Chemical sediment variables from the Faroe area: Organic content, Nitrogen, Phosphorus, Zinc, and Copper

Evnafrøðiligar bleytbotnsdátur á føroyskum havøki: lívrunnið tilfar, nitrogen, fosfor, sink og kopar

Jan Sørensen, Jákup K. Bærentsen, Jógvan F. Hansen, Ámundur Nolsø og Birna V. Trygvadóttir

Kaldbak Marine Biological Laboratory, Mjólkargøta, FO-180 Kaldbak, Faroe Islands.
Phone +298 736060, Fax +298 736061, e-mail: Jan@havbotnur.fo, Jakup@havbotnur.fo, JFH@havbotnur.fo, Amundur@havbotnur.fo, Birna@havbotnur.fo.

Úrtak

Havlívfrøðiliga royndarstøðin hevur síðan 1998 gjørt regluligar kanningar av botnsigi í føroyskum firðum. Kanningarnar fevndu um fylgjandi evnafrøðiligu brigdlar: nøgd av lívrunnum tilfari (gløðitap), sinki, kopari og heildarnøgd av køvievni og fosfori. Greinin viðger broytni av hesum og fevnir um 229 staksýni.

Í hesi grein eru eisini savnað úrslit, sum onnur hava almannakunngjørt um somu evnafrøðiligu broytlar.

Úrslitini eru bólkað eftir dýpi og eftir hvørjum slagi av botnsigi, ið tað snýr seg um. Eisini verður hugt eftir, hvussu virðini eru inni við land og borið verður saman við, hvussu tað er útiá.

Inni við land var nøgdin av lívrunnum tilfari, nitrogeni, fosfori, sinki og kopari í botnsiginum ávikavist: 0,5-13,0 %, 0,14-4,01 g/kg, 0,43-2,02 g/kg, 12-98 mg/kg og 14-120 mg/kg. Útiá var innihaldið av lívrunnum tilfari millum 1,3 og 5,6 %, meðan innihaldið av sinki og kopari vóru 13-47 mg/kg og 5-38 mg/kg.

Abstract

Since 1998 Kaldbak Marine Biological Laboratory (KMBL) has regularly performed seabed surveys in Faroese fjords. The analyses performed on the sediments included the chemical variables: Organic content (loss on ignition), total nitrogen, total phosphorus, zinc and copper. This paper deals with the variability of the variables in the Faroe area.

The results of 229 seabed samples are included. Inshore data are compared and related to depth intervals and according to sediment types. Sediment data from inshore waters are compared to sediment data from offshore localities.

Also included in this paper are eight reports that include data on the above mentioned chemical variables.

From inshore waters the concentration of organic matter, total nitrogen, total phosphorous, zinc and copper in the sediments was, respectively: 0.5-13.0 %, 0.14-4.01 g/kg, 0.43-2.02 g/kg, 12-98 mg/kg and 14-120 mg/kg. Organic content from offshore localities showed values from 1.3 to 5.6 % while the content of zinc and copper were 13-47 mg/kg and 5-38 mg/kg, respectively.

Fróðskaparrit 57. bók 2009: 159-181

Introduction

As part of the marine environmental monitoring program instituted by the Faroese government, Kaldbak Marine Biological Laboratory (KMBL) has conducted about 40 seabed sampling surveys a year since 1998. The samples were analyzed for selected chemicals, pH and redox-potential of the sediment, as well as macro fauna and other more descriptive variables. The chemical variables analyzed were: organic content in the sediment expressed as loss on ignition (LOI), total nitrogen, total phosphorus, zinc and copper. This paper will give an overview of the chemical variables in relation to depth and to sediment type.

The environmental monitoring sampling program included sites that were heavily impacted by local outlets of organic materials (especially from salmon farms) and sites of no or little impact. The present paper only deals with reference stations and stations that were expected to be natural or with no known impact source.

LOI, nitrogen, phosphorus, zinc and copper are used by the Faroese Environmental Protection Agency as restrictive indicators of the maximum allowed environmental impact on the seabed. In this paper, the authors present an overview of the general range in which these selected chemicals are found, as they are in the top two centimeters of soft bottom sediments from a wide selection of sampling stations in Faroese inshore locations.

To give a more complete picture of the chemical range in which these selected chemicals are found in the whole of the Faroe area, we have also included previously reported data from shallow waters (Bloch *et al*.,1986; Gaard, 1990; Hoydal and Dam, 2004; Johansen, 2006) and deeper waters (Grøsvik *et al*., 2000; Josefson, 2001; Mannvik and Petersen, 2002; Kaldbak Marine Biological Laboratory, 2006)

The combination of a complex topography, different water masses and different current systems make the seabed fabric in the Faroe area difficult to describe. An overview of the current systems of this area can be found in Hansen and Østerhus (2000). Inside the fjords, soft sediments can be found only in the deepest parts, while the slopes from the seashore towards the middle of the fjord can be a mixture of all types of sediments, changing over only short distances. Information on Faroese inshore seabed features is scarce, but a general description of the Faroe area can be found in Bruntse and Tendal (2001). Tendal *et al*. (2005) describe the area thus: "The crude picture is that of very mixed gravelly bottoms sometimes with rocky outcrops on the shelf and slope, and better sorted bottoms with decreasing grain size at larger depths. A substantial component on all bottoms is debris deposited during the last ice age (Waagstein and Rasmussen, 1975). On the plateau, shell fragments of many sizes are abundant, sometimes giving the bottom the character of shell-gravel or shell-sand. Soft bottoms are found in the fjords and in a few depressions on the outer shelf.

The overall aim of this paper is to describe the natural variation of organic content (LOI), nitrogen, phosphorous, zinc and copper in marine sediments from the Faroe area.

Materials and methods

Data from KMBL are mostly from the top two centimetres of seabed sediment samples. Samples were mainly collected with van Veen-type grabs. In the period 1998-2001, a small number of samples are from the top five centimetres of core samples.

Untreated samples can differ widely in organic content due to different particle sizes and the content of live animals with large specimens, e.g., specimens of *Aphrodita aculeata* (Polychaeta) and *Arctica islandica* (Bivalvia) and decaying kelp. To make samples more homogeneous, all samples since 2001 have been sieved through 0.5 mm sieves before analysis, which is a likely predictor that the LOI-values will be somewhat lower compared to non-sieved samples.

Immediately after collecting the samples they were transferred into plastic containers and kept frozen until analyzed at the laboratory.

Organic matter is found by loss on ignition (LOI) and is expressed as % weight loss of dry weight.

All samples from KMBL were analyzed at the Faroese Food and Veterinary Agency Laboratory and ALcontrol Laboratories, Sweden. For other authors, no information is available.

1998-2000 Food and Veterinary Agency Laboratory

- Nitrogen - Kjeldahl mod. NMKL 6.
- Phosphorus - NMKL/SLF.
- Zinc - AAS Dansk Standard 259.
- Copper - FAAS mod. Dansk Standard 259 263.
- LOI - Dansk Standard 204.

2001-2003 Food and Veterinary Agency Laboratory

- Nitrogen - destruction, Kjeldahl NMKL 6, 3rd ed. mod.
- Phosphorus - destruction, autoanalyzer SLF, mod.
- Zinc - Flame photometry, Dansk Standard 263, mod.
- Copper - Flame photometry, Dansk Standard 263, mod.
- LOI - 550 °C Dansk Standard 204.

2003-2008 ALcontrol

- Nitrogen - NTOT-NDK, SS028101-1.
- Phosphorus - Svensk Standard-EN 13346 mod. / SS11885-1.
- Zinc, Copper - SS-EN 13346 mod. / Svensk Standard11885-1.
- LOI - Svensk Standard-EN 12879-1.

2008-2009 Food- and Veterinary Agency Laboratory

- Nitrogen - destruction, Kjeldahl NMKL 6, 3rd ed. mod.
- Phosphorus - destruction, autoanalyzer SLF, mod.
- Zinc - Flame photometry, Dansk Standard 263, mod.
- Copper - Flame photometry, mod. ISO 11047, 1st ed.
- LOI - 550 °C NMKL 173, 2nd ed. 2005, mod.

ALcontrol Laboratories gives these analytical uncertainties: LOI ±15 %, total-nitrogen ±10-15 %, total-phosphorus ±20-25 %, zinc ±25-30 %, copper ±20-30 %.
The Food and Veterinary Agency's laboratory gives these analytical uncertainties: LOI ±10 %, total-nitrogen ±2.5 %, total-phos-

Depth	LOI	Total-N	Total-P	Total-N/LOI	Total-P/LOI	Zinc	Copper	Zinc/LOI	Copper/LOI
	%	g/kg	g/kg	g/g	g/g	mg/kg	mg/kg	mg/g	mg/g
0-19 m									
Min	3.0	1.30	0.74	0.024	0.015	35	33	0.7	0.7
Max	7.5	1.90	1.30	0.033	0.024	96	99	1.7	1.9
Mean	4.8	1.48	1.03	0.028	0.019	59	62	1.3	1.4
Std. dev.	1.1	0.23	0.22	0.004	0.003	17	17	0.3	0.4
n	17	6	6	6	6	14	14	14	14
20-39 m									
Min	1.5	0.14	0.43	0.007	0.007	12	14	0.3	0.3
Max	13.0	4.01	2.02	0.043	0.059	88	120	3.9	3.6
Mean	5.3	1.41	0.98	0.026	0.022	52	60	1.1	1.3
Std. dev.	2.2	0.79	0.33	0.009	0.010	13	18	0.5	0.7
n	89	38	38	38	38	89	89	89	89
40-59 m									
Min	0.5	0.91	0.60	0.017	0.010	29	36	0.6	0.6
Max	11.1	3.20	1.30	0.324	0.170	74	88	8.6	12.0
Mean	5.8	1.91	0.88	0.042	0.021	51	62	1.1	1.3
Std. dev.	1.9	0.53	0.18	0.059	0.031	10	14	1.1	1.5
n	56	25	25	25	25	53	53	53	53
60-82 m									
Min	4.8	1.37	0.67	0.024	0.011	41	48	0.6	0.8
Max	8.4	2.27	0.96	0.031	0.014	49	68	0.9	1.2
Mean	6.3	1.71	0.80	0.027	0.013	45	61	0.7	1.0
Std. dev.	1.9	0.49	0.15	0.004	0.001	4	11	0.1	0.2
n	3	3	3	3	3	3	3	3	3
No depth info									
Min	1.4	0.11	0.10	0.002	0.002	28	35	0.5	0.6
Max	10.4	1.94	1.62	0.058	0.033	98	100	6.0	7.3
Mean	5.5	1.02	0.79	0.024	0.020	55	60	1.1	1.2
Std. dev.	2.0	0.59	0.30	0.014	0.008	14	16	0.7	0.9
n	64	19	19	19	19	55	56	55	56
All samples									
Min	0.5	0.14	0.43	0.007	0.007	12	14	0.3	0.3
Max	13.0	4.01	2.02	0.324	0.170	98	120	8.6	12.0
Mean	5.4	1.49	0.92	0.031	0.021	53	61	1.1	1.3
Std. dev.	2.0	0.70	0.27	0.032	0.018	13	17	0.8	1.0
n	229	91	91	91	91	214	215	214	215

Table 1. Loss on ignition (LOI), total nitrogen (Total-N), total phosphorus (Total-P), zinc and copper organized by depth intervals. A total of 229 samples were analyzed. n = number of samples.

phorus ±15 %, zinc ±10 %, copper ±10 %.

Generally, depth was obtained by echo sounder. In only a very few cases was depth measured directly or estimated from depth-contour maps.

Results

Table 1 and 2 show a total of 229 sediment samples from inshore waters in the Faroe Islands, sampled in the period 1999-2008 by KMBL. Figure 1 shows the sampled locations. All samples are in the depth range 2-82 m and represent all types of seabed sediments.

Sediment type was always estimated on the spot by the person responsible for the sampling.

In Table 1, mean values, range and standard deviation (std. dev.) on LOI, total nitrogen, total phosphorus, zinc and copper are given according to depth intervals and in Table 2 according to sediment types.

Mean LOI value for all samples was 5.4 % in the range 0.5-13.0 % with a std. dev. of 2.0 %. There seems to be a slight increase in shallow water LOI values when going from seashore to deeper waters. Mean LOI values were from 4.8 % in the depth range 0-19 m to 6.3 % at depth range 60-82 m (Fig. 2.a). Clay and mixed clay had slightly higher LOI values, compared to the more sandy sediment types (Fig. 2.b). Clay and mixed clay have mean LOI values of 6.2 % and 5.7 %, while sand, gravelly sand and mixed sand have values of 4.6, 4.6 and 5.6 %, respectively.

Total nitrogen has a mean value of 1.49 g/kg dry matter with a minimum value of 0.14 g/kg and a maximum value of 4.01 g/kg. There was a small increase in nitrogen content from shallow to deeper waters (Fig. 3.a). When total nitrogen is calculated against LOI and compared to depth, essentially no difference is observed (Fig. 3.b). Mean value of total nitrogen calculated against LOI is 0.031 g/g. Minimum value is 0.007 g/g and maximum value is 0.324 g/g. Compared to sediment types, there is slightly less nitrogen in sand and gravelly sand (0.51 and 1.27 g/kg), compared to clay and mixed clay (1.64 and 1.47 g/kg) (Fig.4.a). The same tendency can be seen when compared to LOI values, but less distinct (Fig. 4.b).

Total phosphorus has a mean value of 0.92 g/kg dry matter with a minimum value of 0.43 g/kg and a maximum value of 2.02 g/kg. There was a small decrease from the shallower to the deeper parts of the fjords (Fig. 3.c). When total phosphorus is calculated against LOI and compared to depth no difference can be noted (Fig. 3.d). Mean value of total phosphorus calculated against LOI is 0.021 g/g. Minimum is 0.007 and maximum is 0.170 g/g LOI. Compared to sediment types, there were minor differences in values, but without any clear tendency (Fig. 4.c and 4.d).

Total mean value for zinc in the sediment is 53 mg/kg dry matter. Highest value

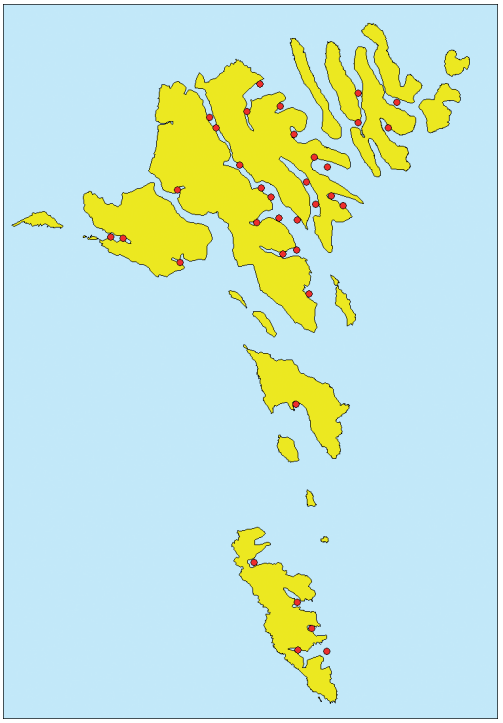

Figure 1. The localities of samples collected by KMBL (data in Table 1 and 2). Each dot may represent several samples from the same sampling area.

Sediment	LOI	Total-N	Total-P	Total-N/LOI	Total-P/LOI	Zinc	Copper	Zinc/LOI	Copper/LOI
	%	g/kg	g/kg	g/g	g/g	mg/kg	mg/kg	mg/g	mg/g
Clay									
Min	0.5	0.77	0.60	0.017	0.010	29	38	0.5	0.5
Max	11.1	3.20	1.62	0.324	0.170	96	120	8.6	12.0
Mean	6.2	1.64	0.97	0.046	0.027	55	66	1.0	1.3
Std. dev.	2.0	0.63	0.30	0.074	0.039	14	16	1.0	1.4
n	78	16	16	16	16	70	71	70	71
Mixed clay									
Min	3.0	0.49	0.67	0.013	0.011	34	35	0.5	0.6
Max	8.8	2.00	1.19	0.036	0.026	65	99	1.6	1.9
Mean	5.7	1.47	0.83	0.027	0.016	51	60	1.0	1.1
Std. dev.	1.7	0.47	0.17	0.006	0.004	10	18	0.3	0.4
n	20	10	10	10	10	20	20	20	20
Gravelly sand									
Min	1.4	0.19	0.49	0.007	0.011	12	19	0.3	0.4
Max	11.1	2.37	2.02	0.058	0.059	82	110	6.0	7.3
Mean	4.6	1.27	0.89	0.029	0.023	51	61	1.2	1.5
Std. dev.	1.6	0.68	0.33	0.013	0.013	12	16	0.7	0.9
n	80	22	22	22	22	74	74	74	74
Sand									
Min	2.2	0.22	0.65	0.010	0.023	35	14	0.6	0.4
Max	6.2	0.79	0.91	0.020	0.029	54	50	1.6	1.4
Mean	4.6	0.51	0.78	0.015	0.026	43	34	1.1	0.8
Std. dev.	1.6	0.40	0.18	0.007	0.005	9	13	0.4	0.4
n	5	2	2	2	2	5	5	5	5
Mixed sand									
Min	1.5	0.14	0.43	0.003	0.002	35	36	0.5	0.6
Max	12.7	4.01	1.63	0.041	0.043	82	83	3.9	3.7
Mean	5.6	1.54	0.93	0.027	0.018	53	54	1.1	1.1
Std. dev.	2.1	0.86	0.25	0.009	0.007	13	12	0.6	0.6
n	35	34	34	34	34	35	35	35	35
No info. on sediment									
Min	3.7	1.03	0.66	0.012	0.007	38	39	0.4	0.3
Max	13.0	1.50	1.30	0.029	0.026	98	77	1.9	1.7
Mean	5.8	1.31	1.04	0.023	0.019	57	58	1.1	1.2
Std. dev.	2.6	0.22	0.20	0.006	0.006	17	13	0.5	0.4
n	11	7	7	7	7	10	10	10	10
All samples									
Min	0.5	0.14	0.43	0.007	0.007	12	14	0.3	0.3
Max	13.0	4.01	2.02	0.324	0.170	98	120	8.6	12.0
Mean	5.4	1.49	0.92	0.031	0.021	53	61	1.1	1.3
Std. dev.	2.0	0.70	0.27	0.032	0.018	13	17	0.8	1.0
n	229	91	91	91	91	214	215	214	215

Table 2. Loss on ignition (LOI), total nitrogen (Total-N), total phosphorus (Total-P), zinc and copper organized by sediment types. A total of 229 samples were analyzed. n = number of samples.

found was 98 mg/kg dry matter and the lowest value 12 mg/kg. When total mean zinc values are compared to depth, there is a small decrease in zinc concentration with depth (Fig. 3.e). When total mean zinc is calculated against LOI and compared to depth, there is also a small decrease (Fig. 3.f). Mean value of zinc calculated against LOI is 1.1

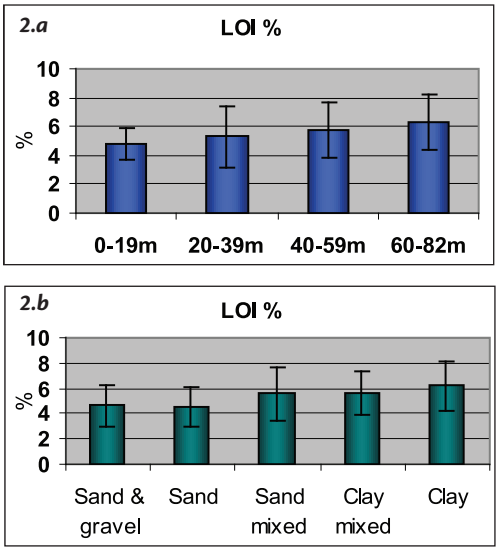

Figure 2. Mean LOI values (± standard deviation) in sediments of Faroese fjords. 2.a: Organic content in relation to intervals of depth (Table 1). 2.b: Organic content in relation to sediment types (Table 2).

mg/g. Minimum value is 0.3 and maximum value is 8.6 mg/g. Compared to sediment types only the sand-type seems to have a lower mean value than the other sediment types (Fig. 4.e), but the same tendency cannot be recognized when the zinc values are calculated against the organic content in the sediment (Fig. 4.f).

Total mean value for copper in the sediment is 61 mg/kg dry matter. Highest value found was 120 mg/kg dry matter and the lowest value was 14 mg/kg. When total mean copper values are compared to depth, no difference can be noted (Fig. 3.g). When total mean copper value is calculated against LOI and compared to depth, a small decrease can be noted (Fig. 3.h). Mean value of copper calculated against LOI is 1.3 mg/g. Minimum value is 0.3 and maximum value is

Station	*1985 May LOI %*	*1985 Aug LOI %*	*1985 Oct a LOI %*	*1985 Oct b LOI %*
SK05	*6.6*	*7.1*	*10.0*	*5.5*
SK07	*10.4*	*9.8*	*10.5*	
SK15	*7.8*	*7.5*		
SU05	*6.9*	*6.9*		
KA09	*7.5*	*7.1*		
KA13	*7.5*	*8.4*		
KA05				*7.5*
KO07		*6.7*		
KO11		*5.7*		
SU05	*6.9*	*6.9*		
SU15	*6.7*	*4.9*		
SU21	*8.2*	*4.5*		
SU37	*10.1*	*9.5*		
SU41	*6.9*	*8.5*		*7.6*
SU47	*2.4*			
FU05	*4.9*	*4.4*		
FU13		*4.4*		
FU17	*5.4*			
FU21	*5.7*	*5.7*		
LA09		*4.5*		
GO09		*4.5*		
GO13		*4.3*		
BO11		*5.2*		
AR07	*4.6*	*4.4*		
HV19		*5.3*		
HV35		*5.3*		
HV43		*4.5*		
HA20		*4.8*		
HA07		*3.9*		
KL09		*2.7*		
VE57		*4.1*		
SO03		*3.0*		
SO13		*4.4*		
S019		*7.0*		
TR19		*10.1*		
TR07		*4.5*		
VA05		*6.7*		
VA13		*3.7*		
LO05		*6.1*		

Table 3. LOI (%) data from Faroese fjords in 1985. Data from Bloch *et al.* (1986).

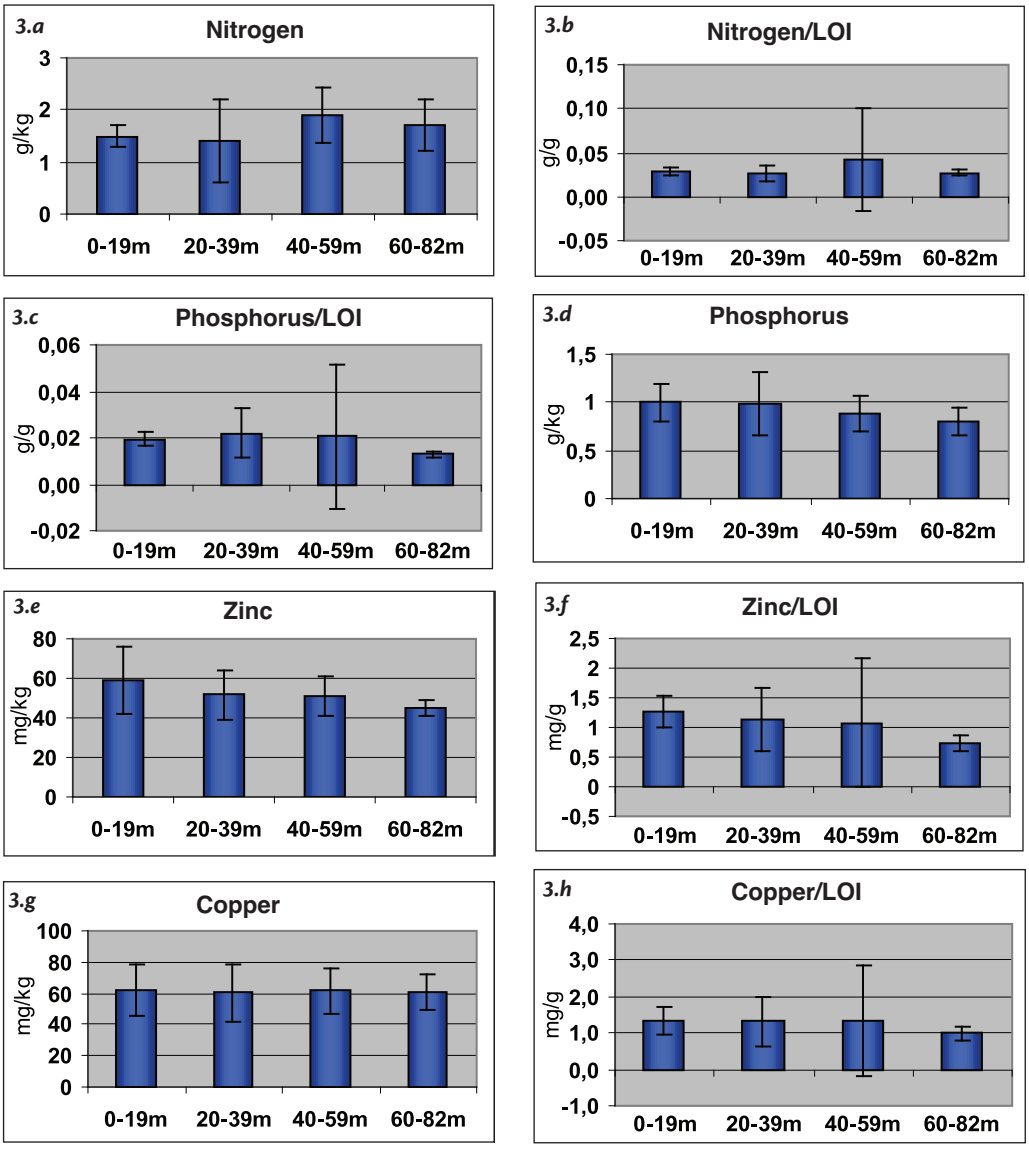

Figure 3. Sediment values (± standard deviation) in relation to depth intervals (Table 1). Left side shows absolute values and right side figures show the values related to the organic content of the sample.

12.0. When copper values are compared to sediment types, the sand-type has a lower mean value than the other sediment types, 34 mg/kg compared to 66, 60, 61 and 54 mg/kg dry matter (Fig 4.g and 4.h).

Previously reported data

From the literature, we have found eight re-

Station	*LOI % 0 cm*	*LOI % 1 cm*	*LOI % 3 cm*	*LOI % 5 cm*
SK05				
02.04.1987	*11.3*	*11.8*	*8.5*	*8.3*
22.04.1987	*12.8*	*13.8*	*9.4*	*8.4*
06.05.1987	*11.6*	*10.4*	*10.2*	*10.0*
04.06.1987	*10.2*	*7.6*	*6.9*	*7.0*
18.06.1987	*11.4*	*6.2*	*5.8*	*4.7*
27.07.1987	*13.6*	*12.5*	*9.1*	*8.6*
SK07				
02.04.1987	*12.2*	*11.7*	*10.9*	*10.9*
22.04.1987	*12.0*	*9.8*	*10.1*	*10.4*
06.05.1987	*11.6*	*10.4*	*10.2*	*10.0*
27.07.1987	*9.7*	*10.3*	*10.8*	*9.5*

Table 4. LOI (%) of sediments from Skálafjørður in 1987. Data from Gaard (1990).

ports that contain data about marine sediment chemical variables from the Faroe area (LOI, total nitrogen, total phosphorus, zinc and copper). Four of the reports are from offshore locations (Grøsvik *et al.*, 2000; Josefson, 2001; Mannvik and Petersen, 2002; Kaldbak Marine Biological Laboratory, 2006) and another four reports deal with data from inshore locations (Bloch *et al.*, 1986; Gaard, 1990; Hoydal and Dam, 2004; Johansen, 2006).

Bloch *et al.* (1986) gave single sample LOI values from most Faroese fjords (Fig. 5). They used 0.1 m^2 van Veen-type grabs for sampling, but gave no descriptive information about the samples. A single sample was taken at each station. At four stations, samples were collected more than once a year.

Gaard (1990) sampled two localities in Skálafjørður (Fig. 6). Samples were taken at station SK05, which at 67 meters is the deepest part of the fjord, and at SK07, which has a depth of about 57 meters. At station SK05, six samples were taken in the period April to July (1987) and four samples were taken in the same period at station SK07. A single sample was taken at each station each time and LOI was measured at depths 0, 1, 3 and 5 cm into the sediment.

The sediment type is silty clay (Gaard, pers. comm.) and Gaard (1990) used a 14 cm wide HAPS corer to obtain the samples. LOI values were found by combusting dry sediment for 3 hours at 450 °C.

Hoydal and Dam (2004) gave data from five Faroese fjords (Fig. 7), Skálafjørður (SK), Funningsfjørður (FU), Kaldbaksfjørður (KA), Kollafjørður (KO) and Sundini (SU). Table 6 contains information on LOI and copper from 2000, 2001 and 2003 and Table 5 contains information on LOI, total nitro-

	LOI *%*	*Cu* *mg/kg*
SK05 (1)	*9.0*	*110.5*
SK05 (2)	*8.4*	*70.1*
SK05 (3)	*8.8*	*110.9*
SK07	*10.7*	*115.9*
SK09	*11.8*	*96.6*
KA05	*9.1*	*102.8*
KA05	*9.1*	*97.3*
KA09	*7.6*	*106.4*
KO07	*6.6*	*93.1*
SU05	*5.1*	*78.1*
SU15	*6.8*	*89.3*
SU15	*6.8*	*92.8*
SU37	*6.9*	*93.2*
SU41	*6.4*	*86.4*
FU13	*3.7*	*76.5*
FU17 (1)	*4.4*	*81.8*
FU17 (2)	*3.3*	*65.4*
FU21 (1)	*5.9*	*98.4*
FU21 (2)	*6.8*	*105.8*
FU21 (3)	*5.1*	*97.9*

Table 5. LOI and copper values in sediments from Faroese fjords in 1997. Numbers in brackets are replicated samples. Data from Hoydal and Dam (2004).

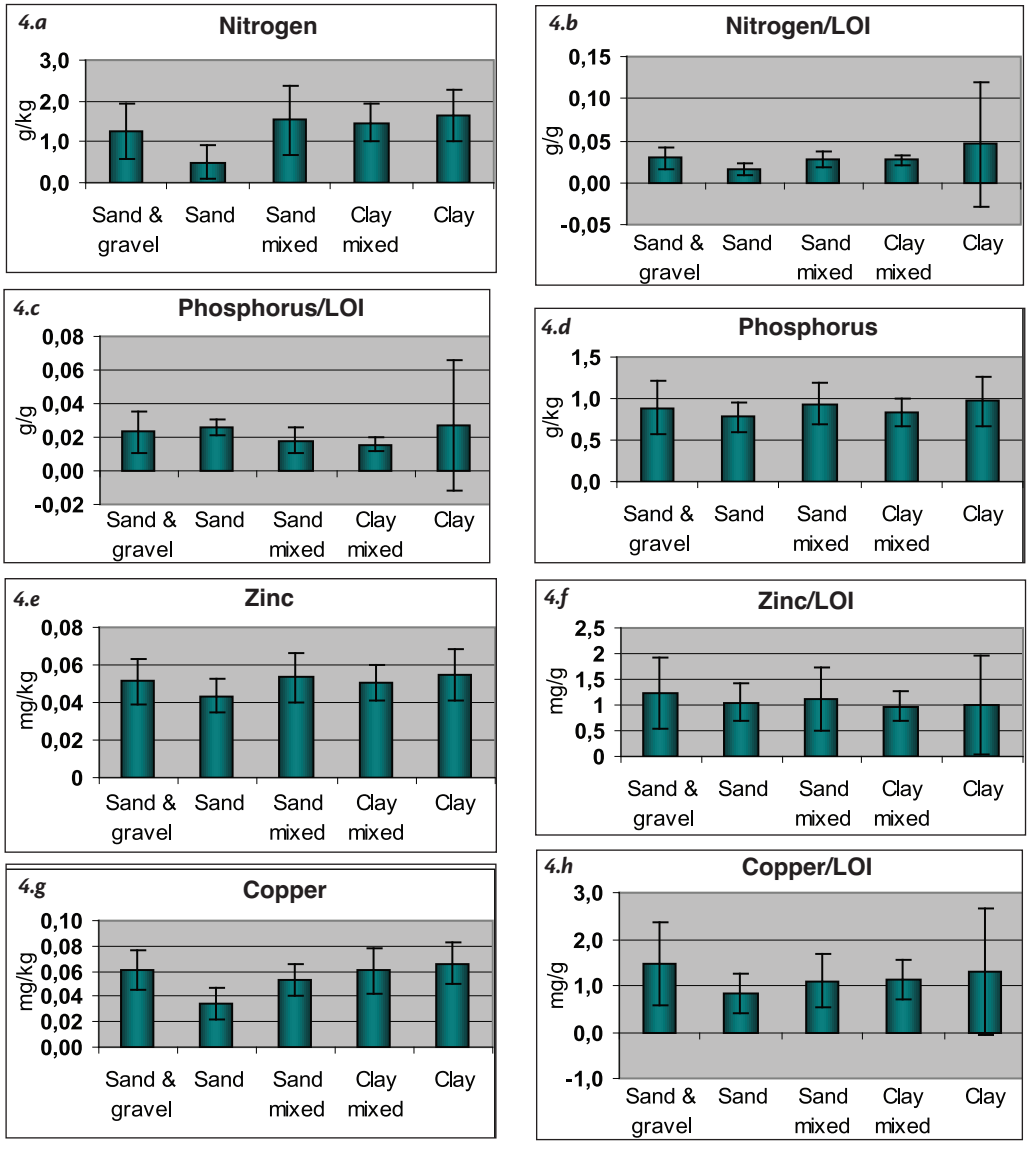

Figure 4. Sediment values (± standard deviation) in relation to sediment type, from Table 2. Left side shows absolute values and right side figures shows the values related to the organic content of the sample.

gen, total phosphorus, zinc and copper from 1997. No information is given about the sediment type or how the samples were obtained.

Johansen (2006) reported on mean concentrations of selected environmentally related chemical variables from eight Faroese localities (Fig. 8). Three of these localities

	LOI	*Nitrogen*	*Phosphorus*	*Zinc*	*Copper*
	%	*g/kg*	*g/kg*	*mg/kg*	*mg/kg*
SK05 (2000)	*7.7*	*2.8*	*1.0*	*58.2*	*57.5*
SK05 (2001)	*8.1*	*3.6*	*1.4*	*76.8*	*75.2*
SK05 (2003)	*13.3*	*4.3*	*1.3*	*80.0*	*82.3*
SK07 (2000)	*12.6*	*4.7*	*1.4*	*87.0*	*88.4*
SK09 (2000)	*13.1*	*4.9*	*1.5*	*89.7*	*96.3*
KA05 (2000)	*9.4*	*3.6*	*1.1*	*61.8*	*72.0*
KA05 (2001)	*9.5*	*3.7*	*1.3*	*64.7*	*69.1*
KA05 (2003)	*12.7*	*4.0*	*1.4*	*72.8*	*73.9*
KA09 (2000)	*10.0*	*3.1*	*1.1*	*58.1*	*79.8*
KA09 (2001)	*8.7*	*3.1*	*1.2*	*63.3*	*70.9*
KO07 (2000)	*6.8*	*2.4*	*1.1*	*58.9*	*64.8*
SU05 (2000)	*9.4*	*2.9*	*0.8*	*48.4*	*64.8*
SU05 (2001)	*7.3*	*2.8*	*1.0*	*48.5*	*49.4*
SU05 (2003)	*9.4*	*2.6*	*0.9*	*54.3*	*53.9*
SU15 (2000)	*9.3*	*2.7*	*1.0*	*52.0*	*55.8*

Table 6. LOI, total-nitrogen, total-phosphorus, zinc and copper values in sediments from Skálafjørður, Kaldbaksfjørður, Kollafjørður and Sundini . Years are shown in brackets. Data from Hoydal and Dam (2004).

(Húsavík, Hvalba and Tjørnuvík) have exposed bays and have a low population. Haraldssund, Árnafjørður, Sundini and Kaldbaksfjørður are low-population areas, but are used for aquaculture, which is known as a source of high organic input. Skálafjørður is a sheltered sill fjord with a relatively high population and has also been used for aquaculture purposes.

In Table 7, there are two groupings. The first five locations are from outlying regions of the archipelago, while the last three are more centrally located.

In the first grouping (outlying regions), two replicate samples were taken at different depths and the number of stations taken at each site was from 2-4 (Table 7). Samples were taken by either scuba diver, gravity core

	n	*Sediment*	*Gear*	*LOI*	*Nitrogen*	*Phosphorus*	*Zinc*	*Copper*
				%	*g/kg*	*g/kg*	*mg/kg*	*mg/kg*
Haraldssund	*8*	*Sand/Gravel*	*Core*	*5.8*	*1.0*	*0.7*	*50*	*80*
Hvalba	*6*	*Sand/Gravel*	*Grab*	*3.6*	*0.4*	*0.8*	*55*	*58*
Árnafjørður	*8*	*Mixed*	*Core*	*4.9*	*0.9*	*0.5*	*41*	*59*
Húsavík	*4*	*Mixed*	*Core*	*2.4*	*0.4*	*0.9*	*74*	*82*
Tjørnuvík	*8*	*Sand/Gravel*	*Core*	*2.7*	*0.3*	*0.7*	*57*	*80*
Sundini (SU05)	*2*		*Core*	*7.5*	*2.2*	*0.9*	*60*	*77*
Kaldbaksfjørður (KA05)	*2*		*Core*	*10.7*	*3.6*	*1.6*	*85*	*110*
Skálafjørður (SK05)	*2*		*Core*	*13.0*	*4.7*	*1.4*	*91*	*109*

Table 7. Mean values for LOI, total-nitrogen, total-phosphorus, zinc and copper from eight Faroese fjord/bay locations. Data from Johansen (2006).

Figure 5. Sampling sites reported by Bloch et al. (1986).

or by van-Veen type grab. Due to the small sample volume, some of the core samples were from the top 4 cm of the sediment. In the centrally located sites (SU05, KA05 and SK05), two replicate core samples were analyzed.

In the period from 1987-1990 **Josefson (2001)** took samples at two soft bottom locations on the Faroe Plateau (Skeivibanki and East off Suðuroy) at a depth of 317-367 m (Fig. 9). Samples were obtained with 0.1 m^2 van Veen-type grab and a two cm surface layer of the sediment was used for analysis. No further information about pre-treatment or methods of analysis was given.

In a survey southeast off the Faroe Plateau in 1999, **Grøsvik *et al.* (2000)** took 20 seabed samples from eleven different locations (Fig. 10). Samples were analyzed for different chemical variables; among these were LOI, zinc and copper. All samples were collected with a 0.1 m^2 van-Veen-type grab and analyzed by Rogaland Research Laboratory. Metals were analyzed after sieving of the dried material (0.5 mm sieve).

All samples were described to be from sandy sediments, and the stations had a depth between 275 and 580 m.

In **Mannvik and Petersen (2002)**, there is information about seabed chemical variables from a survey southeast off the Faroe Islands in the Faroe-Shetland Channel at a depth of 820-1180 m (Fig. 11). The samples were obtained with 0.5 m^2 box-corer. Three replicates from each station were used to give a mean value for the top 0-1 cm of the sediment. Samples were analyzed by Akvaplan-niva.

The sediments were described as fine to coarse sands.

KMBL (2006) sampled the seabed around the "Brugdan" hydrocarbon exploration well before and after drilling operations. Because of a possible impact from the drilling operations on the seabed only data from the first survey (before drilling) are included in this paper. Eighteen samples were

	Samples	*Depth*	*LOI*
	n	*m*	*%*
W87	*3*	*329-350*	*2.8-3.3*
W88	*15*	*317-367*	*2.7-3.9*
E87	*1*	*350*	*4.3*
E88	*2*	*349-351*	*3.3-4.1*

Table 8. Data from Josefson (2001) LOI data from two locations on the Faroe shelf.

Station	Depth	Sediment	LOI	Zinc	Copper
	m		%	mg/kg	mg/kg
1.a	453	Fine Sand	4.0	28.6	13.1
1.b	458	Fine Sand	3.5	29.8	13.7
1.c	464	Coarse sand	2.6	33.8	18.9
1.d	486	Fine Sand	3.3	19.4	7.6
2	459	Medium sand	3.3	35.8	17.8
4	440	Coarse sand	2.7	36.7	16.7
5	461	Fine Sand	3.8	24.3	10.5
6	580	Coarse sand	2.7	42.7	27.0
7	470	Fine Sand	3.3	38.5	17.1
8	487	Fine Sand	3.4	28.6	12.7
9.a	463	Fine Sand	4.2	33.0	15.7
9.b	480	Fine Sand	4.0	30.1	13.6
9.c	469	Fine Sand	4.1	30.0	13.2
9.d	341	Medium sand	2.9	35.1	28.7
10.a	517	Medium sand	3.1	23.6	17.3
10.b	424	Medium sand	3.3	22.1	16.3
10.c	389	Medium sand	3.1	24.8	20.8
10.d	354	Medium sand	3.3	20.8	17.1
10.e	275	Medium sand	2.5	11.2	9.1
10.f	494	Medium sand	2.4	15.9	12.0
Min			2.4	11.2	7.6
Max			4.2	42.7	28.7
Mean			3.3	28.2	15.9
Std. dev.			0.5	8.0	5.3

Table 9. Sediment values of LOI, copper and zinc from south of the Faroe Islands on the northern slope of the Faroe Shetland Channel. Data from Grøsvik *et al.* (2000).

analyzed for LOI, copper and zinc. Samples were taken from the top 2 cm of undisturbed seabed sediment and samples were obtained by 0.1 m^2 van-Veen-type grab. Samples were analyzed at ALcontrol Laboratories, Sweden. Positioning accuracy of the sample sites was within ± 5 meters.

The stations are all within a distance of 1250 m and vary between 460-489 m in depth (Table 11). The sediments were described as gravelly sands to silt/clay sands.

Comparability of data.

When comparing data from different sources it is important to consider the comparability. Differences could be found in the way samples were taken, in treatment after sampling or prior to analysis, and in the method of analysis. The most important single source factor of error is without a doubt the uncertainty of precise localization of a sample site when comparing samples from the same site. This may particularly be the case for the oldest samples, when the accuracy of positioning systems was less precise.

Approximately all samples in Table 1 and 2 were sieved (0.5 mm) before analysis. There is no doubt that in some cases this has an ef-

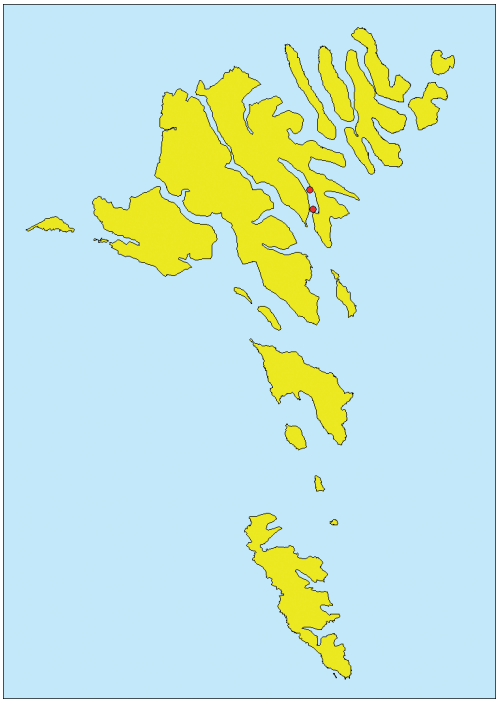

Figure 6. Sampling sites reported by Gaard (1990).

fect when compared to untreated samples. In un-sieved samples it is reasonable to expect a high content of large, non-organic particles to influence the result, as well as large numbers of small tube dwelling worms (e.g., *Myriochele* sp. and *Phoronida* sp.) or just a few specimens of large bodied animals (e.g., *Arctica islandica*). Seaweed would also influence the result. Sieving eliminates the variability of samples and makes comparison results more reliable. There is no information on any sieving of the sediment before analysis by other authors so it is reasonable to expect the analyses to be done on untreated sediments.

Some of the sites in this study are repeatedly sampled. There are a few replicates, some are sampled more than once a year and many are sampled about yearly. In such cases, it should be possible to get a crude chemical picture of the natural variance at the site. Comparison between sites should therefore be done with caution, especially because there is so little information about the samples and sampling procedures.

The stability of organic content (LOI values)

One of the interesting questions this study could help answer is how stable or changeable is the organic content in the upper layers of the seabed. Is it constant at the same site or does the organic content change temporarily according to sources of organic input?

Due to various reasons, it is difficult to collect sufficient quality data on organic content from the same site over a long period of time. In Table 12, all available data from two of the stations from Skálafjørður, SK05 and SK07 are shown. SK05 is in the middle of the fjord at the deepest part at a depth of about 67 m and SK07 about 2 km north of SK05. Both are soft bottom localities. The data from these two stations are from untreated samples.

There are 24 samples from SK05 and 13 from SK07 (Bloch *et al*., 1986; Gaard, 1990; Hoydal and Dam, 2004 and Johansen, 2006). In 1985 and 1987, several samples were taken during the summer period (no replicates). In 1997, three replicates were analyzed from SK05 and, in 2005, two replicates. In the years 2000, 2001 and 2003, one single sample was analyzed at each site.

The overall lowest value from SK05 was 5.5 % and the highest was 13.9 %. At station

SK07 these were respectively 9.7 % and 12.6 %. The LOI mean value for all samples was 10.0 % for SK05 and 10.9 % for SK07.

From the data in Table 12 it is not possible to recognize any pattern of change. The LOI values of SK05 were highly variable, while LOI values at SK07 seem to be more constant. There is no obvious reason for the variability of the LOI values at SK05, but patchiness and imprecise positioning could explain the differences. It is, however, difficult to explain why SK07 has more constant LOI values compared to SK05.

In Table 13, data from four sites at different localities are shown. These are data from sieved samples (0.5 mm). One of the localities (Gøtuvík) has been sampled for nine consecutive years, the others for four to five years. All four localities show variable values of organic content in the sediment. Miðvágur seems to be less variable than the other localities and a possible explanation could be that this is an exposed site with sandy sediments. Gøtuvík, which has been sampled for nine consecutive years, varied between 3.2 and 9.5 %.

The data in Table 13 are from sieved samples and are, therefore, not directly comparable to SK05 and SK07 in Table 12.

Station	***Depth***	***Sediment***	***LOI***	***Zinc***	***Copper***
	m		*g/kg*	*mg/kg*	*mg/kg*
1	*1100*	*Fine Sand*	*1.5*	*18.5*	*7.8*
2	*1148*	*Medium sand*	*1.5*	*21.7*	*6.1*
3	*1090*	*Fine Sand*	*1.3*	*13.4*	*5.3*
6	*1180*	*Coarse sand*	*1.5*	*21.5*	*9.3*
8	*820*	*Fine Sand*	*2.9*	*20.5*	*10.8*
9	*930*	*Fine Sand*	*2.2*	*17.3*	*9.3*
11	*970*	*Fine Sand*	*1.7*	*13.9*	*7.1*
12	*990*	*Medium sand*	*1.6*	*13.6*	*5.7*
13	*1020*	*Fine Sand*	*2.0*	*16.1*	*8.2*
14	*990*	*Fine Sand*	*1.7*	*13.9*	*6.3*
15	*1050*	*Fine Sand*	*2.6*	*9.1*	*21.8*
16	*1050*	*Fine Sand*	*1.9*	*16.0*	*7.8*
17	*1060*	*Fine Sand*	*2.2*	*17.2*	*8.0*
18	*1080*	*Fine Sand*	*2.0*	*15.0*	*7.3*
19	*1070*	*Fine Sand*	*2.7*	*16.3*	*8.5*
20	*1100*	*Fine Sand*	*2.9*	*17.2*	*8.9*
Min			*1.3*	*13.4*	*5.3*
Max			*2.9*	*21.8*	*10.8*
Mean			*2.0*	*17.1*	*7.8*
Std. dev.			*0.5*	*2.9*	*1.5*

Table 10. Values of LOI, copper and zinc from the deep slope of the Faroe Shetland channel. Data from Mannvik and Petersen (2002).

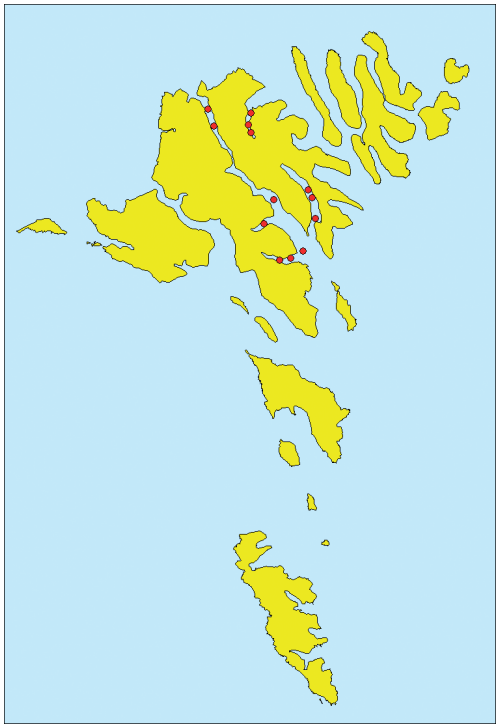

Figure 7. Sampling sites reported by Hoydal and Dam (2004).

The normal range of organic content, nitrogen, phosphorus, zinc and copper in the surface layers of seabed sediments in the Faroe area

Organic content (LOI)

The data collected by Kaldbak Marine Biological Laboratory showed a wide variance of organic content in the sediment. The overall lowest value found was 0.5 % and the highest was 13.0 % (Table 1 and 2).

Bloch *et al.* (1986) found values between 2.4 % and 10.5 %. Gaard (1990) gave information on organic content from two locations (SK05 and SK07) and found values between 6.2 % and 13.8 %. Hoydal and Dam (2004) analyzed sediment samples from 13 locations and found values between 3.3 % and 13.3 %, and Johansen (2006), who sampled at eight different locations, found mean LOI values from 2.4 % to 13.0 %.

Therefore, the overall variability of organic matter in seabed sediments from Faroese inshore waters is between 0.5 % and 13.8 %.

Josefson (2001) found LOI values between 2.7 and 4.3 % at depths from 317-367 m.

Grøsvik *et al.* (2000) found LOI values from 2.4 to 4.2 % with a mean of 3.3 % in samples from depths between 275 and 580 m.

Mannvik and Petersen (2002) found LOI values in the range 1.3-2.9 % with a mean value of 2.0 %. They sampled in the Faroe-Shetland Channel at depths between 820-1148 m.

Kaldbak Marine Biological Laboratory (2006) sampled just off the Faroe shelf at depths around 470 m and found LOI values in the range 1.9-5.6 % with a mean value of 2.7 %.

From these four reports from deeper waters, it can be concluded that values for organic content in the offshore sediments were from 1.3-5.6 % and means were 3.3 %, 2.0 % and 2.7 %, respectively.

Nitrogen

Very few data on total nitrogen in marine sediments from the Faroe Islands are available. Besides the data collected by KMBL (91 samples), there are only two reports with further information. Hoydal and Dam (2004) analyzed 15 samples from soft sediments in

Station	*Depth*	*LOI*	*Copper*	*Zinc*	*Copper*	*Zinc*
		%	*mg/kg*	*mg/kg*	*mg/g LOI*	*mg/g LOI*
E250-1	*487*	*2.4*	*22*	*35*	*9.2*	*14.6*
E250-2	*487*	*1.9*	*28*	*40*	*14.7*	*21.1*
E250-3	*485*	*2.3*	*28*	*45*	*12.2*	*19.6*
N250-1	*474*	*2.1*	*34*	*43*	*16.2*	*20.5*
N250-2	*475*	*2.8*	*38*	*43*	*13.6*	*15.4*
N250-3	*476*	*2.3*	*32*	*41*	*13.9*	*17.8*
W250-1	*474*	*2.5*	*25*	*37*	*10.0*	*14.8*
W250-2	*474*	*2.6*	*26*	*40*	*10.0*	*15.4*
W250-3	*474*	*2.1*	*27*	*42*	*12.9*	*20.0*
S250-1	*460*	*2.5*	*25*	*40*	*10.0*	*16.0*
S250-2	*480*	*2.9*	*27*	*41*	*9.3*	*14.1*
S250-3	*460*	*2.7*	*24*	*40*	*8.9*	*14.8*
S500-1	*481*	*2.4*	*32*	*47*	*13.3*	*19.6*
S500-2	*482*	*5.6*	*30*	*42*	*5.4*	*7.5*
S500-3	*482*	*2.7*	*25*	*39*	*9.3*	*14.4*
S1000-1	*484*	*2.7*	*25*	*38*	*9.3*	*14.1*
S1000-2	*484*	*2.9*	*26*	*39*	*9.0*	*13.4*
S1000-3	*484*	*2.4*	*25*	*42*	*10.4*	*17.5*
Min		*1.9*	*22*	*35*	*5.4*	*7.5*
Max		*5.6*	*38*	*47*	*16.2*	*21.1*
Mean		*2.7*	*27.7*	*40.8*	*11.0*	*16.1*
Std. dev.		*0.8*	*4.0*	*2.8*	*2.7*	*3.3*

Table 11. Values of LOI, copper and zinc from the southeastern region of the slope of the Faroe shelf. Depths between 460 and 489 m. Data from Kaldbak Marine Biological Laboratory (2006).

Faroese fjords; Johansen (2006) analyzed 34 samples from exposed bays and Kaldbak Marine Biological Laboratory (2006) analyzed 18 samples southeast of the Faroes off the Faroe shelf.

Table 1 and 2 show that total nitrogen in the surface layers of sediments from Faroese near shore waters is between 0.14 and 4.01 g/kg. In relation to the organic content, the values were from 0.007 to 0.324 gram nitrogen per gram organic matter.

Hoydal and Dam (2004) obtained slightly higher values; the average was 3.4 g/kg in the range 2.4-4.9. The reason for the higher values could be because the samples were from softer sediments with a higher organic content or due to analysis of non-sieved samples.

In the outlaying regions Johansen (2006) found very low nitrogen values. The samples were between 0.3 and 1.0 g/kg. A likely explanation is that the samples were obtained from exposed sandy sediment bays with low organic content.

Phosphorus

Phosphorus and nitrogen are vital in biological systems because of their function as macro nutrients and are therefore often analyzed as a pair. All samples analyzed for nitrogen were also analyzed for phosphorus.

In the samples from KMBL (Table 1 and

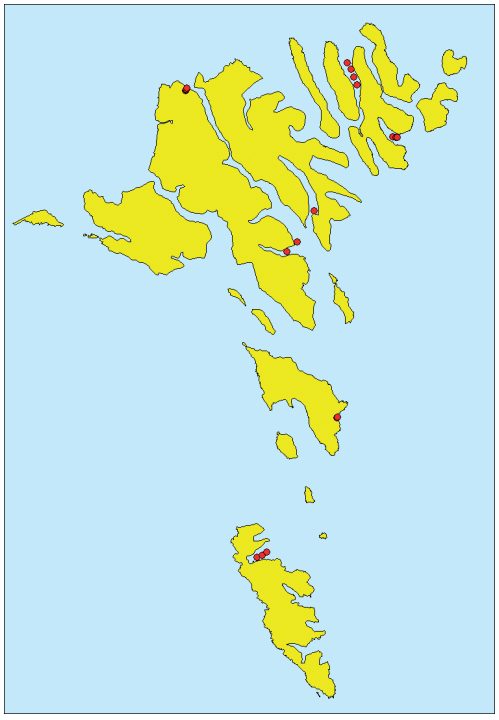

Figure 8. Sampling sites reported by Johansen (2006).

2), it can be seen that total phosphorus was between 0.43-2.02 g/kg. In relation to the organic content, the values were from 0.007 to 0.170 gram phosphorus per gram organic matter. When compared to Dam *et al.* (2003) and Johansen (2006), very little difference is seen between the samples. Hoydal and Dam (2004) had values between 0.8 and 1.5 g/kg and Johansen (2006) found values from 0.5 to 0.9 g phosphorus per kg dry sediment in the outlaying regions.

Zinc

In addition to the data in Table 1 and 2, there are two other reports from shallow waters (Hoydal and Dam, 2004; Johansen, 2006) and three reports (Grøsvik *et al.*, 2000; Mannvik and Petersen, 2002; Kaldbak Marine Biological Laboratory, 2006) from deeper waters around the Faroes with information on zinc concentrations in the seabed sediments. The values from shallow waters (< 100 m) are between 12-98 mg zinc per kg dry sediment, while the data from deeper waters (>274 m) are in the range 11-47 mg zinc per kg dry sediment. It seems like shallow inshore sediments have somewhat higher values, compared to sediments from deeper waters.

	*1985**	*1987***	*1987***	*1997#*	*2000#*	*2001#*	*2003#*	*2005##*
SK05	*6.6*	*11.3*	*11.8*	*9.0*	*7.7*	*8.1*	*13.3*	*12.1*
	7.1	*12.8*	*13.8*	*8.4*				*13.9*
	10.0	*11.6*	*10.4*	*8.8*				
	5.5	*10.2*	*7.6*					
		11.4	*6.2*					
		13.6	*12.5*					
SK07	*10.4*	*12.2*	*11.7*	*10.7*	*12.6*			
	9.8	*12.0*	*9.8*					
	10.5	*11.6*	*10.4*					
		9.7	*10.3*					

Table 12. LOI values (%) for all reported samples from SK05 and SK07. Data from Bloch et al., 1986 (*); Gaard, 1990 (**), Hoydal and Dam, 2004 (#) and Johansen, 2006(##). The values for 2005 are given as a mean value in Table 7.

Copper

In Table 1 and 2, it can be seen that total copper in the surface layers of sediments from Faroese near shore waters is between 14-120 mg/kg, with a mean value of 61 mg/kg. In relation to the organic content, the values were from 0.3 to 12.0 mg copper per gram organic matter.

In the data given by Hoydal and Dam (2004) (Table 5) the values of copper were between 65.4-115.9 mg/kg, with a mean value of 93.5 mg/kg. These data are from 1997 and are mainly from very soft sediments in the deeper parts of some Faroese fjords.

The same report presents data from 2000, 2001 and 2003 (Table 6). These values are within the same range 49.4-96.3 mg/ kg dry matter and with a mean of 70 mg/kg. Some of the stations are the same as in Table 5.

From Johansen's (2006) investigation of low-population, exposed bays on the Faroe Islands, it can be seen that copper values were between 58 and 82 mg/kg dry sediment. Johansen also had three stations from more centrally located areas and these had mean values between 77-110 mg/kg dry sediment.

From deeper waters Grøsvik *et al.* (2000), Mannvik and Petersen (2002) and Kaldbak Marine Biological Laboratory (2006) found values between 5 and 38 mg/kg dry sediment with respective means of 16.8 and 28 mg/kg dry sediment.

These deeper stations have a distinctly lower copper value in the sediment, compared to the sediments at the shallow water stations.

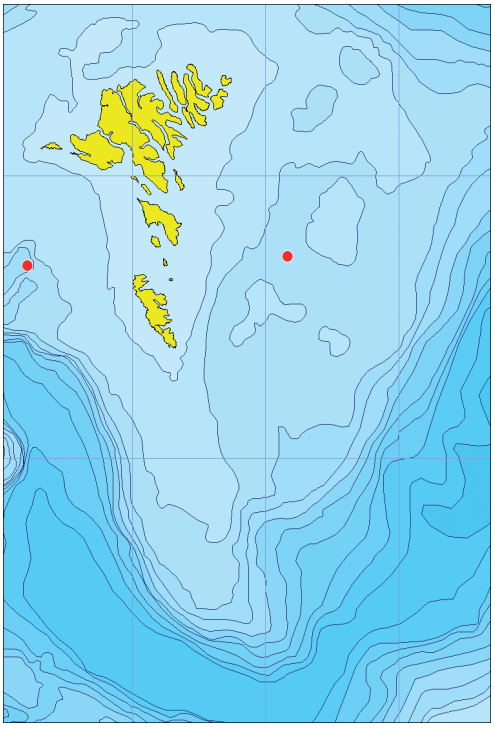

Figure 9. Sampling sites reported by Josefson (2001).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	Min	Max	Mean
Gøtuvík *(38 m)*	3.9	4.0	5.4	9.5	4.7	5.8	4.5	3.2	5.5	3.2	9.5	5.2
Árnafjørður *(37 m)*			3.5	5.1	3.8	3.7				3.5	5.1	4.0
Miðvágur *(20 m)*		2.7		2.6	2.6	3.6	2.3		2.6	2.3	3.6	2.7
Undir síðu *(47 m)*	6.1			4.6	4.8	4.3	7.5			4.3	7.5	5.5

Table 13. LOI values for all reported samples from Gøtuvík, Árnafjørður, Miðvágur and Undir síðu.

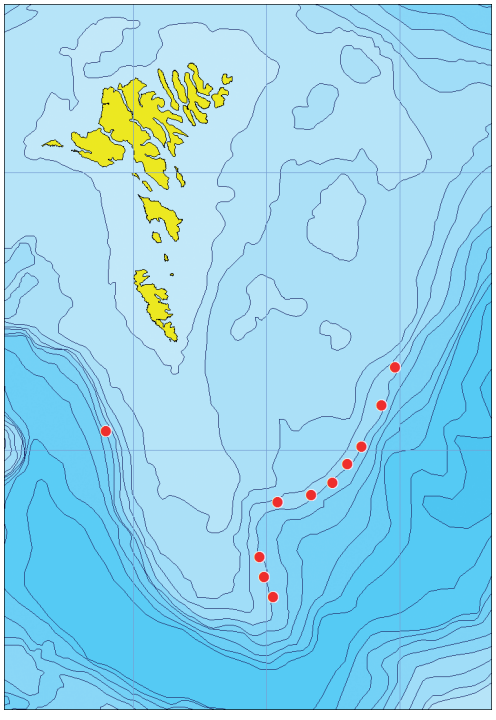

Figure 10. Sampling sites reported by Grøsvik *et al.* (2006).

Discussion

From the data presented in this paper, it may be concluded that chemical variables of seabed sediments in Faroese shallow waters can vary widely within short distances and even within the same locality. Sandy sediments can contain as low as 0.5 % organic matter, while muddy clay from the deeper parts of the fjords may contain as high as 13.8 %. The data indicates a tendency for increasing organic matter in the sediments from the shallow to the deeper regions of the fjords (Table 1 and Fig. 2.a). The opposite is the case with the concentration of zinc (Fig. 3.e and 3.f) and to a lesser degree with phosphorous (Fig. 3.c). The content of nitrogen and copper do not show any relation to depth (Fig. 3.a, b, g, h)

In Table 12 and 13, an effort has been made to compare LOI values from the same locality over a longer period of time. All six localities showed variable LOI values from

	Depth	***LOI***	***Nitrogen***	***Phosphorus***	***Zinc***	***Copper***
	m	*%*	*g/kg*	*g/kg*	*mg/kg*	*mg/kg*
KMBL	*0-82*	*5.4 (0.5-13.0)*	*1.49 (0.14-4.01)*	*0.92 (0.43-2.02)*	*53 (12-98)*	*61 (14-120)*
Bloch et al.	*< 100*	*6.3 (2.4-10.5)*				
Gaard	*< 70*	*11.1 (6.2-13.8)*				
H and D (2004) A	*< 90*	*(3.3-11.8)*				*94 (65-116)*
H and D (2004) B	*< 90*	*9.8 (6.8-13.3)*	*3.4 (2.4-4.9)*	*1.2 (0.8-1.5)*	*65 (48-90)*	*70 (49-96)*
Johansen	*10-25*	*(2.4-5.8)*	*(0.3-1.0)*	*(0.5-0.9)*	*(41-74)*	*(58-82)*
Grøsvik et al.	*275-580*	*3.3 (2.4-4.2)*			*28 (11-43)*	*16 (8-29)*
Josefson W	*317-367*	*2.7-3.9*				
Josefson E	*349-351*	*3.3-4.3*				
M and P (2002)	*820-1180*	*2.0 (1.3-2.9)*			*17 (13-22)*	*8 (5-11)*
KMBS (2006)	*461-489*	*2.7 (1.9-5.6)*			*41 (35-47)*	*28 (22-38)*

Table 14. A summarized list of all available data on marine seabed chemical values (LOI , total nitrogen, total phosphorus, zinc and copper) from the Faroe Islands. Data from Bloch *et al.* (1986); Gaard (1990); Hoydal and Dam (2004); Johansen (2006); Grøsvik *et al.* (2000); Josefson (2001); Mannvik and Petersen (2002); Kaldbak Marine Biological Laboratory, 2006. Josefson-E = eastern sampling location, Josefson-W = western sampling location. Hoydal and Dam (2004) A = data from Table 5, Hoydal and Dam (2004) B = data from Table 6.

year to year, but, aside from SK05, these localities have relative constant values, only disturbed by a single year. If the single deviant values are excluded from the data, SK07 had values between 9.7 and 12.2 % (2000 excluded), Gøtuvík 3.2-5.8 % (2003 excluded), Árnafjørður 3.5-3.8 (2003 excluded), Miðvágur 2.3-2.7 % (2005 excluded) and Undir síðu 4.3-6.1 % (2006 excluded). Primary production on the Faroe Plateau changes from year to year and some of the variability in LOI values could be explained by this fact. Also, since each fjord may be regarded as a separate ecosystem, there may be a variation in primary production between fjords (Gaard *et al*., 1992). Another reason that may underlie the deviant values in LOI is patchiness of the organic content in the sediments within the same locality.

The presented data are from sediment samples collected throughout the year, although the majority of samples were collected from June to December. Some of the variability could be explained by differences in organic content in the sediment at different times of the year.

The fact that organic content in sediments vary and for some years show deviant values demands that a certain number of replicate samples from each locality be taken to maintain reliability, e.g., three replicates.

If inshore data from the Faroe area are compared to offshore data, it seems like the offshore sediments have a lower content of organic materials. Values were between 0.5 - 13.8 % in inshore waters, compared to 1.3 - 5.6 % in offshore sediments.

Besides the data from the present paper, there are only two reports with information on nitrogen and phosphorus in marine sediments from the Faroe Islands (Hoydal and Dam, 2004; Johansen, 2006). All samples are from shallow waters (< 100 m) and the nitrogen values were all between 0.14 and 4.9 g/kg dry sediment, while the phosphorus values were in the range 0.43 - 2.02 g/kg dry sediment. Nitrogen does not show any relation to depth.

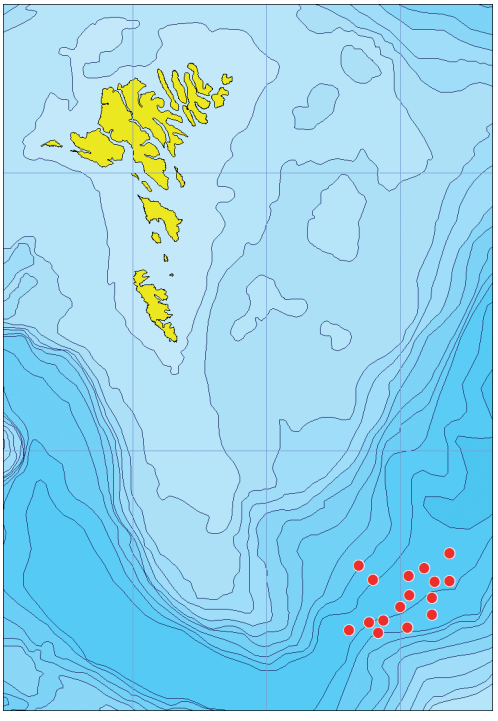

Figure 11. Sampling sites reported by Mannvik and Petersen (2002).

From the data in this paper, it would appear that the copper and zinc concentrations in the inshore sediments are higher in shallow water areas, compared to the deeper areas. Copper had values from 14 to 120 mg/kg dry sediment in shallow waters, compared to 5-38 mg/kg dry sediment in deeper waters. The zinc values were in the range 12-98 mg/kg dry sediment in shallow waters

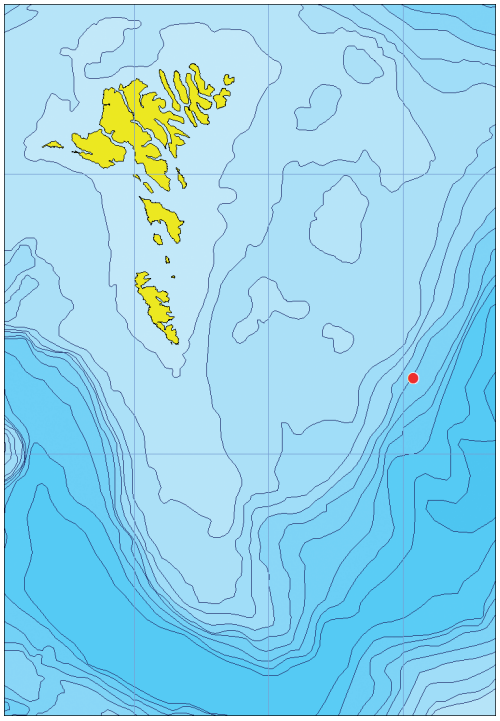

Figure 12. Sampling site reported by KMBL (2006).

and 11-47 mg/kg dry matter in deeper waters.

From seabed environmental surveys from the Shetland side of the Faroe-Shetland Channel, Environmental & Resource Technology, Ltd (2000) gave an overview of chemical sediment variables before and after drilling operations from a number of sites used for exploration drilling for hydrocarbons. The data from the surveys before any drilling showed organic contents between 0.13 to 5.36 %, zinc values from 8-88 mg/kg and copper values from 2-35 mg/kg. These values are within the same concentration range as found in the offshore data from the Faroe area.

From a survey off the Norwegian coast (Vøring Plateau), at depths between 591-1520 m in a region from Trondheim in the south to Bodø in the north, Jensen *et al*. (1999) found values of organic content, zinc and copper in the sediments from 4.0 to 14.7 %, 22.7-78.8 mg/kg and 6.4-38.0 mg/kg, respectively. The copper concentration is very similar to the Faroese offshore area, but the zinc concentration is a bit higher and more like the values found in Faroese inshore sediments. Organic content on the Vøring Plateau is relatively high and is comparable to the high end values found in Faroese inshore waters.

Mannvik *et al*. (2002) summarize a regional environmental seabed survey in the Norwegian sector of the North Sea (58-60° N and 1-2° W) at water depths around 100 m. In total, 230 sediment samples were analyzed, but 22 of these were described as regional and reference stations and showed very low levels of organic content, compared to all other referenced areas. The organic content was between 0.63 and 2.57 %, while zinc and copper had values between 0.9-9.3 mg/kg and 0.6-2.1 mg/kg, respectively.

Botnen *et al.* (1992) found highly variable concentrations of organic matter in sediments from Norwegian inshore sediments. The sediments were described as fine sands to clay with LOI values from 6.75 to 26.50 %. The maximum value was from a sample that contained a large amount of decaying seaweed and is a good example of the importance of homogenization by sieving before analysis. Otherwise the sediment values were comparable to the values found in Faroese inshore waters.

From the examples mentioned above, it may be concluded that chemical variable

values from sediments in the Faroe area are within the same range as comparable areas in Norway and south of the Faroe-Shetland Channel. Deep sea data from the Vøring Plateau showed higher organic content, compared to both the Faroe area and the south of Faroe-Shetland Channel area, while regional data from the Norwegian sector of the North Sea showed a remarkably low organic content in the sediments. Moreover, zinc and copper concentrations were also low. These examples demonstrate the importance of baseline surveys for general area descriptions.

References

Bloch, D., Hansen, B., Joensen, H.P. and Poulsen M. 1986. *Fjarðakanningar 1985*. Report. 343 pp.

Botnen, H.B., Tvedten, Ø. and Johannesen, P.J. 1992. Resipientundersøkelse av oppdrettslokaliteterne ved Turøy, Haverøy, Skorpeosen og Videneskvarven, Fjell kommune. *Institut for fiskeri- og marinbiologi – Dept. of fisheries and marine biology*. Report. 45 pp.

Bruntse, G. and Tendal, O.S. (eds). 2001. Marine biological investigations and assemblages of benthic invertebrates from the Faroe Islands. *Kaldbak Marine Biological Laboratory*. Report. 80 pp.

Environmental and Resource Technology, Ltd. 2000. BP Foinaven (UKCS Blocks 204/24a and 204/19) seabed environmental survey. *Environmental & Resource Technology Ltd*. Report.

Gaard, E. 1990. Sedimentering og niðurbróting av lívrunnum evnum. *Fiskirannsóknir*. 6: 156-187.

Gaard, E., Hansen, B. and Poulsen, M. 1992. Ecological Studies of phytoplankton in a Faroese fjord. ICES CM L: 3, 21 pp.

Grøsvik, B.E., Bjørnstad, B., Nævdal, A., Westerlund, S. and Endre, A. 2000. A baseline study of Greenland halibut off the Faroe Islands. RF – *Rogaland Research*. Report. 85 pp.

Hansen, B. and Østerhus, S. 2000. North Atlantic-Nordic Seas exchanges. *Progress in Oceanography* 45: 109-208.

Hoydal, K. and Dam, M. 2004. Føroya umhvørvi í tølum 2003. *Heilsufrøðiliga Starvsstovan*. p 63-65.

Jensen, T., Bakke, S.M., Faksness, L.-G., Gjøs, N. and Oreld, F. 1999. Grunnlagsundersøkelse Vøring – Miljøundersøkelse på dypt vann 1998. *Det Norske Veritas*. Report. 61 pp.

Johansen, A. 2006. Støðiskanning av føroyskum firðum – Metal og tøðevni í botnsedimenti. *Heilsufrøðiliga Starvsstovan*. Report. 25 pp.

Josefson A. 2001. Macrofauna in soft sediments on the Faroe shelf. In: Bruntse G. and Tendal O.S. (eds). Marine biological investigations and assemblages of benthic invertebrates from the Faroe Islands.. *Kaldbak Marine Biological Laboratory*. Report. 39-43.

Kaldbak Marine Biological Laboratory. 2006. Benthic Investigation around the Exploration Well Brugdan – August and October 2006. *Report*. 41 pp.

Mannvik, H.-P. and Petersen, A. 2002. Enviromental Baseline Study in the Faroe Channel, 2001. *Akvaplan-niva report* nr. APN-411.2201.

Mannvik, H.-P., Petersen, A., Lyngmo, V., Mikkola, F. and Lie Gabrielsen, K. 2002. Enviromental monitoring survey of oil and gas fields in Region II, 2000 – Summary Report. *Akvaplan-niva report* nr. APN-411.1890. 111 pp.

Tendal, O.S., Brattegaard, T., Nørrevang, A. and Sneli, J-A. 2005. The BIOFAR 1 programme: Background, accomplishment and some outcome from inter-Nordic benthos investigations around the Faroe Islands (NE Atlantic). *BIOFAR proceedings* 2005: 9-32.

Waagstein, R. and Rasmussen, J. 1975. Glacial erratic from the sea floor south-east of the Faroe Islands and the limit of glaciation. *Fróðskaparrit* 23: 101-119.