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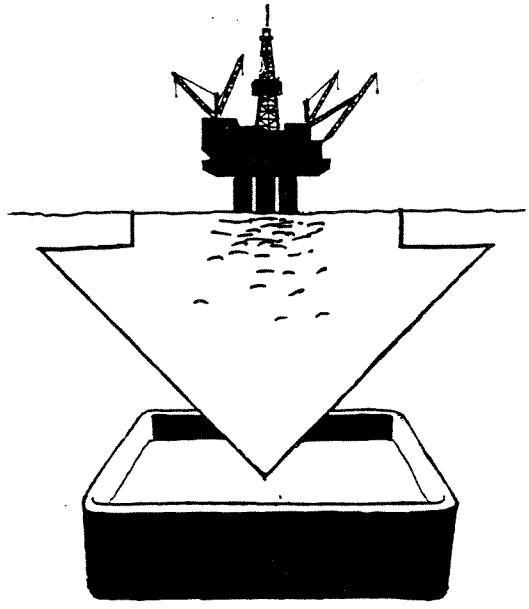
The effect of treated drill cuttings on benthic recruitment and community structure

- an experimental study on a natural seabed



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Abstract: Environmental effects of treated cuttings were tested experimentally in situ. The cuttings originated from drilling with a low toxicity oil based mud. The base oil and aromatic content in the original test material were 0-20% and 0-285 µg/g respectively. Environmental effects were tested by 1) faunal changes after the addition of a 3 mm layer of cuttings on a natural benthic community, and 2) recolonization of azoic sediment mixed with 10 % cuttings. Treatments with cuttings with a high baseoil content (15-20%) resulted in severe effects. Significant but less severe effects could also be seen in cuttings treated with a baseoil content of 2-3 %. Tests with standard thermal treated (200-250 °C) cuttings (baseoil content 0.3 %) gave no significant effects. The solvent washed (hexane) cuttings (baseoil content 1.45%) resulted in few environmental effects. Some effects could, however, be seen on three species of polychaetes. Based on the total species matrix for the experiment on a natural benthic community, the threshold for gross effects on community structure was a sediment base oil concentration of 1000 ppm. Some individual species showed effects at a base oil content between 150 and 1000 ppm.

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THE EFFECT OF TREATED DRILL CUTTINGS ON BENTHIC RECRUITMENT AND COMMUNITY STRUCTURE - AN EXPERIMENTAL STUDY ON A NATURAL SEABED

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PREFACE

Norwegian Institute for Water Research (NIVA) has been commissioned by the Oil Industry International Exploitation and Production Forum (E & P Forum) to perform field experiments in the subtidal to test possible effects of drill cuttings on benthic communities.

Metocean Consultancy Ltd. (now Metocean plc) has acted as E & P Forums representative and have, through Scott McKelvie, managed the day to day business between NIVA and E & P Forum.

The Warren Spring Laboratory (UK) have undertaken preparation, storage and distribution of cuttings to the research groups involved. The cuttings tested were 1)untreated drill cuttings used in the North Sea 2) cuttings that have undergone various treatments to reduce the oil concentration on the cuttings.

Peter Tibbetts and Simon Hird at M-Scan Ltd have been responsible for the hydrocarbon analyses and Bill Harris, Institute of Offshore Engineering at Heriot-Watt University has performed the Metal analyses. M-Scan Ltd. has acted as a central laboratory for both the hydrocarbon and metal analyses.

Project manager at NIVA was John Arthur Berge. The initial planning of the project at NIVA was performed by Torgeir Bakke.

The drill cuttings received from The Warren Spring Laboratory have also been tested by other research groups which have addressed aspects not covered by NIVA. These are:

Delft Hydraulics, The Netherlands: Physical and chemical characteristics of the drill cuttings, flocculation and resuspension.

Brandsma Engineering, USA: Modelling of drill cuttings deposition.

IMW-TNO, The Netherlands: Mesocosm experiments on intertidal organisms

Marine Laboratory, Scottish Office Agriculture and Fisheries Department (SOAFD): Enzyme induction, uptake of hydrocarbon into tissues and histopathology in fish

Oslo, 1. September 1993

John Arthur Berge

CONTENTS

Page

PREFACE ii

CONTENTS iii

SUMMARY 1

1. INTRODUCTION 7

2. METHODS AND CUTTINGS TESTED 9
2.1 Cuttings tested 9
2.2 Experimental site 11
2.3 Experiments on benthic community structure 12
2.4 Settling experiment (I) in boxes 18
2.5 Settling experiment (II) in boxes 21
2.6 Hydrocarbon and metal analyses 22
2.7 Statistical methods 22

3. RESULTS 24
3.1 Experiments on benthic community structure 24
3.1.1 Hydrocarbon and metal analyse 24
3.1.2 Redox potential 31
3.1.3 Community responses 33
3.1.4 Species responses 44
3.2 Settling experiment (I) in boxes 58
3.2.1 Hydrocarbon and metal analyses 58
3.2.2 Redox potential 64
3.2.3 Community responses 65
3.2.4 Species responses 73
3.3 Settling experiment (II) in boxes 78
3.3.1 Hydrocarbon and metal analyses 78
3.3.2 Redox potential 80
3.3.3. Community responses 80
3.3.4 Species responses 86

CONTENTS (continued)

Page

4. DISCUSSION AND CONCLUSIONS..... 88

5. REFERENCES..... 92

APPENDIX..... 95

A . Results from hydrocarbon analyses of sediment..... 95

B. Results from metal analyses of sediment..... 96

C, Results from redox measurements in the sediment..... 107

D, Results from benthic fauna analyses..... 111

SUMMARY

The main findings of the study can be summarised as follows: Treatments with cuttings with a high baseoil content (15-20%) resulted in severe effects. Significant but less severe effects could also be seen in cuttings treated with a baseoil content of 2-3 %. Test with thermal treated (200-250 °C) cuttings (baseoil content 0.3 %) gave no significant effects. The solvent washed (hexane) cuttings (baseoil content 1.45%) resulted in few environmental effects. Some effects could, however, be seen on three species of polychaetes (Prionospio malmgreni, Spiophanes bombyx and Spio sp.). Based on the total species matrix for the experiment on a natural benthic community, the threshold for gross effects on community structure was a sediment base oil concentration of 1000 ppm. Some individual species showed effects at a base oil content between 150 and 1000 ppm.

During offshore drilling activities large quantities of drill cuttings and adhering drilling muds are discharged into the sea and subsequently settle on the seabed. These discharges have resulted in increased oil content in sediment and biological effects on benthic communities out to at least to 2-5 km from some installations in the North Sea.

Before 1991, the maximum oil content allowed in discharged cuttings in the North Sea was 10% in the Norwegian sector (NCS) and 15% in the UK sector. From 1993, the discharge of oil based mud (OBM) adhering to cuttings is generally not allowed in NCS, without special approval by the Norwegian authorities.

In order to meet the environmental requirements of authorities, the oil industry has increased efforts in developing techniques that will reduce or eliminate oil from cuttings. The oil content can be reduced by cleaning the cuttings before discharge.

The primary objective of the present experiments, was to assess environmental effects of discharged cuttings from drilling with a low toxicity oil based mud (OBM), which have been treated by various methods in order to reduce the base oil content.

The experiments have been performed in the Oslofjord, Norway at a depth of 10-15 m. Environmental effects were studied in benthic subtidal communities.

A total of 10 treatments (plus untreated controls) were tested. These were:

Cuttings no.	*Base oil (%)*	*Aromatic comp. (µg/g)*	*Description*
1	0.025	not detected	Ground rock, sand, barite and clay to mimic the particle size distribution of the bulk cuttings sample received from offshore
2	15.85	79.5	Cuttings sample as received from the shaker
3	19.6	39.5	Centrifuging
4	14.75	16.5	Centrifuging with surfactant, contains alkylphenol
5	1.45	42.5	Best achievable solvent wash (hexane) by prototype plant
6	2.85	25.5	Sample 5 blended with sample 2
7	2.9	26.5	From inefficient operated solvent extraction process
8	0.295	2.05	Standard thermal treatment process (200-250 °C)
9	1.95	9.5	As case no 8 but added recovered oil in order to simulate inefficient thermal treatment.
11	5.15	285	Water wash treatment

The primary cuttings were collected directly from the shale shakers on a BP platform on the Miller field of block 16/8b of the UK sector. The drilling fluid used throughout the collection interval was a low toxicity oil based mud using BP 83 HF as the continuous phase and calcium chloride brine as the discontinuous phase.

Both effects of a layer of cuttings on a natural established benthic sediment community and larval recruitment to cuttings-treated sediment in boxes placed on the sea floor have been investigated.

Two main types of experiments were performed:

Method - Experiments on intact benthic sediment communities.

The experiments were performed within 20 square fiberglass frames (1m x 1 m) on the sea floor. These frames defined the experimental plots where the different types of cuttings were distributed. The cuttings were distributed on the sediment surface by preparing an "ice sandwich" in a 7 cm high trays (1m x 1m) in a 3 step procedure.

1. A 1.5 cm layer (15 litre) of sea water was frozen in the bottom of each tray .

2. Cuttings (3 litre) where mixed mechanically with 10 litre of sea-water and spread as evenly as possible on top of the first layer of ice, and allowed to freeze.

3. An 1-2 cm layer of sea-water was allowed to freeze on top of the layer containing the cuttings.

Sandwiches were made for all treatments. "Control sandwiches" were made with sea-water alone. These ice sandwiches were used for distributing the cuttings evenly on top of the sediment in each experimental plot. This was performed by divers placing the ice sandwich (bottom up) on top of each frame. As the sandwich thawed, the cuttings settled evenly (3 mm layer) onto the benthic system within each frame.

Cores were collected in each experimental plot at the start (Oct. 1991) and termination (June 1992) of the experiments for metal and hydrocarbon analyses. Approximately one week after adding the cuttings to the sediment surface, the first samples for fauna analyses were collected. Such samples were also collected in the middle (Feb. 1992) and end of the experiments. Animals retained on a 1 and 0.5 mm sieve were identified and enumerated.

Method - Settling experiments

In these experiments the pattern and intensity of settlement of benthic animals to azoic sediment with cuttings added was tested. The experiment was performed by placing sediment contaminated with cuttings on the sea floor in experimental boxes (surface area 0.24 m^2). Each box contained a 9 cm thick layer of homogenised clean sediment on top of which a 3 cm layer of sediment spiked with 10 % (volume) of cuttings was laid. The sediment used for the settling experiments was collected at 30 m depth in the Oslo fjord. A total of 32 boxes were prepared and placed frozen on the sea floor on the 30. July .

Sixteen boxes were retrieved after approximately 3 months exposure in situ whereas the remaining boxes were retrieved after 7.5 months.

Cores were taken in each box for analyses of hydrocarbons and metals. Only the top 2 cm of the sediment were used for the analyses. Redox potential in sediment was measured at the end of all experiments.
The remaining sediment was sieved for macrofauna (animals retained on 1 mm sieve) identification and enumeration.

For all experiments, biological effects at the community level were assessed by multi dimensional scaling (MDS) and by calculating diversity measures. At the species level biological effects were assessed by testing for abundance differences between the different treatments.

Ranked environmental effects of cuttings

The different experiments generally rank the treatments similarly:

Environmental effect ranked for each of the experiments. For each row the lowest number (1) indicates a large environmental effect whereas the highest number (total number of treatments in the experiment) indicates no or little environmental effect. Within each row similar numbers indicate that treatment effects can not be separated. Comparison between rows must be done based on the rank within each row and not on the absolute numbers. Cut.n=cuttings n

A: Effects of a 3 mm layer, community level.
B: Effects of a 3 mm layer , species level.
C: Settling in boxes, community level.
D: Settling in boxes, species level.
E: Additional settling experiment .
NT=Not tested.

	Cont.	Cut.1	Cut.2	Cut.3	Cut.4	Cut.5	Cut.6	Cut.7	Cut.8	Cut.9	Cut.11
A	8	8	1	1	1	7	4	4	8	4	NT
B	8	8	1	2	2	7	5	4	8	5	NT
C	4	4	1	1	1	4	4	4	NT	NT	NT
D	7	7	2	2	1	6	4	4	NT	NT	NT
E	3	NT	1	NT	NT	NT	NT	NT	NT	NT	2

For all the experiments cuttings 2-4 gave the largest environmental effect. Whereas cuttings 1 and Cuttings 8 together with the Control had the least effect. Cuttings 6, Cuttings 7 and Cuttings 9 gave totally less effects than Cuttings 2-4 but more than Cuttings 5.

The best precision for determining the no effect concentration of baseoil were found for the experiments where a 3 mm layer of cuttings was distributed on top of the sediment because the number of concentrations tested were higher (the total suite of cases were not tested in all the experiments). This has probably affected the results more than the experimental approach as such. It can thus not be stated which of the two methods is best for evaluating effects of drilling discharges.

The total cadmium (Cd), lead (Pb) and Zinc (Zn) concentrations in case 8, 9 and especially case 1 (reference sediment) were high compared with "background" concentrations in coastal sediment. The effects of heavy metals will however depend on other factors such as availability, which for the present cuttings probably have been low (Delvigne 1993).

The plots and boxes that received the reference material (Cuttings no. 1) with a high level of metals (Pb, Cd, Zn and Ba) grouped together with the control plots for all the main experiments. This indicates that the metal concentration (Ba: 1100-300 µg/g dry weight (dw.), Cd: 2-5 µ g/g dw., Pb: 300-800 µg/g dw. and Zn: 160-450 µg/g dw.) had no effect.

From monitoring in the Norwegian sector a conservative lower limit for effects of barium to a selected number of species is set to 500 ppm. The present experiment indicates that the no effect concentration for barium probably is above 700-1100 µg/g dw.

Community structure experiment

The community structure in the different plots added a layer of 3 mm of cuttings at the start of the experiment was still relatively homogenous after 1 week and no single species dominated the community. After 3.5 and 7 months a clear separation of the different treatments could be identified. The control plots (and the plots treated with reference material (Cuttings no. 1) clustered together and were distinctly separated from the high oil plots (cuttings no. 2,3 and 4) and the medium oil plots (Cuttings 6,7 and 9). After 3.5 months *Capitella capitata* dominated the samples from plots treated with Cuttings 2-4 and thus reduced diversity significantly. *C. capitata* were still abundant in these plots after 7 months. By the end of the experiments, a massive settlement of *Polydora* species in all plots had reduced the dominance of *Capitella* in the high oil treatments.

Based on the total species matrix it can be concluded that community structure was not significantly affected in plots treated with Cuttings 5 and 8. The base oil content in the low oil treatments (Cuttings 5 and 8) at the start of the experiment was below 990 ppm. The community structure was, however, significantly affected at concentrations in the range 1200-2000 ppm, indicating that threshold for effects on gross community structure (MDS plots) was found at a base oil concentrations of approximately 1000 ppm.

The experiments suggest that the standard thermal treatment process (Cuttings 8) and the best achievable solvent wash (Cuttings 5) results in cuttings that have no/few identifiable effects on gross community structure in the sediment, at least as long as the discharged amount of cuttings does not exceed 10 % (volume) in the top 3 cm of the sediment.

The addition of Cuttings 5 did, however, give significant negative effects on 3 species of polychaetes (*Prionospio malmgreni, Spiophanes bombyx* and *Spio sp).* Plots to which thermally treated cuttings (Cuttings 8) were added, were the only treatment where no significant effects on individual species could be detected. This indicates that the no effect concentration for individual species abundance is in the range 150-990 ppm baseoil in sediment.

Settling experiment

The species compositions in the community structure experiments and the settling experiments were different. The main difference was that the settling experiment was totally dominated by one crustacean species (*Upogebia deltaura*).

There was a strong positive correlation between the abundance of *Upogebia* and redox potential. There was also a negative correlation between base oil concentration and redox potential. Whether *Upogebia* was affected by the concentration of base oil (or aromatic content) directly or through the effect of hydrocarbons on redoxpotential can not be stated. *Upogebia* was probably especially sensitive because of its deep burrowing behaviour.

Chemical results

The relative concentration of the base oil in the sediment at the start of the experiments reflected the concentration in the original cuttings added to the sediment and suggests a simple dilution. The maximum base oil and Σ 2-6 ring aromatic hydrocarbons concentrations found

in the top 2 cm of the sediment in both types of experiments were 25400 µg/g dw. and 9172 ng/g dw. respectively following the treatment with Cut 2.

The lowest concentrations (Base oil: 2-4µg/g dw., Σ 2-6 ring aromatic hydrocarbons: 206-287 ng/g dw.) were found in sediment not treated (controls) or treated with reference material.

A comparison of the base oil level in the sediment in the experimental boxes (settling experiment) with the concentration in the experimental plots on the sea floor (community structure experiment) showed that the initial concentration in the two experiments were very similar.

A reduction in base oil concentration (20-50%) over the duration of the experiment was seen for Cuttings 2, 3 and 4 throughout the experiments where cuttings initially were distributed in a 3 mm layer on top of the sediment. In other treatments the results did not show any change in concentration (Cuttings 7) or even increased somewhat. The Σ 2-6 ring aromatic compounds in the top 2 cm of the sediment seemed to have increased (2-5 times) in all types of cuttings except case 2.

A general trend observed in the boxes added Cuttings 2, 3 and 4 was that both the concentration of base oil and Σ 2-6 ring aromatic compounds in the sediment in the middle of the experiments (November 1991) were lower than the concentration at the start and at the end of the experiment.

The variability in the chemical analyses has not been addressed in these experiments and some of the apparent differences could have been caused by analytical or sampling variability. The general trend indicate that the concentrations have not changed dramatically during the experiments.

The concentration of metals in the ambient sediment was in the range expected for non contaminated areas. The concentrations of Cu, Pb, Hg, Ni and Zn in the sediment used in the settling experiments were, however, higher than expected for non contaminated areas.

The barium (Ba) concentration in the top 2 cm of the sediment (after a 3 mm layer of cuttings had been distributed) varied between 600-1250 µg/g dw.. In the settling experiments the concentration of barium was in the range 300-660 µg/g dw.

In the experiments with intact benthic communities, a reduction in the concentration of barium was indicated over the experimental period for the top 2 cm of sediment for a majority of the treatments. In the settling experiments, a similar reduction could only be seen for treatment with cuttings 2,3, 4. The reduction in the concentration can be caused by depuration to the overlying water or by burial below the 2 cm of sediment sampled. Leaching experiments indicate that the metals in the cuttings are strongly bound to the mineral particles in the cuttings. Burial or resuspension are thus probably the most likely mechanisms for the reduction in the barium concentration.

The high concentration of Cd , Pb and Zn in the reference material (Cuttings 1) was clearly reflected in the concentration of these metals in sediment (Cd: 1.5-5 µg/g dw., Pb: 800-230 µg/g dw., Zn: 440-160 µg/g dw) from the plots/boxes treated with reference material. For both types of experiments the redox potential in the sediment was lowest in sediment treated with Cuttings 2-4 and highest in sediment treated with reference material (Cuttings 1) or in untreated controls. The result indicate that the base oil content in the added material is the main factor determining the redox potential in the sediment.

1. INTRODUCTION

During offshore drilling activities large quantities of drill cuttings with adhering drilling muds (also called drilling fluids) are discharged into the sea and subsequently settle on the seabed. The drilling muds used are specialised formulations with varying physical and chemical properties depending partly on the technical requirements during the actual drilling operation. The properties of the drilling mud are determined by their content of different additives. Drilling muds are used to maintain hydrostatic pressure control in the well, lubricate the drill bit, remove drill cuttings from the well, and stabilise the wall of the well during drilling. Two main components in the mud are 1) some organic compound or oil (mixture of organic compounds), used mainly for lubrication and 2) barite ($BaSO_4$) which is used because of its high density suited for controlling hydrostatic pressure.

Historically, most drilling in the North Sea was performed using water based mud (Davies et al 1984). In mid- to late 1970s more use has been made of oil-based muds (OBM) (Davies et al., 1989) because of their more optimal properties under difficult drilling conditions. OBMs were originally formulated on a diesel base, but environmental concern led to the development and increasing use of alternative base oils with a lower aromatic content and reduced toxicity (Dicks et al. 1986/87). More recently, other drilling muds have also been developed (Petrofree, Novadril, Aquamul) were the mineral oil is replaced by other compounds like fatty acid esters (2-ethylhexyldodekanoate) (Bakke and Laake, 1991), poly-alpha-olefin compounds (Schaanning and Laake, 1993) or liquid di-isodecyl ether (Laake et al. 1992)

The discharge of OBM has resulted in increased oil content in sediment near production platforms (Davies et al., 1984). In an overview of environmental effects of offshore mining discharges to the North Sea , Zevenboom et al. 1992 refers to background levels of hydrocarbons in North Sea sediment in the range 0.2-15 mg oil/kg dry wt. and oil concentrations in sediment near discharge sites as high as 10-100 g/kg dry wt. Elevated levels of hydrocarbons were found out to 1-12 km from the discharge site depending on national sector, level of input, multiple or single wells, type of cuttings (washed or unwashed) and hydrography (Zevenboom et al. 1992). OBM are however not the only source for hydrocarbons in the North Sea.

The extent of the biological effects of oil activities has been debated. It was previously widely held that the impact extends only to a 1 km radius from the installation (Davies et al. 1984). Later reports (Reiersen et al 1989, Gray et al 1990, Bakke et al. 1989) suggest that biological effect in benthic communities may occur further out, at least to 2-5 km for some installations (Reiersen et al 1989, Gray et al 1990) and perhaps beyond 10 km (Bakke et al. 1989).

The total oil content of the cuttings has been a major environmental concern. Before 1991, the maximum oil content allowed in discharged cuttings in the Norwegian sector of the North Sea was 10 %, in the UK sector 15 %. From 1993, the discharge of cuttings with adhering OBM are generally not allowed in the Norwegian sector. Under drilling conditions where the technical properties of OBM are required for safety or operational reasons, OBM may be used after approval by the Norwegian authorities. In such special cases, the oil content of the discharged cuttings must be below 1 %. Different regulations are used in the different national sectors. Permission to use drilling muds where the base oil is replaced with other organic compounds is given on a case to case basis (in the Norwegian sector). There is no limit to the

content of organic substitute in the discharged cuttings from drilling with such muds. The Norwegian authorities, however, require that the cuttings are treated before discharged to the sea.

The regulations concerning the base oil content in cuttings enforced in the Norwegian sector are based on the environmental effects on benthic communities caused by high levels of oil in the sediment. The oil content can be reduced by 1) cleaning the cuttings before discharge 2) replacing the oil with other organic compounds 3) using water based mud where this is possible. However, negative effects of water based muds are also found both in laboratory and mesocosm tests (Bakke et al. 1989; Duke and Parrish, 1984; Menzie, 1982; Neff et al. 1989a. Parrish et al 1989, Tagatz et al. 1982) and through monitoring around platforms where water based muds have been used (Addy et al. 1984, Hartley and Ferbrache, 1983; Mulder et al. 1988).

In order to meet the environmental requirements from authorities the oil industry has increased effort towards the development of techniques that will reduce or eliminate oil from cuttings. Research into the development of new techniques is being concentrated on improved cleaning of the cuttings prior to discharge, or the use of alternative drilling muds, which may have less impact on the environment.

The primary objective of the present experiments was to assess effects on benthic subtidal organisms and communities of cuttings from drilling with a low toxicity oil based mud, which have been treated by various methods (centrifugation, centrifugation with surfactant, solvent wash, water wash, thermal treatment) in order to reduce the base oil content.

Both effects on recruitment of larval benthic organisms and on established benthic communities have been explored by field experiments. The experiments have been performed on a natural seabed near NIVA Marine Research Station Solbergstrand (MRSS) in the Oslofjord, Norway.

The results from the experiments are meant to 1) provide information to help determine the oil content limitation for drilling discharges such that the cuttings will not cause a significant environmental impact on the seabed 2) provide protocols for assessment of the environmental impact of future drilling discharges.

2. METHODS AND CUTTINGS TESTED

2.1 Cuttings tested

Warren Spring Laboratory prepared, stored and co-ordinated the treatment and distribution of the cuttings used in the experiments (Collins and Gooriah, 1992). The primary cuttings were collected directly from the shale shakers on a BP platform on the Miller field of block 16/8b of the UK sector. The cuttings were collected from the 12 1/4 inch hole section at a depth range between 11000 and 14000 ft, where the formations are predominantly limestone and mudstone of the Cretaceous era. The drilling fluid used throughout the collection interval was a low toxicity, oil based mud using BP 83 HF as the continuous phase and calcium chloride brine as the discontinuous phase. For further details see Collins and Gooriah (1992). The primary cuttings were treated by different methods (Table 1)

Table 1. Basic description of the treatment , base oil content (%) and total concentration of measured aromatic compounds (µg/g) in the cuttings tested. nd=not detected.

Case no./ cuttings no.	Base oil (%)[1)]	Aromatic comp.[1)]	Treatment	Description
1	0.025	nd	Reference	Ground rock, sand, barite and clay to mimic the particle size distribution of the bulk cuttings sample received from offshore
2	15.85	79.5	None	Cuttings sample as received from the shaker
3	19.6	39.5	Centrifuge	Centrifuging
4	14.75	16.5	Centrifuge	Centrifuging with surfactant, contains alkylphenol
5	1.45	42.5	Solvent	Best achievable solvent wash (hexane) by prototype plant
6	2.85	25.5	Solvent	Sample 5 blended with sample 2
7	2.9	26.5	Solvent	From inefficient operated solvent extraction process
8	0.295	2.05	Thermal	Standard thermal treatment process (200-250 °C)
9	1.95	9.5	Thermal	As case no 8 but added recovered oil in order to simulate inefficient thermal treatment.
11	5.15	285	Wash	Water wash treatment

1) Concentrations shown are the mean of two analyses

The metal content of the cuttings tested are seen in table 2. The cadmium (Cd), lead (Pb) and Zink (Zn) concentrations in case 8, 9 and especially case 1 (reference sediment) were high

compared with "background" concentrations in coastal sediment without known nearby point sources of contamination (Knutzen and Skei, 1990). The "background" concentration for these three metals are suggested to be 0.2 µg/g d.w.(Cd), 20 µg/g d.w.(Pb) and 100µg/g d.w. (Zn) in such areas. A further comparison of the metal content in the cuttings with background concentration in coastal sediment (Table 2) indicates that Hg, V, and Fe do not require further attention in the present context since the concentration in the cuttings is lower than the background level in coastal sediment. A similar conclusion can be drawn for the content of Pb in Case 1,3,4,5,7. For Cd, Cu, Ni and Zn the concentration level in all the cuttings is higher than suggeste background levels in coastal sediment.

Table 2. Metal content in the the different cuttings treatments (µg/g dry weight material) (Data from Collins and Gooriah, 1992). Concentrations shown are the mean of two analyses.
Concentrations shown in bottom row (BGC) are suggested environmental quality criteria for sediment (Knutzen and Skei, 1990) and indicate the background concentration (BGC) in unpolluted coastal sediment.

Case no.	Ba	Cd	Cu	Fe	Pb	Mn	Hg	Ni	V	Zn
1	518.0	22.40	61.30	18081.0	3763	691.0	0.02	24.35	25.00	1656.5
2	397.5	0.38	40.10	14690.0	15.75	779.0	0.08	37.35	38.75	192.5
3	380.5	0.38	43.25	14395.5	12.15	849.5	0.08	40.75	42.25	156.0
4	389.0	0.53	41.85	14057.0	17.05	843.5	0.08	40.25	34.90	134.0
5	320.0	0.53	42.65	17789.5	17.90	1002.5	0.08	47.55	38.45	158.5
6	346.0	0.53	41.70	17209.5	26.65	945.0	0.08	45.20	38.85	163.0
7	324.0	0.48	42.30	16504.0	17.10	962.5	0.08	47.35	37.70	144.0
8	300.5	1.37	75.85	20644.5	270.0	2014	0.08	37.45	30.00	547.0
9	300.5	1.47	82.70	21268.5	279.5	2046	0.08	41.20	26.30	619.0
11										
BGC	100-200[1]	0,2	25	30000	20	120-140[2)]	0,1	20	100	100

[1]Bakke et al. 1989
[2)]Ambient sediment at the experimental site.

2.2 Experimental site

The experiments were conducted in the Oslo fjord (Norway) near NIVA Marine Research Station Solbergstrand (MRSS) located 5.4 km south of Drøbak on the east side of the fjord (Fig.1). The experimental area was located on the sea floor at 10-15 m depth approximately 100 m south of Elveskjær. The bottom in the area consisted of fine sand. The area has previously been used for testing effects of drill cuttings on benthic communities (Bakke et al. 1985) and effects of crude oil on recolonization (Berge et al. 1991).

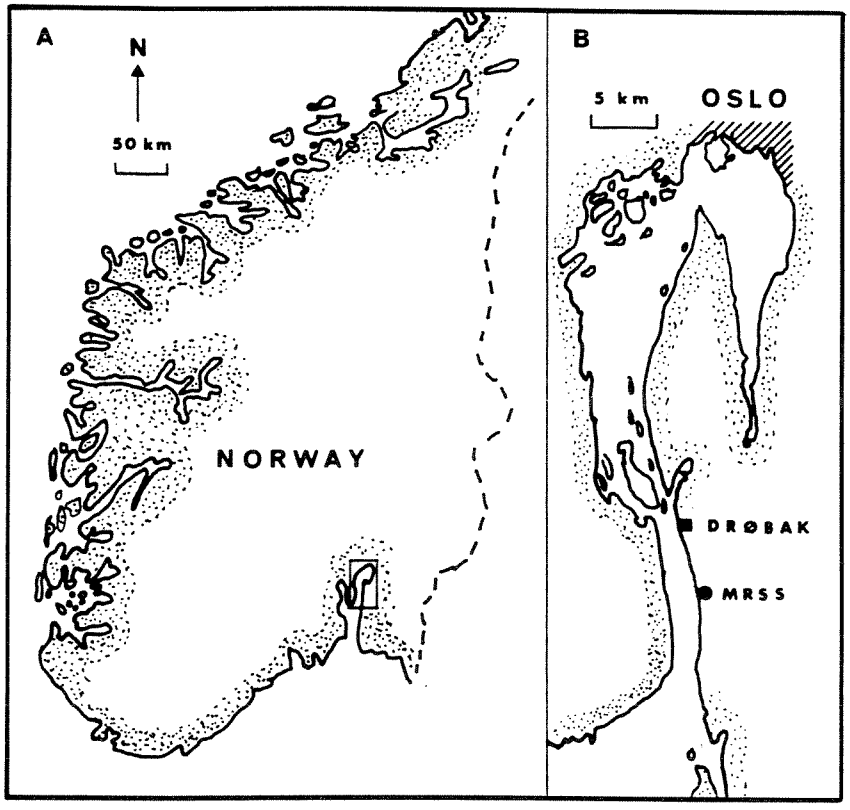

Fig. 1. Map showing the location of the experimental site in the Oslo fjord, Norway.

2.3 Experiments on benthic community structure

In these experiments 9 different types of cuttings (Cuttings no. 1, 2, 3, 4, 5, 6, 7, 8, 9) were distributed onto a natural benthic community on the sea floor at 10-15 m depth in order to test possible effects on an established benthic community. In the experiments the different types of cuttings were distributed on the sediment surface.

The experiments were performed by placing 20 square (1 x 1 m) fiberglass frames, 23 cm high, on and partly into the sea floor. These frames were arranged in a regular grid approximately 4 m apart (Fig. 2). These frames define the 20 experimental plots where the different types of cuttings were distributed The fiberglass frames were made by cutting off the bottoms (including 7 cm of the walls) of 20 aquaria (surface area 1 m^2, height 30 cm), originally designed for rearing juvenile fish.

In the 7 cm high trays formed by the bottoms cut off from these aquaria , an "ice sandwich " was prepared (see Fig. 2) in a 3 step procedure.

Step 1. A 1.5 cm layer (15 litre) of sea water was frozen in the bottom of each tray.

Step 2. Cuttings (3 litre) where mixed mechanically with 10 litre of sea-water spread as evenly as possible on top of the first layer of ice, and allowed to freeze.

Step 3. An 1-2 cm layer of sea-water was allowed to freeze on top of the layer containing the cuttings.

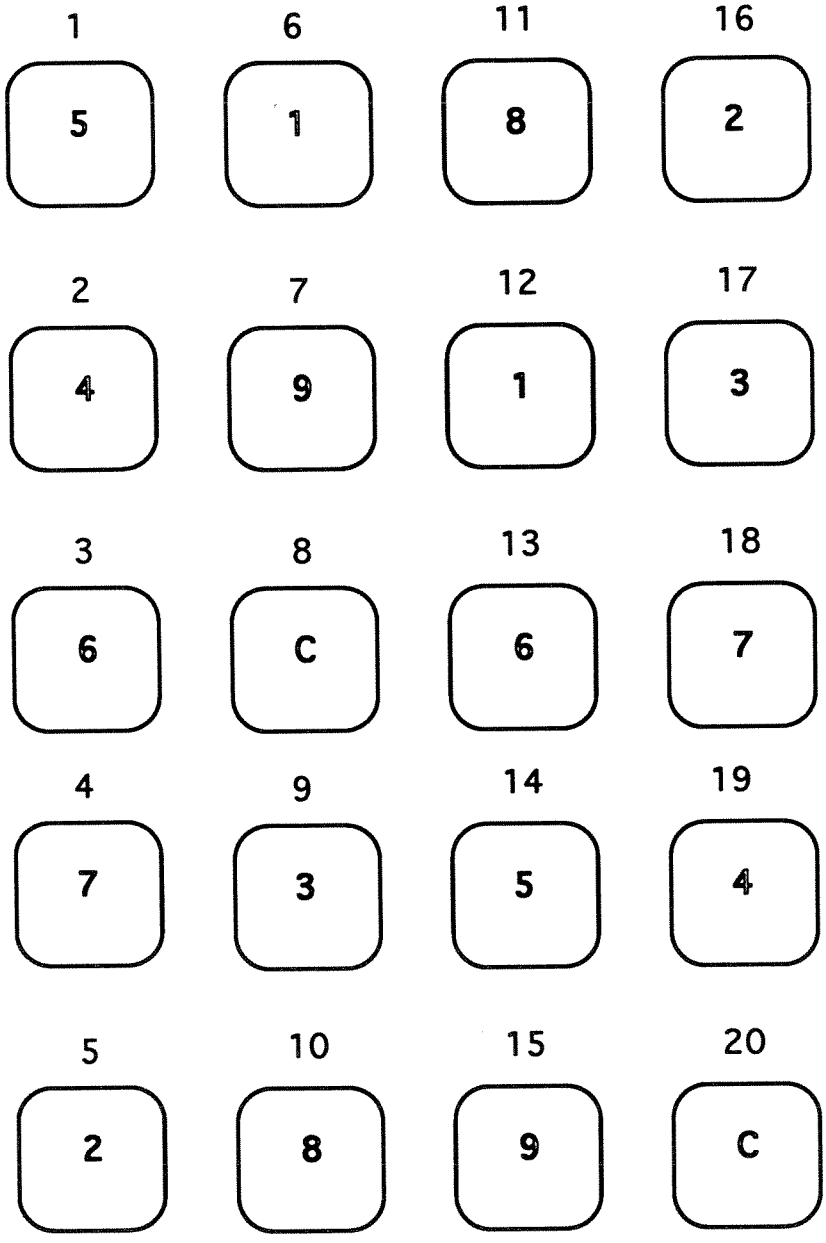

Fig. 2. Relative position of the experimental plots on the sea floor. The number above each plot indicate the plot number. Number inside each plot indicates the case no. for the cuttings added to the sediment surface in the plot, C=control plot with no addition of particulate material.

This procedure gives a 3 layered frozen sandwich (Fig. 3). Two sandwiches were made for each type of cuttings. For control purposes, 2 sandwiches were also made with sea-water alone. These ice sandwiches were used for distributing the cuttings evenly on top of the sediment in each experimental plot. This was performed by placing the ice sandwich bottom up on top of each frame (approximately 20 cm above the sediment) on the sea floor (Fig. 4.). As the sandwich thawed, the cuttings settled evenly onto the benthic system within each frame (Fig. 5.). A net prevented larger parts of the cuttings to settle before they had thawed. The device used for distributing the cuttings was left on top of the frames overnight in order to allow the fines to settle.

The ice-sandwiches were prepared and stored in an freezer-container located on the shore near where the experiments were to be performed (2 minutes by boat). Scuba divers were used to mount the sandwiches on top of the frame on the sea floor. The time needed for the divers to take a sandwich from the surface and mount it on top of a frame on the sea floor was 3-5 minutes and did not allow significant thawing of the frozen cuttings layer.

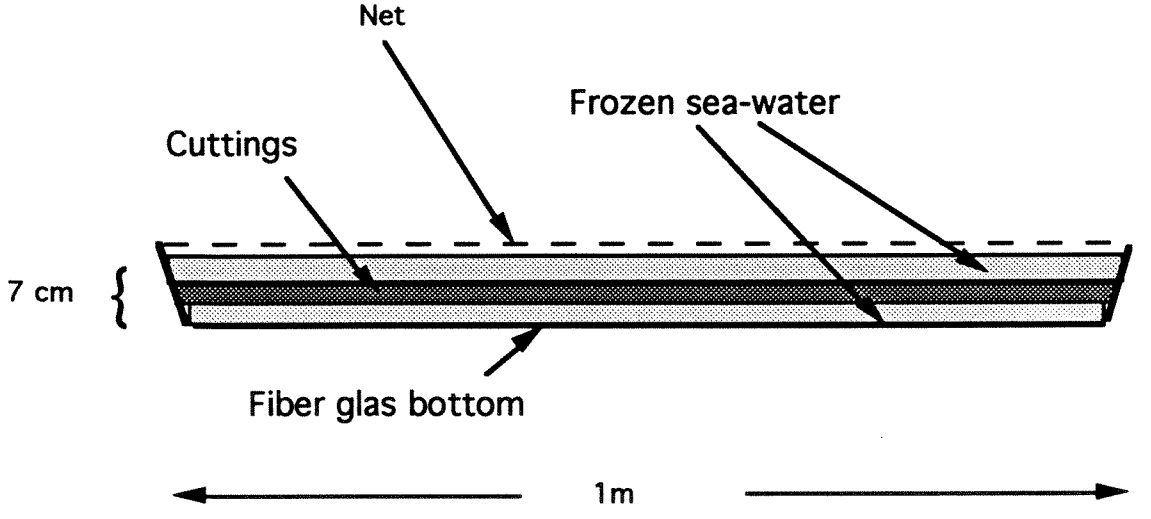

Fig. 3 Schematic figure showing the composition of "Ice sandwich".

This method for distributing the cuttings to sediment had been tested in NIVA´ s indoor soft bottom mesocosm at Solbergstrand before it was used under field conditions. This test showed (visual inspection) that the cuttings were evenly distributed on the sediment, the temperature in the water inside the frame was reduced by not more than approximately 3 ^{o}C (see fig 6) during the first 1-2 hours after placing the sandwich in position and the oxygen concentration was reduced by 1 mg/l overnight (from an original level of approximately 8 mg/l). It is anticipated that the temperature reduction during thawing in situ was similar to the pilot test situation. The oxygen reduction during the 24 hour period when the dosing device was mounted on top of the fibre glass frame in situ was not measured. However assuming a relatively high oxygen consumption of 400 $\mu mol/m^2$ h (see Bakke et al. 1989c) would result in a mean concentration drop of 1.5 mg/ml in the water volume enclosed under the dosing device. As the oxygen concentration, in situ at this depth probably was in the range 6-8 mg/l, a reduction of 1.5 mg/l is considered insignificant for the infauna.

The 3 ^{o}C reduction in temperature during the first 1-2 hours was not considered significant since the experiments were to be performed at a depth were such short term temperature fluctuations can be seen.

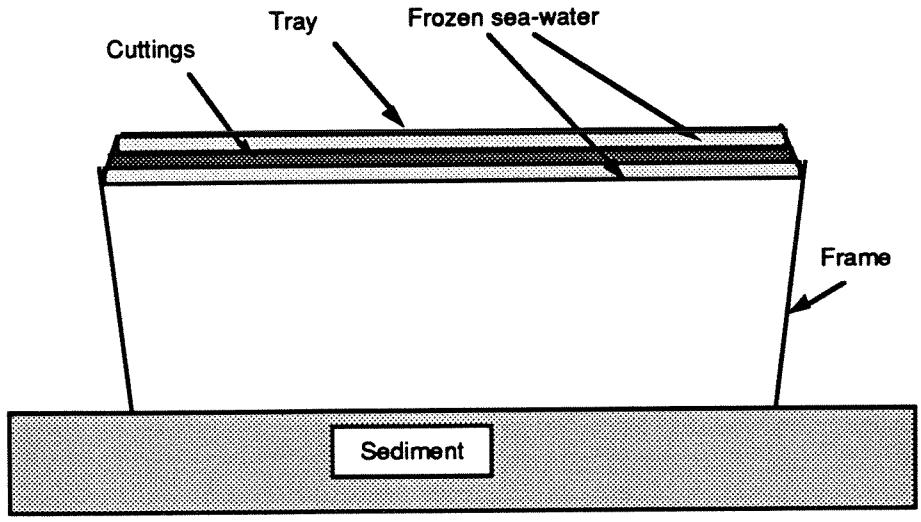

Fig. 4. "Ice sandwich" mounted on top of the frame that defines the experimental plot on the sea floor.

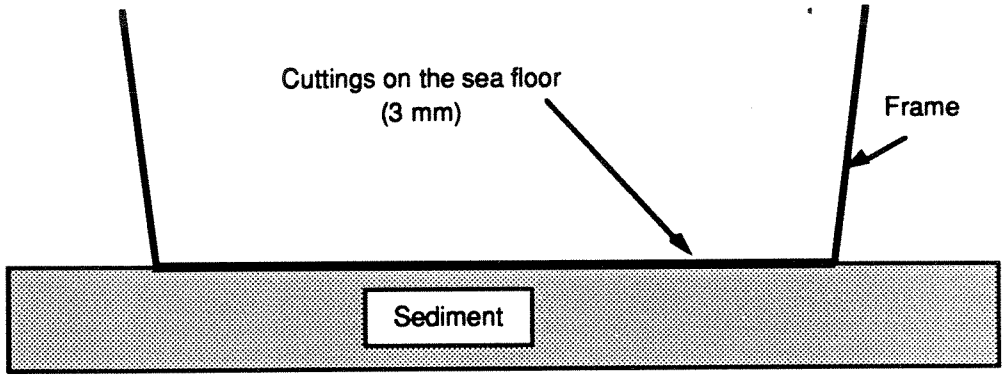

Fig. 5. Cuttings inside the frame on the sediment surface after thawing of the Ice sandwich.

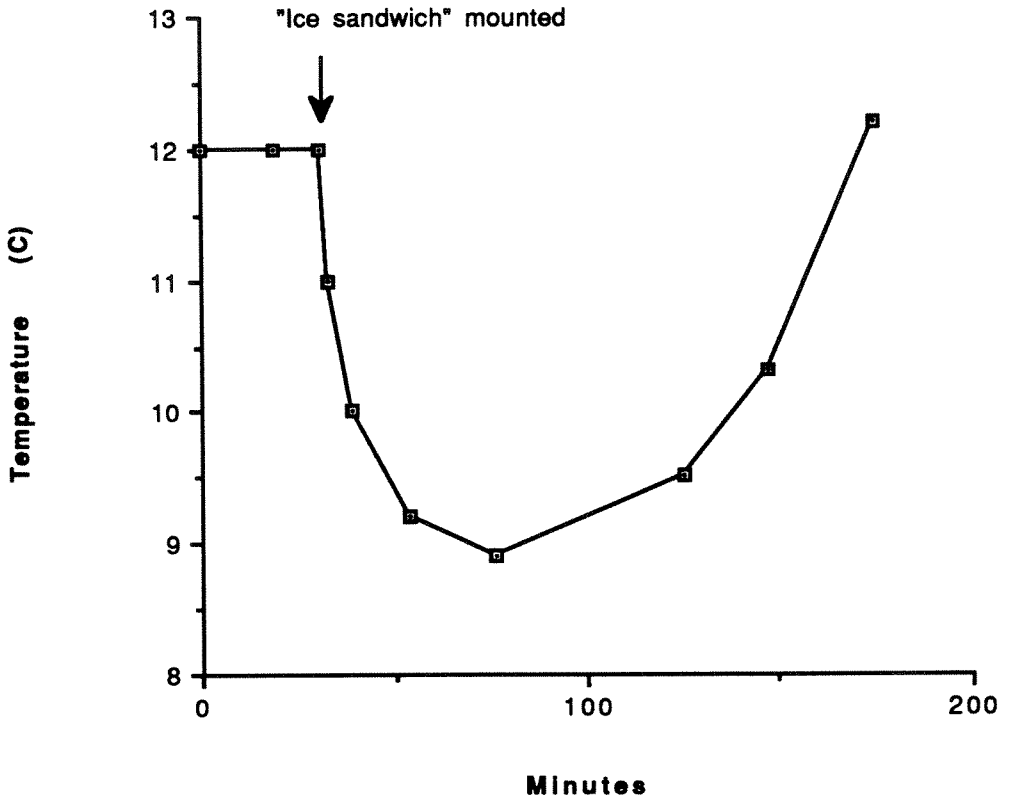

Fig.6. Temperature of sea-water at the sediment surface during thawing of sandwich duringtesting in mesocosm.

The 3 litre of cuttings distributed to each experimental plot (1 m^2) would, if mixed into the top 3 cm of the sediment, give a similar concentration of cuttings as used in the Settling Response experiments (see section 3.4). Two cores (inner diametr=4.3 cm) for chemical analyses were collected in each experimental plot at the start and termination of the experiments (see table 3) The top 2 cm of each of the 4 core from plots with similar treatments were pooled, homogenised by stirring and devided in two separate samples, one for hydrocarbon analyses (M-scan) and one for metal analyses (IOE). The sediment samples for analyses of hydrocarbons and metals were kept frozen until analysed.

Approximately one week after adding the cuttings to the sediment surface, the first samples for faunal analyses were collected. 10 cores (diameter =6cm) were collected in each plot and the top 5 cm of each core were preserved in 10 % neutralised formalin. Similar sampling was repeated after approximately 3 and 7.5 months (Table 3).

Sampling schedule for the settling experiment are seen in Table 3.

Table 3 Sampling schedule for the experiments on an intact benthic community. The different types of cuttings tested are shown. Cont.=untreated (no cuttings) controls.

Event	Date
Start	
Distribution of sediment	7. October 1991
Collecting samples for chemical analyses	10. October 1991
Collecting samples for faunal analyses	15. October 1991
Middle	
Collection of samples for faunal analyses	26 and 27 Feb. 1992
Termination	
Collecting samples for chemical analyses	1. June 1992
Collecting samples for faunal analyses	1-2 June 1992
Redox measurements in sediment	1-2 June 1992
Cuttings tested	Cont., 1, 2,3,4,5,6,7,8,9

The sediment collected at the start and in the middle of the experiment for fauna analyses, were sieved with a 1mm and 0.5 mm sieve. The fauna retained on the sieves were identified to species or lowest attainable taxonomic level under a binocular microscope and counted. At the end of the experiment only the fauna retained on the 1 mm sieve were enumerated.

At the termination of the experiments redox potential measurements were performed in one core from each plot at a depth of 2 cm from the sediment surface. Redox potential were determined using a Radiometer P101 platina electrode together with the internal reference of a pH-electrode (Orion Ross 81-04 glass combination electrode). The redox potential were obtained by adding 431 mV to the potential recorded on the Pt-electrode (Zobell, 1946).

2.4 Settling experiment (I) in boxes

In these experiments the pattern and intensity of settlement of benthic animals to azoic sediment to which different types of drill cuttings were added, was tested. The parameters tested in these experiments were the pattern and intensity of settlement/recolonization of benthic animals to azoic sediment with different types of drill cuttings (Cuttings no. 1, 2, 3, 4, 5 6, 7, see table 1). The community that develops in each test box during such the experiments will be governed by the species composition of potential settlers in the area (pelagic and benthic) and their ability to respond to physical and chemical signals from the substrate (how attractive/repellent are the different cuttings types) and their survival after settlement (toxicity).

The experiment was performed by placing sediment contaminated with cuttings on the sea floor in experimental boxes (Fig.7) with a surface area of approximately 0.24 m^2 and a vertical side of 15 cm. The boxes contained a 9 cm thick layer of homogenised clean sediment on top of which a 3 cm layer of sediment spiked with 10 % (volume) of cuttings was laid (Fig. 7). The control boxes contained a 12 cm layer of homogenised clean sediment.

The sediment used for the settling experiments was collected at 30 m depth in the Oslo fjord (Bjørnehodebukta). The main volume (75 % volume) was collected using a dredge shortly before the boxes were prepared whereas the remaining 25 % was collected by grab some time earlier and kept in the soft bottom mesocosm at Solbergstrand until used for these experiments.

Homogenization of the sediment was performed in a cement mixer for 15 minutes. The bottom layers were frozen in order to stabilise the sediment before the contaminated top layer was spread out. The cuttings and sediment for the top layer were mixed mechanically for 15 minutes before spreading.

Samples for chemical analyses were taken from the control sediment and the 7 mixtures of cuttings.

After the preparation of the top layer a lid was mounted on each box and the boxes were frozen in order to kill possible remaining fauna and to stabilise the sediment. Altogether 32 boxes were fully prepared and placed frozen on the sea floor (10-14 m depth) on the July, 30, and the lids removed from the boxes the following day.

The boxes were arranged in a grid (7 x 6) approximately 3m apart (Fig. 8). Box 1- 20 were retrieved after approximately 3 months exposure in situ whereas box 21-40 were retrieved after 7.5 months. (See table 4). The position of each of the replicate treatments within the two parts of the grid was random. Experimental boxes were not placed in position 2, 3, 9, 12, 24, 29 37, and 38 because NIVA had only received 7 out of 9 types of cuttings intended to be tested.
Upon retrieval a lid was mounted on each box. The boxes were taken to the surface and placed in the soft bottom mesocosm at MRSS for 1-2 days for sampling purposes. For a description of the soft bottom mesocosm see Berge et al 1986. Cores (inner diameter 6 cm) were taken in each box for analyses of hydrocarbons and metals. In November, one core was collected in each box; whereas in March, two cores were collected. Only the top 2 cm of the sediment were used for the analyses. Cores from boxes with similar treatment were pooled and homogenised (for each sampling occasion) before being divided in two, for HC analyses and metal analyses.

Redox measurements were done directly into the sediment in the experimental boxes. Redox potentials were recorded at a depth of 2 cm from the sediment surface
The sediment in each box was sieved with a 1 mm sieve. The fauna retained on the sieves were identified to species or lowest attainable taxonomic level under a binocular microscope and counted.

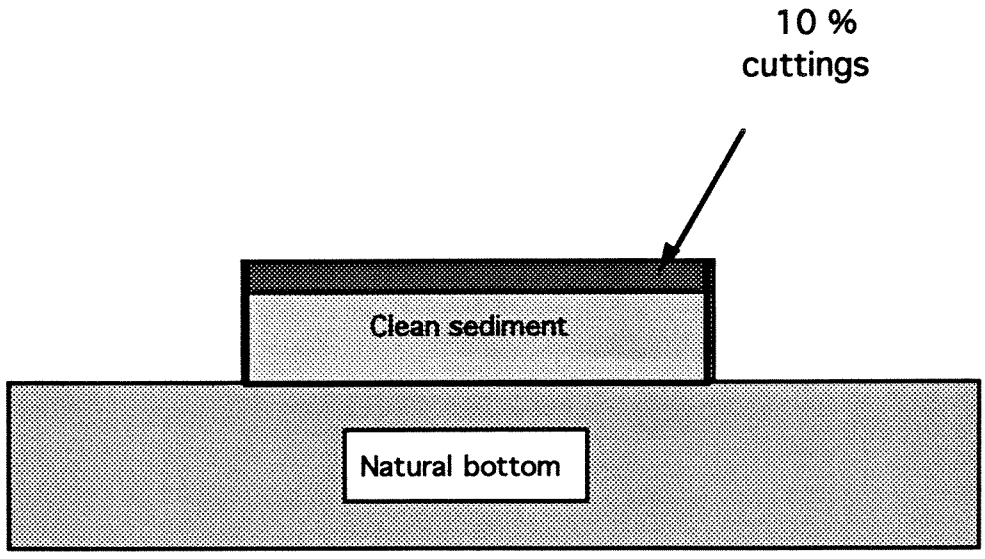

Fig. 7. Experimental box on the sea floor

Sampling schedule for the settling experiment are seen in Table 4.

Table 4. Sampling performed in settling experiment (I) and different cuttings tested. Cont.=untreated (no cuttings) controls.

Event	Date	Type of sample
Start	31. July 1991	Chemistry
Middle	5. November 1991	Chemistry, Fauna
End	17. March 1992	Chemistry, Fauna, Redox
Cuttings tested	Cont., 1,2,3,4,5,6,7	

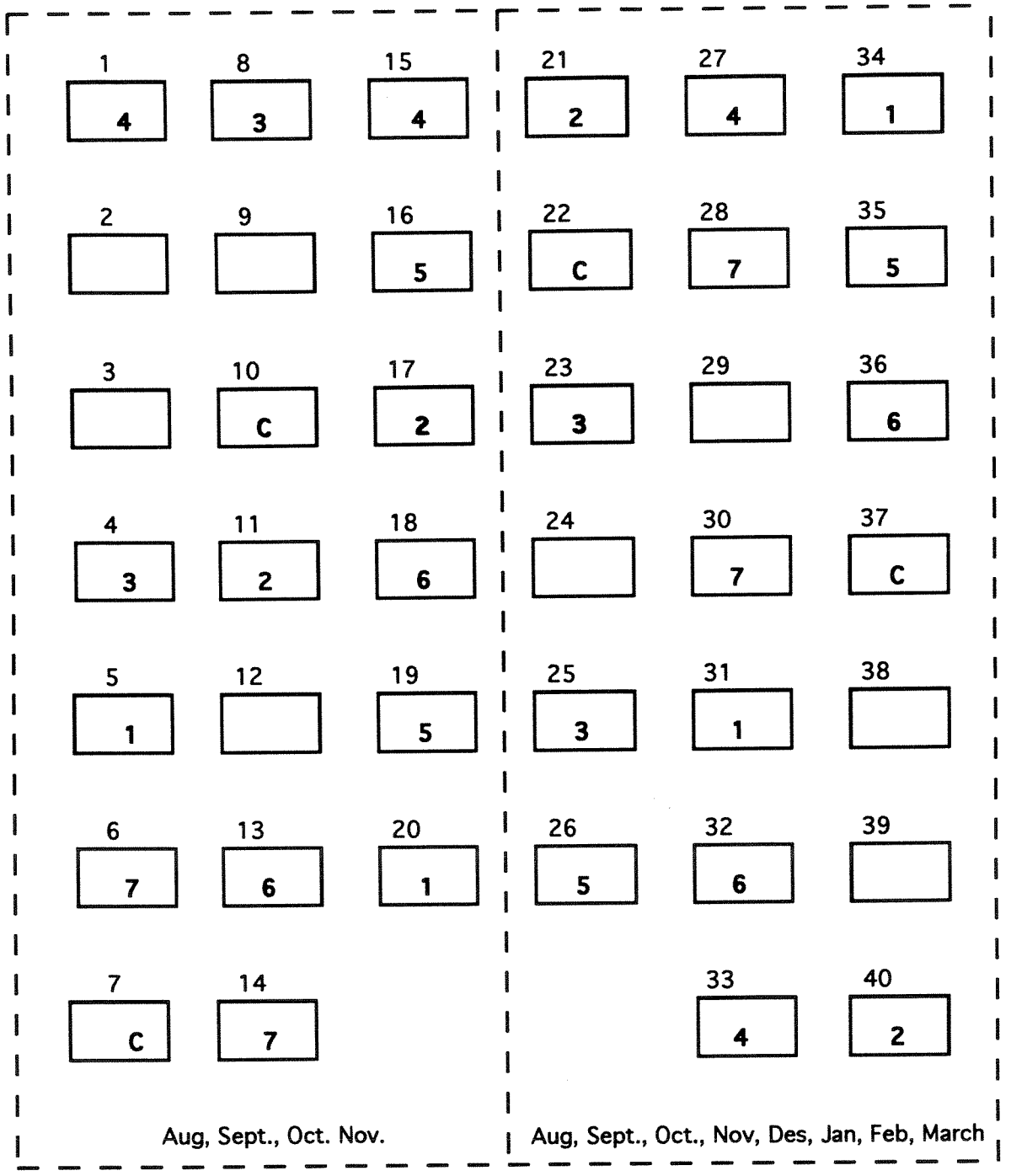

Fig. 8 Relative position of the experimental boxs on the sea floor. The number above each square indicate the box number. Number inside square indicate the case no. for the cuttings mixed into the top 3 cm of sediment in each box, C=control box with no addition of cuttings to the top 3 cm of sediment. Squares assigned box no. 2, 3, 9, 12, 24, 29,38, 39 were empty spaces on the sea floor.

2.5 Settling experiment (II) in boxes

In these experiments cuttings no. 11 and 2 were tested in a similar manner as in the settling experiment (I) above. Distribution of boxes on the sea floor is seen in Fig. 9.

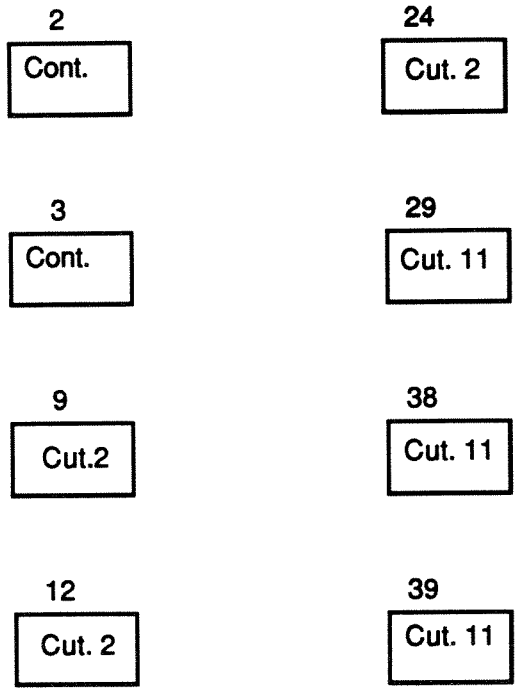

Fig. 9. Relative position of the experimental boxes on the sea floor in the second settling experiment. Treatment are indicated inside the boxes. Box no. are indicated above each box.

Sampling schedule for the settling experiment are seen in Table 5.

Table 5. Sampling performed in settling experiment (II) and the different cuttings tested. Cont.=untreated (no cuttings) controls.

Event	Date	Type of sample
Start	8. April 1992	Sediment chemistry
End	1. September 1992	Sediment chemistry. Fauna, Redox
Cuttings tested	Cont., 2, 11	

2.6 Hydrocarbon and metal analyses

The purpose of these analyses was to document the concentration level in the sediment in the different treatments throughout the experimental period and not to perform detailed chemical monitoring during the experiments. The result of the chemical analyses reported will not be discussed in detail.

The analyses has been performed on pooled samples from plots /boxes with similar treatments. Replicate analyses have not been performed.

Hydrocarbons

Upon thawing, samples were homogenised and a sub-sample (ca. 50g) weighed out. The samples were wet extracted with an isopropanol/hexane mixture and saponified with potassium hydroxide to remove glycerides and fatty acids. The resulting total neutrals were fractionated using a silica chromatography column to separate aliphatic and aromatic hydrocarbons. Aliphatic and aromatic fractions were analysed by gas-liquid chromatography/flame ionisation detektor (GLC/FID) and gas-liquid chromatography/mass spectrometry (GLC/MS), respectively.

The concentration of base oil aliphatic hydrocarbons in the samples was detected by reference to the added internal standard, squalane, over the GC retention range previously observed for the oily cuttings used in the experiments. Any contribution from obvious biogenic compounds over this base oil range has been deducted.

Heavy metals

An aliquot of each sediment sample was ground to pass a 500µm sieve. 4g of the ground sediment was extracted with acid (7m nitric acid, 70°C) for four hours. The acid digest was diluted to 100 ml prior to analysis by Atomic absorption. Eight elements (Ba, Cu, Fe, Pb, Mn, Ni, V and Zn) were determined using a flame cell while Cd was determined using a graphite furnace. Mercury (Hg) was determined using the "cold vapour" technique.

2.7 Statistical methods

Multivariate analyses of the species abundance date and the diversity measures were performed using PRIMER (Plymouth Routines In Multivariate Ecological Research), a statistical program prepared by Plymouth Marine Laboratory specially designed to treat benthic community data.

This program were used to perform an ordination of treatments by Multi dimensional scaling (MDS) based on the ranked Bray-Curtis similarity matrix calculated from square root transformed data (Clarke and Green 1988).

The sub program ANOSIM in PRIMER were also used to test differences between groups of treatments. ANOSIM performs a randomisation/permutation test (Clarke 1988) and is based on the similarity matrix calculated from the species data. MDS has is a method which have

been used for detecting effects of pollution in the North Sea (Gray et al., 1990) and in other areas (Agard et al., 1993).

ANOVA and t-tests were performed using StatView SE+Graphics™ for Macintosh.

Species diversity were calculated using the Shannon-Wiener diversity index (Shannon and Weaver 1963). The formula for calculating diversity (H) is:

$$H=\sum_{i=1}^{s} pi \log_2 pi$$

were $p_i=n_i/N$ (n_i being the number of individuals of the ith species and N the total number of individuals in the sample.

3. RESULTS

3.1 Experiments on benthic community structure

3.1.1 Hydrocarbon and metal analyses.

The concentration of base oil and Σ 2-6 ring aromatic hydrocarbons at the start and end of the experiments are shown in Fig. 10 and 11 (the total data set is found in Appendix A1). The relative concentration of the base oil and aromatic compounds in the sediment at the start of the experiment reflected the concentration in the original cuttings added to the sediment surface (Fig. 12).

A reduction in base oil concentration was seen throughout the experimental period for case no. 2, 3 and 4 which originally had the highest concentration, whereas the other cases did not show any change in concentration (Cutt7) or even increased somewhat (Cut.6). The background level of "baseoil" in the control plots was low (2-5 µg/g) and indicates that no contamination of "baseoil" components from external sources has taken place throughout the experimental period. The Σ 2-6 ring aromatic compounds in the top 2 cm of the sediment seemed to have increased in all types of cuttings except case 2. An increase in the concentration of aromatic compounds in the order of 200-300 ng/g was also seen in the control plots and might indicate contamination from external sources. However an increase from external sources can not account for the much larger increase (4824 ng/g in case 3) indicated for some of the other cases (Fig.11). The variability in the analyses has not been addressed in these experiments and some of the apparent differences is probably caused by analytical or sampling variability. The pooling of the four sediment samples should however reduce the variability caused by possible sediment heterogeneity. Although there are some differences in concentration between the start and end of the experiments, 4 different groups of experimental plots can be distinguished throughout the experiment based on the base oil concentration. These four groups are:

1. Control group with base oil concentration 2-10 µg/g: control , case 1
2. Low oil group with base oil concentration 150-1200µg/g: case 5, case 8
3. Medium oil group with base oil concentration 1200-2800µg/g: case 6, case 7, case 9
4. High oil group with base oil concentration 5100-25400µg/g: case 2, case 3, case 4

The concentration of aromatic compounds in the cutting at the start of the experiment (Fig. 11) conforms with the ranking seen above for C and case 1 (Control group) , case 8 ("low aromatic"), case 7 and case 9 ("medium aromatic,") and case 2, and case 3 ("high aromatic"). Whereas case 4, 5 and 6 have changed rank.

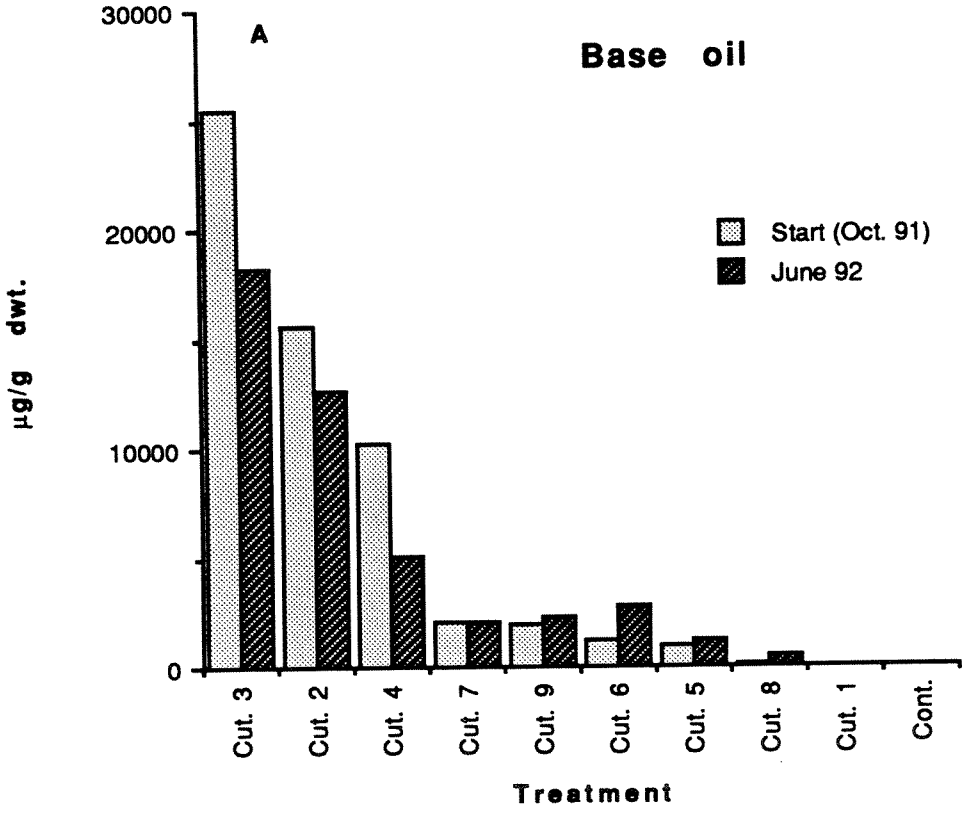

Fig. 10. Concentration of base oil in the top 2 cm of the sediment at the start and end of the experiments on the natural seabed. Treatment no. on the abscissa corresponds to the numbers seen in table 1 and are arranged in order of decreasing concentration of base oil at the start of the experiment.

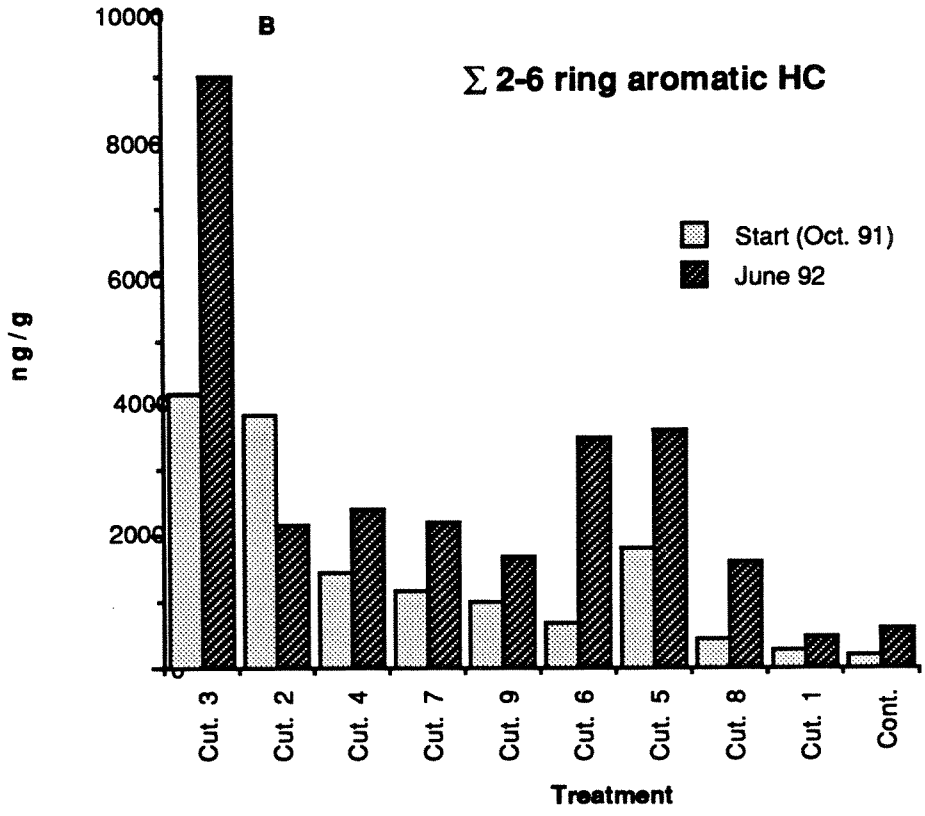

Fig. 11. Concentration of Σ 2-6 ring aromatic compounds (B) in the top 2 cm of the sediment at the start and end of the experiments on the natural seabed. Treatment no. on the abscissa corresponds to the numbers seen in table 1 and are arranged in order of decreasing concentration of base oil at the start of the experiment.

The concentrations of barium, cadmium, lead and zinc are seen in Fig. 13 and 14. The total data for the metal analyses for this experiment are seen in Appendix B1. Plots of the remaining metals (Cu, Fe, Hg, Ni, V, Mn) not presented in Fig. 13 and 14, can also be found in Appendix B1-1. The concentrations of metals in the ambient sediment (control plot) were in the range expected for non contaminated areas. The high concentration of Cd, Pb and Zn in the naturally occurring (onshore) reference material (Case 1) was clearly reflected in the concentration of these metals in sediment from the plots treated with reference material. The concentration level found in these plots were so high that the sediment, based on suggested marine sediment environmental quality criteria (Knutzen and Skei, 1990), can be characterised as polluted (Zn) to highly polluted (Pb). During the experiment, the content of these 3 metals (Cd, Pb, Zn) in the top 2 cm of the sediment was reduced to 30-50 % of the concentration found in October (Fig. 13 and 14). The barium level increased after dosing in all treatments to a level of 500-1250 µg/g dw., whereas the concentration in the natural sediment remained constant at approximately 50 µg/g dw. throughout the experimental period.

A reduction in the concentration of barium was observed in the top 2 cm of sediment for most of the treatments. The reduction in the concentration of Cd, Pb and Zn seen in plots treated

with Case 1 and in Barium for all but one Case (Case 9) can be caused by depuration to the overlying water or by burial below the 2 cm of sediment sampled. Leaching experiments indicate that the metals in the cuttings are strongly bound to the mineral particles in the cuttings (Delvigne, 1993). The most likely explanation for the reduction is burial of the added minerals to a depth below the top 2 cm sampled. On the other hand, the reduction in the concentration of barium does not correspond to the apparent increase in the aromatic hydrocarbon (Fig 11) and Vanadium (Appendix B1-1) level observed during the experiments.

The addition of cuttings to the experimental plot did not result in any dramatic increase for the other metals, the concentration of Hg,, Ni, Fe, Cu were within the range expected in non polluted areas. A similar conclusion can be drawn for Cd, Pb and Zn except for Case 1,.

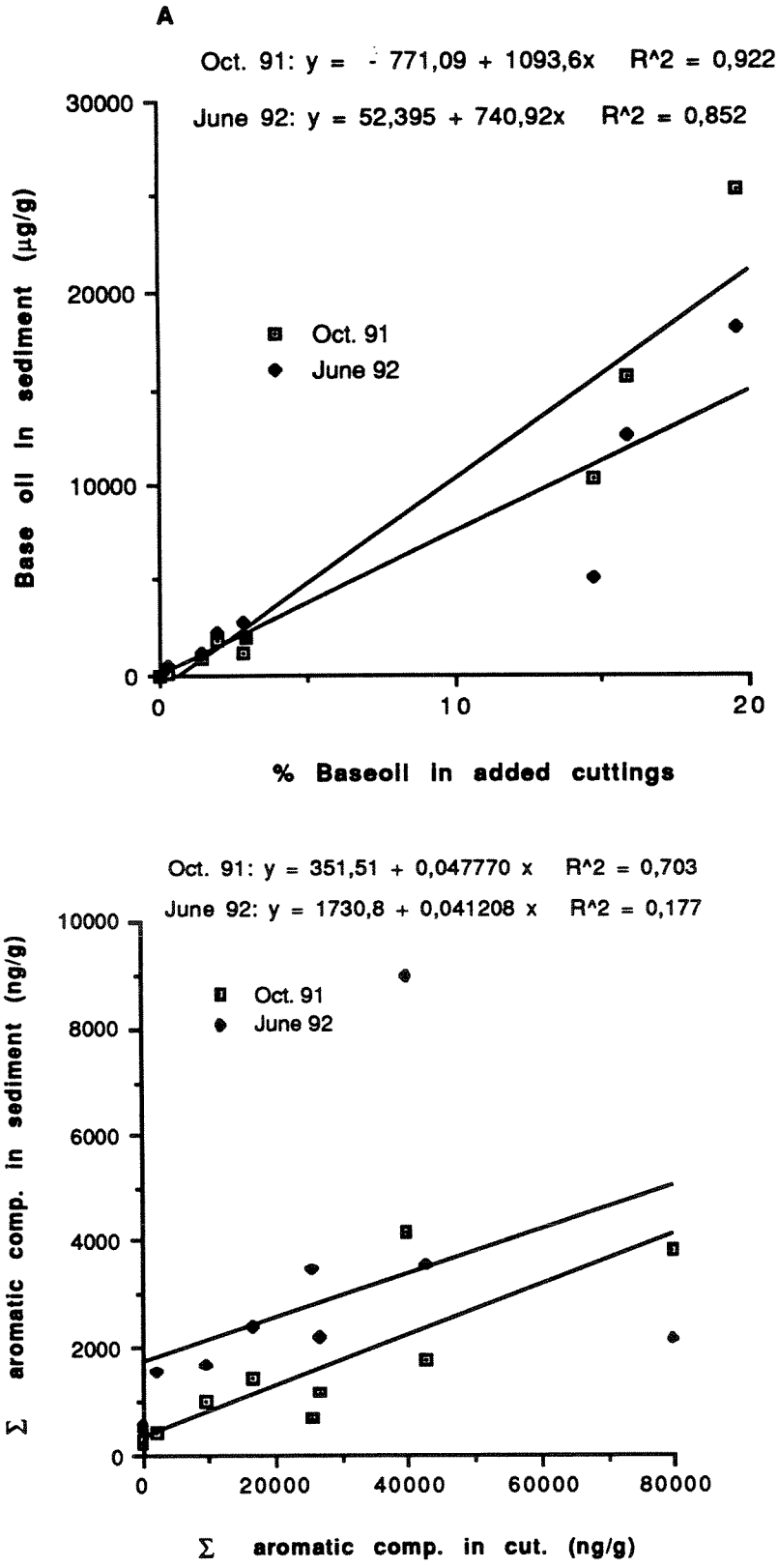

Fig. 12. Concentration of base oil (A) and sum 2-6 ring aromatic HC (B) in sediment as a function of the concentration in the added cuttings.

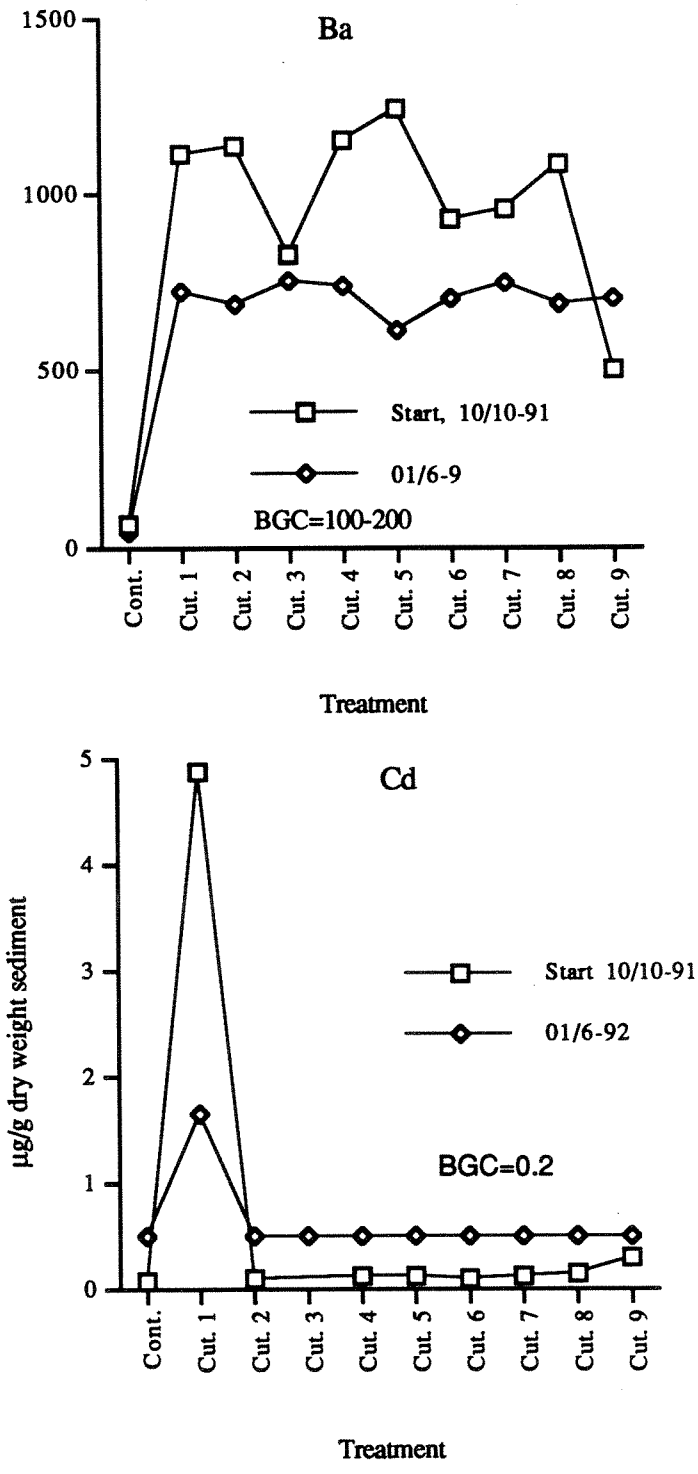

Fig. 13. Barium and cadmium, concentration in the top 2 cm of the sediment at the start (October 1991) and at the end of the experiment (June 1992) on the intact community. Values for Cd at the start of the experiment (Cut.3) are not shown because of obvious analytical or sampling error. BGC=Background level in coastal areas without any known point sourcs.

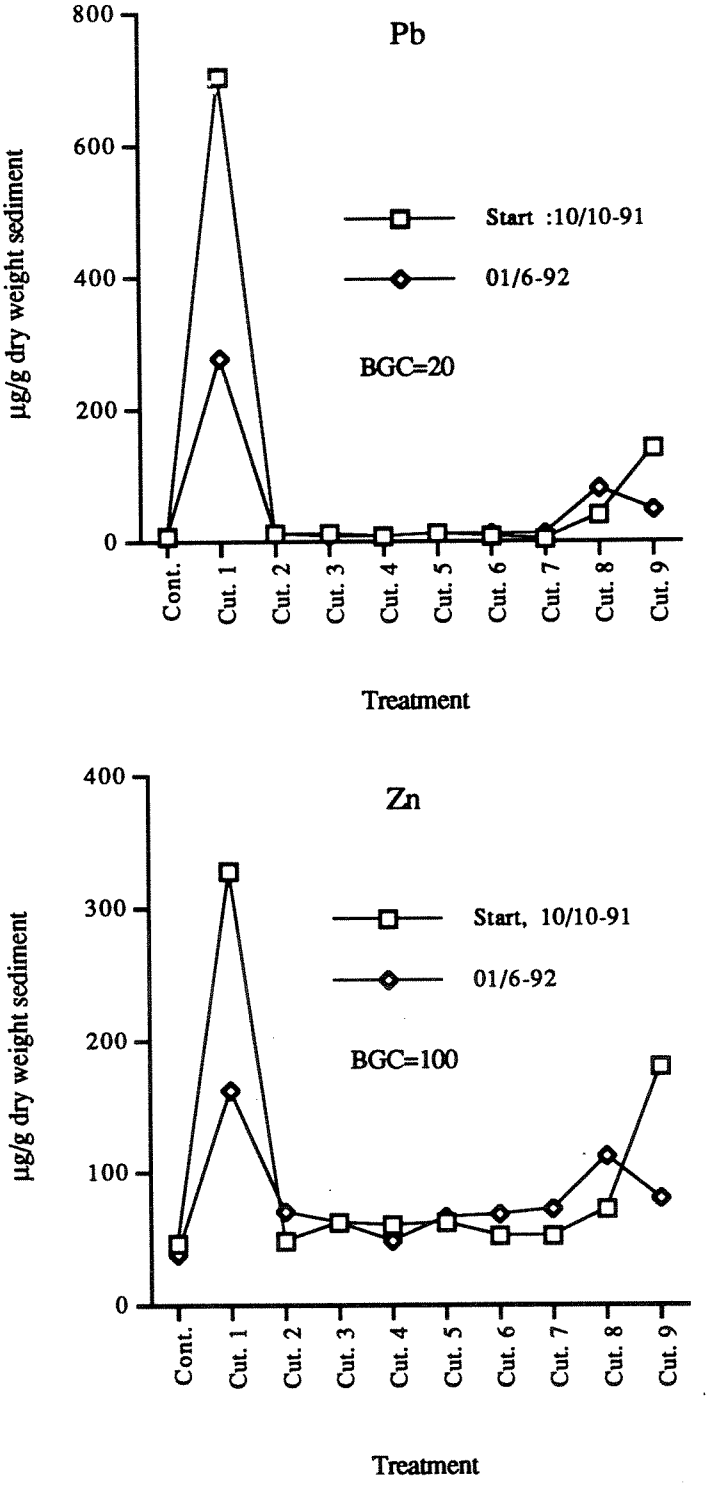

Fig. 14. Lead and zinc concentration in the top 2 cm of the sediment at the start (October 1991) and at the end of the experiment (June 1992). BGC=Background level in coastal areas without any known point sources of metal discharges.

3.1.2 Redox potential

The highest redox potential was seen in the plots to wich the reference material (Cuttings no. 1) was addedand the control plot where no material was added (Fig.15.). Redox potential showed the lowest (negative) values in plots treated with cuttings no. 2, 3, and 4. The results indicate that the base oil content in the added material is the main factor determining the redox potential in the sediment. There was a considerable difference (110 mV) between the redox potential in the control plot and the plot to which a reference material was added. A t-test indicate that the differance was highly significant (p=0.01). However a one factor ANOVA considering the total variance in the data, indicates that there was no significant difference between these two treatments (Table 6). Significant differences were, however, seen between cut. 1 and the other treatments (Table 6). Only two replicate measurements have been performed for each treatment. When considering the total variance in the material means have to be at least 131 mV apart in order to be significant different. The power of the statistical tests is thus weak.

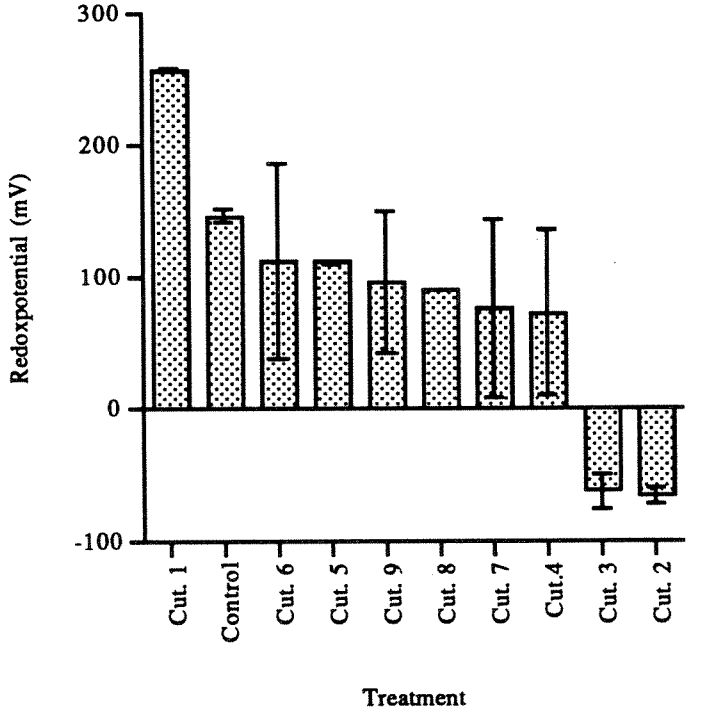

Fig. 15. Redox potential at a sediment depth of 2 cm measured in cores at the termination of the community structure experiments (June 1992). Vertical bar indicate ±1 standard error of the mean. Please note that standard error for Cut.8 was to small to be shown on the figure.

Table. 6. Results from one factor ANOVA on redox data collected at the termination of community structure experiments, July 1992. x=significant differance (p=0.05), ns=no significant differance.

	Cont.	Cut. 1	Cut. 2	Cut. 3	Cut. 4	Cut. 5	Cut. 6	Cut. 7	Cut. 8
Cont.									
Cut. 1	ns								
Cut. 2	x	x							
Cut. 3	x	x	ns						
Cut. 4	ns	x	x	x					
Cut. 5	ns	x	x	x	ns				
Cut. 6	ns	x	x	x	ns	ns			
Cut. 7	ns	x	x	x	ns	ns	ns		
Cut. 8	ns	x	x	x	ns	ns	ns	ns	
Cut. 9	ns	x	x	x	ns	ns	ns	ns	ns

3.1.3. Community responses

The calculated community structure parameters are based on the abundance data (Apendix D1-3). Fig. 16 and 17 shows the total number of individuals and species found in the different plots during the experiment. The number of individuals changed considerably during the experiment (Fig. 16). At the start of the experiments the number of individuals ranged between 29-164. Four months later the total number of individuals were approximately in the same range except where cuttings no. 2-4 had been added to the plots. The increase in these plots was mainly caused by settling of the opportunistic polychaete *Capitella capitata* (Fig. 18). At the end of the experiments the total abundance had increased considerably in all plots caused by a massive settlement of *Polydora* spp (mainly *Polydora socialis*). The increase in abundance of *Capitella* in plots to which cuttings no. 2-4 were added could, however, still be identified. The number of species changed considerably less than the number of individuals (Fig. 17).

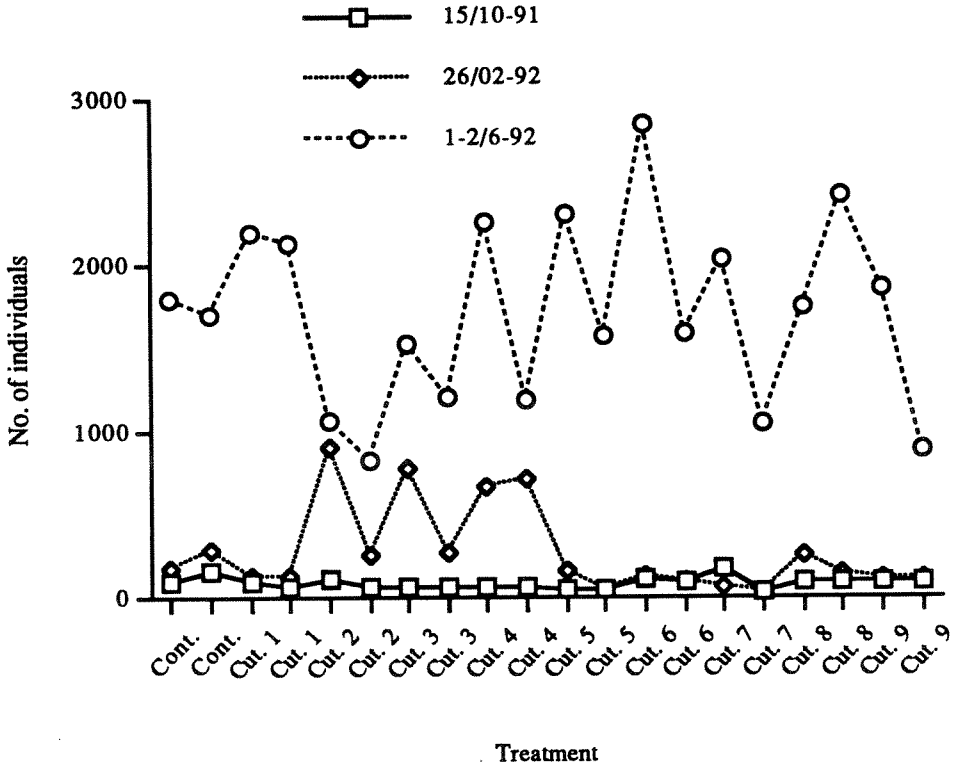

Fig. 16. Total number of macrofauna individuals in experimental plots during the community structure experiments. Abundance in plots for October 1991 and February 1992 are based on the number of animals from 10 cores retained on a 500 µm sieve whereas abundance at the end of the experiment (June 1992) is based on the number of animals from 9 cores retained on a 1000 µm sieve.

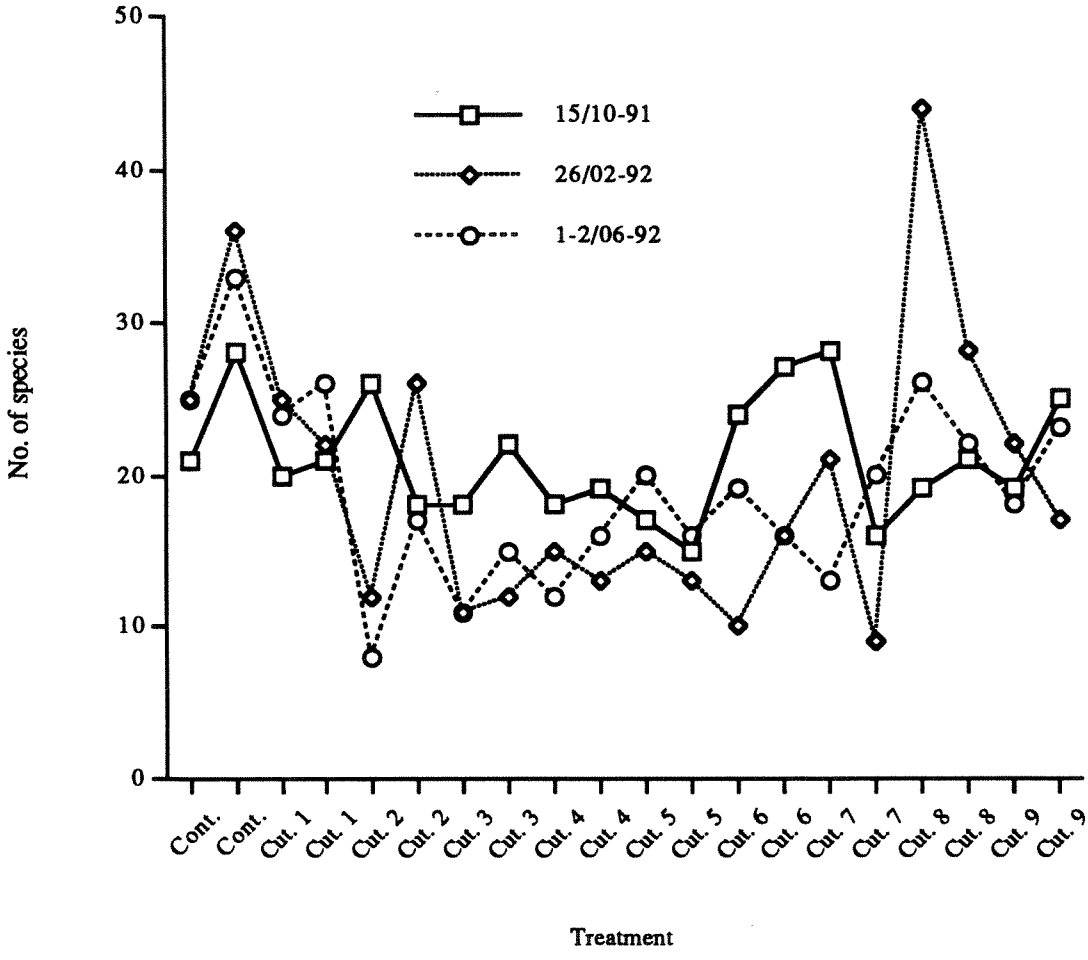

Fig. 17. Total number of species in experimental plots during the community structure experiments. The number of species in plots for October 1991 and February 1992 are based on the animals from 10 cores retained on a 500 µm sieve, whereas the number of species at the end of the experiment (June 1992) is based on animals from 9 cores retained on a 1000 µm sieve.

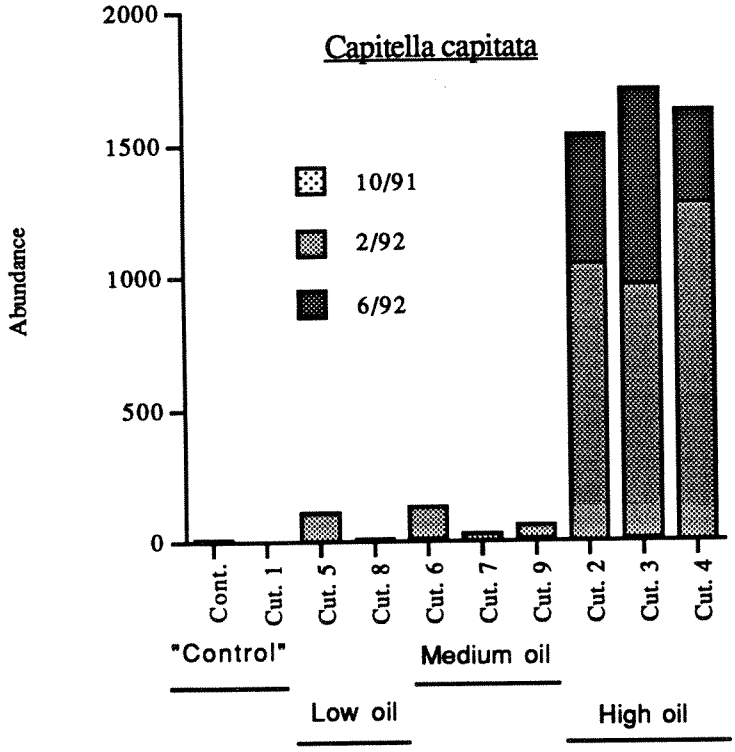

Fig.18. Total abundance of *Capitella capitata* found in plots at the start, middle and end of the community structure experiment.

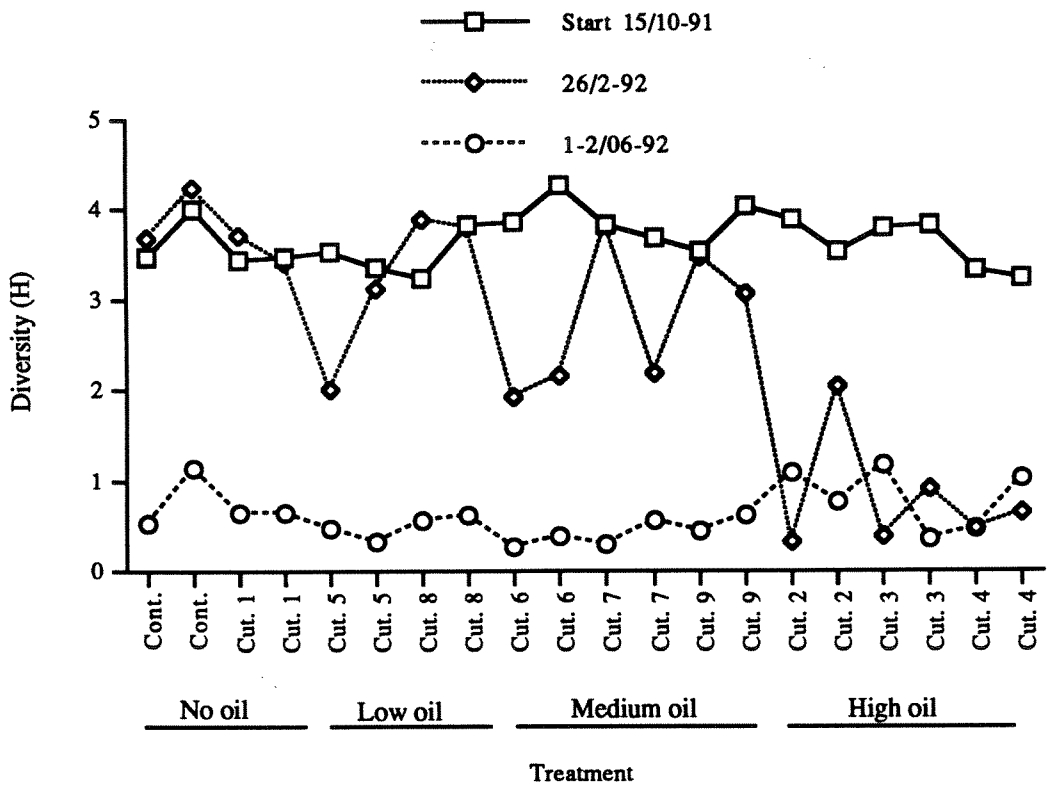

Fig. 19. Diversity (Shannon-Wiener index) of macrofauna in experimental plots during the community structure experiments. Data for October 1991 and February 1992 are based on sediment from 10 cores (sieve 500 µm) whereas abundance at the end of the experiment (June 1992) are based on 9 cores (sieve 1mm).

Diversity reflects the increase in dominance caused by the massive settling of *Capitella* and *Polydora*. No single species dominated the community at the start of the experiment, thus the diversity was relatively high in all plots. At the end of the experiment the total dominance of *Polydora* reduced the diversity to below 1 for most plots. Diversity changed little during the first 3-4 months in the control plots and in the plots with added reference material (Cut. 1). Also the plots dosed with thermally treated cuttings showed only small changes in diversity during the first 3-4 months. In the same period the diversity was considerably reduced in the plots with cuttings added with a high base oil content (cut. 2-4).

The species number and abundance data together with the results from the similarity and MDS plots (Fig. 20-21) indicate that the community structure in the different plots at the start of the experiment was relatively homogenous without any clusters separated due to the specific levels of baseoil or metal content of the sediment. After 3.5 and 7 months a clear separation of the different treatments can be identified (Fig. 22-25). By categorising the experimental plots according to oil content (see section 3.1.1) and testing for significant differences between clusters in the MDS-plot (Fig. 22) it is possible to identify significant treatment effects (table 7). The control plots (and the plots treated with reference material (Cut. no. 1)) cluster together and are distinctly separated from the high oil plots (cut. no. 2,3 and 4) and the medium oil cuttings. The high oil treatments are significantly different from the 3 other treatment groups on both sampling dates (Table 7).

Based on the total species matrix it can be concluded that community structure as expressed through MDS-plots was not significantly effected in the low oil treatment. The base oil content in the low oil treatments at the start of the experiment was below 990 ppm. The community structure was however significantly affected at concentrations in the range 1200-2000 ppm. The base oil content was not reduced during the experiments.

The experiments thus indicate that threshold for effects on gross community structure is found at a baseoil concentration of approximately 1000 ppm. Within the frame of these experiments it seems that the standard thermal treatment process and the best achievable solvent wash (See table 1) results in cuttings which have no identifiable effects on gross community structure in the sediment, at least as long as the discharged amount of cuttings does not exceed 10 % (volume) in the top 3 cm of the sediment.

The plots that received the reference material (cut. no. 1) with a high level of Pb, Cd, Zn and Ba , grouped together with the control plots. This indicates that the metal concentration (Ba: 1000 µg/g dw., Cd: 2-5 µ g/g dw., Pb: 300-700 µg/g dw. and Zn: 160-330 µg/g dw.) had no effect on benthic gross community structure as described by the MDS-plots, number of species, number of individuals and diversity. A strong negative correlation between diversity and copper concentration in sediment has been found (Rygg and Skei, 1984), and a negative moderate or low correlation was found for Pb, Zn and Cd. There are few studies that address effects of the metal content in sediment with community structure parameters. These results indicate that the base oil content of cuttings is more critical for the effects on benthic communities than are heavy metals (Ba, Cd, Zn, Pb). The effect of metals in sediment is probably related to the bioavailability of the metals. The leaching experiments performed with the cuttings (Delvigne, 1993) indicate that the metals are strongly bound to the mineral particles and thus indicate a low level of bioavailability. A low level of bioavailability is also indicated by the intertidal mesocosm tests performed (T. Bowmer et al. 1993)

Table 7. Results from testing differences between clusters in the MDS-plot using ANOSIM.
A. Based on data from 26/2-92.
B. Based on data from 1-2/6-92.

A

	Control (C+1)	Low oil (5,8)	Medium oil (6, 7, 9)
Low oil (5,8)			
Medium oil (6, 7, 9)	#[1]		
High oil (2,3,4)	##[2]	##[2]	##[2]

B

	Control (C+1)	Low oil (5,8)	Medium oil (6, 7, 9)
Low oil (5,8)			
Medium oil (6, 7, 9)	##[2]		
High oil (2,3,4)	##[2]	##[2]	##[2]

[1] p=0,05
[2] p=0,001

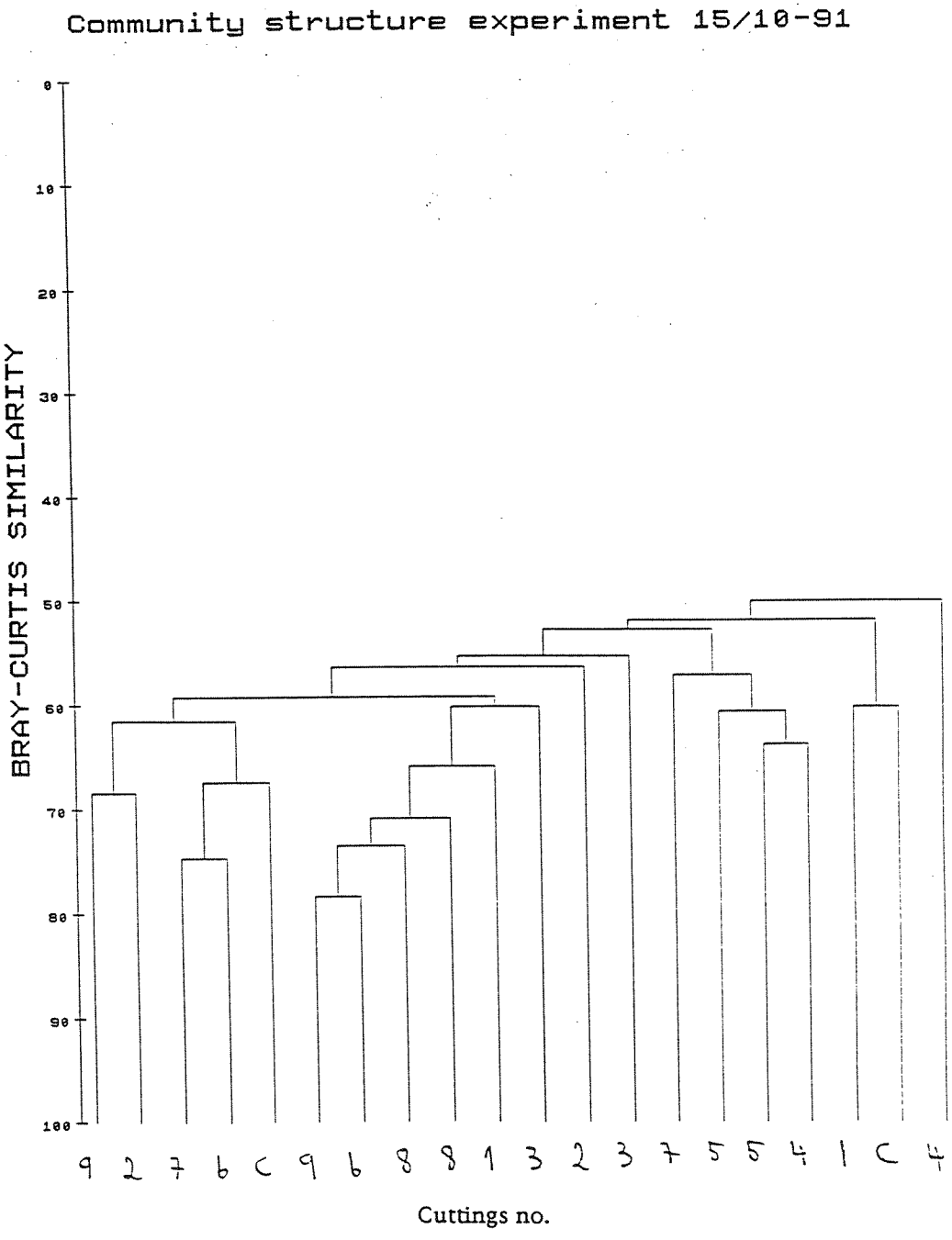

Fig. 20. Bray-curtis similarity plot based on the species abundance data at the start of the community structure experiments

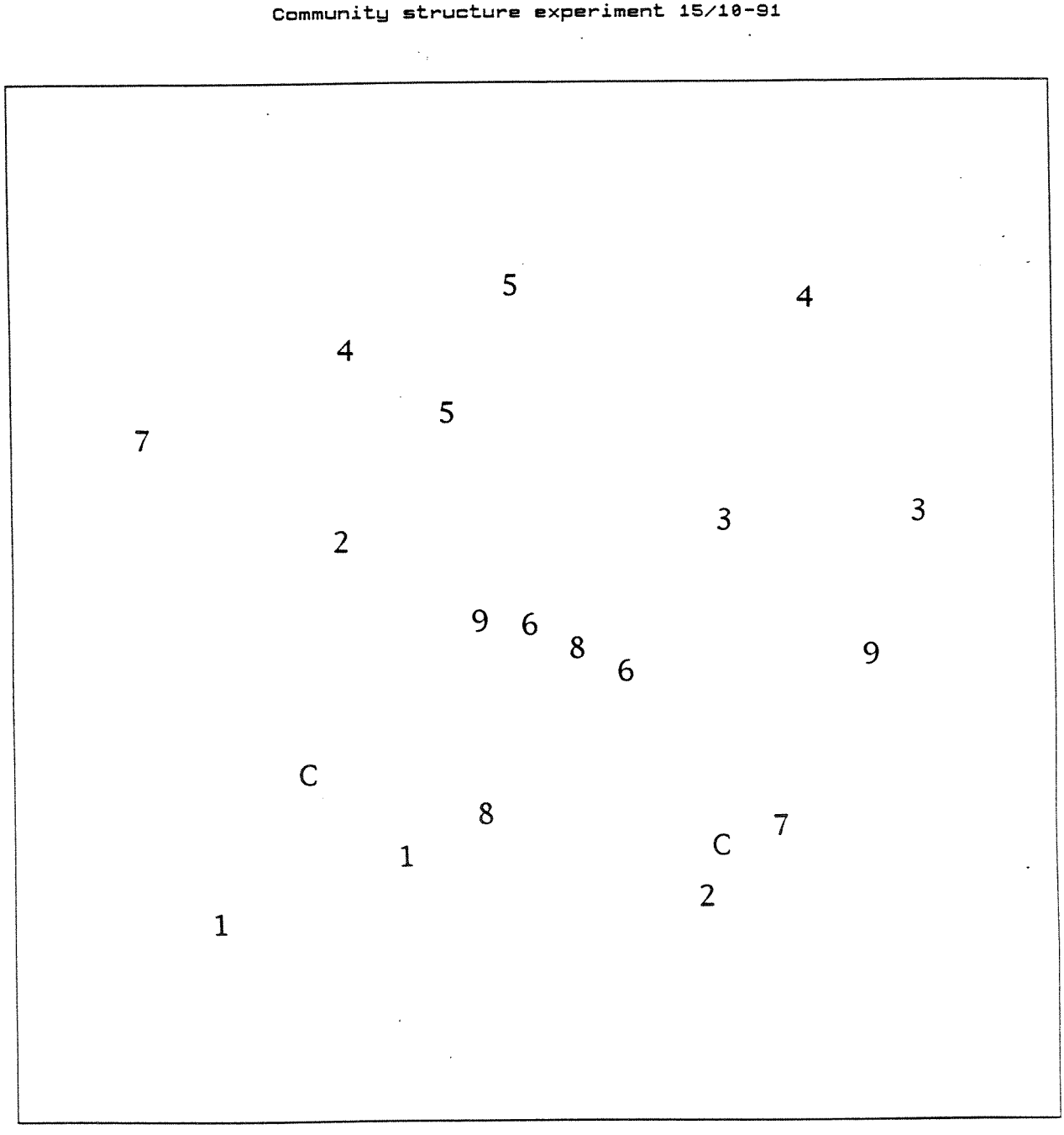

Fig. 21. Multi dimensional scaling (MDS) plot based on the species abundance data at the start of the community structure experiments.

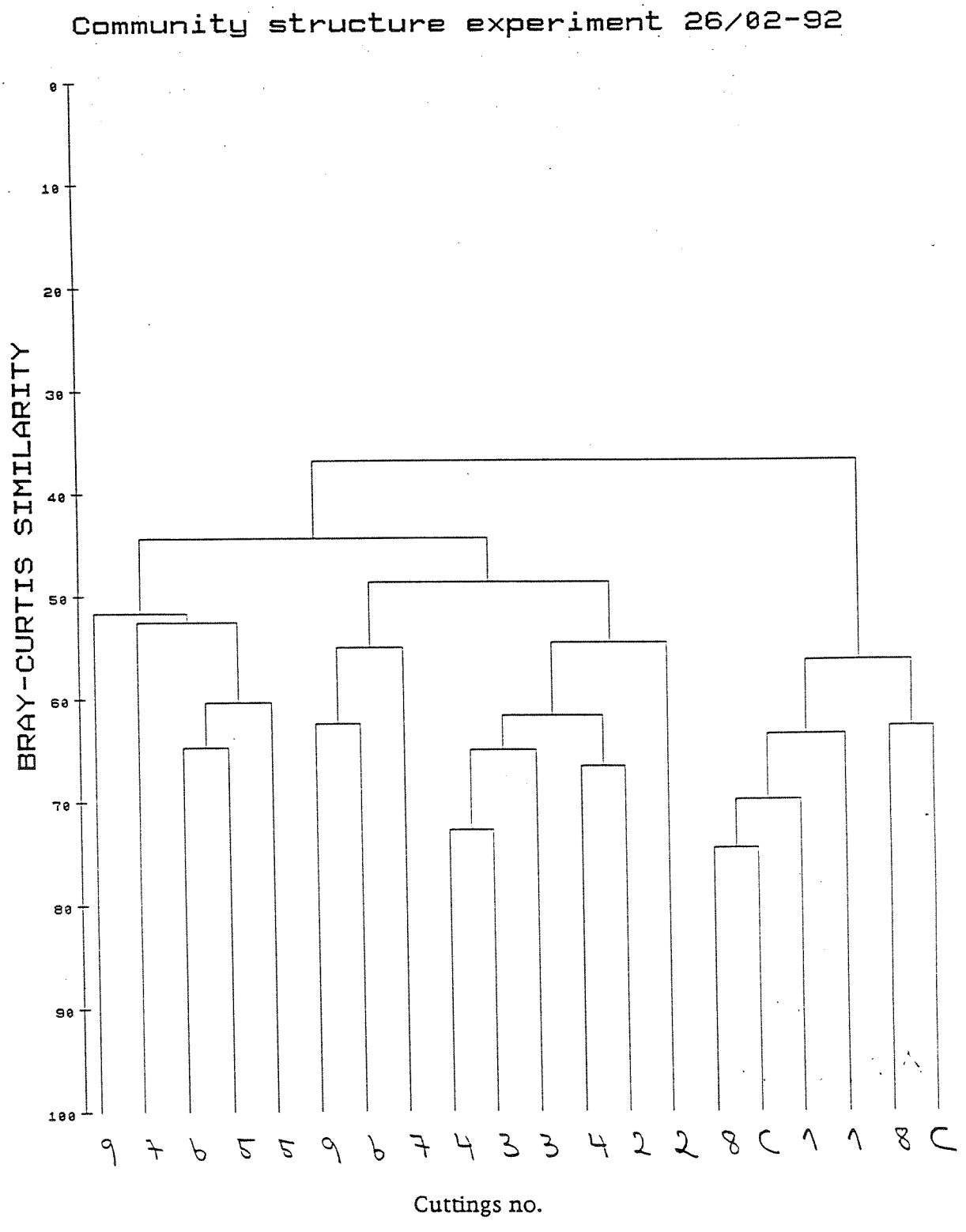

Fig. 22. Bray-curtis similarity plot based on the species abundance data from samples collected 26/2-92 in the community structure experiments.

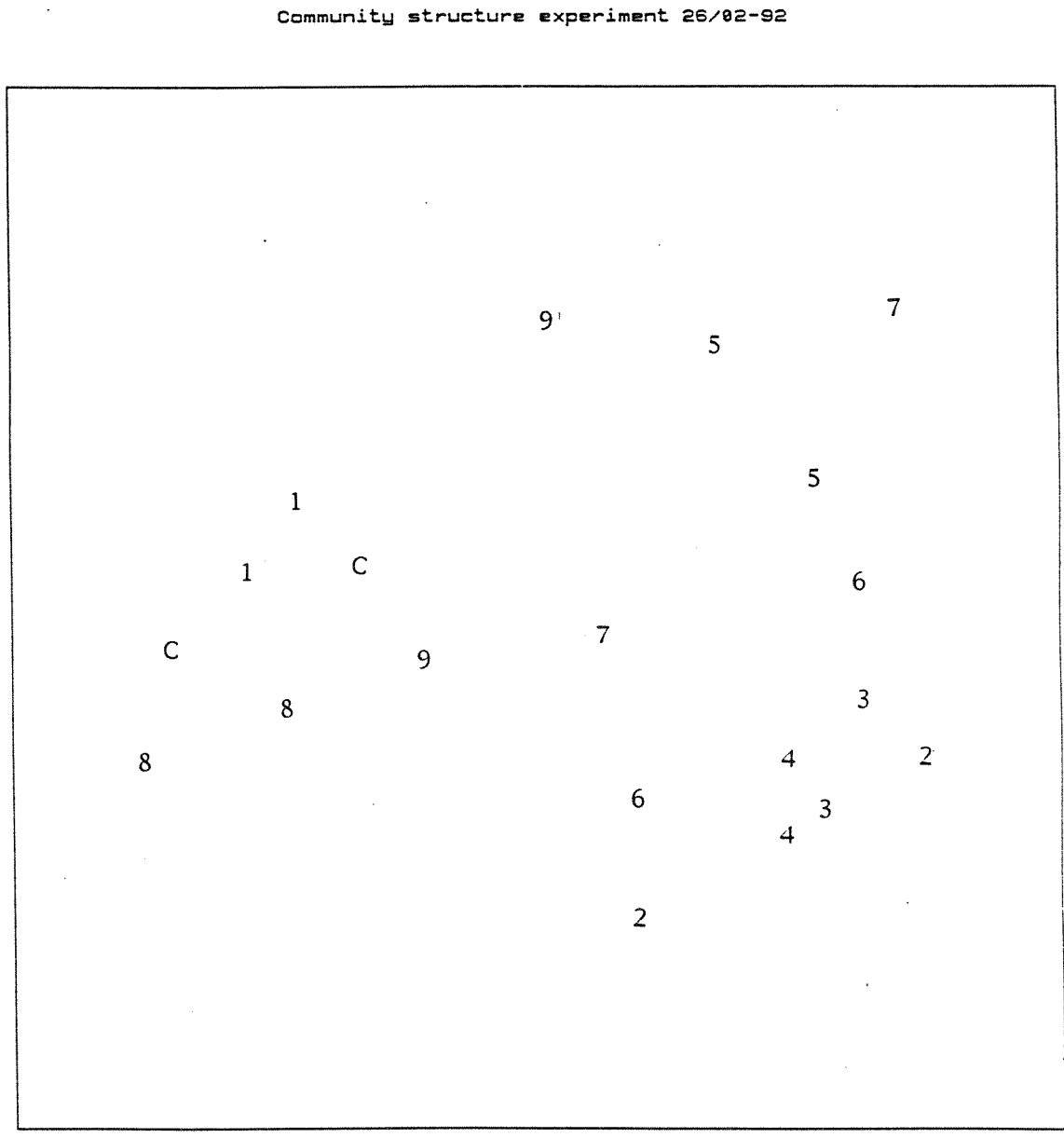

Fig. 23. Multi dimensional scaling (MDS) plot based on the species abundance data from samples collected 26/2-92 in the community structure experiments.

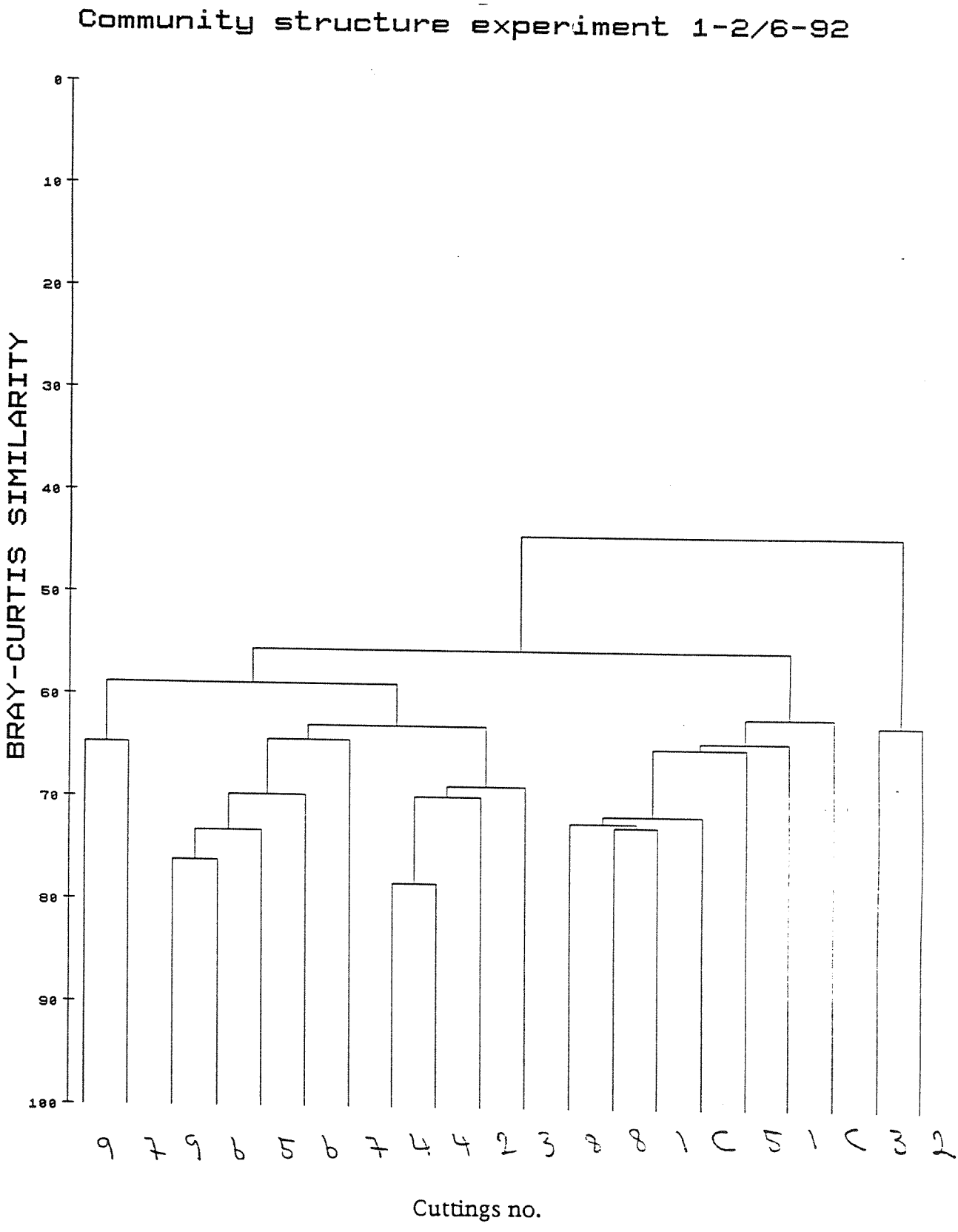

Fig. 24. Bray-curtis similarity plot based on the species abundance data from samples collected 1-2/6-92 in the community structure experiments.

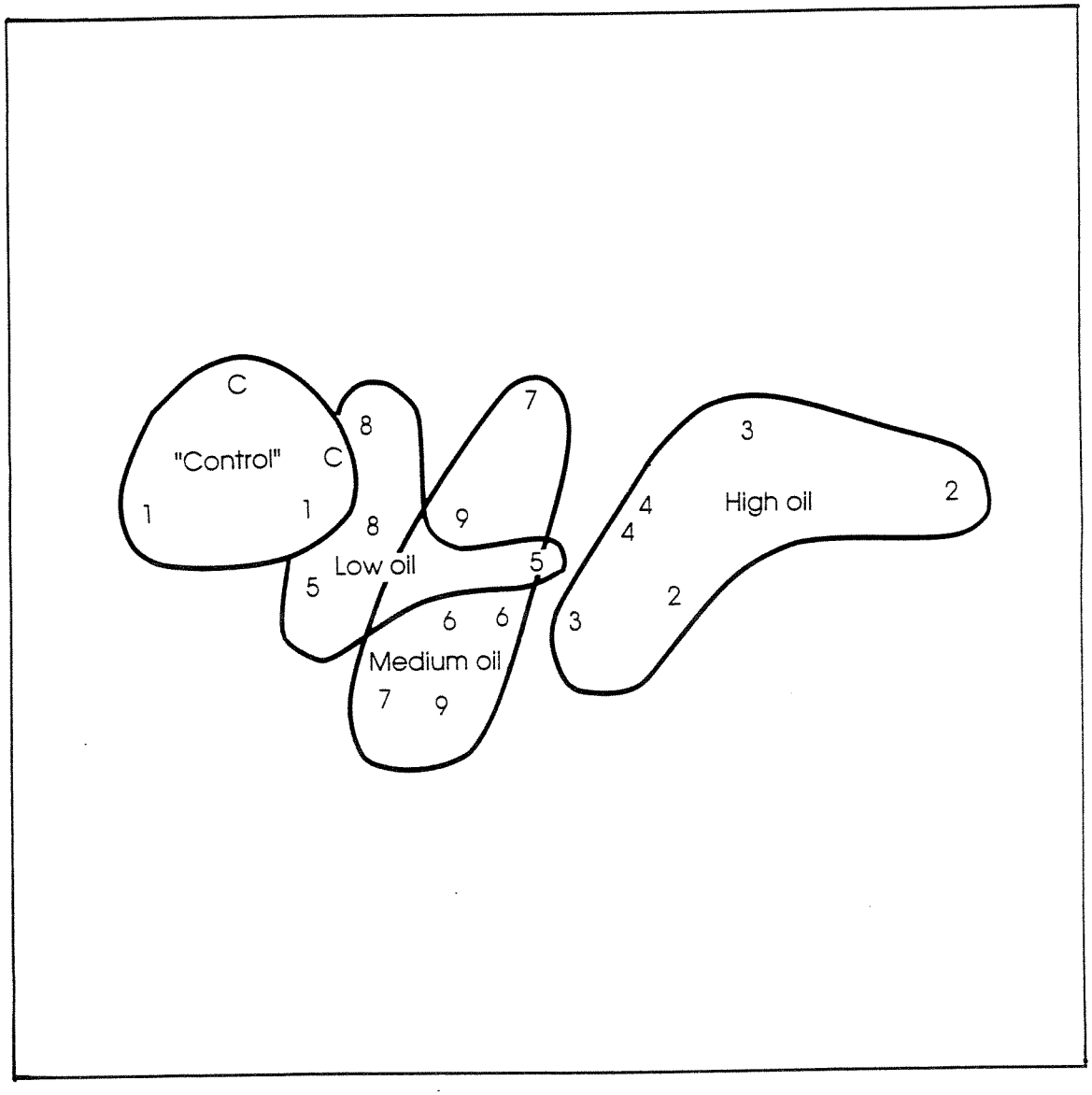

Fig. 25. Multi dimensional scaling (MDS) plot based on the species abundance data from samples collected 1-2/6-92 in the community structure experiments.

3.1.4 Species responses

Major taxa

The densities of major taxa found during the experiments are seen in fig. 26 to 29.
Polychaetes dominated the samples especially at end of the experiment (fig. 26), whereas other major taxa were less abundant (See fig. 27-29). At the start of the experiment there were some differences in densities of major taxa between treatments. Some of these differences were significant (Fig. 29). Since the first sampling was done one week after adding the cuttings some of the density differences seen between the treatments at the start of the experiment may have been caused by an early effect of the cuttings, natural random variation may, however, also have contributed. It is suspected that early effects may have been resposible for the results seen for crustaceans and bivalves after one week (fig. 27-29). There were however no significant differences (one factor ANOVA) between any of the treatments (Cut. 2-9) and the controls (C+Cut. 1) for polychaetes and bivalves whereas such differences were found for the crustaceans. Compared to the controls a significant increase in denseties of Polycheates was found in plots treated with cuttings no. 2-4 in February 92 (Fig. 26). This increase is mainly a result of settlement of opportunistic species (*Capitella*, see fig. 3*1*) which more than compensated for the reduced densities of other species (see individual species resposes below). The polychaete deseties at the end of the experiments (Fig. 26) are mainly driven by a massive settlement of *Polydora* in all plots (see Fig. 36). For bivalve densities Cut. 8 was the only treatment which was not found to be significantly different from the contol (Fig. 28).

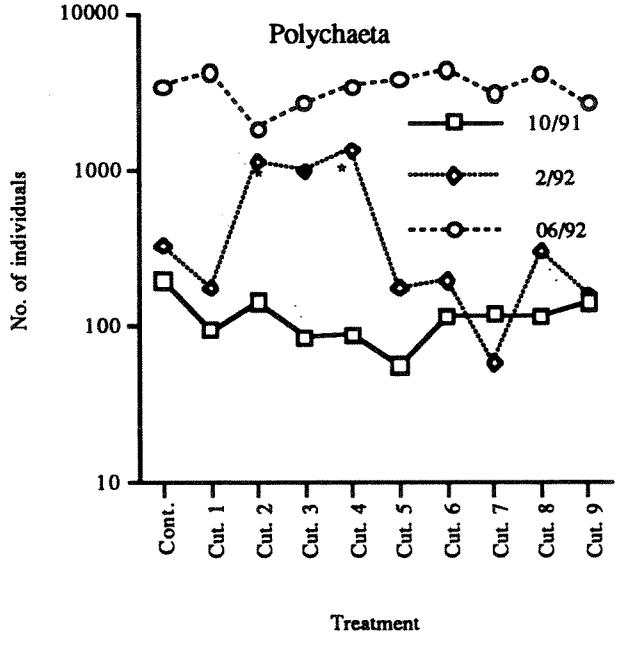

Fig. 26. Total abundance of polychaetes found in plots at the start, in the middle and end of the community structure experiment. *= Mean abundance significantly different (p=0.05, one factor ANOVA) from mean of the four plots not treated with cuttings (Cont., Cut. 1) in the middle of the experiment (2/92).

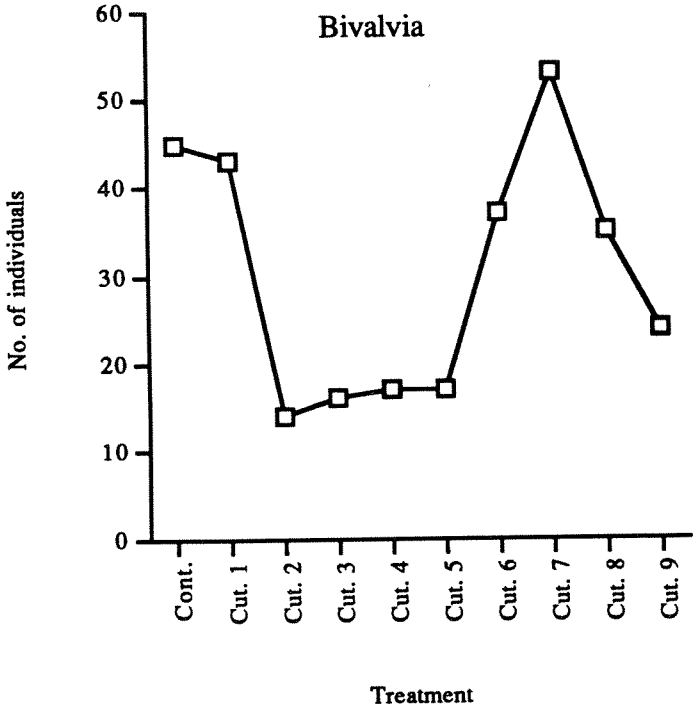

Fig.27. Total abundance of bivalves found in plots at the start of the community structure experiment (10/91).

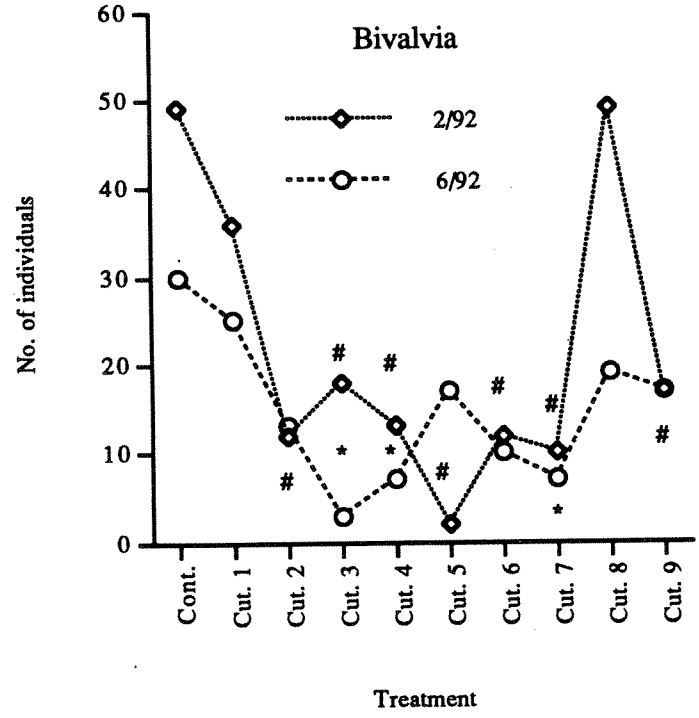

Fig.28. Total abundance of bivalves found in plots with similar treatment in the middle and end of the community structure experiment. *= Mean abundance significant different (p=0.05, one factor ANOVA) from mean of the four plots without cuttings (Cont., Cut. 1) in the middle of the experiment (2/92). #= Mean abundance significant different at the end of the experiment (6/92) relative to plots without cuttings (Cont., Cut.1).

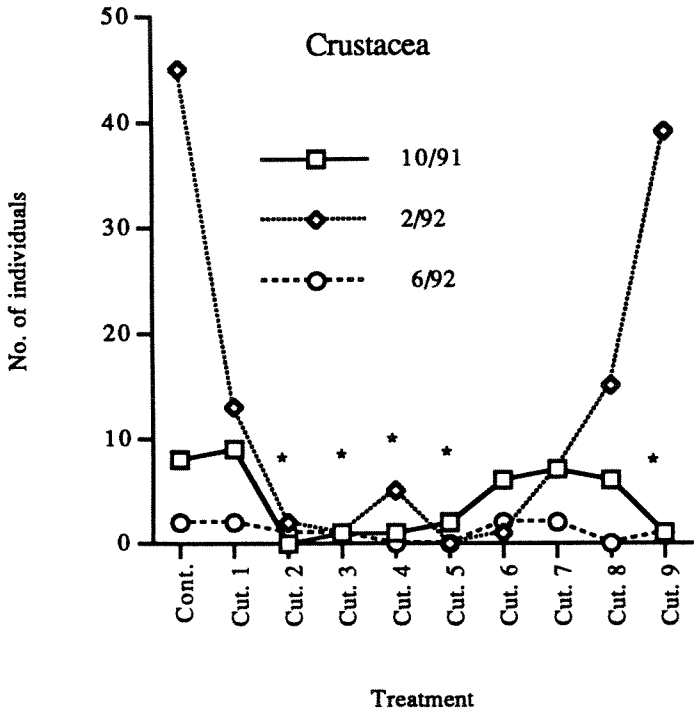

Fig.29. Total abundance of crustaceans found in plots with similar treatment at thes start ,middle and end of the community structure experiment. *= Mean abundance significant different (p=0.05, one factor ANOVA) from mean of the four plots withou cuttings (Cont., Cut. 1) at the start of the experiment (10/91).

Species

Densities of species represented with a total of at least 50 individuals in all plots on any of the three sampling occasions are seen in fig. 30-44. For each species and sampling occasion represented in the figures, diffrences in densities between treatment and control (C+Cut. 1) have been tested (one factor ANOVA, p=0.05). Significant difference found in the tests are illustrated in the figures. Several types of species responses were seen. Classical oportunistic species like *Capitella capitata* (Fig.31) increased in the three treatments with the highest base oil content (Cut. 2-4). Whereas, *Polydora*, after a mass settlement, was abundant in all treatments at the end of the experiment (Fig. 36). Some of the species were especially negatively affected by the added cuttings. These were *Anaitides groenlandica* (Fig. 30), *Eteone sp.* (Fig. 33), *Prionospio malmgreni* (Fig. 37), *Spiophanes bombyx* (Fig. 40) and *Spio sp.* (Fig. 41). Whereas othes species, like *Chaetozone setosa* (Fig. 32), *Paradoneis lyra* (Fig. 35), *Prionospio cirrifera* (Fig. 38), *Scoloplos armiger* (Fig. 39), *Thyasira flexuosa* (Fig. 42) were not found to be significantly affected.

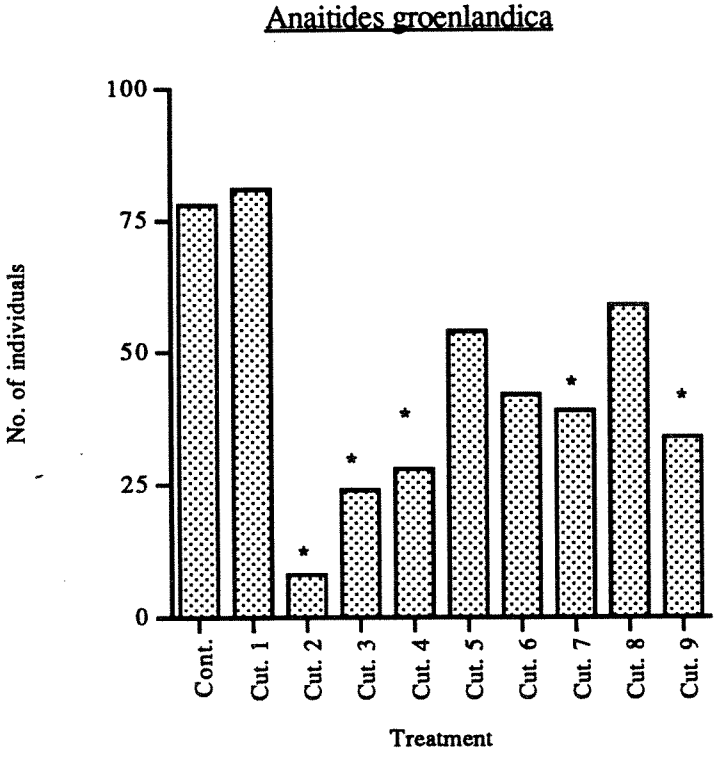

Fig.30. Total abundance of *Anaitides groenlandica* found in plots with similar treatment at the end of the experiments. *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots not added hydrocarbon (Cont., Cut. 1).

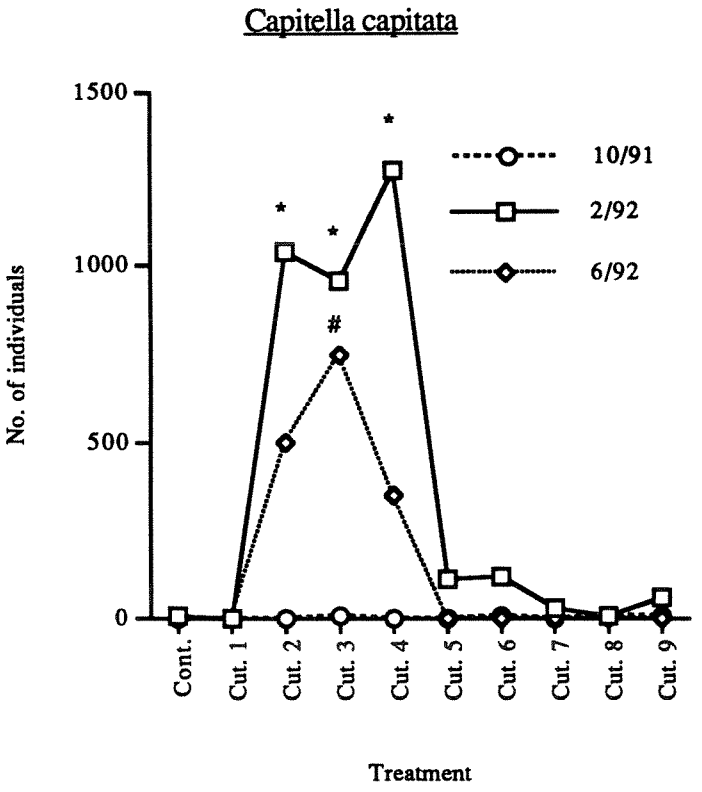

Fig. 31. Total abundance of *Capitella capitata* found in plots with similar treatment.
at the start, in the middle and end of the community structure experiment. *= Mean abundance significant different (p=0.05, one factor ANOVA) from mean of the four plots without cuttings (Cont., Cut. 1) in the middle of the experiment (2/92). #= Mean abundance significant different at the end of the experiment (6/92).

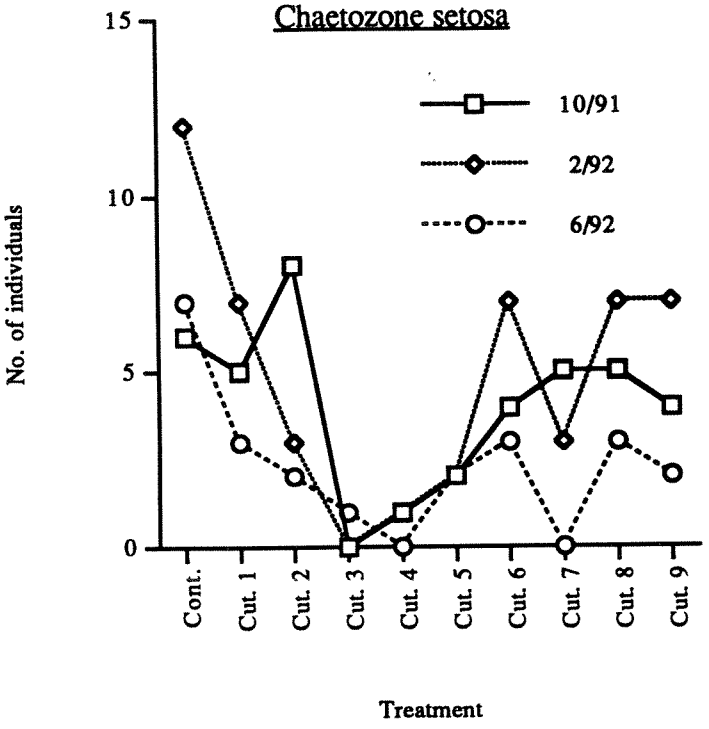

Fig. 32. Total abundance of *Chaetozone setosa* found in plots .

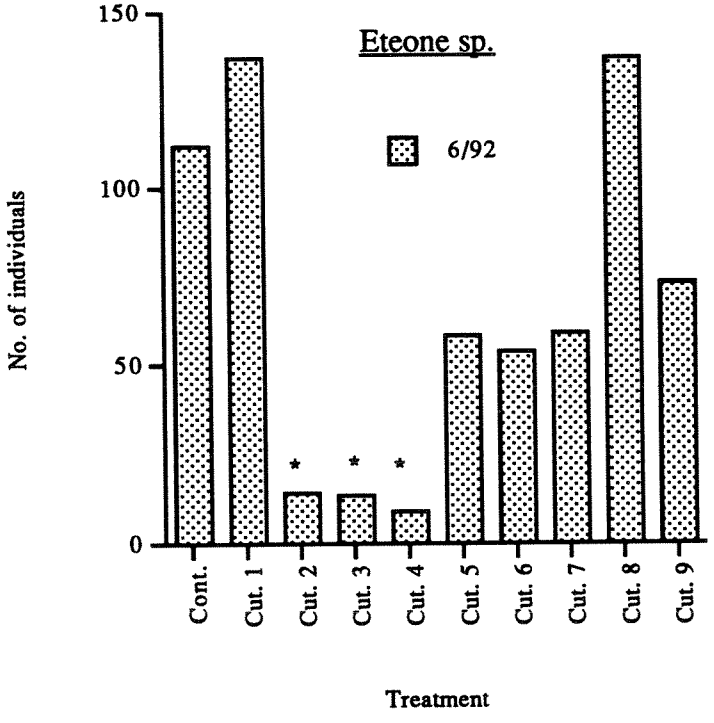

Fig. 33. Total abundance of *Eteone sp.* found in plots in June 1992. *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1). Data for start and middle are not shown because of low densities.

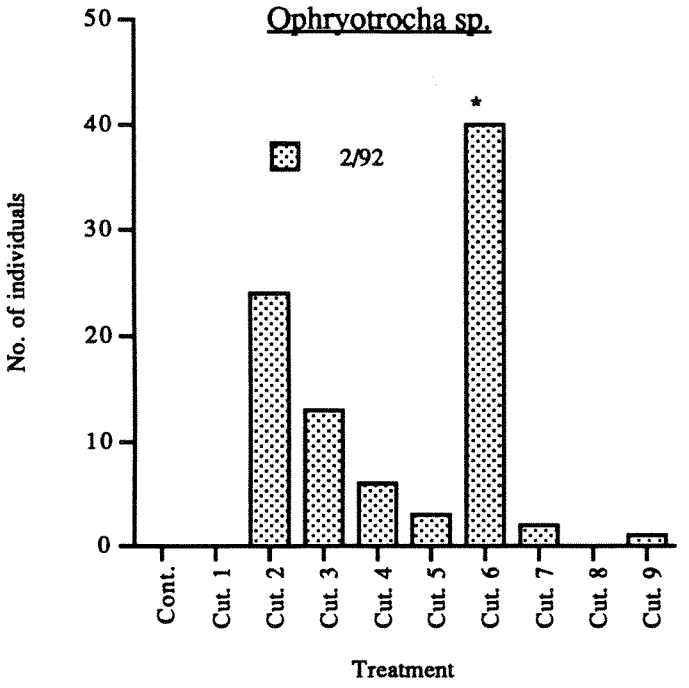

Fig. 34. Total abundance of *Ophryotrocha sp.* found in plots in February 1992 . *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1). This species was not identified in samples collected at the start and end of the experiments.

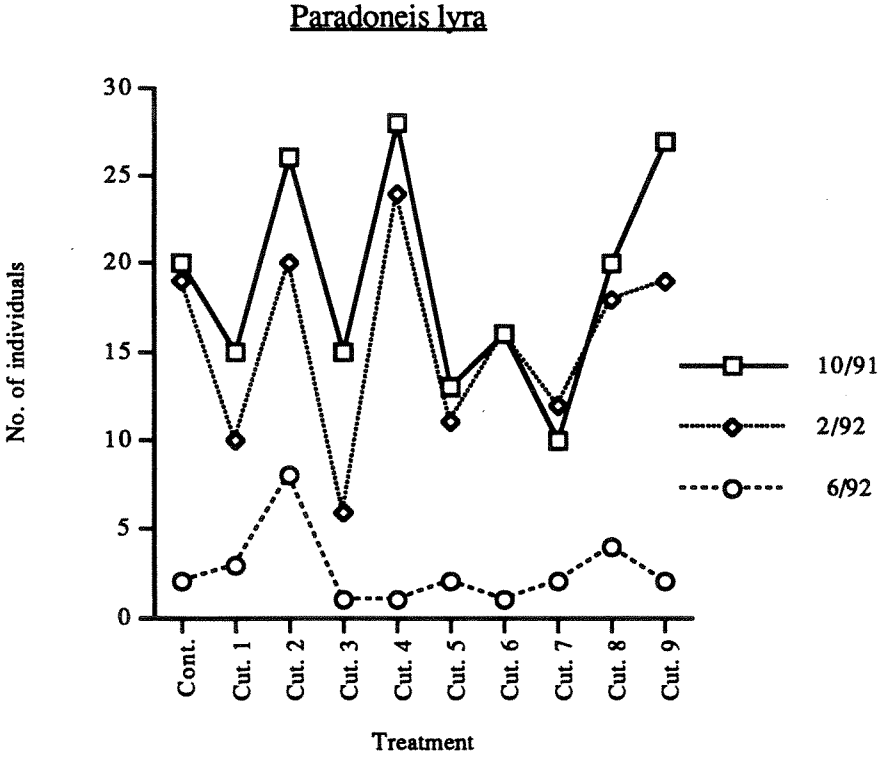

Fig. 35. Total abundance of *Paradoneis lyra* found in plots with similar treatment. No significant differance between treatments and plots without cuttings (Cont., Cut.1).

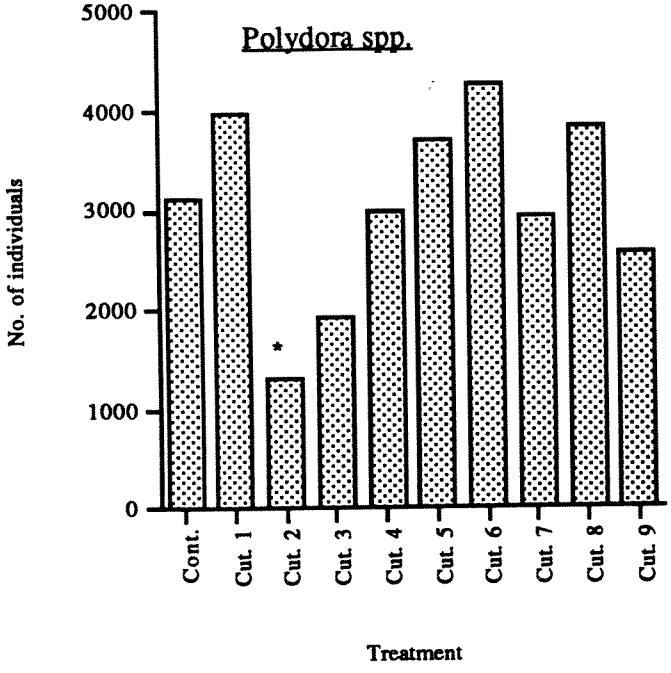

Fig. 36. Total abundance of *Polydora spp* found in plots with similar treatment at the end of the experiments (June, 1992). *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1).

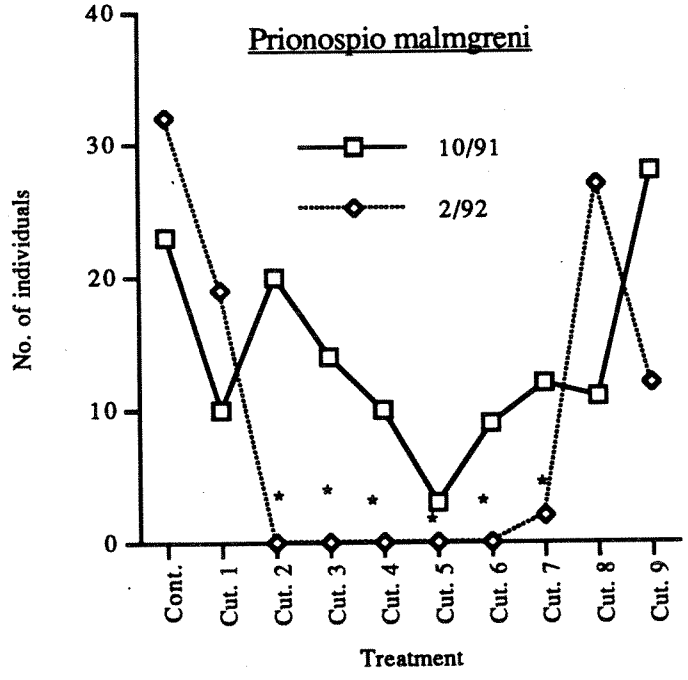

Fig. 37. Total abundance of *Prionospio malmgreni* found in plots with similar treatment at the start end in the middle of the community structure experiment. *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1).

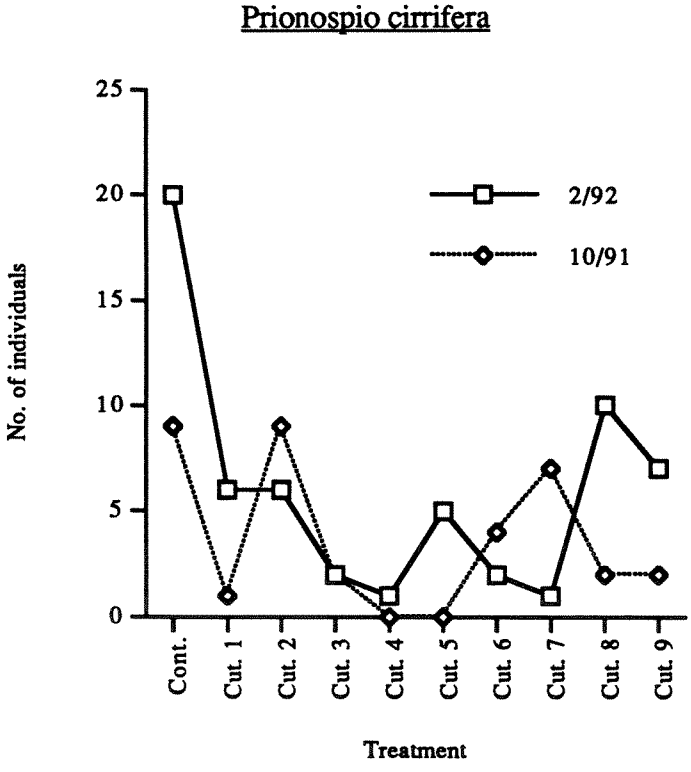

Fig. 38. Total abundance of *Prionospio cirrifera* found in plots with similar treatments at the start and in the middle of the community structure experiment.

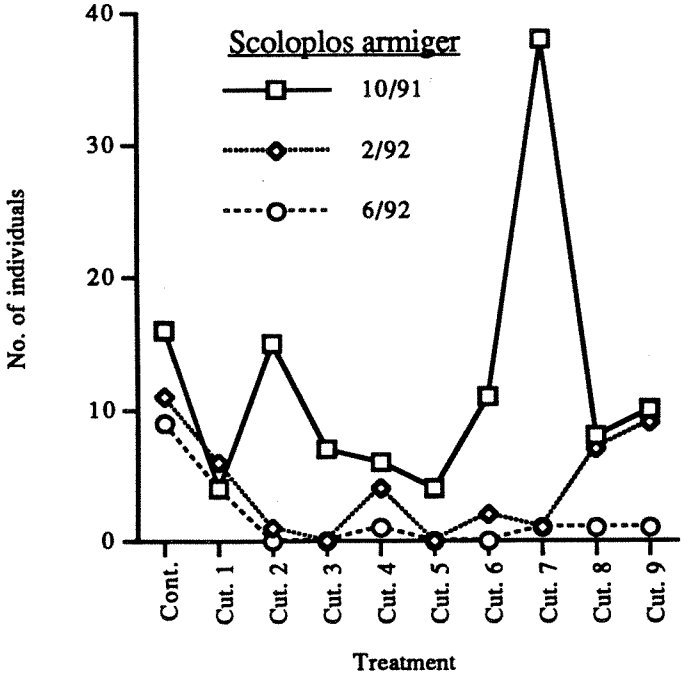

Fig. 39. Total abundance of *Scoloplos armiger* found in plots with similar treatment at the start, middle and end of the community structure experiment.

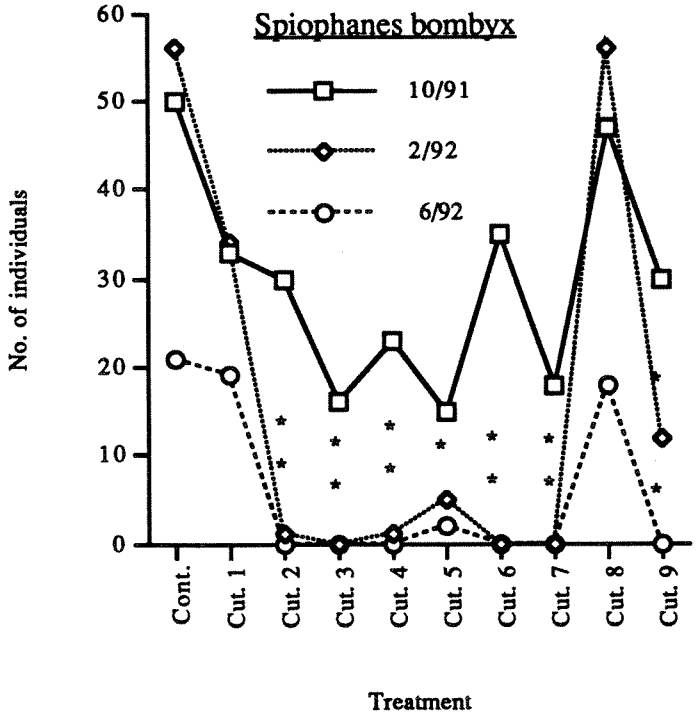

Fig. 40. Total abundance of *Spiophanes bombyx* found in plots with similar treatment at the start,, middle and end of the community structure experiment. * above symbol = Mean abundance pr plot are significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1).

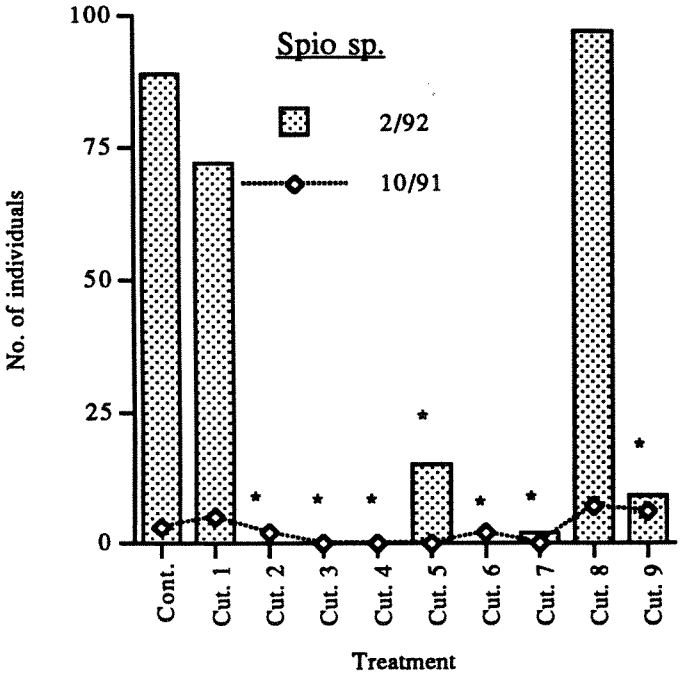

Fig. 41. Total abundance of *Spio sp.* found in plots at the start and the middle of the community structure experiment. *= Mean abundance (in February 1992) significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1).

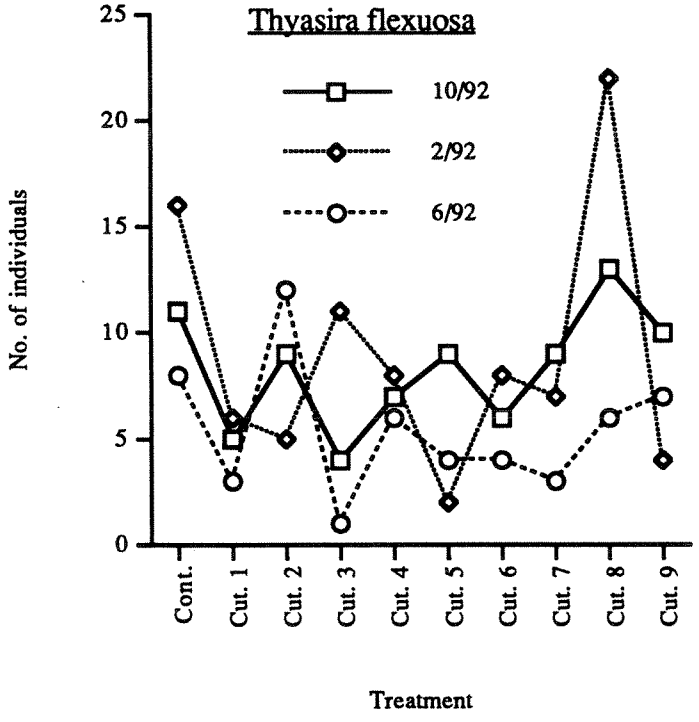

Fig. 42. Total abundance of *Thyasira flexuosa* found in plots at the start, middle and the of the community structure experiment. Mean abundance not significant different from mean of the four plots without cuttings.

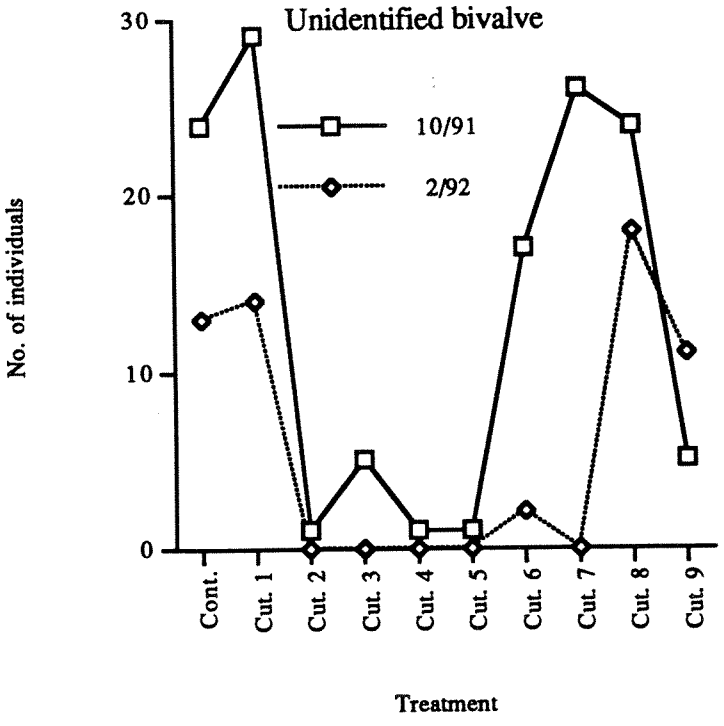

Fig. 43. Total abundance of an unidentified small (juvenile?) bivalve found in plots with similar treatment at the start and the middle of the community structure experiment. *= Mean abundance significant (p=0.05, one factor ANOVA) different from mean of the four plots without cuttings (Cont., Cut. 1).

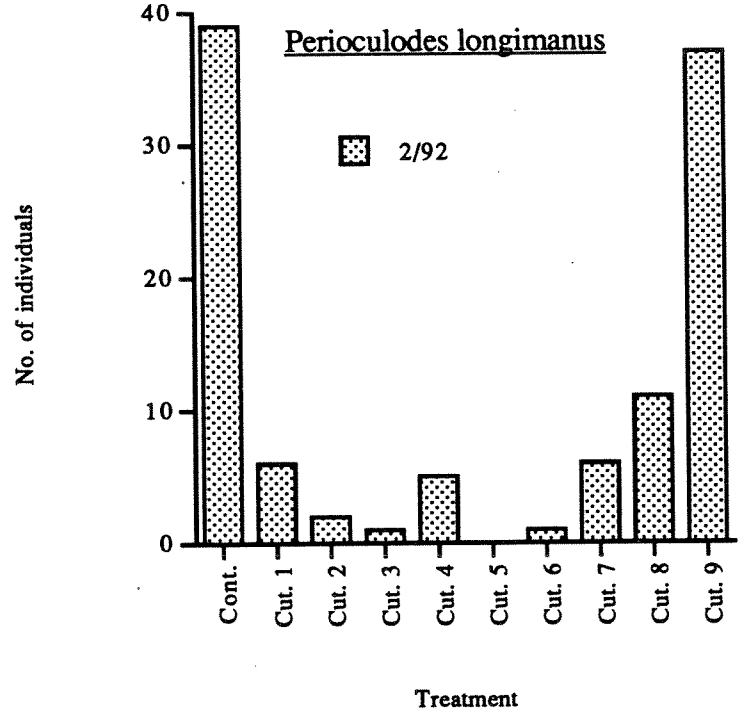

Fig. 44. Total abundance of *Perioculodes longimanus* found at the middle of the community structure experiment. Mean abundance not significant different from mean of the four plots without cuttings (Cont., Cut. 1).

Significant differences betwen treatment and control (Cont+Cut.1) for all the species are shown in Table 8. For each treatment the number of instances where significant higher densities were found in control plots are shown. By ranking this number in order of decreasing magnitude it is possible to rank the cutting types in order of decreasing environmental effect. This procedure gives the following result:

Cut.2>Cut. 3 and Cut. 4>Cut.7>Cut.6 and Cut.9>Cut.5>Cut. 8

This ranking is in good agreement with the results from the community structure parameters (see chapter 3.1.3).

The most environmentally harmful effect was seen in plots treated with cuttings received directly of the shaker (Cut. 2) or centrifuged (Cut.3, Cut. 4). Plots added only standard thermally treated cuttings (Cut. 8) was the only treatment where no significant differences from control were found for any of the tested species. The concentration of baseoil at the start of the experiment in plots treated with Cut.8 was 150 ppm. Even the addition of the best achievable solvent washed cuttings (Cut. 5) (concentration of base oil in sediment=990 ppm) gave negative effects on *Prionospio malmgreni, Spiophanes bombyx* and *Spio sp.*.

This indicates that the no effect concentration based on baseoil content was somewhere in the range 150-990 ppm.

This is somewhat lower than indicated from the statistical testing of the results from the MDS plots (see table 8). This difference is probably mainly related to the way the different treatments were grouped when testing for significant community structure differences. Since plots treated with Cut. 8 and Cut. 5 (low oil cuttings) were grouped together and tested as such, possible significant differences between these two treatment could not be identified because the test require 4 test replicates in order to give reliable results. There is, however, also the possibility that individual species effects may not show up at the community level

Table 8. Table showing significant difference (p=0.05, one factor ANOVA) between treatment and control (Cont.. Cut. 1). * = mean abundance in control > mean abundance in treatment and significant difference are found. #=mean abundance in control < mean abundance in treatment and significant difference are found. n=No significant difference between treatment and control. Please note that the tests are based on the total varians.

	Date	Cut. 2	Cut. 3	Cut. 4	Cut. 5	Cut. 6	Cut. 7	Cut. 8	Cut. 9
Species									
Anaitides groenlandica	6/92	*	*	*	n	n	*	n	*
Capitella capitata	2/92	#	#	#	n	n	n	n	n
Capitella capitata	6/92	n	#	n	n	n	n	n	n
Chaetozone setosa	10/91	n	n	n	n	n	n	n	n
Chaetozone setosa	2/92	n	n	n	n	n	n	n	n
Chaetozone setosa	6/92	n	n	n	n	n	n	n	n
Eteone sp.	6/92	*	*	*	n	n	n	n	n
Ophryotrocha sp.	2/92	n	n	n	n	#	n	n	n
Paradoneis lyra	10/91	n	n	n	n	n	n	n	n
Paradoneis lyra	2/92	n	n	n	n	n	n	n	n
Paradoneis lyra	6/92	n	n	n	n	n	n	n	n
Polydora sp	6/92	*	n	n	n	n	n	n	n
Prionospio malmgreni	10/91	n	n	n	n	n	n	n	n
Prionospio malmgreni	2/92	*	*	*	*	*	*	n	n
Prionospio cirrifera	10/92	n	n	n	n	n	n	n	n
Prionospio cirrifera	2/92	n	n	n	n	n	n	n	n
Scoloplos armiger	10/91	n	n	n	n	n	n	n	n
Scoloplos armiger	2//92	n	n	n	n	n	n	n	n
Spiophanes bombyx	10/91	n	n	n	n	n	n	n	n
Spiophanes bombyx	2/92	*	*	*	*	*	*	n	*
Spiophanes bombyx	6/92	*	*	*	n	*	*	n	*
Spio sp	2/92	*	*	*	*	*	*	n	*
Thyasira flexuosa	10/91	n	n	n	n	n	n	n	n
Thyasira flexuosa	2/92	n	n	n	n	n	n	n	n
Thyasira flexuosa	6/92	n	n	n	n	n	n	n	n
Unidentified bivalve	10/91	n	n	n	n	n	n	n	n
Unidentified bivalve	2/92	n	n	n	n	n	n	n	n
Perioculodes longimanus	2/92	n	n	n	n	n	n	n	n
Total no. of *		7	6	6	3	4	5	0	4
Total no. of #		1	2	1	0	1	0	0	0

3.2 Settling experiment (I) in boxes

3.2.1 Hydrocarbon and metal analyses

The concentrations of base oil and Σ 2-6 ring aromatic hydrocarbons at the start, middle and end of the experiments are shown in Fig. 45-46 (the total data set is found in Appendix A2). The relative concentration of the base oil in the sediment at the start of the experiment reflected the concentration in the original cuttings added to the sediment surface .

A general trend observed in boxes added Case 2, 3 and 4 cuttings was that both the concentration of base oil and Σ 2-6 ring aromatic compounds in the sediment in November were lower than the concentration at the start and at the end of the experiment. The background level of "base oil" in the control plots was low both at the start and the end of the experiment indicating that significant contamination from external sources did not take place during the experiments. A comparison of the base oil level in the sediment in the experimental boxes (settling experiment I) with the concentration in the experimental plots on the sea floor (community structure experiment) indicates that the initial concentration in the two experiments was very similar (Fig. 47).

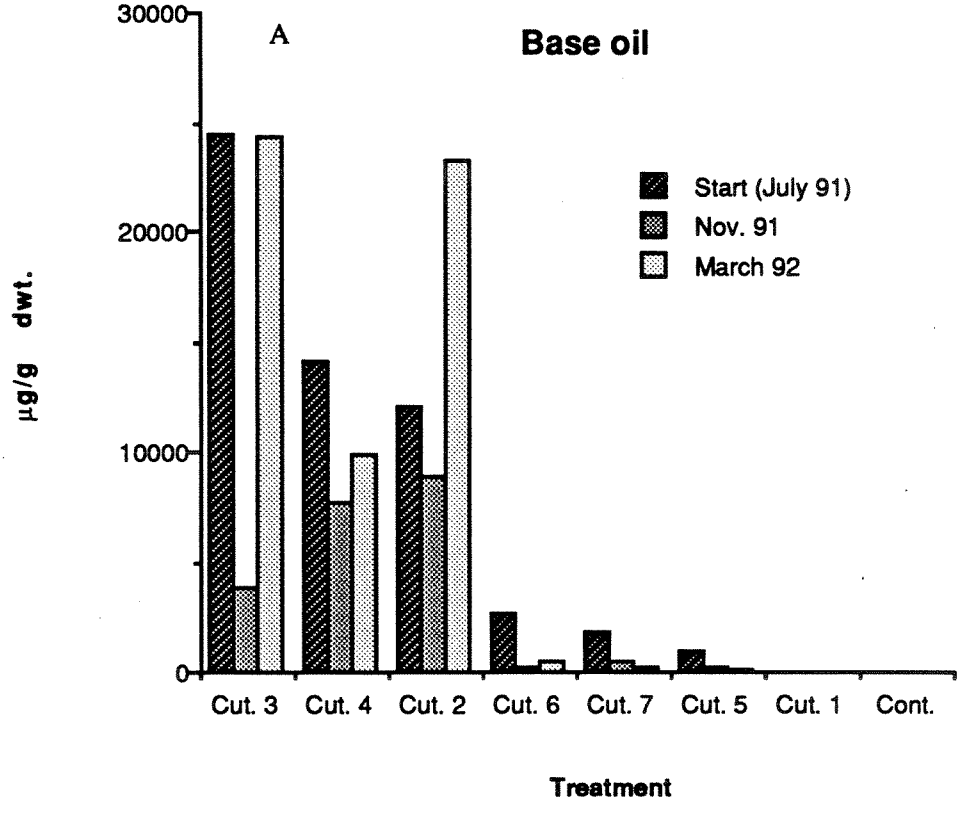

Fig. 45. Concentration of base oil in sediment in the experimental boxes at the start middle and end of the experiments . Treatment no. on the abscissa corresponds to the numbers seen in table 1 and are arranged in order of decreasing concentration of base oil at the start of the experiment.

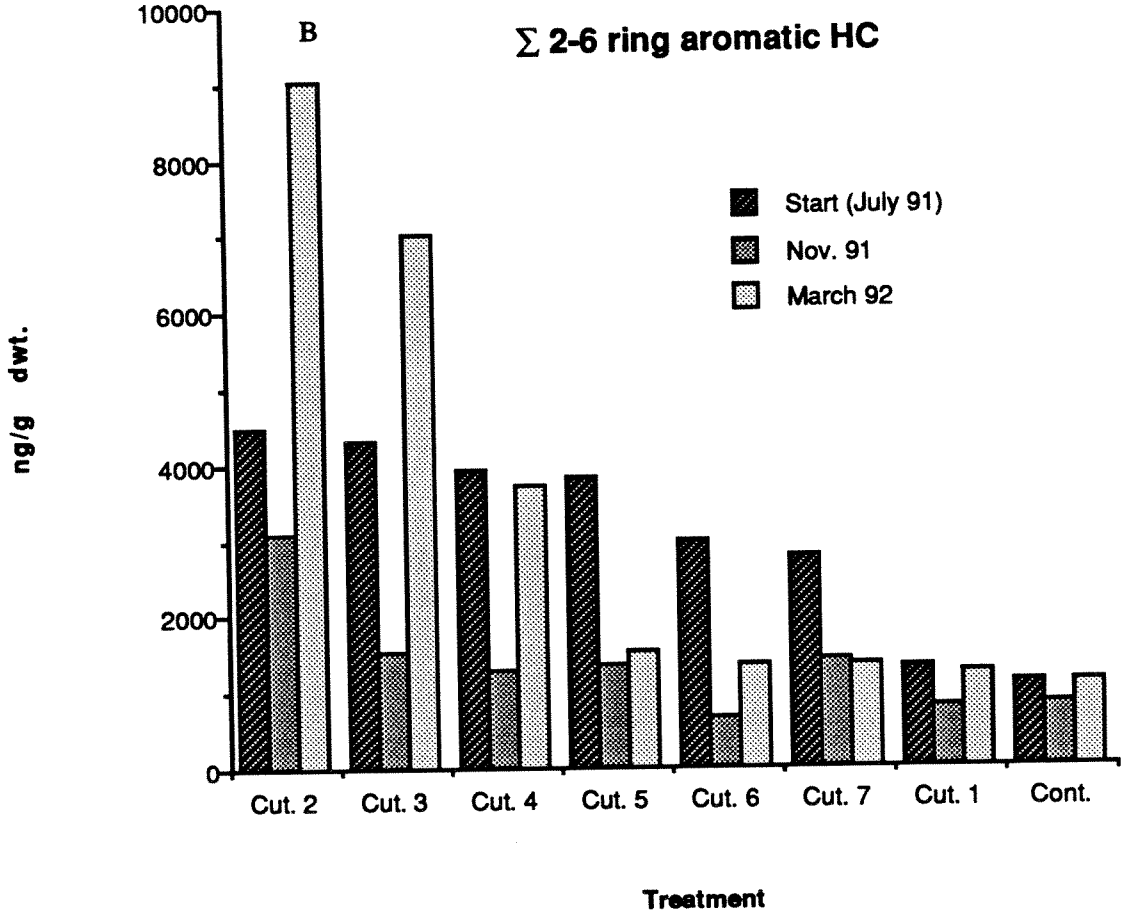

Fig. 46. Concentration of Σ 2-6 ring aromatic compounds in sediment in the experimental boxes at the start middle and end of the experiments. Treatment no. on the abscissa corresponds to the numbers seen in table 1 and are arranged in order of decreasing concentration of base oil at the start of the experiment.

The level of aromatic compounds was somewhat higher in the sediment used for the recolonization experiment (825-1120 ng/g dwt.) compared with the background level in the area where the experiments were performed (untreated plots in the community study, see Fig. 11).

Also , in the settling experiments there are differences in concentration throughout the experimental period. Three different groups of experimental plots can be distinguished throughout the experiment based on the base oil concentration. These three are:

1. Control group with base oil concentration 13-34 µg/g: control , case 1
2. Low oil group with base oil concentration 220-2700 µg/g: case 5, case 6, case 7
3. High oil group with base oil concentration 7700-24500µg/g: case 2, case 3, case 4

The low group includes both the low and medium group identified in the community structure experiments.

The differences in the aromatic compounds between the different cutting types are also seen in these experiments, but not as clearlyas for the base oil.

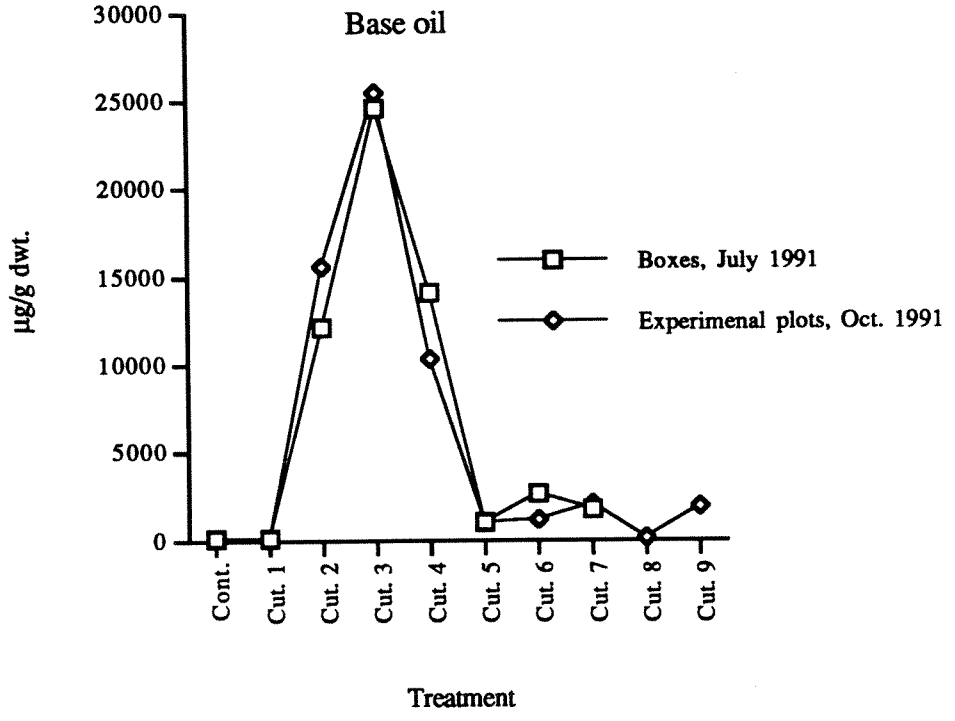

Fig. 47. The baseoil content in sediment receiving similar cuttings at the start of the settling experiments in boxes and the community structure experiments on the natural sea floor.

The concentration of barium, cadmium, lead and zinc are seen in Fig. 48-49. The total data for the metal analyses for this experiment are seen in Appendix B2. Plots of the remaining metals (Cu, Fe, Hg,Ni, V, Mn) not presented in Fig 48-49 can also be found in Appendix B2-1. The concentrations of Cu, Pb, Hg, Ni and Zn in the control sediment (control boxes) were higher than expected for non contaminated areas. This may be a function of the mixing process using a cement mixer or caused by a possible higher metal level in the original sediment used for the experiments. The high concentrations of Cd, Pb and Zn in Case 1 cuttings were also in these experiments reflected in the concentration of these metals in sediment from the plots treated with reference material. During the experiment, the content of Pb and Zn in March 1992 was reduced to 30-50 % of the concentration found at the start of the experiments in July 1991. The barium level increased in all treatments to a level of 300-650 µg/g dw. after dosing,. Whereas the concentration in the natural sediment remained constant at approximately 100 µg/g dw. throughout the experimental period.

A reduction in the concentration of barium was indicated for the top 2 cm of sediment for the treatments with a high concentration of base oil (Case 2, 3, 4) . The reduction in the concentration of Cd, Pb and Zn seen in plots treated with Case 1 could have been caused by depuration to the overlying water or to burial below the 2 cm of sediment sampled. Leaching experiments indicate that the metals in the cuttings are strongly bound to the mineral particles in the cuttings. A possible explanation for the reduction in concentration for these metals is

dilution of the added minerals in the top 3 cm of the sediment with the underlying sediment. This explanation is however not consistent with the observed concentration of Ba which showed no sign of reduction during the experiment in boxes treated with Case 1 cuttings (fig 48).

The addition of cuttings to the experimental boxes did not result in any dramatic increase for the other metals. The concentration of Cu, Pb, Hg,, Ni, Zn were somewhat above the range expected in pristine areas because of the somewhat elevated concentration of metals in the experimental sediment.

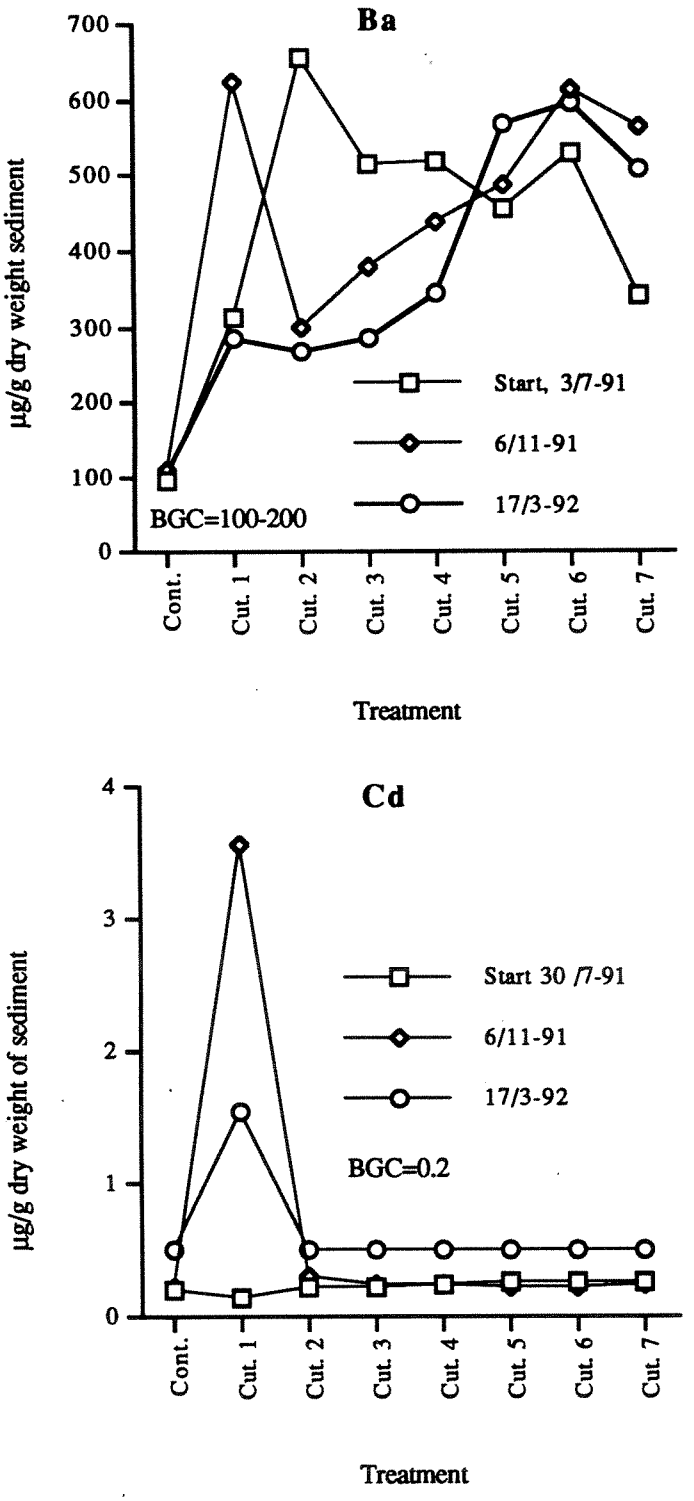

Fig. 48 Barium and cadmium concentration in the top 2 cm of the sediment in experimental boxes reiceiving similar treatment at the start (July 1991), middle (November 1991) and end of the experiment (March 1992). BGC=Background concentration.

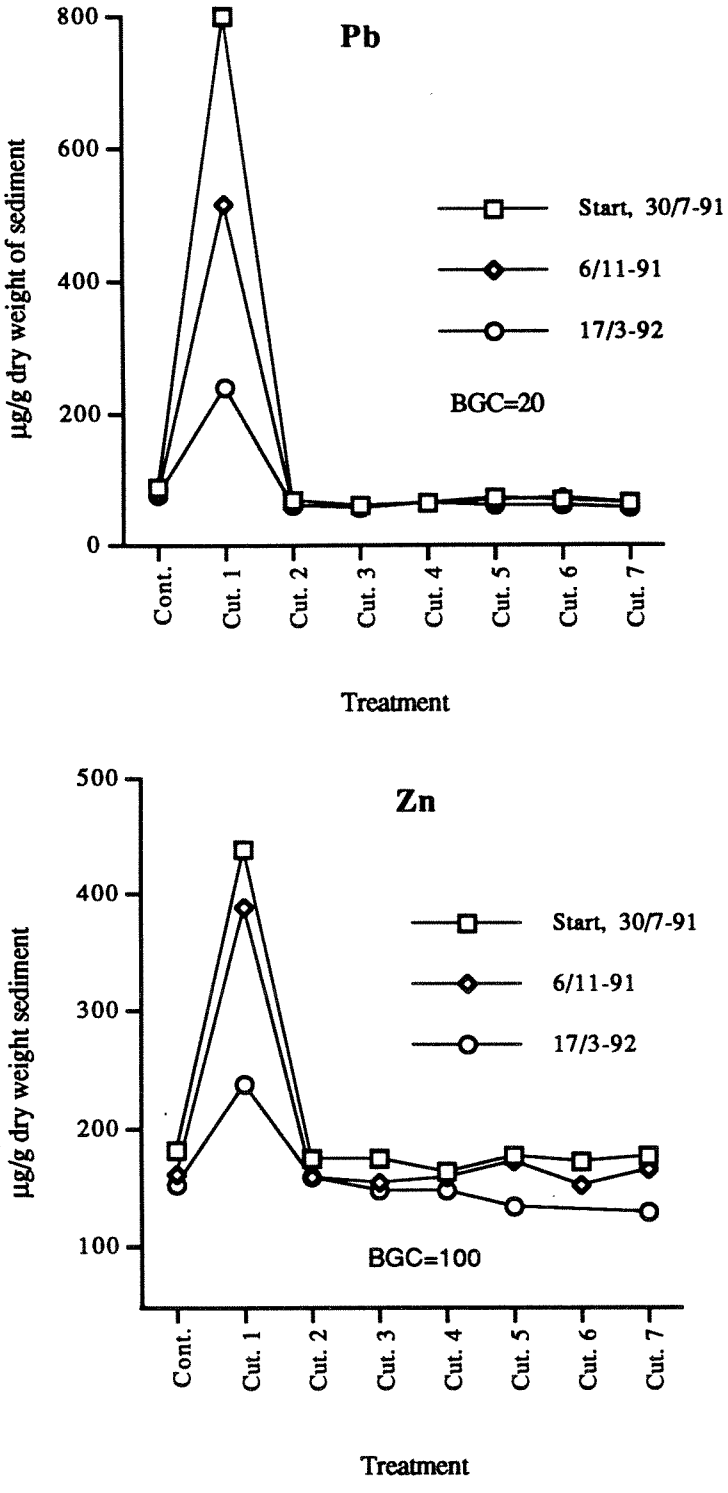

Fig. 49. Lead and zinc concentration in the top 2 cm of the sediment in experimental boxes reiceiving similar treatment at the start (July 1991), middle (November 1991) and end of the experiment (March 1992). BGC=Background concentration.

3.2.2 Redox potential

The redox potentials in the experimental boxes at the termination of the experiments are seen in fig. 50. The highest values were found in the control boxes and the boxes added reference material. The redox potential in these two treatments were within a range of 10 mV and thus far less than was apparent for the community structure experiments (Fig. 15). No significant difference was seen between these two treatments irrespectrive of if the total variance in the data set was considered (table 9) or if the data for these two treatments were tested separately. The lowest redox potentials were found in treatments receiving particulate matter with a high base oil content (Case 2, Case 3 Case 4). These three treatments were significantly different from treatment with cuttings no. 5 and 6, but not significantly different from treatment with cuttings no. 7. (Table 9). Treatment with cuttings no. 7 washowever significantly different from control and Cut. no. 1 (reference material).

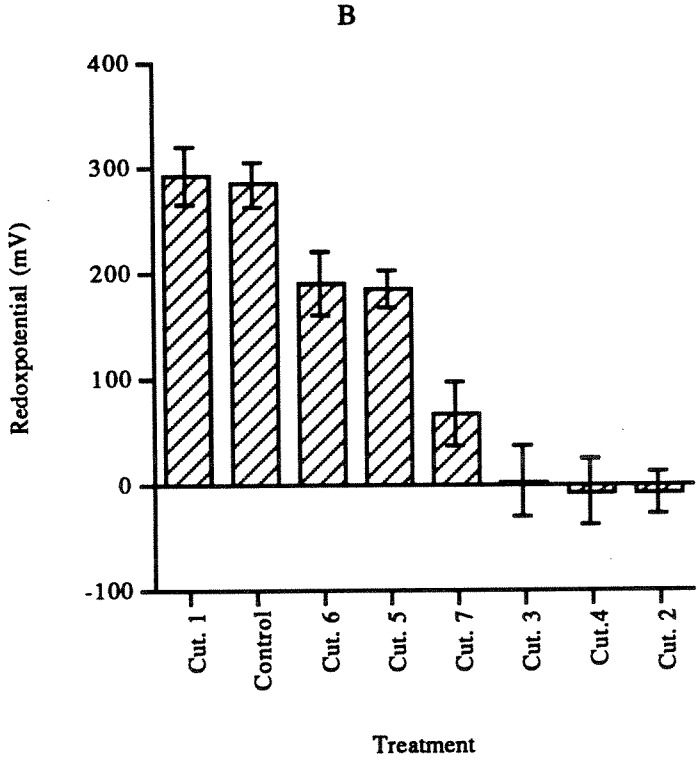

Fig. 50. Redox potential at a sediment depth of 2 cm measured at the termination of the settling experiments (March 1992). Vertical bar indicate ±1 Standard error of the mean.

Table. 9. Results from one factor ANOVA on redox data collected at the termination of settling response experiments, March 1992. x=significant differance (p=0.05), ns=no significant differance.

	Cont.	Cut. 1	Cut. 2	Cut. 3	Cut. 4	Cut. 5	Cut. 6
Cont.							
Cut. 1	ns						
Cut. 2	x	x					
Cut. 3	x	x	ns				
Cut. 4	x	x	ns	ns			
Cut. 5	x	x	x	x	x		
Cut. 6	x	x	x	x	x	ns	
Cut. 7	x	x	ns	ns	ns	x	x

3.2.3 Community responses

Community structure parameters are based on the abundance of the individual species found for each treatment (Appendix D4, D5). The total abundance and no. of species in each experimental box are shown in figures 51 and 52 and diversity and evenness in figures 53 and 54. The mean number of individuals in boxes treated with Cut.2-4 was significantly different from the control boxes (Cont, Cut.1) in November. No such difference were identified in March 92.
No significant difference in number of species between controls and treatment was seen apart from for Cut.7 in November 1991.

Mean diversity in boxes treated with high oil cuttings (Cut. 2-4) was however significantly higher than in the controls (Cont.+Cut.1) except for Cut. 2 in March 1992, The observed increase in diversity in the high oil cuttings is opposite to the response seen in the community structure experiments (see fig. 19) and is mainly related to the reduced dominance (increased evenness) of *Upogebia deltaura* (the overall dominating species in the experiment,) in the high oil treatments.

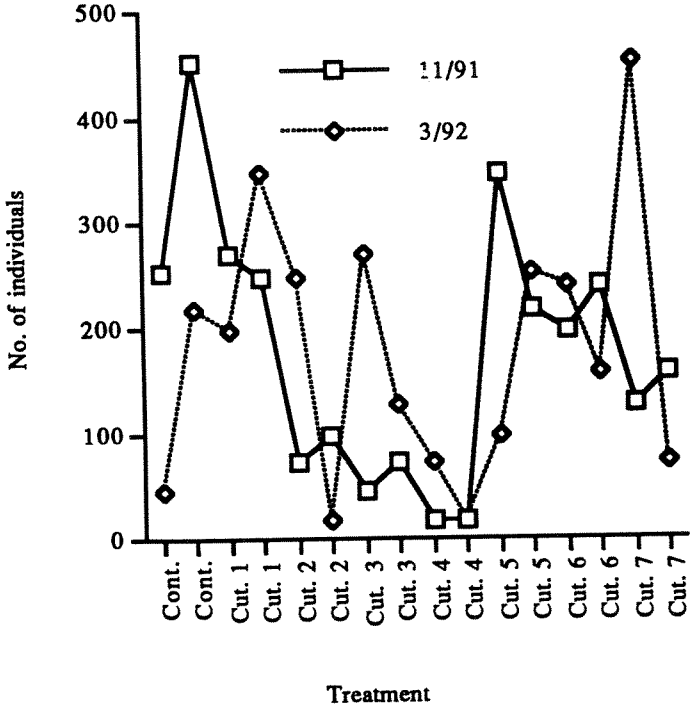

Fig. 51. Total number of individuals in experimental boxes during the settling experiments. The results from two replicate treatments are shown for each sampling date.

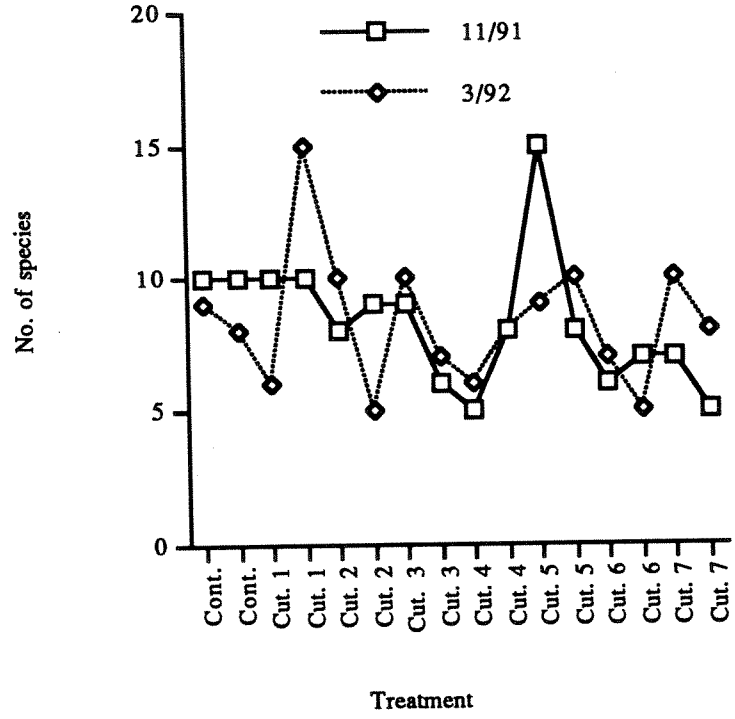

Fig. 52. Total number of species in experimental boxes during the settling experiments. The results from two replicate treatments are shown for each sampling date.

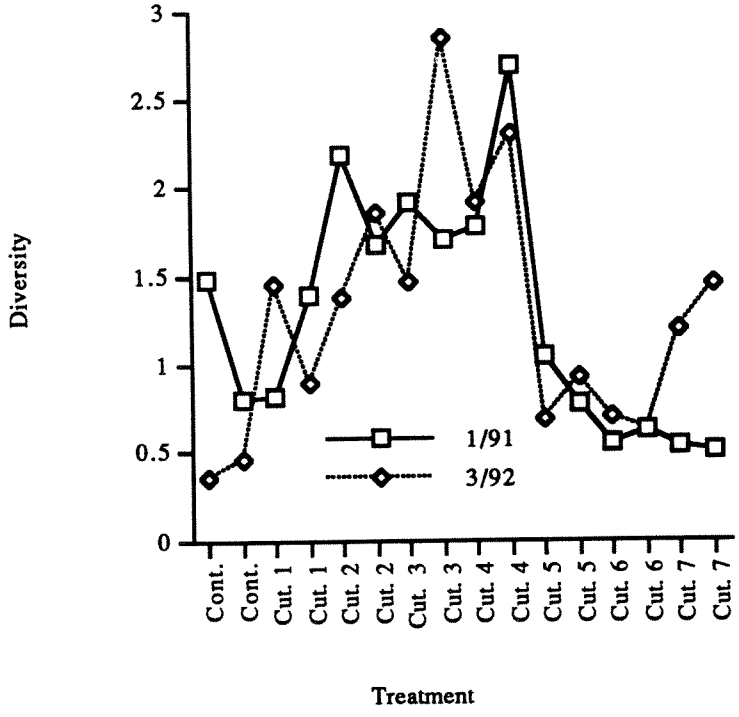

Fig. 53. Diversity (Shannon-Wiener) of macrofauna in experimental boxes during the settling experiments. The results from two replicate treatments are shown for each sampling date.

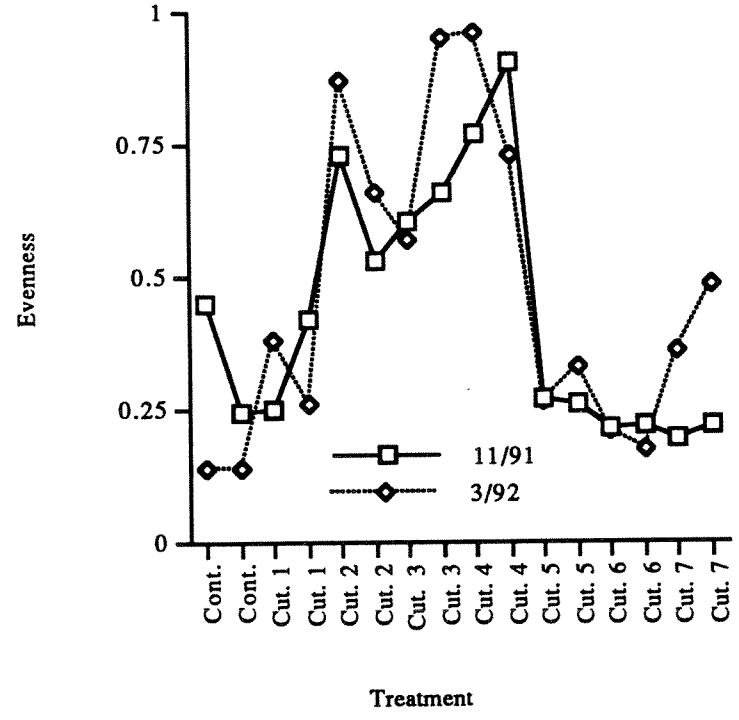

Fig. 54. Evenness of macrofauna in experimental boxes during the settling experiments. The results from two replicate treatments are shown for each sampling date.

Results from the multivariate analyses of the species data are seen in fig 55-58. The similarity plots and the MDS-plots generally gave a similar result after 3 and 7.5 months. On both occasions control boxes (C) and boxes treated with reference material (Cut.1) clustered together and indicate that the high metal content in boxes treated with reference material did not affect gross community structure. Boxes treated with Cut.2-4 were clearly separated from the control boxes (C+Cut.1). Apart from one experimental box collected in November 1991 and treated with Cut.7 and one collected in March and treated with Cut. 6 the low oil boxes (Cut. 5, Cut.6, Cut.7) seem to cluster together with the controls. Significant differences in clusters were only found between control boxes and high oil boxes and low oil boxes and high oil boxes (Table 10).

Table 10. Results from testing differences between clusters in the MDS-plot from the settling experiments.
A. Based on data from November 1991
B. Based on data from March 1992

A

	Control (C+1)	Low oil (5,6,7)
Low oil (5,6,7)		
High oil (2,3,4)	##[2]	##[2]

B

	Control (C+1)	Low oil (5,6,7)
Low oil (5,6,7)		
High oil (2,3,4)	#[1]	##[2]

[1]p=0,05
[2]p=0,001

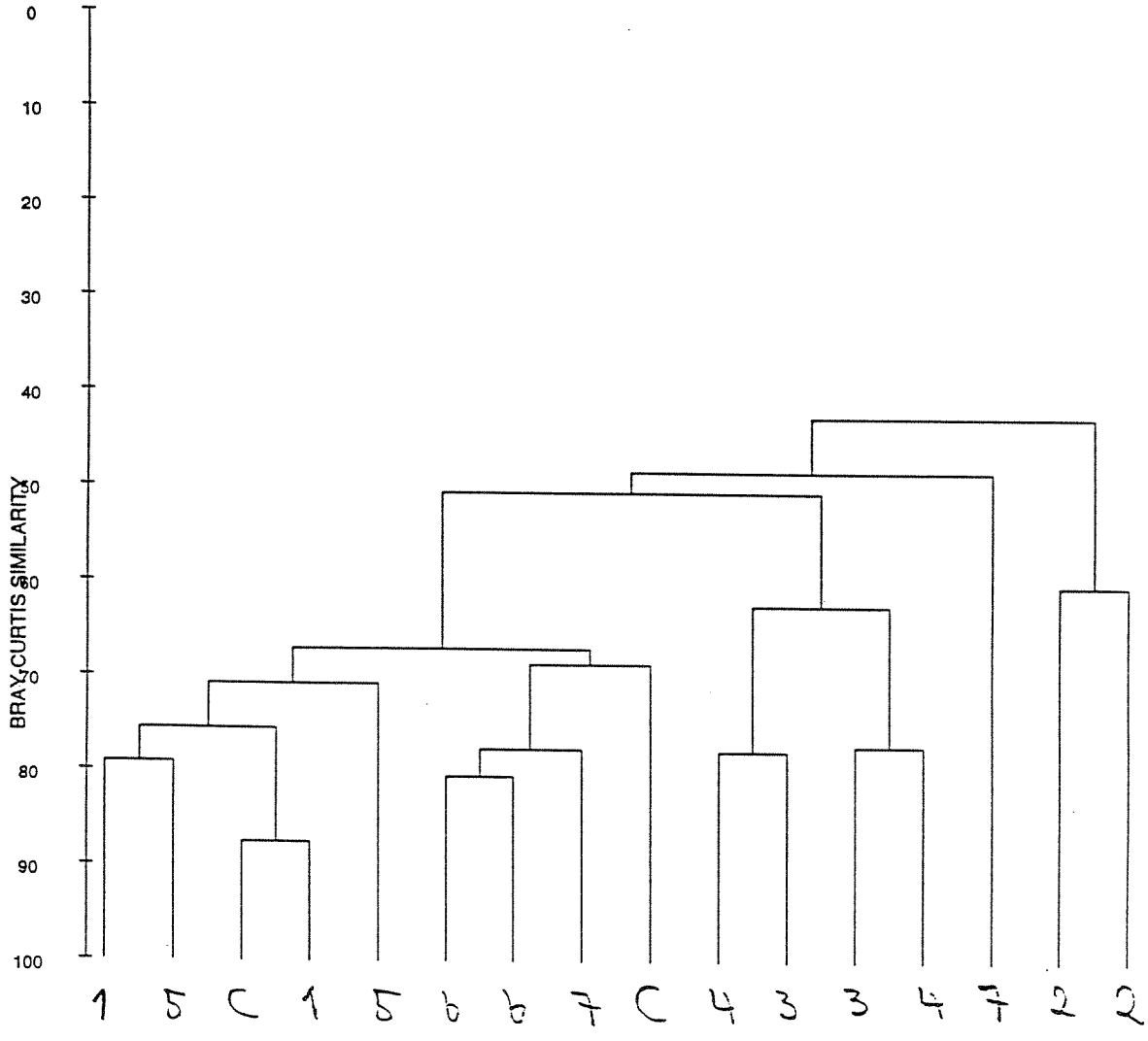

Fig. 55. Bray-Curtis similarity plot based on the species abundance data from experimental boxes collected in November 1991 in the community structure experiments.

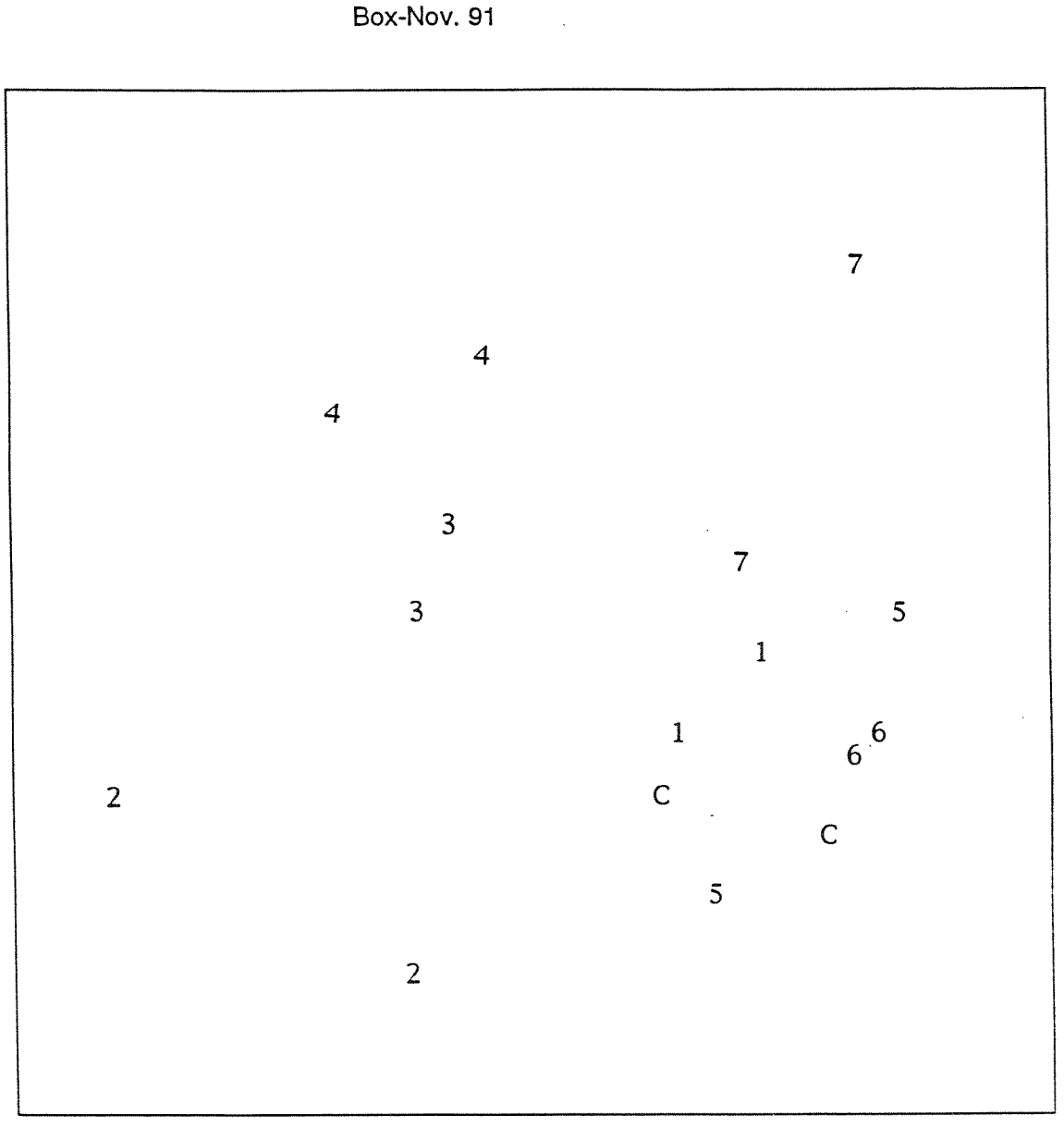

Fig. 56. MDS-plot based on the species abundance data from experimental boxes collected in November 1991 in the settling experiments.

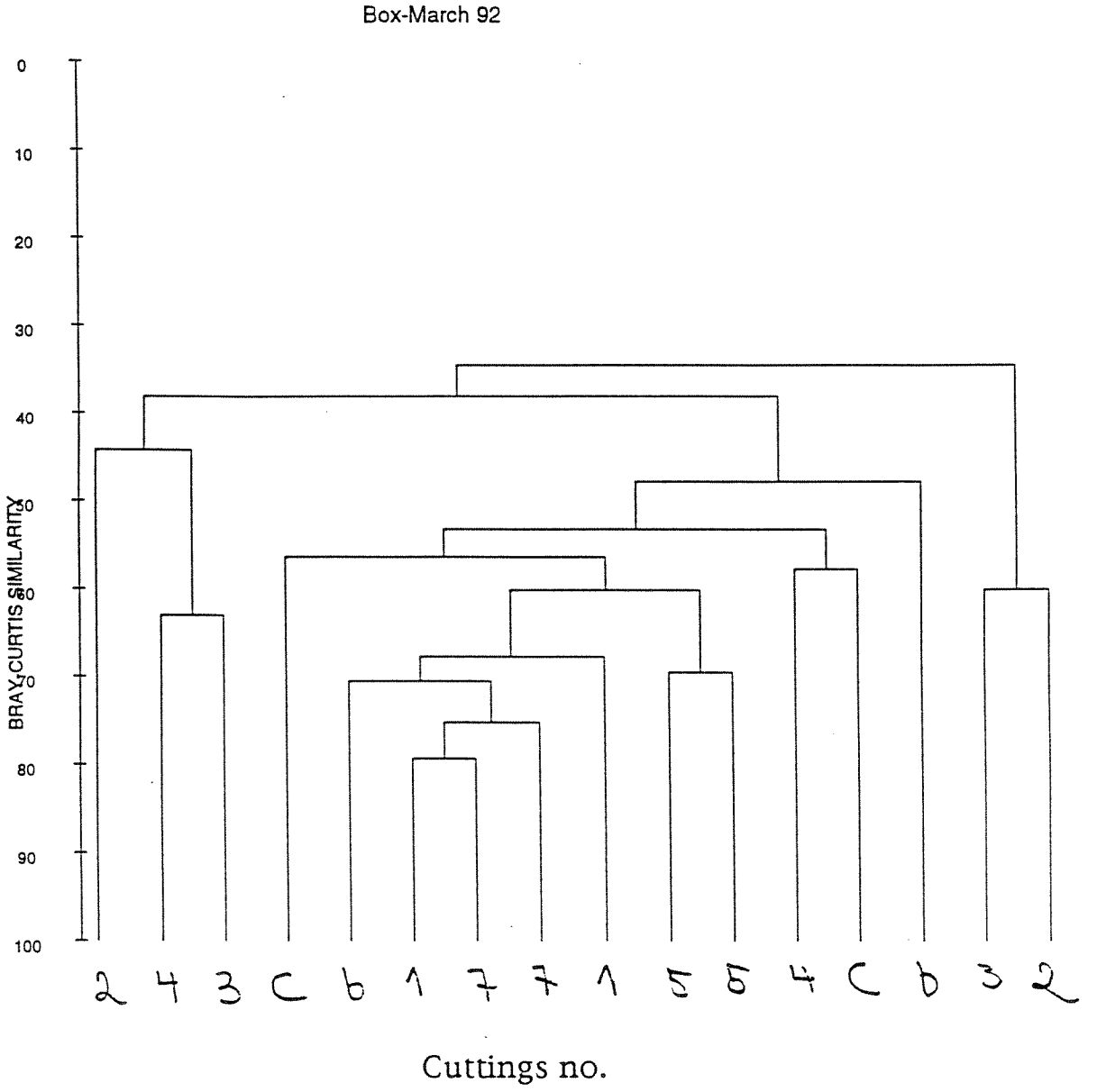

Fig. 57. Bray-Curtis similarity plot based on the species abundance data from boxes collected in March 1992 in the settling experiments.

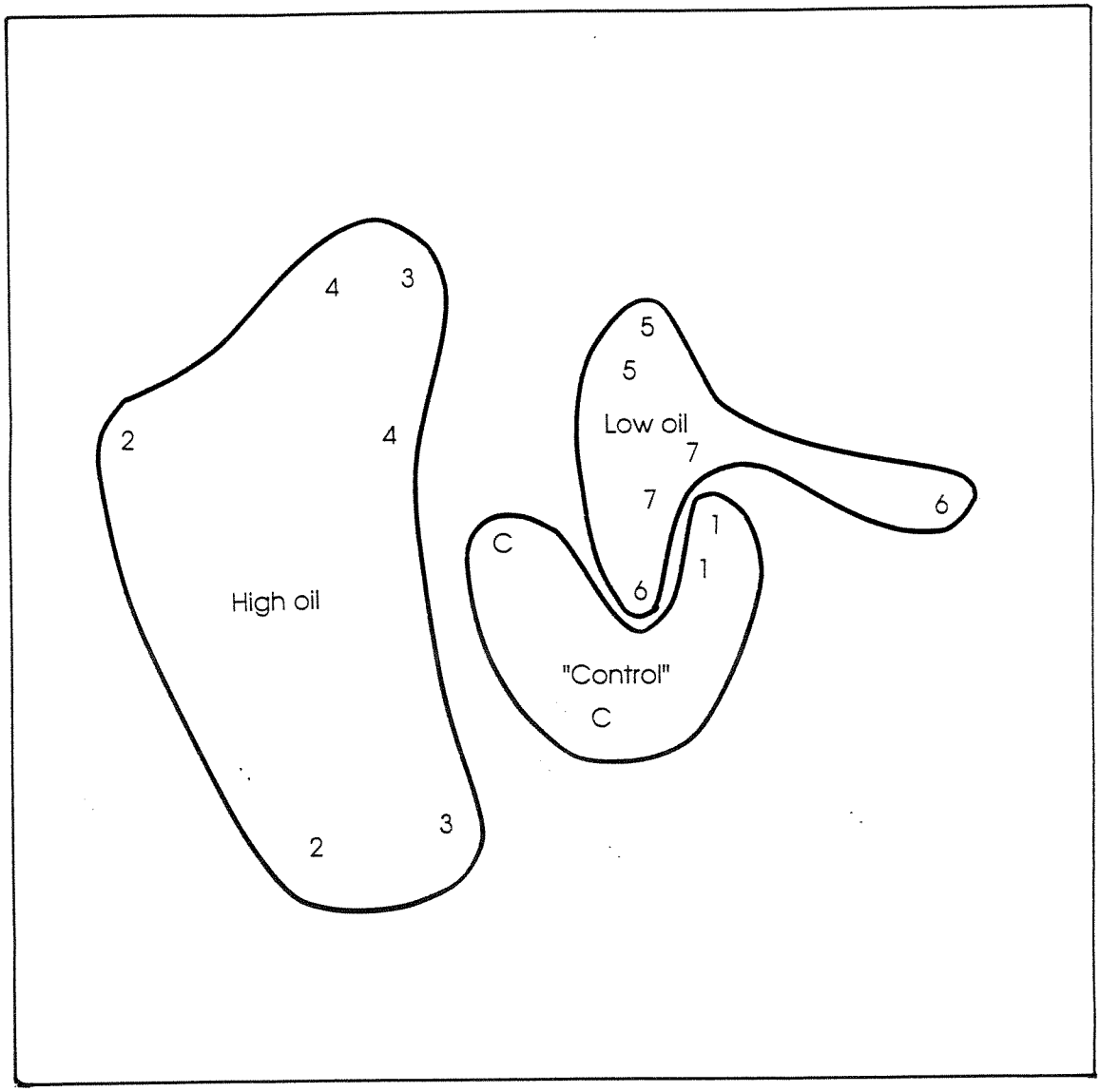

Fig. 58. MDS-plot based on the species abundance data from boxes collected in March 1992 in the settling experiments.

3.2.4 Species responses

The dominating species found in the settling experiments was the decapod crustacean *Upogebia deltaura*, an important but often overlooked species in shallow subtidal bottoms in Scandinavia (Tunberg, 1986). This species lives in burrows in the sediment. Under natural conditions most specimens are found deeper than 20 cm down in the sediment. Most of the specimens found in the settling experiment seemed to be confined to burrows at the bottom of the boxes. The total numbers of specimens of *Upogebia* in each treatment are seen in Fig. 59. The abundance within each treatment deviated little for the two sampling occasions except for Cut.5. The numbers of specimens in all treatments (Cut.2-7) were significantly different from control boxes (C+Cut.1) in March 1992 whereas in November 1991 significant difference from controls was only found for the high oil treatments (Cut. 2-4)

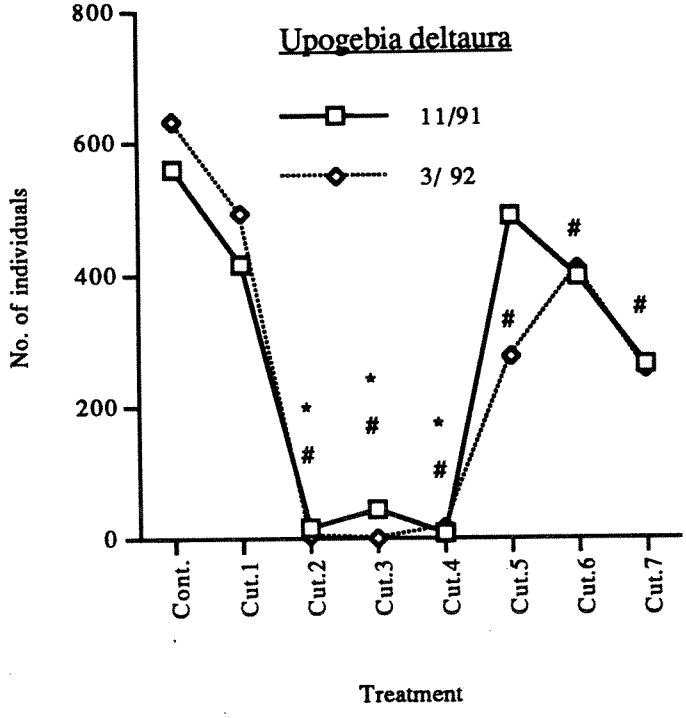

Fig. 59. Total abundance of *Upogebia deltaura* found in experimental settling boxes . *= Mean abundance in November 1991 significant different (p=0.05, one factor ANOVA) from mean of the four boxes not added cuttings (Cont., Cut. 1) . #= Mean abundance in March 1992 significant different from boxes not added cuttings.

There is a strong positive correlation between the abundance of *Upogebia* and redox potential for redodox potentials above 50 mV (Fig. 60). There was also a negative correlation between base oil concentration and redox potential (Fig. 61). Whether *Upogebia* is affected by the concentration of base oil (or aromatic content) directly or through the effect of hydrocarbons on redox potential cannot be stated. It has , however, from other investigations been shown that a low redox potential will affect macrofauna (Pearson, and Rice, 1979). *Upogebia* is probably particularly sensitive because of its deep burrowing behaviour.

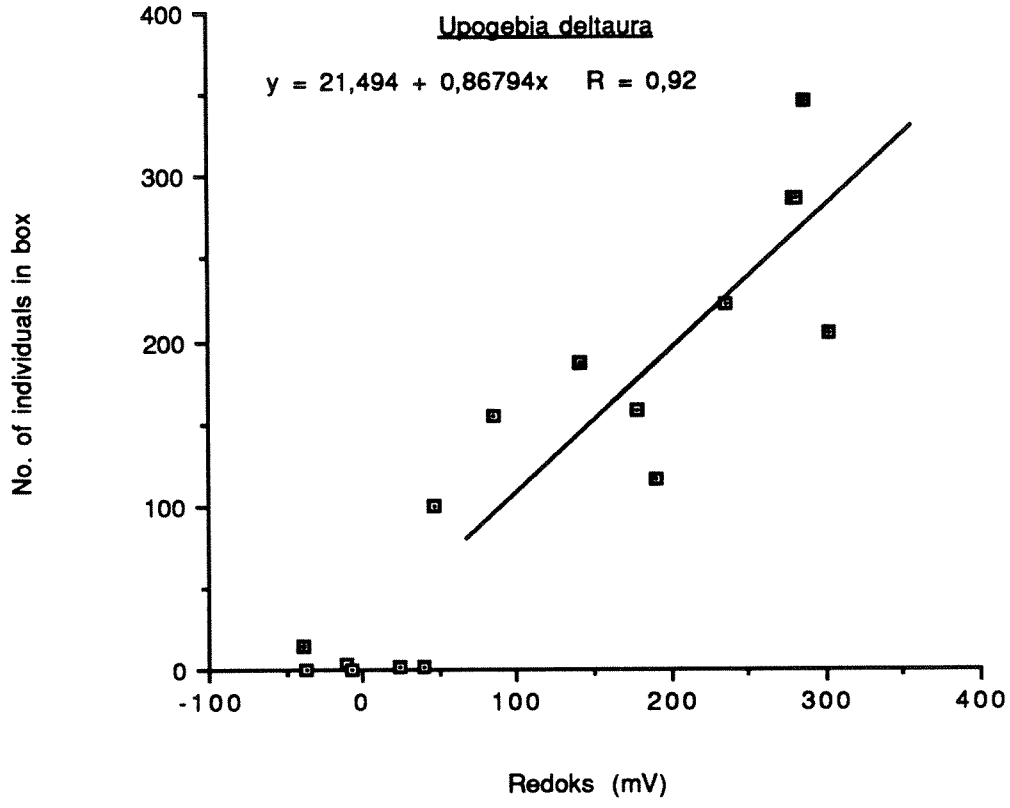

Fig.60. Abundance of *Upogebia deltaura* in experimental boxes in March as a function of mean values of redox potential measured 2 cm below the sediment surface.

The bivalve *Corbula gibba* was significantly affected in November in boxes treated with Cut. 4, 6 and 7 (Fig. 62) wheras no significant effect could be demonstrated in March. The bivalve *Cultellus pellucidus* showed a similar pattern of response both in November 1991 and March 1992 except for the control (Cont.) treatment where the abundance had decreased considerably at the end of the experiments (Fig. 63). The abundance of *C. pellucidus* was significantly affected in the three high oil treatments (Cut. 2, 3. and 4) in November but not in March 1992.

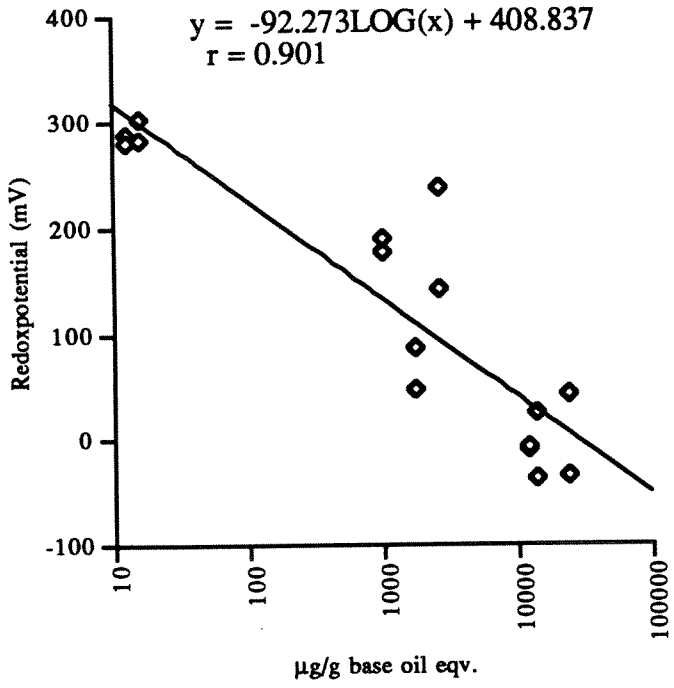

Fig. 61 Redox potential in experimental boxes in March 1992 as a function of concentration of base oil at the start of the experiment.

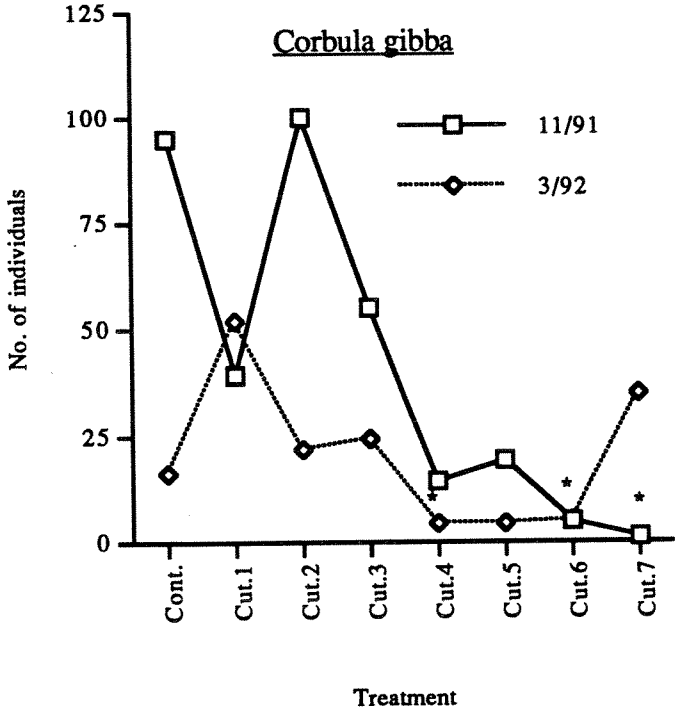

Fig. 62. Total abundance of *Corbula gibba* found in experimental settling boxes . *= Mean abundance in November 1991 significant different (p=0.05, one factor ANOVA) from mean of the four boxes not added cuttings (Cont., Cut. 1). #= Mean abundance in March 1992 significant different from boxes not added cuttings.

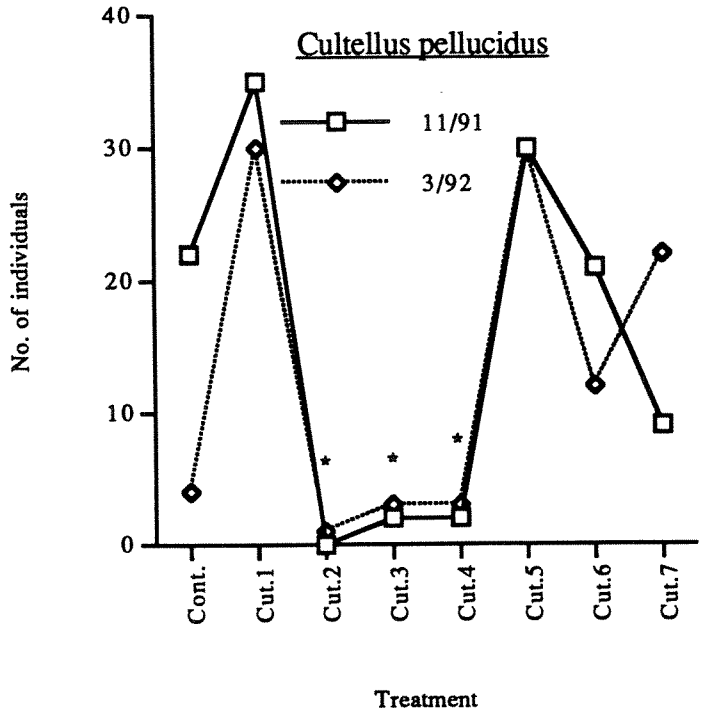

Fig. 63. Total abundance of *Cultellus pellucidus* found in experimental settling boxes . *= Mean abundance in November 1991 significant different (p=0.05, one factor ANOVA) from mean of the four boxes not added cuttings (Cont., Cut. 1). #= Mean abundance in March 1992 significant different from boxes not added cuttings.

The results of individual species responses of the 3 dominating species in the experiment are seen in table 11. From this table it is possible to rank the different treatments in order of decreasing environmental effect.

Cut.4>Cut.3, Cut.2>Cut.6, Cut. 7>Cut.5

Table 11. Table showing significant difference (p=0.05, one factor ANOVA) between treatment and control (Cont.. Cut. 1). * = mean abundance in control > mean abundance in treatment and significant difference are found. n=No significant difference between treatment and control.

	Date	Cut. 2	Cut. 3	Cut. 4	Cut. 5	Cut. 6	Cut. 7
Species							
Upogebia deltaura	11/91	*	*	*	n	n	n
Upogebia deltaura	3/92	*	*	*	*	*	*
Corbulla gibba	11/91	n	n	*	n	*	*
Corbulla gibba	3/92	n	n	n	n	n	n
Cultellus pellucidus	11/91	*	*	*	n	n	n
Cultellus pellucidus	3/92	n	n	n	n	n	n
Total no. of *		3	3	4	1	2	2

The community structure experiment and the settling experiment generally correspond well in terms of ranking of the different treatments according to environmental effects. The species which were involved in the two tests were ,however, very different and considerably fewer species were involved in the settling experiment.

The high base oil treatments (Cut. 2, Cut.3, Cut.4) gave significant effects both on community parameters and on individual species responses in both experiments. In the low base oil range in the settling experiments, significant effects on individuals species were only found in March 1992 for *Upogebia deltaura*. Unfortunately, Cut. 8 (and 9) were not included in the settling experiments which has resulted in lower precision in determining the concentration level for no significant effect. The concentration at the start of the settling experiment in boxes treated with Cut. 5 was 1000 ppm and was reduced to 120 ppm at the end of the experiment. This means that the no effect concentration for *Upogebia* based on baseoil equivalents must be below the start concentration of 1000 ppm. This concentration level corresponds well with the upper limit (990 ppm) of the no effect concentration indicated in the community structure experiments. Since effects of Cut.5 were not found on the first sampling when the highest concentration of baseoil was measured, it is believed that initial settlement of *Upogebia* was not effected at concentrations in the range 280-1000 ppm base oil equivalents.

3.3 Settling experiment (II) in boxes

During this experiment a considerable erosion was observed in the boxes and especially in one of the control boxes where only 3 cm of sediment remained when the experiment was terminated. In the other 7 boxes the mean sediment depth ranged between 5.75-7 cm.

3.3.1 Hydrocarbon and metal analyses

The concentration of base oil and Σ 2-6 ring aromatic hydrocarbons at the start and end of the settling experiments with Case 11 are seen in fig. 64 (data are found in appendix table A3). A reduction in base oil concentration was seen during the experimental period. A reduction was also seen in the aromatic components for the two treatments added cuttings. Whereas an apparent increase was observed in the control boxes. In spite of the dramatic erosion observed the relative difference in base oil concentration between the different treatments was maintained. The metal content (mainly Pb, Hg, Ni) in the sediment used for these experiments (Apendix B3) was also somewhat high compared to what is expected in sediment from pristine areas (see table 2).

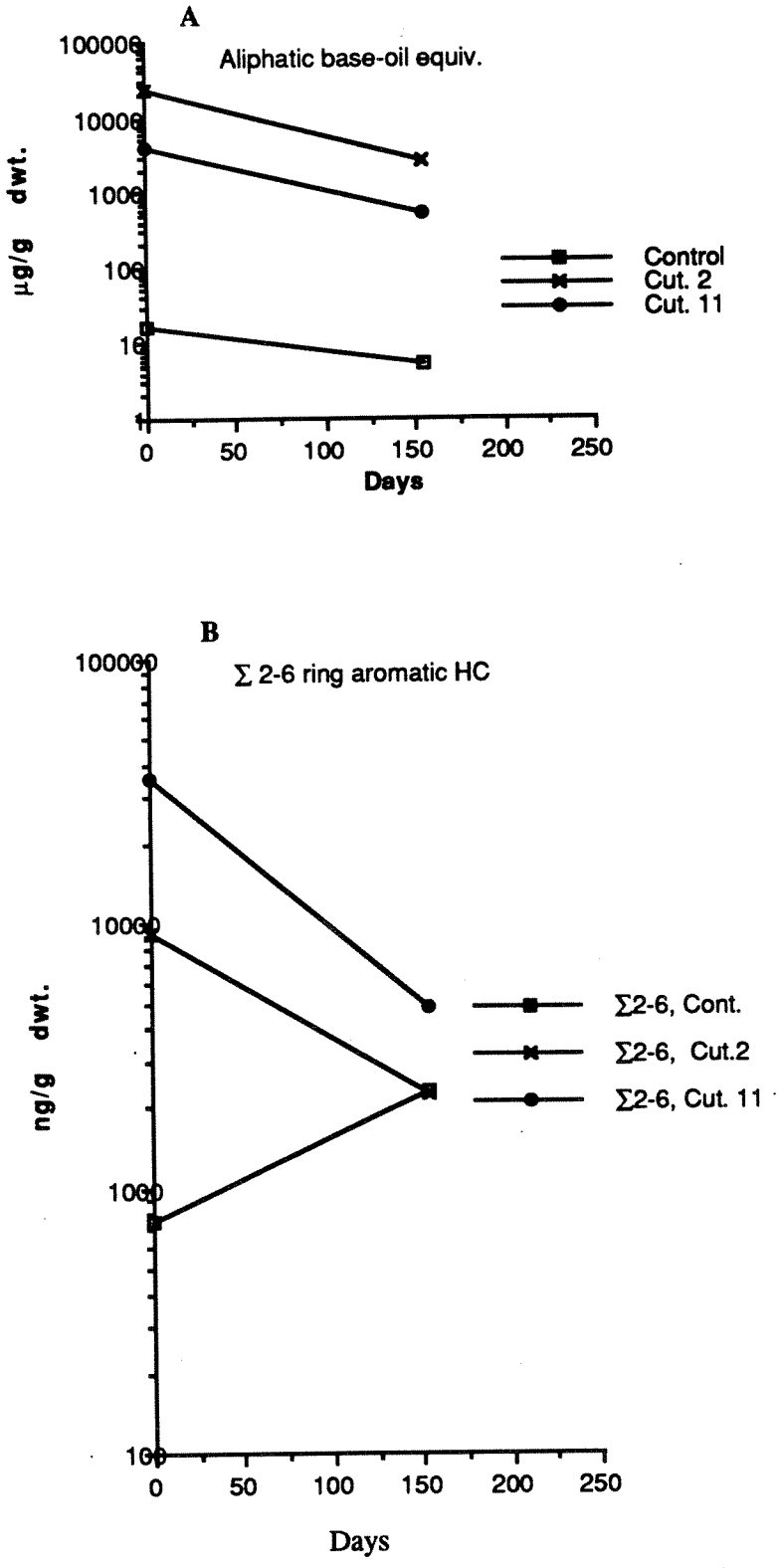

Fig. 64. Concentration of base oil (A) and Σ 2-6 ring aromatic compounds (B) in the top 2 cm of the sediment at the start and end of the settling experiments (II) in boxes Treatment no. on the abscissa corresponds to the numbers seen in table 1 and are arranged in order of decreasing concentration of base oil at the start of the experiment.

3.3.2 Redox potential

Redox potentials in the experimental boxes at the termination of the experiments are seen in fig. 65. Both treatment added cuttings showed negative redox potential. A significant difference was found between the redox potential in the control sediment and the two other treatments. Slightly higher values of redox potential were found in boxes with cuttings no. 11 than no. 2. The difference in redox potential between these two treatments was, however, not significant. The redox potential found in the control sediment and in boxes treated with cut. no. 2 was considerably lower than in similarly treated boxes sampled in March 1992. Generally one would expect lower redox potential after a warm summer than after a somewhat colder winter.

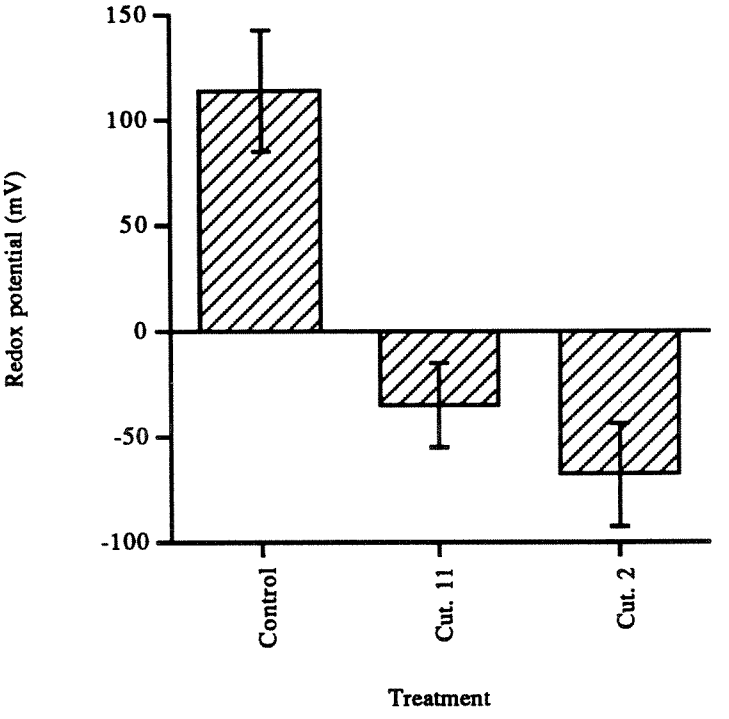

Fig. 65. Mean values of redox potential at a sediment depth of 2 cm in experimental boxes collected in September 1992. ±1 standard error of the mean are indicated.

3.3.3 Community responses

The results of this experiment were less conclusive than the previous two experiments. This is partially because a considerable erosion had taken place in one of the two control boxes leaving only a layer of 3 cm of sediment in this box at the end of the experiment. Whereas the other 7 boxes had a mean sediment layer in the range 5.75-7.12 cm. The erosion probably had affected the number of animals in this control-box (box no. 2) considerably and thus may have biased the results. The biological results from this box are questionable as a control in the experiment , leaving only one relevant box (box no. 3) for the control situation.
The no. of individuals in different treatments are seen in Fig. 66. No significant difference in

total abundance was seen between Cut. 11 and Cut. 2, although Cut. 2 had somewhat lower densities than Cut. 11 (Fig. 66). The no. of species and diversity in cut. 2 were however significantly different from Cut. 11 (Fig. 67-68) and indicate that Cut. 2 have a larger environmental effect than Cut. 11. However, because of the limited data for the control situation it is not possible to perform good comparisons between treatment with Cut. 11 and the control. We have seen from the two previous experiments that diversity can both increase or decrease as a response to treatment with cuttings which contain high levels of base oil (see fig. 19 and 53).

The Bray-curtis similarity plot based on species abundance data for individual boxes as seen in Fig. 69. The MDS-plots (Fig. 70) do not consistently group the different treatments in clear clusters. Total abundance of polychaetes, bivalves and crustaceans (Fig. 71) indicate no treatment effect on polychaetes whereas both bivalves and crustaceans show reduced densities in boxes treated with Cut. 2 and 11. Only for the total number of crustaceans are the treatment effect significant (significant difference between mean abundance for all 3 treatments).

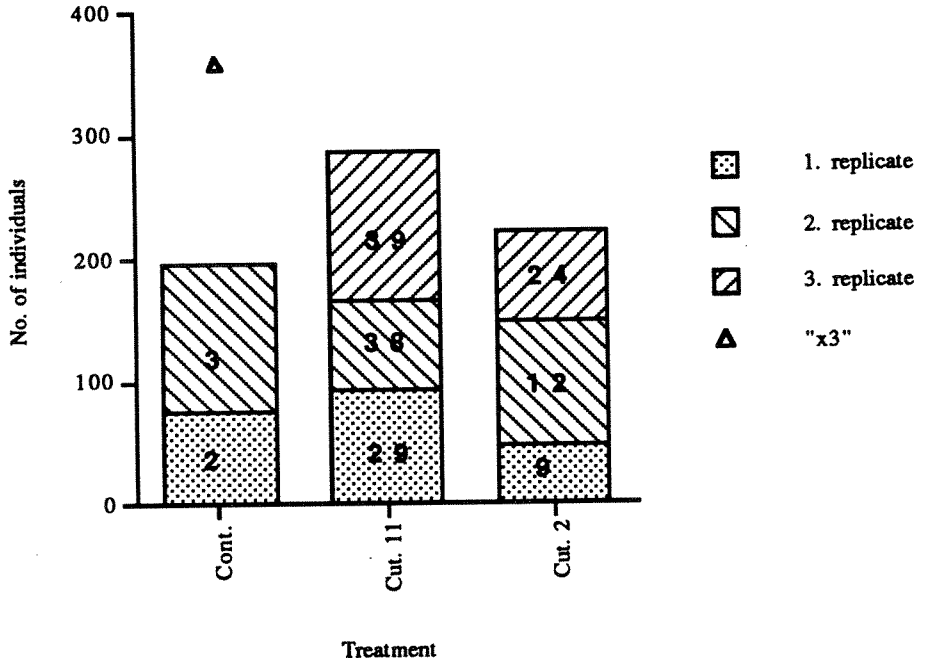

Fig. 66. Total no. of individuals in each experimental box (stacked) at the end of the experiments. Box no. (see Fig.9). are indicated for each replicate. Please note that "x3" indicates the number of individuals in control box no. 3 multiplied by 3.

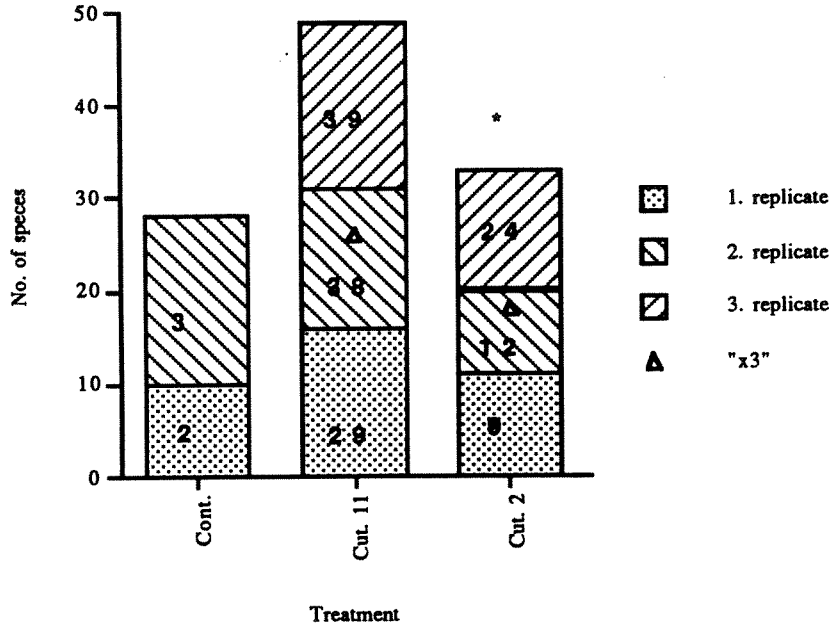

Fig. 67. Total no. of species in each experimental box (stacked) at the end of the experiments. Box no. (see Fig.9). are indicated for each replicate. Please note that "x3" indicates the number of species found totally in the 3 replicate boxes.
* above column indicate significant difference from Cut. 11.

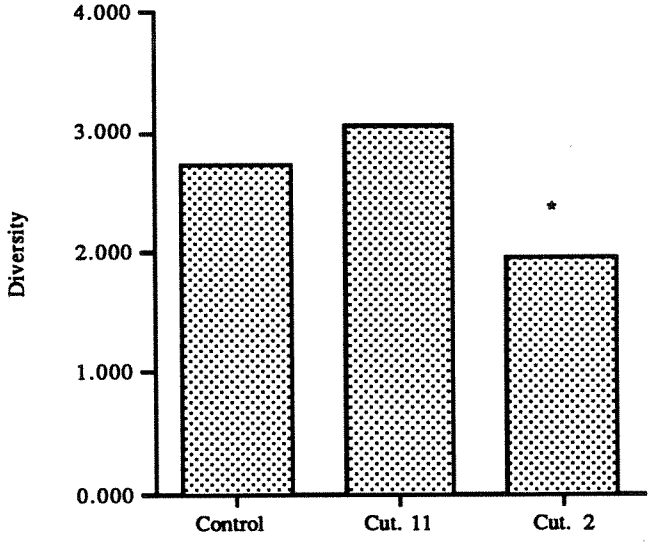

Fig. 68. Mean diversity (Shannon-Wiener) in boxes with different treatments. Please note that diversity shown for Cut. 11 and 2 are mean values based on diversity for 3 individual boxes whereas diversity in control are based on one box (box no. 3). * above column indicate significant difference from Cut. 11.

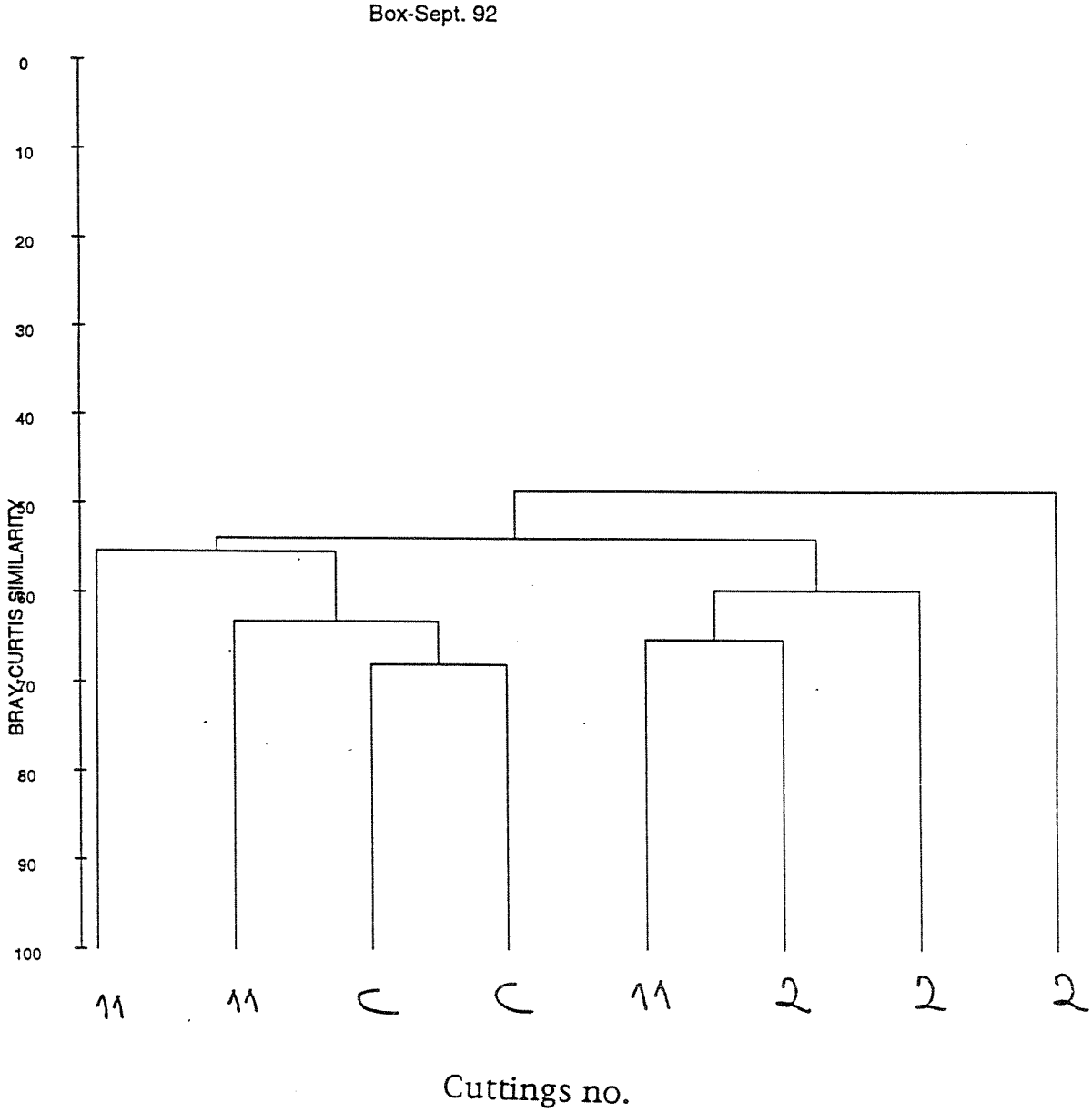

Fig. 69. Bray-curtis similarity plot based on the species abundance data from experimental boxes collected in September 1993.

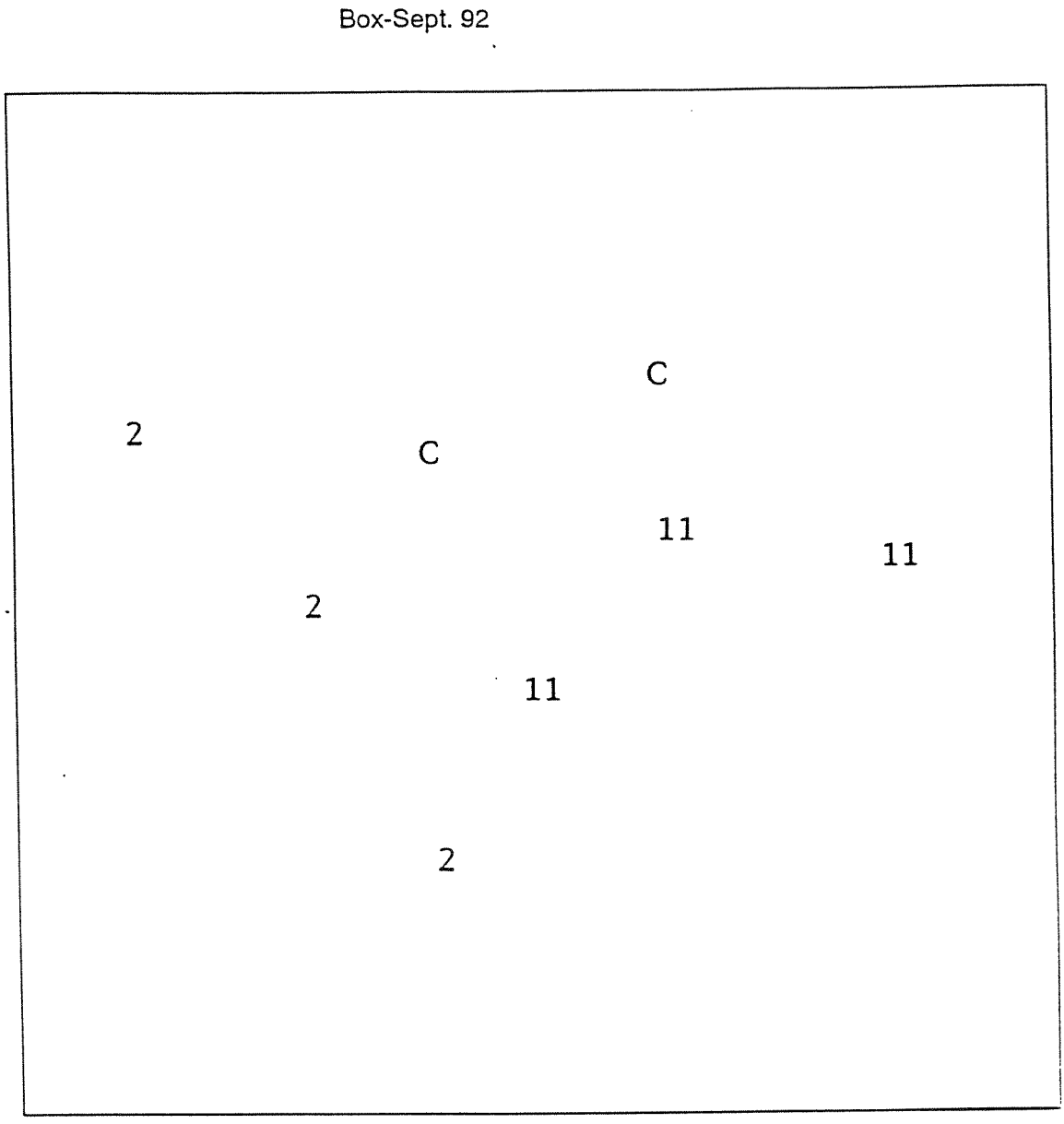

Fig. 70. MDS-plot based on the species abundance data from boxes collected in September 1993.

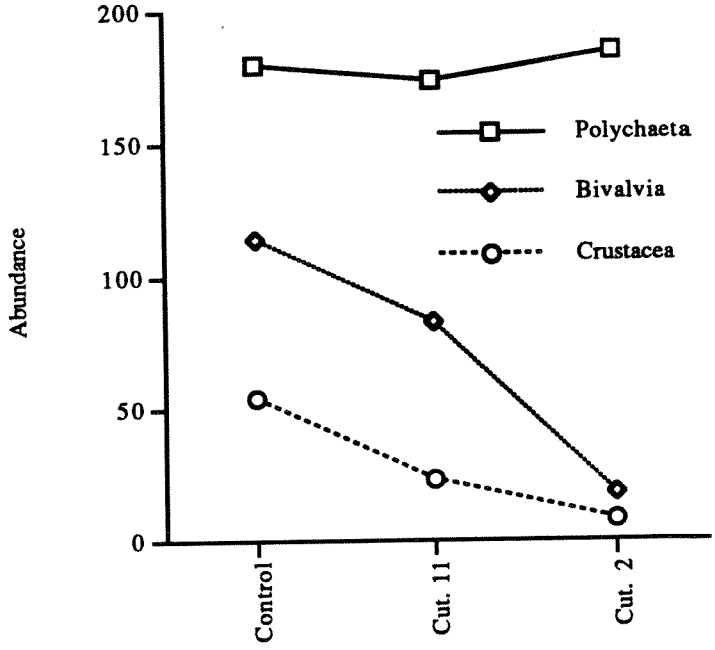

Fig. 71. Total abundance of polychaetes, bivalves and crustaceans in boxes with different treatments at the end of the second settling experiment. Please note that abundance for the control situation is based on the numbers in one control box (Box 3) multiplied by 3, whereas abundance in boxes treated with Cut. 11 and 2 are based on the sum for 3 individual boxes.

3.3.4 Species responses

Few species were found in these experiments and only the polychaete *Nereis virens* and the bivalve *Corbula gibba* were abundant in the control sediment. The abundance of both species was lower in the boxes treated with Cut.2 and 11 compared with the control situation (Fig. 72). None of the differences between treatments were significant. An opposite response was seen in the less abundant *Anaitides groenlandica, Phyllodoce mucosa* and *Polydora socials* (Fig. 73) where an increase was seen in the boxes treated with cuttings. None of the differences in abundance of individual species between treatments were significant.

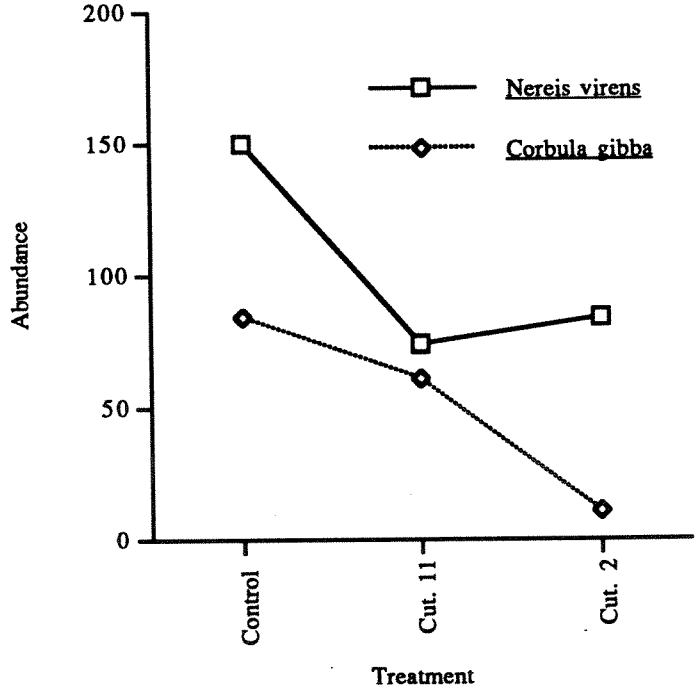

Fig. 72. Total density of the polychaete *Nereis virens* and the bivalve *Corbula gibba* in boxes with different treatments. Please note that abundance for the control situation is based on the numbers in one control box (Box 3) multiplied by 3, whereas abundance in boxes treated with Cut. 11 and 2 are based on the sum for 3 individual boxes.

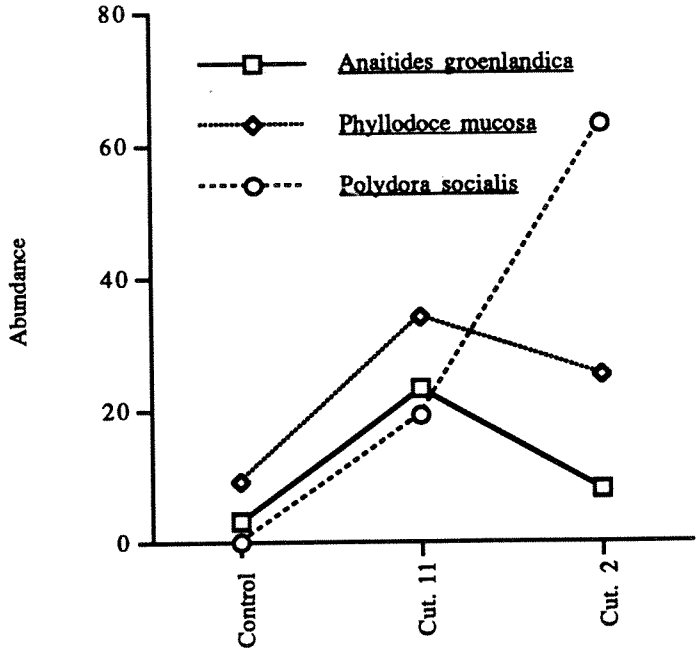

Fig. 73. Total density of the polychaetes *Anaitides groenlandica, Phyllodoce mucosa* and *Polydora socials* in boxes with different treatments. Please note that abundance for the control situation is based on the numbers in one control box (Box 3) multiplied by 3, whereas abundance in boxes treated with Cut. 11 and 2 are based on the sum for 3 individual boxes.

The results from both the community data (chapter 3.3.3) and the individual species data from this experiment are not so conclusive as the two previous experiments, and significant effects are few. The general trend is, however, that Cut. 2 gives a larger environmental effect than Cut. 11. The increase in density of the oportunistic polychaete, *Polydora* especially in boxes treated with Cut. 2 (Fig. 73) can be a response to the pertubation caused by the cuttings. The total abundance (Fig. 71), abundance of bivalves, crustaceans (Fig. 71), *Nereis* and *Corbula* (Fig. 72) indicate that Cut. 11 probably also affects the fauna negatively.

Based on these considerations the most propable ranking of he cuttings in order of decreasing environmental effect are:

Cut. 2>Cut.11>Control

This ranking is consistent with the amount of base oil in each of boxes (see Fig. 64).

4.DISCUSSION AND CONCLUSIONS

The species composition in the community structure experiments and the settling experiments was different (see Appendix D). Despite this, the different experiments generally rank the treatments similarly (Table 12 and 13) without significant inconsistencies. The basic designs of the two types of experiments were also somewhat different since the community structure experiment was intended to test effects on an established community (mainly as mortality) whereas the settling experiment were intended to also test the settling behaviour (avoidance, attraction) of larvae on the different cutting types. At the beginning of the experiments the intended basic difference between the two types of experiments were probably real. After some time however, settling of larvae was an important structuring factor also in the community structure experiment.

For all the experiments Cut. 2-4 gave the largest environmental effect, whereas Cut. 1 (inert material) and Cut.8 (thermal treatment) together with the Control (no treatment) gave the least effect. Cut. 6, Cut.7 and Cut. 9 as a whole gives less effects than Cut. 2-4 but more than Cut. 5.

The total suite of cases was not tested in all the experiments (Table 13). In the community structure experiments all cases were tested whereas in the second settling experiments only Cut. 2 and Cut. 11 were tested. The best precision for determining the no effect concentration of baseoil (NEC) was therefore found for the Community structure experiments. This does not ,however, mean that the experimental approach, used in the community structure experiments is necessarily superior to the settling experiments.

Table 12. Ranking of the different groups of treatments in order of decreasing environmental effect for the different experiments.

A: Community structure experiment , community parameters
B: Community structure experiment, species parameters:
C: Settling experiment (I), community parameters:
D: Settling experiment (I), species data:
E: Settling experiment (II)

Experiment	Rank
A	Cut.2, Cut.3, Cut.4 > Cut 6, Cut.7 Cut.9 > Cut.5, Cut.8, Cut.1, Cont.
B	Cut.2 > Cut. 3, Cut. 4 > Cut.7 > Cut.6, Cut.9 > Cut.5 > Cut. 8, Cut.1, Cont.
C	Cut.2, Cut.3, Cut.4>Cont., Cut.1, Cut.5, Cut.6, Cut.7
D	Cut.4 > Cut.3, Cut.2 > Cut.6, Cut.7 > Cut.5 > Cont., Cut.1
E	Cut.2>Cut.11>Cont.

Table 13. Environmental effect ranked for each of the experiments. For each row the lowest number (1) indicates a large environmental effect whereas the highest number (total number of treatments in the experiment) indicates no or little environmental effect. Within each row similar numbers indicate that treatment effects can not be separated. Comparison between rows must be done based on the rank within each row and not on the absolute numbers

A: Community structure experiment , community parameters
B: Community structure experiment, species parameters:
C: Settling experiment (I), community parameters:
D: Settling experiment (I), species data:
E: Settling experiment (II)
NT=Not tested.

	Cont.	Cut.1	Cut.2	Cut.3	Cut.4	Cut.5	Cut.6	Cut.7	Cut.8	Cut.9	Cut.11
A	8	8	1	1	1	7	4	4	8	4	NT
B	8	8	1	2	2	7	5	4	8	5	NT
C	4	4	1	1	1	4	4	4	NT	NT	NT
D	7	7	2	2	1	6	4	4	NT	NT	NT
E	3	NT	1	NT	NT	NT	NT	NT	NT	NT	2

The community structure experiments (community parameters) indicate that the threshold for effects on gross community structure is found at a base oil concentration of approximately 1000 ppm. Within the framework of these experiments, it is indicated that the standard thermal treatment process and the best achievable solvent wash (See table 1) result in cuttings that have no identifiable effects on gross community structure in the sediment, at least as long as the discharged amount of cuttings do not exceed 10 % (volume) in the top 3 cm of the sediment. The individual species data (Section 3.1.4), however, indicate that some effects could also be found in plots treated with the best acheivable solvent wash cuttings (Cut.5), since negative effects were found on three polychate species, *Prionospio malmgreni*, *Spiophanes bombyx* and *Spio sp.*. This indicates that the no effect concentration is somewat lower than the 1000 ppm menitoned above and probaly in the range 150-990 ppm.

The high base oil treatments (Cut. 2, Cut.3, Cut.4) gave significant effects both on community parameters and on individual species responses in both the community structure experiment and in the main settling experiment. In the low baseoil range in the main settling experiments, significant effects on individuals species were only found in March 1992 for *Upogebia deltaura*. Unfortunately Cut. 8 (and 9) were not included in the settling experiments and this has resulted in lower precision in determining concentration level for no significant effect. The concentration at the start of the settling experiment in boxes treated with Cut. 5 was 1000 ppm and was reduced to 120 ppm at the end of the experiment. This means that the no effect concentration for *Upogebia* based on baseoil equivalents must be below the start concentration of 1000 ppm. This concentration level corresponds well with the upper limit (990 ppm) of the no effect concentration indicated in the community structure experiments. Since effects of Cut.5 were not found on the first sampling when the highest concentration of baseoil was measured it is believed that initial settlement of *Upogebia* was not effected at concentrations in the range 1000-280 ppm base oil equivalents.

The lower and upper limit for a no effect concentration found in these experiments were 150 and 1000 ppm of base oil in sediment. This is somewat higher than the concentrations suggested from offshore monitoring of the North sea (Bakke et. al. 1989, De Jong and

Zevenboom, 1991, Zevenboom et al. 1993 see also table 4.3) but in the same range as have been found for crude oil in the intertidal (Christie and Berge, 1993).

Experiments investigating possible environmental benefits from cleaning cuttings before discharge to the sea are few. Many experiments have, however, been performed to test environmental effects of different types of untreated drill cuttings , some of these are: Tagatz et al. (1985), Bakke et al. (1989a, 1989b), Daan et al. (1990), De Jong and Zvenboom (1991). Discharges of oil based mud cuttings at different sites with and without previous washing have, on the short term, shown higher to similar total oil content in the sediment up to 250 m from the discharge point at washed sites compared to the unwashed site (De Jong and Zevenboom, 1991). Beyond 250 m out to 5000 m a higher oil content was found when washed cuttings were discharged. Washing of the drill cuttings acheived a reduction in the intensity of adverse effects within a few hundreds of meters from the discharge point. There were however no indications that the extent of the total area subjected to environmental stress was reduced (De Jong and Zevenboom, 1991).

Table 14. Resonses of benthic fauna to different concentrations of base oil hydrocarbons in sediment (Zevenboom et al. 1993).

Concentration in sediment (ppm)	Effect
> 100	All types of effects (moderate-severe)
< 100	At least a few effects (moderate)
> 10	Sensitive species in reduced denseties

The plots and boxes which received the reference material (cut. no. 1) with a high level of metals (Pb, Cd, Zn and Ba) grouped together with the control plots for all the main experiments (Table 12) and thus indicate that the metal concentration (Ba: 1100-300 µg/g dw., Cd: 2-5 µ g/g dw., Pb: 300-800 µg/g dw. and Zn: 160-450 µg/g dw.) has no effect. A strong negative correlation between diversity and copper concentration in sediment has been found in other studies(Rygg and Skei, 1984) and a negative moderate or low correlation was found for Pb, Zn and Cd. Where drill cuttings have been discharged after drilling operations, a good positive correlation is found between total hydrocarbon and barium in sediment (Reiersen et al. 1989); both tend to increase in the vicinity of the drilling platform. Also, other parameters like redox potential are related to the distance from the platform. It is difficulte from offshore monitoring to assign environmental effects to single components in the sediment. There are few studies that address effects of the metal content in sediment with biological parameters. From monitoring in the Norwegian sector, a conservative lower limit for effects of barium to a selected number of species is set to 500 ppm (Bakke et al 1989). Whether or not this limit is independent of the response to oil in the same sediment could not be stated. It is, however, most likely more due to oil than to barium.

In the community structure experiments the barium concentration in plots treated with Cut.1 were in the range 700-1100 µg/g dw. and no significant effect were found in these plots. In the same plot the base oil concentration was near background for the North Sea. The present experiment thus indicates that the no effect concentration for barium probably is above 700-1100 µg/g dw. Barite ($BaSO_4$), the primary component of drilling muds appears to be relatively non toxic to many aquatic organisms. Metals associated with drilling mud are found to be virtually nonbioavailable to marine organisms that come in contact with discharged cuttings (Neff et al ., 1989b). The leaching experiments performed with the cuttings used in the

present experiments (Delvigne 1993) indicate that the metals are strongly bound to the mineral particles and thus indicate a low level of bioavailability. A low level of bioavailability is also indicated by the intertidal mesocosm tests performed (Bowmer et al. 1993).
However, estuarine communities developed from planktonic larvae have been affected in settling experiments on sand covered with 0.5 cm of barite or mixed with barite (1 part barite and 3 part of sand by volume) (Tagatz and Tobia, 1978). The concentration of Ba in the sediment was not stated but was probably higher than in the present experiments. The observed impact was probably an effect of the close relationship that exists between the animal communities and the bottom type. These results indicate that the base oil content of cuttings is more critical for the effects on benthic communities than are heavy metals (Ba, Cd, Zn, Pb). The effect of metals in sediment are probably related to their form and bioavailability. As long as the metals are bound to minerals in the drilling wastes (no/little leaching) they have little effects.

The total oil content of the discharges are probably the main factor governing the observed effects. The mechanism for the effects are however unclear and might be mediated both through toxicity of components in the oil directly or indirectly through degradation processes resulting in low redoxpotential/oxygen concentration. If secondary effects like reduced redoxpotential /oxygen concentration are the most important factor, the development of alternative drilling muds where mineral oil is replaced by other organic components is not expected to give large environmental benefits if degradation causes similar redoxpotential effects as oil based mud.

The main findings of the study can be summarised as follows: Treatments with cuttings with a high baseoil content (15-20%) resulted in severe effects. Significant but less severe effects could also be seen in cuttings treated with a baseoil content of 2-3 %. Test with thermal treated (200-250 ^{o}C) cuttings (baseoil content 0.3 %) gave no significant effects. The solvent washed (hexane) cuttings (baseoil content 1.45%) resulted in few environmental effects. Some effects could, however, be seen on three species of polychaetes (*Prionospio malmgreni, Spiophanes bombyx* and *Spio sp.*). Based on the total species matrix for the experiment on a natural benthic community, the threshold for gross effects on community structure was a sediment base oil concentration of 1000 ppm. Some individual species showed effects at a base oil content between 150 and 1000 ppm.

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APPENDIX A . Results from hydrocarbon analyses of sediment

A1. Hydrocarbon analyses-Experiments on benthic community structure

Treatment	Base oil (µg/g dw.) Oct. 1991	Base oil (µg/g dw.) June 1992	Σ aromat (ng/g dw.) Oct. 1991	Σ aromat (ng/g dw.) June 1992
Cont.	2	5	206	586
Cut. 1	4	9,7	287	495,6
Cut. 2	15600	12600	3839	2165,8
Cut. 3	25400	18200	4191	9015
Cut. 4	10300	5100	1433	2412,1
Cut. 5	990	1200	1799	3599,6
Cut. 6	1200	2800	687	3479,7
Cut. 7	2000	2000	1168	2223,6
Cut. 8	150	540	438	1587,6
Cut. 9	1900	2280	1006	1696,7

A2. Hydrocarbon analyses-Settling experiment (I) in boxes

Treatment	Base oil (µg/g dw.) July 1991	Base oil (µg/g dw.) Nov. 1991	Base oil (µg/g dw.) March 1992	Σ aromat (ng/g dw.) July 1991	Σ aromat (ng/g dw.) Nov. 1991	Σ aromat (ng/g dw.) March 1992
Cont.	13	15	22	1120	825	1119
Cut. 1	16	14	34	1307	801	1250
Cut. 2	12100	8900	23200	4469	3078	9031
Cut. 3	24500	3800	24300	4312	1532	7021
Cut. 4	14100	7700	9900	3927	1280	3709
Cut. 5	1000	280	120	3818	1343	1544
Cut. 6	2700	220	460	3000	651	1338
Cut. 7	1800	540	190	2779	1431	1349

A3. Hydrocarbon analyses-Settling experiment (II) in boxes

Treatment	Base oil (µg/g dw.) April 1992	Base oil (µg/g dw.) Sept. 1992	Σ aromat (ng/g dw.) April 1992	Σ aromat (ng/g dw.) Sept. 1992
Cont.	17	5,3	750	2339,7
Cut. 2	23300	2600	9172	2254,6
Cut. 11	4100	520	35346	4875

Appendix B. Results from metal analyses of sediment

B1. Metal analyses-Experiments on benthic community structure. Units are based on dry weight sediment (µg/g dw.)

Case no.	Ba 1991 µg/g	Ba 1992 µg/g	Cd 1991 µg/g	Cd 1992 µg/g	Cu 1991 µg/g	Cu 1992 µg/g	Fe 1991 µg/g	Fe 1992 µg/g	Pb 1991 µg/g	Pb 1992 µg/g
Cont.	62	45	0.08	<0.50	10.9	4.2	11219	9822	7.8	8.4
Cut. 1	1112	726	4.88	1.66	23.8	8.6	11434	10229	704.8	276.7
Cut. 2	1138	687	0.1	<0.50	9.1	16.4	9506	11352	13	12.4
Cut. 3	831	751	4.63 ?	<0.50	14.1	13	10982	10667	13.1	11
Cut. 4	1148	737	0.13	<0.50	16.2	7.8	10538	10229	10.5	9.3
Cut. 5	1243	612	0.14	<0.50	11.5	14.7	10542	11198	13.1	14.2
Cut. 6	926	703	0.11	<0.50	8.6	13.5	10677	11810	10.5	14.7
Cut. 7	957	746	0.12	<0.50	0.8	13.4	11706	11932	5.2	11.9
Cut. 8	1083	689 v	0.16	<0.50 [1)]	9.2	13.2 [1)]	10828	11391 [1)]	39.2	80.4 [1)]
Cut. 9	502	703 [2)]	0.3	<0.50 [2)]	25.9	10.5 [2)]	13343	10468 [2)]	141.3	47.6 [2)]

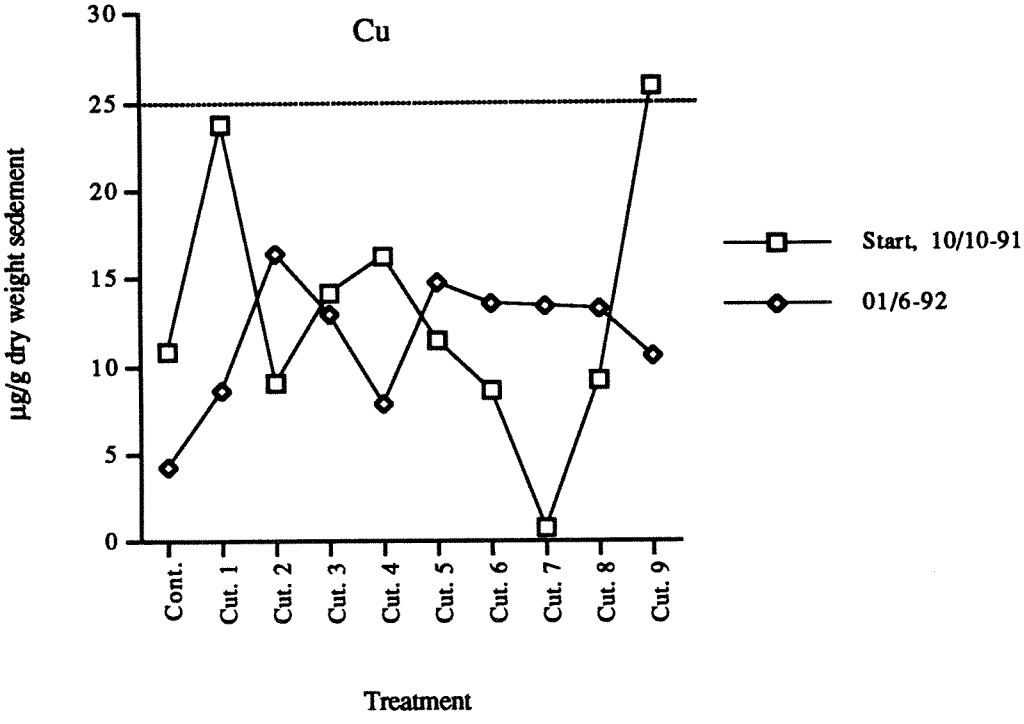
Case no.	Mn 1991 µg/g	Mn 1992 µg/g	Hg 1991 µg/g	Hg 1992 µg/g	Ni 1991 µg/g	Ni 1992 µg/g	V 1991 µg/g	V 1992 µg/g	Zn 1991 µg/g	Zn 1992 µg/g
Cont.	135	117	0.138	0.043	15.3	11.4	15.6	22.3	46.7	37.7
Cut. 1	230	173	0.1	0.100	15.9	12.4	20.9	27.2	328.9	163.1
Cut. 2	208	232	0.06	0.081	15.6	20.4	23.4	37.3	49.3	70.7
Cut. 3	329	213	0.071	0.057	19.3	18.5	28.8	32.6	62.8	63.1
Cut. 4	315	170	0.125	0.052	22	14.5	21	32.6	60.3	49.1
Cut. 5	283	388	0.043	0.092	18.9	19.9	31.5	37.3	62.9	66.7
Cut. 6	199	264	0.104	0.084	16.7	19.9	13.1	39.9	52.3	69.5
Cut. 7	199	268	0.134	0.088	17.8	19.6	18.3	39.8	52.3	71.6
Cut. 8	251	465 [1)]	0.113	0.084 [1)]	14.9	20.7 [1)]	20.9	35.0 [1)]	73.2	112.4 [1)]
Cut. 9	738	249 [2)]	0.172	0.071 [2)]	22.5	13.7 [2)]	23.5	32.4 [2)]	180.5	81.3 [2)]

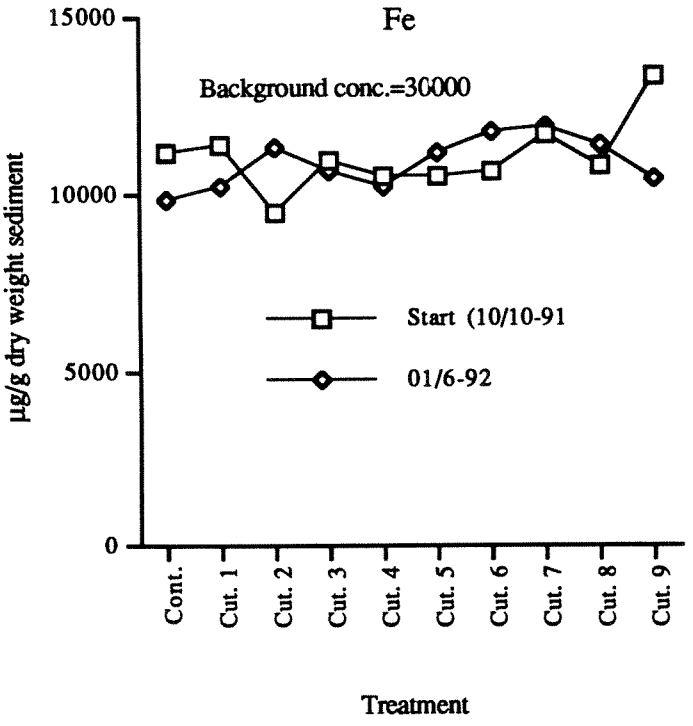
[1)]Only sediment from plot 10 analysed

[2)]Values are uncertain because of an probable error during sampling. The sediment analysed consisted probably of 2/3 of sediment from plots added Case 9 cuttings and 1/3 of sediment added Case 8

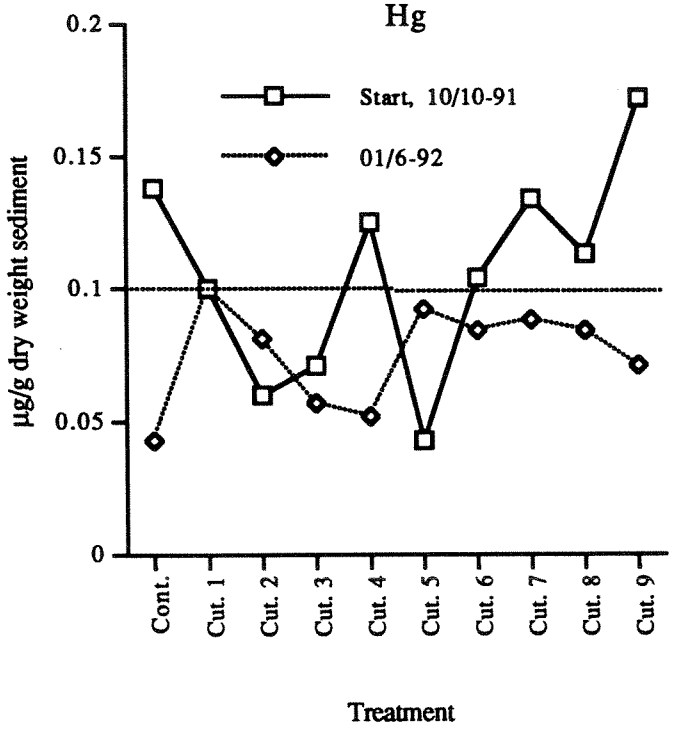
Appendix B1-1

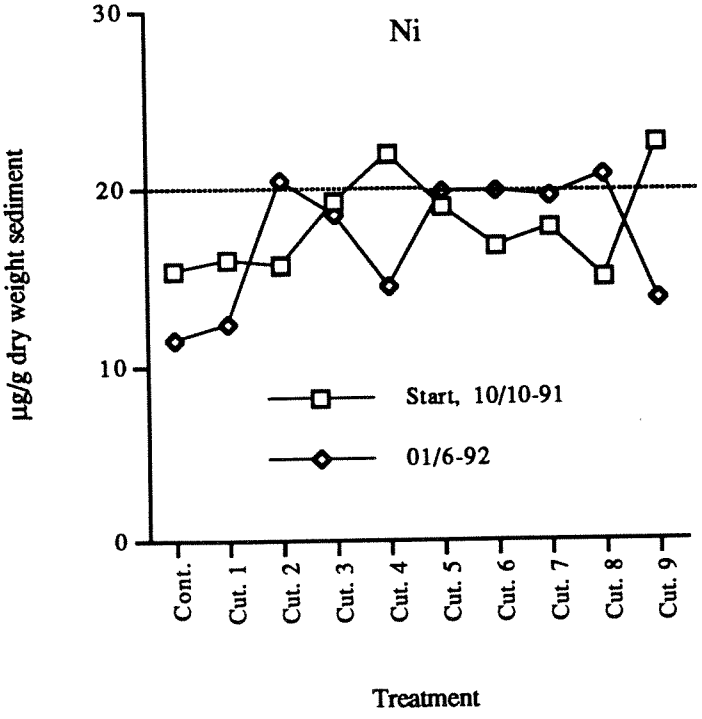
Plots of the concentration of Cu, Fe, Hg, Ni, V and Mn found in the different treatments at the start and end of the community structure experiments. Horizontal dotted line indicate background concentration in coastal sediment.



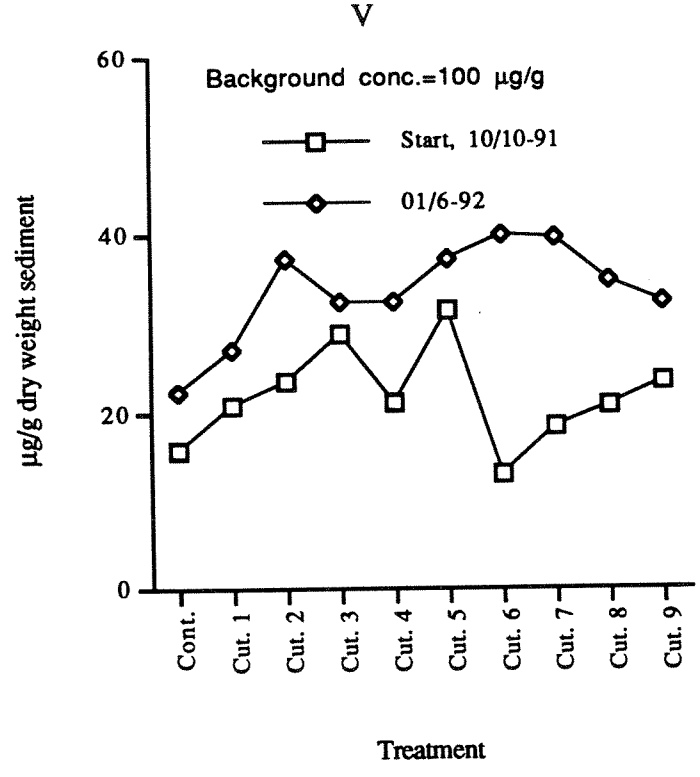


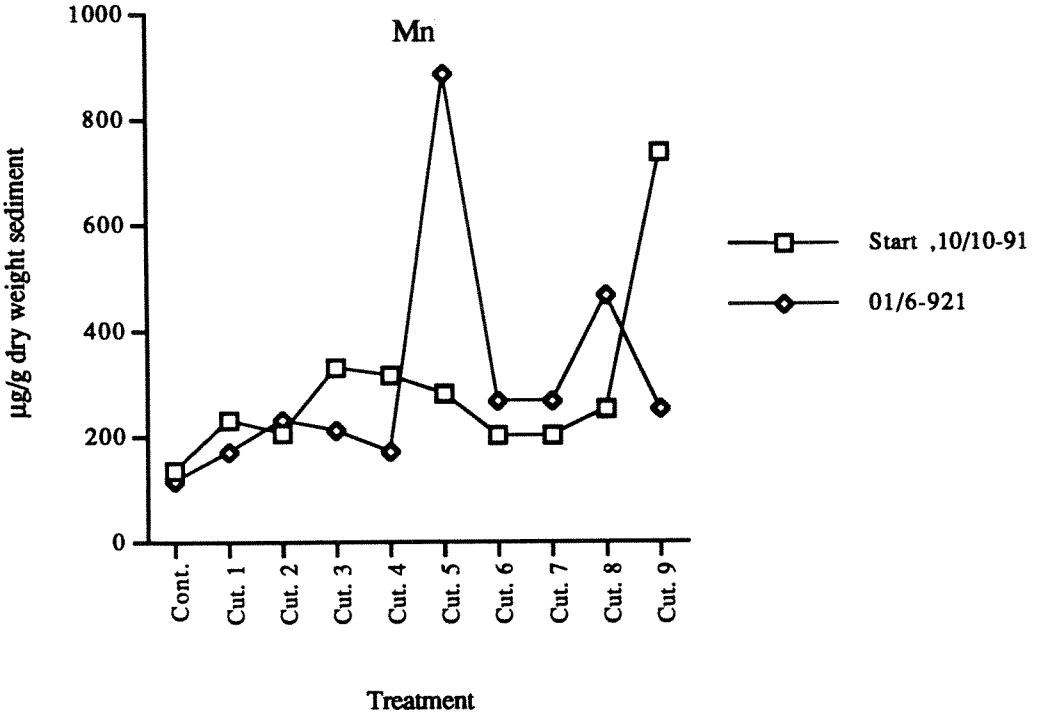
Appendix B1-1 (continued)





Appendix B1-1 (continued)




Mn
1000
800
600
400
200
0
µg/g dry weight sediment
Cont.
Cut. 1
Cut. 2
Cut. 3
Cut. 4
Cut. 5
Cut. 6
Cut. 7
Cut. 8
Cut. 9
Treatment
Start ,10/10-91
01/6-921

B2. Metal analyses-Settling experiment (I) in boxes

B1. Metal analyses in sediment in experimental boxes. Units are based on dry weight sediment (µg/g dw.)

Case no.	Ba July 1991 µg/g	Ba Nov. 1991 µg/g	Ba March 1992 µg/g	Cd July 1991 µg/g	Cd Nov. 1991 µg/g	Cd March 1992 µg/g	Cu July 1991 µg/g	Cu Nov. 1991 µg/g	Cu March 1992 µg/g
Cont.	94	109	105	0,19	0,21	<0,5	35,9	32,7	28,6
Cut. 1	313	624	283	0,13?	3,55	1,53	43,8	40,5	31,3
Cut. 2	656	299	267	0,22	0,29	<0,5	37,8	33,8	32,9
Cut. 3	516	378	285	0,22	0,23	<0,5	39,1	32,0	32,7
Cut. 4	520	438	345	0,23	0,23	<0,5	38,8	34,6	33
Cut. 5	456	487	567	0,25	0,22	<0,5	36,7	37,4	27,4
Cut. 6	529	614	597	0,25	0,21	<0,5	37,8	30,9	25,4
Cut. 7	342	566	509	0,25	0,24	<0,5	38,9	31,7	26,2

Case no.	Fe July 1991 µg/g	Fe Nov. 1991 µg/g	Fe March 1992 µg/g	Pb July 1991 µg/g	Pb Nov. 1991 µg/g	Pb March 1992 µg/g	Mn July 1991 µg/g	Mn Nov. 1991 µg/g	Mn March 1992 µg/g
Cont.	32439	28143	29810	85,8	75,2	72,8	1840	995	1009
Cut. 1	30844	29306	29544	798,5	514,4	238,7	1456	1231	1003
Cut. 2	28118	24549	29421	65,1	57,7	57	1515	154	856
Cut. 3	28589	26767	29688	57,3	57,7	55	1390	866	666
Cut. 4	27394	27352	30570	60,4	62,5	62,4	1260	953	745
Cut. 5	29564	28574	25087	70,8	68,0	59,7	1290	1036	754
Cut. 6	29701	25328	25976	64,8	68,2	57,2	1524	739	564
Cut. 7	29375	27840	26069	62,2	62,9	54,9	1523	865	538

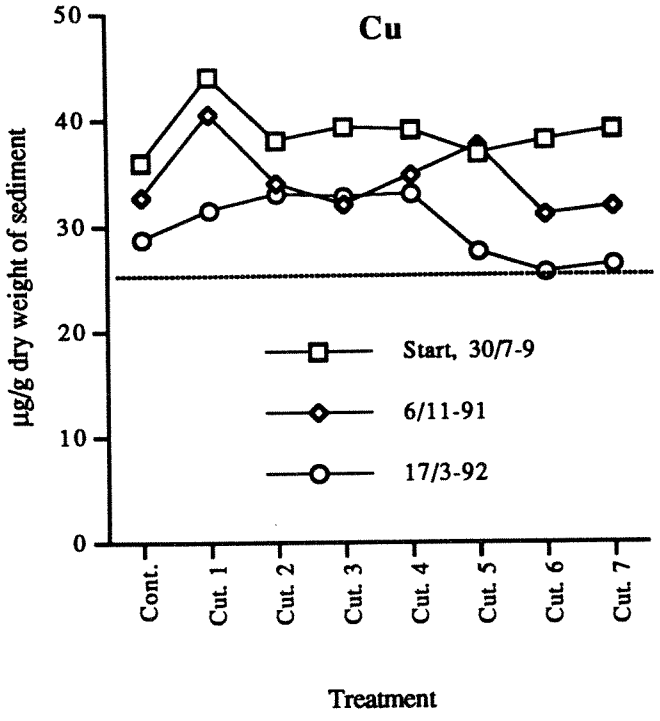
Case no.	Hg July 1991 µg/g	Hg Nov. 1991 µg/g	Hg March 1992 µg/g	Ni July 1991 µg/g	Ni Nov. 1991 µg/g	Ni March 1992 µg/g	V July 1991 µg/g	V Nov. 1991 µg/g	V March 1992 µg/g
Cont.	0,461	0,430	0,403	39,8	36,3	35,6	104	77,7	85,3
Cut. 1	0,178	0,394	0,4	37,6	36,4	34,3	88,7	83,1	89,5
Cut. 2	0,546	0,521	0,395	39,8	70,8	37,6	98,9	70,8	94,1
Cut. 3	0,493	0,470	0,340	40,4	38,1	36	91,1	70,9	77,5
Cut. 4	0,414	0,523	0,394	39,6	38,8	37,7	81,3	80,8	89,9
Cut. 5	0,535	0,451	0,377	41,9	39,3	34,3	102,2	78,5	84,6
Cut. 6	0,495	0,407	0,345	41,7	42,2	33,6	93,3	65,5	74,6
Cut. 7	0,522	0,548	0,369	42,0	40,9	32,5	90,7	78,6	77,4

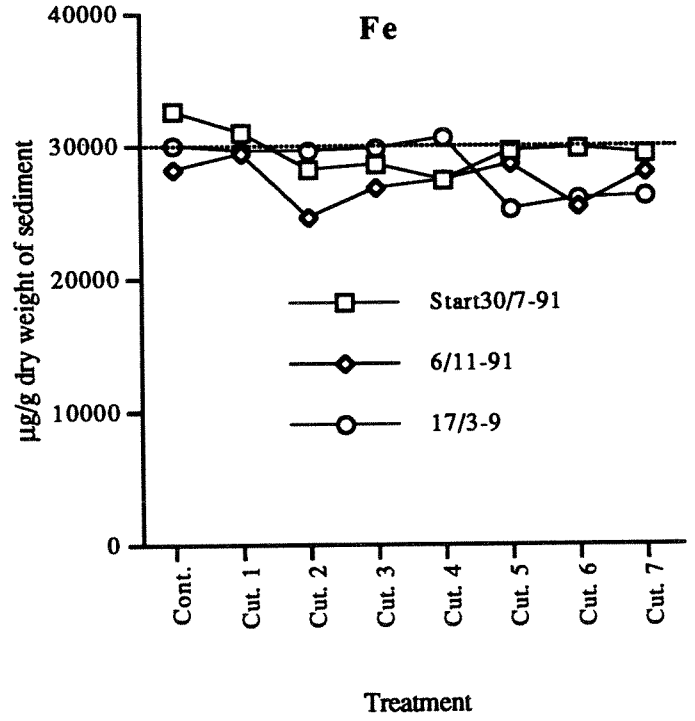
B2 (Continued). Metal analyses in sediment in experimental boxes. Units are based on dry weight sediment (µg/g dw.)

Case no.	Zn July 1991 µg/g	Zn Nov. 1991 µg/g	Zn March 1992 µg/g
Cont.	182,0	160,7	152
Cut. 1	438,4	389,7	239
Cut. 2	174,4	160,0	159
Cut. 3	174,5	154,8	147
Cut. 4	162,7	158,9	184
Cut. 5	178,2	172,7	134
Cut. 6	173,6	152,1	127
Cut. 7	176	165,2	130

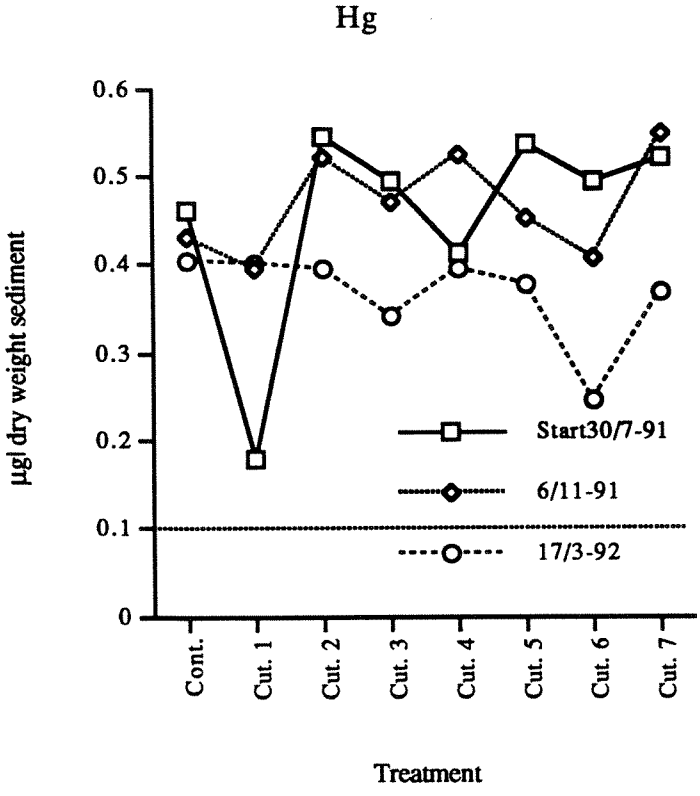
Appendix B2-1

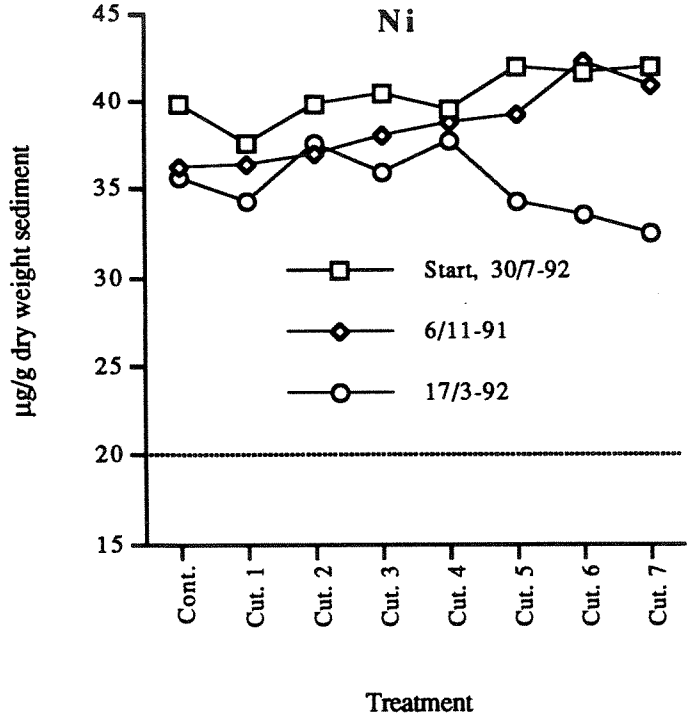
Plots of the concentration of Cu, Fe, Hg, Ni, V, and Mn in the sediment during the settling experiment (I). Horizontal dotted line indicate background concentration in coastal sediment.



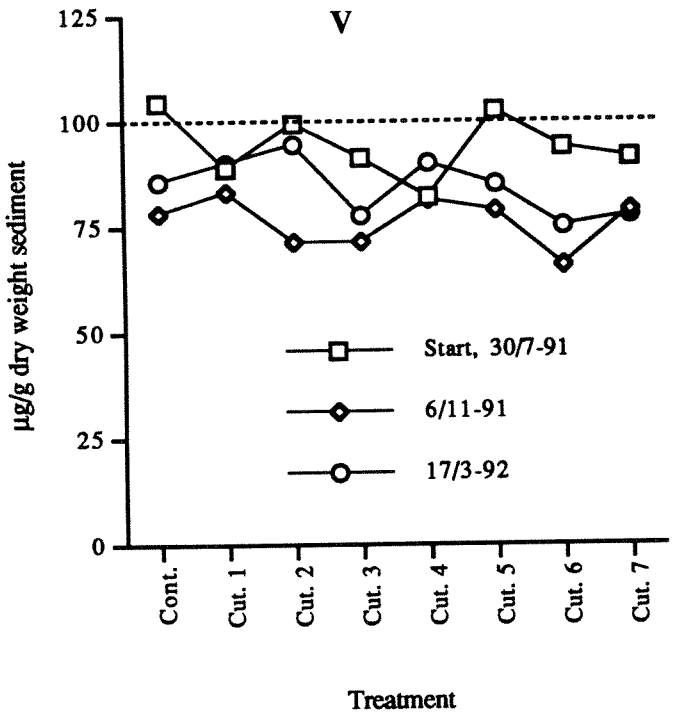


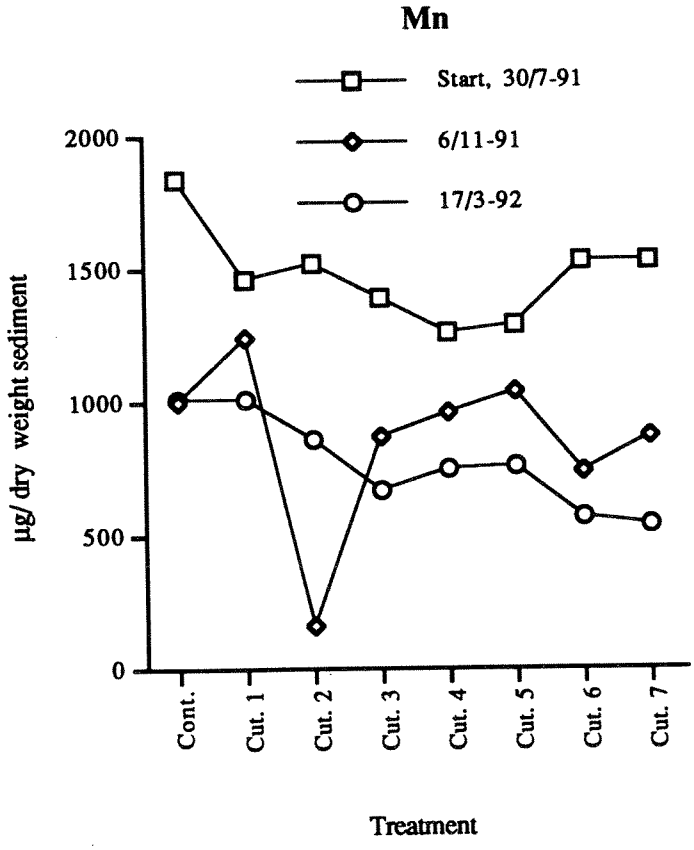
Appendix B2-1 (continued)





Appendix B2-1 (continued)





B3. Metal analyses-Settling experiment (II) in boxes

Results of metal analyses-Experiments in experimental boxes (II). Units are based on dry weight sediment (µg/g dw.)

Case no.	Ba April 1992 µg/g	Ba Sept. 1992 µg/g	Cd April 1992 µg/g	Cd Sept. 1992 µg/g	Cu April 1992 µg/g	Cu Sept. 1992 µg/g	Fe April 1992 µg/g	Fe Sept. 1992 µg/g	Pb April 1992 µg/g	Pb Sept. 1992 µg/g
Cont.	90	75.0	<0.5	<0.50	20.7	23.8	23395	20892.0	47.5	54.9
Cut. 2	449	450.0	<0.5	<0.50	26.4	29.5	24239	23705.0	44.9	70.3
Cut. 11	600	406.0	<0.5	<0.50	25.8	31.1	25205	24051.0	50	58.4

Case no.	Mn April 1992 µg/g	Mn Sept. 1992 µg/g	Hg April 1992 µg/g	Hg Sept. 1992 µg/g	Ni April 1992 µg/g	Ni Sept. 1992 µg/g	V April 1992 µg/g	V Sept. 1992 µg/g	Zn April 1992 µg/g	Zn Sept. 1992 µg/g
Cont.	303	391.0	0.316	0.365	29.7	28.1	50	62.6	87	126.3
Cut. 2	401	465.0	0.31	0.401	32.9	31.0	67.3	65.0	126	140.0
Cut. 11	548	511.0	0.299	0.403	36	31.3	62.5	77.7	123	132.3

Appendix C. Results from redox measurements in the sediment

C1. Redoxpotential at a sediment depth of 2 cm in cores sampled in experimental plots used for the community structure experiments (June 1992).

Plot no.	Treatment	Redox potential (mV)
1	Cut. 5	110
2	Cut. 4	135
3	Cut. 6	186
4	Cut. 7	7
5	Cut. 2	-61
6	Cut. 1	257
7	Cut. 9	41
8	Control	141
9	Cut. 3	-77
10	Cut. 8	90
11	Cut. 8	89
12	Cut. 1	255
13	Cut. 6	37
14	Cut. 5	112
15	Cut. 9	149
16	Cut. 2	-73
17	Cut. 3	-50
18	Cut. 7	143
19	Cut. 4	9
20	Control	151

C2. Redoxpotential measured at a sediment depth of 2 cm in experimental boxes used for Settling experiments (I) (March 1992).

Box no.	Treatment	pH	Redoxpotential (mV)
21	Cut. 2	7,6	-21
21	Cut. 2	6,74	-48
21	Cut. 2	6,77	45
22	Control	7,69	241
22	Control	7,79	299
22	Control	7,71	321
23	Cut. 3	6,74	-28
23	Cut. 3	6,74	-131
23	Cut. 3	7,08	50
25	Cut. 3	6,98	122
25	Cut. 3	6,74	2
25	Cut. 3	6,74	-2
26	Cut. 5	7,69	262
26	Cut. 5	7,79	178
26	Cut. 5	7,79	129
27	Cut. 4	7,27	73
27	Cut. 4	7,07	-42
27	Cut. 4	7,06	39
28	Cut. 7	7,58	142
28	Cut. 7	7,53	112
28	Cut. 7	7,69	4
30	Cut. 7	7,45	147
30	Cut. 7	7,06	-2
30	Cut. 7	7,5	-4
31	Cut. 1	7,76	262
31	Cut. 1	7,75	418
31	Cut. 1	7,79	225
32	Cut. 6	7,49	64
32	Cut. 6	7,91	154
32	Cut. 6	7,8	205
33	Cut. 4	7,48	63
33	Cut. 4	7,27	-58
33	Cut. 4	7,27	-123
34	Cut. 1	7,63	260
34	Cut. 1	7,82	311
34	Cut. 1	7,9	273
35	Cut. 5	7,68	196
35	Cut. 5	7,69	162
35	Cut. 5	7,9	175
36	Cut. 6	7,77	189
36	Cut. 6	7,79	272
36	Cut. 6	7,85	248
37	Control	7,79	300
37	Control	7,65	336

C2 (Continued). Redoxpotential measured at a sediment depth of 2 cm in experimental boxes used for Settling experiments (I) (March 1992).

Box no.	Treatment	pH	Redoxpotential (mV)
37	Control	7,79	200
40	Cut. 2	6,84	0
40	Cut. 2	6,53	45
40	Cut. 2	6,45	-75

C3. Redox potential measured at a sediment depth of 2 cm in experimental used for settling experiment (II) in boxes (September 1992).

Plot no.	Treatment	Redox potential (mV)
Box 2	Control	166
Box 2	Control	153
Box 2	Control	258
Box 2	Control	37
Box 3	Control	45
Box 3	Control	83
Box 3	Control	144
Box 3	Control	19
Box 9	Cut. 2	9
Box 9	Cut. 2	-138
Box 9	Cut. 2	-185
Box 9	Cut. 2	-172
Box 12	Cut. 2	-97
Box 12	Cut. 2	90
Box 12	Cut. 2	-64
Box 12	Cut. 2	-85
Box 24	Cut. 2	-109
Box 24	Cut. 2	-95
Box 24	Cut. 2	-19
Box 24	Cut. 2	45
Box 29	Cut. 11	22
Box 29	Cut. 11	-7
Box 29	Cut. 11	1
Box 29	Cut. 11	-37
Box 38	Cut. 11	-153
Box 38	Cut. 11	11
Box 38	Cut. 11	-38
Box 38	Cut. 11	-125
Box 39	Cut. 11	80
Box 39	Cut. 11	-1
Box 39	Cut. 11	-63
Box 39	Cut. 11	-117

APPENDIX D. Results from benthic fauna analyses

D1. Community structure experiments in plots on the bottom.

Data from 15/10-91.

Data:	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91
Experimental plot no.	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Sieve (1mm+0.5mm=B):	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Cuttings type:	C	C	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Species																				
Nemertinea indet	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Edwardsia sp.	1	1	0	0	0	0	2	0	1	1	4	6	7	1	1	2	3	3	3	5
cf. Ampharete sp.	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Anaitides groenlandica	1	0	0	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0
Anobothus gracilis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Aricidea minuta	1	0	4	0	6	6	0	1	3	1	2	2	4	2	3	1	0	0	5	1
Capitella capitata	0	0	0	0	0	0	3	1	0	0	0	0	1	2	0	0	0	2	1	0
Caulleriella sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Chaetozone minuta	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3
Chaetozone setosa	5	1	3	2	5	3	0	0	0	1	1	1	1	3	4	1	2	3	4	0
Chone duneri	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chone cf. infundibuliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus cirratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cirratulus juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplocirrus glaucus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone spp.	1	2	1	1	1	0	0	0	1	0	2	0	2	0	0	1	1	0	2	0
Exogene sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gattyana cirrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniada sp. juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0
Harmothoe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroides norwegica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jasminera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kefersteinia cirrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus fragilis	0	3	0	0	6	0	1	2	0	1	0	0	2	3	4	0	1	0	0	1
Myriochele oculata	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Myriochele sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neptys juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys ciliata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi	1	1	3	2	1	2	0	3	1	0	2	1	2	2	0	1	0	0	3	1
Nephtys longosetosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereimyra punctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophryotrocha sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1
Paradoneis lyra	6	14	7	8	13	13	9	6	6	22	3	10	10	6	10	0	9	11	18	9
Paraonis gracilis	0	2	0	0	1	1	1	1	1	3	1	5	1	1	1	0	4	0	0	5
Paraonidae indet.	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Pectinaria auricoma	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Pectinaria koreni	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0
Pherusa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa plumosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pholoë minuta	0	3	2	1	1	0	3	2	0	0	0	0	3	2	3	0	2	3	1	3
Phyllodoce mucosa	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0
Phyllodoce sp. (juv)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodocidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poecilochaetus serpens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Polychaeta indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycirrus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora sp. (socialis)	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pomatoceros triqueter	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio cirrefera	0	9	0	1	7	2	1	1	0	0	0	0	3	1	6	1	1	1	0	2
Prionospio sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio malmgreni	3	22	8	2	14	6	8	6	6	4	3	0	4	5	11	1	7	4	17	11
Prionospio ochelmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora pulchera	0	0	0	1	0	0	0	1	0	1	1	0	2	1	3	0	0	0	1	0
Pseudopolydora antennata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora paucibranchiata	1	8	0	0	0	0	2	0	0	1	0	0	0	1	1	0	1	0	0	3
Sabellidae sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scoloplos armiger	8	8	4	0	10	5	2	5	1	5	3	1	5	6	37	1	3	5	4	6
Scalibregma inflatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Serpulidae juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Data form 15/10-91 (continued)

Experimental plot no.	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Cuttings type:	C	C	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Sphaerodrum sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	30	20	13	20	17	13	3	13	20	3	14	1	26	9	17	1	37	10	14	16
Spiophanes kroyeri	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio filicornis	2	9	0	0	1	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0
Spio mecznikowianus	4	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
Spionidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio sp.	3	0	5	0	1	1	0	0	0	0	0	0	2	0	0	0	4	3	1	5
Syllidae juv.	0	0		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Syllidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebellidae juv.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochochaeta multisetosa	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Abra nitida/prismatica	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Arctica islandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astarte sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia indet	1	6	1	7	1	0	2	3	2	0	2	4	9	5	12	4	2	6	3	6
Bivalvia I (brun flekk)	0	24	29	0	1	0	4	1	1	0	0	1	5	12	26	0	3	21	5	0
Chlamys cf. varia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbula gibba	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cultellus pellucidus	0	1	1	0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Lucinoma borealis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Montacuta ferrugunosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. M. bidentata	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Mya cf. truncata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilacea indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parvicardium ovale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parvicardium scabrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Parvicardium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spisula subtruncata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thyasira flexuosa	4	7	1	4	6	3	3	1	3	4	2	7	1	5	5	4	10	3	2	8
cf. Tellina tenuis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Venus striatula	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica alderi	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0
Pycnogonida indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Amphipoda indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphelisca brevicornis	2	0	2	1	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0
Amphelisca tenuicornis	2	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Aora gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Carcinus maenas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheirocratus sp.	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
cf. Corophium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crangon crangon	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Mysidae sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagurus bernhardus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perioculodes longimanus	0	0	0	2	0	0	0	0	0	0	2	0	0	4	4	0	2	2	1	0
Pleurogonium rubicundum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synchelidium haplocheles	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thoralus cranchii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia deltaura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cumacea indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phascolion strombi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astreoidea indet (Asterias rubens?)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinocardium cordatum	5	1	0	1	0	2	0	0	2		1	0	1	1	3	0	2	3	2	1
Ophiura albida	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Ophiuroidea indet (juv. skive ca. 2-3 mm)	0	2	1	0	0	1	0	1	0	0	0	2	2	3	0	1	1	2	1	0
Psammechinus miliaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"Varia"	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3	0	2	0	1
"Unindentified no. 2"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"Unindentified no. 1"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total no. of individuals	84	158	91	60	103	63	50	54	56	54	45	44	97	81	164	29	95	90	88	95
Total no. of species	21	28	20	21	25	17	18	22	18	19	17	15	24	27	28	15	19	20	19	24

D2. Community structure experiments in plots on the bottom. Data from 26-27/2-92.

Date: 26-27/2-92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92	2/92
Experimental plot:	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Sieve (1mm+0.5mm)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Cuttings type:	C	C	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Species																				
Nemertinea indet	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
Edwardsia sp.	1	7	3	4	1	2	3	0	2	5	0	0	0	1	4	0	1	1	1	0
cf. Ampharete sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Analtides groenlandica	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Anobothus gracilis	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Aricidea minuta	2	0	4	3	0	0	0	0	0	0	4	0	0	0	0	0	0	1	1	1
Capitella capitata	1	0	0	0	863	178	731	228	626	647	99	9	63	56	8	18	0	1	10	47
Caulleriella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetozone minuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetozone setosa	5	7	3	4	1	2	0	0	1	0	1	1	4	3	2	1	4	3	3	4
Chone duneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chone cf. infundibuliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus cirratus	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	0	1	0	0	0
Cirratulus juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplocirrus glaucus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone spp.	2	1	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	4	0	2
Exogene sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gattyana cirrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Glycera sp	0	5	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Goniada sp. juv	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Goniada maculata	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0
Harmothoe sp.	0	0	0	0	0	4	0	1	1	0	0	0	0	0	0	0	1	1	0	0
Heteromastus filiformis	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Hydroides norwegica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jasminera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Kefersteinia cirrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelone sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus fragilis	2	5	0	0	0	2	1	1	2	5	1	1	1	1	1	3	3	2	0	2
Myriochele oculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Myriochele sp.	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neptys juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys sp.	3	3	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0
Nephtys ciliata	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Nephtys hombergi	1	0	3	1	0	0	2	1	1	0	5	1	3	0	2	0	0	1	2	0
Nephtys longosetosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereimyra punctata	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ophelina acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophryotrocha sp.	0	0	0	0	10	14	7	6	5	1	1	2	37	3	1	1	0	0	1	0
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paradoneis lyra	6	13	5	5	9	11	3	3	7	17	3	8	10	6	8	4	13	5	9	10
Paraonis gracilis	0	4	0	1	1	0	1	0	0	4	0	3	0	1	0	0	3	0	2	4
Paraonidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pectinaria auricoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria koreni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pherusa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa plumosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pholoë minuta	4	2	1	2	0	6	2	3	0	3	3	0	0	0	0	1	1	0	0	3
Phyllodoce mucosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Phyllodoce sp (juv)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Phyllodocidae indet	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poecilochaetus serpens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycirrus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora sp. (socialis)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pomatoceros triqueter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio cirrelfera	3	17	3	3	1	5	2	0	0	1	3	2	2	0	1	0	10	0	0	7
Prionospio sp.	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2	0	0
Prionospio malmgreni	10	22	8	11	0	0	0	0	0	0	0	0	0	0	1	1	7	20	4	8
Prionospio ochelmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pseudopolydora pulchera	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	1
Pseudopolydora antennata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Pseudopolydora sp.	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	3
Pseudopolydora paucibranchiata	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	37	3	3	0
Sabellidae sp.	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Scoloplos armiger	6	5	3	3	0	1	0	0	0	4	0	0	1	1	1	0	6	1	0	9
Scalibregma inflatum	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Serpulidae juv.	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Data from 26-27/2-92 (Continued)

Experimental plot:	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Cuttings type:	C	C	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Sphaerodrum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	24	32	14	20	0	1	0	0	1	0	5	0	0	0	0	0	30	26	10	2
Spiophanes kroyeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Spio filicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio mecznikowianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio sp.	30	59	35	37	0	0	0	0	0	0	14	1	0	0	0	2	72	26	4	5
Syllidae juv.	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebellidae juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochochaeta multisetosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abra nitida/prismatica	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0
Arctica islandica	0	0	0		1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astarte sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia indet	3	11	1	12	0	4	0	7	2	4	0	0	0	1	0	0	2	2	1	0
Bivalvia I (brun flekk)	12	1	12	2	0	0	0	0	0	0	0	0	0	2	0	0	7	11	11	0
Chlamys cf. varia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbula gibba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
Cultellus pellucidus	2	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lucinoma borealis	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Montacuta ferrugnosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
cf. M. bidentata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mya cf. truncata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilacea indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parvicardium ovale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parvicardium scabrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Parvicardium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spisula subtruncata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Thyasira flexuosa	6	10	5	1	4	1	5	6	1	7	0	2	1	7	7	0	13	9	4	0
cf. Tellina tenuis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Venus striatula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica alderi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pycnogonida indet.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda indet.	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Amphipoda indet	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
Amphelisca brevicornis	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Amphelisca tenuicornis	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Aora gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carcinus maenas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheirocratus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Corophium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crangon crangon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidae sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagurus bernhardus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perioculodes longimanus	37	2	4	2	1	1	0	1	5	0	0	0	0	1	6	0	1	10	37	0
Pleurogonium rubicundum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synchelidium haplocheles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thoralus cranchii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia deltaura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phascolion strombi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astreoidea indet (Asterias rubens?)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinocardium cordatum	2	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1		0
Ophiura albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroidea indet (juv. skive ca. 2-3 mm)	0	2	0	0	0	4	0	1	0	0	0	0	0	1	0	0	1	2	1	0
Psammechinus miliaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"Varia"	1	2	3	0	0	0	6	1	0	0	0	0	0	0	1	0	2	2	1	0
"Unidentified no. 1	0	1	0	0	0	2	0	0	0	0	0	0	0	1	2	0	3	0	2	0
"Unidentified no. 2"	0	6	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Total no. of individuals	167	276	117	119	895	251	763	259	659	701	147	33	123	87	52	32	250	141	111	111
No. of speciesd	25	36	25	22	12	26	11	12	15	13	12	13	10	16	21	9	44	28	22	17

D3. Community structure experiments in plots on the bottom. Data from 1-2/6-92.

Data:	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92	6-92
Experimental plot:	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Sieve size:	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm	1 mm
Cuttings type:	Cont.	Cont.	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Species																				
Nemertinea indet	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Edwardsia sp.	2	1	0	5	0	2	0	1	5	3	7	1	0	0	0	0	2	3	1	0
cf. Ampharete sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Analtides groenlandica	30	48	45	36	0	8	13	11	22	6	40	14	24	18	26	13	21	38	27	7
Anobothus gracilis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea minuta	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capitella capitata	0	0	0	0	473	23	737	9	106	243	0	0	0	0	0	0	0	0	0	0
Caulleriella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetozone minuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetozone setosa	5	2	3	0	0	2	0	1	0	0	2	0	1	2	0	0	0	3	0	2
Chone duneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chone cf. infundibuliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus cirratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplocirrus glaucus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone spp.	31	81	72	65	0	14	7	6	4	5	41	17	22	32	29	30	39	98	51	22
Exogene sp	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gattyana cirrosa	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera sp	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniada sp. juv	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harmothoe sp.	1	0	0	3	0	2	1	3	7	2	4	3	4	1	0	3	2	2	4	2
Heteromastus filiformis	1	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	1
Hydroides norwegica	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jasminera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kefersteinia cirrata	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Magelone sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus fragilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriochele oculata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Myriochele sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neptys juv.	0	2	2	2	0	0	0	0	0	0	3	2	3	0	0	2	0	2	0	2
Nephtys sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	4	0	0
Nephtys ciliata	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi	0	0	0	1	1	1	0	0	1	3	3	2	2	0	1	0	0	0	1	0
Nephtys longosetosa	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Nereimyra punctata	2	2	0	3	0	2	0	2	2	1	0	0	1	1	2	2	2	1	1	1
Ophelina acuminata	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophryotrocha sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paradoneis lyra	1	1	0	3	1	7	1	0	0	1	0	2	1	0	2	0	2	2	1	1
Paraonis gracilis	0	1	0	0	0	0	0	0	0	2	0	1	1	0	0	0	1	0	0	1
Paraonidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria auricoma	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Pectinaria koreni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Pherusa plumosa	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pholoë minuta	4	1	5	9	1	2	1	4	0	3	2	1	0	2	2	0	0	2	0	1
Phyllodoce mucosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodoce sp (juv)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodocidae indet	1	7	2	2	0	0	0	0	0	0	1	0	0	0	2	1	2	3	2	0
Poecilochaetus serpens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta indet.	0	0	0	0	0	2	0	0	1	0	0	1	1	1	0	0	0	0	1	0
Polycirrus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polydora sp. (socialis)	1674	1439	2000	1959	579	745	759	1157	2097	904	2174	1516	2761	1513	1952	975	1638	2211	1740	826
Pomatoceros triqueter	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1
Prionospio cirrelfera	5	17	1	1	0	0	0	0	1	1	0	0	0	1	1	0	7	2	3	0
Prionospio sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio malmgreni	1	11	3	4	0	0	1	0	0	0	0	0	0	0	0	0	2	4	0	0
Prionospio ocheimani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora pulchera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora antennata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopolydora sp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pseudopolydora paucibranchiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabellidae sp.	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Scoloplos armiger	1	8	3	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1
Scalibregma inflatum	0	5	2	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0
Serpulidae juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Data from 1-2/6-92 (continued)

Experimental plot:	8	20	6	12	5	16	9	17	2	19	1	14	3	13	4	18	10	11	7	15
Cuttings type:	Cont.	Cont.	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
Sphaerodrum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	3	18	11	8	0	0	0	0	0	0	2	0	0	0	0	0	1	17	0	0
Spiophanes kroyeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio filicornis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio mecznikowianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Spio sp.	0	14	0	0	0	0	1	2	2	1	2	1	4	1	1	1	1	2	3	1
Syllidae juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllidae indet	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebellidae juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochochaeta multisetosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abra nitida/prismatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctica islandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astarte sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia indet	2	7	8	3	0	0	0	2	0	0	4	2	2	2	0	3	4	1	2	4
Bivalvia I (brun flekk)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlamys cf. varia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbula gibba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cultellus pellucidus	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0
Lucinoma borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Montacuta ferrugnosa	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
cf. M. bidentata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mya cf. truncata	1	5	3	3	0	0	0	0	0	0	2	0	0	0	0	0	5	0	0	0
Mytilacea indet	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parvicardium ovale	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Parvicardium scabrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Parvicardium	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Spisula subtruncata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thyasira flexuosa	5	3	0	3	4	8	0	1	2	4	0	4	2	2	0	3	3	3	1	6
cf. Tellina tenuis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Venus striatula	0	0	0	0	0		0		0	1	0	0	0	0	0	0	1	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica alderi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pycnogonida indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda indet	0	0	0		0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0
Amphelisca brevicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphelisca tenuicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aora gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carcinus maenas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheirocratus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Corophium	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Crangon crangon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidae sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagurus bernhardus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perioculodes longimanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurogonium rubicundum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synchelidium haplocheles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thoralus cranchii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia deltaura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea indet	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
																				0
Phascolion strombi	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astreoidea indet (Asterias rubens?)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinocardium cordatum	0	0	2	2	0	0	0	0	0	0	1	0	1	0	0	0	2	2	0	1
Ophiura albida	0	0	1	0	0	0	0	0	0	0	2	0	1	0	0	1	1	2	1	0
Ophiuroidea indet (juv. skive ca. 2-3 mm)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Psammechinus millaris	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
"Varia"	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
"Unidentified no. 1"	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
"Unidentified no. 2"	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Total no. of individuals	1779	1692	2176	2123	1061	822	1523	1202	2250	1181	2297	1569	2834	1581	2022	1043	1745	2406	1842	888
No. of species	25	33	24	26	8	17	11	15	12	16	20	16	19	16	13	20	26	22	18	23

D4. Fauna analyses-Settling experiment (I) in boxes

Data from 6/11-1991.

Box no.:	Box 1	Box 4	Box 5	Box 6	Box 7	Box 8	Box 10	Box 11	Box 13	Box 14	Box 15	Box 16	Box 17	Box 18	Box 19	Box 20
Treatment:	Cut. 4	Cut. 3	Cut. 1	Cut. 7	Control	Cut. 3	Control	Cut. 2	Cut. 6	Cut. 7	Cut. 4	Cut. 5	Cut. 2	Cut. 6	Cut. 5	Cut. 1
Species																
Anaitides groenlandica	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Chone cf. infundibuliformis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Harmothoe sp.	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nepthys hombergi	1	2	1	2	0	1	2	0	0	0	1	3	2	1	3	2
Pherusa plumosa	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Prionospio cirrelfera	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pseudopolydora pulchera	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1
					0	0	0	0	0	0	0	0	0	0	0	0
Chlamys cf. varia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Corbula gibba	10	27	17	1	55	28	40	35	3	0	4	16	65	2	3	22
Cultellus pellucidus	2	1	8	2	16	1	6		6	7		12		15	18	27
"Mysella bidentata" muligens P. pillastra	0	0	1	0		6	1	3	0	0	0	6	1	0	0	0
Parvicardium ovale	0	2	1	0	1	0	1	11	3	0	2	1	9	0	0	1
Parvicardium scabrum	0	0	0	0	0	0	1	8	0	0	0	1	3	1	0	0
Spisula subtruncata	0	0	1	2	6	0	4		1			2		1	1	10
					0	0	0	0	0	0	0	0	0	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda indet	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Carcinus maenas	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1
Pagurus bernhardus	0	1	1	0	0	0	2	0	0	0	1	1	0	0	1	1
Thoralus cranchii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Upogebia deltaura	2	9	236	119	167	33	393	2	181	144	5	295	13	216	190	181
					0	0	0	0	0	0	0	0	0	0	0	0
Astreoidea indet (Asterias rubens?)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ophiura albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ophiuroidea indet (juv. approx. 2-3 mm)	0	0	3	1	3	0	3	0	2	0	0	2	2	3	0	0
Psammechinus miliaris	2	1		1	1	3	0	11	0	3	3	0	0	0	0	0
Tot. no. of individuals	17	45	270	128	252	72	453	72	196	156	18	346	97	239	218	247
No. of species	4	9	10	7	10	6	10	8	6	5	8	15	9	7	8	10

D5. Settling experiemnts. Data from 17/3-92.

Box no.:	Box 21	Box 22	Box 23	Box 25	Box26	Box 27	Box 28	Box 30	Box 31	Box 32	Box 33	Box 34	Box 35	Box 36	Box 37	Box 40
Treatment:	Cut.2	Control	Cut. 3	Cut.3	Cut. 5	Cut.4	Cut 7	Cut. 7	Cut. 1	Cut. 6	Cut. 4	Cut. 1	Cut. 5	Cut. 6	Control	Cut. 2
Species																
Anaitides groenlandica	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0
Chone cf. infundibuliformis	0	0	0	0	0	0			0	1	0	0	0	0	0	0
Glycera alba	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0
Goniada maculata	0	0	0	0	0	0	1		1	0	0	0	0	0	0	0
Harmothoe sp.	1	0	1	1	0	0	0	2	1	0	0	1	0	1	1	0
Nepthys hombergi		1	3	1	2	1	3	4	3	1	1	5	0	3	0	0
Nepthys cf. ciliata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nereimyra punctata				1					0	0	0	0	0	0	0	0
Pherusa plumosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Spio sp.	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Prionospio cirrelfera	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pseudopolydora pulchera	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Scalibregma inflatum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
									0	0	0	0	0	0	0	0
Lepidopleurus asellus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lepodochiton cinereus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
									0	0	0	0	0	0	0	0
Tellinacea indet	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Corbula gibba	21	10	23	1	1	2	15	20	33		2	19	3	5	6	1
Cultellus pellucidus	1		2	1	17		9	13	18	4	3	12	13	8	4	
"Mysella bidentata" muligens V. pullastra	1	0	2	0	0	0	0	0	0	0	0	0	0	1	1	0
Parvicardium ovale	8	2	0	0	0	0	0	0	1	0	1	0	0	0	1	2
Parvicardium scabrum	4	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Spisula subtruncata	0	0	0	0	0	0	3	0	8	1	0	1	0	2	1	0
Acanthocardia aculeata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Amphelisca brevicornis	0	0	0	0	0	0	0	0	2	0	0	1	2	0	0	0
Amphelisca tenuicornis	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
Amphipoda indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carcinus maenas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dexamine spinosa	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pagurus bernhardus	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Pandalina brevirostris	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Thoralus cranchii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia deltaura	0	345	0	1	115	2	154	100	204	186	14	286	159	222	286	4
Astreoidea indet (Asterias rubens?)	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ophiura albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroidea indet (juv. approx. 2-3 mm)	0	3	0	0	0	0	2	1	1	1	0	3	0	1	0	0
Psammechinus miliaris	0	0	0	3	2	1	2	0	1	0	2	0	1	0	0	0
Echinoidea indet (3-4 mm)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Tot no. of individuals	37	362	32	10	139	6	191	142	276	201	26	331	179	245	303	7
No. of species	7	6	6	7	6	4	10	8	14	13	9	11	6	10	10	3

D6. Fauna analyses-Settling experiment (II) in boxes. Darts from September 1992.

Box no.:	Box 2	Box 3	Box 9	Box 12	Box 24	Box 29	Box 38	Box 39
Treatment:	Control	Control	Cut. 2	Cut.2	Cut. 2	Cut.11	Cut.11	Cut. 11
Species/Taxa								
Analtides groenlandica	1	1	1	8	1	10	2	11
Capitella capitata	0	2	0	0	0	1	0	0
Chone cf. infundibuliformis	0	0	0	0	0	0	0	0
Eteone sp.	0	0	0	0	0	0	0	4
Eteone (Hyperetone) lactea	0	0	1	0	1	0	0	0
Glycera alba	0	0	0	0	0	1	1	0
Goniada maculata	0	0	0	0	0	0	0	0
Harmothoe sp.	0	0	1	0	0	0	0	1
Kefersteinia cirrata	0	0	0	0	1	0	0	0
Nephtys hombergi	0	0	0	0	0	0	0	1
Nephtys cf. ciliata	0	0	0	0	0	0	0	0
Nephtys cirrosa	0	0	0	0	0	0	1	0
Nereimyra punctata	0	0	1	0	0	2	0	0
Nereis virens	47	50	36	13	35	27	28	19
Pherusa plumosa	0	0	0	0	0	0	0	0
Phyllodoce mucosa	4	3	1	10	14	16	7	11
Phyllodoce cf. maculata	0	0	0	0	0	0	0	1
Polydora cf socialis (ciliata?)	0	0	0	62	1	5	1	13
Spio sp.	2	2	0	0	0	4	3	2
Pectinaria koreni	0	1	0	0	0	0	0	1
Prionospio cirrelfera	0	0	0	0	0	0	0	0
Pseudopolydora pulchera	0	0	0	0	0	0	0	0
Scalibregma inflatum	0	1	0	0	0	1	0	0
	0	0	0	0	0	0	0	0
Philine aperta	0	0	0	1	0	0	0	0
Lepidopleurus asellus	0	0	1	0	0	0	0	0
Lepodochiton cinereus	0	0	0	0	0	0	0	0
Buccinum undatum	0	0	0	0	0	0	0	0
Tellinacea indet								
Hiatellacea indet.	0	0	0	0	0	1	0	1
Corbula gibba	2	28	0	0	11	12	17	32
Mya cf. truncata	2	4	0	0	0	1	0	0
Cultellus pellucidus	1	3	0	1	0	2	1	11
"Mysella bidentata"	0	1	0	0	0	0	0	1
Parvicardium ovale	0	0	0	3	1	0	2	0
Parvicardium scabrum	0	0	0	0	2	0	1	0
Spisula subtruncata	0	1	0	0	0	0	0	0
Acanthocardia aculeata	0	0	0	0	0	0	0	0
Bivalvia indet	0	1	0	0	0	0	1	0
Amphelisca brevicornis	0	0	0	0	0	0	0	0
Amphelisca tenuicornis	0	0	0	0	0	0	0	0
Amphipoda indet								
Carcinus maenas	0	2	0	0	0	1	0	1
Dexamine spinosa	0	0	0	0	0	0	0	0
Pagurus bernhardus	14	3	3	2	1	5	7	
Pandalina brevirostris	0	0	0	0	0	0	0	0
Thoralus cranchii	0	0	0	0	0	0	0	0
Upogebia deltaura	0	0	0	0	0	0	1	3
Div. amphipoder	0	13	1	0	1	2	0	3
Astreoidea indet (Asterias rubens?)	1	2	1	0	1	0	0	0
Ophiura albida	0	0	0	0	0	0	0	0
Ophiuroidea indet (juv. 2-3 mm)	0	0	0	0	0	0	0	0
Psammechinus miliaris	2	1	1	2	4	0	1	4
Tot. no. of individuals	76	119	48	100	74	91	74	120
No. of species	10	18	11	9	13	16	15	18

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