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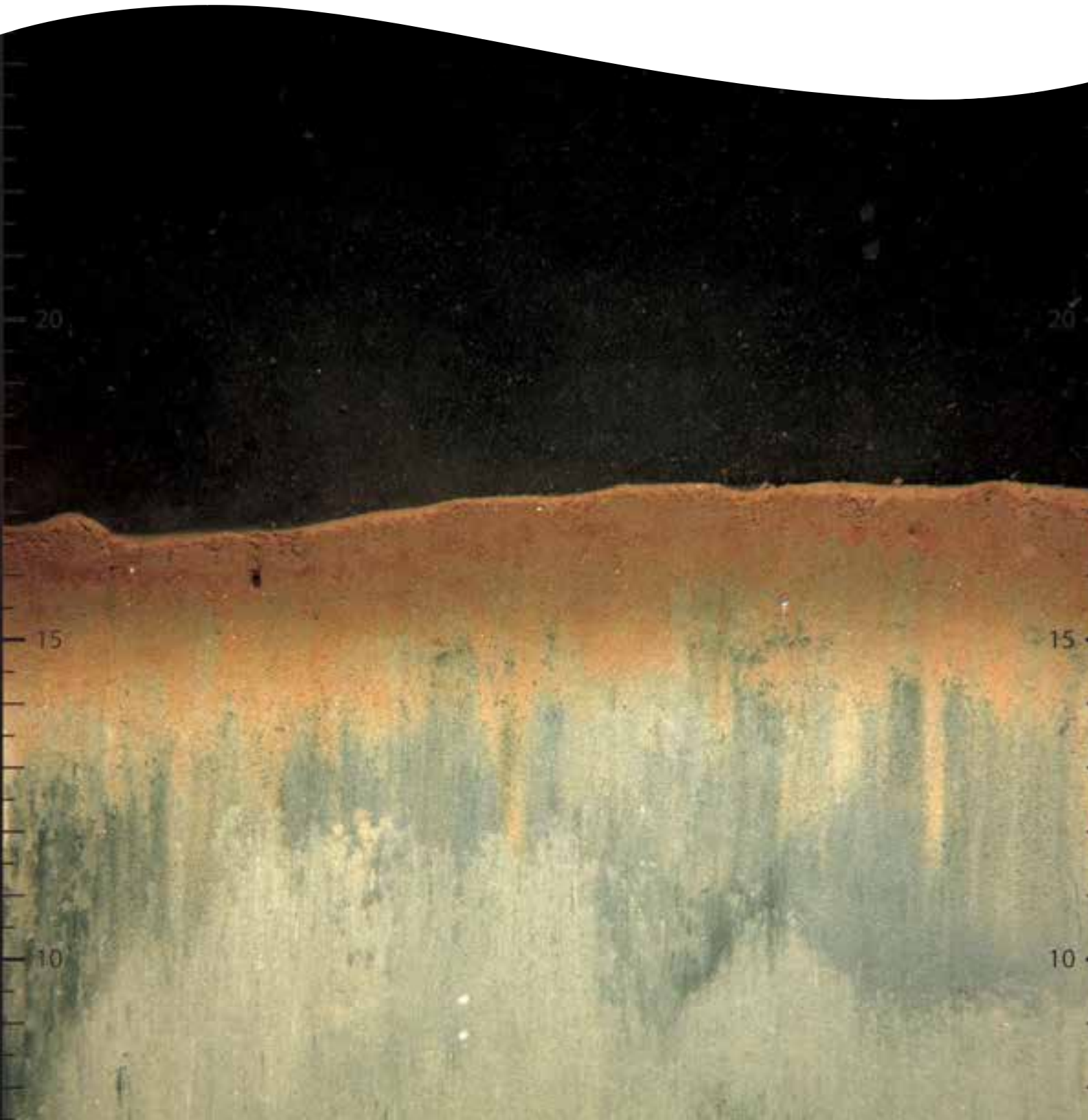
Thin layer capping of fjord sediments in Grenland. Chemical and biological monitoring 2009-2013



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REPORT

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Abstract

A field experiment on thin layer capping was initiated in the Grenland fjords in September 2009. A primary objective of the field experiment was to assess the capacity of the different cap designs to reduce bioavailability of dioxins as well as the disturbance and recovery expected of the benthic habitat and macrofauna communities. The test fields were investigated in samples collected in 2009, shortly after capping, and in 2010, one year after capping. The bioavailability was determined in box-cores transferred from the test fields to a mesocosm laboratory for *ex situ* measurements of uptake of dioxins in sediment-living organisms and passive samplers exposed in the overlying water. The results showed that caps containing activated carbon effectively reduced the bioavailability of dioxins, but adverse effects were found on benthic communities. In one of the two test fields treated with activated carbon, the community severely deteriorated during the first year after capping. In order to follow the further succession of the benthic community and the degree of sustainment of dioxin immobilization, extended monitoring was performed in 2012 and 2013, 3-4 years after cap placement. Here we report the results from this latter investigation and compare with the results obtained in the previous investigations. The new results confirmed maintenance of positive effects of activated carbon on the bioavailability of dioxins. The benthic habitat appeared to have improved since 2010, but adverse effects were still present in the macrofauna communities, in particular at one of the test fields treated with activated carbon at which recovery appeared to have stagnated at about two years after cap placement.

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1. Tiltak	1. Remediation
2. Dioksiner	2. Dioxins
3. Bunnfauna	3. Benthic macrofauna
4. Felteksperiment	4. Field experiment

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Thin layer capping of fjord sediments in Grenland

Chemical and biological monitoring 2009-2013

Forside: SPI-bilde fra felt i Ormerfjorden tatt 3 år etter tildekking med leire og aktivt kull.

Preface

In September 2009, thin layer capping was performed in 4 test fields in Eidangerfjorden and Ormerfjorden, Grenland, and monitoring was maintained until May 2011 under the three projects *Opticap* (NGI), *Thinc* (NIVA), and *Carbocap* (University in Stockholm). The first period of observations showed the need for a prolonged investigation period and an extended monitoring program was granted by the Norwegian Environment Agency in the autumn of 2012 and co-funded by Hydro (17 additional fauna samples). In this program, NIVA was responsible for characterization of benthic habitats and measurements of the bioavailability of dioxins. Stockholm University (SU) was subcontracted for macrofauna investigations. Field surveys were conducted in 2012 and 2013 using RV Trygve Braarud, UiO. This report is a joint NIVA&SU report which primarily describes data obtained in 2012 and 2013, but data back to before cap placement has been included in the time series presented and considered in discussions and conclusions. Bjørnar Beylich has been responsible for the SPI investigations and BHQ index assessment. Caroline Raymond, SU, was responsible for macrofauna. Morten Schaanning was project manager and responsible for the measurements of dioxins in organisms and passive samplers. Espen Eek was project manager at NGI and Hilde Beate Keilen liaison at the Environment Agency.
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Oslo, 15.09.2014

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Summary

A field experiment on thin layer capping was initiated in the Grenland fjords in September 2009. In Eidangerfjorden one field of 40 000 m² at 95m depth was capped with 1-2 cm dredged clay mixed with activated carbon. A similar cap was applied to one field of 10 000 m² at 30m depth in Ormerfjorden. In the same area, two other fields of the same size as capped with, respectively, two cm crushed limestone and four cm dredged clay. The limestone was characterized by very low content of organic carbon and a large fraction of coarse (gravel size) particles. Reference locations were established in each fjord, nearby but unaffected by the capping operations.

The capacity of the different cap designs to reduce bioavailability of dioxins as well as the disturbance and recovery of the macrofauna communities was investigated in samples collected in 2009, one month after capping, in 2010, one year after capping and finally in 2012 or 2013, 4 years after capping.

The bioavailability was determined in box-cores transferred in December 2012 to a mesocosm laboratory for *ex situ* measurements of uptake of dioxins in two sediment-living organisms, the polychaete *Nereis diversicolor* and the gastropode *Hinia reticulata* (common dog whelk). Both organisms were collected at a non-contaminated location in the outer Oslofjord and added to each box-core sample. After exposure times of 3-5 months, the organisms were recollected and mixed samples of 10-20 individuals of each specie was analyzed for dioxins (i.e. polychlorinated dibenzo-*p*-dioxins and dibenzofurans or PCDD/F). Passive samplers were simultaneously exposed in the overlying water for measurements of dioxins leaking out from the sediments. During these measurements the water was slowly exchanged with sea water supplied from 60m depth in the outer Oslofjord, stirred to avoid stratification and aerated to avoid oxygen deficiency.

Macrofauna was analyzed in 3-5 grab samples from each field. Supplementary assessment of the benthic habitat was done from analyses of SPI-images (Sediment Profile Image) at 9-16 stations at each field. Additional four (total 7) SPI-surveys were performed for better documentation of the succession at each field.

Bioavailability was determined as the ratio of dioxin concentration in polychaete, gastropode or passive sampler exposed in box-cores from the capped fields divided by the corresponding concentration (same matrix, same time) in box-cores from the reference location. In total 10 such ratios were determined at each field. In 2009 only gastropods were exposed. In 2010 all three matrixes were analyzed and in 2013 all three matrixes were analyzed in duplicate box-cores from each field.

Statistical analyses showed significantly reduced bioavailability at both fields treated with activated carbon mixed with dredged clay (AC/clay). The mean ratios were 0.288 in Eidangerfjorden and 0.309 in Ormerfjorden, corresponding to reduction of bioavailability of 71.2% and 69.1%, respectively. The cap efficiency decreased for the gastropods from about 80% in 2009 and 2010 to about 60% in 2013. For the polychaetes and passive samplers, however, the efficiency had not changed between 2010 and 2013. It was argued that this difference was a result of the snails being more exposed to dioxins via food uptake, whereas the polychaetes and passive samplers are more controlled by concentrations of dioxins in the surrounding water.

At the field treated with crushed limestone the mean ratio was 1.62. This showed an unexpected, but statistically significant increase of dioxin bioavailability. Low (near zero) concentration of organic carbon and less diffusion resistance in the coarse lime stone material added are both factors which may tend to increase bioavailability of dioxins. At the field treated with dredged clay only, the ratio was 0.758 and not statistically different from the reference field. This cap material was very similar to the sediments at the reference location both with regard to organic carbon and grain size distribution.

Mirroring the results on cap efficiency with regard to dioxin retention, both SPI and macrofauna investigations showed adverse effects of the activated carbon treatments, but in spite of the 2-4 times thicker layers of crushed limestone and dredged clay, only minor disturbances were found at these two fields. The main findings from the macrofauna investigations were:

- In Eidangerfjorden, the ecological classification based on various biodiversity indices showed good or very good conditions at all fields and all surveys. The indices were, however, consistently lower at the field treated with AC/clay than at the reference field and both indices showed minimum values at the AC/clay treatment in 2010, one year after capping.

- In Ormerfjorden, at the reference fields and fields treated with crushed limestone or clay, the biodiversity indices showed good or moderate conditions throughout the experimental period.
- In Ormerfjorden, at the AC/clay treatment the conditions deteriorated from good or moderate conditions in 2009 to bad or very bad in 2010.
- In Ormerfjorden, at the AC/clay treatment the conditions improved during the last period to poor or moderate conditions in 2013.
- In both fjords, macrobenthic communities at fields treated with AC were still disturbed 4 years after capping and biomass was at a minimum level,
- but colonization with small, opportunistic species indicated that recovery had begun.
- Filter feeders (e.g. brittle stars) and echinoderms (e.g. *Brissopsis lyrifera*) appeared particularly vulnerable to activated carbon. The fact that these organisms were much more abundant at the shallow test fields in Ormerfjorden might explain the more adverse effects in this fjord compared to the deeper field in Eidangerfjorden.

The SPI investigations confirmed maximum disturbance of the benthic habitat in 2010, one year after cap placement. Surveys in May 2011 and December 2012 showed gradually improved conditions in Eidangerfjorden and at the final survey in October 2013, the habitat was not clearly different from pre-cap conditions and reference location. In Ormerfjorden, however, the recovery of the benthic habitat appeared to stagnate after the survey in May 2010. Thus a high degree of consistency was found between the macrofauna and SPI investigations.

The powdered activated carbon used in these caps had a particle size of about 20 μm which is a typical size of the particles captured by filter feeders. Also, activated carbon is known to bind to dissolved and suspended food items. Thus disturbance of feeding behavior and food uptake appeared to be the most likely explanations to the effects observed on the benthic communities.

Follow-up investigations are recommended to assess the maintenance of cap efficiencies and to ascertain that continued recovery of the benthic communities will occur.

1. Introduction

1.1 Objectives

The primary objective of thin capping is to develop a method to reduce the release of contaminants from sediments to fjord water and biota. As a supplement to theoretical modeling and small scale laboratory and mesocosm experiments, a field experiment was conducted to test the technical and engineering challenges of cap placement and cap performance on a real seabed.

Because the thin cap method is intended for remediation of large areas with potentially high ecological status, a secondary objective of the field and mesocosm experiments was to assess the changes imposed by thin caps on benthic community composition.

Previous results from the field experiment have been reported in Schaanning et al., 2011 and Schaanning and Allan, 2011. This report address primarily the investigations performed 3-4 years after capping, but results from the previous investigations are included when relevant.

1.2 The field experiment

The test fields were established in September 2009. Field codes and brief description of treatments and obtained cap thickness are given in **Table 1** Locations are shown in **Figure 1**. A complete description of the capping operation is given in Eek et al., 2011.

In Ormerfjorden, 3 fields of 10 000 m^2 at 24-32 m depth were treated with 1) gravel supplied from the limestone quarry operated by Norsk Avfallshåndtering (NOAH) at Langøya, 2) silty-clay sediments suction-dredged at 10-20 m depth in a nearby location and 3) sediments dredged from the same location amended with 2 kg m^{-2} activated carbon. A fourth field was left untreated for control purposes. At the dredging site, the moderately contaminated top layer (ca 1 m) was suctioned off and shipped to a land-deposit before dredging sediments for the capping operation (Eek et al., 2011).

In Eidangerfjorden, one field (FE5) of 40 000 m^2 at 92-96 m depth was capped with suction-dredged silty-clay sediments amended with 2 kg m^{-2} activated carbon. In this fjord the reference location was situated at 85 m depth to the north of the test field. Trawling is a regular activity in Eidangerfjorden. In understanding with the local fishermen, FE5 is not trawled during the field experiment and the reference field is beyond reach of the trawling gear due to topographic restrictions.

Table 1. Field names and treatments. Mean cap thickness ± 1 standard deviation as given in Eek et al., 2011.

Fjord	Field	Treatments	Cap thick-ness (cm)	Typical depth (m)	Field Area (m^2)
Ormerfjorden	FO 1	Crushed limestone	2.1 ± 1.2	30	10 000
Ormerfjorden	FO 2	Dredged clay	3.7 ± 1.1	30	10 000
Ormerfjorden	FO 3	Active Carbon in clay	1.1 ± 0.6	26	10 000
Ormerfjorden	FO 4	Reference	-	30	-
Eidangerfjorden	FE 5	Active Carbon in clay	1.2 ± 0.3	95	40 000
Eidangerfjorden	FE 6	Reference	-	85	-

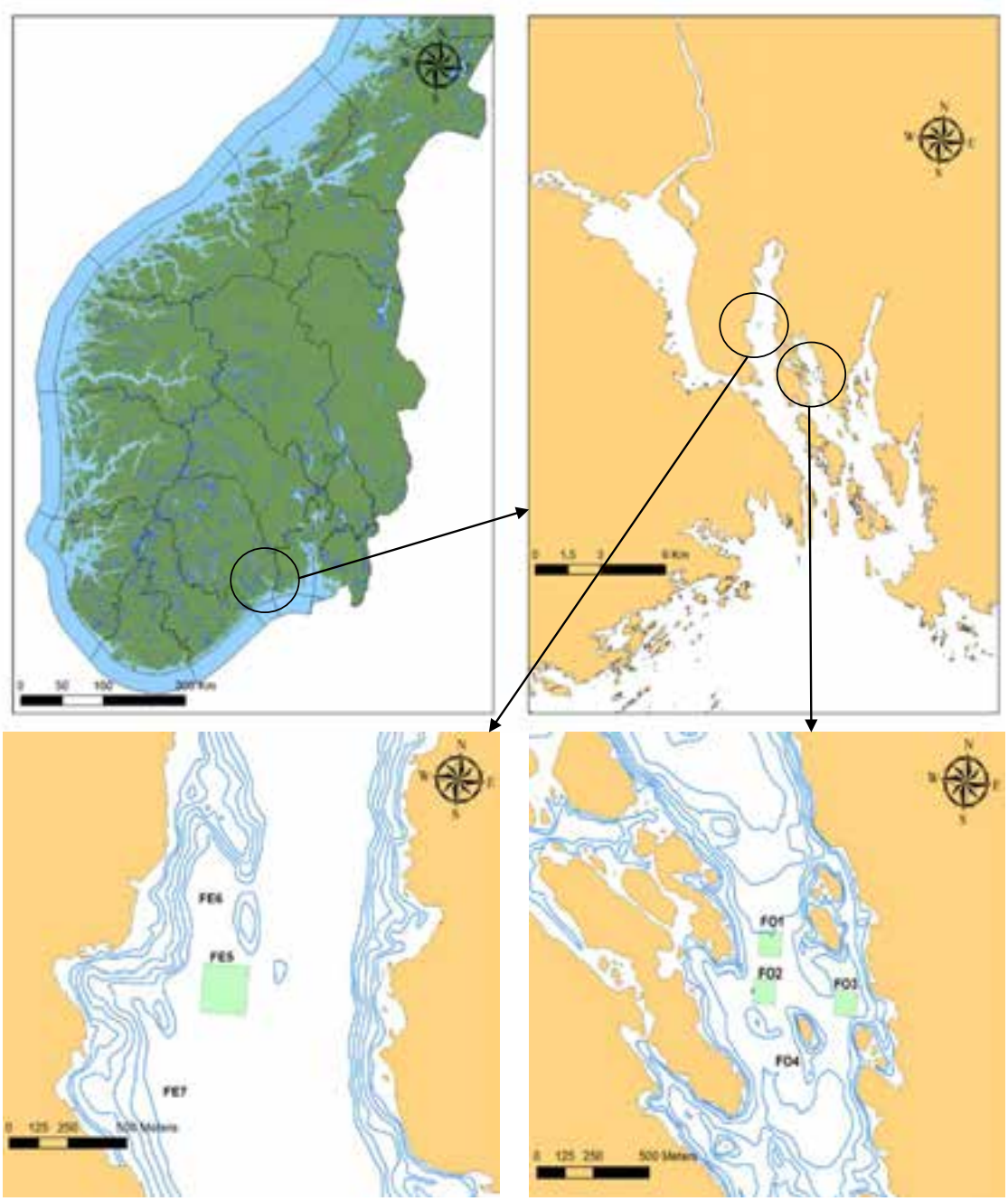


Figure 1. Map showing the Grenlandfjord area (top) and test plots in Eidangerfjorden (low left) and Ormerfjorden (low right).

2. Bioavailability

2.1 Method

2.1.1 Box-core sampling and mesocosm set-up

Two box-core samples were sampled from each of the test plots 5.- 6.12.2012 and transferred to the Solbergstrand mesocosm. The samples were collected with a 0.1 m² KC-Denmark™ box corer with transparent polycarbonate liners attached inside the steel box. On deck, a steel sheet was inserted at the base of the liner to provide the bottom of the box core sample. The liner with

apparently undisturbed cap and approximately 30 cm of layered sediment with inherent organisms and niches, was released from the steel box and placed on deck. The overlying water was removed through a siphon to reduce erosion of the sediment surface during transportation and handling. A lid was placed on top of the liner and the boxes were stored on deck until transport to the research station at Solbergstrand. Because of the unusual cold weather (-4- -8ºC), the cores were placed on a warm deck and covered with insulation blankets until transportation to the mesocosm facility. The transport was done in a closed van and all boxes were submersed in mesocosm sea water less than 12 hours after sampling. Benthic infaunal species often respond to stress from oxygen deficiency or contaminant exposure by escape to the sediment surface. No such behavior was observed in the boxes throughout sampling and transfer to the mesocosm.

In the mesocosm (Berge et al., 1986), artificial light and a continuous supply of fjord water from 60 m depth (Skagerrak/Outer Oslofjord) were used to maintain an experimental environment resembling the conditions at the fjord sampling locations, i.e. dim light, temperatures of 8-10°C, salinities of 34-35 PSU and 7-9 mg O_2 L^{-1}. The water overlying the sediments in each box was continuously exchanged with the fjord water to maintain high (>60%) degree of saturation with O_2.

Throughout the period of measurements, the boxes were continuously flushed with the sea water supplied from the fjord at a rate of 0.5-1 ml min^{-1}, and an airlift system (Schaanning et al., 2006) ensured a well-mixed and oxygen saturated overlying water. In addition to the 12 box-cores with field sediments one empty box was integrated in the set-up with identical aeration and water exchange.

2.1.2 Exposure and sample preparation

The present box-core study is a follow-up of previous studies on the experimental fields established in September 2009. An overview of all box-core measurements performed on sediments from this field experiment is shown in **Table 2**. Polychaetes were collected from a tidal flat on the western side of Jeløya, Outer Oslofjord in November 2012 and stored in sediment aquaria until transfer to the box-core samples 27.12.2012, 20 individuals to each box. Gastropods were not found in November 2012 and could not be found until May 2013 when ca 400 individuals were captured on the same tidal flat and 20 added to each box. All organisms were retrieved 13.-15.08.2013 by careful washing of the sediment through sifts down to 1 mm mesh size. The gastropods were dismantled and soft-tissues from the snails recaptured from each box were quickly rinsed in sea water, blotted dry and transferred to prebaked glass containers. The polychaetes were left overnight for depuration in glass beakers with ca 250 ml sea water, blotted dry and transferred to prebaked glass containers.

Passive samplers (SPMD's) were exposed in the overlying water in each box during the period 10.01.-13.04.2013. An experimental blanc was simultaneously exposed in the box without sediments, and a laboratory blanc from the same batch of SPMDs were stored at 4ºC in the metal container together with the empty containers assigned to each of the SPMD's exposed in the experimental boxes. The SPMDs were mounted on a stainless steel rack strapped on to the lid of each box. On retrieval, the SPMDs were carefully rinsed in sea water and blotted dry on soft paper tissues before being put back into the metal boxes in which they were delivered.

2.1.3 Calculation and units

In the organisms, unit of bioaccumulation is expressed in pg g^{-1} wet weight. For the passive samplers the uptake depends primarily on the sediment area and the time of exposure. Assuming saturation of the membranes was not approached during exposure, the uptake will increase with increased sediment area and period of exposure. Dividing the total uptake by sediment area and time of exposure the membranes provide a flux measurement expressed as pg m^{-2} day^{-1} (Josefson et al., 2012).

An estimate of the uncertainty of the box-core method was calculated for the duplicate boxes transferred to the mesocosm in 2012 which showed a relative deviation from the means 32,6%.

Table 2. Overview of all mesocosm measurements performed on sediments sampled in box-core liners at the experimental fields for thin-layer capping established in Ormerfjorden and Eidangerfjorden in September 2009

	2009	2010	2012
Maintenance in mesocosm	15.10.2009-7.1.2010	11.11.2010 - 9.7. 2011	6.12.2012 - 15.8.2013
Number of cores	2x6	3x6	2x6
Passive sampler	none	LDPE Dec.10-Mar.11 n=6 pooled, Umeå	SPMD Jan.13-Apr.13 n=12, Ökometric
Hinia reticulata	30 ind. Nov.09 - Jan.10 n=6 pooled, Umeå	20 ind. added/box May.11 - Jul.12 n=6 pooled, Umeå	20 ind. added/box May.13 - Aug.13 n=12, Ökometric
Nereis diversicolor	none	20 ind. added/box Nov.10 - Jul.12 n=6 pooled, Umeå	20 ind. added/box Dec.12 - Aug.13 n=12, Ökometric

2.1.4 Chemical analyses

All samples were stored at -20ºC until shipment to the laboratory in Germany (Ökometric Gmbh, Bayreuther Institut für Umweltforschung). Typical detection limits are shown in **Table 3**. Toxicity equivalents were calculated using conversion factors given by World Health Organisation, 2005.

Results from the analyses of air blanks (**Table 3**) showed that all components were less than detection limits in the SPMD samplers. The experimental blank revealed some uptake of furans (<7.5 pg) from the Oslofjord (60 m) water flowing through the empty experimental box, but the dioxins were below detection limits. In the two boxes with sediments from the AC-clay capped sediments the uptake of dioxins was close to or below detection limits, whereas some uptake of furans was found. In the uncapped reference area, most components were well above detection limits.

Table 3. Amount of contaminants in SPMD's exposed 10.1.-16.4. 2013, in mesocosm laboratory air 1m above the water surface (Air blank), in box-core liner without sediments (experimental blank) and in duplicate box-cores from capped and uncapped test plots in Eidangerfjorden. Unit = pg/SPMD.

	Air bl.	Exp. bl.	AC-clay		Reference	
			FE5a	FE5b	FE6a	FE6b
2,3,7,8-TCDD	< 0.5	< 0.5	< 0.5	< 0.6	< 0.8	< 0.5
1,2,3,7,8-PeCDD	< 0.5	< 0.5	< 0.5	< 0.8	< 0.9	1.5
1,2,3,4,7,8-HxCDD	< 0.5	< 0.5	< 0.6	< 0.5	1.2	1.6
1,2,3,6,7,8-HxCDD	< 0.5	< 0.5	1.2	< 0.6	2.2	2.6
1,2,3,7,8,9-HxCDD	< 0.5	< 0.5	1.0	< 0.5	0.9	2.2
1,2,3,4,6,7,8-HpCDD	< 2.5	< 2.5	5.2	< 4	9.8	19.3
OCDD	< 5.0	< 5.0	< 6.0	< 6.0	7.1	17.7
2,3,7,8-TCDF	< 0.5	3.9	6.9	4.8	19.5	15.4
1,2,3,7,8-PeCDF	< 0.5	2.5	10.5	6.5	21.3	25.0
2,3,4,7,8-PeCDF	< 0.5	1.4	5.2	2.8	11.6	13.0
1,2,3,4,7,8-HxCDF	< 0.5	3.9	22.4	11.7	40.8	59.8
1,2,3,6,7,8-HxCDF	< 0.5	1.9	13.5	5.3	26.6	30.7
1,2,3,7,8,9-HxCDF	< 0.5	< 0.5	< 0.8	< 0.8	2.7	3.7
2,3,4,6,7,8-HxCDF	< 0.5	< 0.8	2.3	1.3	5.2	7.1
1,2,3,4,6,7,8-HpCDF	< 2.5	7.5	35.8	19.8	75.4	108.0
1,2,3,4,7,8,9-HpCDF	< 2.5	< 2.5	5.3	3.8	11.0	14.6
OCDF	< 5.0	< 5.0	33.8	22.1	90.2	238.0

2.2 Results and discussion

2.2.1 Congener distribution

The different sample matrixes showed a high degree of consistency with regard to the congeners contributing to total toxicity equivalents(fig. 3.1). Of the seven dioxin congeners, only pentachlorinated (12378 PeCDD) contributed beyond background levels and only in a few of the boxes. Those were in particular uncapped sediments from Ormerfjorden and the AC-clay treatment in Eidangerfjorden 2009 and 2010.

Thus, total toxicity equivalents resulted almost completely from the furans. 2,3,4,7,8-PeCDF and 1,2,3,4,7,8-HxCDF appeared main contributors, whereas 1,2,3,7,8-PeCDF and hepta- and octa-furans contributed less. **Figure 2** shows that the AC-clay treatments (filled symbols) tend to occur at the low end of the range of observations of all congeners in all matrixes. For the gastropods this tendency was more obvious in 2010 and 2012 than in 2009.

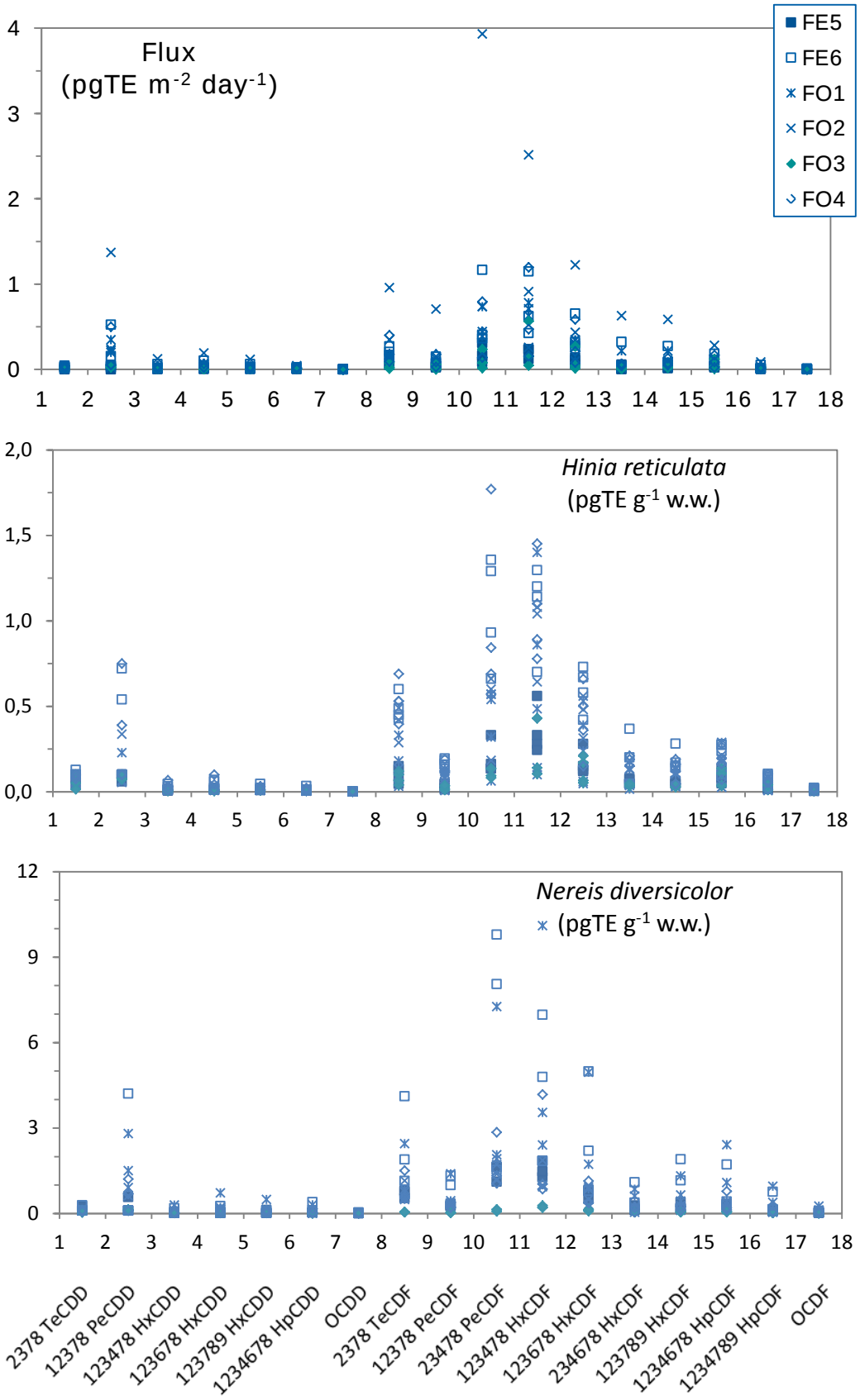


Figure 2. Dioxin and furan toxicity equivalents in passive samplers (top), polychaetes (middle) and gastropods (bottom) exposed in boxcore samples collected in Oct. 2009, Nov. 2010 and Dec. 2012.

2.2.2 Comparison between the two reference locations

At the two reference locations the mean concentrations of dioxins in gastropods exposed to the sediments (± 1 standard deviation) were respectively 4.6 ± 1.0 pg g^{-1} w.w. in Eidangerfjorden and 4.2 ± 0.8 pg g^{-1} w.w. in Ormerfjorden (Figure 3). No clear variations were found with time or between the two locations.

Correspondingly, the fluxes were 2.9 ± 1.8 pg m^{-2} day^{-1} in Eidangerfjorden and 2.2 ± 1.8 pg m^{-2} day^{-1} in Ormerfjorden. The big difference between the two replicate boxes collected in Ormerfjorden in 2012 indicated relative large random errors in these measurements. Comparing the fluxes measured in all duplicate samples (reference and capped fields), the average deviation from field mean was 33.1% (n=6 pairs) which was large compared to the correspondingly estimated uncertainty of 10.7% for the dioxins accumulated in the gastropods. Thus neither the fluxes showed any systematic difference between the two fjord locations or between 2010 and 2012.

In the polychaetes the concentrations of dioxins were often high compared to those determined in the gastropods, but similar to the flux measurements the concentrations in the polychaetes were highly variable. Both the mean concentration of 21.7 ± 13.4 pg g^{-1} w.w. in Eidangerfjorden and 13.4 ± 5.2 pg g^{-1} w.w. in Ormerfjorden and the average deviation of 33.3% from the mean concentration in the duplicate samples from each field (n=6 pairs), showed a variability similarly large as the variability found for the flux measurements. The data shown in Figure 3 indicates higher concentrations in the polychaetes exposed in sediments from Eidangerfjorden than Ormerfjorden. Although not statistically significant, considering all measurements in 2010 and 2012, both mean and median concentrations were higher in Eidangerfjorden (mean=13.9 pg g^{-1}, median=6.7 pg g^{-1}, n=6) than Ormerfjorden (mean=8.3 pg g^{-1}, median=4.9 pg g^{-1}, n=12).

There may be several reasons why the polychaetes accumulate more dioxins than the gastropods. The gastropods feed closer to the surface where concentrations of dioxins in the sediments are lower than in the older sediments deeper down where the polychaetes spend most of their time. The difference may also be explained by the shell protecting most of the gastropod soft tissue from direct uptake from the pore water, and feeding behaviour which for the gastrodpods is dominated by selective ingestion of nutritious food items whereas the polychaetes mostly feed by whole sediment ingestion.

Sediment concentrations of dioxins, and in particular the vertical variation is not well documented, but judging from the available data and mercury proxies (Schaanning and Allan, 2011), the concentrations of dioxins in the sediments should be approximately twice as high in Eidangerfjorden as in Ormerfjorden. The absence of a corresponding difference in dioxin fluxes and tissue concentrations indicated that the dioxins in Eidangerfjorden were less bioavailable. Eek et al. (2011) found higher concentrations of organic carbon in Eidangerfjorden sediments than in Ormerfjorden, and this difference was confirmed in sediments collected in 2012 in which concentrations of 3.30% TOC was observed in a box-core from FE6 as compared to 1.56% at FO4. The bioavailability of organic contaminants is generally known to decrease with increasing abundance of organic carbon. Therefore, the higher TOC-levels in Eidangerfjorden may counteract the higher concentrations of dioxins and explain the lack of a clear difference in bioaccumulation and sediment-to-water fluxes.

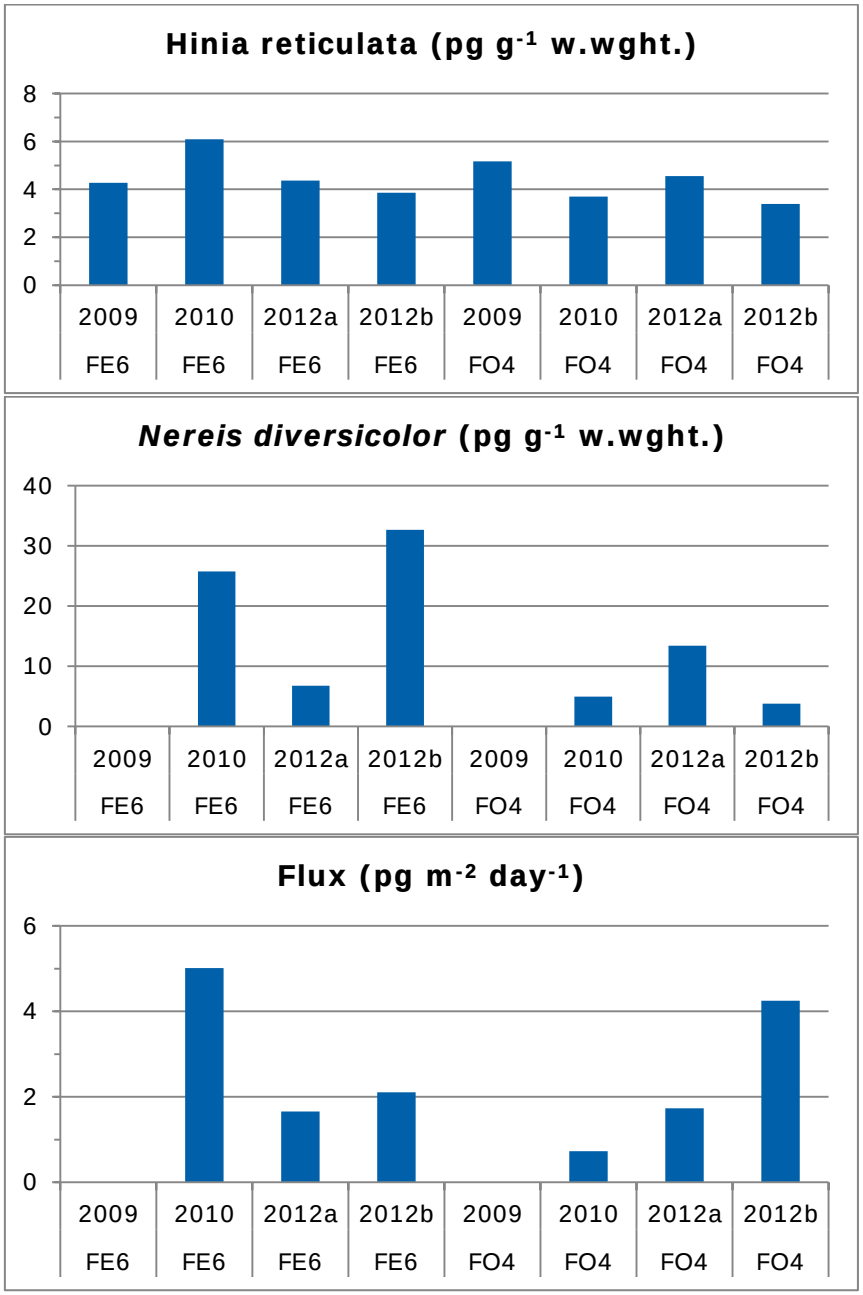


Figure 3. Bioaccumulation and flux of dioxins (SumPCDD/F WHO-TE) at the reference locations in Eidangerfjorden (FE6) and Ormerfjorden (FO4).

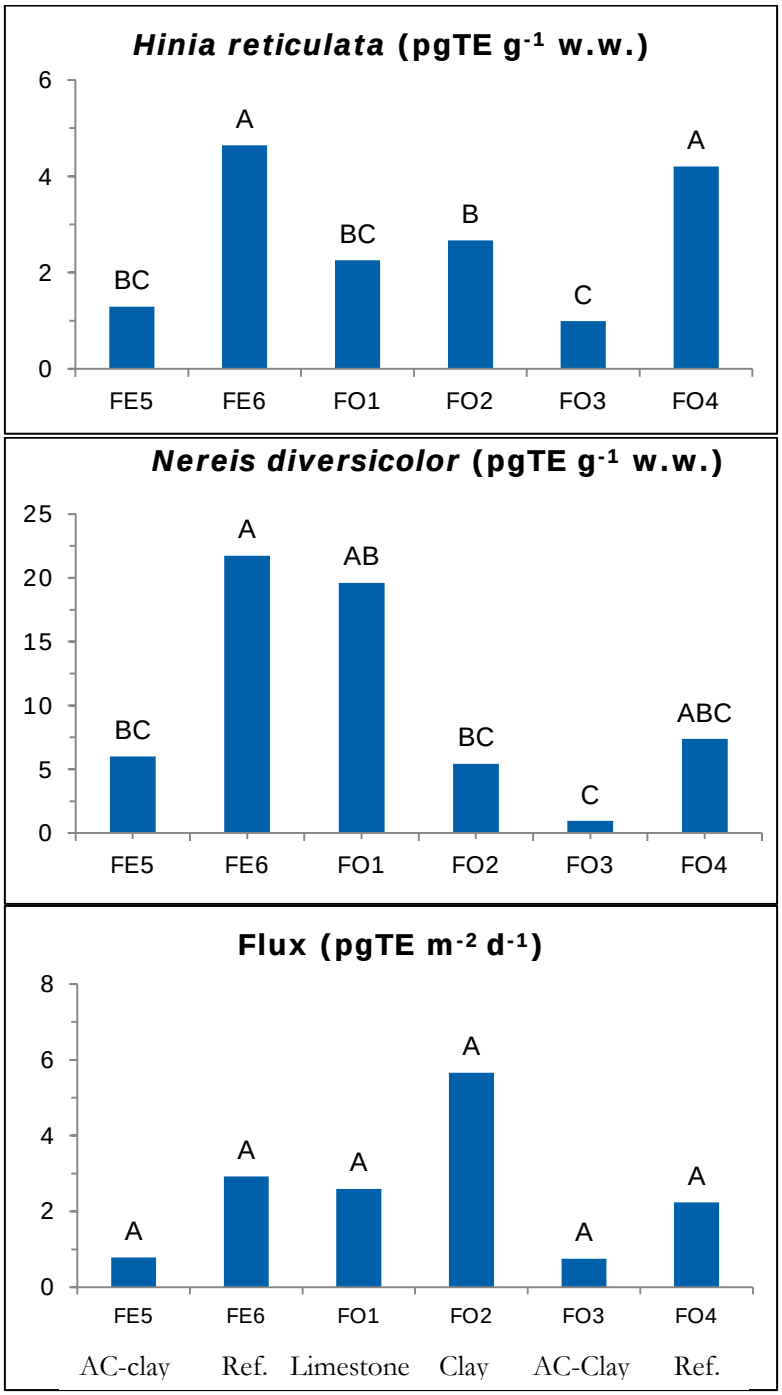


Figure 4. Mean fluxes and concentrations of dioxins in polychaetes and gastropods at the six test fields in Eidangerfjorden (FE) and Ormerfjorden (FO) 0-4 years after thin cap placement. Letters above each bar show the results of one-way analyses of variation (Student's t-test). Bars not connected by the same letter are different at the 0.05 significance level. Analyses of one sample from each treatment in 2009 and 2010, and two in 2012 yielded n=3 for flux and Nereis, n=4 for Hinia.

2.2.3 Cap efficiency

Because of the absence of any clear impact from fjord locations or sampling time on the bioavailability of dioxins, we assume that different cap treatments is the only factor responsible for differences between the various test fields with regard to tissue concentration and fluxes.

The lowest fluxes were observed at the two fields treated with activated carbon, but one-way analyses of variation (ANOVA) showed that the differences between any of the six locations were not statistically significant at the recommended 95% significance level (**Figure 4**, lower diagram).

Similarly, the gastropods (**Figure 4**, upper diagram) showed lower tissue concentrations in the two fields treated with activated carbon, but unlike the fluxes, the gastropods showed lower accumulation of dioxins in all sediments treated with a cap. The statistical comparison showed that all caps provided gastropods with lower concentrations of dioxins than the reference fields. In Ormerfjorden the field treated with a 1,2 cm layer (**Table 1**) of clay spiked with activated carbon (FO3) provided gastropods with significantly less dioxins than the field capped with a much thicker layer (3.7 cm) of clay only.

Also the polychaetes (**Figure 4**, middle diagram) showed low accumulation of dioxins in sediments treated with AC-clay caps. In Ormerfjorden, the AC-clay treatment was significantly lower than crushed limestone treatment, but not significantly lower than the uncapped reference.

Comparison of the results within each of the three sample matrixes showed a very clear tendency that the lowest dioxin toxicities were observed in the AC-clay treatments, but unclear effects of the limestone and clay only treatments. Because of small sample sizes (n=24 for the gastropods, n=18 for polychaetes and membranes) the power of the statistical analyses of the polychaete and flux data was unacceptable. This was shown by a retrospective power analyses which calculates the probability (p) and minimum number of samples (LSN) required for the test to be significant. For the gastropods, p=0.9987 and LSN=12 showed that the actual n=24 had provided sufficient power to accept the results of the t-test shown in **Figure 4**. However, for the polychaetes and flux the power was low (p=0.6587, LSN=19 for gastropods; p=0.298, LSN=37 for the fluxes).

In order to improve the power of the statistical analyses, the data were normalized by dividing each observed flux or bioaccumulation by the respective observation at the reference field in the same fjord and time. The mean of the ten ratios observed at each field (n=10) and the statistical comparison is shown in Figure 5. In this case the total number of analyses was 60, which provided sufficiently high power (p=0.9999, LSN = 39). At the fields capped with AC and clay, the overall efficiencies corresponded to 71,2% reduction of dioxin toxicity equivalents in Eidangerfjorden and 69,1% in Ormerfjorden.

The level of dioxin toxicity equivalents in the samples from the field treated with clay only (FO2) was not significantly different from the corresponding reference location, but interestingly, the toxicity equivalents had increased significantly at the sediments capped with crushed limestone. This was primarily a result of contributions from the flux and polychaete data. The layer thickness was found to be on the average 2.1 cm which was nearly twice the thickness of the AC-clay treatments but only slightly more than half the thickness of clay only (**Table 1**). Compared to the dredged clay, the limestone is a coarser material providing larger pore space and less diffusion resistance. The limestone also contained less organic matter than the other cap materials (Eek et al., 2011). Both factors would tend to favor higher concentrations of dioxins in the pore water of the limestone cap. If the concentrations in the water column is constantly low and the concentrations in the pore water is higher within the limestone cap than on the reference field, concentration gradients between the interstitial and overlying water, and consequently the flux, will be higher. Relatively high pore water concentrations of dioxins could also explain higher concentrations in the polychaetes than in gastropods which are protected from pore water exposure by shells. Compared to the polycheaetes, the gastropods are likely to take up more of the dioxins through their diet. If

they feed selectively on nutritious food items the main food source would be derived from the organic matter settling from the watercolumn at all fields.

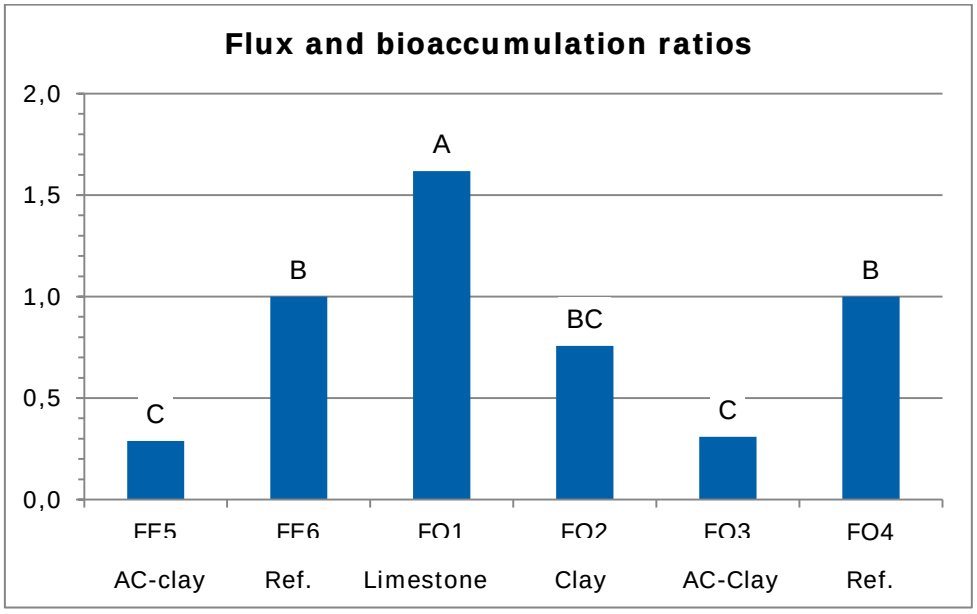


Figure 5. Overall bioavailability at the six test fields in Eidangerfjorden (FE) and Ormerfjorden (FO) 0-4 years after thin cap placement. Letters above each bar show the results of one-way analyses of variation (Student's t-test). Bars not connected by the same letter are different at the 0.05 significance level.

2.2.4 Time trends

Linear regression analyses was used to investigate if there was any significant change with time in the accumulation of dioxin toxicity equivalents at the two test fields treated with activated carbon and clay (Figure 6). The pooled flux and polychaete ratios showed no correlation with time ($R2 = 0.05$), but the gastropods showed a significant upwards trend ($R2 = 0.49$, $p<0.05$). Thus it appears that the effect of the AC-clay cap is slightly less persistent for the gastropods than for the flux and polychaetes. If, as assumed in the previous section, dioxin fluxes and tissue concentrations in the polychaetes are primarily controlled by pore water concentrations of dioxins, whereas dioxin tissue concentrations in gastropods are more controlled by food items, the post cap deposition of dioxins associated with suspended organic particles may be less available to the activated carbon in the cap than the dioxins dissolved in the pore water. These may be more controlled by upwards diffusion from the old sediments below the cap and retained upon contact with the AC-cap layer. The polychaete burrows may be important both as flux channels in the sediment and mixing sites for AC and dissolved dioxins.

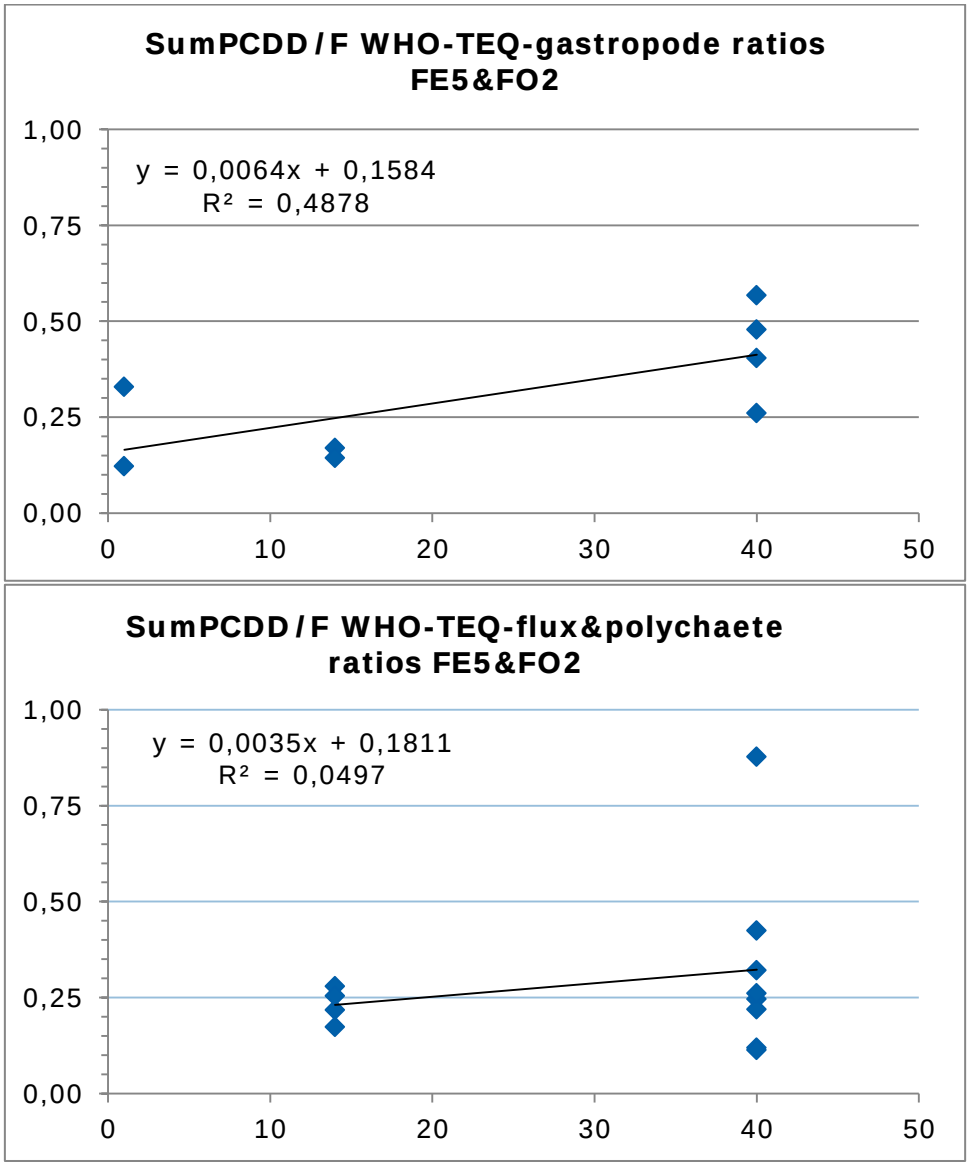


Figure 6. Time trends analysed by linear regression on the dioxin toxicity equivalent ratios in gatsropde Hinia reticulate (top) and passive samplers in water column and the polychaete Hereis diversicolor (bottom). X-axis display box-core sampling in months after capping.

2.3 Conclusions on cap efficiency

- During the period 1-40 months after capping, bioavailability of dioxin toxicity equivalents was measured in 60 samples of polychaetes and gastropods exposed in box-cored sediments and passive samplers exposed in the overlying water.
- The data showed that fjord location and time after capping was less important for dioxin accumulation in the samples than the different cap designs tested.
- Compared to reference locations, dioxin accumulation increased in the crushed limestone treatment. This was related to low concentration (near zero) of organic carbon and less diffusion resistance in the coarse cap material.
- The clay cap neither increased nor decreased dioxin accumulation in the three sample matrixes. This was related to the similarity between the clay cap and reference sediment with regard to grain size and concentration of organic carbon.

- In the AC-clay cap, the average reduction of dioxin toxicity equivalents was close to 70% both in Eidangerfjorden and Ormerfjorden. This was related to immobilization of dioxins adsorbed on the activated carbon.
- During the study period, the passive samplers and polychaetes showed no significant change of cap efficiency, but the gastropods showed a slight decrease from ca 80% in 2009 to ca 60% in 2013. This difference was explained by a high degree of food intake control of dioxin levels in the gastropod and a high degree of pore water controlled level of dioxins in the polychaetes and passive samplers.

3. Benthic habitat quality

3.1 SPI measurements and BHQ index

A digital CMOS camera (Canon D50), was used to take vertical *in situ* photos through a prism (26 x 17,3 cm) as indicated in **Figure 7 (**Nilsson & Rosenberg, 1997). After each deployment, the sediment profile images (SPI) were transferred to a computer and stored. SPI image enhancement and measurement was done in Adobe Photoshop Extended CS4. The depth of the apparent redox potential discontinuity (aRPD) was measured as the distance from the sediment surface to the borderline between rusty brown and green to grey or sometimes even black sediment. In each image the mean aRPD was calculated as the area of aRPD coverage divided by the width of the image, and the benthic habitat quality (BHQ) index was calculated (Nilsson & Rosenberg, 1997). This index parameterises surface structures (faecal, tubes, feeding pit and mounds), sub-surface structures (infauna, burrows, oxic voids) and the aRPD. Each of these properties (surface structure, subsurface structure and aRPD) is scoring up to 5p to a total of 15p as the highest score in an image. The BHQ index is a quick method which allows sampling of a higher number of stations compared to quantitative macrofauna analyses. It is related to the faunal successional stages in the Pearson-Rosenberg model (**Figure 7**) (Pearson and Rosenberg 1978, Nilsson & Rosenberg, 2006).

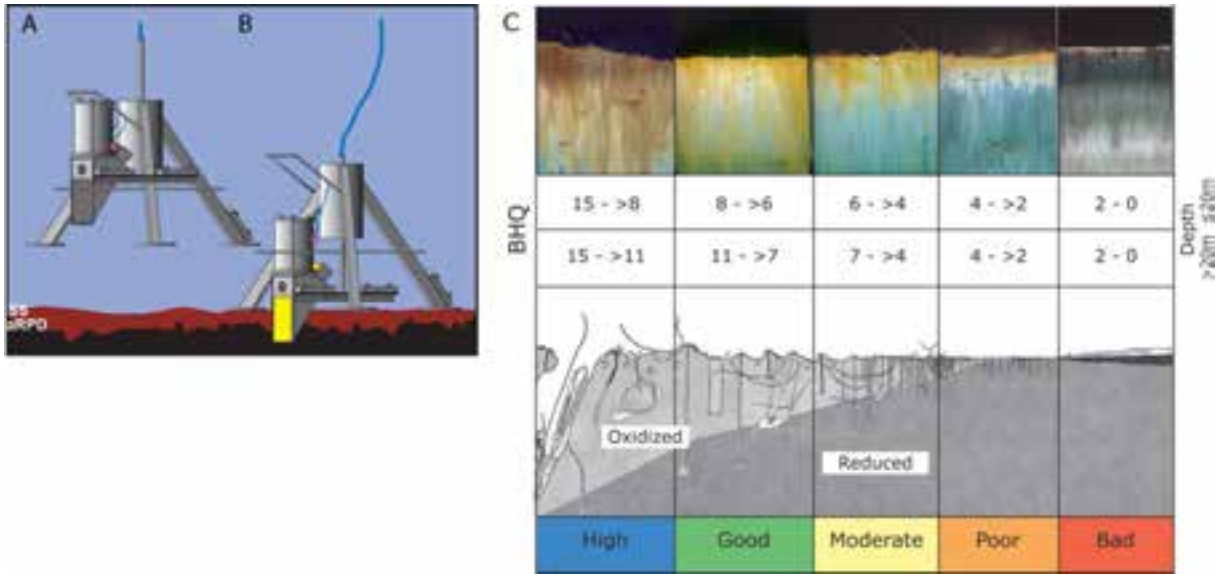


Figure 7. A,B) diagram of a sediment profile camera in operation. C) model of faunal successional stages along a gradient of increasing disturbance and corresponding classification system for the benthic habitat quality index (BHQ). Based on Pearson and Rosenberg (1978), Nilsson and Rosenberg (1997), Rosenberg et al. (2004).

In this investigation, BHQ was determined from 2-3 images taken at each field before capping and at the two reference locations after capping. At the 100x100m capped fields in Ormerfjorden (FO1-3) BHQ was determined from 9 images taken in a 25x25m grid system covering each field. In Eidangerfjorden BHQ was determined from 16 images taken in a corresponding grid system covering the AC-clay field. The grid system (Schaanning et al., 2011) gave a total of 312 BHQ-indices determined at stations evenly distributed over the capped fields.

3.2 Results and discussion

3.2.1 Cap images

The SPI-images from the reference location (FE6) Eidangerfjorden show no clear changes during the study period May 2009-November 2013 (Figure 8). A brownish material is present in a top layer of 3-5 cm layer. This is the bioturbated layer with assumed higher content of organic matter. Below the top layer, the brownish material is occasionally drawn downwards in burrows or other types of bioturbation. Be aware, however, that the apparent downward mixing is occasionally difficult to distinguish from so-called smearing, a process in which material sticks to the glass of the camera housing and follows the glass down during camera penetration. Black spots/areas are visible in some of the images at 10-15 cm depth. The black colour is generally assumed to result from anoxic degradation of organic matter, high rates of sulphate reduction and precipitation of ferrous sulphide.

At the AC-clay field in Eidangerfjorden (FE5) a thin layer of black activated carbon is present on top of the sediment in October 2009, 1 month after cap placement. Black colour below this 1-2 cm layer was found to result from smearing. In May 2010 a few mm of new, brownish material had been deposited on top of the AC-clay layer. Most likely this material has been deposited from the watercolumn, but bioturbation and upwards transport from below the cap may also contribute to the material laid down on top of the cap. The deposited material may be a mixture of new material sinking down from the surface layer and sediments resuspended from basin slopes and deep bottoms and transported to the capped areas by lateral water movements. The remaining photos in this time series shows a steady increasing thickness of this layer from a few mm in 2010 to ca 3 cm in November 2013 corresponding to 7-8 mm/year. This growth rate is high compared to the sedimentation rates of 1-2 mm determined by dated cores from Frierfjorden (Næs, et al., 2004). However the organic matter present in the top layer will be substantially degraded and compacted as it is buried deeper into the sediments. The growth rate of the brownish top layer shown by the photos in Figure 8 is most likely a result of sedimentation of new and resuspended material from the water column and mixing by bioturbation with cap material and old sediments from below the cap. The blurring of the sharp contours of the AC-clay cap in October 2009 supports the idea that the AC-clay cap is extensively mixed into the brow top layer.

In Ormerfjorden, the photos shown in Figure 8 revealed several mounds and hollows indicating activity of larger organisms (e.g. FO4, May 09 and May 11). The lighter surface layer frequently extend downwards 2-3 cm, but the lower boundary is much more variable than in Eidangerfjorden and the apparently lower content of organic matter was confirmed by the chemical analyses cited in ch. 2.2. At FO3 the black AC-clay cap appeared clearly in October 2009 and as in Eidangerfjorden a brownish top layer develops steadily over the following months and years. The thickness was however not more than ca 1 cm by the end of 2013 indicating less input of new material from the water column. This is reasonable as the abundance of suspended particles will increase with increasing depth in this fjord area (Allan, Schaanning and Beylich, 2011).

The thick layer of dredged clay at FO2 was clearly visible in the photos throughout the experimental period. The lighter appearance of the clay cap helped visualizing some very deep burrows in particular in October 2010, but also in 2012 and 2013 deep burrows appears to mix cap material down to 15 cm depth or more.

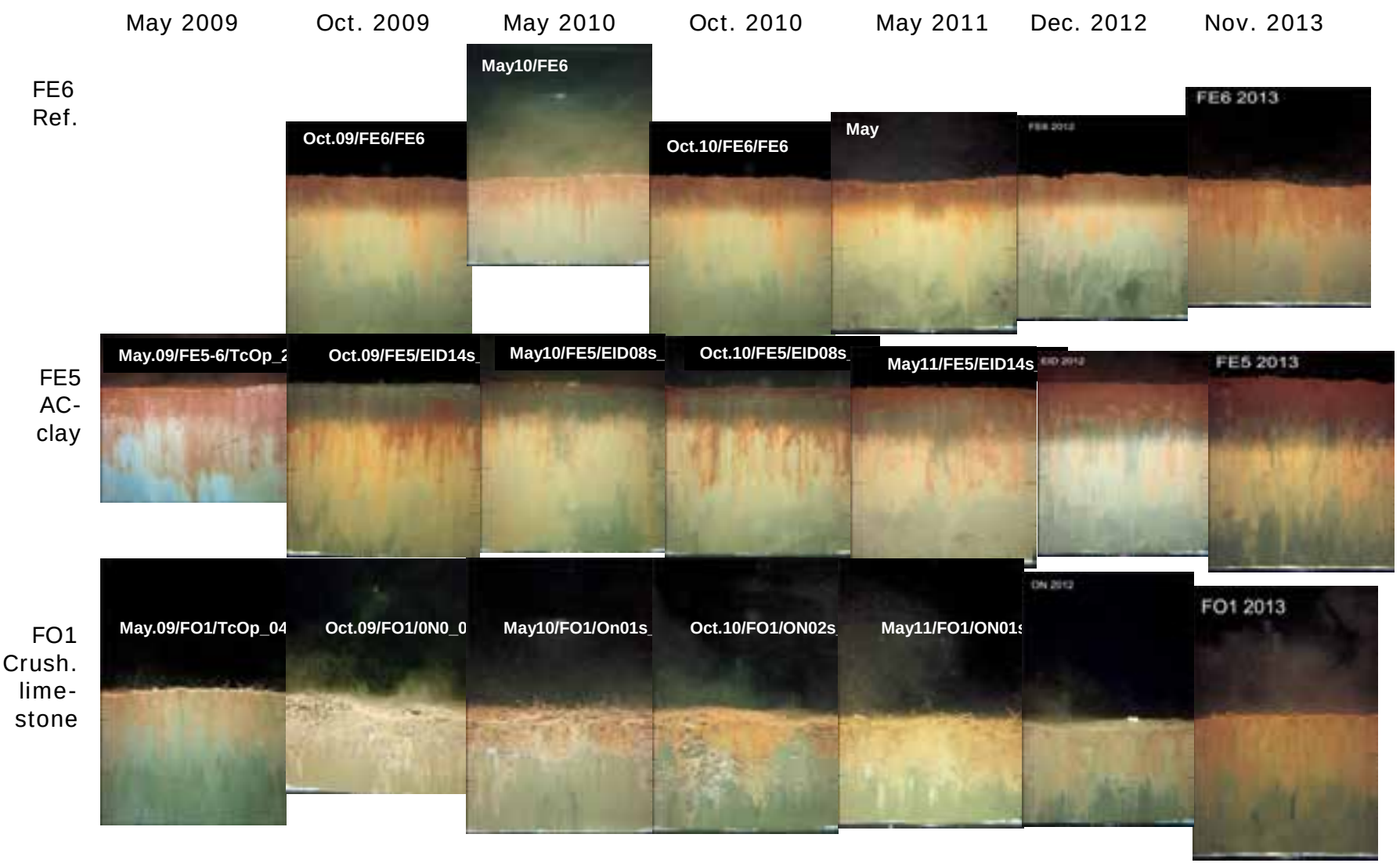
Some very coarse fractions of the crushed limestone are seen in all photos taken after the cap placement in September 2009. The images also show how the space between the coarse material is filled with more fine-grained material, most likely fine fractions of the limestone added. Grain size analyses showed that the crushed limestone was a mixture of ca 50% fine gravel (2-4 mm), 35% sand (0.06-2 mm) and 15% of silt and clay (<0.06 mm) (NGI analyses 2008-04-08) and Hg-analyses showed that mercury concentrations was near zero within the cap layer (Schaanning and Allan., 2012), which it would not have been if ambient fjord sediments had contributed to the fine fractions shown in the images. Evertebrate structures protruding into the water column was visible both before and 8 months after cap placement, indicating rapid colonization of the limestone cap.

3.2.2 BHQ index

In May 2009, before capping, the habitat was classified as "good" on all locations (Figure 9). The indices appeared little affected by the capping operation ca 1 month before the survey in October 2009 and in May 2010 all locations were still classified as "good". During the summer of 2010, however BHQ decreased at all fields, also the two reference fields. The strongest decrease was however, observed at the AC-clay fields resulting in a mean BHQ of 4.4 at FE5 and 4.7 at FO3 (both classified as "moderate"). Statistical comparison of all indices observed in November 2010 showed that the habitats at both AC-clay fields were significantly lower than the reference location in Eidangerfjorden (FE6) and the field in Ormerfjorden treated with clay only (FO2) (Schaanning et al., 2011). The BHQ at the field treated with crushed limestone (FO1) was also low (5.7) but significantly different from the reference field (FE6) only. In May 2011 the indices had increased at all fields, but the two AC-clay fields were still classified as "moderate" and significantly different from the reference fields (Schaanning et al., 2011). From May 2011 to December 2012 and October 2013, the habitat index normalized at FE5, but remained nearly unchanged at "moderate" level at FO3 (Figure 9).

3.3 Conclusions on SPI

- All cap layers were clearly visible in the images throughout the 49 months between the capping event and the last survey in October 2013.
- The cap layers became covered with a brownish top layer increasing from a few mm in May 2010 to ca 1 cm in Ormerfjorden and ca 3 cm in Eidangerfjorden in October 2013.
- At both fields treated with clay and activated carbon, the BHQ index decreased to a minimum value in October 2010, one year after capping.
- In Eidangerfjorden, but not in Ormerfjorden, the BHQ-index normalized to precap values in 2012 and 2013.



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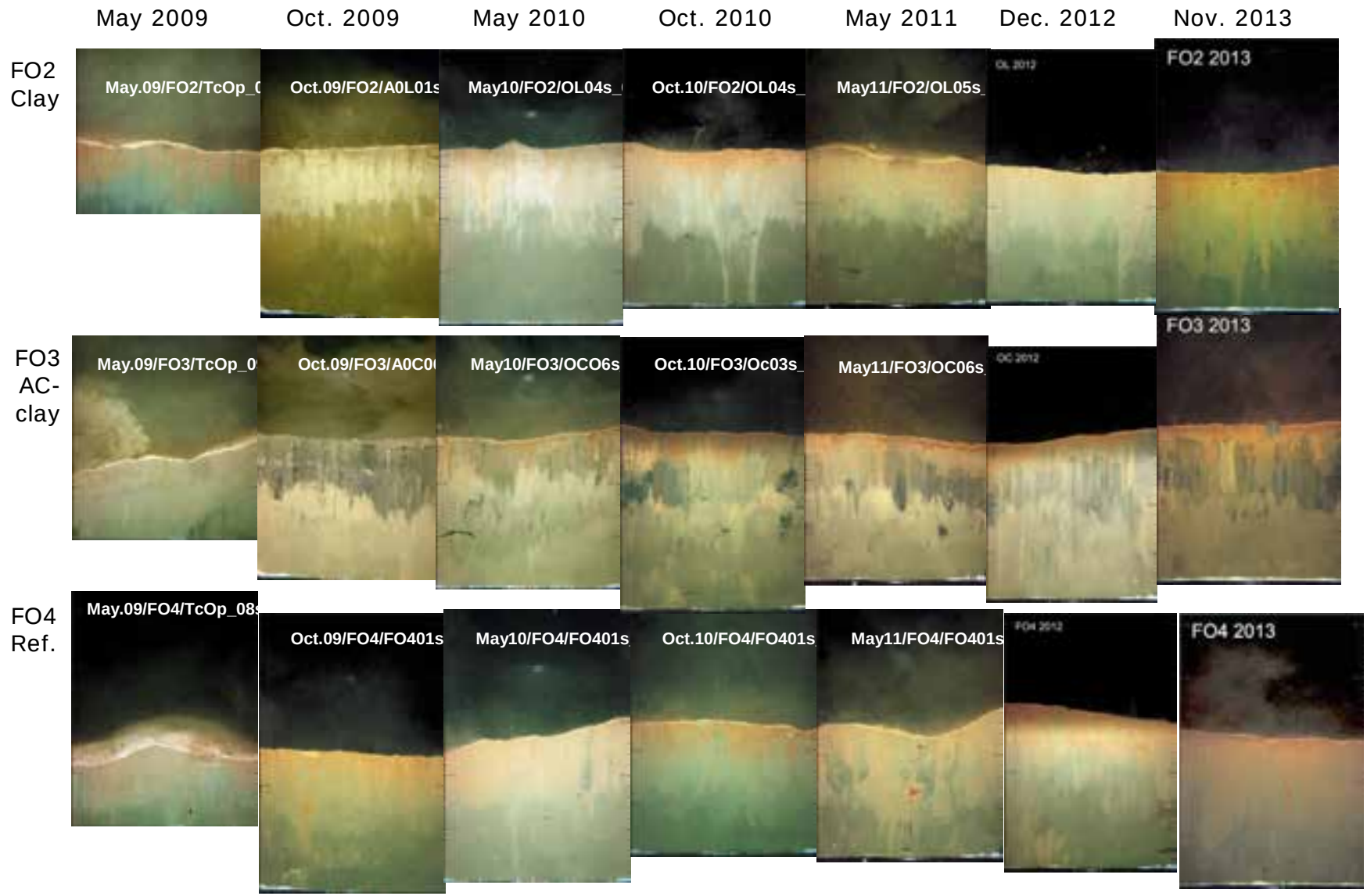

Figure 8. Selected SPI images from experimental fields in Eidangerfjorden and Ormerfjorden. Cap placement performed in September 2009.

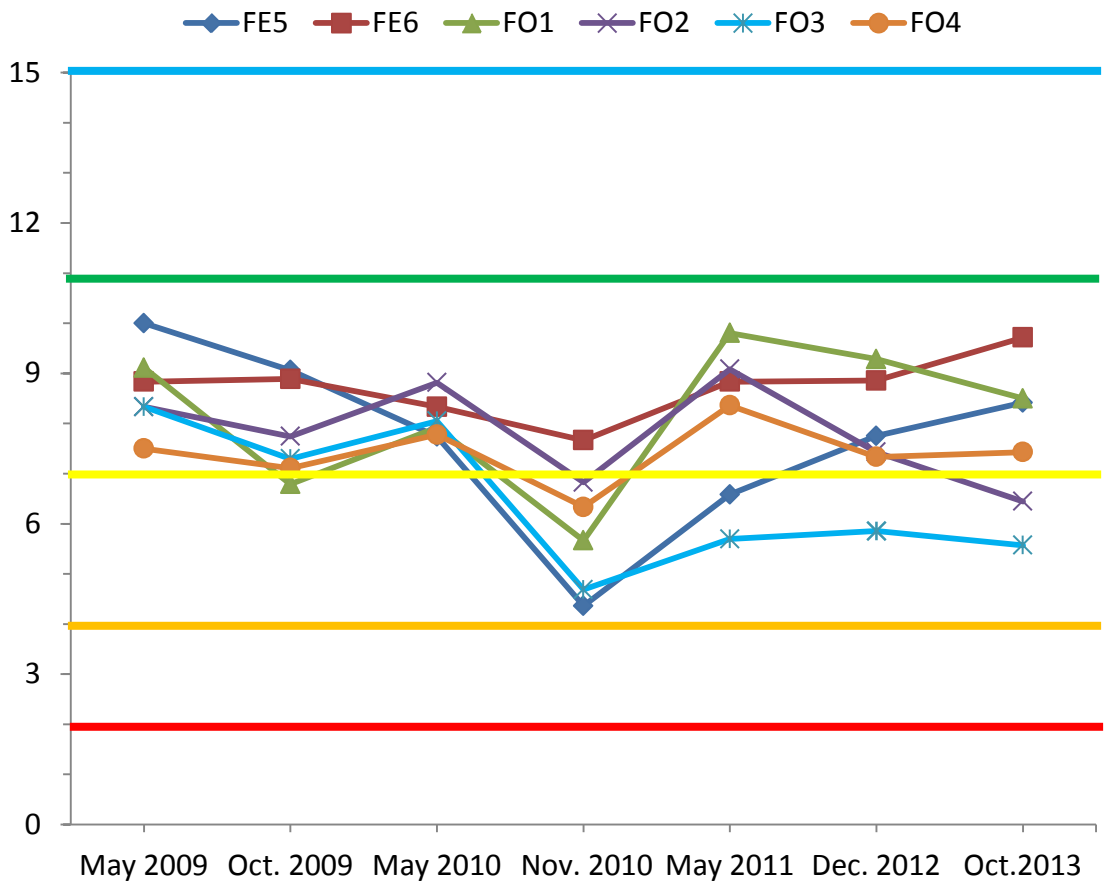

Figure 9. Benthic Habitat Quality (BHQ) index determined from SPI image analyses at reference fields (FE6, FO4) and fields capped with crushed limestone (FO1), dredged clay (FO2) and dredged clay with activated carbon (FE5, FO3). Horizontal lines show classification system from "bad habitat quality"(below red line) to "high habitat quality" (above green line) shown in **Figure 7**. Each point represent mean of 2-16 BHQ values.

4. Benthic macrofauna

4.1 Methods

4.1.1 Sampling

Benthic macrofauna was sampled with a van Veen grab with a sampling area of approx. 0.1 m^2. The grab sample positions were pre-determined and localized with DGPS in the coordinate system WGS-84. One month after capping (October 2009), three replicate grabs were taken per field (n=3). Fourteen month after capping (November 2010), five replicate grabs were taken per field (n=5). Forty-nine month after capping (October 2013), also five replicate grabs were taken per field (n=5). The samples were immediately sieved through a 1 mm mesh size sieve and conserved in 4% formaldehyde (buffered with hexamethylene tetramine) and stored for 3 months before taxonomy identification. All specimens for the major taxonomic groups were with few exceptions identified to species level. Species within the groups Nemertea and Turbellaria cannot be identified as preserved material and were therefore reported as groups. Abundance (number of individuals) and biomass (g wet weight) were determined for each taxon (see Appendix B.). Further, all species were also classified into functional groups based on their feeding strategies, which is analyzed in a complementary article (Samuelsson et al, manuscript in prep.)

4.1.2 Statistical methods

The benthic macrofauna community is strongly variable among fjords depending on factors such as depth, water exchange, current regime, grain size, organic carbon input, salinity, light etc. Therefore, the experiments at 30 m depth in Ormerfjorden and at 100 m depth in Eidangerfjorden were treated separately in all statistical analyses.

Differences among capping treatments were analyzed with permutational analysis of variance (PERMANOVA) (Anderson 2001, McArdle and Anderson 2001) using PRIMER 6 + PERMANOVA statistical software package (Plymouth Laboratories, England). The data on abundances, number of species and biomass were analyzed using Euclidian distances in a planned comparison (contrast) to achieve the relevant comparisons only. The experimental treatments were compared to untreated reference fields, and in Ormerfjorden also to the Clay treatment which can be considered as a capping control. The variances were first tested using PERM-disp, and optimal transformations were chosen to avoid heterogeneous variances (see footnotes in **Table 6** and **Table 7** for information about transformations). Post-hoc pair-wise comparisons with Monte-Carlo sampling were carried out in the PERMANOVA platform, in order to discriminate between treatments at the separate sampling occasions ('Month'). The significance level for all statistical tests were set at $\alpha = 0.05$.

From the multivariate matrix of benthic community data, non-metric multidimensional (nMDS) scaling plots (with Bray-Curtis similarity index as distance measure) were also created to analyze relative similarities of the benthic communities in the 2-dimensional graphs (one for each fjord). The statistical analyses, on the other hand, were performed on ungrouped data. In order to increase the detail level in the figures, all species were assigned into one of the five taxonomic groups; Polychaeta (Annelida), Mollusca, Crustacea (Arthropoda), Echinodermata and Varia (including Cnidaria, Nemertea, Phoronida, Platyhelminthes and Sipuncula). Complete species lists are given in Appendix B.

4.1.3 Classification of ecological status and diversity

Samples were classed by ecological status using the marine Benthic Quality Index (BQI_m) (HVMFS 2013:19), and the Shannon-Wiener (H') diversity index (Veileder 01:2009). BQI_m is not normally used in Norway, but in a recent field capping study in the Trondheim harbour the BQI_m index was

found to perform well compared to the Shannon-Wiener index H' and the Norwegian Quality Index (NQI) (Cornelissen et al, 2011).

The BQI_m takes into account the specific species resistance to ecological disturbances, where each species has an individual sensitivity value based on empirical data. Calculation of BQI_m is based on the relative abundance of sensitive and tolerant species, the total number of species in the sample and to some respect the total abundance in the sample.

$$BQI_m = \left[\sum_{i=1}^{S_{classified}} \left(\frac{N_i}{N_{classified}} \right) \times Sensitivity\ value_i \right] \times log_{10}(S+1) \times \left(\frac{N_{total}}{N_{total}+5} \right)$$

where $S_{classified}$ is the number of taxa having a sensitivity value, N_i is the number of individuals of taxon *i*, $N_{classified}$ is the total number of individuals of taxa having a sensitivity value, the *Sensitivity value*$_i$ is the sensitivity value for taxon *i*, *S* is the total number of taxa, and N_{total} is the total number of individuals in the sample (0.1 m^2) (formula and description text from Leonardsson et al, 2009). Class boundaries are given in Table 4.

The diversity index Shannon-Wiener (H') was used for ecological classification according to Norwegian guidelines for benthic monitoring (Veileder 01:2009). The H' numbers were achieved from PRIMER (see Appendix A.), calculated according to:

$$H' = -\Sigma\ (p_i) * (\log_2 p_i)$$

where p_i = proportion of individuals in the sample belonging to species *i*. Class boundaries are given in Table 4. The principle difference between BQI_m and H' is that H' does not take species sensitivity into consideration.

Table 4. Classification boundaries based on BQI_m index (boundary values from the Swedish west coast >20 m, HVMFS 2013:19) and Shannon-Wiener index, H' (Veileder 01:2009).

Index	I	II	III	IV	V
BQIm	High	Good	Moderate	Poor	Bad
	>15.7	15.7 - 12.0	12.0 - 8.0	8.0 - 4.0	<4.0
H'	Very good	Good	Moderate	Bad	Very Bad
	> 3.8	3.8 - 3.0	3.0 - 1.9	1.9 - 0.9	< 0.9

4.2 Results and discussion

A total of 9748 benthic organisms from 194 species were included in the analyses, where 1253 specimens (from 116 species) were from the 18 samples taken in 2009 (1 month), 3184 specimens (from 125 species) were from the 35 samples taken in 2010 (14 months), and 5311 specimens (from 142 species) were from the 35 samples taken in 2013 (49 months). The statistical analyses of the number of individuals (abundance), number of species and biomass is given in **Table 6** for Ormerfjorden and **Table 7** for Eidangerfjorden.

Table 5. Results from PERMANOVA analyses on abundance, number of species and biomass in Ormerfjorden. Compilation of p-values for relevant comparisons between treatments (fields) and time (months). p-values <0,05 are shown in bold.

Ormefjorden

Permanova Global test		p-values		
Source	df	Abundance	No. of Species	Biomass
Month	2	**0.0001**	**0.0044**	**0.0406**
Field	3	**0.0001**	**0.0001**	**0.0002**
AC+clay (FO3) vs **REF** (FO4)	1	**0.0001**	**0.0001**	**0.0007**
AC+clay (FO3) vs **Clay** (FO2)	1	**0.0001**	**0.0001**	**0.0004**
Clay (FO2) vs **REF** (FO4)	1	**0.0005**	0.0976	0.5317
Lime (FO1) vs **REF** (FO4)	1	**0.0115**	0.1828	**0.0167**
Lime (FO1) vs **Clay** (FO2)	1	0.3074	0.9129	**0.0064**
Month x Field	6	**0.0283**	0.1068	**0.0085**
Month x **AC+clay** (FO3) vs **REF** (FO4)	2	**0.0059**	**0.0008**	**0.0281**
Month x **AC+clay** (FO3) vs **Clay** (FO2)	2	**0.0111**	0.0706	0.1454
Month x **Clay** (FO2) vs **REF** (FO4)	2	0.4114	0.3713	0.1335
Month x **Lime** (FO1) vs **REF** (FO4)	2	0.2388	0.8995	0.1067
Month x **Lime** (FO1) vs **Clay** (FO2)	2	0.1117	0.7139	0.1640
Res	40			
Total	51			

Permanova post hoc tests		p-values		
pairwise comparison, fields	month	Abundance	No. of Species	Biomass
AC+clay (FO3) vs **REF** (FO4)	1	**0.0460**	0.9119	0.9534
AC+clay (FO3) vs **Clay** (FO2)	1	**0.0008**	0.1582	0.4254
Clay (FO2) vs **REF** (FO4)	1	**0.0091**	0.1230	0.3659
Lime (FO1) vs **REF** (FO4)	1	0.6923	0.3712	**0.0416**
Lime (FO1) vs **Clay** (FO2)	1	0.3522	0.7586	**0.0380**
AC+clay (FO3) vs **REF** (FO4)	14	**0.0003**	**0.0001**	**0.0475**
AC+clay (FO3) vs **Clay** (FO2)	14	**0.0001**	**0.0004**	**0.0099**
Clay (FO2) vs **REF** (FO4)	14	0.1643	0.9430	0.2518
Lime (FO1) vs **REF** (FO4)	14	0.0731	0.4121	0.8393
Lime (FO1) vs **Clay** (FO2)	14	0.2730	0.5244	0.3481
AC+clay (FO3) vs **REF** (FO4)	49	**0.0134**	**0.0018**	**0.0001**
AC+clay (FO3) vs **Clay** (FO2)	49	**0.0028**	**0.0001**	**0.0003**
Clay (FO2) vs **REF** (FO4)	49	**0.0300**	0.4449	0.1198
Lime (FO1) vs **REF** (FO4)	49	**0.0193**	0.6176	**0.0219**
Lime (FO1) vs **Clay** (FO2)	49	0.0848	0.9416	0.2527

Data were transformed to avoid heterogeneity; square-root for abundance, non-transformed for number of species, fourth-root for biomass.

Table 6. Results from PERMANOVA analyses on abundance, number of species and biomass in Eidangerfjorden. Compilation of p-values for relevant comparisons between treatments (fields) and time (months). p-values <0,05 are shown in bold.

Eidangerfjorden

Permanova Global test		p-values		
Source	df	Abundance	No. of Species	Biomass
Month	2	**0.0017**	0.2822	0.9690
Field	2	**0.0051**	**0.0001**	**0.0001**
AC+clay (FE5) vs **REF** (FE6)	1	**0.0027**	**0.0002**	**0.0001**
AC+clay (FE5) vs **REFx** (FE7)	1	**0.0029**	0.0991	**0.0435**
REF (FE6) vs **REFx** (FE7)	1	0.6449	**0.0042**	**0.0237**
Month x Field[1]	3	0.7512	0.7330	0.4110
Month x **AC+clay** (FE5) vs **REF** (FE6)	2	0.6903	0.8878	0.2619
Month x **AC+clay** (FE5) vs **REFx** (FE7)[1]	1	0.3559	0.4416	0.2914
Month x **REF** (FE6) vs **REFx** (FE7)[1]	1	0.7314	0.3279	0.7857
Res	28			
Total	35			

Permanova post hoc tests		p-values		
pairwise comparison, fields	month	Abundance	No. of Species	Biomass
AC+clay (FE5) vs **REF** (FE6)	1	**0.0054**	**0.0212**	**0.0008**
AC+clay (FE5) vs **REF** (FE6)	14	0.0705	**0.0004**	0.0503
AC+clay (FE5) vs **REFx** (FE7)	14	**0.0489**	**0.0140**	0.5727
REF (FE6) vs **REFx** (FE7)	14	0.8565	**0.0053**	0.1619
AC+clay (FE5) vs **REF** (FE6)	49	0.0560	**0.0211**	**0.0001**
AC+clay (FE5) vs **REFx** (FE7)	49	**0.0459**	0.5969	**0.0155**
REF (FE6) vs **REFx** (RE7)	49	0.6951	0.0595	0.0943

Data were transformed to avoid heterogeneity; square-root for abundance, fourth-root for number of species, 1/Square-root for biomass.

[1] Term has one empty cell since REFx (FE7) was not included after 1 month.

4.2.1 Ecological state assessment

In the Benthic Quality Index (BQI_m), all fields in Ormerfjorden reached moderate ecological status after 1 month, with values varying between 8.71-10.22 (**Table 8**). The experimental fields treated with Clay and Lime and the untreated reference field kept stable on moderate ecological status throughout 14 and 49 months. AC+clay, however, showed a remarkable drop to Bad ecological status after 14 months. After 49 months the status was still Poor.

Based on the Shannon-Wiener index, the AC+clay field in Ormerfjorden went from Good status after 1 month to Bad status after 14 month (**Table 8**). After 49 months the AC+clay field was at Moderate status, the same as for the other fields in Ormerfjorden. Initially the reference field had a lower status compared to the other fields in Ormerfjorden.

The AC+clay treatment in Eidangerfjorden reached Good ecological status both for BQI_m and Shannon-Wiener, although the underlying data on number of species and abundance displayed significant perturbations to the communities by AC+clay.

Table 7. Ecological status based on BQI_m and Shannon-Wiener (H') indices (average values). Classification and colour coding: Class I) High or Very good, Class II) Good, Class III) Moderate, Class IV) Poor or Bad, Class V) Bad or Very bad (For details in classification and boundary layer, see 0.1.3).

			BQI_m			H'		
			1	14	49	1	14	49
Ormerfjorden	FO1	Lime	9.52	9.56	10.76	3.72	3.21	2.71
	FO2	Clay	10.22	8.82	10.99	3.39	2.97	2.74
	FO3	AC+clay	8.71	2.96	6.24	3.68	1.85	2.63
	FO4	REF	8.78	9.46	10.55	2.90	3.17	2.96
Eidangerfjorden	FE5	AC+clay	13.52	12.67	14.15	3.59	3.45	3.69
	FE6	REF1	15.95	15.18	15.96	4.13	4.19	4.30
	FE7	REF2	-	14.09	13.52	-	3.72	3.54

Ecological indices are generally poor in capturing the species composition, the ecological interactions and succession of species. The Shannon-Wiener index was originally developed as a diversity index in economical science and not to analyse ecological status. When applied to ecological communities it is often criticized for not discriminating between species. Also BQIm appears to fail in detecting the disturbances in Eidangerfjorden. This study has statistically solid data on the benthic communities, i.e. number of species, their abundance and biomass. The ecological impact of capping on the benthic community and the underlying processes should therefore be based on the solid data rather than an index.

4.2.2 Abundance

The total abundance in Ormerfjorden one month after capping varied from 214 ind/m² in the AC+clay capped field up to 760 ind/m² in the Clay only capped field (Figure 10). The abundance in the Lime field reached 549 ind/m², whereas the reference field reached 412 ind/m². Fourteen month after capping, the total abundance in the AC+clay field had decreased to only 55 ind/m², whereas the Clay capped field showed similar abundance as before with 701 ind/m². In the Lime field, a huge increase in the abundance had occurred, which reached up to 928 ind/m². An increase in species abundance had also occurred in the reference field. Forty-nine months after capping, the total abundance in the AC+clay field had increased to 444 ind/m². However, all fields showed an increase in species abundance compared to previous years; Clay with total abundance of 979 ind/m², Lime with the dramatic increase to 1762 ind/m² and further also the reference field with 739 ind/m².

The abundance in Eidangerfjorden one month after capping varied from 663 ind/m² in the AC+clay field to 983 ind/m² in the reference field. Fourteen months after capping, the abundance in the AC+clay field had increased to 816 ind/m². However, an increase had also occurred in the reference field, with the abundance of 1208 ind/m². A similar abundance of 1236 ind/m² was reached in the second reference field (REFx), established fourteen months after capping at more similar depth as the AC+clay capped field. Forty-nine months after capping, the abundance in the AC+clay field had continued to increase up to 1105 ind/m². However, the abundance in both of the reference fields had also increased, and reached up to 1911 and 2170 ind/m² respectively.

In Ormerfjorden, echinoderms were among the most abundant taxonomic group, mostly consisting of brittle stars (*Amphiura* spp.). The brittle stars were, however, strongly reduced in the AC+clay

field already one month after capping. Forty-nine months after capping, the brittle stars were still absent in the AC+clay field. A reduction in the brittle stars population was observed also in the AC+clay field in Eidangerfjorden. In both fjords, polychaetes were among the most abundant taxonomic group. In the Lime capping in Ormerfjorden, polychaetes increased in abundance with time after capping e.g. *Galathowenia oculata* were very abundant after both fourteen and forty-nine months. In Eidangerfjorden, the abundance of polychaetes was lower in the AC+clay field compared with both reference fields throughout all sampling. In the reference fields, polychaetes such as *Chaetozone setosa, Heteromastus filiformis* and *Scalibregma inflatum* were more abundant, while e.g. *Paramphinome jeffreysi* showed the opposite pattern with more abundance in the AC+clay field. In the AC+clay capping in Ormerfjorden, polychaetes were the most abundant taxonomic group after forty-nine months, mostly consisted of newly settled *Pectinaria koreni*.

In Ormerfjorden, the PERMANOVA global test (**Table 6**) revealed significant differences in abundance between fields, where all field comparisons were significant, except Lime vs Clay. The significant interactions between Month and both 'AC+clay vs REF' and 'AC+clay vs Clay' highlights the different developments in the fields. The stable, or even increasing, abundances in REF and Clay were contrasted by the huge drop in organisms in AC+clay. The PERMANOVA post hoc test (**Table 2**) showed significantly lower abundance in AC+clay compared to REF, as well as AC+clay compared to Clay, in all sampling occasions (1, 14, 49 months). Further, Clay had significantly higher abundance than REF both after 1 month and 49 months. After 49 months, also Lime showed significantly higher abundance compared to REF. The higher abundance in Clay compared to REF can be naturally high organic enrichment in the field, since the abundance is still high forty-nine months after capping.

In Eidangerfjorden, the PERMANOVA global test (**Table 7**) showed significant differences in abundance between fields, where the field interaction between AC+clay and both REF fields were significantly different. The PERMANOVA post hoc test (**Table 7**) show significantly lower abundance in AC+clay field compared with REF after 1 month. After both fourteen and forty-nine months, AC+clay also show significantly lower abundance compared to the REFx field at 90 m depth.

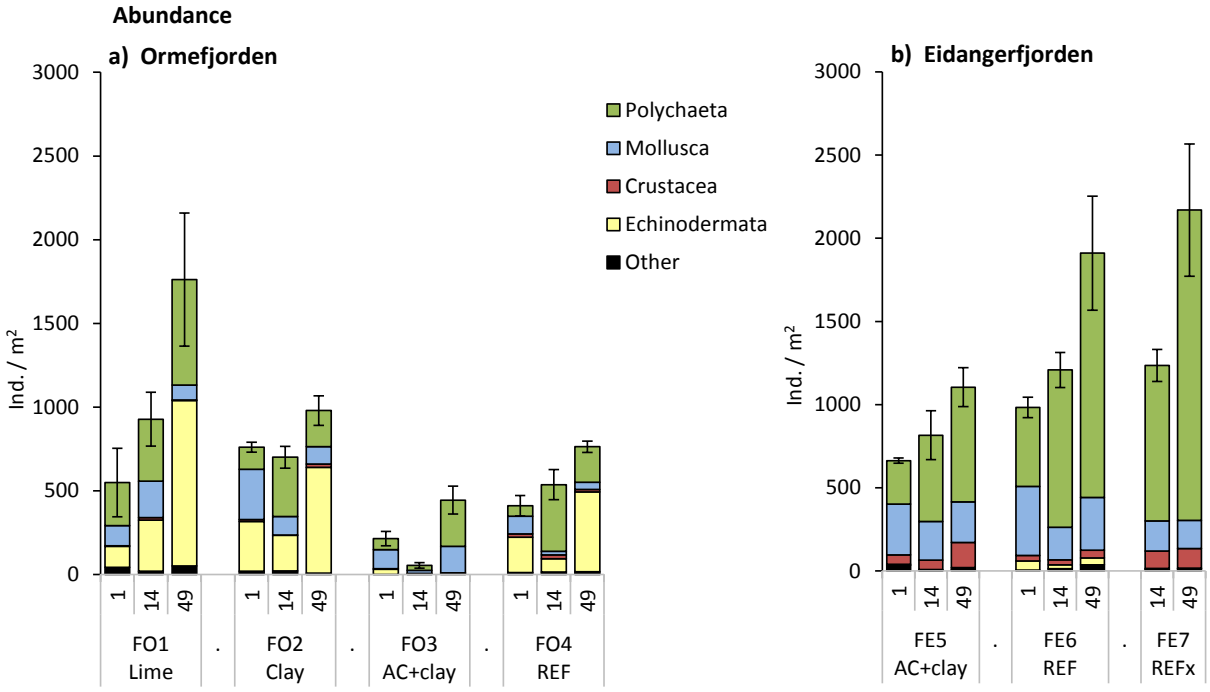

Figure 10. Macrofauna abundance (mean ± SE) in a) Ormerfjorden and b) Eidangerfjorden 1, 14 and 49 months after capping.

4.2.3 Taxonomic groups and number of species

Polychaete worms were, with few exceptions, the most species rich taxonomic group in both fjords, followed by molluscs (**Figure 11**). While molluscs appeared relatively little affected by the AC+clay capping, polychaetes and echinoderms appeared more affected with large reduction in number of species. In Ormerfjorden, the large bioturbating sea urchin *Brissopsis lyrifera* (Echinoderma) showed low abundance (0.7 ind/0.1m²) already one month after capping. After fourteen months, *Brissopsis lyrifera* were very scars (0.2 ind/0.1m²) and after 49 months they were totally absent. Further, low numbers of crustacean species were found in Ormerfjorden, and benthic amphipods were almost absent.

The lowest number of species measured one month after capping occurred in AC+clay in Ormerfjorden, with only 15 species per sample. At the same time, the Clay field reached 22 species and Lime 20 species, but the Reference only 16 species. A dramatic decrease in number of species had occurred fourteen months after capping in the AC+clay field, with only 4 species per sample. A small decrease had also occurred in the Clay field, but it still reached 19 species, which is similar to the number of species in the Lime (20 species) and reference (18 species) fields. At forty-nine months after capping, the AC+clay field showed a small recovery, with 11 species in average per sample. However, the number of species had, at the same time, increased in all of the other fields; both Clay and Lime reached 24 species, and the reference reached 22 species.

The average number of species was in general higher in Eidangerfjorden compared to Ormerfjorden. The number of species per sample in Eidangerfjorden was, however, lesser in AC+clay field (only 22 species per sample), compared to the reference field (35 species). After fourteen months, the number of species in the AC+clay field reached similar number (21 species)

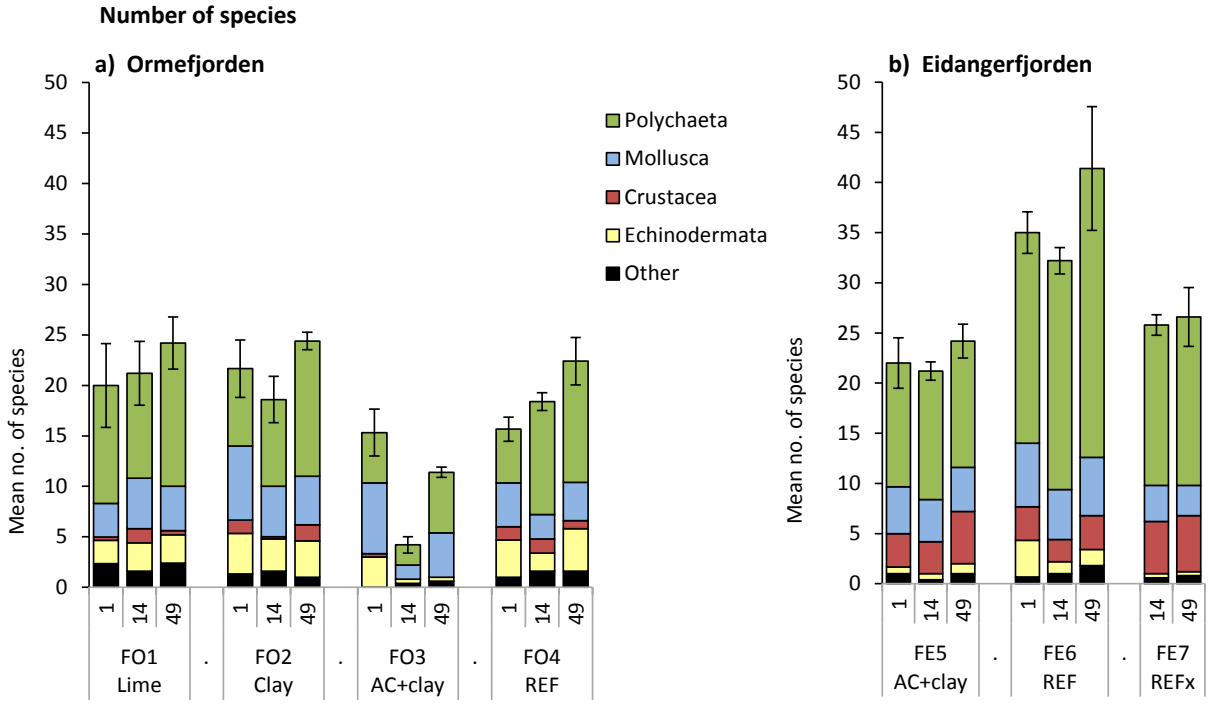

Figure 11. The number of macrofauna species (mean ± SE) in a) Ormerfjorden, and b) Eidangerfjorden 1, 14 and 49 months after capping.

as in the previous sampling. The REF field reached 32 species, meanwhile the REFx field at the same depths as the capped field only reached 26 species. After forty-nine months, the number of species had increased to 24 in the AC+clay field. In the original reference field at 80 m depth (REF), the number of species had increased to 41, while the second reference field at 95 m depth (REFx) only reached 27 species per sample in average.

In Ormerfjorden, the PERMANOVA global test (**Table 6**) showed significant different number of species between fields, where AC+clay vs REF and AC+clay vs Clay only were significantly different. In the 'Month x Field' interaction, only 'Month x AC vs REF' were significantly different. In the PERMANOVA post hoc test (**Table 6**), the number of species in AC+clay was significantly lower compared to both REF and Clay after fourteen and forty-nine months.

The PERMANOVA global test (**Table 7**) showed significant differences between fields in Eidangerfjorden, with differences between AC+clay and REF, as well as differences between the both reference fields. In the PERMANOVA post hoc tests (**Table 7**), the pairwise comparisons revealed significant differences in number of species between AC+clay and REF after one, fourteen and forty-nine months. The AC+clay field were also significantly different from REFx after fourteen months. In the fourteen month sampling, also the two reference fields were significantly different in number of species.

4.2.4 Biomass

The sea urchins *Brissopsis lyrifera* and *Echinocardium cordatum* frequently constituted a large fraction of the total biomass, as well as of the echinoderms biomass (**Figure 12**). Thus, the loss of biomass in the AC+clay field in Ormerfjorden primarily was a result of sea urchin reduction; from 2 sea urchins/0.1 m² after 1 month to 0.2 sea urchins/0.1 m² after 14 months to complete absence after

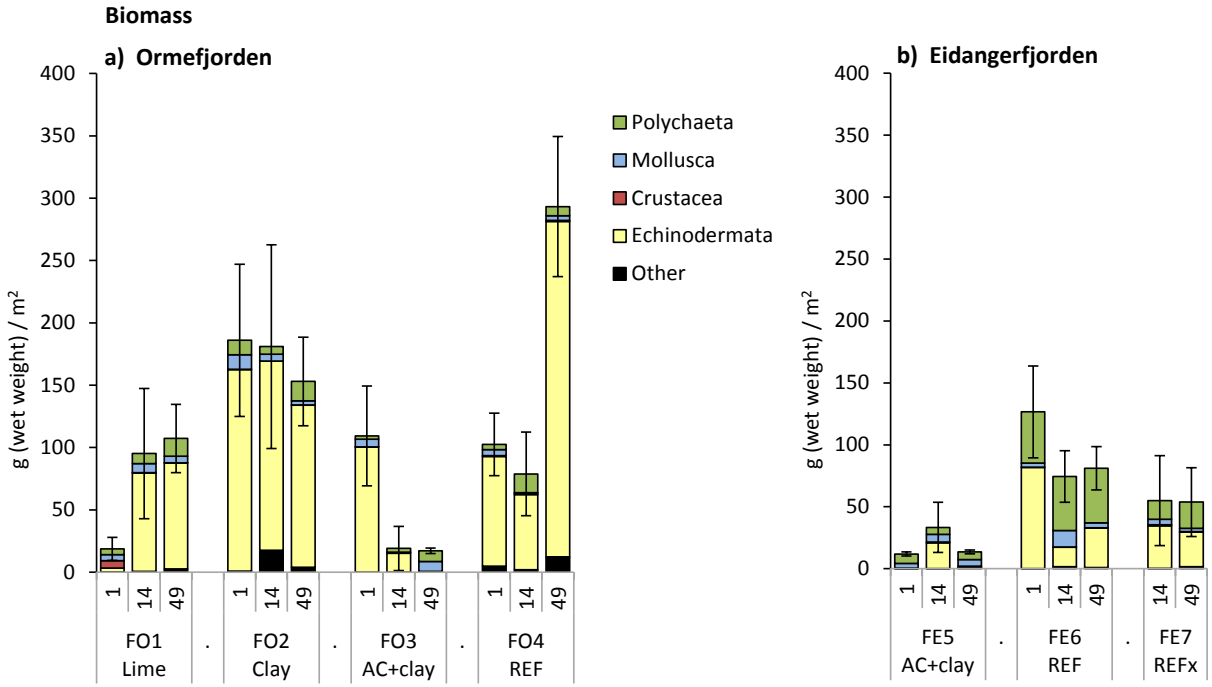

Figure 12. Macrofauna biomass (mean ± SE) in a) Ormerfjorden, and b) Eidangerfjorden 1, 14 and 49 months after capping.

49 months. An opposite development was found at the Lime, with complete absence one month after capping, followed by a recurrence of 1.4 sea urchins/0.1 m^2 after 14 months (which persisted to 49 months) after capping operation.

One month after capping in Ormerfjorden, the total biomass varied from 19 g/m^2 in the Lime field up to 186 g/m^2 in the Clay field. The biomass in AC+clay field reached similar values as the reference field, with 109 g and 103 g/m^2, respectively. After 14 months, the biomass in the Lime field increased to 95 g, meanwhile the biomass in AC+clay field decreased to 19 g/m^2. In the same time, a small decrease in weight could be found in the reference field (79 g/m^2), while the biomass was stable in the Clay field (181 g/m^2). After 49 month, the biomass in the AC+clay field was still low, with only 17 g/m^2. The Lime field showed no major difference in biomass after 49 months (103 g) compared to 14 month, meanwhile the Clay field showed a small decrease to 153 g/m^2. In the reference field, however, the biomass increased to 284 g/m^2.

The biomass in Eidangerfjorden one month after capping varied from 12 g/m^2 in the AC+clay field compared with 127 g/m^2 at the REF from 80 m depth. After fourteen months, the biomass in the AC+clay field had increased to 33 g/m^2, but both reference fields showed higher biomass (74 and 55 g/m^2). After forty-nine months, the biomass decreased to only 14 g/m^2 in the AC+clay field, while both reference fields reached similar biomass as the previous sampling occasion (14 and 54 g/m^2).

The PERMANOVA global test (**Table 6**) from Ormerfjorden showed significant differences between field comparisons, except between Clay and REF. Only AC vs REF showed a significant interaction with time, demonstrating the severe drop in biomass in the AC+clay field whereas REF and Clay showed stable or increasing biomass. The PERMANOVA post hoc tests (**Table 6**) showed significant difference in Lime compared to both REF and Clay after one month. A difference between Lime and REF also occurred after forty-nine months. The biomass in AC+clay was significantly different from both REF and Clay after both fourteen and forty-nine months.

In Eidangerfjorden, the PERMANOVA global test (**Table 7**) showed a significant difference in fields, and all fields were significantly different. In the PERMANOVA post hoc tests (**Table 7**), the biomass in AC+clay were significantly lower compared to the reference (REF) after one month. No significant difference was found after 14 months. However, after forty-nine month, the biomass in AC+clay was significantly lower compared to both reference fields.

4.2.5 Community analysis and interpretations

In Ormerfjorden, the AC+clay samples were clearly separated from the other samples in the non-metric multidimensional scaling plot (nMDS, **Figure 13**a). Suspension/filter feeders were severely affected and almost totally eradicated, mostly because of the loss of brittle stars (*Amphiura* spp.). After 14 months, the AC+clay samples showed increased heterogeneity, which indicate stress in the benthic community. The scattered pattern in AC+clay reflects the decline from 1 to 14 months in the number of species and abundances. At this point not only suspension/filter feeders (e.g. *Amphiura* spp.) were affected, also deposit and subsurface deposit feeders (e.g. polychaete species) were almost absent. After 49 months, the AC+clay data points were more clustered as a result of the increased abundances. However, AC+clay data points were still separated from samples in the other treatments in the nMDS plot. This is a probably because the new and disturbed community is dissimilar to the native communities in the REF and Clay field. The community in AC+clay showed after 49 months a lack of deep bioturbators e.g. the sea urchin *Brissopsis lyrifera*, and was dominated by species active only in the sediment surface. Clay and REF showed rather similar communities and data points from these two treatments are grouped together in the nMDS plot. The Lime samples were separated from the other treatments after 1 and 14 months. However,

Lime was found closer to both REF and Clay after 49 months, indicating that the community in Lime had become more similar to REF and Clay communities.

In Eidangerfjorden, the nMDS (**Figure 13**b) also showed a fairly clear separation between all fields and sampling occasions. The AC+clay data points, in the lower part of the diagram, separate from both reference fields. As the fields in Eidangerfjorden are situated at depths between 80-100 m, suspension/filter feeders are naturally fewer in this fjord compared to the fields in the shallower Ormerfjorden. A natural lack of the active carbon sensitive suspension/filter feeders can probably be an explanation for the less dramatic effect from AC on the benthic community in Eidangerfjorden. The community was, nevertheless, significantly disturbed in the AC+clay field at 95 m depth still after 49 months where deposit feeding species were most affected by active carbon treatment.

The brittle stars *Amphiura* spp. and the sea urchin *Brissopsis lyrifera* were the dominant echinoderms in both fjords, but were clearly depleted in both AC+clay treated fields at the different depths. Loss of sea urchins has been linked to reduced ecosystem productivity (Lohrer et al., 2004), and due to their size and bulldozing bioturbation activity, sea urchins may be considered key species with a potential impact on the remaining community structure and function (Widdicombe et al., 2004). Also *Amphiura filiformis* may be considered a key species (e.g. Solan and Kennedy, 2002), and *Amphiura* spp. was for instance found to account for up to 80% of the total flux of O_2 into the sediment (Vopel, 2003). Thus, it seems likely that the loss of brittle stars and sea urchins in the first place may lead to further disturbances on the community level. Further, the loss of deeper bioturbators may reduce oxygenation of the sediments. This may alter recycling of nutrients and ultimately reduce the productivity in the fjord system.

The benthic habitats and macrofaunal communities at both 30 m and 90 m depth showed significantly negative effects of thin capping with active carbon. The effects persisted after 49 months. Indications were found that the community on AC+clay in Eidangerfjorden had improved slightly since the survey in 2010, but in Ormerfjorden effects had remained clearly altered compared to reference and other cap treatments. Effects of active carbon on the benthic ecosystem have previously been found in a box core experiment reported by Näslund et al. (2012), where the number of species was reduced by 50 percent compared to experimental controls. At a TBT-contaminated site nearby a shipyard at Fiskarstrand, W.Norway, Trannum et al. (2011) found slightly better developement of the macrofauna community at a field capped with fine grained limestone compared to a field capped with fine grained limestone mixed with AC.

The mechanism explaining the effects of activated carbon may be complex and beyond the scope of this work. One hypothesis could be that the particle size range of the activated carbon coincides with the size preference of food particles for many suspension/filter feeders, and the AC particles can therefore interfere with the extraction of food for these types of organisms. Another mechanism could be that labile organic substances, which represent important items for deposit feeders, also bind to active carbon and thereby reduce food availability for deposit feeders. Hence, activated carbon may be considered to cause a lowering of the overall carrying capacity in the community. This could in turn strike harder on the community at the less deep site in Ormerfjorden, since this sediment has a lower content of organic carbon available compared to the deeper sediment in Eidangerfjorden. Moreover, the higher temperature at 30 meters (12ºC in November 2012) compared to 100 meters (7ºC) would also generate a higher metabolic rate and a higher demand of food. Hence would a lowering (sequestration) of available food generate a larger drop in the overall carrying capacity in Ormerfjorden compared to Eidangerfjorden, and consequently have a more severe effect on this community compared to the community at the greater depth (Samuelsson, 2013).

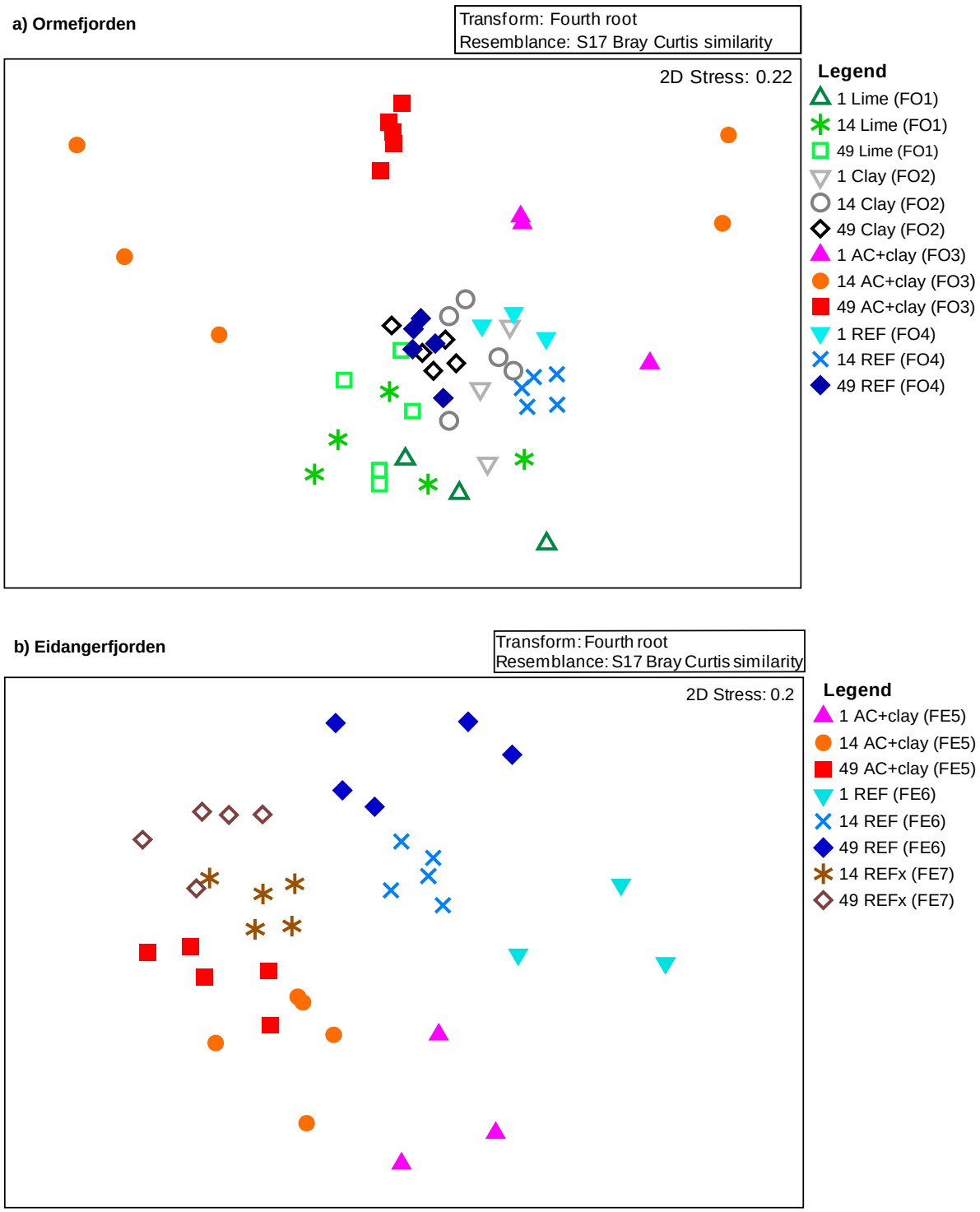

Figure 13. Non-metric multidimensional scaling plot (nMDS) showing similarity between the macrobenthic communities analyzed in each sample in a) Ormerfjordenand b) Eidangerfjorden

4.3 Summary of conclusions on disturbance and recovery of benthic community

- Crushed limestone had initial negative effects on larger benthic organisms such as sea urchins. After 49 months, the total abundance was remarkably high, but the biomass indicated a dominance of rather small organisms.
- The Clay field showed only small differences compared to the reference field. These effects could be due to natural differences in the fjord, such as spatial differences in sedimentation of organic material.
- Effects of AC+clay at 30 m depth in Ormerfjorden:
    - After one month, the community showed disturbance in terms of reduced abundance. Suspension/filter feeders were severely affected and almost totally eradicated.
    - After fourteen months, the abundance had been further reduced, and number of species and biomass had also decreased. Besides suspension/filter feeders, other groups e.g. deposit feeders, had also been adversely affected.
    - After forty-nine months, the number of species and abundance showed an increase compared to the sampling after 14 months, but the analyses still displayed a disturbed benthic community reduced in number of species, abundance and biomass compared to reference and Clay fields. The community was dominated by small recruits e.g. of the deposit feeding *Pectinaria koreni*. Suspension/filter feeders were still absent and no large bioturbators were found.
- Effects of AC+clay at 90 m depth in Eidangerfjorden:
    - The community in this field was less disturbed than the similarly treated community in Ormerfjorden, but significant and persistent effects were observed, in particular with regard to biomass.
    - Since suspension/filter feeders are normally less abundant at 80-100 m depth compared to 30 meters, the effects on number of species and abundance were less severe.
- The negative effects of the AC+clay treatments were probably related to AC particle size range. This coincides with the size preference of food particles for many suspension/filter feeders, and can therefore interfere with the extraction of food for these types of organisms. Larger particle size of AC has been used in several other remediation studies, with less severe disturbances to organisms reported. Also binding of nutritious material to AC may reduce food availability and growth of the benthic community.
- Thin-layer capping can probably be used as a remediation technique, since Clay showed minor disturbance to the benthic community. However, the active component must be further investigated e.g. AC with larger particle size.
- Since the effects of AC+clay were still severe 4 years (49 months) after capping, continued monitoring of the benthic community is recommended to follow possible benthic recovery.

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Appendix A. Macrofauna univariate results

Fjord	Month	Field name	Field	Sample	No. of species	Abundance	Biomass	BQI_m	H'(log2)
Ormefjorden	1	Lime	FO1	A	22	70	20,9	9,69	3,54
Ormefjorden	1	Lime	FO1	B	12	20	1,9	7,77	3,45
Ormefjorden	1	Lime	FO1	C	26	102	33,6	11,10	4,16
Ormefjorden	1	Clay	FO2	A	24	95	243,7	11,07	3,58
Ormefjorden	1	Clay	FO2	B	16	88	64,1	8,51	2,77
Ormefjorden	1	Clay	FO2	C	25	83	250,4	11,07	3,82
Ormefjorden	1	AC+clay	FO3	A	20	35	165,7	10,26	4,10
Ormefjorden	1	AC+clay	FO3	B	13	19	31,9	7,68	3,51
Ormefjorden	1	AC+clay	FO3	C	13	21	130,4	8,18	3,42
Ormefjorden	1	REF	FO4	A	18	62	54,0	9,32	3,12
Ormefjorden	1	REF	FO4	B	14	43	137,6	8,29	2,52
Ormefjorden	1	REF	FO4	C	15	39	116,3	8,74	3,05
Ormefjorden	14	Lime	FO1	A	26	146	22,6	10,17	3,53
Ormefjorden	14	Lime	FO1	B	28	144	91,1	9,77	3,64
Ormefjorden	14	Lime	FO1	C	24	120	37,9	10,37	3,22
Ormefjorden	14	Lime	FO1	D	11	52	26,2	8,17	3,01
Ormefjorden	14	Lime	FO1	E	17	77	298,4	9,22	2,66
Ormefjorden	14	Clay	FO2	A	13	105	58,3	7,35	2,41
Ormefjorden	14	Clay	FO2	B	21	80	89,6	9,93	3,51
Ormefjorden	14	Clay	FO2	C	26	91	471,7	9,75	3,51
Ormefjorden	14	Clay	FO2	D	18	66	248,4	9,04	3,11
Ormefjorden	14	Clay	FO2	E	15	65	36,8	8,01	2,30
Ormefjorden	14	AC+clay	FO3	A	3	4	0,8	2,20	1,50
Ormefjorden	14	AC+clay	FO3	B	5	6	3,4	3,74	2,25
Ormefjorden	14	AC+clay	FO3	C	3	3	0,9	1,69	1,58
Ormefjorden	14	AC+clay	FO3	D	3	5	0,8	2,21	1,52
Ormefjorden	14	AC+clay	FO3	E	7	14	89,6	4,97	2,41
Ormefjorden	14	REF	FO4	A	17	57	79,3	9,37	3,10
Ormefjorden	14	REF	FO4	B	21	95	23,9	9,64	2,56
Ormefjorden	14	REF	FO4	C	17	35	7,4	9,01	3,62
Ormefjorden	14	REF	FO4	D	17	75	84,8	8,96	2,88
Ormefjorden	14	REF	FO4	E	20	50	198,7	10,34	3,67
Ormefjorden	49	Lime	FO1	A	31	305	79,0	11,17	3,41
Ormefjorden	49	Lime	FO1	B	28	322	102,1	11,60	2,70
Ormefjorden	49	Lime	FO1	C	24	183	72,6	10,96	2,30
Ormefjorden	49	Lime	FO1	D	16	99	53,6	9,23	2,57
Ormefjorden	49	Lime	FO1	E	22	118	208,5	10,83	2,57
Ormefjorden	49	Clay	FO2	A	25	91	88,9	10,99	2,88
Ormefjorden	49	Clay	FO2	B	27	123	177,0	11,33	2,75
Ormefjorden	49	Clay	FO2	C	22	110	276,0	10,80	2,43
Ormefjorden	49	Clay	FO2	D	23	149	79,9	10,66	2,19
Ormefjorden	49	Clay	FO2	E	25	98	143,5	11,17	3,43
Ormefjorden	49	AC+clay	FO3	A	12	66	21,8	6,43	2,58
Ormefjorden	49	AC+clay	FO3	B	11	32	13,0	5,69	2,87
Ormefjorden	49	AC+clay	FO3	C	11	39	10,7	6,96	3,15
Ormefjorden	49	AC+clay	FO3	D	13	39	19,2	7,34	3,10
Ormefjorden	49	AC+clay	FO3	E	10	83	21,0	4,79	1,46
Ormefjorden	49	REF	FO4	A	17	91	347,3	9,63	2,23
Ormefjorden	49	REF	FO4	B	21	83	290,9	10,32	2,77
Ormefjorden	49	REF	FO4	C	20	76	87,8	9,97	2,49
Ormefjorden	49	REF	FO4	D	23	82	266,0	10,75	3,47
Ormefjorden	49	REF	FO4	E	31	99	425,6	12,15	3,83

Fjord	Month	Field name	Field	Sample	No. of species	Abundance	Biomass	BQI_m	H'(log2)
Eidangerfjorden	1	AC+clay	FE5	A	24	75	15,4	13,65	3,73
Eidangerfjorden	1	AC+clay	FE5	B	17	81	10,6	12,44	3,26
Eidangerfjorden	1	AC+clay	FE5	C	25	76	9,8	14,45	3,77
Eidangerfjorden	1	REF	FE6	A	34	109	182,5	15,87	4,31
Eidangerfjorden	1	REF	FE6	B	39	129	56,4	16,11	4,20
Eidangerfjorden	1	REF	FE6	C	32	106	140,9	15,86	3,89
Eidangerfjorden	14	AC+clay	FE5	A	23	51	114,3	12,28	3,92
Eidangerfjorden	14	AC+clay	FE5	B	22	130	10,5	13,40	3,12
Eidangerfjorden	14	AC+clay	FE5	C	23	109	16,9	13,41	3,57
Eidangerfjorden	14	AC+clay	FE5	D	19	57	10,7	11,65	3,64
Eidangerfjorden	14	AC+clay	FE5	E	19	127	14,5	12,61	2,98
Eidangerfjorden	14	REF	FE6	A	34	114	111,6	15,58	4,47
Eidangerfjorden	14	REF	FE6	B	29	111	22,1	14,03	3,94
Eidangerfjorden	14	REF	FE6	C	35	146	128,7	15,89	4,44
Eidangerfjorden	14	REF	FE6	D	29	173	75,3	14,63	3,84
Eidangerfjorden	14	REF	FE6	E	34	158	34,2	15,77	4,26
Eidangerfjorden	14	REFx	FE7	A	24	155	13,4	14,09	3,48
Eidangerfjorden	14	REFx	FE7	B	26	146	16,9	14,57	3,71
Eidangerfjorden	14	REFx	FE7	C	23	100	11,9	12,95	3,79
Eidangerfjorden	14	REFx	FE7	D	29	159	199,3	14,97	3,78
Eidangerfjorden	14	REFx	FE7	E	26	158	32,9	13,86	3,86
Eidangerfjorden	49	AC+clay	FE5	A	24	158	13,2	14,19	3,39
Eidangerfjorden	49	AC+clay	FE5	B	30	164	15,7	15,35	4,04
Eidangerfjorden	49	AC+clay	FE5	C	25	98	18,0	13,88	3,85
Eidangerfjorden	49	AC+clay	FE5	D	22	104	12,5	13,85	3,63
Eidangerfjorden	49	AC+clay	FE5	E	20	120	8,5	13,49	3,54
Eidangerfjorden	49	REF	FE6	A	38	277	52,0	15,71	4,06
Eidangerfjorden	49	REF	FE6	B	23	112	62,8	12,63	3,61
Eidangerfjorden	49	REF	FE6	C	61	343	130,9	18,51	4,97
Eidangerfjorden	49	REF	FE6	D	39	180	44,9	15,60	4,44
Eidangerfjorden	49	REF	FE6	E	46	202	115,0	17,26	4,44
Eidangerfjorden	49	REFx	FE7	A	35	243	27,7	14,97	3,91
Eidangerfjorden	49	REFx	FE7	B	19	314	22,8	12,46	3,32
Eidangerfjorden	49	REFx	FE7	C	30	258	37,9	14,04	3,62
Eidangerfjorden	49	REFx	FE7	D	27	362	163,9	13,79	3,31
Eidangerfjorden	49	REFx	FE7	E	21	88	16,7	12,36	3,56

Appendix B. Species lists

Field FO1 (Limestone)		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe hibernica					1	<0,005									1	<0,005					1	0,02			6	0,18
Annelida	Ampharete baltica															3	0,02										
Annelida	Anobothrus gracilis									1	0,03	1	0,03	4	<0,005			1	0,05								
Annelida	Brada villosa									1	<0,005	1	<0,005									1	0,02				
Annelida	Chaetopterus norvegicus													1	2,45												
Annelida	Chaetozone setosa	1	<0,005			3	<0,005			1	0,01	2	0,02					1	<0,005								
Annelida	Chone fauveli																							1	0,37		
Annelida	Diplocirrus glaucus	1	0,01			3	0,01	2	0,01					9	0,02			5	0,08	14	0,11	2	0,01			6	0,02
Annelida	Eclysippe eliasoni							4	<0,005																		
Annelida	Euchone papillosa							1	<0,005			3	<0,005					3	0,01			3	0,01				
Annelida	Galathowenia oculata					5	0,01	14	0,15	16	0,13	1	<0,005					74	1,18	15	0,14	3	0,03				
Annelida	Glycera alba	2	0,01	2	0,01	5	0,06	1	0,06	1	0,01			2	0,09			3	0,08	2	0,08	3	0,08	2	0,1		
Annelida	Goniada maculata			1	0,05							2	0,06					4	0,16	3	0,19	1	0,01	3	0,09	4	0,07
Annelida	Heteromastus filiformis	1	<0,005			9	0,01			1	<0,005							15	0,03	13	0,05						
Annelida	Laonice bahusiensis					1	0,02																				
Annelida	Lipobranchius jeffreysii							1	0,02							1	0,05					1	0,09			1	0,63
Annelida	Lumbriclymene minor							1	<0,005																		
Annelida	Magelona minuta	1	<0,005																								
Annelida	Maldane sarsi					4	0,23			1	0,04									4	0,08						
Annelida	Nephtys incisa											1	0,04													3	0,04
Annelida	Ophiodromus flexuosus					1	<0,005	1	0,02											1	<0,005						
Annelida	Owenia fusiformis					1	0,19			1	0,01							1	0,11			1	0,09				
Annelida	Pectinaria auricoma											4	0,01	1	<0,005	1	<0,005			2	0,13	5	0,16	9	0,61		
Annelida	Pectinaria belgica																			7	0,21					1	<0,005
Annelida	Pectinaria koreni											2	0,07			2	0,57	14	0,17					1	<0,005		
Annelida	Pholoe baltica			1	<0,005	1	0,01					1	<0,005	6	0,01			22	0,05	14	0,02	2	<0,005				
Annelida	Pholoe pallida	1	<0,005																								
Annelida	Phyllodoce groenlandica																					1	0,37				
Annelida	Pilargis verrucosa			1	0,03															1	0,04						
Annelida	Podarkeopsis helgolandicus					1	0,01																				
Annelida	Polydora spp.					1	<0,005	29	0,01	31	0,01	4	<0,005					5	<0,005								
Annelida	Praxillella affinis																	1	0,07	2	0,10			1	0,08	5	0,13
Annelida	Praxillella praetermissa	1	<0,005	1	<0,005	2	<0,005			3	0,08																
Annelida	Prionospio cirrifera							1	<0,005																	1	<0,005
Annelida	Prionospio fallax	9	0,01	3	<0,005	11	0,01											2	<0,005								
Annelida	Prionospio multibranchiata	1	<0,005																								
Annelida	Rhodine loveni									1	0,02																
Annelida	Sabellidae									1	<0,005																

Annelida	Sabellides octocirrata																	8	0,02			11	0,03	2	<0,005	1	<0,005
Annelida	Scalibregma inflatum	2	0,40			5	0,41			4	0,02	17	0,36	7	0,08	7	0,03	5	0,22	7	0,58	2	0,28	7	0,08	4	0,04
Annelida	Spiophanes kroeyeri											2	0,02							2	0,04					1	0,01
Annelida	Streblosoma bairdi																									1	0,23
Annelida	Terebellides stroemi													1	<0,005			7	0,08	6	0,07	1	0,01				
Annelida	Tharyx killariensis	2	<0,005	2	<0,005																						
Annelida	Trichobranchus roseus					3	0,03	6	0,02	4	0,03									1	0,03	2	0,05	1	0,03	1	0,02
Arthropoda	Ampelisca gibba									1	<0,005																
Arthropoda	Ampelisca macrocephala							1	<0,005																		
Arthropoda	Callianassa subterranea															3	0,07										
Arthropoda	Diastylis boecki							1	0,01	1	0,01					1	<0,005	1	<0,005								
Arthropoda	Eriopisa elongata															1	<0,005										
Arthropoda	Leucothoe lilljeborgii																									1	<0,005
Arthropoda	Pagurus bernhardus					1	2,08																				
Cnidaria	Anthozoa							1	<0,005			1	0,03														
Cnidaria	Cerianthus lloydii									1	<0,005											1	0,06				
Cnidaria	Edwardsiidae	1	<0,005					2	0,06	3	<0,005	1	<0,005									2	0,24				
Echinodermata	Amphiura chiajei	2	0,09			5	0,02	3	0,16	5	0,14	1	0,23			2	0,55	5	0,71	6	1,02	5	0,64	9	0,60	3	0,66
Echinodermata	Amphiura filiformis	17	0,80	2	0,02	16	0,08	24	0,57	22	0,76	50	2,49	14	0,27	42	4,19	97	5,37	192	8,07	121	5,08	52	3,92	71	9,14
Echinodermata	Brissopsis lyrifera									1	5,82					5	28,51									1	11,86
Echinodermata	Echinocardium cordatum									1	2,21																
Echinodermata	Labidoplax buskii					1	0,01	5	0,01									8	0,05			5	0,06			1	<0,005
Echinodermata	Luidia sarsi	1	0,01																								
Echinodermata	Ophiocten affinis															2	<0,005										
Mollusca	Abra nitida																	1	<0,005	2	0,04					1	<0,005
Mollusca	Antalis entalis											1	0,64			1	0,54					1	0,63			1	1,02
Mollusca	Chaetoderma nitidulum							1	0,1															1	0,06		
Mollusca	Corbula gibba	14	0,80	2	<0,005	7	0,63	3	0,17	11	0,51	7	0,29	4	0,04	1	0,02	5	0,24	4	0,55			1	0,18		
Mollusca	Cuspidaria cuspidata																	1	0,02								
Mollusca	Cylichna cylindracea	1	0,02									1	0,01														
Mollusca	Ennucula tenuis							5	0,43	2	0,24																
Mollusca	Hyala vitrea			3	0,01	2	<0,005			1	<0,005	9	0,03			3	<0,005			3	<0,005						
Mollusca	Mysella bidentata											5	<0,005					2	<0,005	1	<0,005			1	<0,005	2	<0,005
Mollusca	Nucula nitidosa							2	0,1											7	0,15						
Mollusca	Nucula sulcata																	2	0,02								
Mollusca	Parvicardium minimum									1	<0,005																
Mollusca	Parvicardium pinnulatum							1	0,05																		
Mollusca	Philine scabra							1	0,01	3	0,05	1	<0,005	3	0,07			4	0,03	2	0,04						
Mollusca	Polinices montagui	1	0,08																								
Mollusca	Polinices pulchella	2	0,05																								
Mollusca	Thyasira equalis																			3	0,02						
Mollusca	Thyasira flexuosa	7	0,10			3	0,04	33	0,49	24	0,42	2	0,03					4	0,13	3	0,03						
Nemertea	Cerebratulus	1	<0,005					2	0,15																		
Nemertea	Nemertea			1	<0,005	9	0,01									1	0,09	1	0,29	1	0,04	1	<0,005				
Sipuncula	Phascolion strombus					1	0,02											1	<0,005					1	0,02		
Sipuncula	Thysanocardia procera	1	0,01	1	0,07													2	0,01	4	0,06	7	0,48	7	0,09	2	0,23

Field FO2 (Clay)		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe hibernica	3	0,06	1	0,01	8	0,21	1	0,03	1	0,02	1	0,04			1	<0,005	3	0,05	2	0,08	3	0,14	3	0,08	2	0,07
Annelida	Ampharete finmarchica									4	0,01																
Annelida	Brada villosa																					1	0,15				
Annelida	Chaetopterus norvegicus															1	0,12							1	0,16		
Annelida	Chaetozone setosa															1	<0,005	3	0,03	1	0,01			3	0,02	2	0,01
Annelida	Diplocirrus glaucus	4	0,03			3	0,02	1	0,01	3	<0,005	1	<0,005	2	0,02			2	0,02	4	0,03	4	0,03			2	0,01
Annelida	Eunoe nodosa											1	<0,005														
Annelida	Galathowenia oculata																			1	<0,005						
Annelida	Gattyana cirrhosa											2	<0,005														
Annelida	Glycera alba			1	0,01			3	0,07			1	<0,005	1	0,02	1	0,02	2	0,09	2	0,07			1	0,04	1	0,04
Annelida	Glycera rouxii	1	0,08							1	0,22																
Annelida	Goniada maculata													2	0,12			3	0,03	2	0,02	2	0,04			1	0,02
Annelida	Heteromastus filiformis	1	<0,005													1	<0,005	1	0,02								
Annelida	Laonice bahusiensis	1	0,01																								
Annelida	Lipobranchius jeffreysii																					1	0,53				
Annelida	Magelona filiformis																	1	<0,005								
Annelida	Nephtys incisa					1	0,07	3	0,38	2	0,29	2	0,24	2	0,35	1	0,18	1	0,06	1	<0,005			5	0,16	1	0,06
Annelida	Ophiodromus flexuosus													1	<0,005									1	0,06		
Annelida	Pectinaria auricoma	1	0,01	3	0,16															1	0,03						
Annelida	Pectinaria belgica	2	<0,005			2	1,53							1	0,44					3	1,72	2	3,95	1	<0,005	11	0,17
Annelida	Pectinaria koreni											2	0,13														
Annelida	Pholoe baltica																	1	<0,005	2	<0,005					1	<0,005
Annelida	Phyllodoce groenlandica							1	<0,005															1	<0,005		
Annelida	Polycirrus spp.																	2	0,03	2	0,01	1	<0,005	1	<0,005	1	0,07
Annelida	Polydora spp.	1	<0,005					9	<0,005			2	<0,005														
Annelida	Polyphysia crassa			3	0,84	1	0,90																				
Annelida	Praxillella affinis																	1	0,06	1	0,03	2	0,07	1	0,02		
Annelida	Praxillella praetermissa	1	0,03																								
Annelida	Prionospia dubia																	1	0,03								
Annelida	Prionospio fallax									3	<0,005																
Annelida	Psamathe fusca													1	<0,005												
Annelida	Rhodine gracilior																			1	0,21						
Annelida	Scalibregma inflatum	1	<0,005					53	0,28	18	0,10	21	0,08	6	0,03	39	0,14	3	0,02			1	0,01	5	0,04	1	<0,005
Annelida	Spiochaetopterus typicus																	1	0,24								
Annelida	Spiophanes kroeyeri	1	0,04	2	0,01	1	0,01			2	0,04	1	0,05					2	0,02	2	0,03	1	0,01			1	<0,005
Annelida	Terebellides stroemi	3	0,03							1	0,01					4	0,02	1	0,02							1	0,03
Annelida	Trichobranchus roseus											1	0,02							3	0,02	2	0,04	1	0,02	1	0,04
Arthropoda	Callianassa subterranea	1	<0,005	1	0,01	1	0,01											2	0,03					1	<0,005	2	0,06
Arthropoda	Diastylis boecki																	1	0,01								
Arthropoda	Eriopisa elongata					1	<0,005			1	<0,005									1	<0,005	2	<0,005	2	<0,005		
Arthropoda	Leucothoe lilljeborgii																							1	<0,005		
Cnidaria	Edwardsiidae			1	0,01	1	<0,005			4	0,06	1	0,02	1	<0,005					1	<0,005						
Echinodermata	Amphiura chiajei	2	0,39	4	0,60	1	0,30			4	0,88			4	1,21			3	0,26	3	0,32	3	0,20	4	0,29	7	0,71
Echinodermata	Amphiura filiformis	23	0,66	41	1,94	24	1,35	18	0,32	21	1,52	27	1,15	29	2,14	8	0,33	52	3,95	74	4,82	71	6,21	102	8,23	39	3,69
Echinodermata	Brissopsis lyrifera	2	25,51			2	17,49	1	4,71	1	6,07	1	7,52	1	6,48	1	2,85			1	9,73	2	17,84			2	8,53

Echinodermata	Echinocardium cordatum					2	5,3					3	9,82	2	7,95												
Echinodermata	Echinocardium flavescens			1	2,99													1	5,32	1	0,53	1	2,53			1	2,61
Echinodermata	Labidoplax buskii																							1	<0,005		
Echinodermata	Leptopentacta elongata			1	0,03					1	0,49																
Echinodermata	Luidia sarsi	1	<0,005																								
Echinodermata	Mesothuria intestinalis											1	34,7														
Mollusca	Abra nitida					1	0,01					1	0,06							1	<0,005	1	<0,005	2	<0,005	4	0,05
Mollusca	Antalis entalis					1	0,68															1	0,36				
Mollusca	Chaetoderma nitidulum	1	0,03	1	0,06							2	0,14														
Mollusca	Corbula gibba	7	1	13	0,5	10	0,63	6	0,54	6	0,43	9	0,5	5	0,05	2	0,33	1	0,05	6	0,65			3	0,02	6	0,35
Mollusca	Cuspidaria obesa					1	0,08																				
Mollusca	Cylichna cylindracea					3	0,05			1	0,02									2	0,03					4	0,04
Mollusca	Ennucula tenuis													1	0,08												
Mollusca	Hyala vitrea	19	0,05	2	0,01	4	0,01			3	<0,005	1	<0,005			1	<0,005	1	<0,005	1	<0,005	4	<0,005				
Mollusca	Montacuta ferruginosa																	1	0,01								
Mollusca	Myrtea spinifera											1	0,03														
Mollusca	Mysella bidentata					2	<0,005																				
Mollusca	Nucula nitidosa	13	0,35	8	0,27	2	0,09					2	0,03	3	0,17	2	0,14										
Mollusca	Nucula sulcata																							1	<0,005	2	0,04
Mollusca	Phaxas pellucida											2	0,03														
Mollusca	Philine scabra	1	0,01			3	0,05	1	0,06	1	0,01	1	<0,005					1	<0,005	3	0,03	2	0,02	7	0,08	3	0,07
Mollusca	Polinices pulchella					1	0,15					1	0,14			1	0,07										
Mollusca	Tellimya tenella					3	<0,005																				
Mollusca	Thyasira flexuosa	4	0,03	5	0,02			7	0,21			3	0,08									2	<0,005			1	<0,005
Mollusca	Thyasira sarsii													1	<0,005												
Nemertea	Cerebratulus spp.													3	9,78					1	2,23			1	0,05		
Sipuncula	Golfingia vulgaris									1	0,17																
Sipuncula	Thysanocardia procera	1	0,06			4	0,24	1	0,15	1	0,05					1	0,06					1	0,03			1	0,04

		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
Field FO3 (AC+clay)		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe hibernica	1	0,02													5	0,12	1	0,02	1	0,04						
Annelida	Bylgides elegans																							1	<0,005		
Annelida	Chaetopterus norvegicus															1	1,11										
Annelida	Chaetozone setosa																	1	<0,005			2	0,012				
Annelida	Cossura longocirrata	1	<0,005																								
Annelida	Diplocirrus glaucus	1	0,01																			3	0,01			1	<0,005
Annelida	Glycera alba															1	<0,005										
Annelida	Goniada maculata															1	0,02			1	0,01					1	0,11
Annelida	Heteromastus filiformis	1	0,01	1	<0,005																	3	0,011	4	<0,005	1	<0,005
Annelida	Levinsenia gracilis																							1	<0,005		
Annelida	Magelona filiformis																	1	<0,005	1	<0,005	2	0,002	1	<0,005		
Annelida	Nephtys incisa	3	0,25	4	0,33			2	0,06	2	0,19							5	0,38	4	0,28	2	0,163	2	0,34	1	0,12
Annelida	Notomastus latericeus									1	0,14													1	<0,005		
Annelida	Pectinaria koreni																	29	0,10	11	0,78	10	0,208	9	0,62	59	1,66
Annelida	Polycirrus spp.	2	0,01			1	0,01																				

Annelida	Polydora spp.																	1	<0,005								
Annelida	Sabellides octocirrata																			1	<0,005						
Annelida	Scalibregma inflatum	1	0,01	1	0,03	2	0,18							2	0,03												
Annelida	Spiophanes kroeyeri							1	0,01	1	0,03																
Annelida	Trichobranchus roseus	1	0,01	2	0,03	1	0,03																				
Arthropoda	Callianassa subterranea					1	0,02																				
Echinodermata	Amphiura filiformis			1	<0,005	1	<0,005	1	0,02																		
Echinodermata	Brissopsis lyrifera	1	8,79			1	9,25									1	8,84										
Echinodermata	Echinocardium cordatum	2	8,58	1	3,24	1	5,30																				
Echinodermata	Leptopentacta elongata																							1	0,20		
Echinodermata	Luidia sarsi	2	0,01			1	<0,005																				
Echinodermata	Marthasterias glacialis cf.																					1	0,009				
Mollusca	Abra nitida	1	<0,005	2	0,04							1	0,08					6	1,35			4	0,631	2	0,44	1	0,12
Mollusca	Corbula gibba	3	0,73	1	<0,005	1	0,33									4	0,31			2	0,06			2	0,19		
Mollusca	Cylichna cylindracea	2	0,02	1	0,01	5	0,05			1	0,02																
Mollusca	Hyala vitrea	5	0,02	2	0,01	2	0,01											1	<0,005								
Mollusca	Montacuta ferruginosa	3	<0,005	1	<0,005	1	<0,005																				
Mollusca	Nucula sulcata	1	0,79															13	0,46	6	0,18	7	0,121	11	0,31	15	0,38
Mollusca	Parvicardium minimum	1	<0,005																								
Mollusca	Philine scabra			1	0,01									2	0,05			3	0,04	1	0,02	2	0,021	1	0,01	1	0,01
Mollusca	Polinices pulchella	1	0,03	1	<0,005																						
Mollusca	Tellimya tenella	2	0,01			3	0,01																				
Mollusca	Thyasira flexuosa																	4	0,08	3	0,04	3	0,065	3	0,10	1	0,03
Mollusca	Thyasira sarsii											1	0,01	1	0,01	1	0,01										
Nemertea	Cerebratulus spp.											1	0,02														
Nemertea	Nemertea																	1	0,09							2	<0,005
Sipuncula	Golfingia vulgaris									1	0,01																
Sipuncula	Thysanocardia procera																			1	0,09						

		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
Field FO4 (Reference)		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe hibernica			4	0,08	1	0,03	3	0,10	3	0,07			2	0,09			6	0,11	3	0,12	5	0,12	4	0,15	2	0,04
Annelida	Bylgides elegans																			1	<0,005						
Annelida	Chaetopterus norvegicus									1	1,37																
Annelida	Chaetozone setosa							1	<0,005											1	<0,005	2	<0,005	3	0,02	1	<0,005
Annelida	Diplocirrus glaucus	1	0,01	1	0,01			4	0,04	5	0,04	2	<0,005	2	<0,005	2	<0,005	3	<0,005			2	0,03	3	0,03	6	0,05
Annelida	Galathowenia oculata																									1	0,01
Annelida	Glycera alba							1	0,05	1	0,01			2	0,07			1	<0,005	1	0,08	1	0,08			1	0,01
Annelida	Goniada maculata			1	0,06	1	0,07	1	0,02									1	<0,005	2	0,08	1	0,02	2	0,05	3	0,05
Annelida	Heteromastus filiformis									1	0,02	2	0,01					1	<0,005								
Annelida	Lipobranchius jeffreysii	1	0,82																	1	0,64						
Annelida	Maldanidae									1	0,02																
Annelida	Nephtys incisa	1	0,09	1	0,02	1	0,09	1	0,07	1	<0,005	2	0,17	1	0,16	1	0,08	1	0,06	1	0,07	1	0,01	1	0,02	4	0,12
Annelida	Ophiodromus flexuosus							1	0,04	2	0,03	1	0,02	2	0,06	2	0,04					1	0,02				
Annelida	Owenia fusiformis																					1	0,01				
Annelida	Pectinaria auricoma									1	<0,005	2	0,01											1	0,02		

Annelida	Pectinaria belgica							4	4,29			1	<0,005							1	0,63						
Annelida	Pholoe baltica											1	<0,005	1	<0,005	1	0,01	1	<0,005								
Annelida	Podarkeopsis helgolandicus					1	0,01															1	0,03				
Annelida	Polycirrus spp.	1	0,02															1	0,01							1	0,08
Annelida	Polydora spp.							1	<0,005																		
Annelida	Praxillella affinis													2	0,07			3	0,15	3	0,2	3	0,12	2	0,09	8	0,3
Annelida	Praxillella praetermissa	2	0,07					3	0,09							2	0,07										
Annelida	Prionospio fallax																									1	<0,005
Annelida	Scalibregma inflatum							23	0,09	56	0,21	10	0,12	35	0,53	8	0,05	1	0,03	1	0,01			4	0,05	1	<0,005
Annelida	Scolelepis tridentata									1	<0,005															2	0,01
Annelida	Sosane sulcata																	1	0,03								
Annelida	Spiophanes kroeyeri	2	0,05			2	0,03	2	0,03	2	0,06	2	0,03	2	0,03	3	0,06			1	<0,005	1	<0,005			1	0,01
Annelida	Streblosoma bairdi									1	0,05	1	0,05	1	0,07	2	0,01										
Annelida	Terebellides stroemi			1	0,01					6	0,03			8	0,09	1	0,02	1	<0,005	4	0,04	1	<0,005	2	0,03	4	0,06
Annelida	Trichobranchus roseus																									1	0,02
Arthropoda	Ampelisca tenuicornis																							1	<0,005	1	<0,005
Arthropoda	Callianassa subterranea	1	0,12	2	0,04	1	0,02			1	0,01	3	0,12	3	0,08	3	0,13							4	0,55	3	0,06
Arthropoda	Diastylis laevis															1	0,02										
Arthropoda	Eriopisa elongata	3	0,01							1	<0,005																
Arthropoda	Oedicerotidae									1	<0,005																
Cnidaria	Edwardsiidae											1	<0,005			1	<0,005	1	0,02							2	0,02
Echinodermata	Amphiura chiajei	1	0,06	1	0,14	1	0,02											3	0,19	4	0,25	2	0,19	1	0,15	1	0,06
Echinodermata	Amphiura filiformis	24	0,91	24	1,63	17	0,50	8	0,24	7	0,10	3	0,09	9	0,59	14	0,50	59	6,64	47	4,35	47	3,41	28	2,61	36	2,33
Echinodermata	Brissopsis lyrifera	1	3,18	1	7,89	2	11,07							1	7,69	1	14,72	4	31,55	3	25,42			2	11,03	3	32,82
Echinodermata	Echinocardium cordatum			1	5,36			1	3,95							2	7,12										
Echinodermata	Echinocardium flavescens																	3	1,67	2	1,04			15	15,97	5	11,28
Echinodermata	Labidoplax buskii																									1	0,05
Echinodermata	Leptopentacta elongata																			1	0,01					1	0,56
Echinodermata	Luidia sarsi	1	0,01																								
Mollusca	Abra alba																							1	<0,005		
Mollusca	Abra nitida	1	0,04	1	0,06																	1	<0,005	1	0,02	1	<0,005
Mollusca	Antalis entalis																									1	1,51
Mollusca	Chaetoderma nitidulum			1	0,07	1	0,05																	1	0,03		
Mollusca	Corbula gibba	12	0,61	3	0,58	3	0,19			1	<0,005									1	0,29			1	0,04		
Mollusca	Cylichna cylindracea	4	0,05			3	0,04									2	0,03					1	0,02				
Mollusca	Hyala vitrea	2	<0,005			2	0,01	1	<0,005							1	<0,005										
Mollusca	Mysella bidentata																									1	<0,005
Mollusca	Mysia undata							1	0,12																		
Mollusca	Nucula nitidosa	2	0,02					1	0,07			1	0,08														
Mollusca	Nucula sulcata																			2	<0,005					1	<0,005
Mollusca	Parvicardium minimum																									1	0,05
Mollusca	Parvicardium pinnulatum													1	0,05	1	0,07										
Mollusca	Philine scabra					2	0,01			1	0,01					1	0,04			2	0,03	1	<0,005	1	0,01		
Mollusca	Thyasira flexuosa											1	<0,005									2	<0,005	2	0,01	2	<0,005
Nemertea	Cerebratulus spp.																					1	6,13				
Nemertea	Nemertea					1	1,42			1	0,72	1	0,02	1	0,09									1	<0,005		
Sipuncula	Golfingia vulgaris																			1	0,64						

Sipuncula	Thysanocardia procera	2	0,22	1	0,09							1	0,12	2	0,17	1	0,10					1	0,02	1	0,12	2	0,09

		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
Field FE5 (AC+clay)		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe																					1	0,17				
Annelida	Abyssoninoe hibernica			1	0,09													1	0,06	2	0,05	2	0,04	1	0,02	3	0,08
Annelida	Aphelochaeta sp.							1	<0,005	1	<0,005																
Annelida	Aphelochaeta marioni	2	0,02	4	0,03	1	0,02	3	0,02	4	0,04	3	0,02	6	0,16	4	0,04	23	0,35	20	0,20	6	0,06	3	0,01	9	0,08
Annelida	Bylgides elegans											2	0,02														
Annelida	Ceratocephale loveni	2	0,05	5	0,12	1	0,01	4	0,05	3	0,06	3	0,02	1	<0,005	2	0,03			2	<0,005						
Annelida	Chaetoparia nilssoni	1	<0,005									1	0,01							1	<0,005						
Annelida	Chaetozone setosa	2	0,01	10	0,08			1	<0,005	5	<0,005	4	0,02	2	0,02	4	0,02	5	0,01	2	0,01	2	0,01	1	<0,005	1	<0,005
Annelida	Diplocirrus glaucus			1	0,01	1	0,01			1	<0,005					1	<0,005										
Annelida	Euchone papillosa					2	0,02	1	<0,005	2	0,01					1	<0,005			2	<0,005			2	<0,005		
Annelida	Galathowenia oculata									1	<0,005			1	<0,005			1	<0,005	1	<0,005						
Annelida	Gattyana amondseni											1	0,01														
Annelida	Glycera alba			1	0,02			2	0,09	2	0,06	3	0,18	1	<0,005	4	0,29			1	<0,005	2	0,15	1	0,03		
Annelida	Glycera rouxii											1	0,53									1	0,69				
Annelida	Glycinde nordmanni											1	0,02							1	<0,005			1	<0,005		
Annelida	Goniada maculata									1	<0,005			1	0,03	1	0,02	1	<0,005								
Annelida	Harmothoe spp.											1	0,01														
Annelida	Heteromastus filiformis	2	0,01			2	<0,005	4	0,01	4	<0,005	4	0,01	1	<0,005	3	<0,005	3	<0,005	12	0,03	8	0,02	7	0,01	5	0,01
Annelida	Melinna cristata	2	0,03																			1	0,04				
Annelida	Neoamphitrite affinis	1	0,01																	1	0,07						
Annelida	Neoamphitrite grayi	1	0,61																								
Annelida	Nephtys incisa															1	<0,005	1	<0,005	1	0,06						
Annelida	Nephtys paradoxa																							1	0,09		
Annelida	Ophiodromus flexuosus							1	0,04																		
Annelida	Paramphinome jeffreysi	1	0,01	6	0,03	3	0,02			56	0,21	24	0,07	9	0,03	55	0,20	40	0,17	19	0,09	11	0,04	17	0,07	25	0,11
Annelida	Pholoe baltica																							1	<0,005		
Annelida	Phyllodoce groenlandica																			1	<0,005	1	<0,005			1	<0,005
Annelida	Phyllodoce rosea					1	0,01																				
Annelida	Phylo norvegica					1	0,37																				
Annelida	Pista cristata	1	0,07	2	0,28			1	0,03																		
Annelida	Polydora spp.													1	<0,005												
Annelida	Polynoidae									2	<0,005			1	<0,005	1	<0,005										
Annelida	Praxillella affinis	1	<0,005																								
Annelida	Prionospia dubia	1	0,01	1	<0,005																						
Annelida	Prionospio cirrifera																	17	0,02	21	0,04	19	0,06	13	0,03	15	0,03
Annelida	Prionospio fallax																			4	<0,005						
Annelida	Rhodine loveni	2	0,18			1	0,03	2	0,09			1	0,02			2	0,04										
Annelida	Scalibregma inflatum			2	0,06	1	0,02					1	0,01					2	0,02			1	0,02	1	<0,005	1	<0,005
Annelida	Scoletoma fragilis													1	0,24												
Annelida	Spiophanes kroeyeri	7	0,16	7	0,10	10	0,13	5	0,05	14	0,09	9	0,04	2	0,02	15	0,16	12	0,10	13	0,12	5	0,04	13	0,11	10	0,09
Annelida	Terebellides stroemi					1	<0,005																				
Arthropoda	Arrhis phyllonyx							1	0,02			3	0,07	6	0,14	3	0,06	2	0,02			1	0,02			3	0,04

Arthropoda	Campylaspis costata					1	<0,005																				
Arthropoda	Diastylis boecki			1	0,01																						
Arthropoda	Diastylis cornuta																	2	0,01					1	<0,005		
Arthropoda	Diastyloides serratus					6	0,01					1	<0,005														
Arthropoda	Eudorella emarginata							1	<0,005	3	<0,005			3	0,02	2	<0,005	4	<0,005	7	0,02	1	<0,005	4	0,01	3	0,01
Arthropoda	Eudorella truncatula																	2	<0,005					1	<0,005		
Arthropoda	Gnathia oxyurea			1	<0,005																						
Arthropoda	Hippomedon propinquus																	1	<0,005	1	<0,005						
Arthropoda	Leptostylis longimana					1	<0,005																				
Arthropoda	Leucon nasica					1	<0,005	1	<0,005	2	<0,005			2	0,01	2	<0,005	6	0,03	11	0,05	5	<0,005	8	0,02	8	0,02
Arthropoda	Lysianassidae									1	<0,005																
Arthropoda	Monoculodes carinatus									1	<0,005																
Arthropoda	Philomedes brenda	2	<0,005			4	0,01					1	<0,005					1	<0,005			1	<0,005	2	<0,005	6	<0,005
Arthropoda	Tanaidacea	2	<0,005			1	<0,005																				
Arthropoda	Westwoodilla caecula																			4	0,02	1	<0,005			2	0,01
Echinodermata	Amphiura chiajei							1	0,01									1	0,17	1	0,25			2	0,01		
Echinodermata	Amphiura filiformis					1	<0,005	1	0,01													1	0,04				
Echinodermata	Brissopsis lyrifera							1	12,11																		
Echinodermata	Ophiocten affinis					1	0,08																				
Echinodermata	Ophiura albida																	1	<0,005								
Mollusca	Abra nitida	1	<0,005	1	0,01	3	<0,005	13	0,55	2	0,08	9	0,23	13	0,38	13	0,37			1	0,09			1	0,09		
Mollusca	Corbula gibba	1	0,01																								
Mollusca	Ennucula tenuis	1	<0,005																	2	0,04						
Mollusca	Hyala vitrea	3	0,01																								
Mollusca	Mysella bidentata	1	<0,005																								
Mollusca	Nudibranchia									1	0,02																
Mollusca	Parvicardium pinnulatum							1	0,02																		
Mollusca	Philine aperta																	1	0,03			2	<0,005	1	<0,005		
Mollusca	Philine scabra							3	0,05	3	0,03	4	0,06	1	0,02	1	0,03	1	<0,005	2	<0,005	1	0,04				
Mollusca	Thyasira equalis	22	0,43	28	0,34	18	0,18	1	0,05	17	0,50	27	0,54	3	0,09	12	0,39	29	0,43	21	0,51	17	0,36	20	0,59	22	0,39
Mollusca	Thyasira sarsii					1	<0,005											1	0,03			2	0,10				
Mollusca	Tropidomya abbreviata																									1	0,05
Mollusca	Yoldiella philippiana	10	0,13	5	0,04	12	0,17	1	0,02	4	0,06	4	0,03	2	0,05			3	0,05	5	0,11	4	0,08	3	0,06	2	0,04
Nemertea	Cerebratulus spp.							1	0,04																		
Nemertea	Nemertea																	1	<0,005	1	<0,005	2	0,09			1	<0,005
Platyhelminthes	Turbellaria											1	0,03											1	0,27		
Sipuncula	Phascolion strombus	6	<0,005	5	<0,005	1	<0,005																				

		Month 1 (2009)						Month 14 (2010)										Month 49 (2013)									
Field FE6 (Reference - 80 m)		1 FO1:A		1 FO1:B		1 FO1:C		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Abyssoninoe hibernica	3	0,12	4	0,13	2	0,07	3	0,07	2	0,03	5	0,16	6	0,42	2	0,08	3	0,11	1	0,03	5	0,09	4	0,16	1	0,01
Annelida	Anobothrus gracilis											1	0,01			1	<0,005					1	0,02				
Annelida	Aphelochaeta marioni	4	0,04	2	0,02	4	0,04	2	0,01	9	0,09	15	0,13	20	0,25	11	0,15	11	0,11	8	0,09	11	0,07	9	0,13	6	0,09
Annelida	Brada villosa									2	0,01	1	<0,005	2	0,07	6	0,18	3	0,06					1	0,03		
Annelida	Bylgides elegans									1	<0,005							2	0,01	2	0,02	1	0,01	3	0,00	1	0,01
Annelida	Ceratocephale loveni					3	0,03	4	0,05	2	0,04	4	0,04	3	0,04	2	<0,005	5	0,04	3	0,09	2	0,05	2	0,05		

Annelida	Chaetozone setosa	1	0,01			1	<0,005	13	0,07	1	<0,005	12	0,05	7	0,04	11	0,05	38	0,18	22	0,1	18	0,09	16	0,09	4	0,03
Annelida	Diplocirrus glaucus	2	0,02	3	0,01	1	0,01	1	0,01	5	0,03	1	0,01	1	0,01	3	0,01	8	0,11	3	0,04	9	0,07	1	0,01	10	0,08
Annelida	Drilonereis filum																			1	0,5						
Annelida	Eclysippe eliasoni	2	<0,005			1	0,01	1	<0,005	2	0,01	3	<0,005	1	<0,005	1	<0,005					4	0,01	2	<0,005	4	0,01
Annelida	Eteone sp.																							1	<0,005		
Annelida	Eteone longa cf.																					1	<0,005				
Annelida	Euchone papillosa			1	<0,005	1	0,02	2	<0,005							1	<0,005					1	0,01			1	0,01
Annelida	Eumida bahusiensis													1	<0,005												
Annelida	Exogone verugera																					1	<0,005				
Annelida	Galathowenia oculata					1	<0,005					3	0,02					2	<0,005			6	0,01			1	<0,005
Annelida	Gattyana amondseni			1	<0,005																						
Annelida	Glycera alba	1	0,02			4	0,16	2	0,03	3	0,08	4	0,12	3	0,06	3	0,02			2	0,26	2	0,02	3	0,06	5	0,2
Annelida	Glycera rouxii	2	0,38							2	0,47	1	1,08														
Annelida	Glycinde nordmanni					1	0,01																	1	0,03		
Annelida	Glyphohesione klatti			1	0,01																						
Annelida	Goniada maculata							1	0,04	1	0,05			2	0,07	1	0,01	1	<0,005	1	<0,005	1	0,03	3	0,05		
Annelida	Harmothoe spp.							1	<0,005																		
Annelida	Harmothoe borealis cf.																					2	0,01			1	<0,005
Annelida	Heteromastus filiformis	4	0,02	3	0,01	1	<0,005	7	0,02	11	0,03	9	0,02	5	0,01	8	0,02	39	0,17	21	0,14	25	0,12	8	0,03	19	0,12
Annelida	Iphitime hartmanae	1	0,08																								
Annelida	Jasmineira caudata																					3	<0,005				
Annelida	Laonice bahusiensis																					1	<0,005				
Annelida	Levinsenia gracilis																					5	<0,005			3	<0,005
Annelida	Lipobranchius jeffreysii			2	1,08			6	1,64	2	0,53	5	1,40	3	1,62	5	1,20	3	1,06	3	1,85	1	0,20			1	0,55
Annelida	Lumbrineris gracilis																									1	0,01
Annelida	Maldane sarsi			3	0,01																						
Annelida	Melinna cristata	3	0,03					1	0,03											1	0,12					1	0,04
Annelida	Mugga wahrbergi																					5	<0,005				
Annelida	Neoamphitrite affinis					1	2,36							4	4,32												
Annelida	Nephtys incisa																	1	0,05								
Annelida	Nereiphylla lutea	1	0,01									1	<0,005														
Annelida	Notomastus latericeus	1	0,06	1	0,03																					2	0,15
Annelida	Ophelina sp.																					1	<0,005				
Annelida	Ophelina norvegica															1	0,02	1	0,03								
Annelida	Ophiodromus flexuosus									1	<0,005	2	0,04			1	0,01	1	0,02								
Annelida	Paramphinome jeffreysi			3	0,02	3	0,01	13	0,04	33	0,13	14	0,05	46	0,15	20	0,06	7	0,04	2	<0,005	11	0,04	8	0,01	3	0,02
Annelida	Paramphitrite tetrabranchia	1	0,03	1	0,01	1	0,04					3	0,09			3	0,05										
Annelida	Pectinaria belgica			1	1,67																						
Annelida	Pectinaria koreni									1	0,01			1	0,04												
Annelida	Pholoe baltica							1	<0,005	1	<0,005							1	<0,005			4	0,01	2	<0,005	1	0,01
Annelida	Pholoe pallida							1	<0,005									2	0,01					1	0,01	1	0,01
Annelida	Phyllodoce groenlandica																			1	<0,005					1	0,01
Annelida	Phyllodoce rosea			1	<0,005																			1	<0,005		
Annelida	Phyllodocidae											1	<0,005														
Annelida	Pista sp.																					1	0,11			2	0,34
Annelida	Pista cristata	3	1,04			3	0,03							1	0,12	1	0,03			1	0,36						
Annelida	Polycirrus spp.	1	0,10																			1	0,02	1	0,09	1	0,09

Annelida	Polydora spp.															1	<0,005					7	<0,005			4	<0,005
Annelida	Polynoidae	1	<0,005	1	<0,005			2	0,01			1	<0,005														
Annelida	Polyphysia crassa																							1	0,51		
Annelida	Praxillella affinis	1	<0,005	1	<0,005													2	0,02			6	0,08			2	0,03
Annelida	Praxillella praetermissa																							1	0,06		
Annelida	Prionospia dubia			2	0,02																	16	0,05	7	0,01	10	0,03
Annelida	Prionospio cirrifera							1	<0,005	1	<0,005	1	<0,005					50	0,07	3	0,01	25	0,06	18	0,02	10	0,01
Annelida	Prionospio fallax							4	0,02													2	0,01				
Annelida	Proclea graffii	1	<0,005																								
Annelida	Rhodine loveni			1	0,09	1	0,01	3	0,24	2	0,38	4	0,08			1	0,06	1	0,16	4	0,10	6	0,29	1	0,13	3	0,09
Annelida	Scalibregma inflatum							2	0,12	3	0,01	5	0,03	4	0,01	2	0,02	22	0,45	20	0,32	14	0,15	14	0,33	2	0,04
Annelida	Scoletoma fragilis			1	0,52																			1	0,22	1	0,13
Annelida	Scoletoma impatiens																									1	0,04
Annelida	Sige fusigera																	1	<0,005								
Annelida	Sosane sulcata	1	0,01			1	<0,005											2	0,02			3	0,01			2	0,01
Annelida	Spiophanes kroeyeri	17	0,10	9	0,07	22	0,14	11	0,05	3	0,04	12	0,05	17	0,06	25	0,08	15	0,08	3	0,01	41	0,18	6	0,11	39	0,13
Annelida	Streblosoma bairdi	8	2,60	6	2,34	5	0,73	6	3,35	3	0,37	13	3,07	4	0,28	5	0,88	3	1,93	7	3,17	8	2,52	3	2,13	5	2,75
Annelida	Syllidae																	2	<0,005								
Annelida	Terebellides stroemi			1	<0,005			1	0,04			1	0,02							1	<0,005					1	0,03
Annelida	Tharyx killariensis			1	0,01																						
Annelida	Trichobranchus roseus															1	0,01										
Arthropoda	Ampelisca gibba	1	0,01	2	<0,005	1	<0,005															1	<0,005				
Arthropoda	Ampelisca macrocephala									3	0,01																
Arthropoda	Aora gracilis															2	<0,005										
Arthropoda	Arrhis phyllonyx													2	0,05			1	0,02			1	0,01	1	0,02		
Arthropoda	Callianassa subterranea											1	<0,005														
Arthropoda	Campylaspis costata			1	<0,005																						
Arthropoda	Diastylis boecki							1	<0,005							1	<0,005										
Arthropoda	Diastylis cornuta																					1	0,01				
Arthropoda	Diastyloides biplicatus													1	<0,005												
Arthropoda	Diastyloides serratus															1	<0,005										
Arthropoda	Eriopisa elongata									2	0,03																
Arthropoda	Gnathia oxyurea			2	<0,005																	7	0,02				
Arthropoda	Harpinia antennaria					1	<0,005																				
Arthropoda	Harpinia crenulata	1	<0,005																								
Arthropoda	Hippomedon propinquus																					2	0,01				
Arthropoda	Jassa pusilla																					2	<0,005				
Arthropoda	Leucon nasica																	1	<0,005					1	<0,005		
Arthropoda	Leucothoe lilljeborgii					1	<0,005							2	<0,005			1	<0,005			1	<0,005	3	<0,005		
Arthropoda	Lysianassidae			1	0,02																						
Arthropoda	Monoculodes packardi																					1	<0,005				
Arthropoda	Westwoodilla caecula					1	0,01					1	0,01					1	<0,005			1	0,01			1	0,01
Cnidaria	Edwardsiidae																					1	<0,005				
Echinodermata	Amphiura chiajei	3	0,01	1	<0,005			2	0,13	1	0,01			4	0,17	5	0,36	4	0,49			4	0,77	3	0,40	7	0,58
Echinodermata	Amphiura filiformis	2	0,01	1	<0,005	2	<0,005																				
Echinodermata	Brissopsis lyrifera	4	16,08			1	12,46	1	3,98			1	4,45									2	9,34			1	6,87
Echinodermata	Echinocardium			2	<0,005																						

	flavescens																										
Echinodermata	Luidia sarsi	1	<0,005	1	<0,005																						
Echinodermata	Ophiocten affinis																					2	0,01			1	0,01
Echinodermata	Spatangidae					1	<0,005																				
Mollusca	Abra nitida	2	0,01	13	0,02	1	0,01			4	0,08	1	0,01	3	0,09	1	<0,005	1	<0,005			2	<0,005	24	0,03		
Mollusca	Antalis entalis																							1	0,26		
Mollusca	Chaetoderma nitidulum					1	<0,005			1	0,01											1	0,01				
Mollusca	Cuspidaria spp.			1	0,01																						
Mollusca	Cylichna cylindracea																					1	0,03	1	<0,005		
Mollusca	Ennucula tenuis	7	0,23	3	0,21	1	0,01	2	0,13			1	0,19	1	<0,005	3	0,21	1	0,09			1	0,02			1	0,08
Mollusca	Hyala vitrea			1	<0,005																			1	<0,005	1	<0,005
Mollusca	Mendicula ferruginosa																					3	0,01				
Mollusca	Mysia undata																									1	<0,005
Mollusca	Nudibranchia							1	0,01																		
Mollusca	Philine aperta			2	0,01													1	<0,005								
Mollusca	Philine scabra	1	0,01					1	0,09			1	0,08			1	0,01					2	0,01				
Mollusca	Polinices montagui																									1	0,24
Mollusca	Pseudamussium peslutrae	1	0,02					1	2,56			2	3,00														
Mollusca	Tellimya tenella	2	0,01																			2	0,01			2	<0,005
Mollusca	Thyasira equalis	21	0,18	36	0,15	23	0,11	10	0,13	8	0,09	13	0,30	21	0,33	18	0,26	19	0,29			33	0,43	20	0,09	29	0,26
Mollusca	Thyasira sarsii																	13	0,3								
Mollusca	Tropidomya abbreviata																					1	<0,005				
Mollusca	Yoldiella philippiana	4	0,01	11	0,03	14	0,10	5	0,04	1	<0,005	1	<0,005	5	0,04	8	0,07	4	0,02			14	0,07	2	<0,005	2	0,01
Nemertea	Cerebratulus spp.							1	0,02			2	0,41	2	0,46	2	0,08										
Nemertea	Nemertea			1	<0,005													4	0,07	1	0,01	5	0,07	3	0,14	5	0,23
Platyhelminthes	Turbellaria													1	0,01							1	0,01	1	0,02		
Sipuncula	Phascolion strombus					1	<0,005																				
Xenacoelomorpha	Xenoturbella																			1	0,08						

Field FE6 (Reference - 80 m)		Month 14 (2010)										Month 49 (2013)									
		14 FO1:A		14 FO1:B		14 FO1:C		14 FO1:D		14 FO1:E		49 FO1:A		49 FO1:B		49 FO1:C		49 FO1:D		49 FO1:E	
Phylum	Taxa	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Annelida	Anobothrus gracilis					1	<0,005														
Annelida	Aphelochaeta marioni	11	0,15	12	0,19	9	0,16	20	0,25	17	0,36	9	0,07	25	0,14	21	0,12	7	0,12	3	0,05
Annelida	Brada villosa											1	0,07					2	0,01		
Annelida	Bylgides elegans	1	0,03					2	0,01			3	0,02			1	0,01	2	0,11		
Annelida	Ceratocephale loveni	2	0,05	14	0,28	2	0,04	8	0,06	5	0,04	4	0,05	13	0,39	15	0,25	4	0,24	5	0,29
Annelida	Chaetoparia nilssoni	1	<0,005													2	0,01				
Annelida	Chaetozone setosa	30	0,20	31	0,20	20	0,17	48	0,25	28	0,23	48	0,14	67	0,16	58	0,16	76	0,39	16	0,08
Annelida	Diplocirrus glaucus			1	<0,005							1	0,02					1	0,02		
Annelida	Eteone sp.																			1	<0,005
Annelida	Euchone papillosa							1	<0,005			4	0,01								
Annelida	Galathowenia oculata							1	<0,005	4	0,01	4	0,01	2	0,01	3	0,01	1	<0,005		
Annelida	Glycera alba	3	0,05					2	0,02	3	0,24					1	0,07				
Annelida	Glycera rouxii	1	0,18					1	0,13	1	1,46					1	0,98				
Annelida	Goniada maculata	2	0,05	2	0,11	2	0,05	1	<0,005	1	<0,005	3	0,13					2	0,10	1	0,07
Annelida	Heteromastus filiformis	9	0,04	3	<0,005	17	0,04	3	0,01	11	0,03	10	0,03	24	0,05	31	0,07	40	0,16	5	0,03
Annelida	Lipobranchius jeffreysii					1	0,09														

Annelida	Melinna cristata	1	<0,005	1	0,07			1	0,02	1	<0,005	2	<0,005	2	0,03	2	0,07				
Annelida	Nephtys incisa													1	0,06						
Annelida	Nephtys pulchra													1	0,40						
Annelida	Nereimyra punctata							1	<0,005									1	0,02		
Annelida	Ophelina norvegica					1	0,06														
Annelida	Paramphinome jeffreysi	27	0,08	13	0,03	2	<0,005	5	0,01	20	0,06	45	0,20	38	0,19	17	0,07	67	0,38	17	0,09
Annelida	Pectinaria koreni	1	<0,005	2	<0,005													1	0,02		
Annelida	Pholoe baltica											1	<0,005								
Annelida	Phyllodoce groenlandica											2	0,04			1	0,02				
Annelida	Phyllodoce rosea															2	<0,005				
Annelida	Phylo norvegica			1	0,06							1	0,02								
Annelida	Pista cristata							3	0,56							1	0,28				
Annelida	Pistella lornensis											1	0,19	1	0,02	3	0,51				
Annelida	Polydora spp.									1	<0,005										
Annelida	Polynoidae			1	0,01					2	<0,005										
Annelida	Polyphysia crassa											1	0,98								
Annelida	Prionospio cirrifera			2	<0,005	4	0,02	7	0,01	2	<0,005	28	0,03			4	<0,005	40	0,05	2	<0,005
Annelida	Prionospio fallax															1	<0,005				
Annelida	Rhodine gracilior											1	0,03	2	0,03	1	<0,005			1	<0,005
Annelida	Rhodine loveni					1	0,06	2	0,17	2	0,15					1	0,07				
Annelida	Scalibregma inflatum	1	0,03	5	0,20	8	0,16	4	0,13	5	0,17	23	0,22	57	0,68	49	0,30	63	0,66	16	0,27
Annelida	Sige fusigera			1	<0,005			2	<0,005												
Annelida	Spiophanes kroeyeri	35	0,33	16	0,31	10	0,15	7	0,13	8	0,12	4	0,01	35	0,12	11	0,12	18	0,07	1	0,03
Annelida	Streblosoma bairdi							2	0,22							2	0,74			2	0,33
Annelida	Terebellides stroemi	2	0,03							1	0,04									1	0,38
Arthropoda	Arrhis phyllonyx	7	0,14	1	0,01	5	0,11	3	0,08	1	0,01					1	0,02	1	0,01	1	0,02
Arthropoda	Bathymedon longimanus											1	<0,005								
Arthropoda	Callianassa subterranea			1	<0,005																
Arthropoda	Campylaspis costata			1	<0,005																
Arthropoda	Diastylis cornuta											6	0,04					1	<0,005		
Arthropoda	Diastyloides serratus	2	<0,005	1	<0,005															2	<0,005
Arthropoda	Eriopisa elongata			1	<0,005			2	0,01	1	<0,005							1	<0,005		
Arthropoda	Eudorella emarginata	6	<0,005	2	<0,005			2	<0,005	3	<0,005	6	0,01	5	0,01	1	<0,005	6	0,01	2	<0,005
Arthropoda	Eudorella truncatula											1	<0,005	3	<0,005					1	<0,005
Arthropoda	Gnathia oxyurea															4	0,01				
Arthropoda	Leucon nasica	5	<0,005	3	0,01	3	0,01	5	0,02	2	<0,005	5	0,01	7	<0,005	1	0,00	5	<0,005	1	<0,005
Arthropoda	Leucothoe lilljeborgii			1	<0,005							1	<0,005	1	<0,005	2	<0,005	1	<0,005		
Arthropoda	Lysianassidae					1	<0,005														
Arthropoda	Philomedes brenda											1	<0,005								
Arthropoda	Phoxocephalidae					1	<0,005														
Arthropoda	Westwoodilla caecula	1	<0,005									1	<0,005								
Echinodermata	Brissopsis lyrifera							1	19,84									1	16,31		
Echinodermata	Ophiocten affinis					2	0,03											1	<0,005		
Mollusca	Abra nitida	2	0,04	5	0,17	3	0,05	3	0,05	9	0,19										
Mollusca	Ennucula tenuis	1	0,04									1	0,01	5	0,08					1	0,04
Mollusca	Philine scabra					1	0,01	3	0,16	2	0,11	2	0,04					1	0,01		
Mollusca	Pseudamussium peslutrae							1	0,72												
Mollusca	Tellimya tenella																	2	<0,005		

Mollusca	Thyasira equalis	3	0,08	23	0,18	1	0,03	18	0,27	23	0,46	16	0,24	25	0,27	16	0,23	14	0,3	7	0,18
Mollusca	Tropidomya abbreviata															1	0,04				
Mollusca	Yoldiella philippiana	1	<0,005			2	0,03			4	0,05	3	0,06			2	0,03			2	0,05
Nemertea	Cerebratulus spp.			2	0,08	3	0,09			1	0,05										
Nemertea	Nemertea											2	0,48			2	0,24	3	0,09		
Sipuncula	Phascolion strombus											1	0,09								

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