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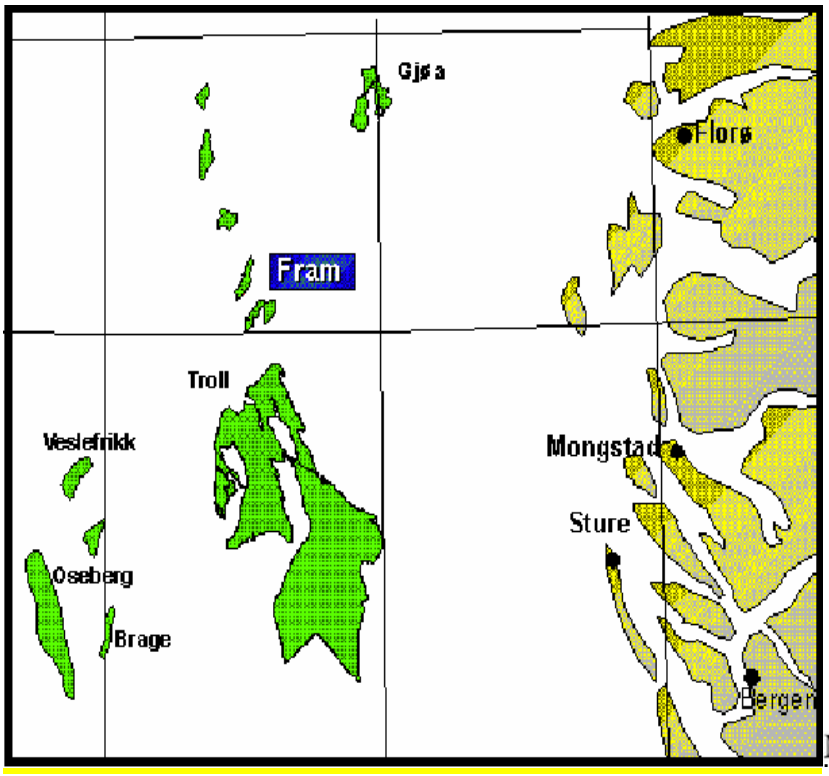
Environmental Baseline Survey Fram Øst 2005:

Report for NORSK HYDRO ASA
Report no.: 2006-0344
Rev 1, 10 April 2006



MANAGING RISK

DNV

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for	
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Client ref: Bjørge Fredheim	

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Contents:

PREFACE

The environmental baseline survey at Fram øst in 2005 has been carried out jointly by Det Norske Veritas and Molab, on behalf of Hydro. Hydros representative has been Bjørge Fredheim.

Personnel

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TOM analysis:	Gaute Botten, Håkon E. Larsen
Metal analyses:	Andreas Parslow, Karina E. Ødegård, Håkon E. Larsen
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Biological analyses:

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	Thomas Møskeland, DNV (Crustacea)
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	Per Bie Wikander, Molltax (Mollusca)

Sorting has taken place at DNV's Biology Laboratory. Karen Marie Brinchmann and Mikkel Petersen have been in charge of the sorting.

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Main Report:	Sam-Arne Nøland
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Molab AS is accredited by Norwegian Accreditation to perform chemical analyses, accreditation number Test 032. The accreditation is according to NS-EN ISO/IEC 17025.
The accreditation includes methods for determination of total hydrocarbon content (THC), polycyclic aromatic hydrocarbons (PAH), selected hydrocarbons (NPD), metals and total organic matter (TOM).

DNV's Biology laboratory (DNV Consulting) is accredited by Norsk Akkreditering for sampling of marine sediments for chemical and biological analyses, and to perform out biological analyses, accreditation number TEST 083. Accreditation is according to NS-EN ISO/IEC 17025.

1.0 RESUMÉ

This report presents the results from the environmental baseline survey at Fram Øst in 2005. 20 stations were sampled, two of them including deeper sediment layers.

The sediments are characterized by grain size distribution and by content of total organic matter (TOM). The sediments are analysed for the contents of total amounts of hydrocarbons (THC) and metals. NPD, PAH and decalins were analysed for the stations where samples from different layers were sampled.

The survey at Fram Øst in 2005 has revealed the following:

- Sediments consisting of silt and clay are dominating the area. The average median particle diameter is 5.97. The silt and clay content is higher than 98 % for all except one station. The content of gravel is low.
- The content of total organic matter is high (9.2-12.3 %).
- One station has a somewhat elevated concentration of Ba, otherwise there are no signs of contamination of hydrocarbons, barium and heavy metals in the sediments.
- The mean concentration of THC varies from 7.9 to 16.7 mg/kg.
- The mean concentration of Ba ranges from 213 to 569 mg/kg, and the average is 347 mg/kg.
- The levels of THC, PAH, NPD and metals can be characterized as the natural background level for the area.
- The fauna community reveals high diversity indices and is characterised as undisturbed.

2.0 Summary / Sammendrag

2.1 Summary

Chemical analysis and physical characterization of the sediments

Except for one station (340°/2500m) with a somewhat elevated concentration of Ba there has not been found any signs of pollution of hydrocarbons, barium or heavy metals in the sediment samples collected at Fram Øst in 2005. The sediments have been analyzed as described in Table 2.1.1.

Table 2.1.1. *Analytical methods and physical characterization.*

Analytical method	Parameter
Sediment characterization	
• Grain size distribution	- Distribution of pelit (< 63 µm) and sand (> 63 µm) - Cumulative weight% distribution 63-2000 µm - Median particle diameter (Mdϕ), deviation (SDϕ), skewness (Skϕ) and kurtosis (Kϕ)
• Total organic matter	- % TOM in the sediment
Chemical analysis	
• Hydrocarbons	- THC, sum C_{12}-C_{35} - NPD, naphtalene, phenanthrene/anthracene and dibenzothiophene and their C_1-C_3 alkylated derivatives. Sum and single compounds. - PAH, 16 EPA compounds. Sum and single compounds. - Decalins, sum of C_5-C_8 alkyl decalins.
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb, Zn

The sediments consist mainly of silt and clay. The median particle diameter is between 5.97 and 5.99 for 19 of the 20 stations. These stations had more than 98 % silt and clay, and little gravel. The deviating (FRAM F-E5) station had 87.4 % silt and clay, 11.3 % sand and 1.3 % gravel.

Due to the fine sediment the content of organic matter is high (9.2-12.3 %).

The total hydrocarbon content (THC) varies between 7.9 and 16.7 mg/kg. The level of THC is lower than what was found at the baseline survey at Fram Vest in 2002 (18-49 mg/kg) and at the reference station (Fram A2-7 REF) in 2004 (24.8 mg/kg).

Two downstream stations were analysed for NPD contents. The concentrations of NPD and PAH are low, 0.43-0.48 mg/kg and 0.45-0.56 mg/kg respectively. Decalins are not detected. The results are comparable to the results from the baseline survey at Fram Vest in 2002 and at the reference station in 2004 for decalins, PAH and NDP.

The average concentration of barium (Ba) is 347 mg/kg, and the range is 213-569 mg/kg. FRAM E SI3 has an elevated level of Ba (569 mg/kg) and this is similar to some of the findings at Fram Vest in 2002. The average Ba concentration is comparable to the reference station and the lower levels found at Fram Vest. The concentrations of heavy metals are low.

The concentrations of hydrocarbons, barium and heavy metals can be considered as the natural background levels in this area.

A summary of the results are shown in table 2.1.2.

Biology

The fauna community at Fram Øst reveals high diversity indices and is characterised as undisturbed.

The fauna at two stations, 340º/1500m and 250º/250m, deviate somewhat from the fauna at the other stations.

Variations within chemical and biological parameters:

Table 2.1.2. *Summary of the chemical analyses and physical characterization, Fram Øst 2005.*

Analytical method	Parameter	Average and variation (in parenthesis) at Fram Øst 2005
• Depth	m	359 (354 – 366)
Sediment characterization		
• Grain size distribution (%)	Silt and clay:	98,7 (87.4 - 99.7)
	Sand:	1,2 (0.3 - 11.3)
	Gravel	0,1 (0 - 1.3)
• Median particle diameter	Mdϕ:	5,97 (5.71 - 5.99)
• Total organic matter (%)	TOM:	11,3 (9.2 - 12.3)
Chemical analyses		
• Hydrocarbons (mg/kg)	THC:	13,83 (7.9 - 16.7)
	NPD:	0,45 (0.43 - 0.48)
	PAH:	0,51 (0.45 - 0.56)
	Decalins:	Not detected
• Metals (mg/kg)	Ba:	347 (213 - 569)
	Cd:	0,11 (0.09 - 0.12)
	Cr:	45 (38 - 47)
	Cu:	17,6 (15.8 - 20.4)
	Hg:	0,06 (0.05 - 0.07)
	Pb:	51 (33 - 57)
	Zn:	96 (89 – 128)
Biological analyses (0.5 m^2 samples)		
• Number of species	N	104 (93 – 121)
• Number of individuals	S	1167 (896 – 1448)
• Shannon-Wiener diversity index	H’	5,5 (5.3 - 5.6)
• Expected no. of species per 100 individuals	ES_{100}	40 (39 – 43)

2.2 Sammendrag

Kjemiske analyser og fysisk karakteristikk av sedimentet

Med unntak av en stasjon med forhøyet bariuminnhold (340°/2500m) er det ikke funnet tegn til forurensninger av hydrokarboner, barium eller tungmetaller i sedimentprøvene som ble samlet inn. Prøvene har blitt analysert som angitt i Tabell 2.2.1.

Tabell 2.2.1. *Oversikt over kjemiske analyser og fysisk karakterisering.*

Analyse	Parameter
Sedimentkarakterisering	
• Kornstørrelsesfordeling	- Fordeling av pelit (< 63 µm) og sand (> 63 µm) - Kumulativ vekt% fordeling fra 63-2000 µm - Median partikkel diameter (Mdϕ), standard avvik (SDϕ), skjevhet (Skϕ) og kurtosis (Kϕ)
• Totalt organisk materiale	- % TOM i sedimentet
Kjemiske analyser	
• Hydrokarboner	- THC, sum C_{12}-C_{35} - NPD, naftalen, fenantren/antracen og dibenzotiofen og deres C_{1-3} alkylhomologe. Sum og enkeltforbindelser. - PAH, 16 EPA forbindelser. Sum og enkeltforbindelser. - Dekaliner, sum av C_5-C_8 alkyldekaliner
• Metaller	- Ba, Cd, Cr, Cu, Hg, Pb, Zn

Sedimentene består hovedsakelig av silt og leire. Median partikkeldiameter er mellom 5,97 og 5,99 for 19 av 20 stasjoner. Disse stasjonene har mer enn 98 % silt og leire, og lite grus. Stasjonen som avviker (FRAM F-E5) består av 87,4 % silt og leire, 11,3 % sand og 1,3 % grus.

På grunn av det finkornede sedimentet er innholdet av organisk materiale høyt (9,2-12,3 %).

Totalt innhold av hydrokarboner (THC) varierer mellom 7,9 og 16,7 mg/kg. Innholdet av THC er lavere enn hva som ble funnet på grunnlagsundersøkelsen på Fram Vest i 2002 (18-49 mg/kg) og ved referansestasjonen (Fram A2-7 REF) i 2004 (24.8 mg/kg).

To stasjoner nedstrøms ble analysert for innhold av NPD. Konsentrasjonene av NPD og PAH er også lave, henholdsvis 0,43-0,48 mg/kg og 0,45-0,56 mg/kg. Dekaliner ble ikke detektert. Resultatene for dekaliner, PAH og NDP er sammenlignbare med hva som ble funnet i 2002 og 2004.

Gjennomsnittlig Ba konsentrasjon er 347 mg/kg, og spennet er 213-569 mg/kg. FRAM E SI3 har en forhøyet konsentrasjon av Ba (569 mg/kg) og dette resultatet er sammenlignbart med noen av funnene ved Fram Vest i 2002. Den gjennomsnittlige konsentrasjonen av Ba er sammenlignbar med referansestasjonen i 2004 og lavere enn gjennomsnittet ved Fram Vest. Konsentrasjonen av tungmetaller (Cd, Cr, Cu, Hg, Pb og Zn) er lav.

Nivåene av THC, Ba og tungmetaller kan betraktes som det naturlige bakgrunnsnivået for området.

Et sammendrag av resultatene for 2005 er gitt i Tabell 2.2.2.

Biologi

Faunasamfunnet ved Fram Øst viser høye diversitetsindekser og karakteriseres som relativt sunn.

Stasjonene FRAM E-SI1 (340º/1500m) og FRAM F-E5 (250º/250m) skiller seg ut med en noe annerledes fauna enn på de andre stasjonene ved Fram Øst.

Variasjoner i de kjemiske og biologiske parametrene:

Tabell 2.2.2. *Sammendrag av de kjemiske analysene, fysisk karakterisering og biologiske parametrene, Fram Øst 2005.*

Analyse	Parameter	Gjennomsnitt og variasjon (i parentes) på Fram Øst 2005
• Dyp	m	359 (354 – 366)
Sedimentkarakterisering		
• Kornstørrelsesfordeling	Silt og leire (%):	98,7 (87.4 - 99.7)
	Sand (%):	1,2 (0.3 - 11.3)
	Grus (%):	0,1 (0 - 1.3)
	Median partikkel diameter (ϕ):	5,97 (5.71 - 5.99)
• Totalt organisk materiale (%)	TOM:	11,3 (9.2 - 12.3)
Kjemisk analyse		
• Hydrokarboner (mg/kg)	THC:	13,83 (7.9 - 16.7)
	NPD:	0,45 (0.43 - 0.48)
	PAH:	0,51 (0.45 - 0.56)
	Dekaliner:	Not detected
• Metaller (mg/kg)	Ba:	347 (213 - 569)
	Cd:	0,11 (0.09 - 0.12)
	Cr:	45 (38 - 47)
	Cu:	17,6 (15.8 - 20.4)
	Hg:	0,06 (0.05 - 0.07)
	Pb:	51 (33 - 57)
	Zn:	96 (89 – 128)
Biological analyses		
• Antall arter	N	104 (93 – 121)
• Antall individer	S	1167 (896 – 1448)
• Shannon-Wiener diversitetsindeks	H’	5,5 (5.3 - 5.6)
• Forventet antall arter per 100 individer	ES_{100}	40 (39 – 43)

3.0 Introduction

Hydro is planning an extension to the oil field Fram Øst in the Fram license (PL 090) belonging to region III (subregion Troll). This will comprise an extension of the Sognefjord reservoirs at F-East and C-West in addition to C-West Etive.

3.1 Extension of the oil field Fram

Information about the field, the extension concept and the drilling program is collected from the Environmental Assessment (Ongstad 2004). The plans include installation of two 4-hole well templates on the sea bed. In Figure 3.1.1 a typical well template for sea bed installation is shown. The sub sea installation together with the pipelines at Fram Øst will be overtrawlable and the pipelines will be buried. Rock dumping will only be relevant where the pipelines are crossing other pipelines.

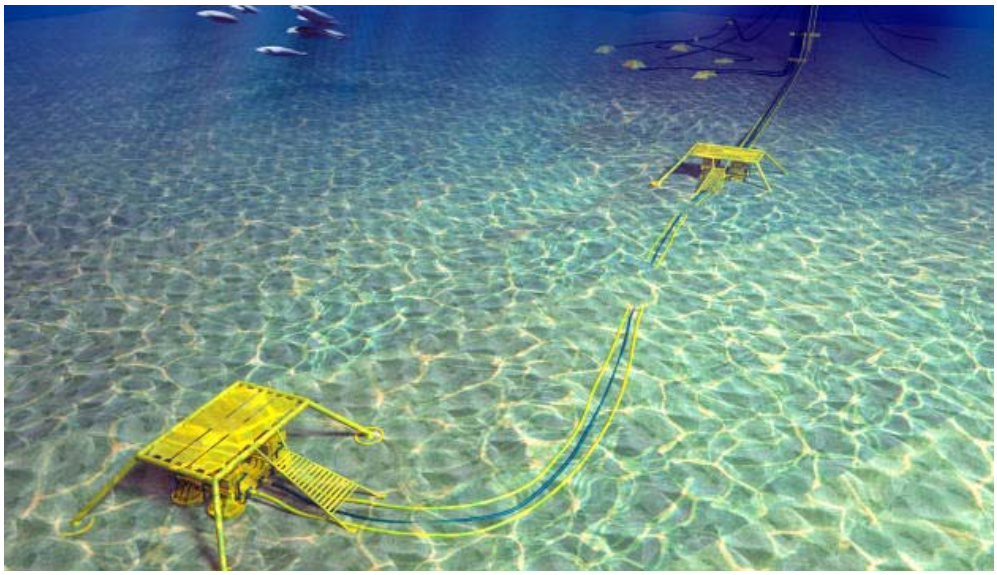


Figure 3.1.1. *Typical 4-hole well template with a safety structure.*

The extension will comprise drilling of five oil wells, two water injection wells, laying out pipelines from Troll C for transport of well stream (12”) and water for injection (12”). Gas lift will be used and therefore one pipeline will be connected to an existing gas injection pipeline from Troll C to Fram Vest.

3.2 Drilling activity

License of production 090, block 35/11 comprises the whole Fram field. In total, nine exploratory wells have been drilled in PL 090. In addition, three exploratory wells have been drilled at B-, F-East and at the H-structure.

Drilling is now planned with both oil based and water based drilling fluids. Fluids polluted with oil and drill cuttings are planned to be re-injected into the subsurface. Some fluids and sludge will be transported ashore. For the other sections (36” and 24”) the drilling fluids and drill cuttings will be discharged into the sea. At these sections they will only use sea-water and green chemicals as drilling fluids.

The extension is preparing for attachment to more wells in the case of further exploration of the resources in the Fram area. Maximally, it is foreseen up to three sea bed structures in connection to Fram Øst or well stream pipelines from Fram Øst.

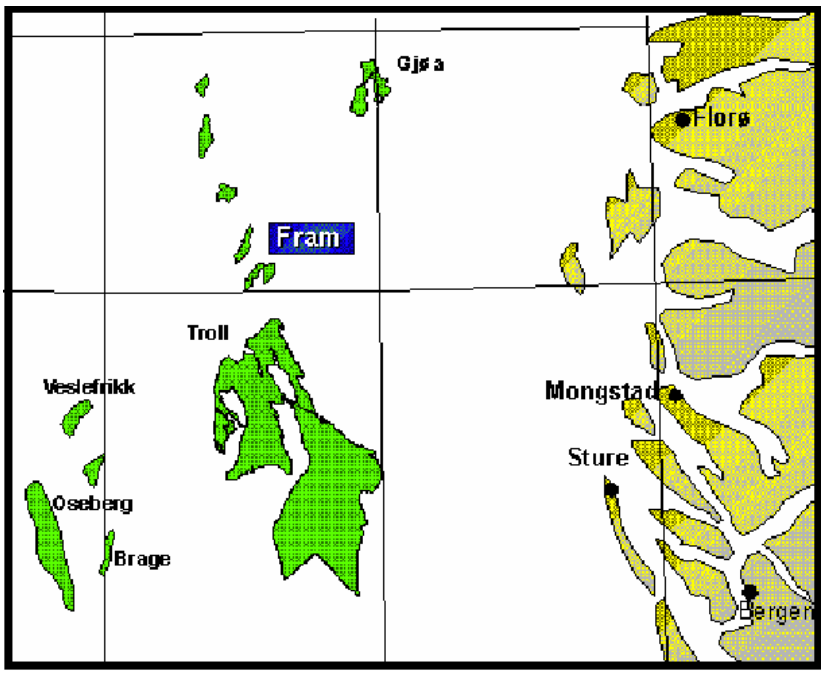


Figure 3.2.1. *Positioning of the Fram field.*

Hydro's target is that discharges/spills of potentially environmentally hazardous chemicals should be reduced to an absolute, though practical minimum for the development drilling. A summary is shown in Table 3.2.1 for the use of drilling fluids and the handling of sludge/drill cuttings from Fram Øst. Only sludge/drill cuttings from the top sections where sea water/green chemicals were used will be discharged into the sea, while the concept otherwise is based on injection into the formation under Utsira.

Table 3.2.1. *Summary of the use of drilling fluids and the handling of sludge/drill cuttings from Fram Øst.*

Section of the well	Type of fluid	Handling of sludge/dril cuttings
36"	Water based	Discharged into the sea, use of sea water/green chemicals (high viscosity pills)
24"	Water based	Discharged into the sea, use of sea water/green chemicals (high viscosity pills)
17 ½"	Oil based	Re-injection. Drill cuttings from the first well will be transported ashore.
12 ¼"	Oil based	Re-injection
8½"	Water based	Re-injection

The backup solution for the re-injection will be to ship the drill cuttings/well fluid ashore for recycling/destruction/depositing. The drilling installation at Fram Øst will be equipped for this activity. Hydro will aim to find solutions that will make use of water based systems as far as practically possible until the drilling starts, but the downhole targets and the formations will be vital for this process.

Hydro also works actively to reduce the use of barite as a weighting material in the wells at Fram Øst. Pilot testing on the use of $CaCO_3$ as a replacement is ongoing and expected to be

finished within 2004. The cleaning up of the wells before production starts will go to Troll C and be handled there.

3.3 Meteorology, oceanography and sea bed conditions

The currents in the North Sea and along the coast of Norway are shown in Figure 3.3.1. Water from the Atlantic Ocean forms the currents in the south-east direction in the deeper water layers on the shelf. In the surface waters the currents are influenced by the vortices in the coastal currents and the wind. The dominating wind direction in the area is south/southwest.

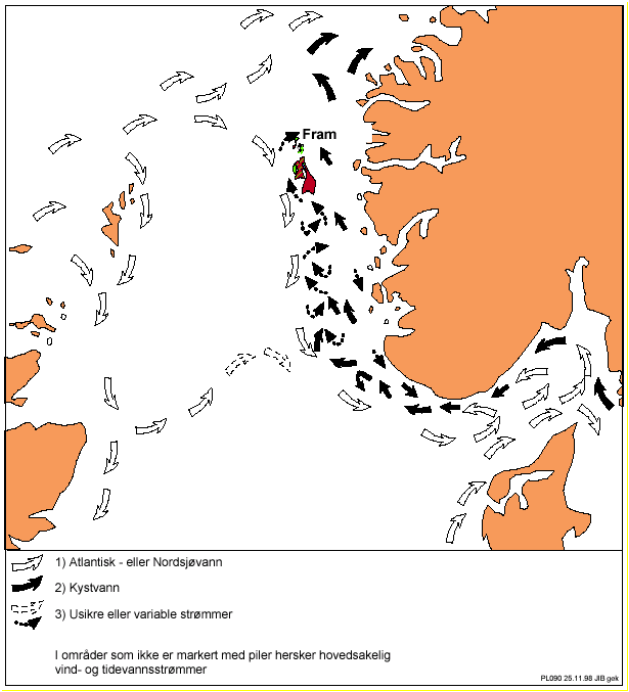


Figure 3.3.1. *The currents in the North Sea and around Fram.*

Fram is positioned in the Norwegian trench. The sea bed is relatively flat with depths varying between 350 and 360 m. In the area there are dips with diameters up to 100 m and up to 8-10 m deep. The Norwegian trench is covered in soft clay and silt. At Fram, this layer is about 20 m thick and contains high levels of organic matter. The silt- and clay contents constitute more than 85 % of the sediment. The sea bed conditions are largely the same as at the Troll field.

4.0 Previous sea bed surveys in the area

In accordance with Aktivitetsforskriften (Activities regulations) § 52 (Dtil, SFT and SHdir 2001), technical appendix 2 in appendix 1 (updated 2003), the environmental monitoring of the pollutions which follows the operational discharges defined for the region is implemented every three years. The environmental surveys in Region III have been carried out since 1998. The surveys of the sediments partly show large variations in the concentrations of the contaminations in the area. In general it is found a reduction in the area of sediment contaminated with oil.

5.0 Materials and Methods

5.1 Field work

5.1.1 Sampling strategy

The sampling programme at Fram Øst is based on the requirements to environmental baseline surveys in Aktivitetsforskriften (Activities regulations) § 52 (Dtil, SFT and SHdir 2001), technical appendix 2 in appendix 1 (updated 2003). The programme is enclosed in Appendix E.

5.1.2 Execution of field work

The field work was performed by DNV in cooperation with MOLAB using the vessel Nothern River in the period 31st of May to 5th of June 2005. The survey was carried out as a part of the regional survey in the Ekofisk area. An extract from the survey report (DNV rep. 2005-0966) is enclosed in Appendix A.

Sampling and analysis were carried out with reference to the Activity Regulations (OD, SFT, Hi, 2003), appendix 1, *Requirement to Environmental Monitoring of the Petroleum Activity on the Norwegian Continental Shelf* – technical appendix 2*, Sediment Monitoring* and DNV procedures for this kind of work.

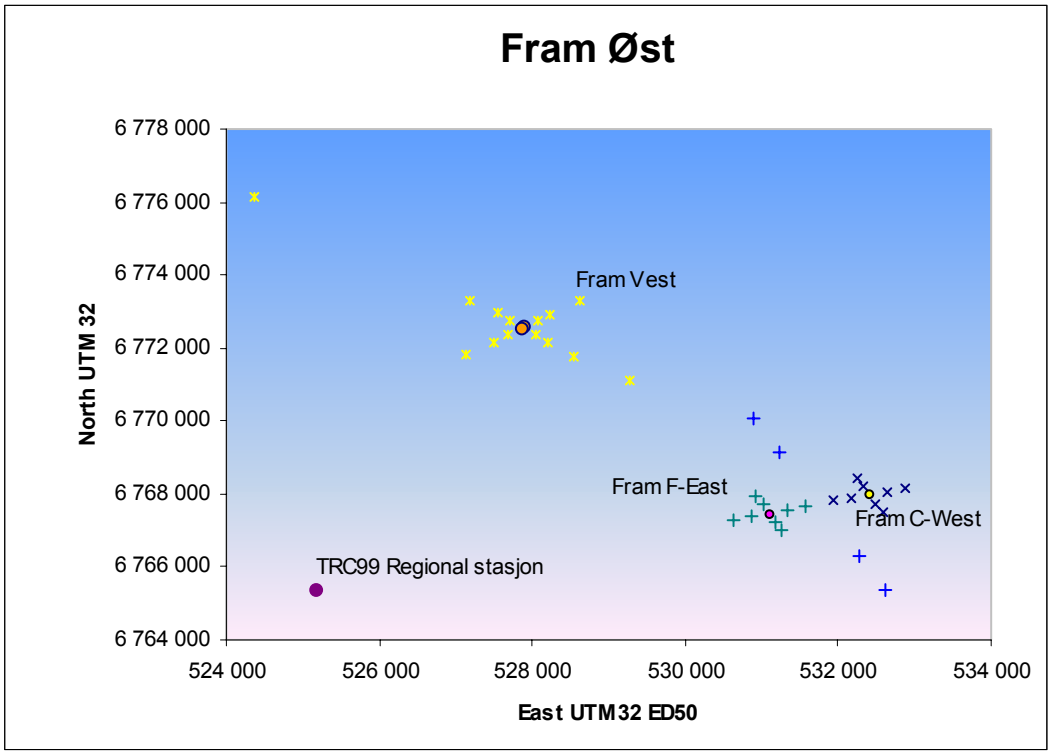
Samples for chemical and biological analysis were collected with a light weight van Veen grab (surface area 0.1 m^2). For chemical analysis the surface sediment (0-1 cm) from three replicate grab samples were collected on each location. On selected stations additional samples were collected from the 1-3 and 3-6 cm layers. Five grab samples were collected for fauna analyses on each location.

The main equipment used was:

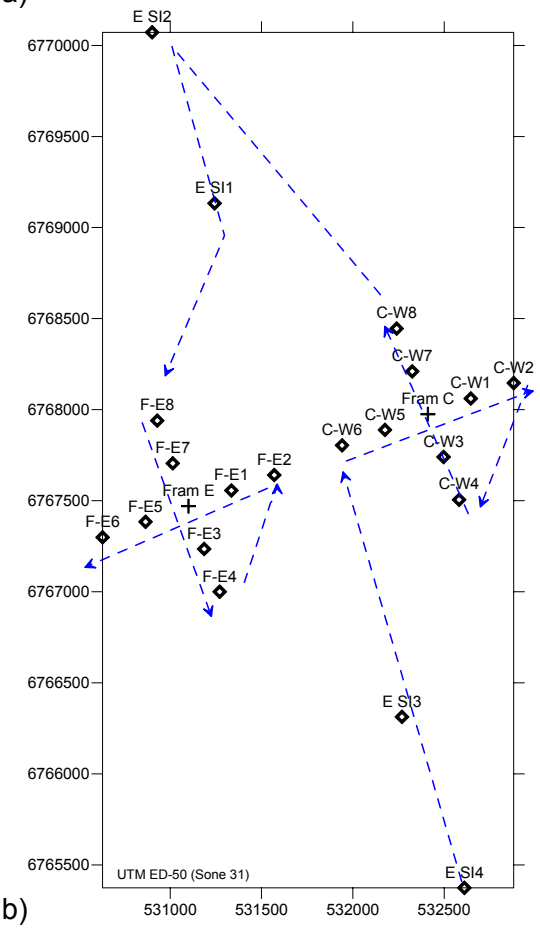
- Light weight van Veen grab
- Reception table for grab in stainless steel
- Washing table for biological samples
- two sets of sieves for washing of biological samples
- Munsels colour chart

The reference station is omitted for Fram Øst. This is on the basis that in general, there is a lot of data and knowledge of the area and a separate reference station would overlap the net of stations at Fram Vest. Data from the reference station at Fram Vest and the regional reference station TRC99 will be used as references for Fram Øst.

Sampling was carried out in accordance with accredited procedures described in *Handbook for the Biology laboratory; sampling of marine sediment and soft bottom analyses* (DNV Operating Procedures – Production; CONNO652-5-1-2). It was emphasized that the sediment surface in the samples should be undisturbed and that the washing/sieving of the fauna samples was carried out gently. Animals were fixed in formalin (4 % neutralized with hexamine), added pink Bengal and stored in 3.7 l plastic buckets. All samples were double marked and packed in solid boxes to avoid damage to the sample packing.



a)



b)

c)

Figure 5.1.1. a) *Stations at Fram Øst and Fram Vest, including regional station TRC99.*
b) *Detailed station map, Fram Øst.* **c)** *Typical sediment sample, Fram Øst.*

The field work was carried out in accordance to the survey program. Details are given in Appendix A.

The vessel was provided with dynamic positioning equipment. This means very precise positioning, and that the vessel can be kept in the exact same position over time. The variance in positioning was better than ±1 m.

5.2 Macro benthic analyses

5.2.1 An introduction to macro benthos

The macro benthic fauna considered in this survey is found living either in, or on sand, silt or clay sediments. This fauna comprises the following main taxonomic groups: Polychaeta, Crustacea, Mollusca, Echinodermata and Varia (remaining groups). Only animals more than 1 mm (macro benthos) are included in the analysis.

Macro benthic fauna are traditionally included in offshore environmental monitoring. The reason for this is that the study of benthic communities can give an indication of the effects of pollution from offshore activities, while chemical monitoring of sediments is aimed at assessing the dispersion and concentration levels of pollutants in the vicinity of offshore installations. The benthic fauna is a suitable biological parameter for monitoring the effects of pollution since most of the species have limited mobility and changes in species composition and densities of individuals can therefore easily be identified. The distribution of the fauna can be related to natural variations in environmental parameters such as depth and type of sediment, but also anthropogenic factors such as discharges of drilling fluids, cuttings and others, including accidental releases of oil and physical disturbances.

5.2.2 Sorting and species identification

In the laboratory the samples were washed on 1 mm sieves with (circular holes) to remove formaldehyde and remaining fine sediment, and then sorted by hand under a magnifying glass. The animals were split into the major taxonomic groups; Echinodermata, Polychaeta, Crustacean, Mollusca and Varia and transferred to 70% ethanol before further identification was undertaken.

The literature used for species identification is recommended in Aktivitetsforskriften (Activities regulations) § 52 (Dtil, SFT and SHdir 2001), technical appendix 2 in appendix 1 (updated 2003). Apart from the exceptions detailed below, all animals were identified to the lowest possible taxonomic level (i.e. generally to species level) and the number of individuals per taxon in each sample was recorded. In accordance with Aktivitetsforskriften, Nematoda, Foraminifera and colonial organisms (i.e. Porifera and Bryozoa), were excluded from any data analyses. Some taxa (i.e. Platyhelminthes, Nemertini, Tunicata and Tanaidacea) were quantified but were not identified further. A number of representative specimens of each of the species/taxa identified were included in our reference collection.

5.2.3 Analytical methods

The statistical and mathematical methods utilised to aid interpretation of the benthic fauna data are summarised below.

- Abundance ratio
- Shannon-Wiener's diversity index, H' (Shannon & Weaver 1963)
- Evenness calculated by Pielou's "evenness" J' (Pielou 1969)

- Expected number of species in a sample of 100 individuals (ES_{100})

- Fauna similarity between stations by Bray-Curtis dissimilarity index d (Bray & Curtis 1957).

The resulting similarity matrix was utilised in multivariate analyses in order to group stations and assess gradients in the benthic communities. These methods were: hierarchical agglomerative classification with group-average sorting (Lance & Williams 1966), ordination with non-metric Multi-Dimensional Scaling (MDS), (Shepard 1962, Kruskal & Wish 1978).

Classification and MDS ordination were carried out using the programme-package PRIMER (**P**lymouth **R**outines **I**n **M**ultivariate **E**cological **R**esearch).

Formulas and further explanations are given in Appendix D.

The raw data is stored in MOD; *MiljøOvervåkingsDatabasen* (Environmental Monitoring Database).

5.3 Chemical analysis and physical characterization of the sediments

Analytical parameters

Analysis	**Parameter**
Sediment characterization	
• Grain size distribution	- Distribution of pelite (<63 µm) and sand (>63 µm) - Cumulative weight % distribution from 63-2000 µm - Median particle diameter (Mdϕ), standard deviation (SDϕ), skewness (Skϕ) and kurtosis (Kϕ)
• Total organic matter (TOM)	- % TOM in the sediment
Chemical analyses	
• Hydrocarbons	- THC, sum C_{12}-C_{35} - NPD, naphthalenes, phenanthrenes and dibenzothiophenes sum and single compounds - PAH, 16 EPA compounds sum and single compounds - Decalins, sum of C_5-C_8 alkyl decalins
• Metals	- Ba, Cd, Cr, Cu, Hg, Pb and Zn

5.4 Sediment characterization

Grain size distribution

The method for grain size distribution analysis is described in Buchanan (1984). The analysis includes a fast mechanical separation of the sand fraction (>63 µm) from the silt and clay fraction. The sand fraction is then dried and sieved over a series of graded sieves.

From each station three subsamples (0-5 cm) from separate grab samples were mixed and homogenized, and one homogenized sample from each station was analyzed. Approximately 10 g of the sample was weighed to the nearest 0.01 g before wet sieving on a 63 µm sieve. The fraction passing this sieve was transferred to a plastic bottle. A separate sample was weighed and dried for dry weight determination. The percentage of silt and clay (<63 µm) of total dry weight in the sample was then calculated.

The fraction >63 µm was dried at 100 °C for 12 hours and sieved over a series of Wenthworth graded sieves (Endecott Test Sieves, London) with mesh sizes ranging from 2000 to 63 µm. The sample was shaken on a Retsch KG testing sieve shaker for ten minutes. The weight

retained upon each sieve was determined to the nearest 0.01 g. The weight of all size fractions was used to prepare cumulative weight % distribution tables for each sampling site. This table was then used in calculating the median particle diameter and deviation, skewness and kurtosis of the particle size distribution. As the grain size distribution was not determined for the fraction <63 µm, the ϕ-value for this fraction was given the value 8. The values for Mdϕ, SDϕ, Skϕ, and Kϕ should therefore be considered as extrapolated results.

The mathematical expressions are given below.

Mdϕ (median particle diameter):

Mdϕ = the ϕ-value of the midpoint (i.e. 50 %) of the cumulative % weight curve. This measures the central tendency of the size frequency distribution.

SDϕ (standard deviation):

SDϕ estimated as:

$$SD\phi = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

SDϕ gives a measure of the distribution in particle size around the Mdϕ, and thus is a measure of the degree of sorting of the particles.

Skϕ (skewness):

Skϕ estimated as:

$$Sk\phi = \frac{\phi 16 + \phi 84 - 2Md\phi}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2Md\phi}{2(\phi 95 - \phi 5)}$$

Skϕ describes the symmetry of the distribution in particle size around the Mdϕ. A completely symmetrical distribution would have Skϕ = 0, negative values indicate displacement of the distribution curve towards coarser sediment, and positive Skϕ indicates displacement towards finer sediment.

Kurtosis, Kϕ:

Kϕ estimated as:

$$K\phi = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

Kϕ describes the peakedness or flatness of a distribution relative to the Normal distribution, i.e. how heavy the tails are (expressed by the ϕ5 and ϕ95 fractions) compared to the central portion of the distribution. For a Normal distribution the expression above gives a Kϕ value of 1.00.

Interpretation tables are enclosed in Table 5.4.1 and Table 5.4.2.

Table 5.4.1. *Grain size distribution. Interpretation of descriptive indiced (Buchanan, 1984).*

Parameter	Index value	Verbal classification
Standard deviation (SDϕ)	< 0.35	Very well sorted
	0.25 - 0.50	Well sorted
	0.50 - 0.70	Moderately well sorted
	0.70 - 1.00	Moderately sorted
	1.00 - 2.00	Poorly sorted
	2.00 - 4.00	Very poorly sorted
	>4.00	Extremely poorly sorted

Cont.

Table 5.4.1 *cont.*

Skewness (Skϕ)	+1.00 to +0.30	Strongly fine skewed
	+0.30 to +0.10	Fine skewed
	+0.10 to -0.10	Symmetrical
	-0.10 to -0.30	Coarse skewed
	-0.30 to -1.00	Strongly coarse skewed
Kurtosis (Kϕ)	<0.67	Very platykurtic
	0.67 - 0.90	Platykurtic
	0.90 - 1.11	Mesokurtic (nearly normal)
	1.11 - 1.50	Leptokurtic
	1.50 - 3.00	Very leptokurtic

Table 5.4.2. *Grain size distribution. Mesh sizes used and Wentworth grade classification (Buchanan, 1984).*

Mesh diameter (μm)	ϕ	Description
4000	-2	Gravel
2000	-1	Very coarse sand
1000	0	Coarse sand
500	+1.0	
355	+1.5	Medium sand
250	+2.0	
180	+2.5	Fine sand
125	+3.0	
90	+3.5	Very fine sand
63	+4.0	
< 63	>+4.5	Silt and clay (pelite)

The silt and clay fraction was given the ϕ-value of 8.

Total organic matter

30-40 g of wet sediment was weighed into a porcelain dish. The sample was heated at 105 °C for minimum 20 hours, cooled and weighed, and then heated to 480 °C for minimum 16 hours. The percent weight loss after the combustion was then calculated, and this value represents the total organic matter content (TOM) in the sediment. Two sediment standards with known TOM and calcium carbonate were heated together with the sediment samples. The calcium carbonate was used as a cross check on potential weight loss due to the conversion of carbonate to oxide.

5.5 Chemical analyses

Hydrocarbons

The chemical analysis comprises determination of the total hydrocarbon content from n-C_{12} to n-C_{35} (THC) and selected hydrocarbons (NPD, PAH and decalins). The analytical steps are shown in Figure 5.5.1. The sediment samples were worked up by saponification, followed by extraction with dichloromethane. The extract was then separated in a non-polar and a polar fraction using a silica column. The non-polar fractions were analyzed for hydrocarbons by use of gas chromatography (GC).

Sample preparation procedure:

The sediment samples were taken in Rilsan bags. Homogenization was performed by stirring in the Rilsan bag, and small portions of the wet sample were taken randomly giving a total weight

of about 50 g. Benthic animals were avoided if possible. Internal standards were added, 5 µg each of naphthalene-d_8, biphenyl-d_{10}, phenanthrene-d_{10}, pyrene-d_{10}, chrysene-d_{12} and perylene-d_{12}. The sample was refluxed with 50 ml 0.5 N KOH in methanol for 2 hours. The mixture was then extracted by 80 mL dichloromethane. The extract was evaporated to approximately 1 mL, re-dissolved in hexane and fractionated (cleaned up) on Bond-Elut silica columns (Isolute, International Sorbent Technology). The hexane fraction was concentrated and analyzed for hydrocarbons.

An aliquot of the wet and homogenized sediment was weighed and dried for 48 hours at 105 °C, for determination of the dry weight.

Quantification:

THC (total hydrocarbon content) was determined by gas chromatography with flame ionization detector, in the boiling range of n-C_{12} alkane to n-C_{35} alkane. The quantification was carried out according to an external standard of the reference oil, a drilling mud base oil (HDF 200). The reported values were corrected for background levels from procedural blanks.

NPD, PAH and decalins were determined by gas chromatography/mass spectrometry operated in the selected ion recording mode (SIR). The quantification was carried out according to the added internal standards and integration of the molecular ions. The following compounds were determined: Naphthalene, phenanthrene/anthracene, dibenzothiophene and their C_1-, C_2- and C_3-alkylated derivatives, acenaphtene, acenaphthylene, fluorene, pyrene/fluoranthene, chrysene/triphenylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene/benzo(j)-fluoranthene/ benzo(k)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene. In addition the sums of selected bicyclic alkanes, C_5 - C_8 alkyl decalins, were determined.

Reference compounds were available for all the aromatic compounds. For each of the C_1 - C_3 alkyl homologue groups one of the isomers was used as reference in the quantification. For the bicyclic alkanes, C_5 - C_8 alkyl decalins, reference compounds were missing, and a response factor was calculated from n-octylcyclohexane with the assumption that the response of the molecular ions are similar. The reported values were corrected for background levels from procedural blanks.

GC-FID conditions:

Gas chromatograph		:	Perkin Elmer Autosystem XL
Column		:	12 m x 0.20 mm i.d., fused silica, crosslinked with dimethyl silicone
Temperatures:	Column	:	50 °C (2 min) – 20 °C/min – 350 °C (8 min)
	Injector	:	320 °C
	Detector	:	350 °C
Carrier gas		:	Helium
Injection volume		:	1 µL
Data system		:	TotalChrom 6.2
HDF 200		:	0.1 – 10 mg/mL hexane

GC/MS conditions:

Mass spectrometer	:	Clarus 500 Mass Spectrometer, Perkin Elmer
Data system	:	TurboMass
Gas chromatograph	:	Clarus 500 Gas Chromatograph, Perkin Elmer
Column:	:	30 m fused silica, 0.25 µm DB-5ms
Temperatures: Column	:	40 °C (2 min) - 20 °C/min - 120 °C - 10 °C/min - 300 °C (15 min)
Injector	:	300 °C
Ion source	:	180 °C
Carrier gas	:	Helium
Ionization	:	Electron impact, 70 eV
Masses (m/z)		
C_0-C_3 naphthalene	:	128, 141, 156, 170
C_0-C_3 phenanthrene	:	178, 192, 206, 220
C_0-C_3 dibenzothiophene	:	184, 198, 212, 226
PAH	:	152, 153, 166, 202, 228, 252, 276, 278
C_5-C_8 decalins	:	208, 222, 236, 250
n-octyl cyclohexane	:	196
Deuterated standards	:	136, 164, 188, 212, 240, 264
Injection volume	:	1 µL

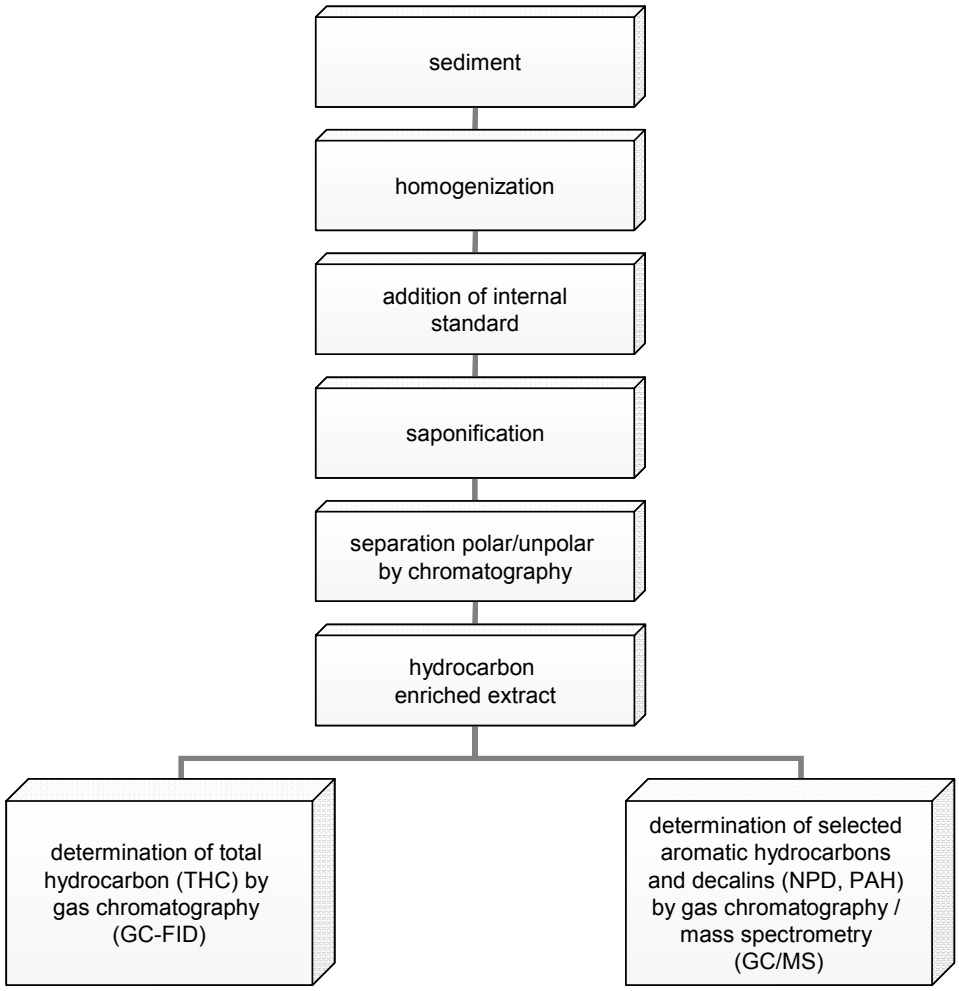


Figure 5.5.1. *Flow scheme of essential steps in the hydrocarbon analyses of sediments.*

Metals

The metal analyses include determination of Ba, Cd, Cr, Cu, Hg, Pb and Zn after digestion with nitric acid (NS 4770).

The wet sediment sample was dried at 40 °C for two days, homogenized and sieved through a 500 µm nylon sieve. The fractions larger and smaller than 0.5 mm were weighed. 1 g of the fraction smaller than 0.5 mm was extracted with 20 mL 7 M nitric acid in a Pyrex decomposition bottle in an autoclave at 120 °C for 30 min. After cooling, 80 mL of distilled water was added to the Pyrex bottle. The clear solution was decanted into a polyethylene bottle until analysis.

Ba, Cr, Cu, Pb and Zn were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES). Cd was determined by atomic absorption, graphite furnace technique (GF-AAS). Hg was determined by atomic adsorption cold vapor technique (CV-AAS) based on NS 4768.

ICP-AES:

Instrument: Thermo Jarrel Ash Iris Advantage

Analytical lines:

Ba: 493.409 nm, Cr: 267.716 nm, Cu: 324.754 nm, Pb: 220.353 nm, Zn: 213.856 nm

GFAAS:

Instrument: Perkin Elmer AAnalyst 600.

Analytical line: Cd: 228.8 nm

The element was measured with a hollow cathode lamp. Ammonium phosphate was used as a modifier.

CVAAS:

Instrument: Perkin Elmer 3100.

Hg was determined at 253.7 nm by use of stannous chloride in hydrochloric acid.

Determination and quantification limits

The limit of detection (LOD) and limit of quantification (LOQ) for THC and metals are calculated as 3 SD (standard deviation) and 10 SD above the measured average blank values respectively, see Table 5.5.1 and Table 5.5.2. This is according to "Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry", Anal.chem. 52 (1980) p. 2242-2249. The LOD and LOQ for NPD, PAH and decalins are based upon the lowest standard that gives sufficient concentration recovery.

Table 5.5.1. *Limit of detection (LOD) and limit of quantification (LOQ), hydrocarbons.*

Analytical parameter	LOD mg/kg	LOQ mg/kg	Blank samples Number
THC	1	5	23
Sum NPD	0.01	0.03	-
Sum PAH	0.005	0.02	-
Sum decalins	0.1	0.3	-

Table 5.5.2. *Limit of detection (LOD) and limit of quantification (LOQ), metals.*

	Ba ICP	Cd GFAAS	Cr ICP	Cu ICP	Hg CVAAS	Pb ICP	Zn ICP
LOD mg/kg	1	0.01	0.2	0.5	0.01	0.5	1
LOQ mg/kg	3	0.04	0.7	2	0.03	2	3

5.6 Quality assurance

Accreditation

DNV's Biology Laboratory is accredited by Norsk Akkreditering to perform sampling of marine sediments for sediment characterisation and chemical/biological analyses, as well as laboratory analyses of macro benthic fauna under accreditation number Test 083. The accreditation is according to NS-EN ISO/IEC 17025.

Molab AS is accredited by Norsk Akkreditering to perform chemical analyses, accreditation number Test 032. The accreditation is according to NS-EN ISO/IEC 17025.

Quality assurance for macro fauna analyses

Procedures including routines for quality assurance related to sorting, species identification and recording of macrobenthos samples are given in DNV's *Biolaboratoriets Kvalitetssystem, Prøvetaking av marint sediment og bløtbunnsanalyser.* A brief summary is given here:

All samples are recorded and double-labelled during fieldwork, and transported in wooden boxes in a steel container. During sorting in the laboratory all relevant information about each sample is recorded (who sorted what and when, time spent, number of bottles etc.). After sorting, each sediment sample is examined for remaining organisms by approved personnel. Each identifier establishes a separate reference collection of species for comparison purpose. To maintain traceability each identifier signs a log to keep track over which grab samples and animal group(s) he or she has been working on. The project reference collection is kept at DNV, Høvik.

Quality assurance for grain size distribution

Six different laboratory reference sediments (from the 2003 survey) were chosen as controls for the grain size distribution.

Quality assurance for total organic matter

Together with the samples, calcium carbonate and two in house standards were heated to 480 °C. The calcium carbonate was used as a control of loss of carbonate from the sediment samples. The in house standards contain known amounts of TOM (0.88 % and 8.31 %). If the results of one or both in house standards were outside the accepted range of variation, the samples were reanalyzed. The results of the analyses are given in Appendix C.

Quality assurance for hydrocarbons

The instruments are regularly calibrated by use of appropriate standards, and instrument performance is checked regularly. The analytical procedures are regularly controlled by analyses of standards, blank samples and quality assurance samples. Standards of mineral oil are analyzed together with the THC samples. For NPD, PAH and decalins, reference samples containing known amounts of the different compounds are analyzed to establish response factors due to differences in extraction, volatility and GC/MS response compared to the internal standards.

In house standards are analyzed regularly. The accuracy of the THC analysis is documented by participation in the international intercalibration exercise SETOC. The accuracy is also controlled by analysis of sediments containing certified amounts of THC

The accuracy of the NPD and PAH analysis is controlled by analysis of in house standards.

Quality assurance for metals

All reagents are of pro analysis grade. In house reference and blank samples are included in the analyses. Accuracy and reproducibility are controlled by the results obtained for the in house reference materials.

5.7 Deviation from Aktivitetsforskriften (Activities Regulations)

The survey was performed according to Aktivitetsforskriften (Activities regulations) § 52 (Dtil, SFT and SHdir 2001), technical appendix 2 in appendix 1 (updated 2003).

6.0 Results and discussion

See Appendix F for a fold out map of the location of the sampling stations.

6.1 Chemical analyses and sediment characterization

The main results of the physical characterization and chemical analyses from the survey at Fram Øst are shown in Table 6.1.1. The results from the baseline survey at Fram Vest in 2002 (Eriksen *et al.*, 2003) and the reference station in 2004 (Mannvik *et al.*, 2005) are included for comparison purposes. The results found in this baseline survey are considered as the natural background level for the area, although one station has a somewhat elevated concentration of Ba. The sediments are fine-grained and dominated by silt and clay. The content of total organic matter is high.

Table 6.1.1. *Summary of the chemical analyses and physical characterization, Fram Øst 2005, including results from the baseline survey at Fram Vest in 2002 and reference station in 2004.*

Sediment characterization	Parameter	Variation at Fram Øst 2005	Variation at Fram Vest 2002	Ref. station Fram A2-7R 2004	Regional TRC 99R 2004
• Grain size distribution	Silt and clay (%):	87.4 - 99.7	99.7 - 99.9	99.1	98.4
	Sand (%):	0.3 - 11.3			
	Gravel (%):	0 - 1.3			
	Median Particle diameter (ϕ):	5.71 - 5.99			
• Total organic matter	TOM (%):	9 - 12.3	11.8 - 14.2	11.2	11.2
Chemical analysis					
• Hydrocarbons (mg/kg)	THC:	7 - 16.7	18 - 49	24.8	24.1
	NPD:	0 - 0.48	0.44 - 0.89	0.295	0.362
	PAH:	0 - 0.56	0.56 - 0.68	0.501	0.687
	Decalins:	Not detected	Not detected	0.092	0.067
• Metals (mg/kg)	Ba:	213 - 569	392 - 777	364	351
	Cd:	0 - 0.12	0.13 - 0.18	0.097	0.091
	Cr:	38 - 47	41 - 50	41.8	40.2
	Cu:	15 - 20.4	18.7 - 21.5	19.3	19.0
	Hg:	0 - 0.07	0.004 - 0.006	0.040	0.033
	Pb:	33 - 57	50 - 68	46.3	45.3
	Zn:	89 - 128	83 - 99	80.8	79.6

6.2 Sediment characterization

Grain size distribution

The main results of the grain size distribution are shown in Table 5.2.1.

A fold out map of the stations at Fram Øst is presented in Appendix F.

All stations consist of silt and clay. The content of silt and clay is higher than 98 % for all except one station, FRAM F-E5, with 87.4 % silt and clay. The content of sand is 11.3 % and gravel amounts to 1.3 % at FRAM F-E5. For the other stations the content of gravel is low and sand makes up for the remaining part of the sediments.

The median particle diameter is between 5.97 and 5.99 for all stations, except FRAM F-E5, with a median particle diameter of 5.71.

The content of silt and clay is similar to what was found at Fram Vest in 2002 and at FRAM A2-7-ref and TRC99R in 2004.

The complete set of results for the grain size distribution is given in Appendix C.

Table 6.2.1. *Grain size distribution, Fram Øst 2005.*

Station	Mdϕ	Classification	Grain size distribution (%)		
			Silt and clay	Sand	Gravel
FRAM F-E1 70°/250 m	5.97	Silt and clay	98.4	1.6	0.0
FRAM F-E2 70°/500 m	5.97	Silt and clay	98.5	1.5	0.0
FRAM F-E3 160°/250 m	5.99	Silt and clay	99.4	0.6	0.0
FRAM F-E4 160°/500 m	5.99	Silt and clay	99.5	0.5	0.0
FRAM F-E5 250°/250 m	5.71	Silt and clay	87.4	11.3	1.3
FRAM F-E6 250°/500 m	5.99	Silt and clay	99.5	0.5	0.0
FRAM F-E7 340°/250 m	5.98	Silt and clay	99.2	0.8	0.0
FRAM F-E8 340°/500 m	5.98	Silt and clay	99.0	1.0	0.0
FRAM C-W1 70°/250 m	5.99	Silt and clay	99.5	0.5	0.0
FRAM C-W2 70°/500 m	5.99	Silt and clay	99.3	0.7	0.0
FRAM C-W3 160°/250 m	5.99	Silt and clay	99.6	0.4	0.0
FRAM C-W4 160°/500 m	5.99	Silt and clay	99.4	0.6	0.0
FRAM C-W5 250°/250 m	5.99	Silt and clay	99.7	0.3	0.0
FRAM C-W6 250°/500 m	5.99	Silt and clay	99.3	0.7	0.0
FRAM C-W7 340°/250 m	5.99	Silt and clay	99.6	0.4	0.0
FRAM C-W8 340°/500 m	5.99	Silt and clay	99.5	0.5	0.0
FRAM E SI1 340°/1500 m	5.99	Silt and clay	99.4	0.5	0.1
FRAM E SI2 340°/2500 m	5.99	Silt and clay	99.6	0.4	0.0
FRAM E SI3 160°/1500 m	5.99	Silt and clay	99.4	0.6	0.0
FRAM E SI4 160°/2500 m	5.99	Silt and clay	99.4	0.5	0.1
Mean	*5.97*	*Silt and clay*	*98.7*	*1.2*	*0.1*

Total organic matter

The TOM-results are shown in Table 6.2.2.

The contents of organic matter are high and range between 9.2 and 12.3 % with an average of 11.3 %. The contents of TOM are somewhat lower than what was found at Fram Vest in 2002 (11.8-14.2 %), but similar to what was found at the reference station and regional station TRC99R in 2004 (11.2 %).

Table 6.2.2. *Total organic matter of dry sediment, Fram Øst 2005.*

Station	TOM (%)		Station	TOM (%)
FRAM F-E1 70°/250 m	10.8		FRAM C-W3 160°/250 m	9.2
FRAM F-E2 70°/500 m	11.5		FRAM C-W4 160°/500 m	11.8
FRAM F-E3 160°/250 m	10.6		FRAM C-W5 250°/250 m	12.0
FRAM F-E4 160°/500 m	11.7		FRAM C-W6 250°/500 m	11.5
FRAM F-E5 250°/250 m	9.9		FRAM C-W7 340°/250 m	11.8
FRAM F-E6 250°/500 m	11.7		FRAM C-W8 340°/500 m	11.5
FRAM F-E7 340°/250 m	9.9		FRAM E SI1 340°/1500 m	11.7
FRAM F-E8 340°/500 m	11.8		FRAM E SI2 340°/2500 m	11.8
FRAM C-W1 70°/250 m	11.8		FRAM E SI3 160°/1500 m	12.3
FRAM C-W2 70°/500 m	11.0		FRAM E SI4 160°/2500 m	11.9
			Mean	***11.3***

6.3 Chemical analysis

In the sediment samples from Fram Øst the following parameters are analysed:

- THC
- NPD, PAH, decalins
- Metals (Ba, Cd, Cr, Cu, Hg, Pb and Zn)

Three replicate samples from the top layer, 0-1 cm, are analysed. In addition, samples of the 1-3 cm and 3-6 cm layer are analysed at two stations.

THC

The results from the THC-analysis are shown in Table 6.3.1.

The mean THC concentrations vary from 7.9 mg/kg (FRAM F-E5) to 16.7 mg/kg (FRAM E SI3). The concentration of THC is somewhat lower than what was found at Fram Vest in 2002 (average about 20 mg/kg) and at the reference station (24.8 mg/kg) and regional station TRC99R (24.1 mg/kg) in 2004. No significant difference is found between the 0-1, 1-3 and 3-6 cm layers. The levels of THC are considered as the natural level for this area.

A bar diagram of the THC contents in the sediments is shown in Figure 6.3.1. Representative gas chromatograms are given in Appendix C.

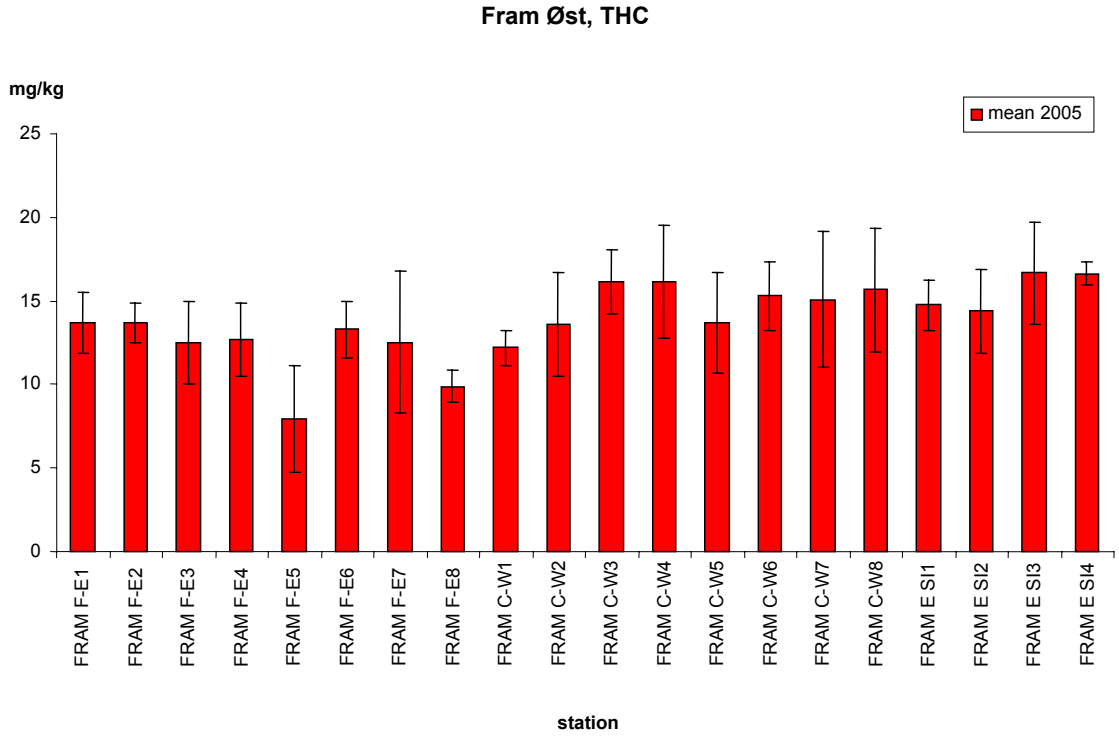


Figure 6.3.1. *Bar diagram of the THC concentrations at Fram Øst 2005.*

Table 6.3.1 *Total hydrocarbon (THC), mg/kg dry sediment, Fram Øst 2005.*

Station		Grab #1	Grab #2	Grab #3	Mean	SD
FRAM F-E1 70°/250 m	0-1 cm	15.5	12.0	13.5	**13.7**	**1.8**
FRAM F-E2 70°/500 m	0-1 cm	14.3	14.5	12.4	**13.7**	**1.2**
FRAM F-E3 160°/250 m	0-1 cm	14.8	12.7	9.9	**12.5**	**2.5**
FRAM F-E4 160°/500 m	0-1 cm	12.8	14.8	10.5	**12.7**	**2.2**
FRAM F-E5 250°/250 m	0-1 cm	11.0	8.2	4.6	**7.9**	**3.2**
FRAM F-E6 250°/500 m	0-1 cm	14.9	13.4	11.5	**13.3**	**1.7**
FRAM F-E7 340°/250 m	0-1 cm	10.4	17.4	9.8	**12.5**	**4.2**
	1-3 cm	18.7				
	3-6 cm	15.6				
FRAM F-E8 340°/500 m	0-1 cm	11.0	9.2	9.4	**9.9**	**1.0**
	1-3 cm	12.4				
	3-6 cm	11.4				
FRAM C-W1 70°/250 m	0-1 cm	11.9	13.4	11.3	**12.2**	**1.1**
FRAM C-W2 70°/500 m	0-1 cm	10.4	13.8	16.6	**13.6**	**3.1**
FRAM C-W3 160°/250 m	0-1 cm	15.8	18.2	14.4	**16.2**	**1.9**
FRAM C-W4 160°/500 m	0-1 cm	17.0	19.0	12.5	**16.2**	**3.3**
FRAM C-W5 250°/250 m	0-1 cm	10.5	16.5	14.0	**13.7**	**3.0**
FRAM C-W6 250°/500 m	0-1 cm	17.7	14.4	13.8	**15.3**	**2.1**
FRAM C-W7 340°/250 m	0-1 cm	14.7	19.3	11.2	**15.1**	**4.1**
FRAM C-W8 340°/500 m	0-1 cm	18.9	11.6	16.6	**15.7**	**3.7**
FRAM E SI1 340°/1500 m	0-1 cm	15.8	15.5	13.0	**14.7**	**1.5**
FRAM E SI2 340°/2500 m	0-1 cm	11.6	15.1	16.5	**14.4**	**2.5**
FRAM E SI3 160°/1500 m	0-1 cm	13.9	16.2	19.9	**16.7**	**3.1**
FRAM E SI4 160°/2500 m	0-1 cm	16.6	17.4	16.0	**16.6**	**0.7**

NPD, PAH and decalins

NPD, PAH and decalins were analyzed for the two downstream stations where samples from different layers were sampled.

The results of the NPD and PAH analyses are shown in Table 6.3.2 and Table 6.3.3. Decalins were not detected. Single compounds are presented in Appendix C.

The concentrations of NPD and PAH are similar to what was found at Fram Vest in 2002 and at the reference and regional station in 2004.

Table 6.3.2. *NPD, mg/kg dry sediment, Fram Øst 2005.*

Station		Grab #1	Grab #2	Grab #3	Mean	SD
FRAM F-E7 340°/250 m	0-1 cm	0.47	0.49	0.46	**0.48**	**0.02**
	1-3 cm	0.53				
	3-6 cm	0.52				
FRAM F-E8 340°/500 m	0-1 cm	0.48	0.48	0.33	**0.43**	**0.08**
	1-3 cm	0.72				
	3-6 cm	0.48				

Table 6.3.3. *PAH, mg/kg dry sediment, Fram Øst 2005.*

Station		Grab #1	Grab #2	Grab #3	Mean	SD
FRAM F-E7 340°/250 m	0-1 cm	0.561	0.546	0.580	**0.562**	**0.017**
	1-3 cm	0.615				
	3-6 cm	0.697				
FRAM F-E8 340°/500 m	0-1 cm	0.454	0.519	0.380	**0.451**	**0.069**
	1-3 cm	0.748				
	3-6 cm	0.686				

Metals

The results are shown in Table 6.3.5. Hg was determined for the two stations where sediments from different layers were sampled.

The concentrations of Ba, Cd, Cr, Cu, Hg, Pb and Zn are generally low and can be considered as the natural background level for the area. A summary of the results is shown in Table 6.3.4. The values are comparable with what was found at Fram Vest in 2002 and at the reference and regional station in 2004.

A bar diagram of the Ba concentrations is shown in Figure 6.3.2. The average Ba concentration is 347 mg/kg and one station (FRAM E SI3) differs somewhat from the others with a concentration of 569 mg/kg. This is in the same range as the higher concentrations found at Fram Vest in 2002, where it was concluded that some stations had elevated concentrations of Ba that might be caused by pollution from drilling activity. Fram Øst is located in an area where the seabed is flat, but with hollows up to 100 m in diameter and 8-10 m deep. The station with elevated Ba-concentration is the deepest station in this survey (366m) whereas the other stations range from 354-361 m. If the station is located in a hollow, then the elevated Ba-concentration might be influenced of Ba from drilling activity in the region.

The average Ba concentration is similar to what was found at the reference station in 2004 (364 mg/kg).

The concentration of metals does not change downwards in the layers.

Table 6.3.4. *Concentration range, mean and SD, metals 0-1 cm, mg/kg dry sediment, Fram Øst 2005.*

Element	Min.		Max.	Mean	SD
Ba	213	-	569	347	75
Cd		-	0.12	0.11	0.01
Cr	38	-	47	17.6	1.4
Cu	15.8	-	20.4	44.6	1.9
Hg	0.05	-	0.07	0.06	-
Pb	33	-	57	50.8	5.1
Zn	89	-	128	96.4	8.0

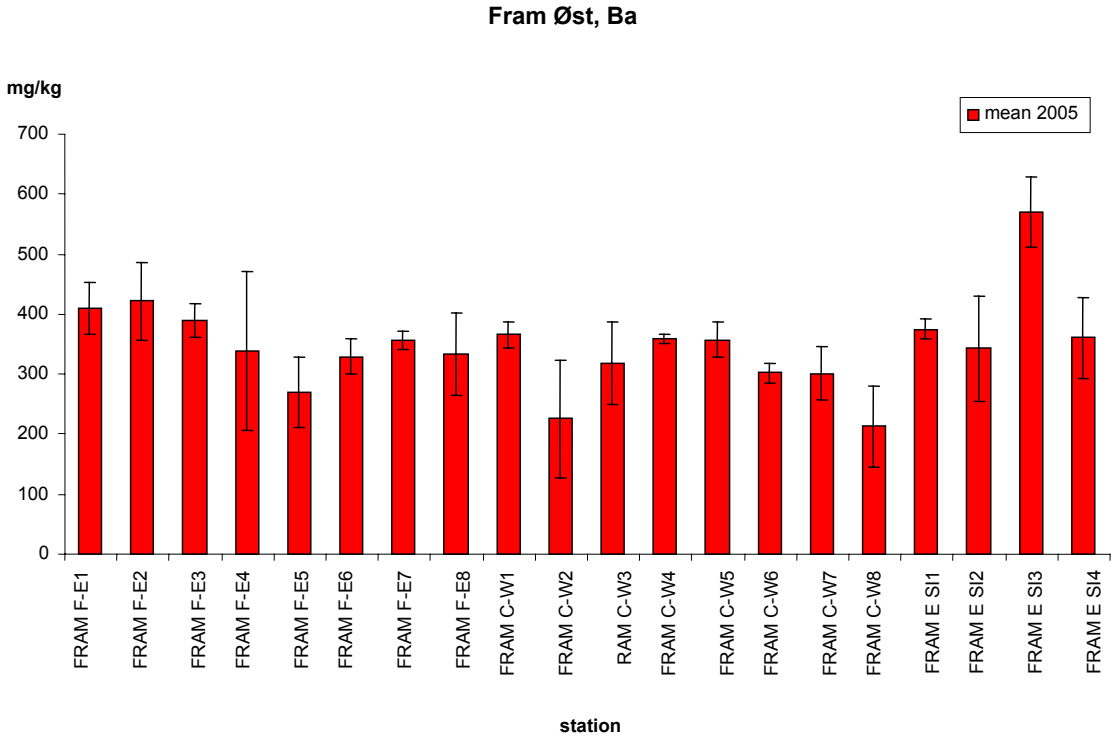


Figure 6.3.2. *Bar diagram of the Ba concentration at Fram Øst 2005.*

Table 6.3.5. *Metals, mg/kg dry sediment, Fram Øst 2005.*

Station	Sample	Ba	Cd	Cr	Cu	Hg	Pb	Zn
FRAM F-E1	1	437	0.12	43.4	18.1		56.8	92.7
70°/250 m	2	360	0.11	45.1	18.3		52.5	94.7
	3	434	0.10	46.9	18.4		58.7	101
	mean	**410**	**0.11**	**45.2**	**18.3**		**56.0**	**96.1**
	SD	**44**	**0.01**	**1.8**	**0.1**		**3.2**	**4.3**
FRAM F-E2	1	414	0.12	44.1	17.5		51.1	94.3
70°/500 m	2	490	0.13	45.7	17.9		53.8	95.6
	3	360	0.09	47.0	18.0		53.5	97.5
	mean	**421**	**0.11**	**45.6**	**17.8**		**52.8**	**95.8**
	SD	**66**	**0.02**	**1.4**	**0.3**		**1.4**	**1.6**
FRAM F-E3	1	378	0.13	45.4	17.4		51.7	94.1
160°/250 m	2	420	0.10	45.0	18.3		51.5	99.5
	3	367	0.11	45.6	18.8		51.0	94.7
	mean	**389**	**0.11**	**45.4**	**18.2**		**51.4**	**96.1**
	SD	**28**	**0.02**	**0.3**	**0.7**		**0.4**	**3.0**
FRAM F-E4	1	187	0.10	48.0	19.0		55.9	98.7
160°/500 m	2	394	0.12	44.1	18.2		49.0	94.0
	3	433	0.12	45.6	20.6		54.5	98.0
	mean	**338**	**0.11**	**45.9**	**19.2**		**53.1**	**96.9**
	SD	**133**	**0.01**	**1.9**	**1.3**		**3.7**	**2.5**

Cont.

Table 6.3.5 *cont.*

FRAM F-E5	1	338	0.13	44.7	18.3		48.3	95.1
250°/250 m	2	239	0.13	40.9	16.5		33.7	88.7
	3	235	0.06	27.1	13.1		16.2	84.4
	mean	**271**	**0.11**	**37.6**	**15.9**		**32.7**	**89.4**
	SD	**59**	**0.04**	**9.3**	**2.6**		**16.1**	**5.4**
FRAM F-E6	1	322	0.12	44.4	18.2		52.8	94.4
250°/500 m	2	361	0.10	45.2	19.1		52.5	96.3
	3	305	0.12	45.1	18.9		51.5	93.1
	mean	**329**	**0.11**	**44.9**	**18.8**		**52.3**	**94.6**
	SD	**29**	**0.01**	**0.4**	**0.5**		**0.7**	**1.6**
FRAM F-E7	1	349	0.10	44.8	18.6	0.07	52.3	95.6
340°/250 m	2	373	0.10	45.8	18.9	0.08	52.1	97.2
	3	347	0.10	44.1	19.5	0.06	48.9	98.3
	mean	**357**	**0.10**	**44.9**	**19.0**	**0.07**	**51.1**	**97.0**
	SD	**15**	**0.00**	**0.9**	**0.4**	**0.01**	**1.9**	**1.3**
1-3 cm	1	357	0.12	44.6	18.4	0.05	50.3	95.7
3-6 cm	1	332	0.09	48.3	17.8	0.06	56.5	102
FRAM F-E8	1	359	0.10	45.2	18.6	0.06	53.5	96.5
340°/500 m	2	255	0.11	43.5	17.3	0.05	39.3	92.5
	3	387	0.12	45.3	18.9	0.05	50.6	99.9
	Mean	**334**	**0.11**	**44.7**	**18.3**	**0.05**	**47.8**	**96.3**
	SD	**70**	**0.01**	**1.0**	**0.9**	**0.01**	**7.5**	**3.7**
1-3 cm	1	305	0.09	46.8	18.3	0.06	56.0	98.7
3-6 cm	1	176	0.13	46.9	19.4	0.06	57.8	106
FRAM C-W1	1	390	0.13	44.7	19.0		55.6	97.0
70°/250 m	2	347	0.13	45.7	18.4		54.0	98.1
	3	361	0.11	44.7	18.7		55.0	95.6
	Mean	**366**	**0.12**	**45.0**	**18.7**		**54.9**	**96.9**
	SD	**22**	**0.01**	**0.5**	**0.3**		**0.8**	**1.3**
FRAM C-W2	1	113	0.13	47.1	19.0		54.9	188
70°/500 m	2	292	0.09	46.2	18.8		56.1	97.3
	3	271	0.09	45.9	18.4		55.6	98.6
	Mean	**225**	**0.10**	**46.4**	**18.7**		**55.6**	**128**
	SD	**98**	**0.02**	**0.6**	**0.3**		**0.6**	**52.0**
FRAM C-W3	1	351	0.11	42.1	17.9		51.0	90.6
160°/250 m	2	365	0.11	43.5	19.1		54.6	94.7
	3	240	0.11	45.8	18.6		54.8	95.8
	mean	**319**	**0.11**	**43.8**	**18.5**		**53.4**	**93.7**
	SD	**68**	**0.00**	**1.8**	**0.6**		**2.1**	**2.7**
FRAM C-W4	1	368	0.14	44.9	22.0		55.4	96.5
160°/500 m	2	358	0.09	45.5	19.4		57.8	99.6
	3	353	0.10	45.5	19.8		58.0	97.2
	mean	**360**	**0.11**	**45.3**	**20.4**		**57.1**	**97.8**
	SD	**8**	**0.03**	**0.3**	**1.4**		**1.4**	**1.6**
FRAM C-W5	1	324	0.12	44.3	18.1		50.2	97.0
250°/250 m	2	366	0.14	41.7	15.8		45.9	87.1
	3	380	0.10	44.9	16.0		51.8	94.5
	mean	**357**	**0.12**	**43.6**	**16.6**		**49.3**	**92.9**
	SD	**29**	**0.02**	**1.7**	**1.3**		**3.0**	**5.2**

Cont.

Table 6.3.5 *cont.*

FRAM C-W6	1	285	0.09	45.3	15.7	51.3	93.8
250°/500 m	2	319	0.13	44.2	15.8	46.0	90.7
	3	302	0.11	45.1	15.7	46.8	92.4
	mean	**302**	**0.11**	**44.9**	**15.8**	**48.0**	**92.3**
	SD	**17**	**0.02**	**0.6**	**0.1**	**2.9**	**1.6**
FRAM C-W7	1	315	0.12	46.6	15.5	52.6	97.6
340°/250 m	2	338	0.09	43.1	16.3	49.2	90.9
	3	251	0.09	44.8	16.0	52.9	94.5
	mean	**301**	**0.10**	**44.9**	**15.9**	**51.6**	**94.4**
	SD	**45**	**0.02**	**1.7**	**0.4**	**2.0**	**3.3**
FRAM C-W8	1	284	0.08	47.8	15.8	54.7	101
340°/500 m	2	205	0.09	46.4	16.2	51.0	104
	3	151	0.10	47.0	17.4	52.6	103
	mean	**213**	**0.09**	**47.1**	**16.4**	**52.8**	**103**
	SD	**67**	**0.01**	**0.7**	**0.8**	**1.8**	**2**
FRAM E SI1	1	385	0.11	45.5	15.8	52.8	95.6
340°/1500 m	2	384	0.12	44.2	16.6	50.0	91.3
	3	356	0.11	43.6	15.3	49.1	89.8
	mean	**375**	**0.12**	**44.4**	**15.9**	**50.6**	**92.2**
	SD	**17**	**0.00**	**0.9**	**0.7**	**1.9**	**3.0**
FRAM E SI2	1	242	0.11	45.6	15.6	47.1	90.3
340°/2500 m	2	406	0.12	43.6	16.3	50.5	91.6
	3	380	0.10	44.4	16.6	50.3	91.8
	mean	**343**	**0.11**	**44.5**	**16.2**	**49.3**	**91.3**
	SD	**88**	**0.00**	**0.9**	**0.7**	**1.9**	**0.8**
FRAM E SI3	1	560	0.11	41.3	16.4	46.9	86.3
160°/1500 m	2	516	0.10	44.4	16.6	50.4	92.7
	3	631	0.10	44.6	16.7	49.1	99.0
	mean	**569**	**0.10**	**43.5**	**16.6**	**48.8**	**92.7**
	SD	**58**	**0.01**	**1.9**	**0.2**	**1.8**	**6.3**
FRAM E SI4	1	379	0.12	42.1	16.6	47.0	89.6
160°/2500 m	2	285	0.11	44.0	15.8	45.6	88.5
	3	417	0.12	44.9	16.9	50.8	94.2
	mean	**360**	**0.11**	**43.7**	**16.4**	**7.8**	**90.8**
	SD	**68**	**0.01**	**1.5**	**0.5**	**2.7**	**3.0**

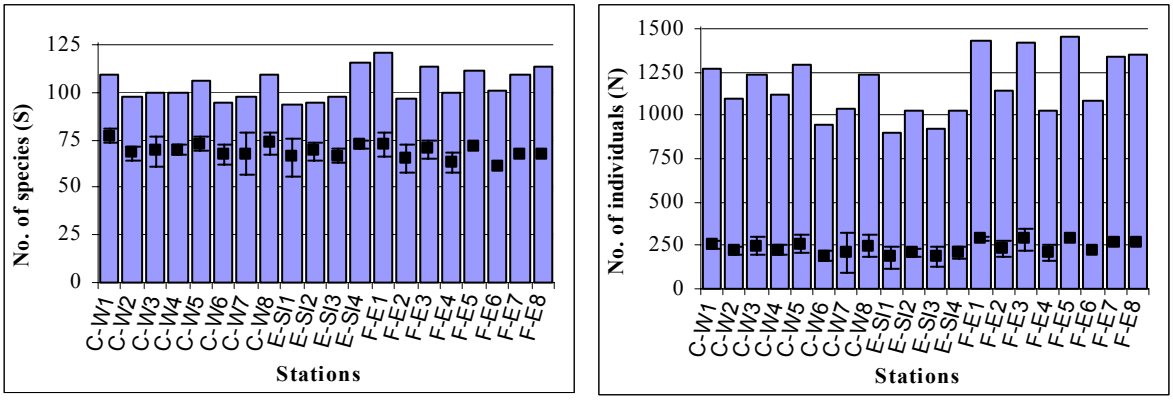
6.4 Biological analyses

A total of 252 species and 23339 individuals were sampled at 20 stations. Greatest abundance was found among the polychaetes (71.2 %) followed by the mollusca which constitute 16.5 %. The echinodermata constitute only 2.1 % of the total number of individuals, see Table 6.3.6. A complete species list is enclosed in the DNV Test Report, Appendix B.

Table 6.3.6. *Number of species and individuals distributed between the main groups, Fram Øst 2005.*

Main animal groups	**Individuals**		**Species**	
	Number	%		Number
Varia	1012	4.3	16	6.3
Polychaeta	16610	71.2	105	41.7
Crustacea	1377	5.9	63	25.0
Mollusca	3861	16.5	51	20.2
Echinodermata	479	2.1	17	6.7
Total	23339	100.0	252	100.0

Figure 6.4.1 shows the numbers of species and individuals sampled at each station and variations between grab samples.



Station	°/m	Station	°/m	Station	°/m	Station	°/m
FRAM C-W1	70/250	FRAM C-W6	250/500	FRAM E-SI3	160/1500	FRAM F-E4	160/500
FRAM C-W2	70/500	FRAM C-W7	340/250	FRAM E-SI4	160/2500	FRAM F-E5	250/250
FRAM C-W3	160/250	FRAM C-W8	340/500	FRAM F-E1	70/250	FRAM F-E6	250/500
FRAM C-W4	160/500	FRAM E-SI1	340/1500	FRAM F-E2	70/500	FRAM F-E7	340/250
FRAM C-W5	250/250	FRAM E-SI2	340/2500	FRAM F-E3	160/250	FRAM F-E8	340/500

Figure 6.4.1. *Numbers of species (S) and individuals (N) per 0.5 m^2, mean values per grab sample and standard deviation, Fram Øst 2005. The prefix "Fram" is excluded from the station names in the figures.*

Diversity and dominant species

The dominant species at each station varied from 7.3 % at FRAM F-E5 (250°/250m) to 10.3 % at FRAM F-E3 (160°/250m). The 10 most abundant species made up from 48.0 % at FRAM C-W8 (340°/500m) to 54.7 % at FRAM E-SI3 (160°/1500m), see Table 6.4.1. Frequently found species were the bristle worms *Heteromastus filiformis, Capitellidae* indet, *Lumbrineridae* indet, *Spiophanes kroyeri* and *Trichobranchidae* indet. The bivalve *Thyasira ferruginea* is also one of the more dominating species. The dominating fauna at Fram is a mix of both carnivore- deposit- and suspension feeders. This is typical for undisturbed sediment dominated by silt and clay.

Table 6.4.1. *The 10 most abundant species at each station, Fram Øst 2005.*

10 most dominating species from each station							
FRAM C-W1	**No.**	**%**	**Cum. %**	**FRAM C-W2**	**No.**	**%**	**Cum. %**
Lumbrineridae indet.	105	8.3	8.3	Capitellidae indet.	87	8.0	8.0
Capitellidae indet.	83	6.5	14.8	Lumbrineridae indet.	82	7.5	15.5
Heteromastus filiformis	81	6.4	21.2	Spiophanes kroyeri	73	6.7	22.2
Trichobranchidae indet.	67	5.3	26.4	Thyasira ferruginea	66	6.0	28.2
Spiophanes kroyeri	62	4.9	31.3	Heteromastus filiformis	62	5.7	33.9
Thyasira ferruginea	54	4.3	35.6	Thyasira eumyaria	57	5.2	39.1
Thyasira eumyaria	51	4.0	39.6	Paramphinome jeffreysii	47	4.3	43.4
Paramphinome jeffreysii	48	3.8	43.4	Kelliella miliaris	40	3.7	47.1
Kelliella miliaris	48	3.8	47.1	Paradiopatra quadricuspis	33	3.0	50.1
Terebellides stroemi	44	3.5	50.6	Levinsenia gracilis	32	2.9	53.0

Cont.

Table 6.4.1. *cont.*

FRAM C-W3	No.	%	Cum. %	FRAM C-W4	No.	%	Cum. %
Lumbrineridae indet.	105	8.5	8.5	Heteromastus filiformis	96	8.6	8.6
Heteromastus filiformis	83	6.7	15.3	Lumbrineridae indet.	93	8.3	16.9
Spiophanes kroyeri	82	6.7	21.9	Spiophanes kroyeri	85	7.6	24.5
Trichobranchidae indet.	65	5.3	27.2	Capitellidae indet.	63	5.6	30.1
Thyasira ferruginea	62	5.0	32.2	Thyasira ferruginea	60	5.4	35.5
Capitellidae indet.	51	4.1	36.4	Terebellides stroemi	49	4.4	39.8
Aphelochaeta sp.	44	3.6	39.9	Aphelochaeta sp.	39	3.5	43.3
Thyasira eumyaria	43	3.5	43.4	Thyasira eumyaria	38	3.4	46.7
Protodorvillea kefersteini	38	3.1	46.5	Kelliella miliaris	37	3.3	50.0
Clymenura borealis	38	3.1	49.6	Paradiopatra quadricuspis	36	3.2	53.2
FRAM C-W5	**No.**	**%**	**Cum. %**	**FRAM C-W6**	**No.**	**%**	**Cum. %**
Heteromastus filiformis	129	10.0	10.0	Heteromastus filiformis	91	9.6	9.6
Lumbrineridae indet.	121	9.4	19.4	Spiophanes kroyeri	66	7.0	16.6
Spiophanes kroyeri	85	6.6	26.0	Thyasira ferruginea	65	6.9	23.5
Capitellidae indet.	83	6.4	32.4	Capitellidae indet.	57	6.0	29.6
Thyasira ferruginea	61	4.7	37.1	Lumbrineridae indet.	57	6.0	35.6
Trichobranchidae indet.	52	4.0	41.1	Paramphinome jeffreysii	43	4.6	40.2
Chaetozone sp. I	40	3.1	44.2	Kelliella miliaris	42	4.5	44.6
Aphelochaeta sp.	40	3.1	47.3	Thyasira eumyaria	33	3.5	48.1
Levinsenia gracilis	39	3.0	50.4	Paradiopatra quadricuspis	32	3.4	51.5
Terebellides stroemi	33	2.6	52.9	Amphilepis norvegica	29	3.1	54.6
FRAM C-W7	**No.**	**%**	**Cum. %**	**FRAM C-W8**	**No.**	**%**	**Cum. %**
Lumbrineridae indet.	100	9.6	9.6	Capitellidae indet.	91	7.4	7.4
Capitellidae indet.	65	6.3	15.9	Lumbrineridae indet.	87	7.0	14.4
Heteromastus filiformis	63	6.1	22.0	Heteromastus filiformis	84	6.8	21.2
Trichobranchidae indet.	53	5.1	27.1	Trichobranchidae indet.	80	6.5	27.7
Spiophanes kroyeri	51	4.9	32.0	Spiophanes kroyeri	58	4.7	32.4
Thyasira ferruginea	49	4.7	36.7	Terebellides stroemi	45	3.6	36.0
Terebellides stroemi	41	4.0	40.7	Paramphinome jeffreysii	40	3.2	39.3
Nemertea spp.	41	4.0	44.7	Levinsenia gracilis	37	3.0	42.3
Kelliella miliaris	34	3.3	47.9	Aphelochaeta sp.	36	2.9	45.2
Paramphinome jeffreysii	34	3.3	51.2	Nemertea spp.	35	2.8	48.0
FRAM E-SI1	**No.**	**%**	**Cum. %**	**FRAM E-SI2**	**No.**	**%**	**Cum. %**
Lumbrineridae indet.	85	9.5	9.5	Lumbrineridae indet.	98	9.6	9.6
Golfingia sp.	54	6.0	15.5	Capitellidae indet.	58	5.7	15.2
Spiophanes kroyeri	54	6.0	21.5	Spiophanes kroyeri	58	5.7	20.9
Heteromastus filiformis	52	5.8	27.3	Thyasira ferruginea	50	4.9	25.8
Thyasira granulosa	41	4.6	31.9	Sphyrapus anomalus	49	4.8	30.5
Kelliella miliaris	41	4.6	36.5	Thyasira eumyaria	49	4.8	35.3
Capitellidae indet.	41	4.6	41.1	Heteromastus filiformis	46	4.5	39.8
Levinsenia gracilis	28	3.1	44.2	Paradiopatra quadricuspis	45	4.4	44.2
Aphelochaeta sp.	28	3.1	47.3	Terebellides stroemi	43	4.2	48.4
Terebellides stroemi	27.00	3.0	50.3	Aphelochaeta sp.	36.00	3.5	51.9

Cont.

Table 6.4.1. *cont.*

FRAM E-SI3	No.	%	Cum. %	FRAM E-SI4	No.	%	Cum. %
Heteromastus filiformis	89	9.7	9.7	Lumbrineridae indet.	78	7.6	7.6
Spiophanes kroyeri	63	6.8	16.5	Capitellidae indet.	75	7.3	14.8
Lumbrineridae indet.	59	6.4	22.9	Spiophanes kroyeri	68	6.6	21.4
Capitellidae indet.	55	6.0	28.9	Heteromastus filiformis	54	5.2	26.7
Thyasira ferruginea	50	5.4	34.3	Trichobranchidae indet.	47	4.6	31.2
Paramphinome jeffreysii	48	5.2	39.5	Kelliella miliaris	43	4.2	35.4
Terebellides stroemi	43	4.7	44.2	Terebellides stroemi	38	3.7	39.1
Thyasira eumyaria	39	4.2	48.4	Thyasira ferruginea	38	3.7	42.8
Trichobranchidae indet.	30	3.3	51.7	Paradiopatra quadricuspis	37	3.6	46.4
Paradiopatra quadricuspis	28.00	3.0	54.7	Thyasira eumyaria	30.00	2.9	49.3
FRAM F-E1	**No.**	**%**	**Cum. %**	**FRAM F-E2**	**No.**	**%**	**Cum. %**
Lumbrineridae indet.	126	8.8	8.8	Lumbrineridae indet.	95	8.3	8.3
Heteromastus filiformis	120	8.4	17.2	Spiophanes kroyeri	78	6.8	15.2
Capitellidae indet.	98	6.9	24.0	Capitellidae indet.	76	6.7	21.8
Spiophanes kroyeri	83	5.8	29.8	Heteromastus filiformis	70	6.1	28.0
Trichobranchidae indet.	58	4.1	33.9	Thyasira ferruginea	58	5.1	33.0
Chaetozone sp. I	46	3.2	37.1	Thyasira eumyaria	49	4.3	37.3
Aphelochaeta sp.	44	3.1	40.2	Paramphinome jeffreysii	45	3.9	41.3
Thyasira ferruginea	44	3.1	43.3	Aphelochaeta sp.	38	3.3	44.6
Terebellides stroemi	41	2.9	46.1	Paradiopatra quadricuspis	37	3.2	47.9
Paramphinome jeffreysii	39.00	2.7	48.9	Protodorvillea kefersteini	33.00	2.9	50.7
FRAM F-E3	**No.**	**%**	**Cum. %**	**FRAM F-E4**	**No.**	**%**	**Cum. %**
Lumbrineridae indet.	146	10.3	10.3	Lumbrineridae indet.	103	10.0	10.0
Spiophanes kroyeri	97	6.9	17.2	Heteromastus filiformis	83	8.1	18.1
Capitellidae indet.	94	6.6	23.8	Capitellidae indet.	75	7.3	25.4
Heteromastus filiformis	91	6.4	30.2	Spiophanes kroyeri	54	5.3	30.6
Trichobranchidae indet.	75	5.3	35.5	Thyasira eumyaria	39	3.8	34.4
Thyasira ferruginea	63	4.5	39.9	Levinsenia gracilis	36	3.5	37.9
Terebellides stroemi	56	4.0	43.9	Terebellides stroemi	34	3.3	41.3
Paramphinome jeffreysii	51	3.6	47.5	Paradiopatra quadricuspis	33	3.2	44.5
Thyasira eumyaria	40	2.8	50.3	Chaetozone sp. I	32	3.1	47.6
Chaetozone sp. I	38	2.7	53.0	Paramphinome jeffreysii	30	2.9	50.5
FRAM F-E5	**No.**	**%**	**Cum. %**	**FRAM F-E6**	**No.**	**%**	**Cum. %**
Capitellidae indet.	106	7.3	7.3	Lumbrineridae indet.	98	9.0	9.0
Spiophanes kroyeri	100	6.9	14.2	Heteromastus filiformis	73	6.7	15.7
Lumbrineridae indet.	97	6.7	20.9	Capitellidae indet.	67	6.2	21.9
Thyasira ferruginea	93	6.4	27.4	Sphyrapus anomalus	53	4.9	26.7
Heteromastus filiformis	75	5.2	32.5	Trichobranchidae indet.	49	4.5	31.2
Terebellides stroemi	69	4.8	37.3	Thyasira ferruginea	47	4.3	35.5
Levinsenia gracilis	47	3.3	40.5	Spiophanes kroyeri	45	4.1	39.7
Paradiopatra quadricuspis	42	2.9	43.4	Terebellides stroemi	41	3.8	43.4
Aphelochaeta sp.	41	2.8	46.3	Thyasira eumyaria	41	3.8	47.2
Paramphinome jeffreysii	39	2.7	49.0	Paramphinome jeffreysii	36	3.3	50.5

Cont.

Table 6.4.1. *cont.*

FRAM F-E7	No.	%	Cum. %	FRAM F-E8	No.	%	Cum. %
Lumbrineridae indet.	116	8.7	8.7	Capitellidae indet.	134	9.9	9.9
Trichobranchidae indet.	93	6.9	15.6	Lumbrineridae indet.	116	8.6	18.5
Heteromastus filiformis	81	6.0	21.6	Heteromastus filiformis	83	6.2	24.7
Spiophanes kroyeri	81	6.0	27.7	Paramphinome jeffreysii	70	5.2	29.9
Capitellidae indet.	77	5.8	33.4	Thyasira ferruginea	61	4.5	34.4
Thyasira ferruginea	72	5.4	38.8	Trichobranchidae indet.	61	4.5	38.9
Terebellides stroemi	51	3.8	42.6	Thyasira eumyaria	51	3.8	42.7
Protodorvillea kefersteini	43	3.2	45.8	Spiophanes kroyeri	49	3.6	46.3
Exogone sp.	42	3.1	49.0	Terebellides stroemi	47	3.5	49.8
Levinsenia gracilis	41	3.1	52.0	Kelliella miliaris	43	3.2	53.0

The numbers of species varied from 93 at FRAM E-SI1 (340°/1500m) to 121 at FRAM F-E1 (70°/250m), see Table 6.4.2. The numbers of individuals were ranging from 921 at FRAM E-SI3 (160°/1500m) to 1448 at FRAM F-E5 (250°/250m). The Shannon Wiener diversity indices were above 5 at all stations, ranging from 5.3 at FRAM C-W6 (250°/500m) to 5.6 at FRAM E-SI4 (160°/2500m) and FRAM F-E1. The Hurlberts indices (ES_{100}) ranged from 39 at FRAM C-W6, FRAM E-SI3 and FRAM F-E7 (340°/250m) to 43 at FRAM E-SI4 (160°/2500m). All indices reveal an undisturbed fauna community.

Table 6.4.2 *Numbers of individuals (N) and species (S), depth, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), and expected number of species per 100 individuals (ES_{100}) for each station at Fram Øst 2005.*

Station	Direction °	Distance m	Depth	S	N	H'	J	ES_{100}
FRAM C-W1	70	250	358	109	1271	5.5	0.8	41
FRAM C-W2	70	500	357	98	1092	5.4	0.8	40
FRAM C-W3	160	250	356	100	1232	5.5	0.8	40
FRAM C-W4	160	500	357	100	1120	5.4	0.8	40
FRAM C-W5	250	250	355	106	1291	5.4	0.8	40
FRAM C-W6	250	500	354	94	944	5.3	0.8	39
FRAM C-W7	340	250	360	98	1037	5.4	0.8	40
FRAM C-W8	340	500	359	109	1235	5.5	0.8	41
FRAM E-SI1	340	1500	360	93	896	5.5	0.8	41
FRAM E-SI2	340	2500	366	94	1025	5.4	0.8	40
FRAM E-SI3	160	1500	358	98	921	5.4	0.8	39
FRAM E-SI4	160	2500	358	116	1031	5.6	0.8	43
FRAM F-E1	70	250	358	121	1431	5.6	0.8	42
FRAM F-E2	70	500	358	97	1141	5.4	0.8	40
FRAM F-E3	160	250	360	113	1417	5.4	0.8	40
FRAM F-E4	160	500	358	100	1028	5.5	0.8	42
FRAM F-E5	250	250	360	111	1448	5.5	0.8	42
FRAM F-E6	250	500	361	101	1089	5.4	0.8	40
FRAM F-E7	340	250	361	109	1340	5.4	0.8	39
FRAM F-E8	340	500	360	113	1350	5.4	0.8	40

Classification and ordination

The dendrogram from the cluster analysis and the MDS plot from the ordination analysis at station level are presented in Figure 6.4.2 and Figure 6.4.3. The similarity between the stations is > 70 %. However, FRAM E-SI1 (340º/1500m) and FRAM F-E5 (250º/250m) differ somewhat from the other stations. The two stations where the only stations with some gravel in the sediment.

The similarity analysis reveals that FRAM E-SI1 (340º/1500m) and FRAM F-E5 (250º/250m) deviates from the other stations mainly because of a higher numbers of the bristle worm *P. cirrifera* and the mussel *Thyasira ferruginea* compared to the other stations. Station FRAM E SI1 differs with a higher number of the mussel *Thyasira granulosa* and the sipunculus *Golfingia* sp. compared to the other station. Common species in the fauna at the other stations are amongst other bristle worms of the *Lumbrineridae* species, *Heteromastus filiformis*, *Capitellidae* indet, *Spiophanes kroyeri, Terebellides stroemi* and *P. jeffreysii*. A good mix of carnivore-, deposit- and suspension feeders in the fauna composition is typical for undisturbed and fine grained sediment.

The Bioenv analyses gave little correlation between the fauna and the abiotic parameters.

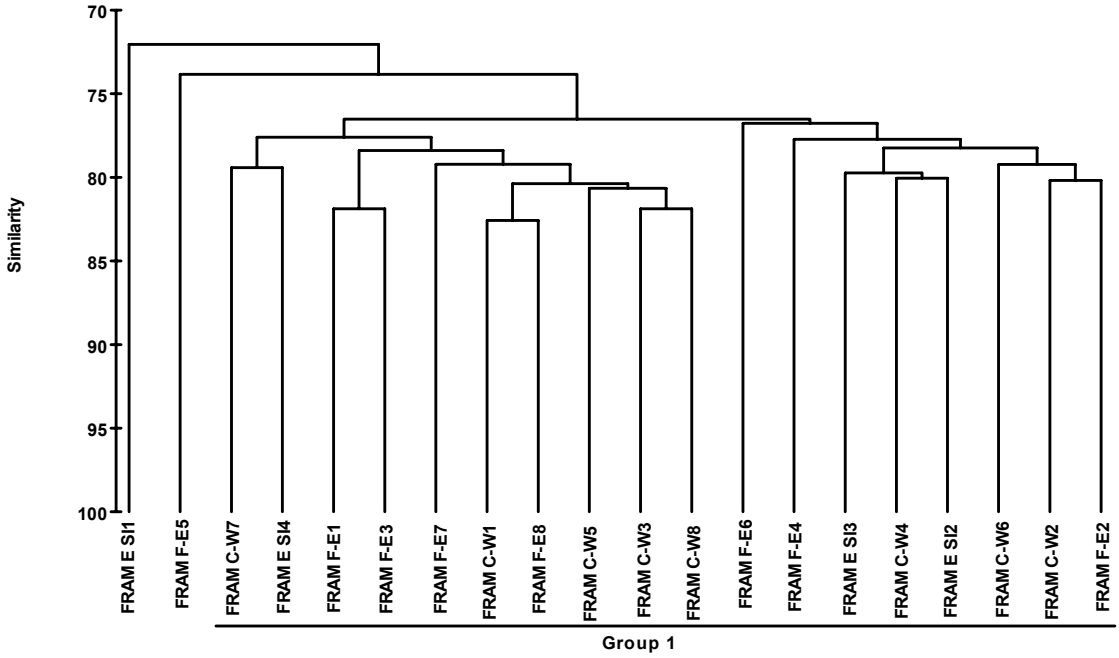


Figure 6.4.2. *Dendrogram of stations from Fram Øst 2005.*

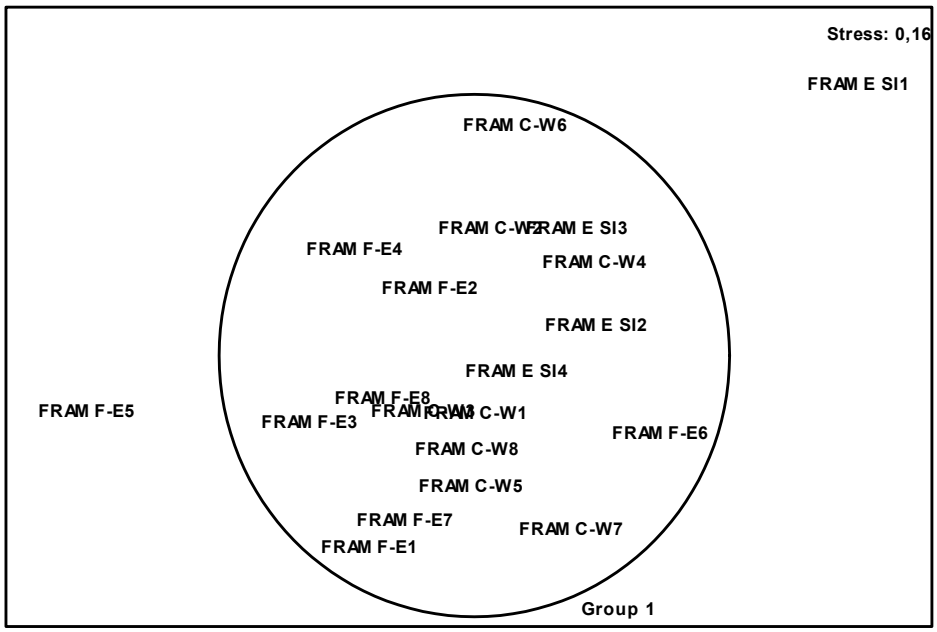


Figure 6.4.3. *MDS plot of stations from Fram Øst 2005.*

6.5 Conclusions

The sediments at Fram Øst are dominated by silt and clay (average median particle diameter 5.97). The content of gravel and sand is low (making up less than 2 % of the weight), except for at one station (FRAM F-E5) where the contents were 1.3 % gravel and 11.3 % sand. This station has a median particle diameter of 5.71.

The contents of organic matter are high and range between 9.2 and 12.3 %. The average content of organic matter is 11.3 %.

One station has an elevated concentration of Ba. Apart from this station, the survey shows that the stations sampled are not influenced by pollution of hydrocarbons, barium or heavy metals.

The concentrations of hydrocarbons (THC) vary from 7.9 mg/kg to 16.7 mg/kg. The concentrations of NPD and PAH are low (highest values are 0.47 and 0.56 mg/kg respectively), and decalins are not detected.

The mean concentrations of barium range from 213 to 569 mg/kg, and the average for all stations is 347 mg/kg.

The results from this survey are comparable to what was found at Fram Vest in 2002 and at the reference station, FRAM A2-7 REF, in 2004.

The fauna community at Fram Øst reveals high biodiversity indices and is characterised as undisturbed. The stations FRAM E-SI1 (340º/1500m) and FRAM F-E5 (250º/250m) deviate somewhat from the other stations at Fram Øst.

7.0 References

Bray, J.R. & J.T. Curtis 1957: An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

Buchanan, J.B., 1984. Sediment analysis. In: Holme, N.S. & A.D. McIntyre (Eds.) *"Methods for the study of marine benthos"*. Second edition. IBP Handbook 16. Blackwell Scientific Publications. Oxford, U.K. pp. 41-65.

Eriksen, V., Tvedten, Ø. and Westerlund, S. (2003), *"Grunnlagsundersøkelse av miljøforholdene ved Fram Vest i 2002"*, Rapport RF – 2003/083.

"Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry", Anal.chem. 52 (1980) p. 2242-2249

Kruskal, J.B. & M. Wish. 1978: Multidimensional scaling. Sage Publishers. California. p. 93.

Lance, G. N. & W.T. Williams, 1967: A general theory of classificatory sorting strategies. II. Clustering systems. -Computer Jour. 10: 271-277.

Mannvik, H.-P., Pettersen, A. and Oug, E. (2005), *"Miljøundersøkelse i Region III, 2004"*, APN-411.3095-1.

Leif Ongstad 2004. Konsekvensutredning Fram Øst, 09.12.2004. NH 832787.

Pielou, E.C., 1969: An introduction to mathematical ecology. Wiley-Interscience, New York.

Ptil (Petroleumsdirektoratet), SFT (Statens Forurensningstilsyn) og Shdir (Sosial- og helsedirektoratet) 2001: FOR 2001-09-03 nr 1157: Forskrift om utføring av aktiviteter i petroleumssektoren (Aktivitetsforskriftene § 52). Forskrift av 3. september 2001. Vedlegg 1 Krav til miljøovervåking av petroleumsvirksomheten på norsk kontinentalsokkel, teknisk vedlegg 2 Sedimentovervåking, http://www.npd.no/regelverk/r2002/Aktivitetsforskriften_n.htm#v1.

Shannon, C.E. & Weaver, W.W. 1963: The mathematical theory of communities. University of Illinois Press. Urbana, Illinois. p. 117.

SFT, 2001. FOR 2001-09-03 nr 1157: Forskrift om utføring av aktiviteter i petroleumsvirksomheten (aktivitetsforskriften). http://www.lovdata.no/for/sf/as/xs-20010903-1157.html (2006-01-18).

Shepard, R.N., 1962. The analysis of proximities: multidimensional scaling with an unknown distance function. Psychometrika 27, 219–246.

APPENDIX

A
Extract from the survey report

O:\635upstream\projects\2005\66110757
Ekofisk\Rapportering\Fram\Appendiks\
Appendix A - Utdrag av toktrapport

- Utdrag toktrapport Ekofisk 2005, rev.2.doc
- App. 1 toktrapp.xls

APPENDIX

B

DNV Test Report (Biology)

O:\635upstream\projects\2005\66110757 Ekofisk\Rapportering\Fram\Appendiks\Appendix B - DNV Prøvingsrapport (biologi)

- Prøvingsrapport Vilje og Fram øst 2005.doc
- Appendix A artslister prøvingsrapport vilje og Fram Øst.xls
- Appendix B prøvingsrapport Vilje og Fram Øst 2005.xls

APPENDIX

C
Analyses Report (Chemistry)

O:\635upstream\projects\2005\66110757 Ekofisk\Rapportering\Fram\Appendiks\Appendix C - Analyserapport – Kjemi\ 22450 Environmental baseline survey Fram Øst 2005-appendix.doc

APPENDIX

D

Statistical analyses

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APPENDIX

E

Sampling and analysing programme

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APPENDIX

F

Fold our map of the stations at Fram Øst

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