	7.5	722	80	4.14
VAR10	434640	6438300	0.57	1.79	44.7	1.1	8.1	9.4	159.3	6.9	817	72	3.05
VAR11	434478	6437835	0.49	1.92	10.1	1.9	7.9	9.6	137.3	6.6	1442	86	2.86
VAR12	434367	6437523	0.50	1.32	1.4	0.8	8.3	7.1	30.2	6.5	1300	83	3.40
VAR13	434219	6437115	0.93	2.68	7.6	0.6	7.1	6.6	14.5	5.8	1351	78	3.19
VAR14R	433187	6434316	0.88	3.37	4.8	0.7	6.3	7.9	16.0	4.7	1218	96	3.20



**Figure 6.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region shallow 97-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.





**Figure 6.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where metals occurred below LSC Sub-region shallow 97-06 are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

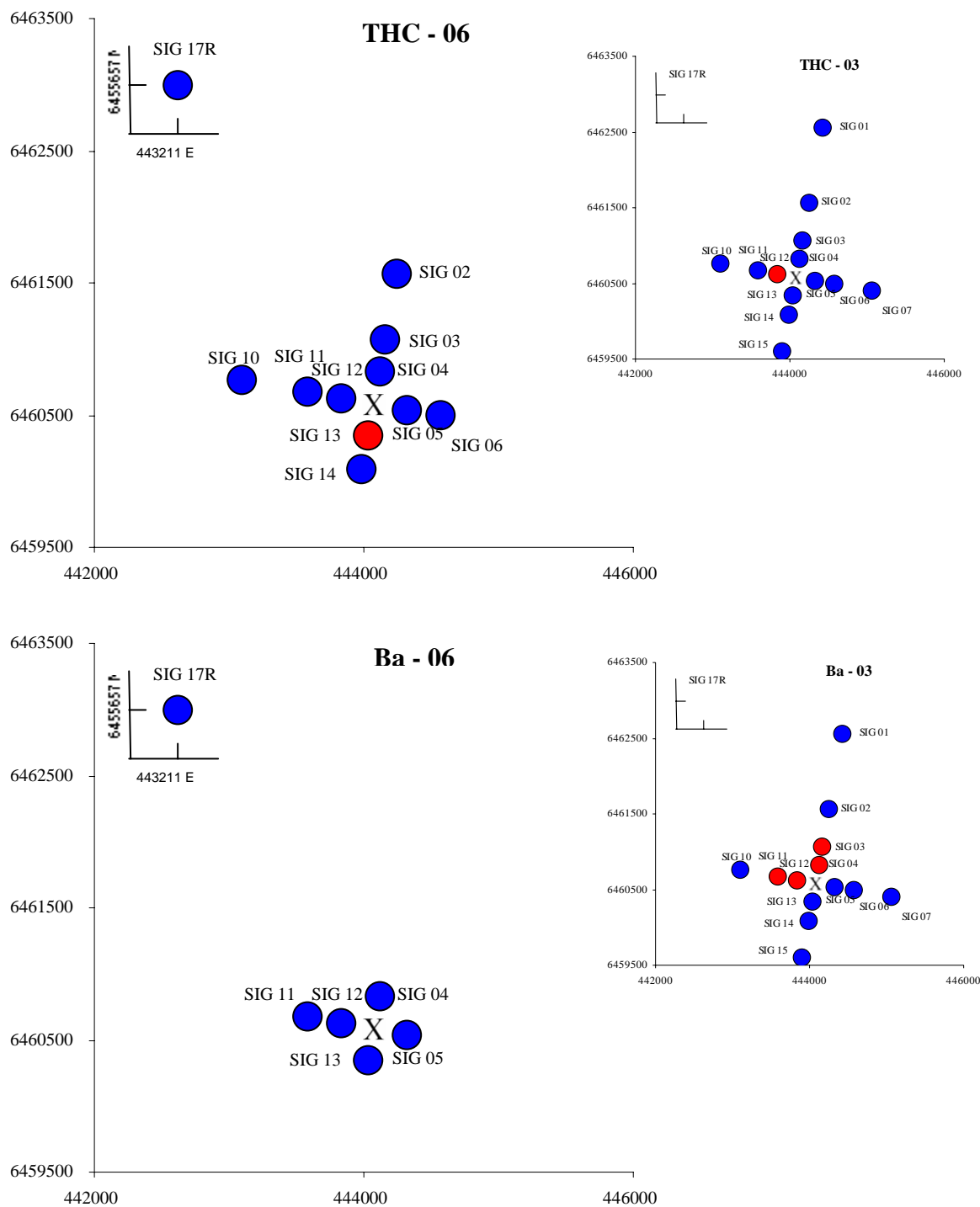
## 7. Sigyn

Sigyn is situated in block 16/7. Production started in December 2003. A baseline survey was undertaken in 2000 and the first monitoring survey was undertaken in 2003.

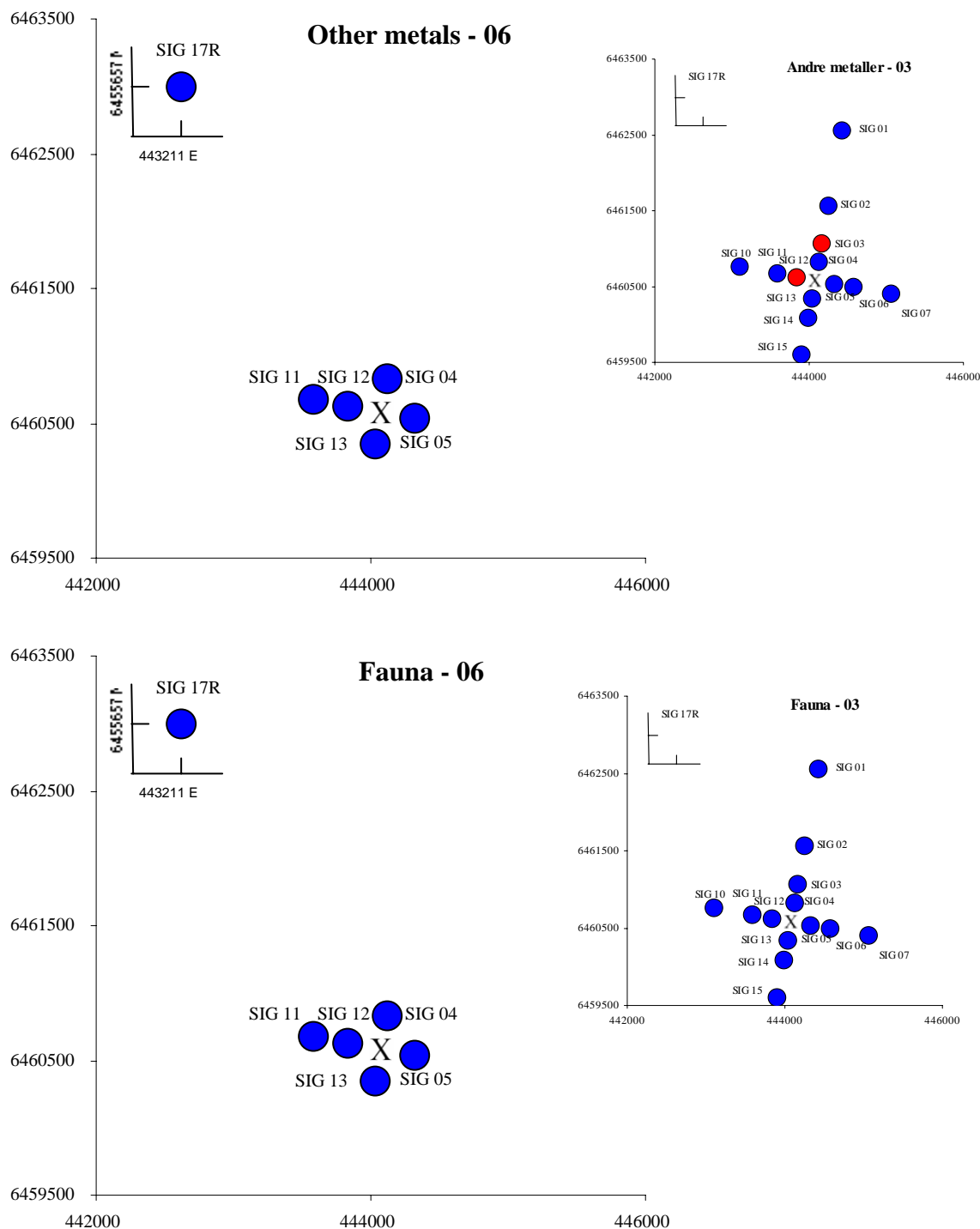
From 2003 to 2006 there was no drilling at Sigyn and only minor discharges. The bottom sediments consist of fine sand with slightly less content of pelitt compared to previous sampling. The content of THC and metals were lower or at the same low level as before. One exception was detected 250 m to the south of the field centre where the THC content had increased. More specimens were found in the fauna samples than in previous years. This was mainly due to natural variation in the population size of the two polychetes *Spiophanes bombyx* and *Spiophanes kroyeri*, and has no relation to the activity at Sigyn. The bottom fauna was in general more similar across the field in 2006 than in 2003 and the fauna assemblage indicates good environmental conditions. The area contaminated by THC (0.02 km<sup>2</sup>) was unchanged compared to 2003. There was no contamination by metals or any disturbed fauna. All transects reached out to uncontaminated sediments.

**Table 7.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Sigyn in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
SIG02	444253	6461566	i.a.	i.a.	1.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SIG03	444166	6461073	i.a.	i.a.	2.4	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SIG04	444122	6460827	0.58	1.38	2.4	0.7	8.4	5.8	15.7	4.8	1542	67	2.90
SIG05	444325	6460538	0.54	1.28	3.0	0.6	8.4	5.5	5.9	4.8	1294	81	3.17
SIG06	444571	6460494	i.a.	i.a.	1.8	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SIG10	443094	6460755	i.a.	i.a.	1.3	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SIG11	443587	6460668	0.49	1.34	4.2	0.4	8.2	5.2	10.4	4.7	1409	65	3.19
SIG12	443833	6460624	0.53	1.43	3.5	0.6	8.5	5.7	17.3	4.8	1524	87	3.41
SIG13	444036	6460335	0.70	1.32	16.0	0.4	8.5	5.4	6.4	4.9	1715	77	2.76
SIG14	443992	6460089	i.a.	i.a.	1.4	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SIG17R	443211	6455657	0.61	2.51	3.5	0.5	6.8	5.3	6.8	4.5	1645	72	2.18



**Figur 7.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region shallow 97-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figur 7.1 fortsetter.** Sampling sites where metals occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where metals occurred below LSC Sub-region shallow 97-06 are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

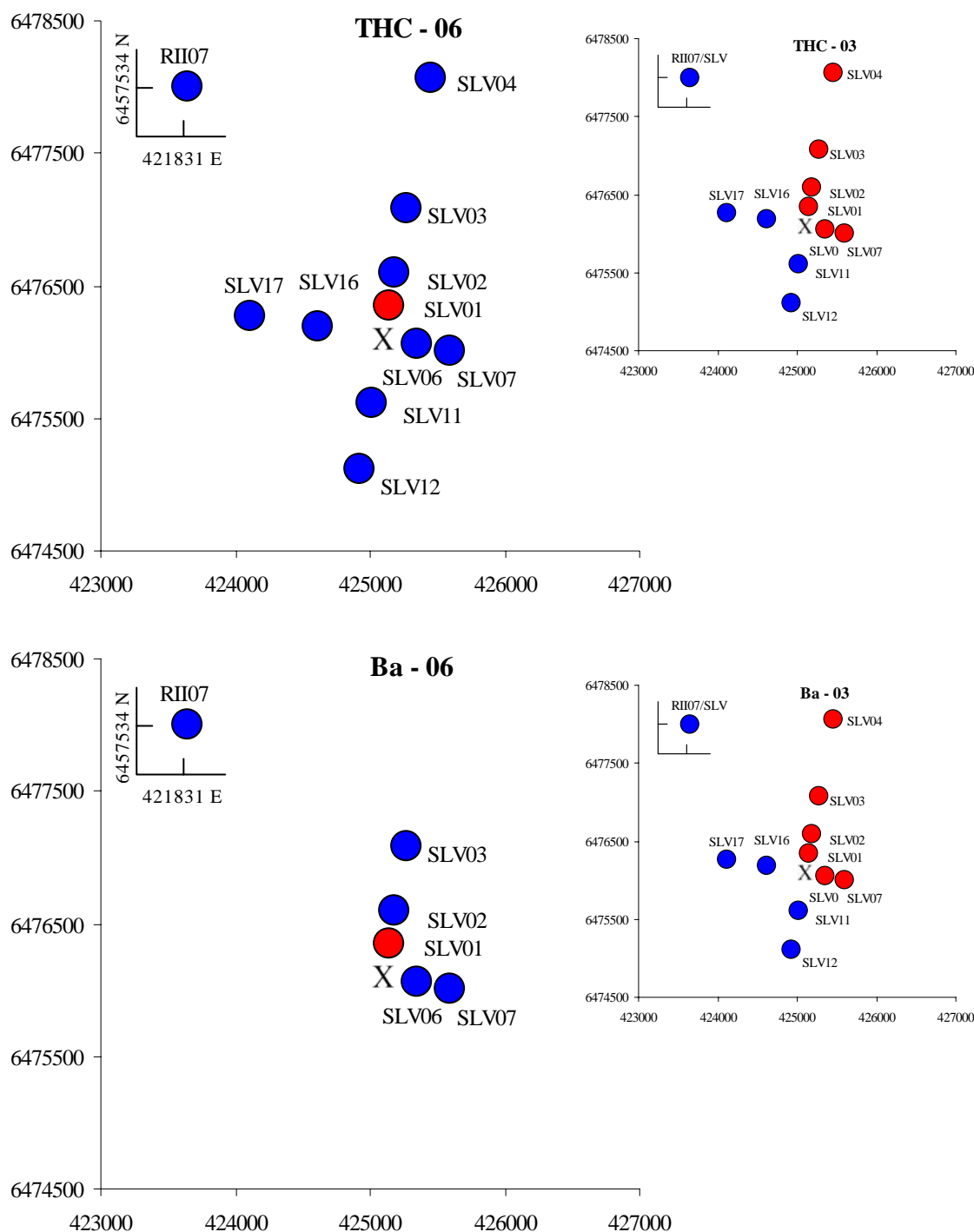
## 8. Sleipner vest

Sleipner vest is situated in block 15/6. Production started in August 1996. A baseline survey was carried out in 1994 and followed by monitoring surveys in 1997, 2000 and 2003.

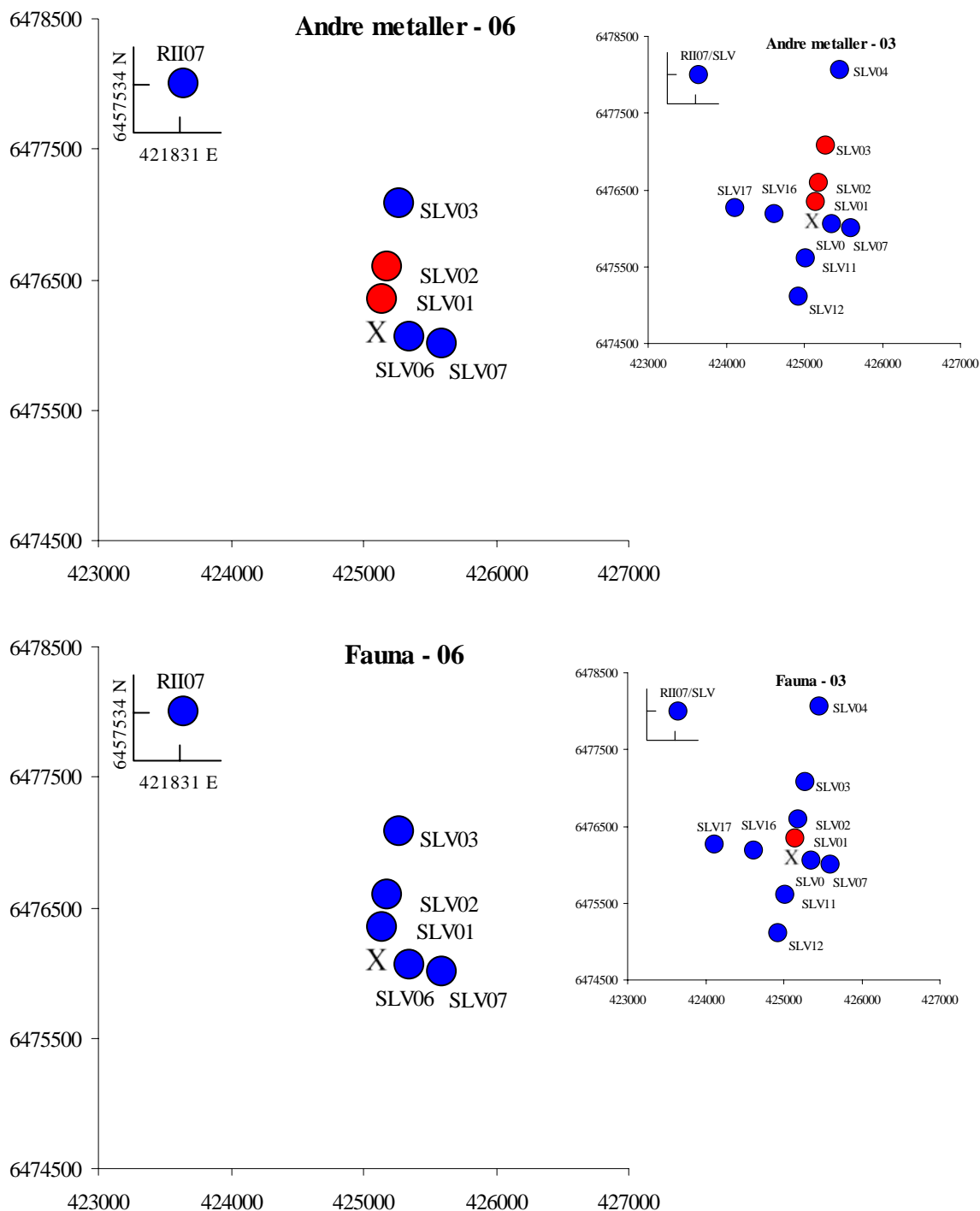
There has been no drilling activity or any major discharges at Sleipner vest since 2000. The bottom sediments consist of fine sand. In general it was lower content of THC, barium and chromium in the sediments in 2006, whereas the other measured metals remained approximately at the same level as before. The number of specimens and species, and the species diversity, was approximately at the same levels as before, although signs of improved environmental conditions were seen at the sampling sites to the north of the field centre. The polychaeta *Paramphinome jeffreysi* was, as in 2003, the most abundant species. The bottom fauna was more similar across the field in 2006 than in 2003. The results indicate no disturbed fauna and improved environmental conditions at Sleipner vest. The area contaminated by THC, barium and other metals were smaller in 2006 than in 2003. The sampling transects were long enough to include uncontaminated sediments.

**Tabell 8.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Sleipner vest in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
SLV01	425143	6476347	3.18	20.06	18.1	6.5	7.8	29.9	210.0	8.8	774	107	5.02
SLV02	425186	6476593	1.70	14.18	4.9	2.3	6.1	12.8	119.5	5.1	799	119	5.70
SLV03	425273	6477086	1.69	15.48	4.8	2.0	6.5	10.7	73.0	4.8	373	105	5.94
SLV04	425446	6478071	i.a.	i.a.	4.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLV06	425345	6476058	1.31	13.02	5.9	1.9	6.1	10.4	79.6	4.7	1001	130	5.72
SLV07	425592	6476014	1.55	14.84	4.0	1.9	6.7	10.8	65.0	5.0	822	113	5.75
SLV11	425012	6475609	i.a.	i.a.	6.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLV12	424926	6475116	i.a.	i.a.	5.5	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLV16	424607	6476188	i.a.	i.a.	4.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLV17	424114	6476275	i.a.	i.a.	4.3	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RH07	421831	6457534	1.26	8.24	5.5	1.1	6.9	8.7	29.0	4.8	1011	123	5.33



**Figure 8.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 8.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

## 9. Sleipner øst

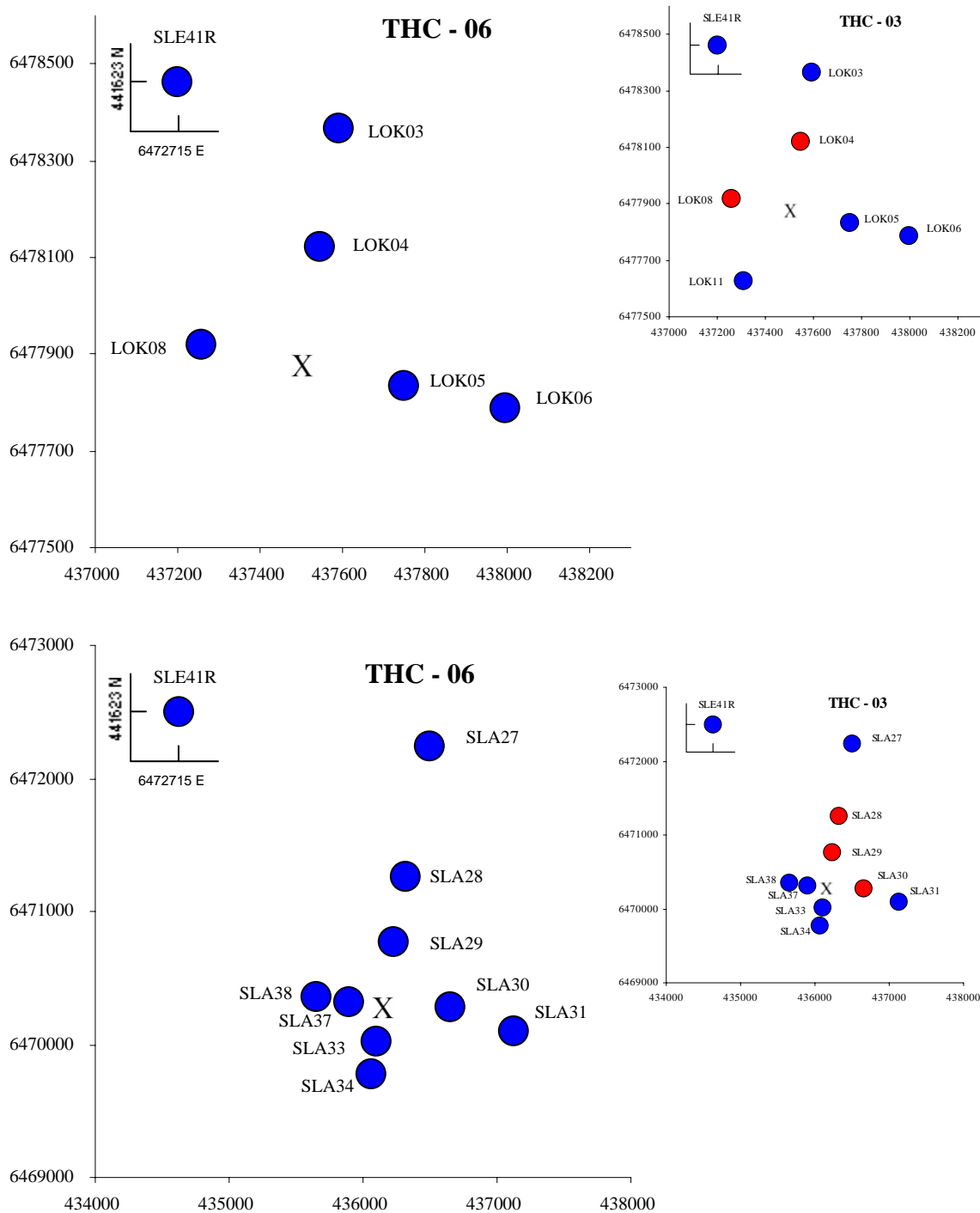
Sleipner øst is situated in block 15/9, and it consists of the Sleipner A platform and the two templates Loke and Sleipner øst. Production started in August 1993. The environmental conditions at the field have previously been surveyed in 1992, 1993, 1997, 2000 and in 2003.

From 2003 to 2006 there has been no drilling activity or any major discharges at Sleipner A. The sediments consisted of fine sand. The content of barium was reduced in 2006 compared to previous surveys, whereas the content of THC, chromium, zinc, lead and chadmiun was lower or at the same level as before. It was significantly more specimens in the samples in 2006 than before. This is most likely due to natural variation in the population of the polychaeta *Spiophanes bombyx* and has no connection to the activity at field. The area contaminated by THC and barium, and the area with disturbed bottom fauna were less in 2006 than in 2003. The area contaminated by other metals, mostly zinc, was larger in 2006 than in 2003. The reduced sampling programme at Loka prohibited calculation of the area contaminated by metals. The transect to the south of the Sleipner A was too short to include sediments uncontaminated by barium.

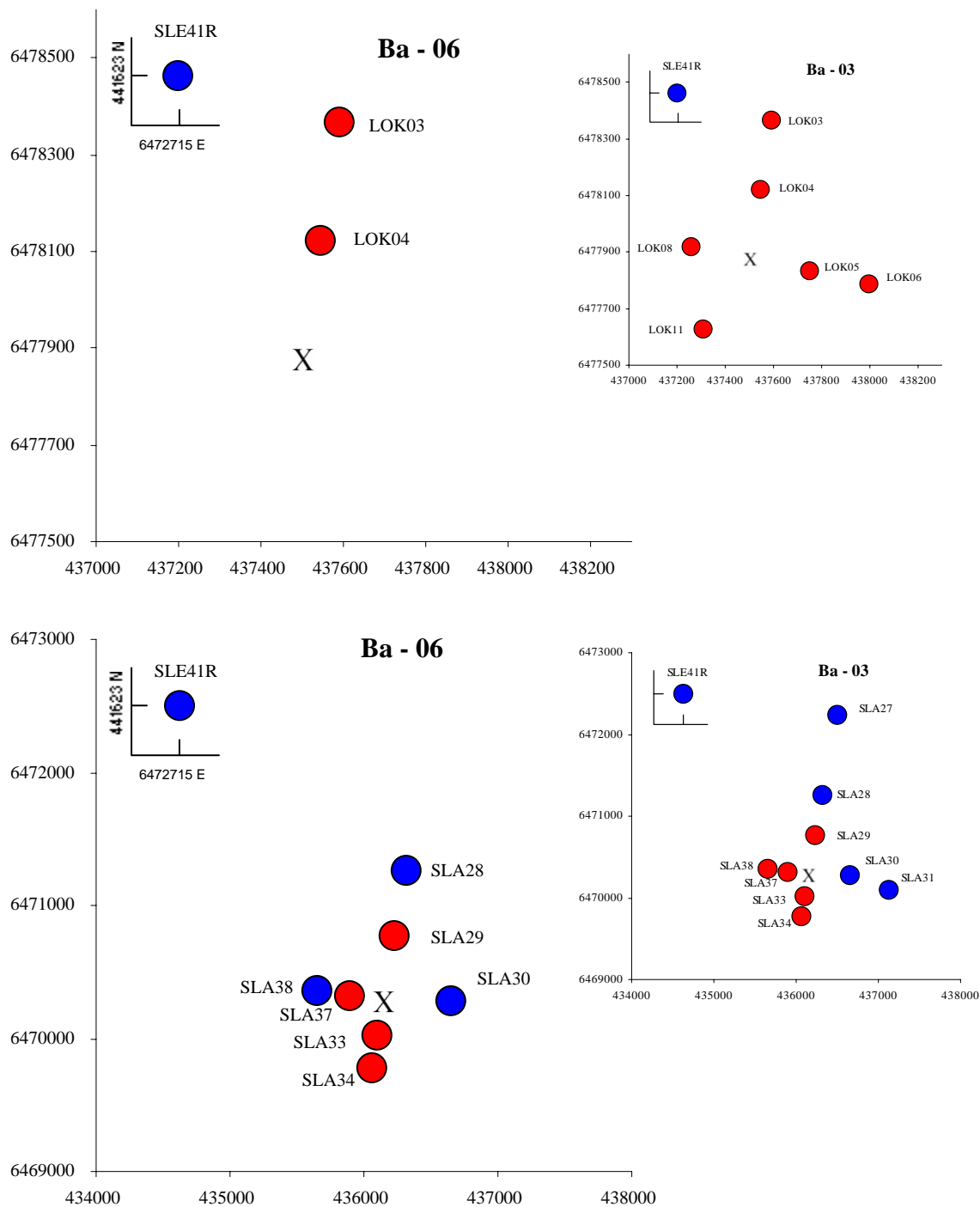
**Table 9.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Sleipner øst in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
LOK03	437590	6478367	i.a.	i.a.	3.2	0.6	6.1	5.6	57.3	4.7	i.a.	i.a.	i.a.
LOK04	437546	6478121	i.a.	i.a.	8.1	1.2	6.2	6.6	203.7	5.5	i.a.	i.a.	i.a.
LOK05	437749	6477832	i.a.	i.a.	3.0	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
LOK06	437995	6477788	i.a.	i.a.	4.0	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
LOK08	437257	6477918	i.a.	i.a.	2.0	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLA27	436497	6472241	i.a.	i.a.	1.6	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLA28	436323	6471256	i.a.	i.a.	3.1	0.8	6.9	6.5	24.4	4.0	i.a.	i.a.	i.a.
SLA29	436236	6470763	0.60	2.00	6.4	1.0	7.6	12.8	67.0	4.9	737	67	4.47
SLA30	436650	6470271	0.59	1.89	2.7	0.6	7.2	6.4	18.0	4.3	689	74	4.43
SLA31	437134	6470097	i.a.	i.a.	4.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
SLA33	436106	6470025	0.69	2.02	4.8	1.2	7.0	10.5	82.8	5.2	738	55	3.80
SLA34	436063	6469779	0.60	1.65	2.5	0.9	7.5	7.3	31.6	4.4	785	69	4.31
SLA37	435903	6470314	0.61	1.99	5.3	0.9	7.1	8.9	49.7	4.5	1041	74	3.80
SLA38	435657	6470358	0.55	1.85	3.4	0.7	7.2	6.9	24.7	4.7	760	77	4.40
SLE41R	441623	6472715	0.48	2.18	3.4	0.4	8.3	5.1	4.9	5.1	451	50	3.78

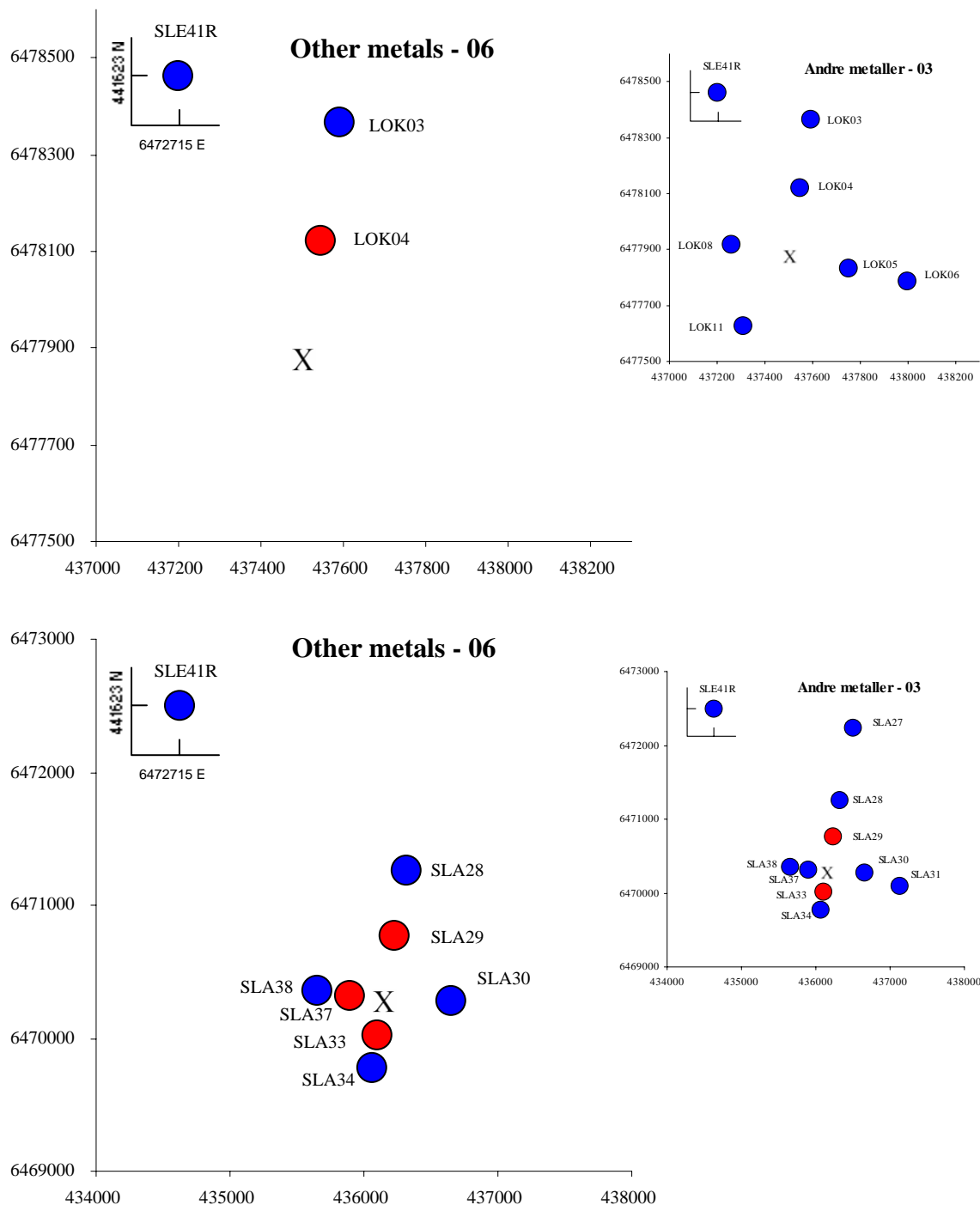




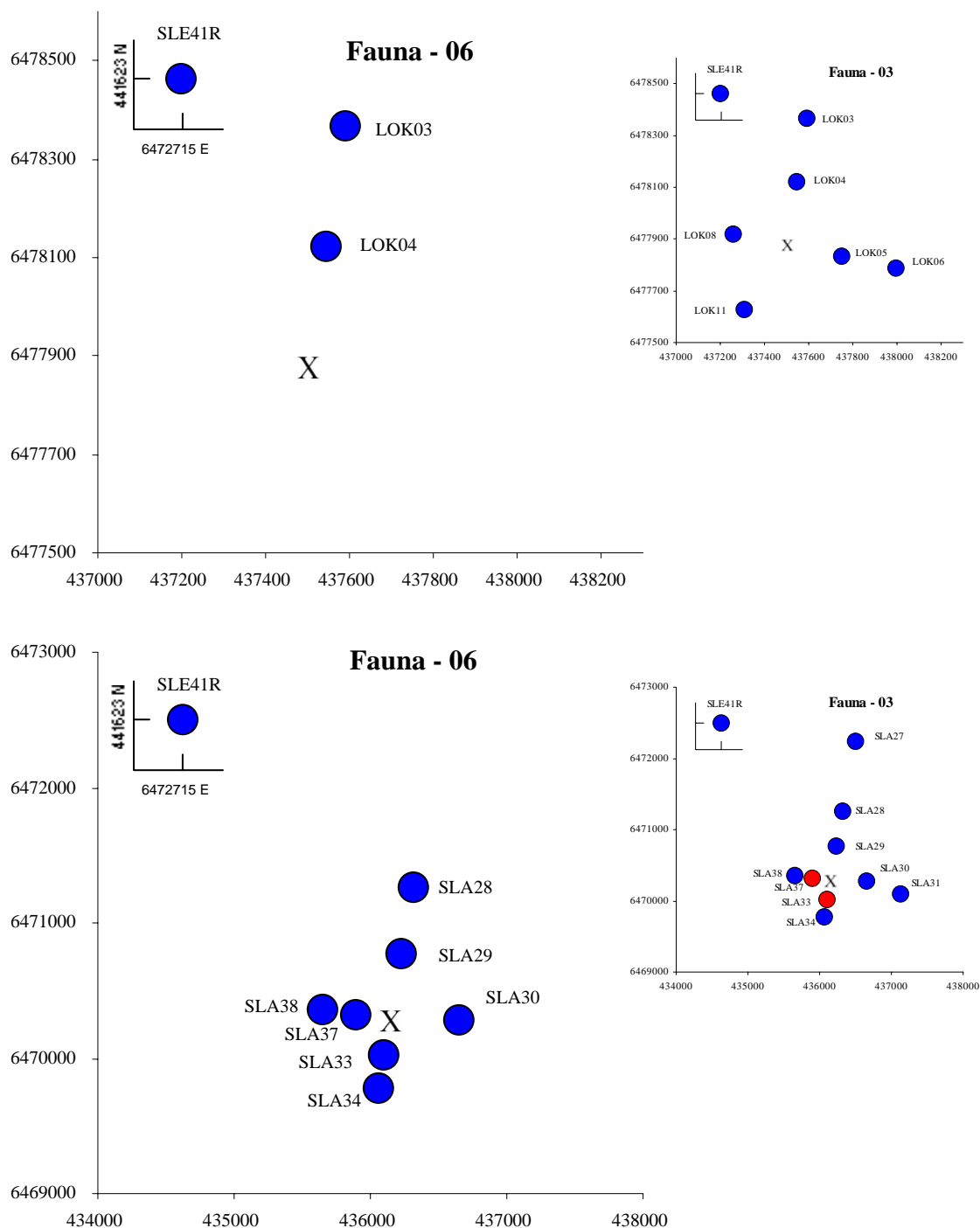
**Figure 9.1.** Sampling sites where THC occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where THC occurred below LSC Sub-region shallow 97-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 9.1 continue.** Sampling sites where barium (Ba) occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where barium (Ba) occurred below LSC Sub-region shallow 97-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 9.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region shallow 97-06 are marked with red circles, whereas sites where metals occurred below LSC Sub-region shallow 97-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 9.1 continue.** Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

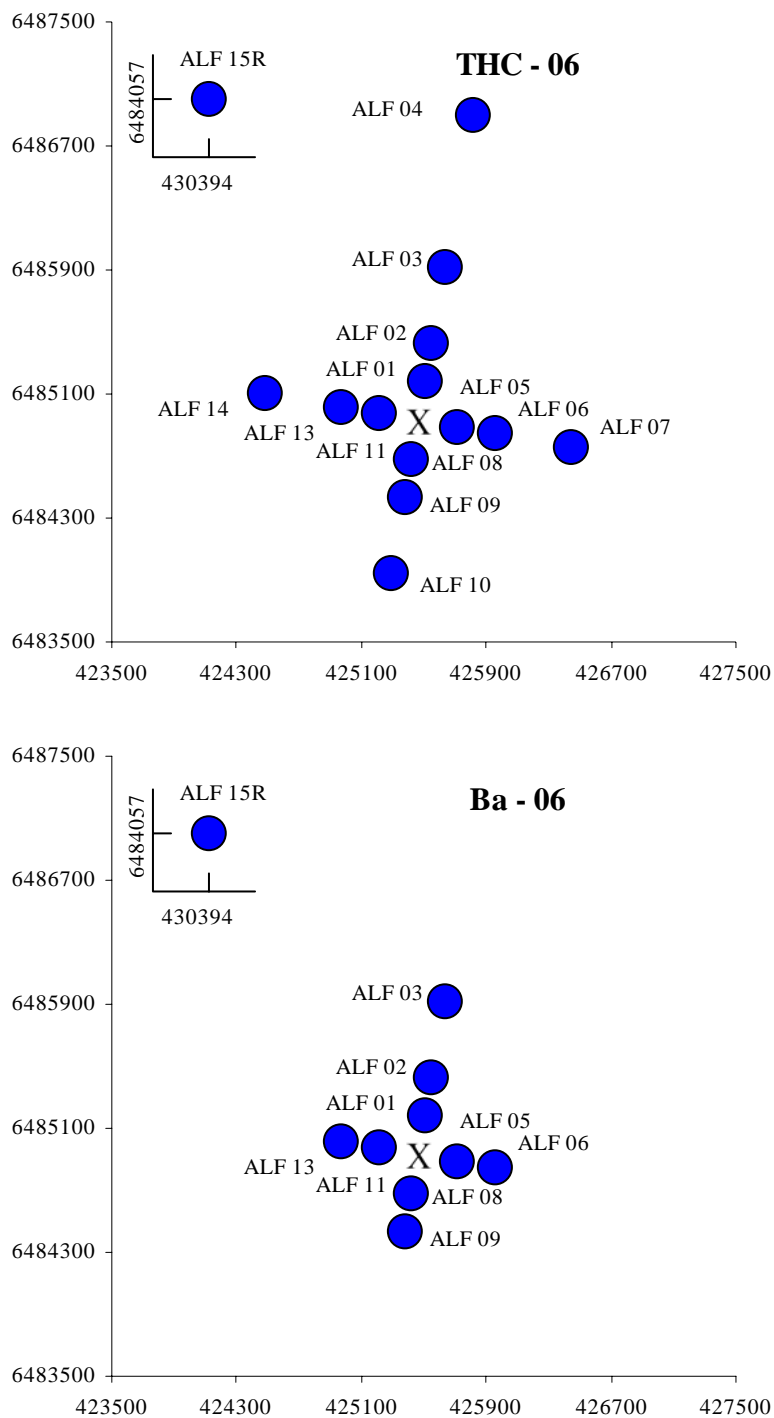
## 10. Alfa Nord

Alfa nord is situated in block 15/6 and it consists of one template and four production wells. A baseline survey was carried out in 2002.

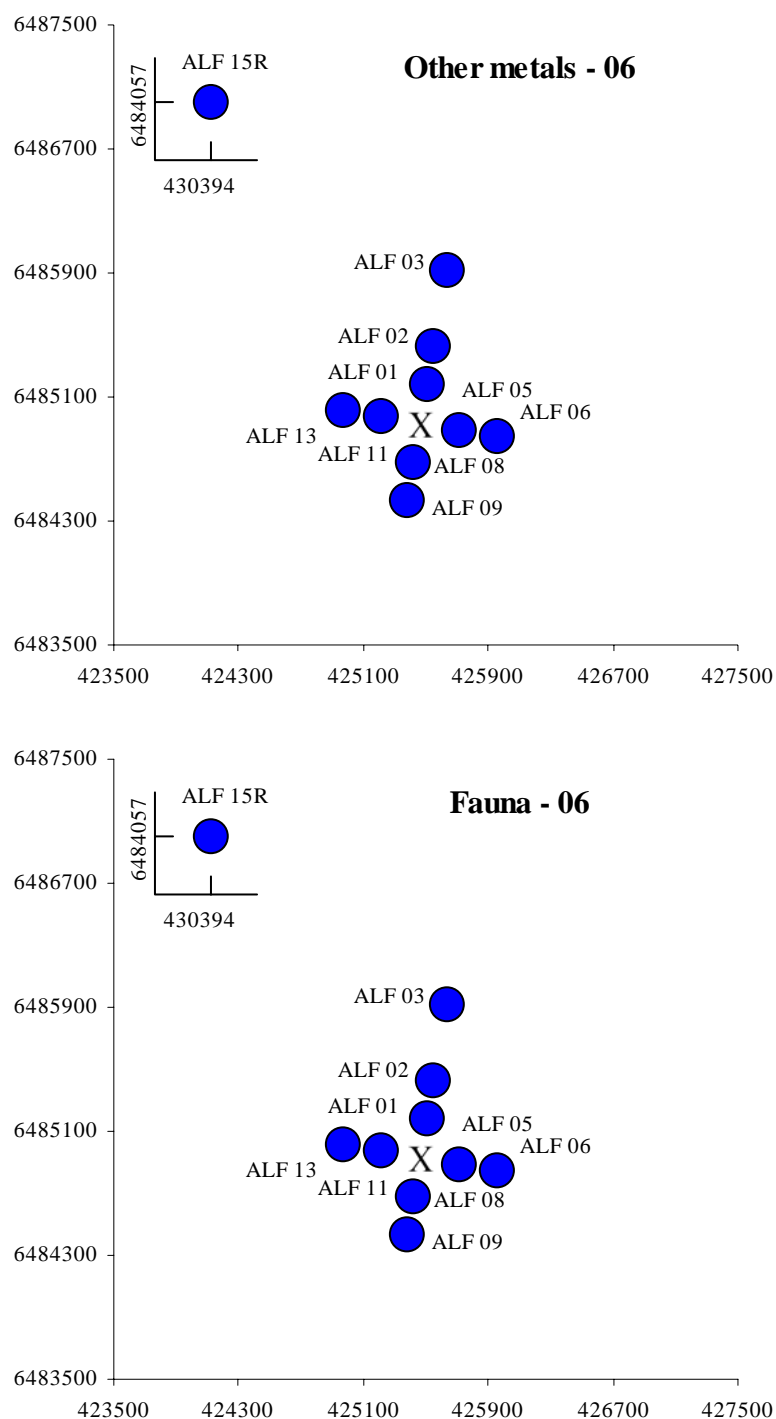
From 2003 to 2006 six new wells were drilled at Alfa Nord, and in both 2003 and 2005 there were some discharges. The bottom sediments consist mostly of fine. It was in general low content of THC and metals in the sediments, although contamination by THC was revealed out to 250 m to the east of the field centre. The bottom fauna was relatively similar across the field and it was undisturbed. The results indicate good environmental conditions at Alfa nord in 2006, and all sampling transects were reaching out to uncontaminated sediments.

**Table 10.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Alfa nord in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
ALF1	425513	6485171	2.18	17.29	9.5	2.2	6.1	11.0	92.1	4.4	748	114	5.65
ALF2	425557	6485417	1.87	17.62	8.2	2.1	6.6	11.6	76.2	4.7	726	107	5.62
ALF3	425644	6485910	2.33	16.90	3.0	1.9	6.2	10.9	62.3	4.5	624	109	5.74
ALF4	425817	6486895	i.a.	i.a.	3.9	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
ALF5	425716	6484882	1.71	15.91	39.0	2.3	5.9	10.8	128.2	4.2	1142	115	5.53
ALF6	425962	6484838	1.89	15.92	4.5	1.6	5.8	9.7	53.0	4.0	870	123	5.88
ALF7	426455	6484751	i.a.	i.a.	4.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
ALF8	425427	6484679	1.80	15.43	3.2	2.1	6.1	11.2	92.9	4.4	921	123	5.77
ALF9	425383	6484433	1.56	15.84	4.7	1.7	6.1	10.7	69.2	4.4	637	99	5.68
ALF10	425296	6483940	i.a.	i.a.	3.1	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
ALF11	425224	6484968	1.72	17.11	5.9	1.6	5.8	9.4	63.5	4.1	549	104	5.64
ALF13	424978	6485012	2.38	18.62	11.0	1.8	6.3	10.7	53.8	4.6	872	107	5.07
ALF14	424485	6485099	i.a.	i.a.	2.8	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
ALF15R	430394	6484057	1.39	12.11	6.0	1.6	6.5	9.9	55.3	4.8	905	135	5.90



**Figure 10.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles.



**Figure 10.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.

## 11. Glitne

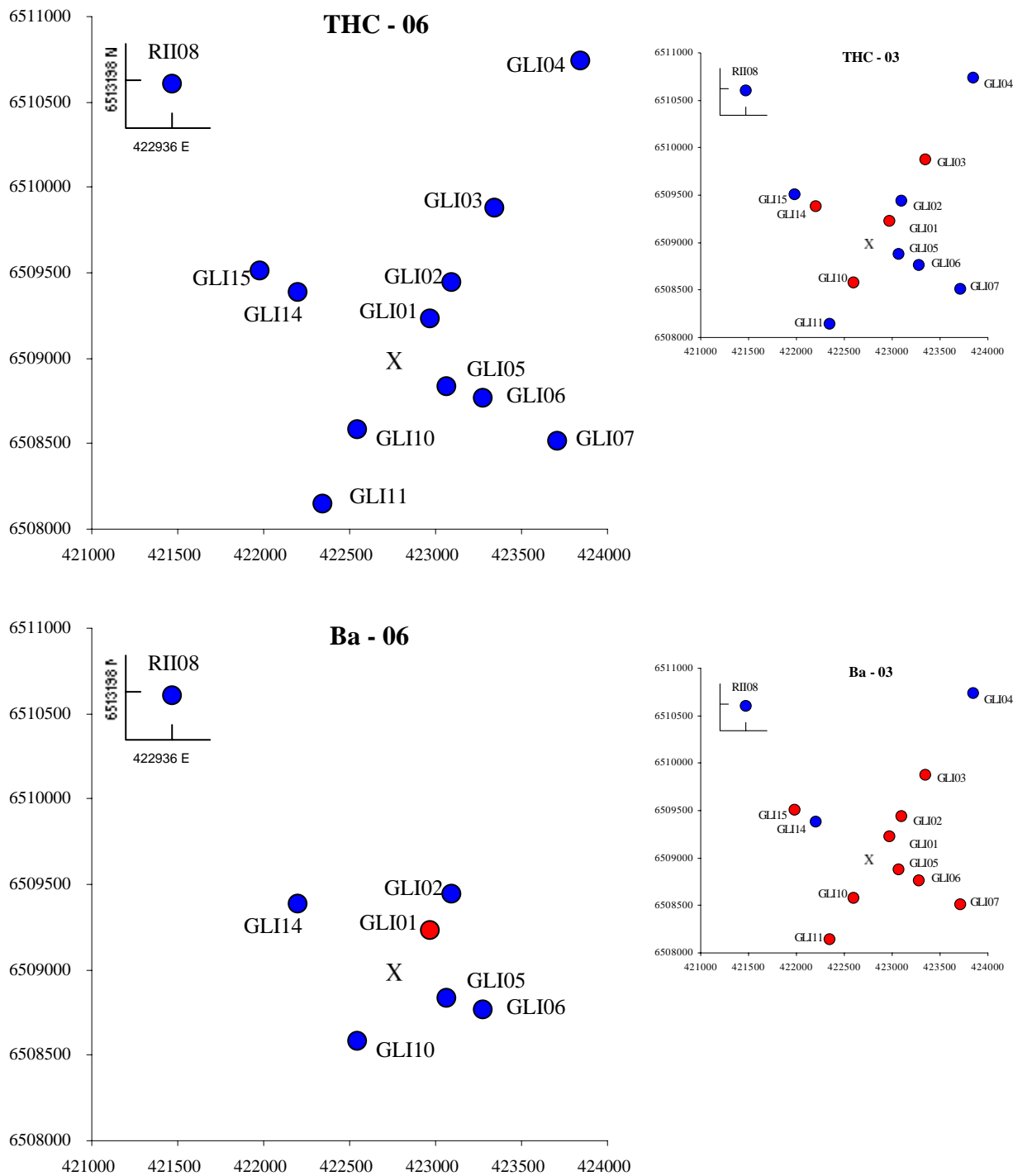
Glitne is situated in block 15/5. Production at field started in August 2002. A baseline survey at Glitne was undertaken during the regional monitoring survey in 2000. The baseline survey was followed by an ordinary monitoring survey in 2003.

From 2003 to 2006 two new wells were drilled at Glitne. The bottom sediment consists of fine sand, with slightly more pelitt and slightly less TOM compared to previous surveys. The content of THC, barium, zinc and chromium were generally lower in 2006, whereas other metals occurred at the same levels as before. Some increase in the number of specimens and species were seen in 2006 compared to 2003, although not more than considered natural variation. The polycheta *Myriochele oculata* was, as in 2003, the most abundant species in the samples, and the bottom fauna assemblage was as similar across the field in 2006, as in 2003. This indicates good environmental conditions at Glitne and still no faunal disturbances. The area contaminated by THC, barium and other metals were smaller in 2006 than in 2003. All transects reached out to uncontaminated sediments in 2006,

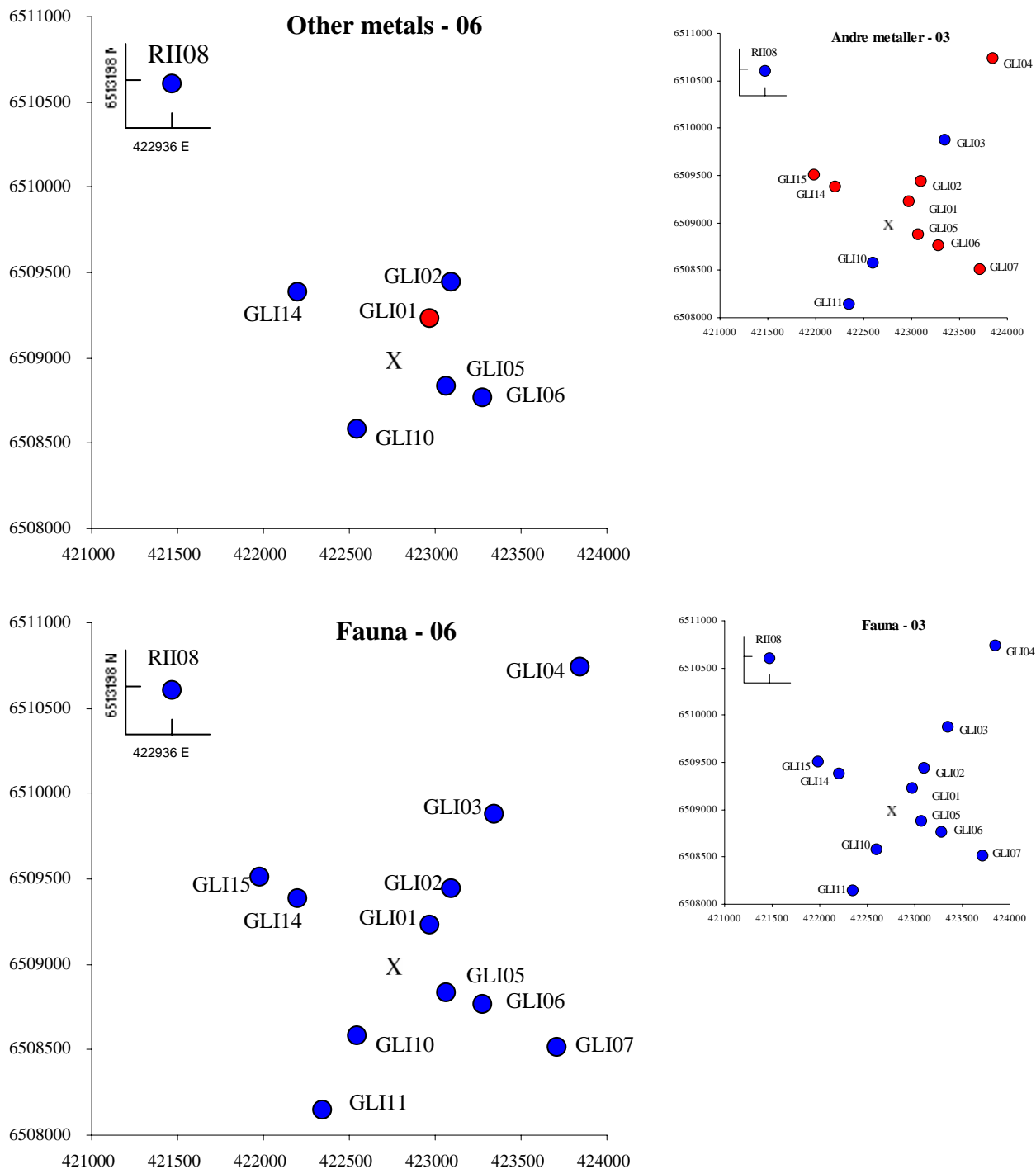
**Table 11.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Glitne in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
GLI01	422975	6509227	1.80	12.63	12.6	2.2	7.4	17.9	188.7	5.7	724	115	5.50
GLI02	423100	6509443	1.46	12.49	5.2	1.6	6.4	9.9	97.0	4.6	1012	126	5.58
GLI03	423350	6509876	i.a.	i.a.	3.0	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
GLI04	423850	6510742	i.a.	i.a.	3.8	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
GLI05	423067	6508835	1.59	13.68	4.4	1.9	7.0	11.8	95.3	5.1	797	111	5.40
GLI06	423283	6508760	1.64	13.86	5.2	1.7	6.2	10.3	66.9	4.8	957	122	5.48
GLI07	423716	6508510	i.a.	i.a.	4.6	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
GLI10	422550	6508577	1.53	13.13	4.6	2.2	6.6	11.2	101.6	5.5	1068	123	5.42
GLI11	422350	6508144	i.a.	i.a.	4.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
GLI14	422200	6509385	1.48	12.56	3.5	1.7	6.4	10.0	72.6	4.9	1045	112	5.23
GLI15	421984	6509510	i.a.	i.a.	5.0	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RHI08	422936	6513198	1.28	12.28	4.9	1.4	5.9	8.9	52.0	4.3	714	122	5.60





**Figure 11.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region central 96-06 are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region central 96-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 11.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

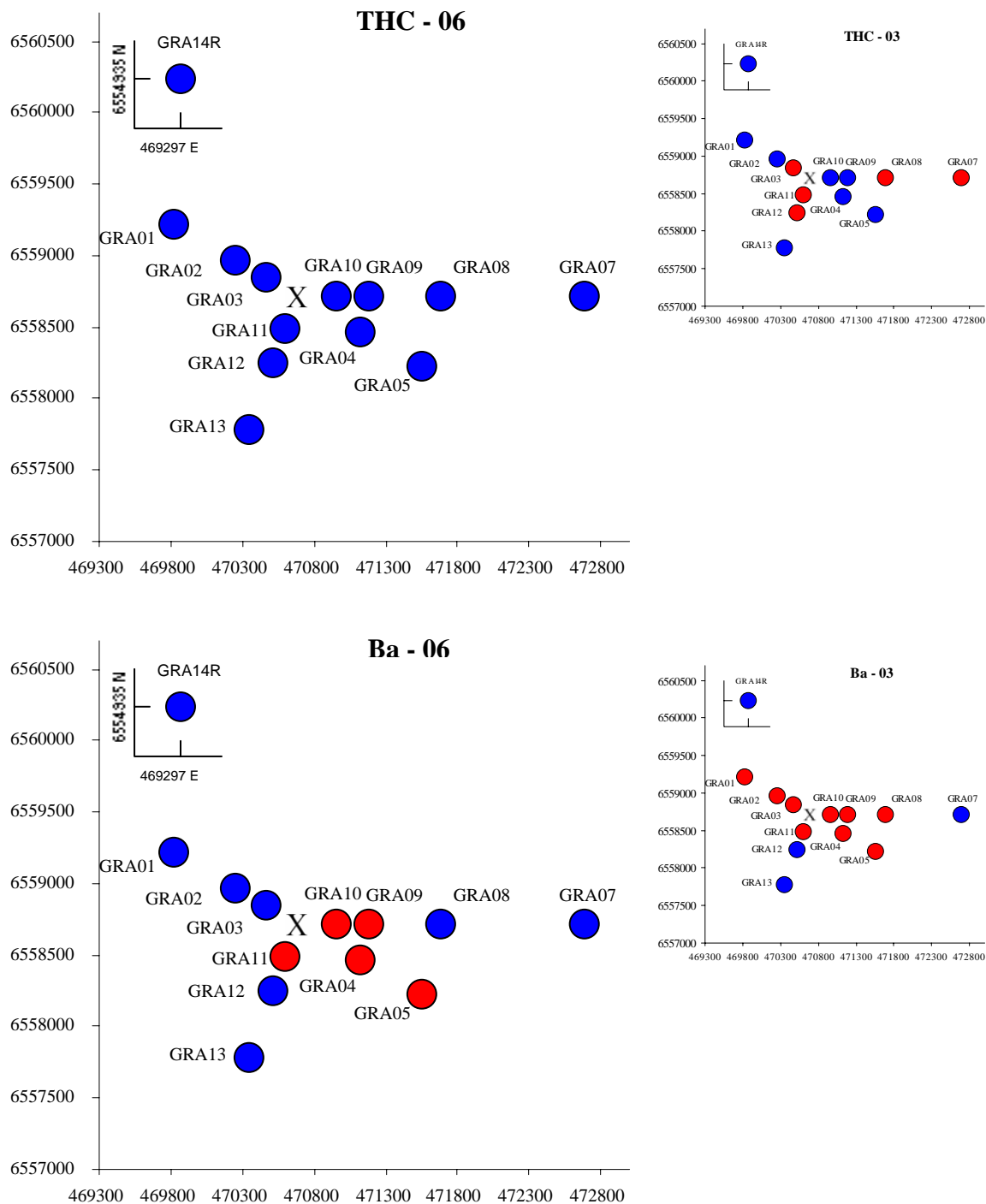
## 12. Grane

Grane is situated in block 25/12 and is renamed from Hermod. Production started in September 2003 at the field. A baseline survey was carried out in 1997 and a monitoring survey was undertaken in 2003.

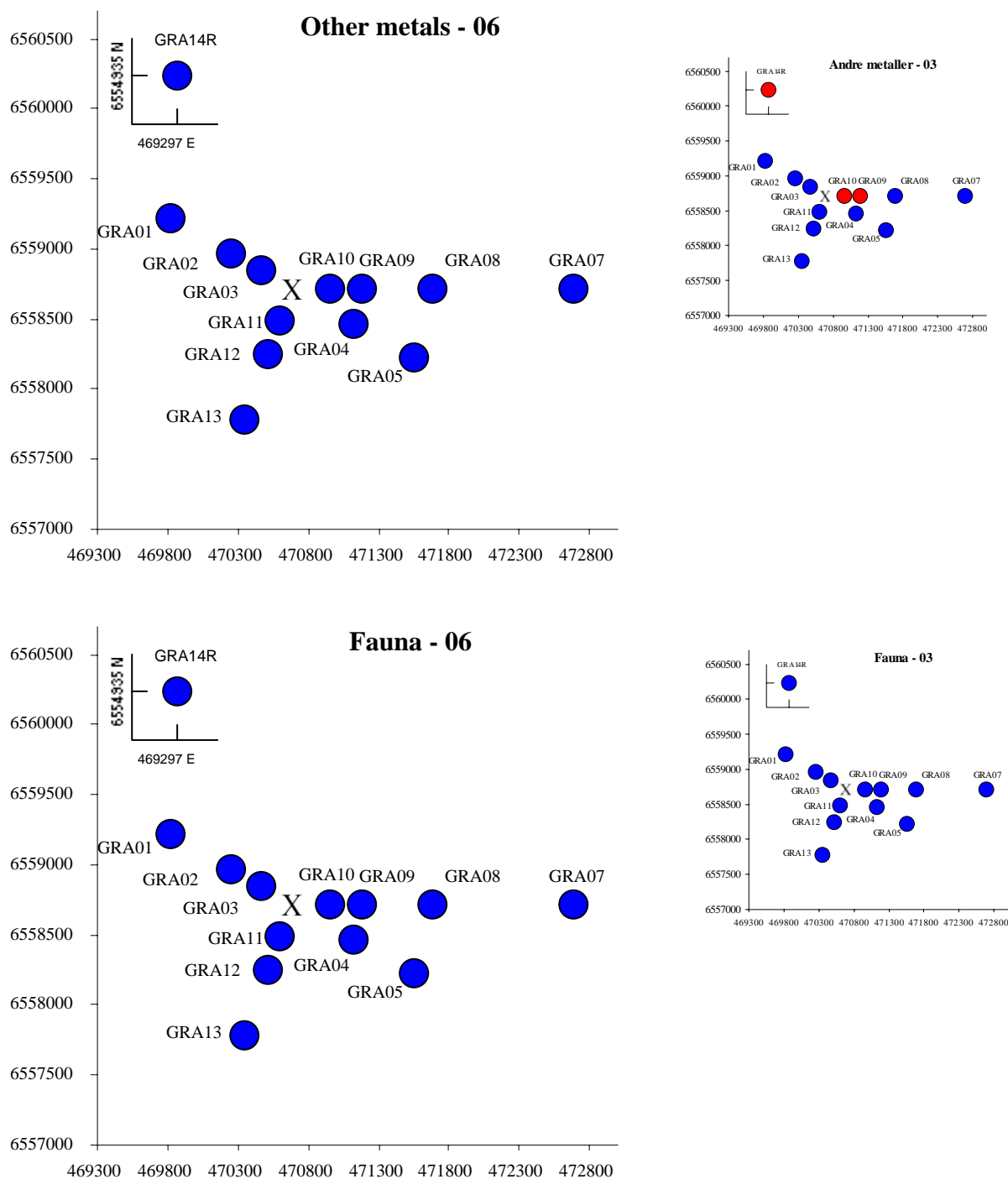
From 2003 until the summer of 2006 twenty new wells were drilled at Grane. The bottom sediments consisted of fine sand with slightly lower TOM content than in 2003. In general it was lower content of THC, barium and chromium in 2006, whereas copper, zinc, lead and cadmium occurred approximately at the same level as before. It was in general higher numbers of specimens and species in the samples in 2006 than in 2003. The polychaeta *Paramphinome jeffreysii* and the polypus *Cerianthus lloydii* were the most abundant species in 2006. The results indicate good environmental conditions at Grane and the bottom fauna remained undisturbed. Sediments contaminated by barium were revealed in 2006, but the area containing contaminated sediments were smaller in 2006 than in 2003.

**Table 12.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Grane in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
GRA01	469823	6559216	1.41	11.85	4.2	2.0	5.4	9.2	94.3	4.2	1261	130	5.15
GRA02	470256	6558966	1.05	11.66	4.5	1.8	5.1	8.4	92.4	3.5	1401	139	4.97
GRA03	470472	6558841	1.24	10.53	8.3	1.6	4.6	7.9	143.0	3.6	1791	125	4.42
GRA04	471122	6558466	1.58	12.42	5.3	1.8	4.8	10.0	155.7	3.9	1161	121	4.89
GRA05	471555	6558216	1.37	12.02	6.3	1.8	5.4	9.2	154.0	4.3	1342	127	5.11
GRA07	472689	6558716	1.39	10.10	6.3	1.7	5.0	8.3	105.0	4.1	1256	120	5.29
GRA08	471689	6558716	1.25	10.04	7.4	1.7	5.2	9.1	107.0	4.4	972	133	4.80
GRA09	471189	6558716	1.36	12.49	5.6	2.0	5.3	9.8	180.0	4.3	1071	122	4.80
GRA10	470959	6558716	1.47	13.33	6.1	2.1	7.3	9.6	191.0	3.5	1676	123	4.22
GRA11	470603	6558481	1.42	11.28	4.8	2.0	8.2	8.6	187.0	3.6	1436	120	4.45
GRA12	470518	6558246	1.87	12.14	7.5	2.1	5.1	9.2	132.0	4.2	1222	112	4.53
GRA13	470347	6557776	1.33	13.00	4.8	1.8	5.2	8.9	89.9	4.5	1673	133	5.16
GRA14R	469297	6554935	1.69	14.73	2.3	2.2	5.7	10.1	75.4	4.6	1213	128	5.03



**Figure 12.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.



**Figure 12.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.

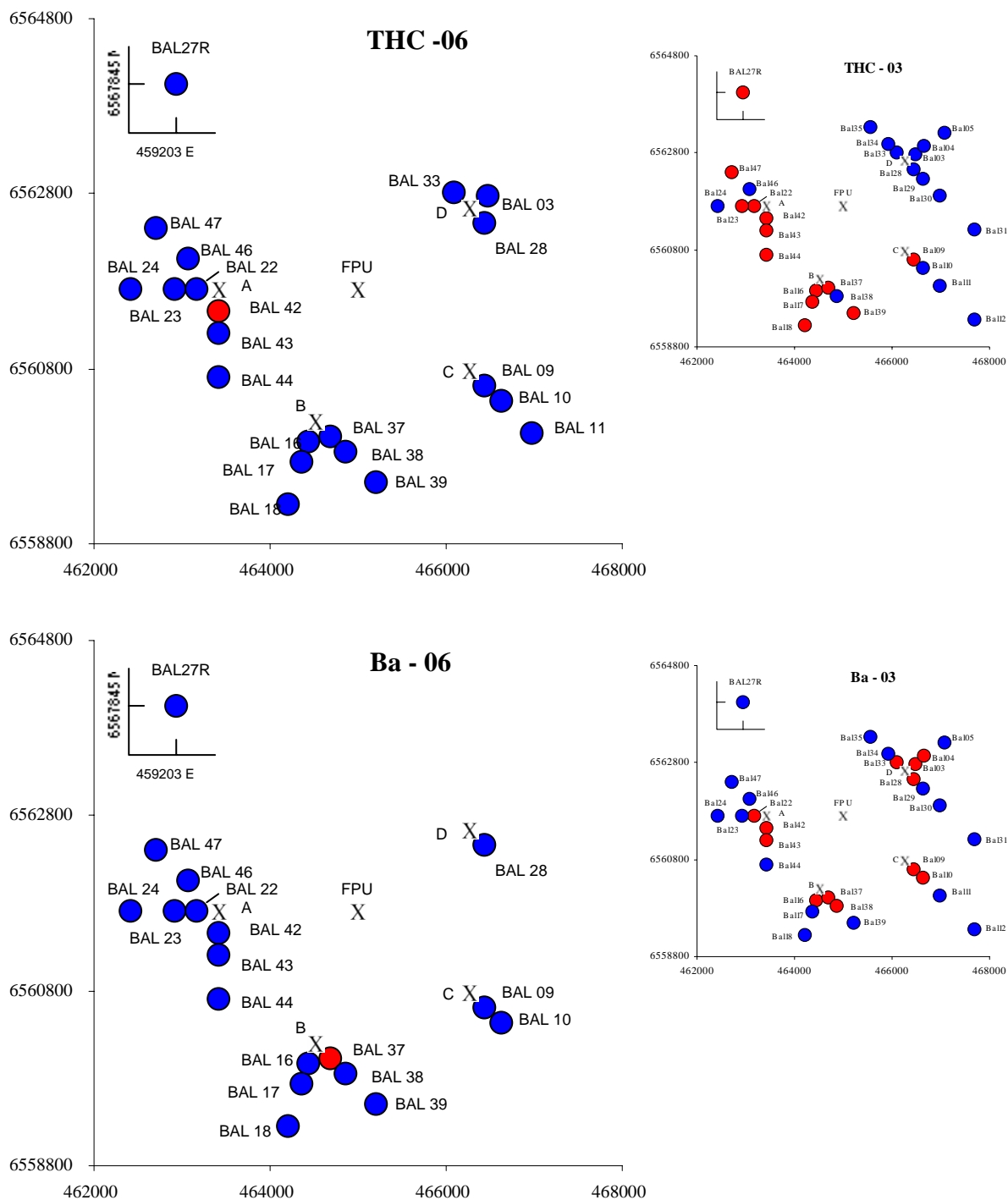
### 13. Balder

Balder is situated in block 25/11, and it consist of Balder FPU (Floating Production Unit), and four templates (A, B, C and D). Development drilling started in May 1999 and the production started in May 1996. A baseline survey at Balder was undertaken in 1997 and monitoring surveys have been undertaken in 2000 and 2003.

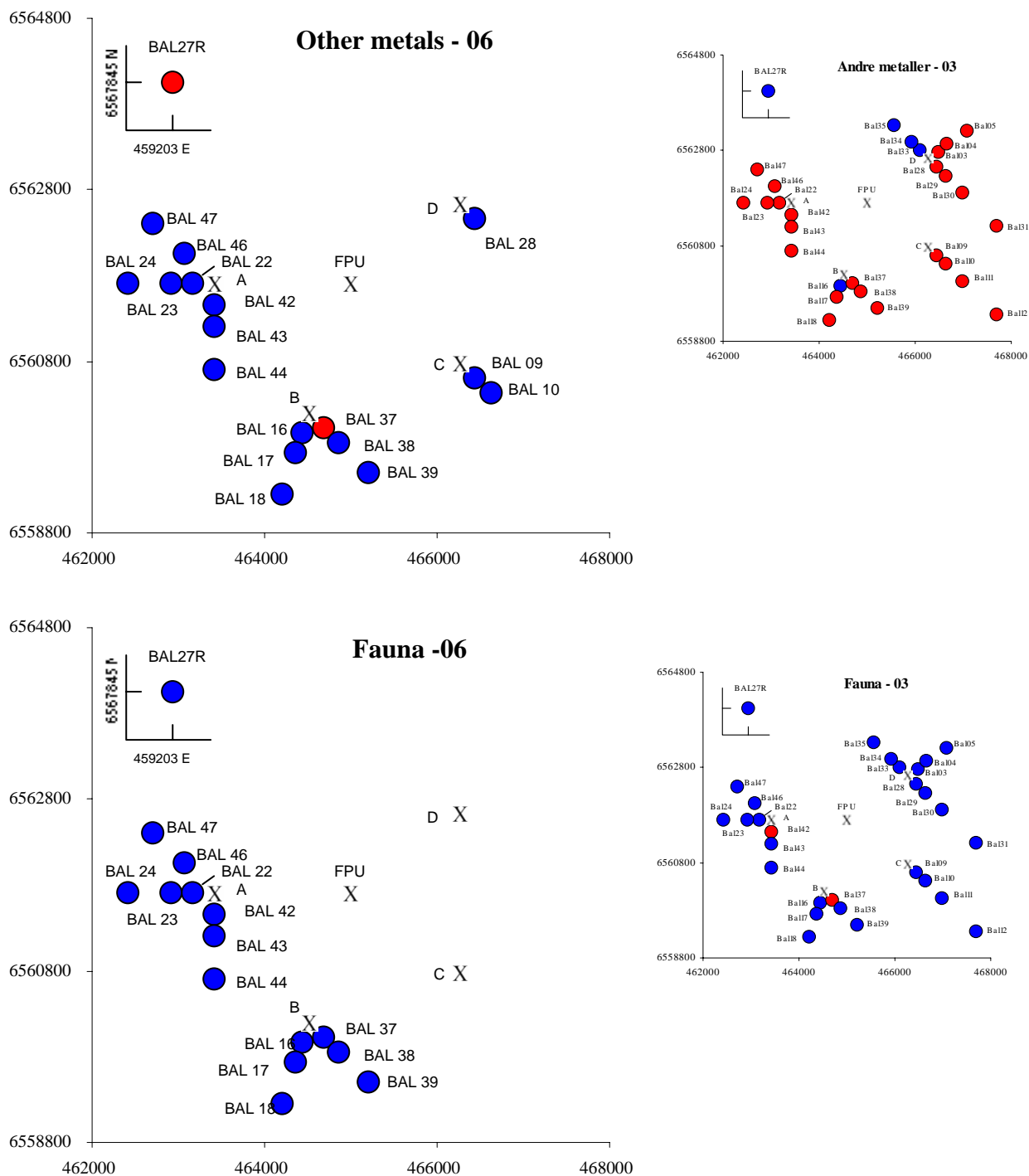
Since 2001 there has been no drilling activity at Balder and neither any large discharge. The sediments consist of 83-88 % sand and 12-17 % pelitt. The content of TOM was 1.3-2 %. It was in general lower concentrations of THC, lead, chromium and barium in the sediments in 2006, whereas copper, zinc and cadmium occurred approximately at the same level as before. THC contaminated sediments was revealed out to 250 m to the south of template A, and sediments contaminated by copper and barium was revealed out to 250 m to the southeast of template B. Disturbed fauna was not revealed in 2006, and the fauna assemblage was more similar across the field in 2006. The results show improved environmental conditions at Balder in 2006 compared to the situation in 2003. The area contaminated by THC, barium and copper was smaller in 2006 than in 2003, and all transects reached out to uncontaminated sediments in 2006.

**Table 13.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Balder in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
BAL03	466476	6562773	i.a.	i.a.	4.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
BAL09	466451	6560597	i.a.	i.a.	7.6	2.1	4.2	8.2	93.7	4.3	i.a.	i.a.	i.a.
BAL10	466628	6560420	i.a.	i.a.	6.5	2.0	4.3	8.4	58.2	4.3	i.a.	i.a.	i.a.
BAL11	466981	6560067	i.a.	i.a.	4.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
BAL16	464436	6559964	1.45	12.79	5.3	1.6	3.9	7.0	42.1	3.4	1366	127	5.07
BAL17	464359	6559726	1.64	12.38	4.8	1.6	4.0	7.1	28.9	3.4	1359	141	5.25
BAL18	464204	6559251	1.56	13.85	3.1	1.7	4.1	7.5	29.8	3.6	1286	131	5.10
BAL22	463175	6561700	2.04	14.22	8.6	1.6	3.9	7.5	40.1	3.7	927	108	5.07
BAL23	462925	6561700	1.73	12.96	6.6	1.5	3.8	7.1	28.3	3.4	1041	114	5.35
BAL24	462425	6561700	1.71	13.16	5.5	1.6	3.8	7.2	26.0	3.5	1192	128	5.40
BAL28	466451	6562449	i.a.	i.a.	5.5	1.9	4.1	8.2	77.3	4.0	i.a.	i.a.	i.a.
BAL33	466097	6562803	i.a.	i.a.	3.8	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
BAL37	464690	6560025	1.56	13.67	9.1	2.6	5.7	10.4	163.0	4.7	1469	132	5.34
BAL38	464867	6559848	1.59	13.01	4.0	1.7	4.0	7.3	46.3	3.8	1596	144	5.34
BAL39	465220	6559495	1.45	12.54	4.7	1.5	3.5	6.6	26.9	3.6	1252	123	5.09
BAL42	463425	6561450	1.71	12.30	16.6	2.1	4.2	8.4	145.3	4.1	1602	130	4.99
BAL43	463425	6561200	1.69	16.45	5.3	2.0	4.2	8.4	63.5	3.9	1377	129	5.33
BAL44	463425	6560700	1.45	13.36	6.3	1.5	3.8	6.7	28.1	3.5	1203	122	5.26
BAL46	463071	6562054	1.59	12.42	1.5	1.6	3.9	7.4	34.7	3.4	1074	123	5.33
BAL47	462718	6562407	1.34	13.55	2.4	1.5	3.6	6.8	24.5	3.3	1198	116	5.04
BAL27R	459203	6567845	1.56	15.87	4.2	1.5	3.8	7.1	26.6	3.6	1292	117	5.22



**Figure 13.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region central 96-06 are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region central 96-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 13.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



## 14. Ringhorne

Ringhorne is situated in block 25/10 and the production started in the spring of 2003. The baseline survey was carried out during the regional sampling cruise in 2000, and the first monitoring survey was undertaken in 2003.

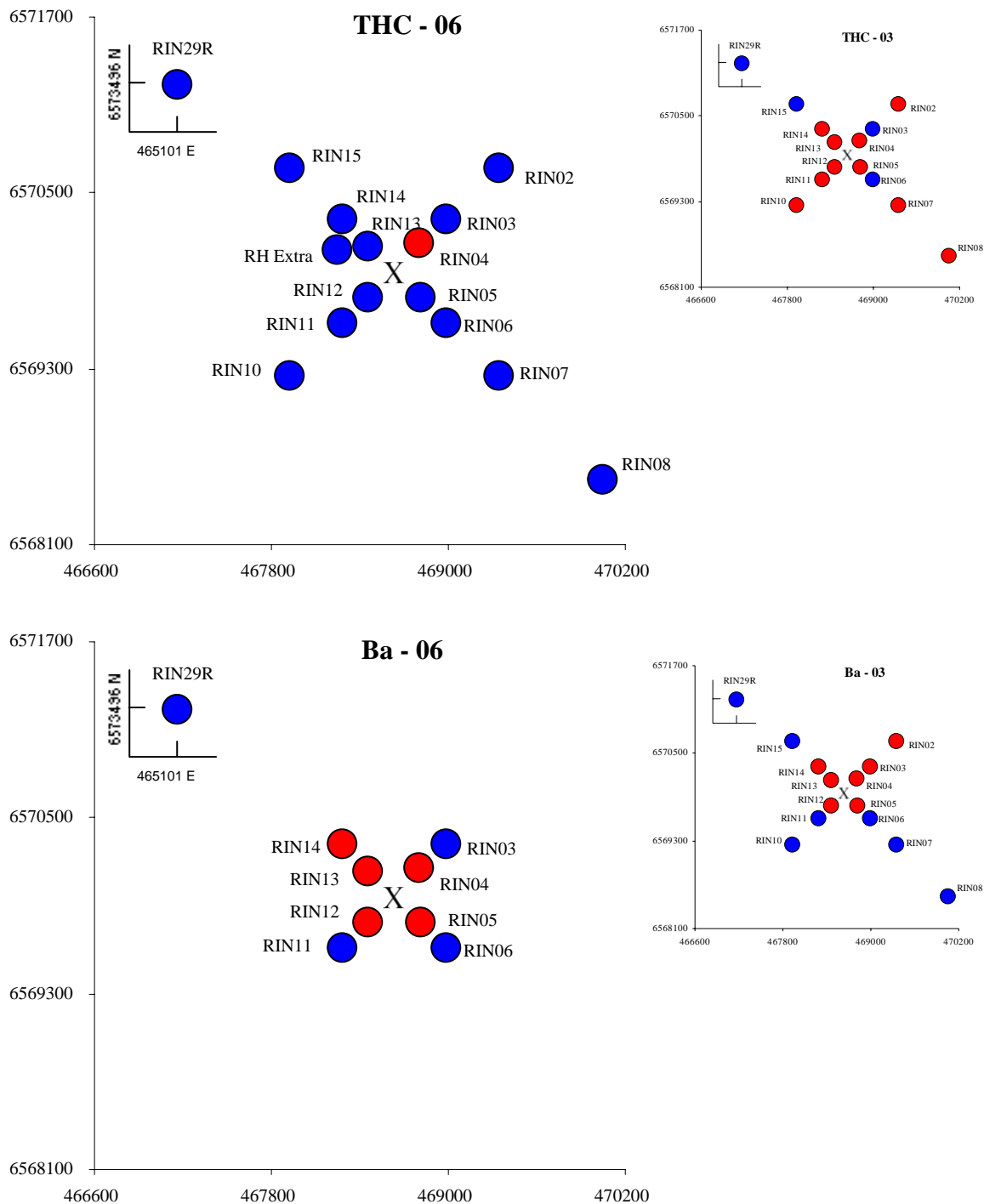
From 2003 to 2005 twenty new wells were drilled at Ringhorne. The sediments consisted of fine sand, although with slightly higher content of pelitt and slightly lower TOM content than before. It was in general lower content of THC, chromium and lead in the sediments in 2006, whereas the content of the other metals occurred approximately at the same levels as before. The number of specimens was higher than before, but the number of species was at the same level or higher than before. The observed changes in the fauna assemblage were within natural variations. The polycheta *Paramphinome jeffreysii* was, as in 2003, the most abundant species in the samples in addition to the polypus *Cerianthus lloydii*. The bottom fauna was in general as similar across the field in 2006 as in 2003.

The results are indicating improved environmental conditions at Ringhorne in 2006 and that the fauna remain undisturbed. The area contaminated by THC and barium was smaller in 2006 than in 2003. All transects reached uncontaminated sediments.

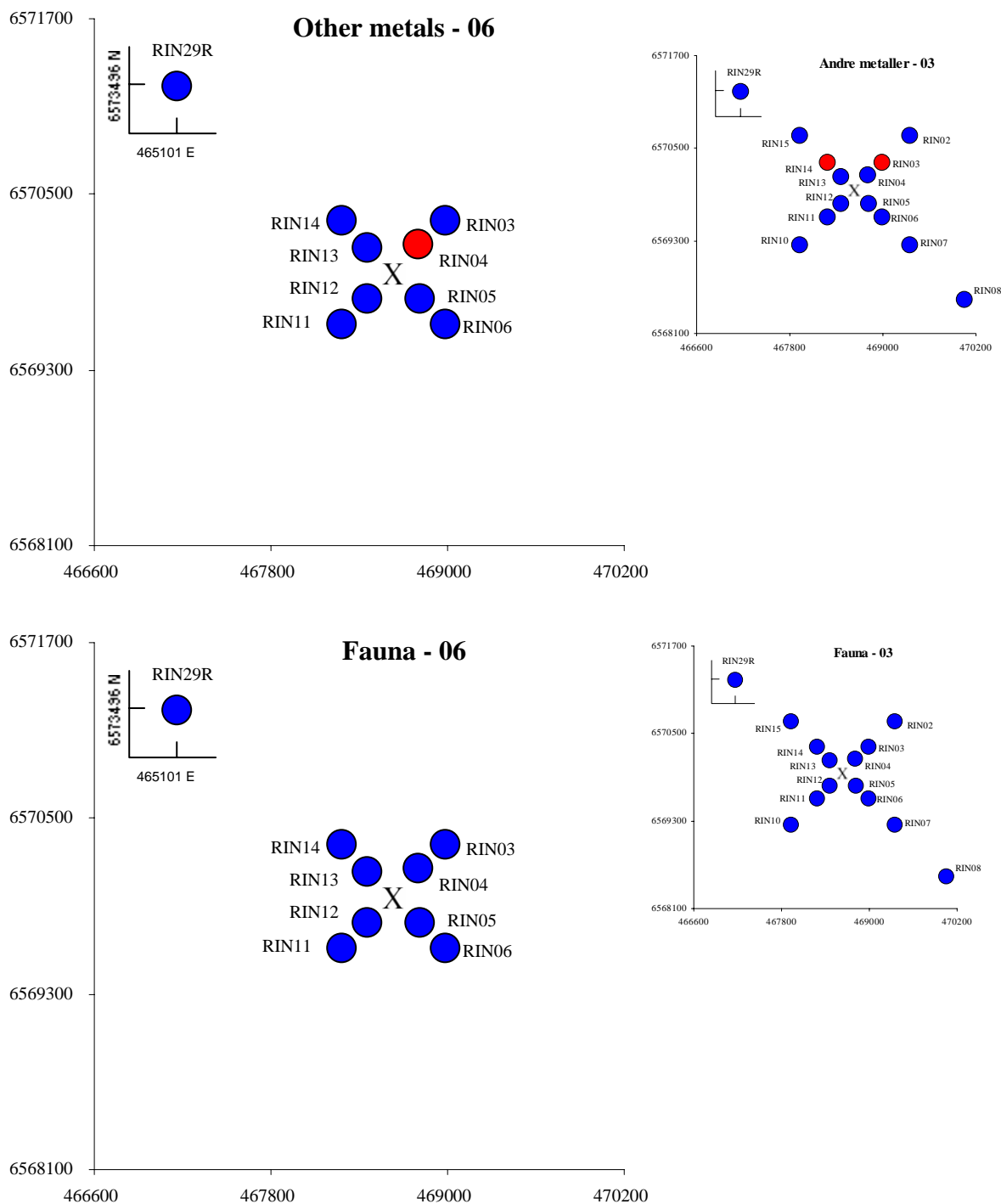
During the survey samples for THC analysis were collected at a position (RH Extra) suffering from an incident back in 2003. At this position where sediments contaminated by THC observed and the bottom fauna at this position were disturbed by the impoverished environmental conditions.

**Table 14.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Ringhorne in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
RIN02	469343	6570667	i.a.	i.a.	2.1	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RIN03	468990	6570314	1.45	13.46	3.1	1.8	4.8	8.4	88.4	3.5	1351	121	4.85
RIN04	468800	6570160	1.49	15.37	17.5	3.2	5.0	10.2	275.3	4.0	1561	110	4.39
RIN05	468813	6569783	1.37	15.21	8.1	1.9	5.1	9.4	245.0	4.1	1417	118	4.67
RIN06	468990	6569606	1.10	20.17	2.4	1.8	5.1	9.6	81.5	3.4	1138	108	5.09
RIN07	469343	6569253	i.a.	i.a.	4.3	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RIN08	470050	6568546	i.a.	i.a.	4.1	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RIN10	467929	6569253	i.a.	i.a.	6.5	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RIN11	468282	6569606	1.67	15.26	4.9	1.8	5.1	8.8	107.0	4.0	1366	120	5.18
RIN12	468459	6569783	1.42	15.27	4.0	1.7	4.9	8.6	286.3	3.8	1938	128	4.49
RIN13	468459	6570137	1.12	16.60	8.9	2.0	5.2	9.3	264.3	4.1	1926	124	4.56
RIN14	468282	6570314	1.25	15.53	4.2	2.1	5.7	10.2	173.3	4.5	1538	111	4.62
RIN15	467929	6570667	i.a.	i.a.	3.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
RIN29R	465101	6573496	1.68	16.74	5.8	2.0	5.7	9.7	56.2	4.3	1200	107	5.09
RH Extra	468246	6570107	i.a.	i.a.	5233.3	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.



**Figure 14.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region central 96-06 are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region central 96-06 are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 14.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

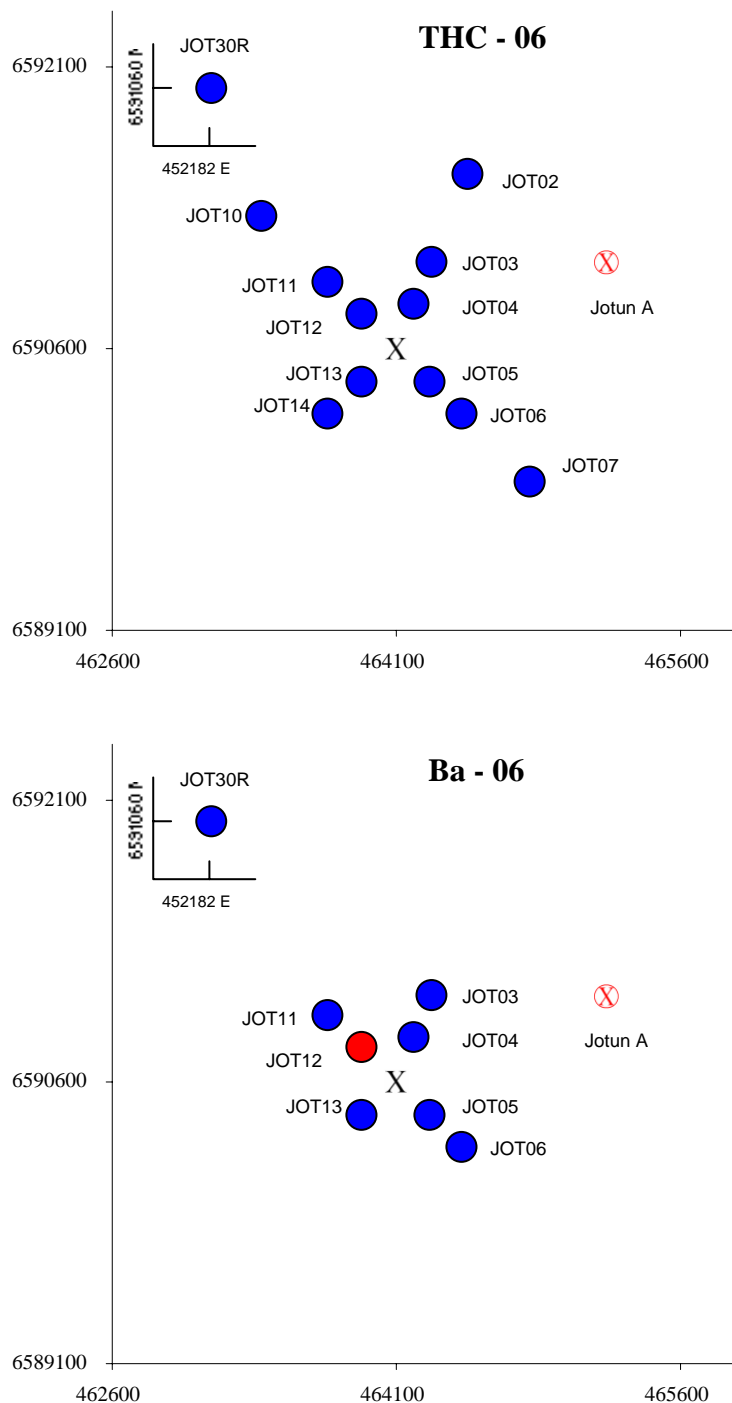
## 15. Jotun

Jotun is situated in block 25/7 and 25/8 and it consist of Jotun A, a floating, production, storage & offloading unit, and Jotun B a well head platform. The production started in October 1999. An environmental baseline survey was undertaken in 1997, and environmental monitoring surveys have been executed in 2000 and in 2003.

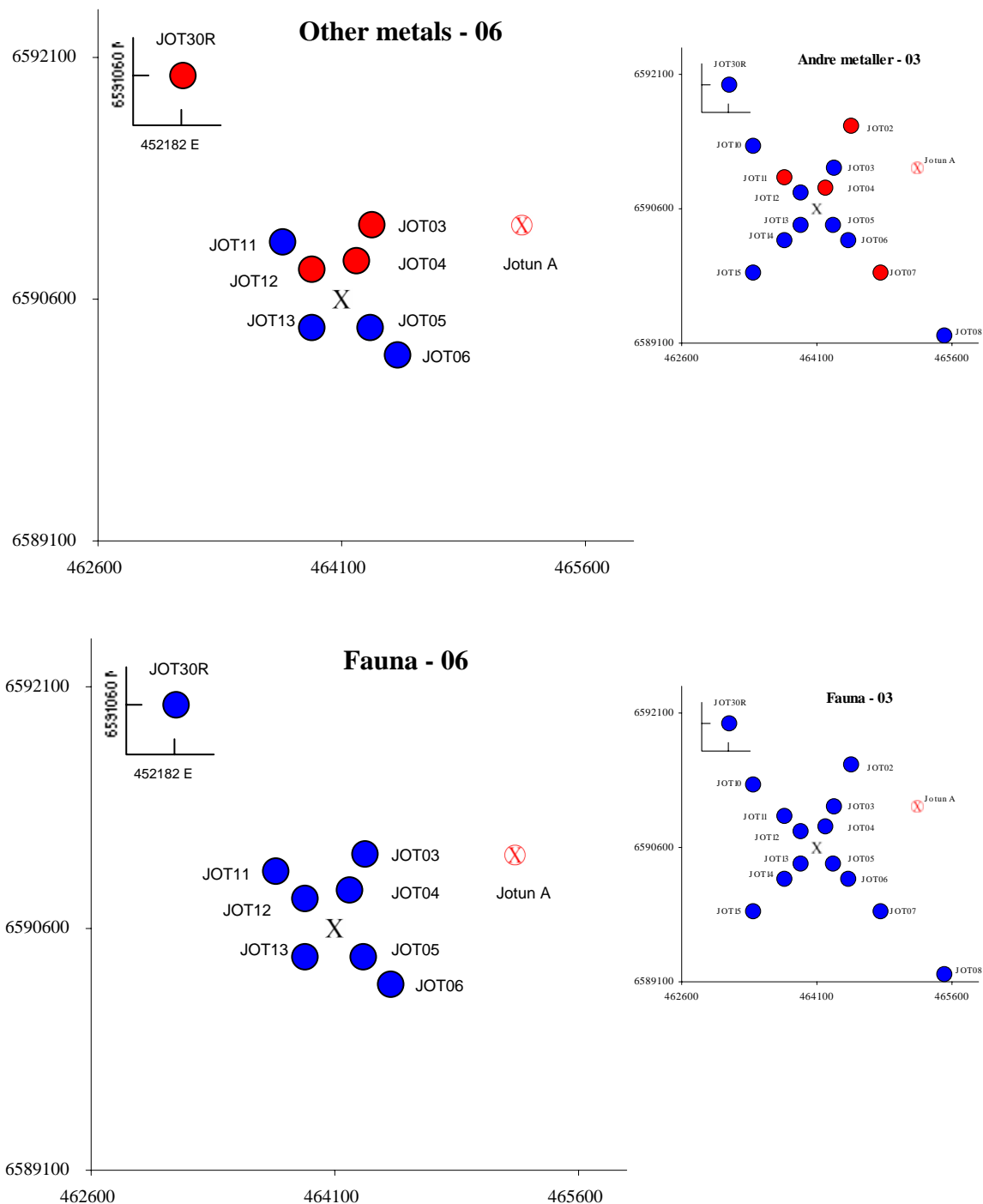
In 2003 three new wells were drilled at Jotun. Since then there has been no drilling activity at the field. The bottom sediments consist of fine sand with slightly higher content of pelitt and slightly lower content of TOM. It was in general lower content of THC, barium, zinc and chromium in 2006, whereas the other metals occurred approximately at the same level as before. Among the bottom fauna more specimens were identified in 2006 then in 2003. The polycheata *Paramphinome jeffreysii* was, as in 2003, the most abundant species, and the fauna was in general as similar across the field in 2006 as in 2003. The result indicates good environmental conditions at Jotun and no disturbed fauna. The area contaminated by THC and barium was less in 2006 than in 2000, however it was slightly larger (0.03 km<sup>2</sup>) for other metals. Uncontaminated sediments was not reached to the northeast

**Table 15.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Jotun in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
JOT02	464483	6591524	i.a.	i.a.	4.1	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
JOT03	464291	6591062	1.97	26.14	2.1	2.4	5.8	11.2	83.1	4.6	1617	123	4.80
JOT04	464196	6590831	2.90	33.31	3.9	3.5	7.5	16.3	144.2	6.0	1600	99	4.48
JOT05	464277	6590423	1.78	23.83	4.5	2.1	5.3	10.1	101.5	4.3	1796	142	4.99
JOT06	464454	6590246	1.67	24.24	2.2	2.2	5.4	10.4	71.0	4.2	1136	106	4.61
JOT07	464807	6589893	i.a.	i.a.	5.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
JOT10	463393	6591307	i.a.	i.a.	4.1	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
JOT11	463746	6590954	1.61	25.24	3.5	2.2	5.6	10.1	66.7	4.0	1122	117	5.14
JOT12	463923	6590777	1.43	22.81	3.6	3.0	5.5	11.1	190.3	4.4	1578	126	4.90
JOT13	463923	6590423	1.58	23.57	4.4	2.0	5.3	9.8	89.1	4.3	1661	125	4.87
JOT14	463746	6590246	i.a.	i.a.	3.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
JOT30R	452182	6590203	2.32	29.73	4.1	2.6	6.0	11.2	52.9	4.7	1052	109	5.24



**Figure 15.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.



**Figure 15.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

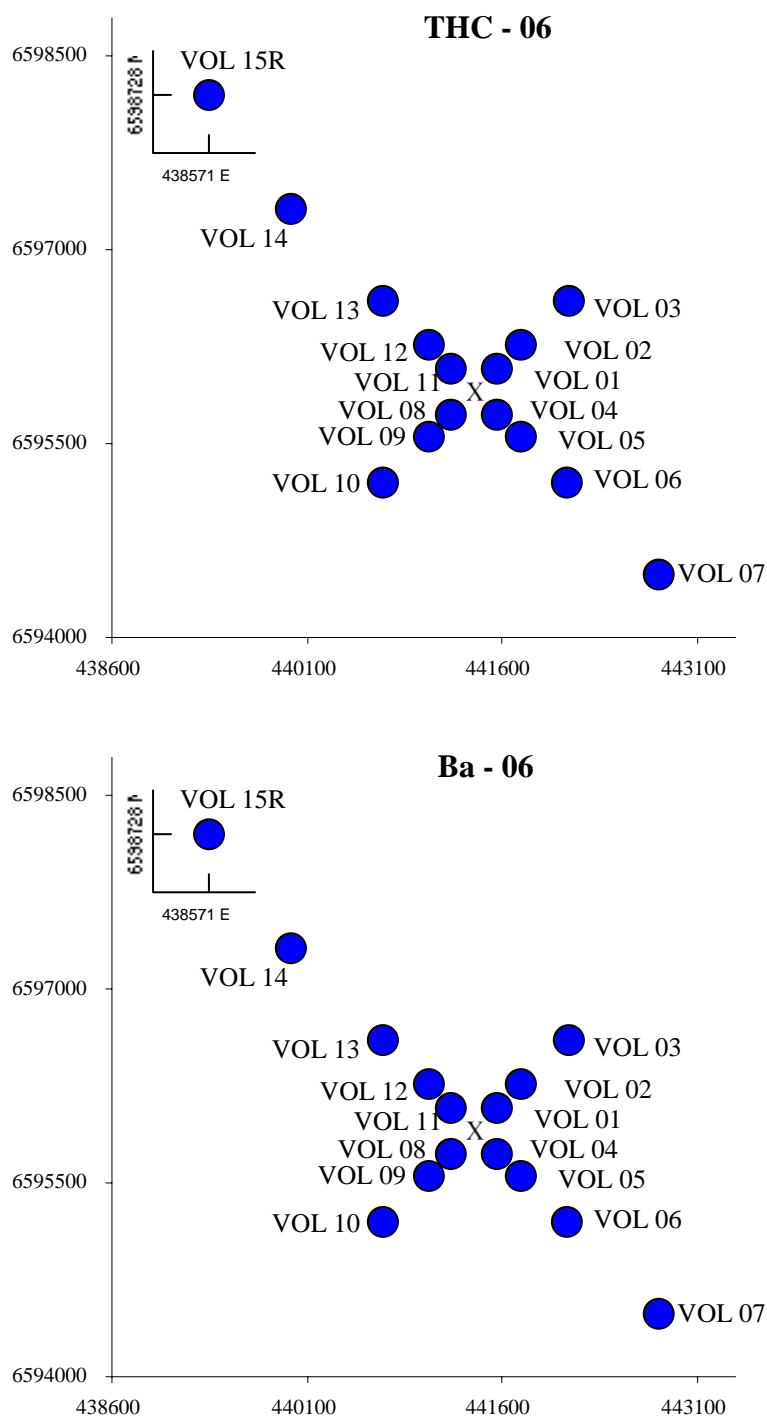
## 16. Volund

Volund is situated in block 24/9. The 2006 survey was a baseline survey at the field.

In 2004 one well was drilled at Volund, and only minor discharges have been reported. The sediments consisted mostly of fine sand. It was generally low concentrations of THC in the sediments. Copper occurred above LSC Sub-region central 96-06 at the 1000 m and the 2000 m sites along the sampling transect toward southeast. At a sampling site 500 m to the southwest of the field centre occurred copper above LSC Sub-region central 96-06. At the sampling sites 2000 m to the southeast occurred cadmium above LSC Sub-region central 96-06. Also zinc was found in concentrations above LSC Sub-region central 96-06 at the sampling site 1000 m to the southeast of the field centre. The bottom fauna was undisturbed at all field specific sampling sites.

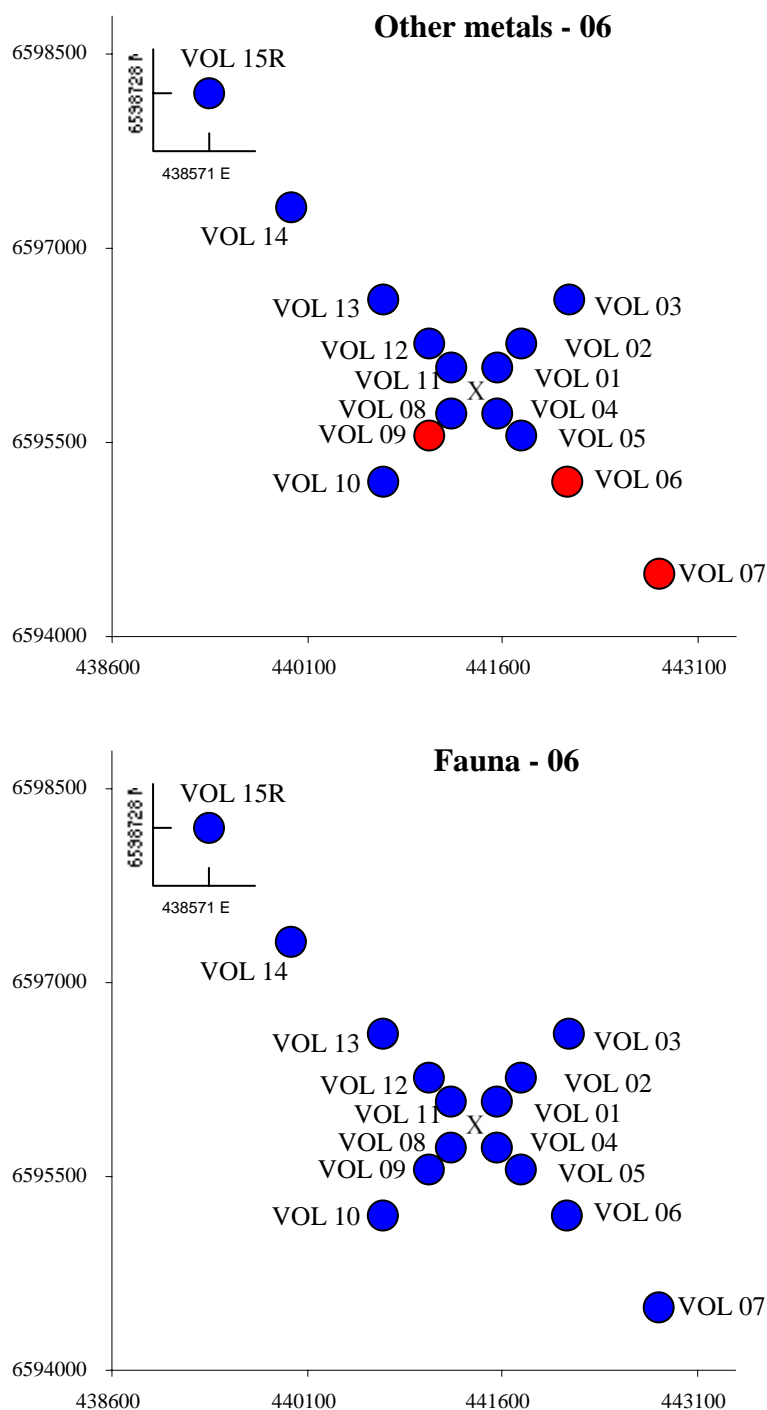
**Table 16.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Volund in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
VOL1	441576	6596076	1.96	21.46	3.6	2.1	5.0	9.1	50.9	3.9	1476	132	5.37
VOL2	441753	6596253	1.93	21.11	3.5	1.9	3.8	7.5	27.9	3.4	1237	120	5.27
VOL3	442119	6596594	1.44	18.58	2.9	1.9	3.9	7.7	31.2	3.5	1451	137	5.40
VOL4	441576	6595723	1.64	19.66	4.6	2.3	5.7	9.9	70.1	4.0	1654	131	5.39
VOL5	441753	6595546	1.84	20.51	3.0	2.3	5.6	9.6	68.3	3.9	1326	127	5.33
VOL6	442107	6595192	1.78	20.20	8.2	2.4	5.9	12.3	70.0	5.5	1304	122	5.25
VOL7	442814	6594485	1.75	20.90	6.3	2.5	5.9	10.1	76.7	4.0	1210	127	5.23
VOL8	441223	6595723	1.62	19.58	5.4	2.1	5.6	9.4	63.4	3.7	1520	144	5.31
VOL9	441046	6595546	1.76	18.80	4.0	2.4	5.5	9.4	61.8	3.7	1451	126	5.32
VOL10	440692	6595192	1.75	19.80	7.5	2.2	5.7	9.3	62.2	3.6	1339	124	5.29
VOL11	441223	6596076	1.53	18.29	6.0	2.0	4.2	8.1	32.7	3.5	1384	119	5.14
VOL12	441046	6596253	1.43	19.41	3.8	1.9	4.0	7.7	30.8	3.5	1621	131	5.21
VOL13	440692	6596607	1.45	17.96	6.2	1.9	4.2	8.0	32.5	3.5	1434	126	5.41
VOL14	439985	6597314	1.34	15.61	6.6	1.9	3.9	7.6	31.6	3.3	1720	144	5.21
VOL15R	438571	6598728	1.11	13.20	3.5	1.4	3.3	6.1	25.7	2.8	1799	146	5.49



**Figure 16.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles.





**Figure 16.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.

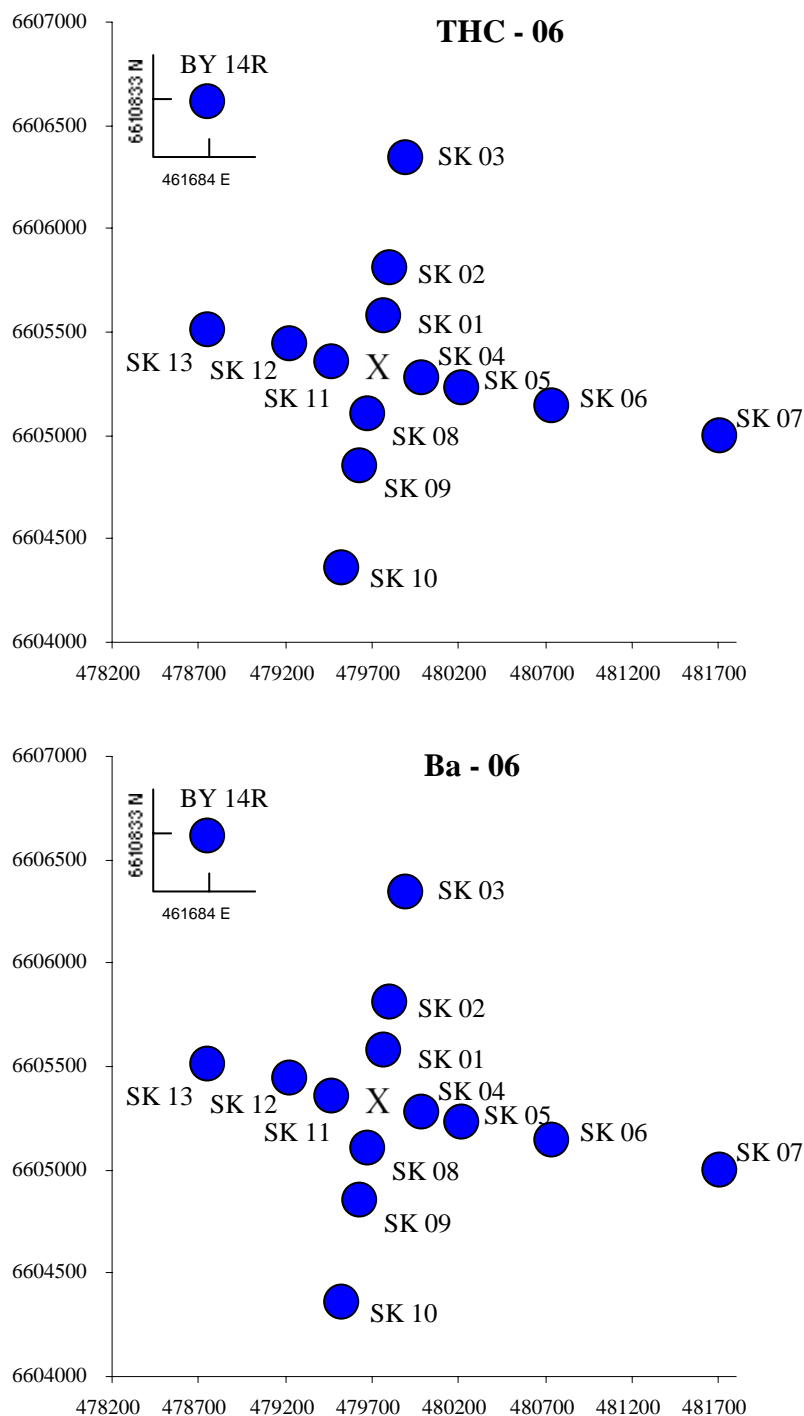
## 17. Skirne

Skirne is situated in block 25/5. Test drilling was undertaken in 1990-91 and production started in March 2004. A baseline survey was carried out in 2002.

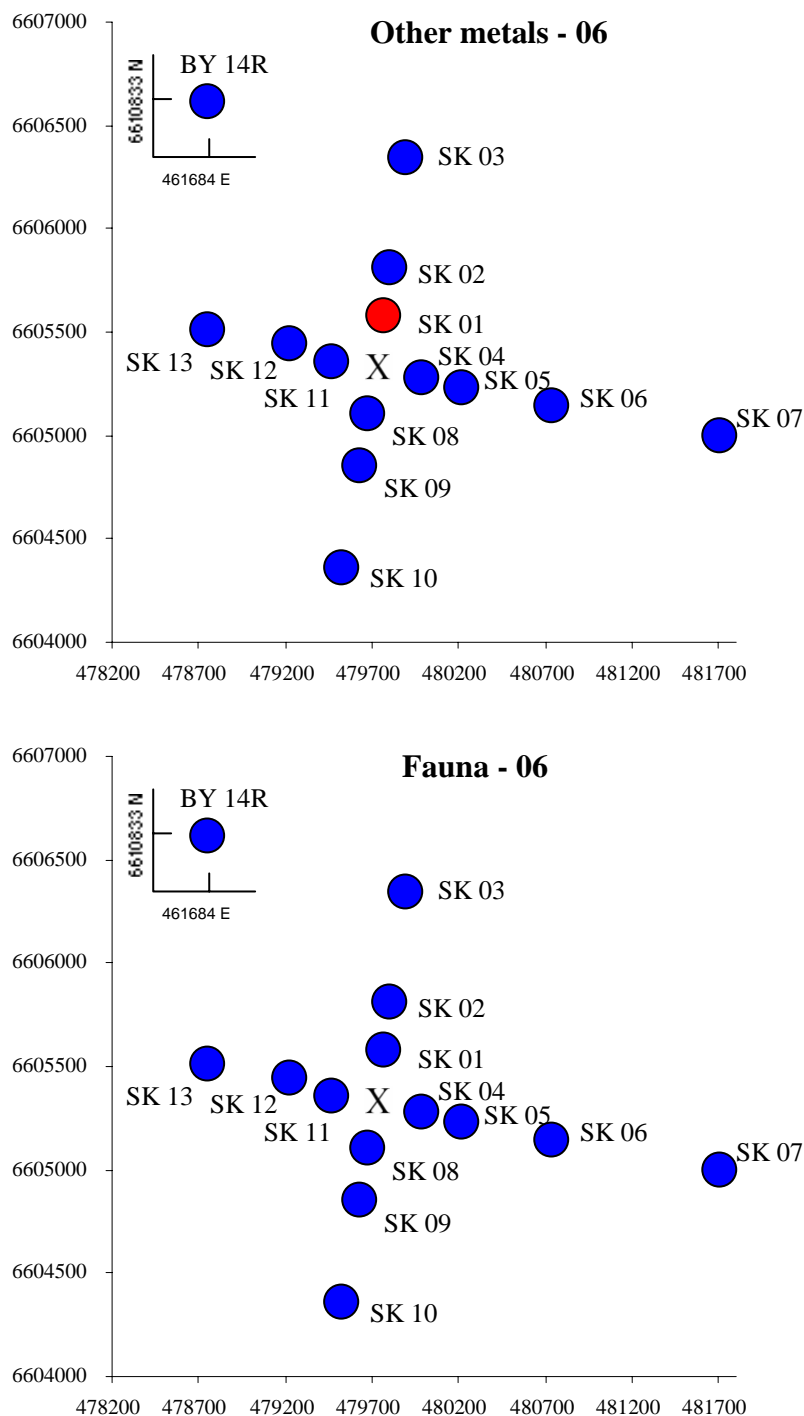
The bottom sediments consisted mainly of fine sand. The THC content in the sediments was at the same levels as in 2002. Whereas barium occurred at lower levels in 2006 than in 2002, except at SK01 where the barium content was higher. Also the other metals occurred at lower levels in 2006, except for cadmium, which occurred at the same or at a slightly higher level. It was in general more specimens and species in the samples in 2006 than in 2002. The polychaetes *Myriochele oculata* and *Owenia borealis* were the most abundant species in 2006. The results indicate good environmental conditions at Skirne and an undisturbed bottom fauna. Contamination by cadmium was revealed at one sampling site in 2006. All transects reached uncontaminated sediments.

**Table 17.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Skirne in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
SK01	479766	6605574	1.17	13.00	5.0	1.8	3.5	7.9	92.5	3.6	2340	157	5.43
SK02	479807	6605810	1.20	11.23	4.5	1.5	3.2	6.7	53.7	3.2	1879	143	5.55
SK03	479898	6606342	1.09	10.99	3.5	1.1	2.5	5.2	22.8	2.7	1995	153	5.61
SK04	479984	6605279	1.31	11.03	5.3	1.3	2.8	5.9	45.7	3.0	2046	142	5.26
SK05	480223	6605225	1.02	10.85	5.4	1.2	2.7	5.8	27.4	2.9	1947	142	5.24
SK06	480737	6605142	1.28	12.90	5.5	1.2	2.6	5.8	23.5	3.1	1904	139	5.21
SK07	481703	6604995	1.21	10.95	3.2	1.2	2.5	5.6	19.6	2.8	1994	134	5.15
SK08	479678	6605108	1.64	11.84	5.0	1.6	2.8	6.2	72.8	3.3	2050	146	5.48
SK09	479635	6604852	1.22	12.03	4.5	1.4	2.9	6.4	32.1	3.2	2302	154	5.51
SK10	479529	6604360	1.16	12.14	2.0	1.3	2.7	5.7	21.4	2.9	1890	140	5.33
SK11	479470	6605353	1.22	12.93	3.2	1.7	3.1	6.8	34.7	3.4	2122	153	5.81
SK12	479230	6605440	1.99	14.02	4.5	1.6	3.6	7.1	37.0	3.7	2050	153	5.73
SK13	478750	6605509	1.35	14.54	5.2	1.5	4.0	7.4	45.4	3.3	2430	152	5.45
BY14R	461684	6610833	0.85	8.81	3.5	1.2	3.3	6.0	68.4	3.0	1794	141	5.51



**Figure 17.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles.



**Figure 17.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.

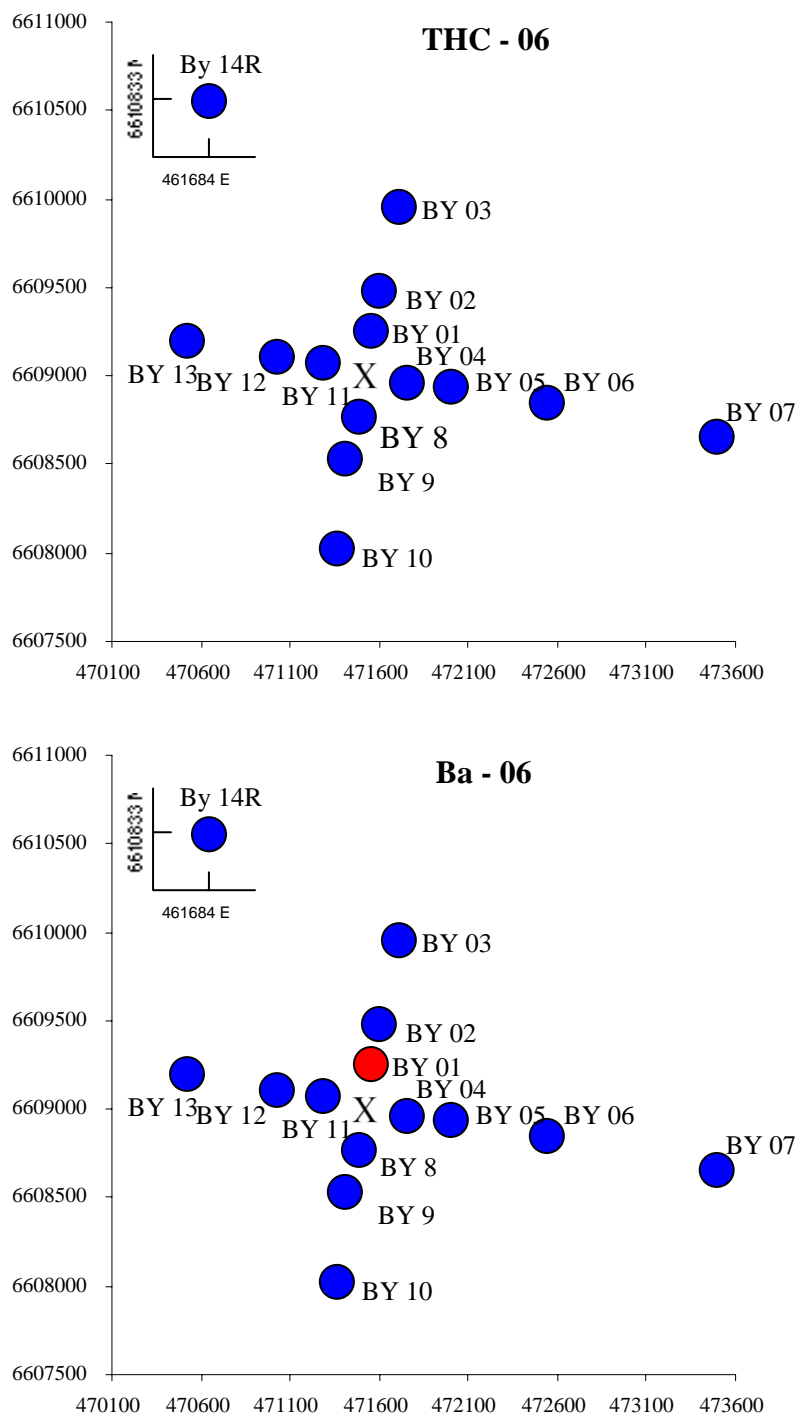
## 18. Byggve

Byggve is situated in block 25/5, and it is part of the Skirne field. There is one template at Byggve. A baseline survey was undertaken in 2002.

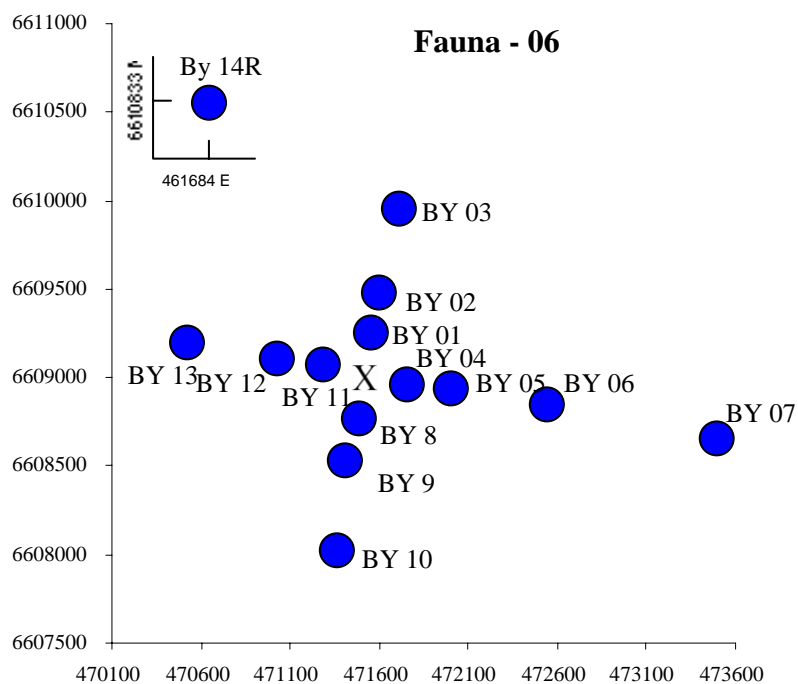
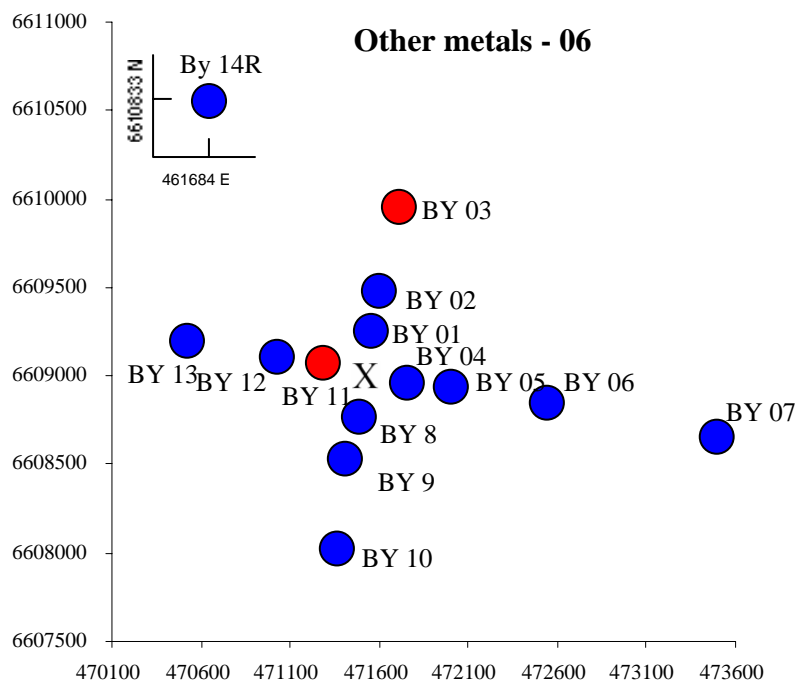
The survey in 2006 was the first survey after the baseline survey in 2002 at Byggve. The bottom sediments consist mainly of fine sand. In general there were lower concentrations of THC, barium, copper, lead, zinc and chromium in 2006, whereas cadmium occurred approximately at the same levels as in 2002 or slightly higher. The barium content had increased closest to the field centre toward north and east, and at BY11 the content of copper, zinc and lead had increased. There was a general increase in number of specimens and species in 2006 compared to 2002. The polycheta *Myriochele oculata*, *Paramphinome jeffreysii* and *Owenia borealis* were the most abundant species in the samples. The species assemblage across the field was as similar in 2006 as in 2002. The results indicate good environmental conditions at Byggve and the bottom fauna remain undisturbed. No sampling sites were contaminated in 2002, whereas one sampling site was contaminated by barium and one sampling site was contaminated by other metals in 2006. Thus the area of barium contaminated sediments and area of sediments contaminated by other metals were larger in 2006 than in 2002.

**Table 18.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Byggve in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
BY1	471554	6609251	1.14	12.84	4.2	1.8	3.8	8.1	161.7	3.5	1584	140	5.59
BY2	471605	6609481	1.51	13.68	2.0	1.6	3.8	7.4	85.9	3.3	1681	131	5.49
BY3	471714	6609945	1.27	11.97	4.8	1.3	3.7	7.0	52.8	2.9	1873	136	5.46
BY4	471760	6608962	1.69	14.47	2.5	1.6	3.7	7.8	120.3	3.4	2056	141	5.51
BY5	472012	6608934	1.55	15.10	3.8	1.8	4.1	7.9	95.2	3.4	1494	131	5.62
BY6	472544	6608840	1.37	12.96	3.7	1.4	3.8	7.0	45.2	3.0	1669	142	5.61
BY7	473499	6608654	1.30	13.16	4.2	1.3	3.8	6.8	38.5	3.1	1781	129	5.14
BY8	471492	6608762	1.12	12.53	3.8	1.5	3.6	6.8	65.5	2.8	1512	128	5.48
BY9	471417	6608530	1.54	13.32	3.9	1.4	3.7	7.0	49.8	3.2	1789	147	5.68
BY10	471371	6608016	1.62	15.67	2.4	1.7	4.0	7.8	63.9	3.6	1811	139	5.71
BY11	471291	6609075	1.62	15.52	2.3	5.1	5.4	58.7	54.0	13.9	2092	157	5.81
BY12	471030	6609106	1.24	13.69	1.5	1.4	3.7	6.9	47.2	3.2	1990	143	5.59
BY13	470528	6609198	1.03	13.36	2.5	1.7	4.0	7.6	53.3	3.5	1990	150	5.63
BY14R	461684	6610833	0.85	8.81	3.5	1.2	3.3	6.0	68.4	3.0	1794	141	5.51



**Figur 18.1.** Sampling sites where metals occurred in concentrations above LSC Sub-region central 96-06 are marked with red circles, whereas sites where metals occurred below LSC Sub-region central 96-06 are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.



**Figur 18.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles.

## 19. Heimdal

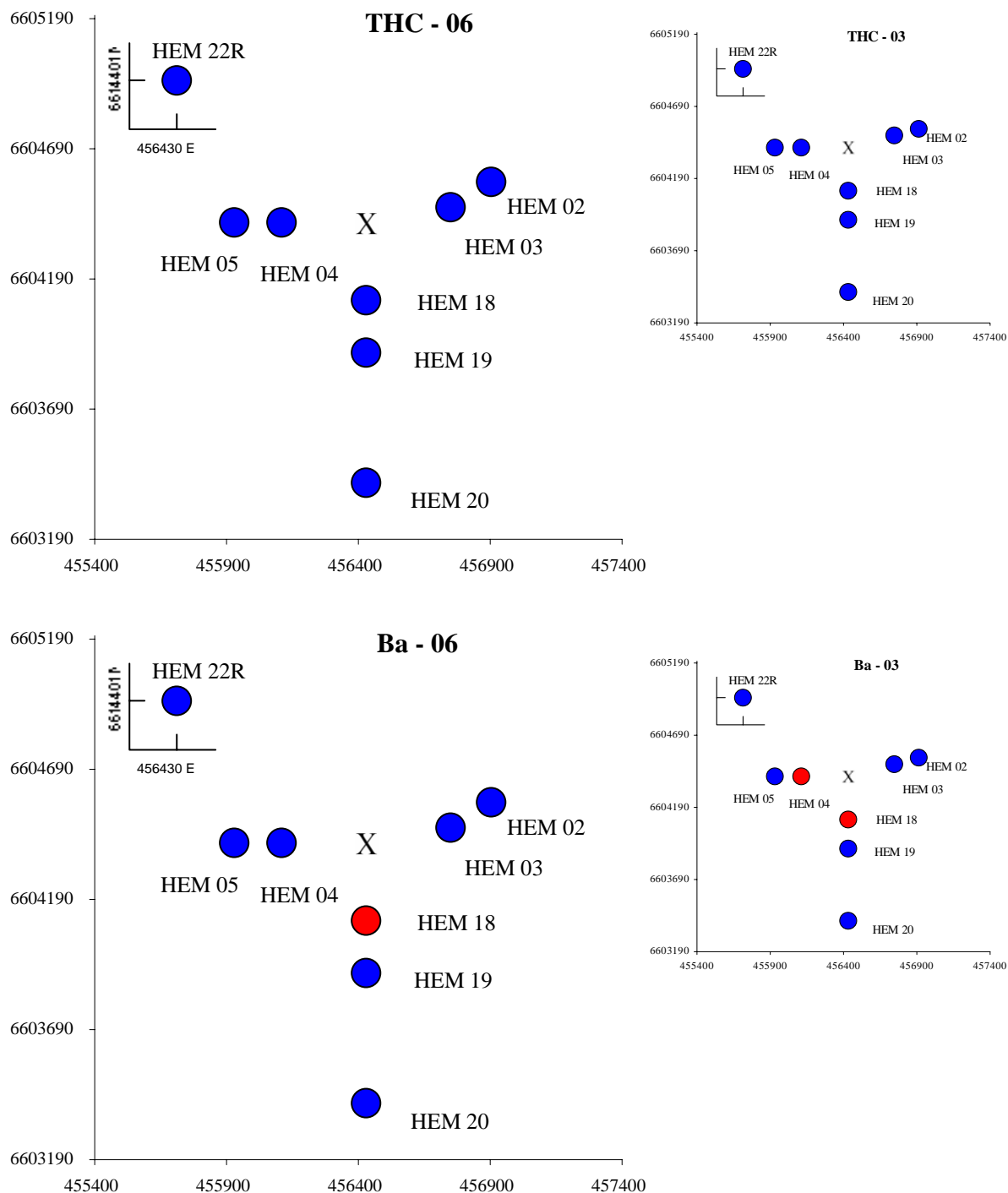
Heimdal is situated in block 25/4. Production at the field started in December 1985. The environmental condition in the vicinity of the field centre has been surveyed during the regional surveys in 1997, 2000 and 2003.

In a number of years there has been no drilling activity at the Heimdal and only minor discharges from the operations. The bottom sediments are still consisting of fine sand, although with slightly higher content of pelitt and slightly lower content of TOM. Compared to previous surveys there was a tendency of slightly lower concentrations of THC, barium and chromium, whereas zinc, lead and cadmium remain at the same levels as before. The copper content was slightly higher then in 2003, and several sampling sites had sediment with copper content above LSC Sub-region<sub>central 96-06</sub>. It was in general some increase in the number of specimens in 2006 compared to 2003. The bottom fauna was in general as similar across the field in 2006 as in 2003, but it was also more similar to the fauna identified at several regional sampling sites. The results indicate good environmental conditions at Heimdal and an undisturbed bottom fauna. The area contaminated by barium and with disturbed bottom fauna were reduced in 2006 compared to 2003. Whereas the area contaminated by other metals was increased, mainly due to the copper content. Transects towards south and west did not reach uncontaminated sediments, due to copper contamination.

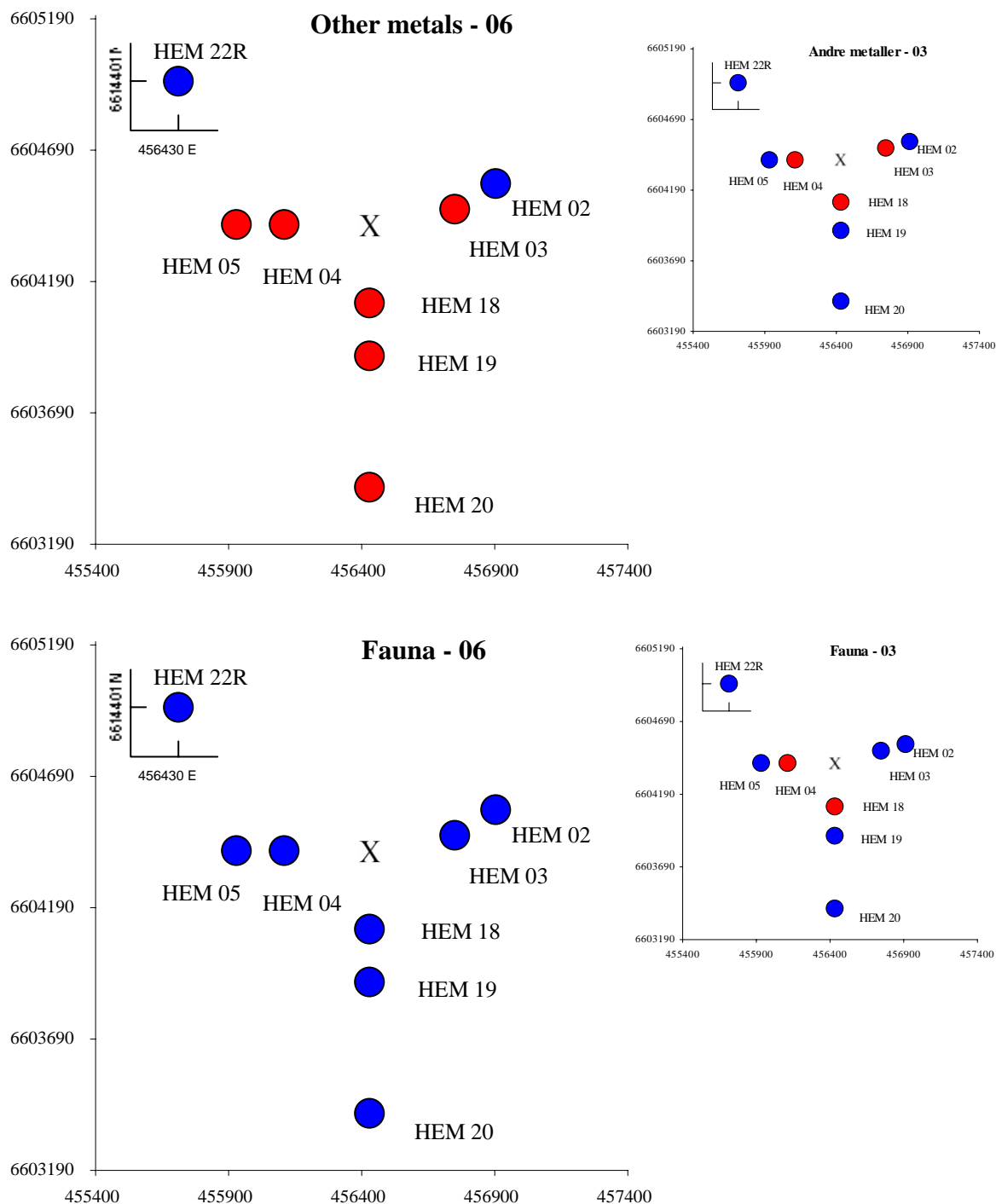
**Table 19.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Heimdal in 2006. Positioning according to UTM ED50 zone 31.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
HEM02	456905	6604555	0.99	11.51	3.7	1.5	3.5	6.7	40.8	2.7	1465	133	5.50
HEM03	456754	6604458	1.05	13.78	5.2	2.8	3.8	9.5	64.0	3.4	1648	139	5.28
HEM04	456110	6604401	1.10	14.36	5.7	2.4	4.7	13.3	97.7	5.3	1457	139	5.29
HEM05	455930	6604401	1.23	14.66	6.1	2.5	4.6	11.7	64.4	4.3	1604	142	5.48
HEM18	456430	6604101	1.00	14.81	5.8	6.3	6.3	33.5	163.0	9.1	1568	138	5.64
HEM19	456430	6603901	1.27	15.11	8.5	2.7	5.1	13.3	82.1	6.2	1666	137	5.37
HEM20	456430	6603401	1.25	18.78	6.2	2.4	5.1	11.0	81.5	4.3	1577	139	5.37
HEM22R	456430	6614401	1.43	15.95	5.1	2.2	4.5	8.2	74.1	3.3	1439	140	5.58





**Figure 19.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.



**Figure 15.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.

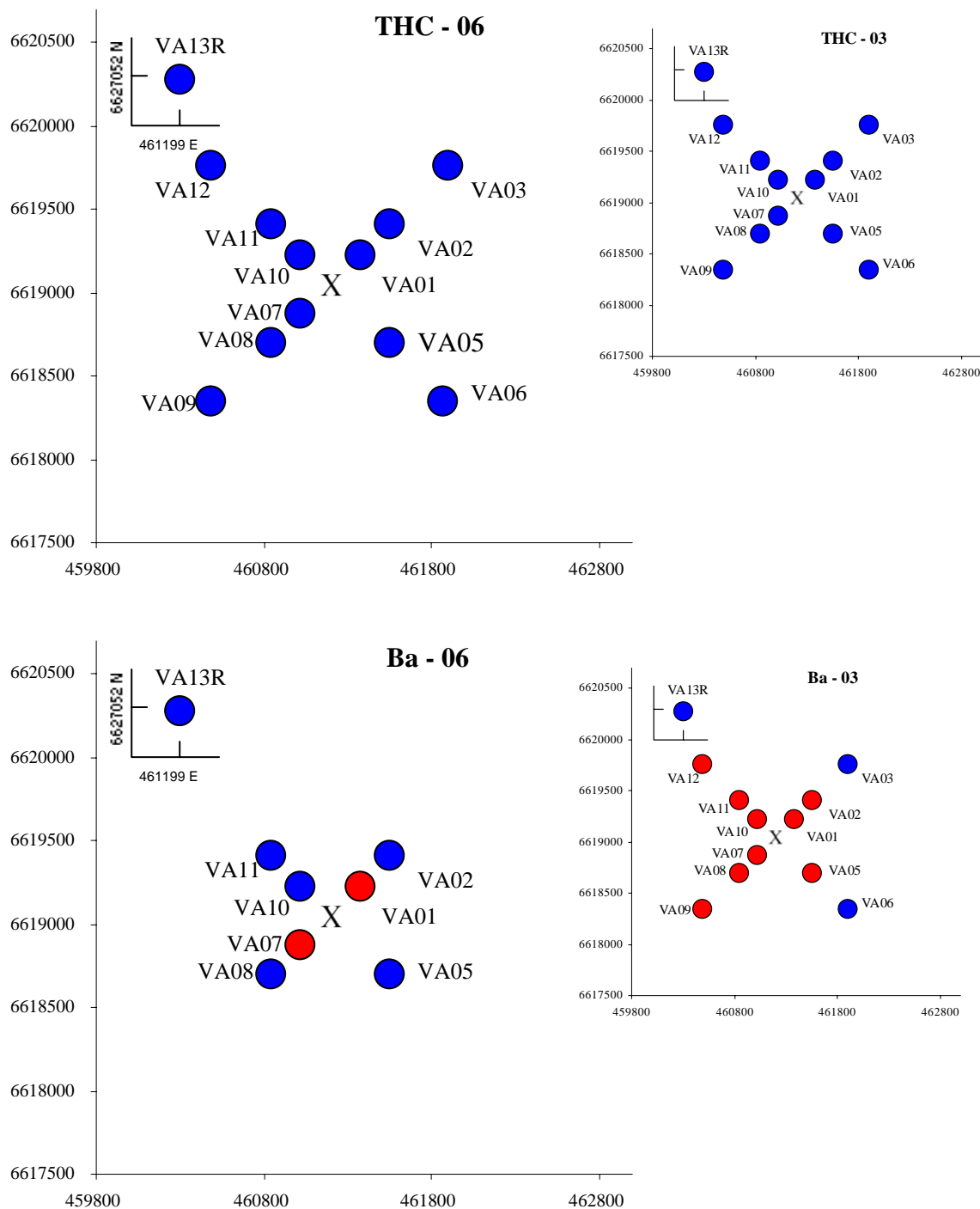
## 20. Vale

Vale is situated in block 25/4, and production started in May 2002. A baseline survey was undertaken in 2001, and the first monitoring survey was undertaken in 2003.

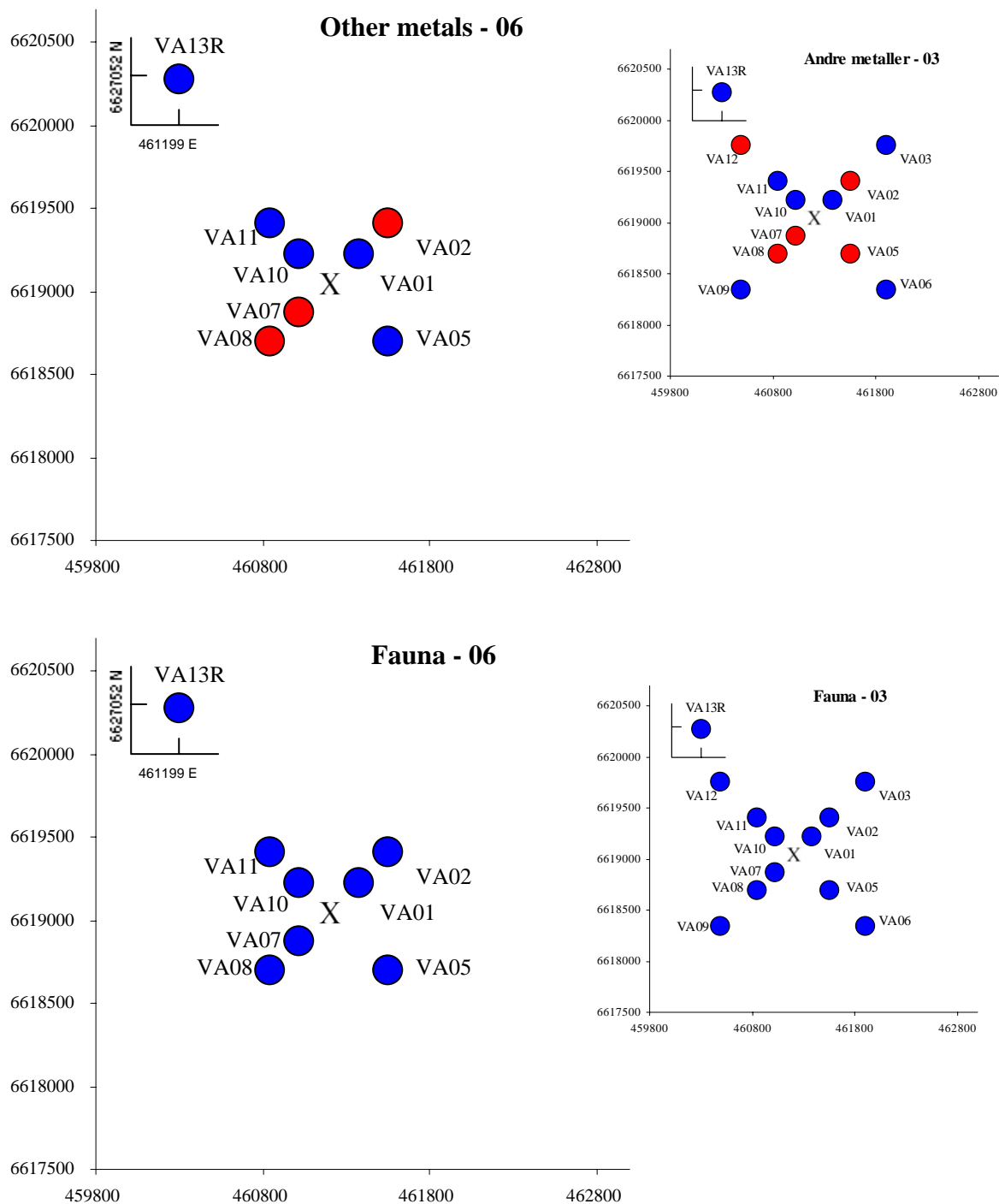
One well has been drilled at Vale since the last monitoring survey in 2003. The bottom sediments are still consisting of fine sand, and slightly lower content of TOM than before. It was a general tendency of reduced concentration of THC at the sampling sites where the concentrations were high in 2003. At the other sampling sites THC occurred at the same levels as before. It was in general a tendency of lower levels of barium, chromium and zinc, whereas copper, lead and cadmium occurred approximately at the same level as before. Some sampling sites had content of copper, zinc, barium and cadmium above LSC Subregion<sub>north 97-06</sub>. It was in general some increase in the number of specimens in 2006 compared to 2003, and the bottom fauna was as similar across the field in 2006 as in 2003. The results indicate good environmental conditions and an undisturbed bottom fauna. The area contaminated by barium and other metals were smaller in 2006 than in 2003. The transect towards southwest did not reach out to uncontaminated sediments due to cadmium contamination at 500 m to the southwest.

**Table 20.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Vale in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

Sampling sites	E	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Number of individuals	Number of taxa	H'
VA01	461376	6619229	0.84	93.54	5.6	1.0	2.5	5.2	93.9	2.8	1277	117	4.81
VA02	461553	6619406	0.91	92.26	4.6	1.4	2.5	8.1	42.6	4.5	1974	124	4.42
VA03	461906	6619759	i.a.	i.a.	4.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
VA05	461553	6618698	0.82	93.44	3.2	0.9	2.4	4.6	23.1	2.6	1751	124	4.63
VA06	461875	6618345	i.a.	i.a.	1.7	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
VA07	461022	6618875	1.13	90.42	8.7	1.4	2.6	5.6	119.1	3.5	1700	120	5.20
VA08	460845	6618698	1.09	89.43	6.8	1.0	2.5	5.1	34.0	2.6	1851	139	5.32
VA09	460492	6618345	i.a.	i.a.	3.3	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
VA10	461022	6619229	0.41	93.99	4.7	0.8	2.0	3.7	53.5	2.9	1417	105	4.82
VA11	460845	6619406	1.06	90.49	4.3	1.0	2.2	4.5	31.6	2.6	1607	123	5.08
VA12	460492	6619759	i.a.	i.a.	3.2	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.	i.a.
VA13R	461199	6627052	0.60	96.10	3.4	0.6	2.0	3.3	12.0	1.9	798	102	4.69



**Figure 20.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>north 97-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>north 97-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006, except for THC.



**Figure 20.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>north 97-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>north 97-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

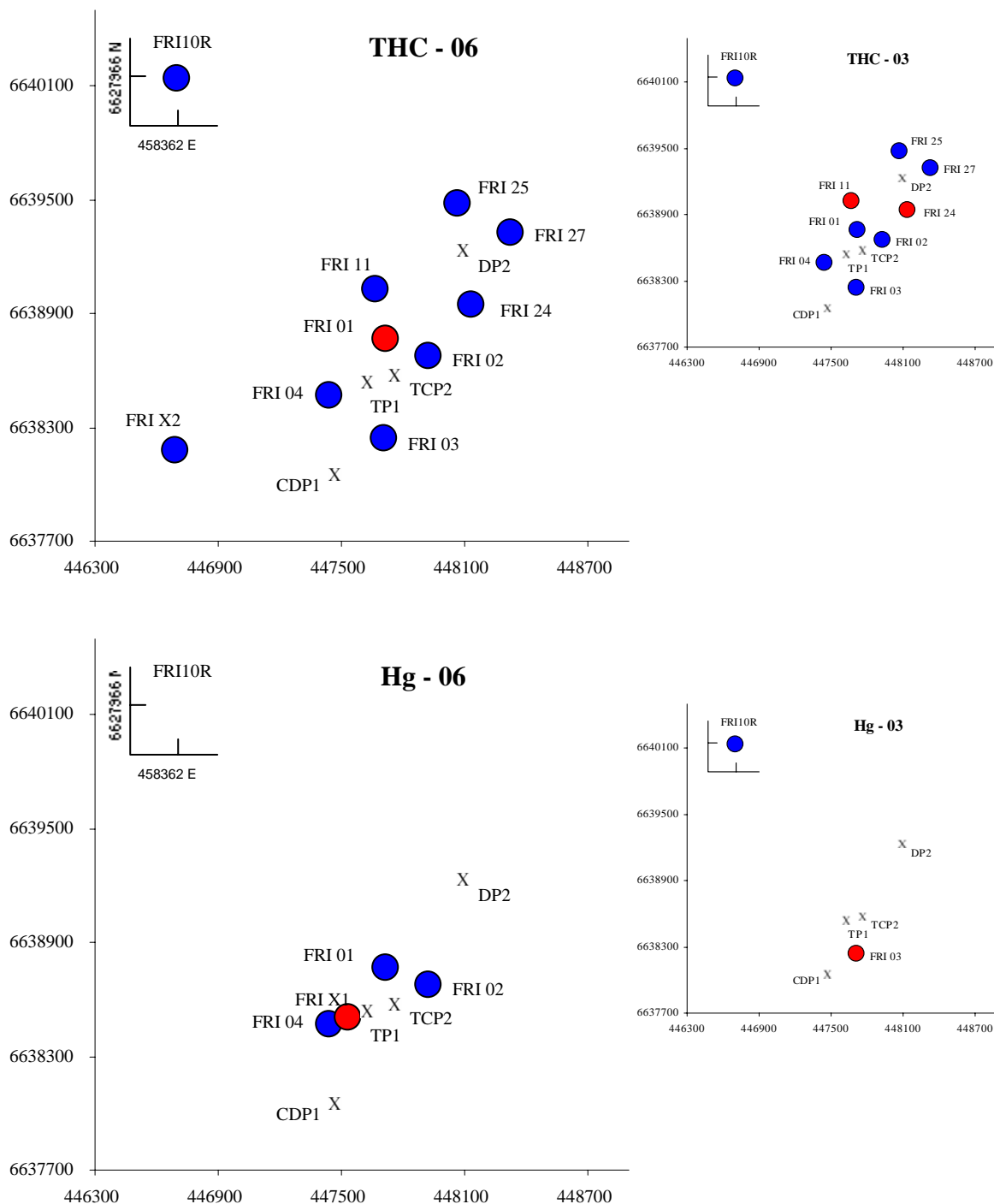
## **21. Frigg**

Frigg is situated in block 25/1. The production at the field started in September 1977 and was finished in October 2004. Between October and December 2004 fourteen wells were permanently closed. During this operation was 9.45 tonnes of chemicals of category green (98.6 %) and yellow (1.4 %) released. In addition was 1.2 kg of mercury released due insufficient equipment efficiency for collection of debris during cleaning operations on Frigg TCP2 and Frigg TP1 (UK sector).

The 2006 survey includes only sampling and measurements of THC and mercury in the sediments. Contamination by THC was revealed at one sampling site 200 m to the north of TCP2, and contamination by mercury was revealed at one sampling site 100 m southwest of TP1. The area of contaminated sea floor was smaller in 2006 than in 2003.

**Table 21.1.** The table lists the sampling site position, the average concentration of oil hydrocarbons (THC) and mercury in the sediments at Frigg in 2006. Positioning according to UTM ED50 zone 31. i.a. = no sampling according to the sampling programme of 2006.

<u>Stasjon</u>	<u>Ø</u>	<u>N</u>	<u>THC</u>	<u>Hg</u>
FRI01	447719	6638770	11.5	0.008
FRI02	447922	6638675	4.6	0.003
FRI03	447709	6638246	7.4	i.a.
FRIX2	446694	6638180	3.1	i.a.
FRI04	447440	6638466	5.2	0.007
FRIX1	447534	6638503	i.a.	0.011
FRI11	447668	6639031	6.3	i.a.
FRI24	448135	6638942	9.4	i.a.
FRI25	448070	6639480	8.8	i.a.
FRI27	448327	6639324	4.8	i.a.
FRI10R	458362	6627966	4.9	i.a.



**Figure 21.1.** Sampling sites where THC and mercury (Hg) occurred in concentrations above LSC Sub-region<sub>north 97-06</sub> are marked with red circles, whereas sites where THC and mercury (Hg) occurred below LSC Sub-region<sub>north 97-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted. Note the difference in number of sampling sites in 2003 and 2006.

## 22. Frøy

Frøy is situated in block 25/2 and 25/5. The production at Frøy started in May 1995 and was finished in March 2001, when the well was permanently plugged and abandoned. The frame work was removed in 2002, and thereafter there have been no activity at the field. The environmental monitoring at Frøy started in 1992. The last survey was in 2003, and it was then revealed contamination by THC out to 500 m toward west, and closer to the field centre toward northwest and southeast. Contamination by metals was revealed at all the field specific sampling sites, whereas faunal disturbance was revealed out to 250 m to the northwest from the field centre.

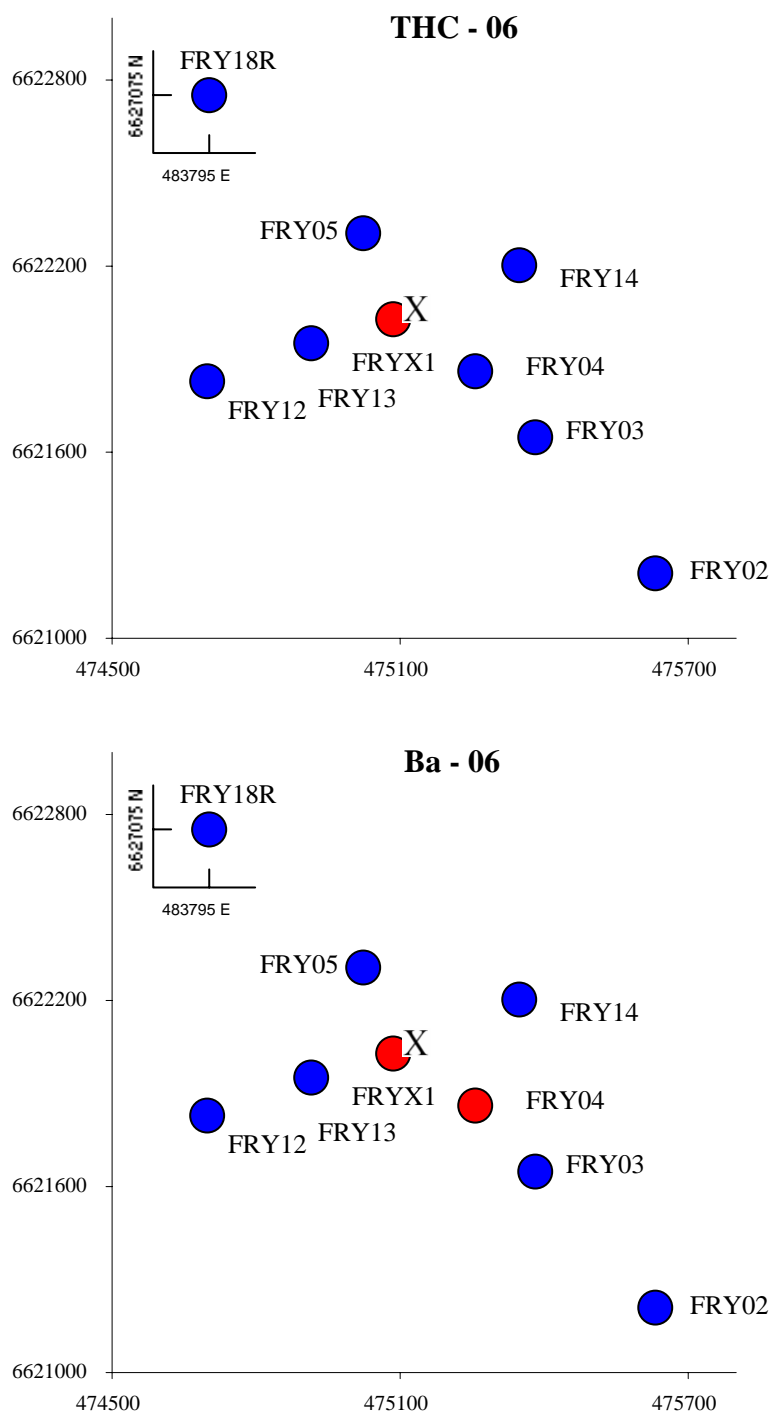
The bottom sediments consisted of fine sand with approximately the same TOM content as in 2003. It was in general lower concentrations of THC, barium and chromium in 2006, whereas copper, zinc, lead and cadmium occurred at approximately at the same low level as before. It was in general more specimens but approximately the same number of species in the samples in 2006 as in 2003. The polychaetes *Owenia borealis* and *Myriochele oculata* were the most abundant species in 2006. The results indicate good environmental conditions at Frøy and the bottom fauna remain undisturbed. On the other hand, disturbed fauna was revealed at a new established sampling site, FRYX1. The bivalves *Thyasira flexuosa* and *Thyasira sarsii* were the most abundant species at FRYX1 along with *Owenia borealis*.

Contamination by THC and most metals, and faunal disturbance were revealed at FRYX1 in 2006. At the ordinary sampling sites contamination by barium was revealed at one sampling site. The contaminated area was smaller in 2006 than in 2003, and all transects reached uncontaminated sediments.

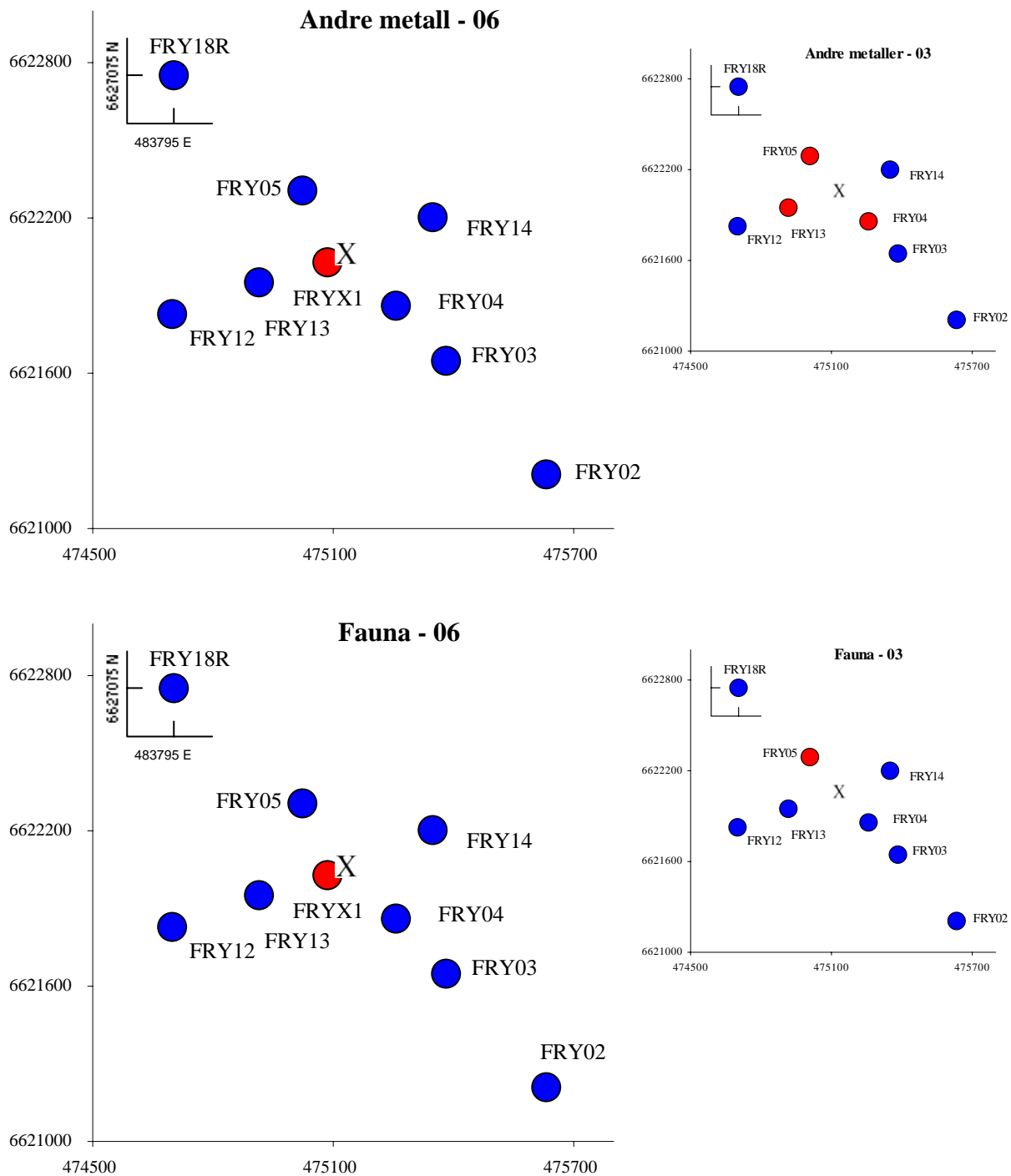
**Table 22.1.** The table lists the sampling site position, the average concentration of total organic matter (TOM), pelite, hydrocarbons (THC), metals (copper, chromium, zinc, barium, lead) in the sediment and number of individuals, number of taxa and diversity index (H') at Frøy in 2006. Positioning according to UTM ED50 zone 31.

Stasjon	Ø	N	TOM	Pelitt	THC	Cu	Cr	Zn	Ba	Pb	Antall individer	Antall taksa	H'
FRY02	475635	6621209	1.96	10.24	1.1	1.5	3.5	6.6	67.5	3.1	2355	136	4.24
FRY03	475385	6621642	1.93	9.56	1.0	1.4	3.4	6.1	74.8	2.6	2562	139	3.87
FRY04	475260	6621859	1.44	12.91	8.9	2.2	4.2	8.7	163.7	3.7	2589	132	4.32
FRY05	475023	6622306	1.64	11.62	4.8	1.7	3.8	7.4	114.9	2.8	2543	128	4.27
FRY12	474702	6621825	1.84	10.34	5.3	2.0	3.5	7.4	71.9	3.0	2350	133	4.15
FRY13	474918	6621950	1.78	9.36	4.6	2.0	3.4	7.7	91.6	2.7	2028	103	3.08
FRY14	475352	6622200	1.75	11.66	1.4	1.6	3.3	6.9	94.6	2.8	2669	140	4.09
FRYX1	475087	6622024	2.17	28.97	256.2	30.8	87.6	45.4	211.3	11.6	1216	72	3.67
FRY18R	483795	6627075	1.62	10.91	6.4	1.3	3.7	6.4	40.4	2.7	2299	128	4.18





**Figure 22.1.** Sampling sites where THC and barium (Ba) occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where THC and barium (Ba) occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.



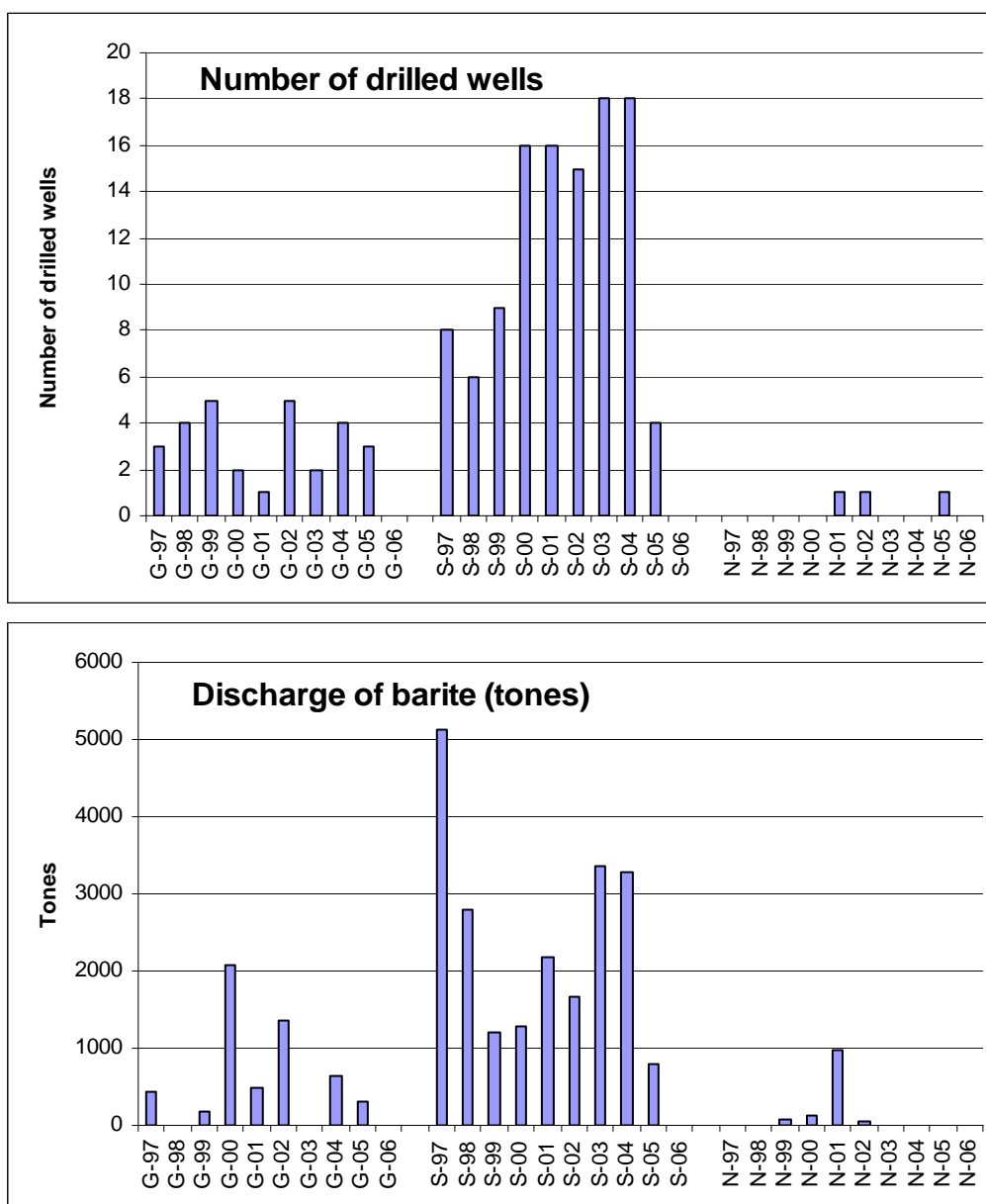
**Figure 22.1 continue.** Sampling sites where metals occurred in concentrations above LSC Sub-region<sub>central 96-06</sub> are marked with red circles, whereas sites where metals occurred below LSC Sub-region<sub>central 96-06</sub> are marked with blue circles. Sampling sites where the bottom fauna was disturbed are marked with red circles, whereas sampling sites with undisturbed fauna are marked with blue circles. The associated regional site is inserted in the upper left corner. In the upper right corner is the status figure from the 2003 survey inserted.

### **23. Status of Region II in 2006**

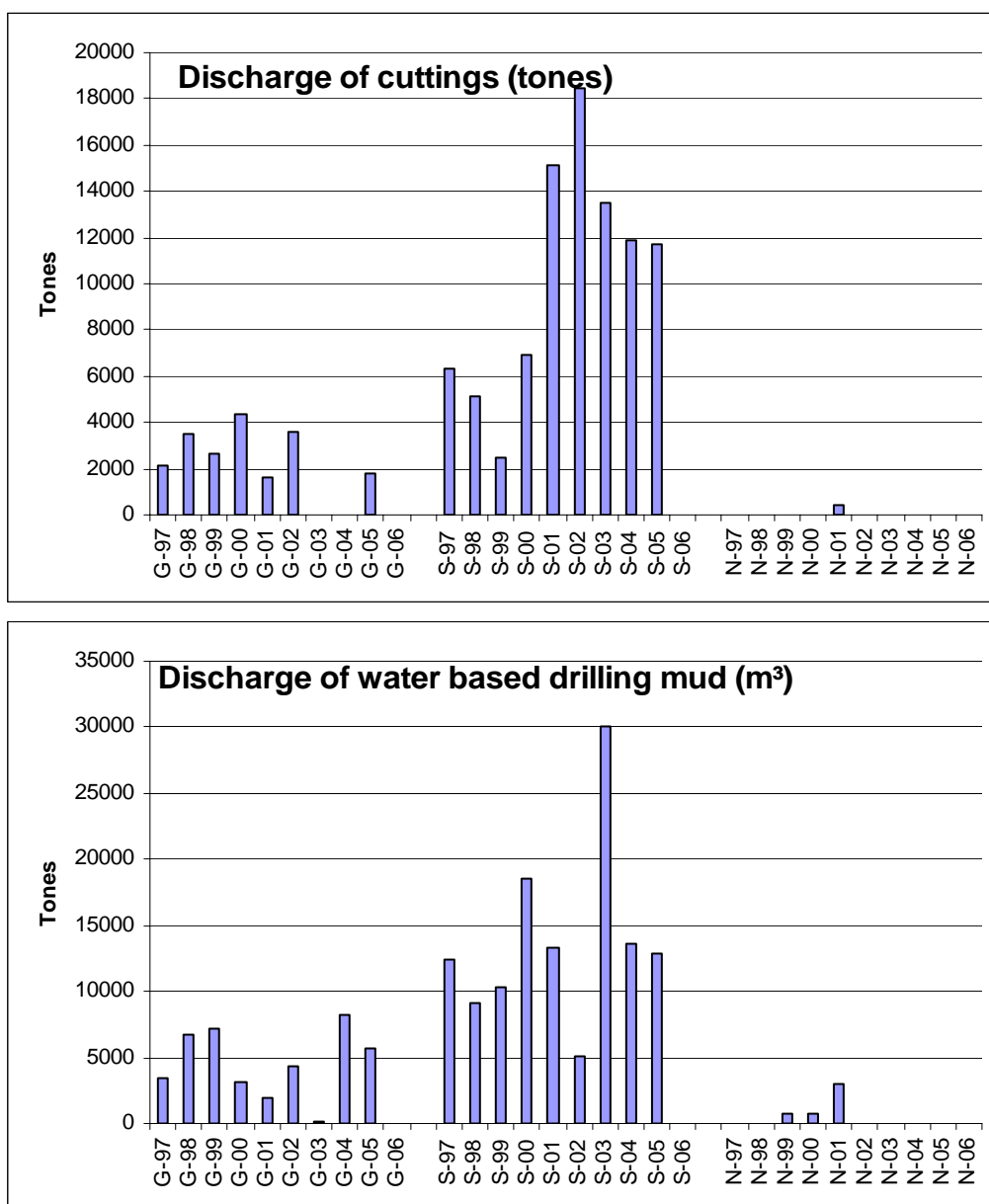
Based on the results in this survey Region II was divided into three sub-regions; a shallow sub-region in the south, a central sub-region in the central part and a northerly sub-region in the north. Between 1997 and 2005 most wells were drilled in the central region, where most of the discharges are (Figure 23.1). The largest area of contaminated sediments and area with faunal disturbance are also in the central sub-region (Figure 23.2). The area with THC and barium contaminated sediments and the area with faunal disturbance are reduced within all three sub-regions and is at its smallest area, or close to the smallest area, since the regional surveys started (Figure 23.2). The area contaminated by other metals has developed differently in the three sub regions. In the shallow sub-region has the area with metal contamination increased, whereas it has decreased in the northern sub-region. It has also decreased in the central sub-region although not to same small area as in 2000 (Figure 23.2).

The estimated size of the area depends both on the concentrations of the measured compounds and of sufficient sampling around the installations so the distribution of the compounds can be estimated. The latter might be difficult as the number of sampling sites varies from cruise to cruise, and when only contaminated samples are collected along a transect. Area of contaminations should thus be regarded as an estimate and not as an absolute value.

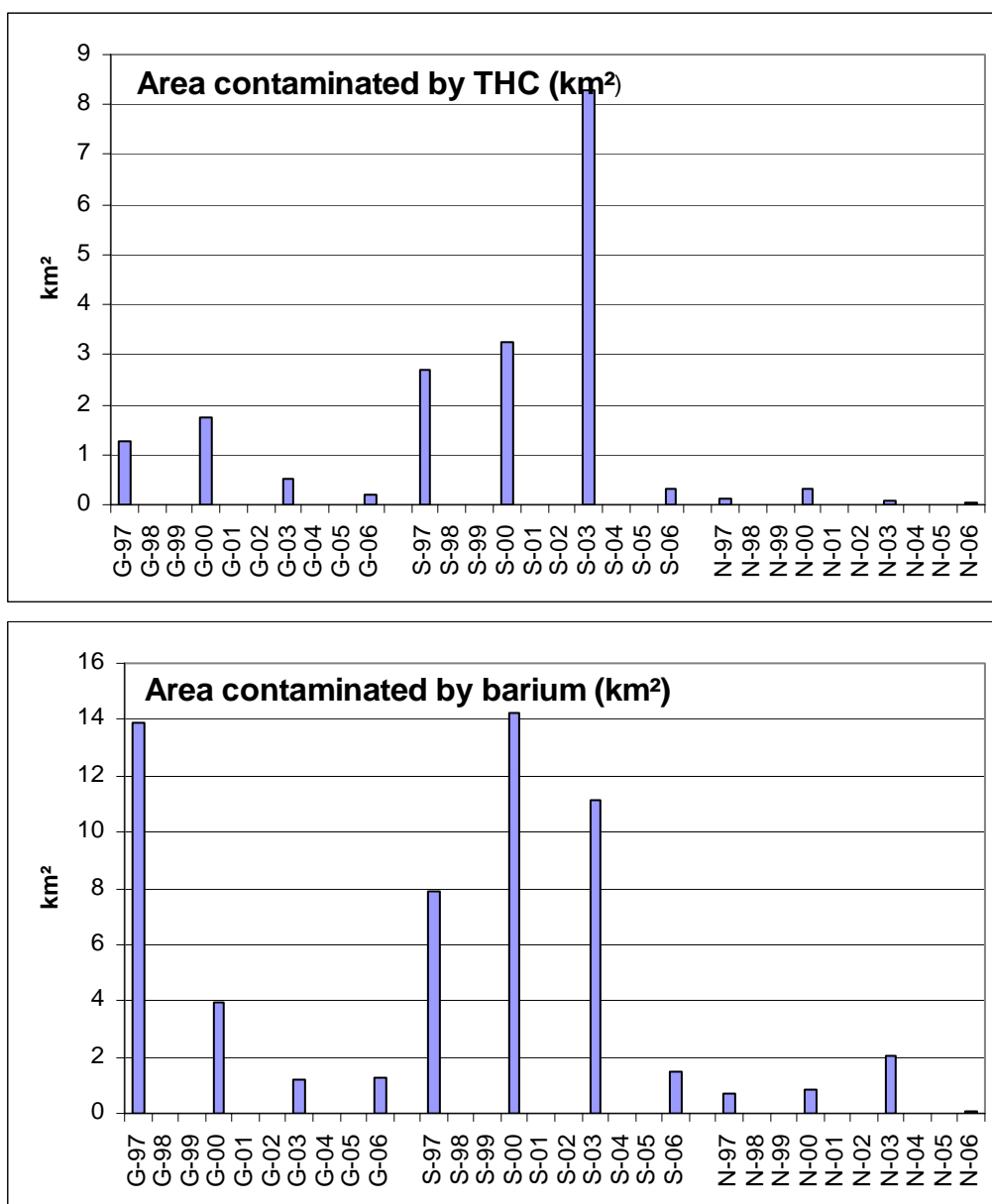
Some of the measured parameters are close to natural background levels (Table 23.1) so the potential for further improvements seems to be limited. On the other hand, the conditions might impair if the current discharge regulations are relaxed.



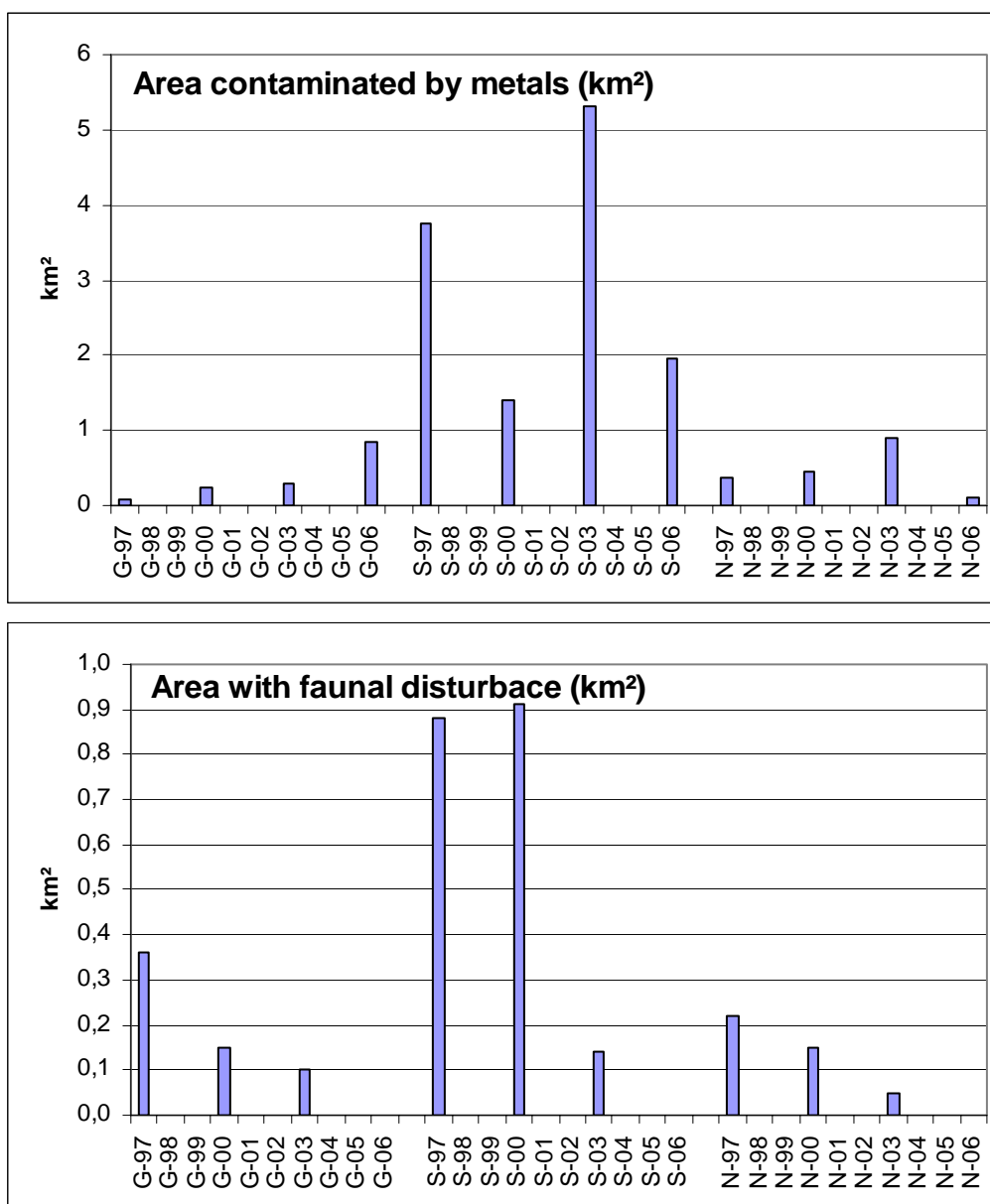
**Figure 23.1.** Number of drilled wells and amount of discharges of baritt, cuttings and water based drilling mud in Region II from 1997 to 2005. The region is divided into three sub-regions: shallow (G), central (S) and north (N). All areas are distributed on the sub-regions.



**Figure 23.1. continue.** Number of drilled wells and amount of discharges of baritt, cuttings and water based drilling mud in Region II from 1997 to 2005. The region is divided into three sub-regions: shallow (G), central (S) and north (N). All areas are distributed on the sub-regions.



**Figure 23.2.** Area (km<sup>2</sup>) of THC and barium contaminated sediments in 1997, 2000, 2003 and 2006 in Region II. The region is divided into three sub-regions: shallow (G), central (S) and north (N). All areas are distributed on the sub-regions.



**Figure 23.2. continue.** Area (km<sup>2</sup>) of metal contaminated sediments and area with disturbed bottom fauna in 1997, 2000, 2003 and 2006 in Region II. The region is divided into three sub-regions: shallow (G), central (S) and north (N). All areas are distributed on the sub-regions.

**Table 23.1.** Range, minimum – maximum values of selected parameters at the regional sampling sites and field specific sampling sites in Region II in 1997, 2000, 2003 and 2006.

Parametre	Background level (min-maxs) at regional sampling sites			
	1997	2000	2003	2006
Total number of sites	23	22	22	23
Water depth (m)	71-123	71-123	77-129	77-129
Median grain size	1.6-3.9	1.6-4.5	1.8-3.7	2.0-3.7
Lead (mg/kg)	2.5-6.1	3.1-6.9	2.1-5.7	1.7-5.1
Cadmium (mg/kg)	0.003-0.023	0.004-0.035	<0.03	<0.03-0.04
Barium (mg/kg)	6-176	8-215	5-146	5-75
THC (mg/kg)	2.0-11.3	2.2-8.9	<3-15.5	2.3-6.4
Diversity H'	3.2-6.1	3.4-5.6	3.5-5.9	2.2-5.9
Number of taxa, site	67-158	46-149	47-141	50-146
Number of specimens, site	402-2744	236-2994	181-1749	451-2299

Parametre	Minimum - maksimum at the field specific sites			
	1997	2000	2003	2006
Total number of sites	168	217	172	212
Water depth (m)	78-126	78-126	79-130	75-130
Median grain size	2.3-4.1	2.7-4.5	2.1-3.5	1.9-3.7
Lead (mg/kg)	2.0-26.3	3.2-31.0	2.6-43.7	2.6-13.9
Cadmium (mg/kg)	0.005-0.085	0.003-0.095	<0.03-0.045	<0.03-0.05
Barium (mg/kg)	11-2480	9-3942	8-709	5.9-286
THC (mg/kg)	1.1-418	1.6-412	<3-154	1.0-45
Diversity H'	3.9-5.9	3.1-5.9	4.1-5.9	2.8-5.9
Number of taxa, site	54-173	37-154	45-146	55-157
Number of specimens, site	235-3748	165-2635	162-1549	373-2669