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BIOLOGICAL EFFECTS OF DISCHARGED OIL-CONTAMINATED DRILL CUTTINGS IN THE NORTH SEA

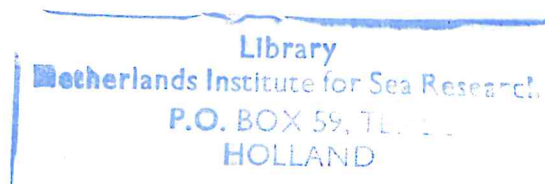
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This study was commissioned by the North Sea Directorate (RWS)
and carried out in 1987 and 1988

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SUMMARY AND CONCLUSIONS

Biological investigations on the effects of discharges of oil based muds (OBM) around drill sites on the Dutch part of the continental shelf have been carried out since 1985. The aim of the research project is to detect, on a spatial scale, how these discharges affect the composition and functioning of the natural benthic fauna and how long such effects can be observed after termination of the drilling activities. Besides, the development and standardization of suitable monitoring techniques is subject of study. Biological research is consistently performed in combination with chemical research on the distribution of oil contaminants in the sediment. The present report, which is the third on results of the biological part of the research programme, deals with data obtained in 1987 and 1988. In this period field surveys were carried out around 3 drilling locations and tentative experiments were performed with contaminated sediment from 2 of these locations.

In 1987 short term effects were investigated around location L4a during 2 monitoring surveys, which took place 4 and 8 months, respectively, after termination of the drilling-operations (2 wells drilled with low-aromatic OBM). The observed fauna composition at varying distances from the dischargepoint could be compared to the fauna composition of the area observed during a baseline study in 1986. Long term effects were studied in 1987 in the area around K12a, where extensive drilling activities (5 wells drilled with diesel based muds) were terminated 3 years before. In addition to the field survey, a few intact sediment cores were collected at this location, to explore the potentialities of experiments in indoor incubated boxcosms. At both locations, L4a and K12a, the sea floor was photo-graphed *in situ* on a number of stations, to test the usefulness of photographic monitoring as an alternative for the time consuming work involved in the analysis of conventional grab samples.

In 1988 the study of long term effects was continued by a follow-up survey at K12a. This year also a location (F18.9) was visited in the sedimentation area. At this location 1 well was drilled one month before, which was attended by a relatively large amount of OBM discharged. Sediment of this location was used in boxcosm experiments, to study the functioning of the natural infauna, and of some introduced test species, in severely contaminated, moderately contaminated and clean sediment sections.

A summary of results and conclusions, derived from the data collected in 1987 and 1988, is given below:

1. *Location L4a*: As well 4 as 8 months after termination of the dumpings, the macrofauna was found to be substantially impoverished within 100 m from the platform.

2. *Location L4a*: At stations at larger distance (≥ 250 m) no reduction in species richness or fauna abundance was observed. However, compared to the situation before drilling operations took place, a change in the composition of the benthic fauna was established. These changes were most pronounced at the 250-m and 500-m stations and became less distinct with increasing distance, indicating an effect of sediment contamination.

3. *Location L4a*: Five species sensitive to OBM contamination showed, after a period of 8 months, a density gradient, which ran over the whole sampled transect (5000 m). This might indicate, that densities of these species are affected upto as far as at least 1000 m.

4. *Location K12a*: In the course of 4 years following drilling activities, spatial effects on the benthic community steadily decreased from 750-1000 m off the platform to < 250 m from the platform.

5. *Location K12a*: Although there is no conclusive evidence for a substantial decrease of OBM contamination levels within 100 m from the platform, the benthic community seems to recover even within this area. It is suggested that recovery might be explained by either a decrease in toxicity of the oil by weathering or a decrease in availability of toxic compounds to the benthic fauna, assuming that they occur enclosed in pockets of cuttings and muds.

6. *Location K12a*: The recovery of the environmental conditions for the benthic community should be verified in a follow-up survey. Patchiness in the distribution of contaminated cuttings should be regarded as a major factor in the detection of biological effects.

7. *Location F18.9*: Within 500 m from the dischargepoint macrofauna abundance and species richness were significantly reduced. The fauna characteristics of the 750-m station (residual current direction) were intermediate compared to those observed at ≤ 500 and ≥ 1000 m, respectively.

8. *Location F18.9*: Within 500 m a gradual increase in intensity of observed effects in the direction of the well was only slightly indicated. This might be most plausibly explained by imperfection in positioning in

the vicinity of the dischargepoint, where the sampling stations were chosen close to each other.

9. *Location F18.9*: The distribution pattern of some sensitive species indicates that biological effects stretch out as far as 1000 or 2000 m.

10. *In situ photographs*: Underwater photography did not reveal a useful alternative for conventional grab sampling.

11. *Field dose-effect relationships*: Not one of 7 effects, that have been described on the basis of the results of the field surveys, acts as a quantitative variable, that can be universally related to any contamination level. In a qualitative sense the effects to be expected at different oil concentrations in the sediment (mg/kg dry weight) may be described as follows:

≥ 100 mg/kg: all defined effects may occur

10-100 mg/kg: at least a few effects should be expected

1 -10 mg/kg: sensitive species may occur in reduced numbers

These indications concern short-term effects (≤ 2 year after discharge). At longer term the number of effects may be reduced.

12. *Boxcosm experiments*: Boxcosms, incubated under semi-natural conditions, provide an excellent opportunity for long term dose-effect studies.

13. *Boxcosm experiments*: A positive correlation was observed between oil concentrations in the sediment and mortality of the natural infauna. This holds for nearly all taxa present among the infauna.

14. *Boxcosm experiments*: Enhanced oil concentrations in the sediment increased mortality in 3 of 5 introduced species. In the other 2 species no response was observed.

15. *Boxcosm experiments*: The sea urchin (*Echinocardium cordatum*) seems to meet the required qualifications of a test species. Mortality in this species appeared a sensitive response variable. Moreover, the species displays sublethal effects (burrowing depth, loss of spines). Slight mortality and sublethal effects were established in *Echinocardium* already at a concentration of 9 mg/kg dry sediment.

16. *Discussion*: 'Relative macrofauna abundance' is a useful and illustrative effect parameter, that is open for statistical treatment and may serve as an alternative for conventional diversity indices.

17. *Discussion*: The accumulated information obtained from all surveys performed since 1985 has significantly increased our knowledge of 'sensitive' and 'opportunistic' species. A list of such species, published in this report, will facilitate the interpretation of field data to be collected in forthcoming surveys.

SAMENVATTING EN CONCLUSIES

Sedert 1985 wordt biologisch onderzoek verricht naar de effecten van lozingen van oliehoudend boorgruis op de zeebodem rond mijnbouwinstallaties op het Nederlands Continentaal Plat. Het onderzoek heeft tot doel ruimtelijk vast te stellen, welke effecten deze lozingen hebben op samenstelling en functioneren van de natuurlijke bodemfauna en hoelang dergelijke effecten na beëindiging van de booraktiviteiten (en daarmee van de lozingen) aantoonbaar zijn. Daarnaast is de ontwikkeling en standaardisering van geschikte monitoring-technieken onderwerp van studie. Het biologisch onderzoek vindt steeds plaats in combinatie met chemisch onderzoek naar de verspreiding van olie-componenten. Dit rapport is de derde publikatie van resultaten van het biologische onderzoeksprogramma en behandelt de gegevens, die in 1987 en 1988 verkregen zijn aan de hand van veldwerk rond 3 boorlokaties en experimenteel werk met verontreinigd sediment van 2 van deze lokaties.

In 1987 werden korte-termijn effecten onderzocht tijdens 2 routine monitoring surveys rond de lokatie L4a, die werden uitgevoerd 4 resp. 8 maanden, nadat hier 2 boringen met low-aromatic oil based muds (OBM) hadden plaats gevonden. De waargenomen bodemfauna-samenstelling op verschillende stations rond deze lokatie kon worden vergeleken met die, welke gevonden werd tijdens een baseline-studie, voorafgaande aan de OBM-boringen.

Lange-termijn effecten werden in 1987 bestudeerd aan de hand van de ontwikkeling van de bodemfauna in het gebied rond K12a, nu 3 jaar na de beëindiging van intensieve booraktiviteiten (5 boringen met diesel-houdende en low-tox OBM). Tijdens de survey werden op deze lokatie tevens enkele intakte bodemkernen verzameld, om ervaring op te doen met de experimentele mogelijkheden van in het laboratorium geïncubeerde boxcosms. Zowel bij L4a als bij K12a werden op een aantal bemonsterde stations foto-opnames gemaakt, om de bruikbaarheid van bodemfotografie te testen als alternatief voor de arbeidsintensieve biologische routine-monitoring.

In 1988 werd bij K12a, ter continuering van de lange termijn studie, opnieuw een survey uitgevoerd. Daarnaast werd voor het eerst een lokatie (F 18.9) in het sedimentatiegebied bezocht, waar een maand tevoren 1 exploratieput was geboord, hetgeen gepaard ging met een relatief zware lozing van OBM-houdend boorgruis. Met sediment van deze lokatie werd bovendien een uitgebreid boxcosm-experiment opgezet, waarin het functioneren van de natuurlijke infauna, alsook van enkele uitgezette proefdier-soorten, werd bestudeerd op sterk vervuilde, minder vervuilde en schone bodemkernen, zoals die daadwerkelijk rond een lozingspunt voorkomen. In belan-

grijke mate betrof het hier nog een verkennend onderzoek naar diverse mogelijkheden van een experimentele laboratorium-opstelling met sedimenten in hun natuurlijke gelaagdheid, maar met een verschillende gradatie van vervuiling.

Dit rapport behandelt veldgegevens en experimentele resultaten voor iedere lokatie apart. Vervolgens wordt aan de hand van de 5 uitgevoerde surveys besproken in hoeverre gecombineerde biologische en chemische veldgegevens inzicht geven in dosis-effekt relaties, zoals die in zee optreden. Een apart hoofdstuk is gewijd aan *in situ* bodem-fotografie. In de discussie wordt aan de hand van alle tussen 1985 en 1988 uitgevoerde veld-surveys, een overzicht gegeven van die soorten, die min of meer stelselmatig indicaties hebben gegeven, gevoelig te reageren op verontreiniging van het sediment met OBM-houdend boorgruis. Ook wordt argumentatie aangevoerd voor het bestaan van enkele duidelijk opportunistische soorten. Vervolgens worden korte en lange termijn trends op de bezochte lokaties nader beschouwd aan de hand van de verspreiding van gevoelige soorten. Tenslotte worden toegepaste statistische procedures en additionele monitoring-technieken in het kort besproken.

Samenvattend hebben de in 1987 en 1988 verzamelde gegevens geleid tot de volgende resultaten en conclusies:

1. *Lokatie L4a:* Deze lokatie vertoonde zowel 4 als 8 maanden na beëindiging van de lozingen een aanzienlijk verarmde makrofauna binnen 100 m van het lozingspunt.
2. *Lokatie L4a:* Op stations op grotere afstand (≥ 250 m) werd geen verarming van de fauna geconstateerd. Wel kon ten opzichte van de situatie, voordat OBM-boringen hadden plaats gehad, een verandering worden vastgesteld in de faunasamenstelling van de bodem. Deze veranderingen waren het sterkst op stations dichtbij het lozingspunt (250 en 500 m) en namen met toenemende afstand geleidelijk in intensiteit af, hetgeen wijst op een effect van lozing van OBM-houdend boorgruis.
3. *Lokatie L4a:* Vijf voor OBM-lozing gevoelige soorten vertoonden 8 maanden na de lozingen een dichtheidsgradient, die zich over het gehele bemonsterde transect voortzette, hetgeen suggereert, dat deze soorten in hun verspreidingsdichtheid effect ondervinden tot voorbij 1000 m.
4. *Lokatie K12a:* In de loop van een periode van 4 jaar, die verstreken sinds de booraktiviteiten op dit platform werden beëindigd, is de afstand, tot waar effecten van lozing van oliehoudend boorgruis op de benthische gemeenschap werden waargenomen, geleidelijk afgenomen van 750 á 1000 m tot minder dan 250 m van het platform.
5. *Lokatie K12a:* Hoewel voor een aanzienlijke

concentratie-vermindering van OBM-contaminanten rond het platform geen overtuigende aanwijzing is, lijkt ook binnen een straal van 100 m de macrofauna zich in 1988 te herstellen. Als mogelijke verklaringen voor een dergelijk herstel zijn aangevoerd, dat de olie door verwerking minder toxisch kan zijn geworden of dat toxische bestanddelen minder beschikbaar komen, omdat deze in de bodem wellicht ingesloten, in 'pockets' van cuttings en muds, voorkomen.

6. *Lokatie K12a*: Of van een duidelijk herstel bij K12a sprake is, dient in een vervolg-survey geverifieerd te worden. Vooral patchiness in de verspreiding van oliehoudend boorgruis moet gezien worden als een belangrijke faktor, die van invloed is op het al of niet waarnemen van effecten.

7. *Lokatie F 18.9*: Binnen een straal van 500 m van het lozingspunt is de macrofauna in belangrijke mate verarmd, hetgeen zich in de bodemonsters onder meer manifesteert in een gereduceerde soorten-rijkdom. De faunakaracteristieken van het station 750 m reststroom zijn intermediair in vergelijking tot die waargenomen op ≤ 500 m, respectievelijk ≥ 1000 m.

8. *Lokatie F 18.9*: Binnen 500 m was een (verwachte) graduele toename in de intensiteit van effecten in de richting van het lozingspunt slechts in geringe mate waarneembaar. Dit vindt ongetwijfeld zijn oorzaak in het onnauwkeurig functioneren van de positie-bepalings apparatuur (Decca) in de directe omgeving van het lozingspunt, waar de monsterpunten dichter bij elkaar liggen dan daarbuiten.

9. *Lokatie F 18.9*: Er bestaan aanwijzingen, dat enkele gevoelige soorten in hun verspreiding de invloed van lozingen ondervinden tot op 1000 à 2000 m.

10. *Bodemfotografie*: *In situ* fotografie biedt geen bruikbaar alternatief voor bodemfauna-bemonstering.

11. *Dosis-effekt relaties uit veldwaarnemingen*: Geen enkel van een 7-tal gedefinieerde effecten, die uit faunistisch veldonderzoek naar voren kunnen komen, is kwantitatief universeel te relateren aan een willekeurige graad van contaminatie van het sediment. In kwalitatieve zin kan de aard van te verwachten effecten bij verschillende concentraties olie in het sediment (mg/kg drooggewicht) zeer globaal als volgt worden aangeduid:

≥ 100 mg/kg: Alle gedefinieerde effecten kunnen optreden

10-100 mg/kg: Een beperkt aantal effecten mag zeker worden verwacht

1-10 mg/kg: Gevoelige soorten kunnen in gereduceerde dichtheden voorkomen

Deze aanduidingen gelden binnen 2 jaar na lozing. Op langere termijn kan het aantal effecten afnemen.

12. *Boxcosm-experimenten*: Boxcosms, in het laboratorium geïncubeerd onder semi-natuurlijke omstandigheden, bieden een geschikte mogelijkheid voor het uitvoeren van lang durende (enige maanden) experimenten ten behoeve van dosis-effekt studies.

13. *Boxcosm-experimenten*: Sterfte onder de natuurlijke infauna was in omvang positief gecorreleerd met de olieconcentratie in het sediment. Dit geldt voor bijna alle aanwezige diergroepen.

14. *Boxcosm-experimenten*: Verhoogde olieconcentraties in het sediment gingen gepaard met verhoogde sterfte onder 3 van de 5 uitgezette testsoorten. Bij de andere 2 werd geen respons waargenomen.

15. *Boxcosm-experimenten*: De zeeklit (*Echinocardium cordatum*) voldeed het beste aan de eisen, die aan een testorganisme kunnen worden gesteld. Niet alleen blijkt sterfte onder deze soort de meest gevoelige respons variabele bij verhoogde olieconcentraties, ook sublethale effecten (afwijkend ingraafgedrag en stekelverlies) zijn bij dit organisme waar te nemen. Geringe sterfte en sublethale effecten werden bij *Echinocardium* reeds waargenomen bij een olieconcentratie van 9 mg/kg droog sediment.

16. *Discussie*: 'Relative macrofauna abundance' is een illustratieve effectparameter, die een bruikbaar en statistisch hanteerbaar alternatief vormt voor traditionele diversiteitsindices.

17. *Discussie*: Op basis van alle sinds 1985 uitgevoerde veldsurveys is in belangrijke mate inzicht verkregen in onze kennis van zgn. 'gevoelige' en 'opportunistische' soorten. De in dit rapport opgenomen lijst van soorten, die als zodanig kunnen worden gekwalificeerd, kan als een belangrijke referentie fungeren bij de interpretatie van gegevens te verzamelen bij eventuele toekomstige surveys.

1 INTRODUCTION

1.1. GENERAL PART

During drilling activities in the North Sea, large quantities of drill cuttings and grit are discharged and subsequently settle on the seabed. The material is contaminated with variable amounts of drilling muds, necessarily employed to perform the drilling process. Among the muds used, 2 main types can be discerned, viz. water-based muds (WBM) and oil-based muds (OBM). When WBM are used, both cuttings and drilling fluid are discharged, whereas OBM are partly recovered before the cuttings are dumped. Technical and economic advantages of OBM compared to WBM have increased the use of OBM in drilling operations and, as a consequence, the amount of oil discharged. The discharge of cuttings with adhering muds may be expected to affect the structure and functioning of the benthic community (e.g. DICKS, 1982; DAVIES *et al.* 1984; MATHESON, 1986).

In the framework of the Paris convention (1980), the Dutch Ministry of Transport and Public Works (RWS, North Sea Directorate) has initiated a research program on the Dutch Continental Shelf to detect effects of this kind of bottom pollution on the benthic fauna. This project, also financed by the Ministry of Economics and the Ministry of Housing, Physical Planning and Environment (VROM), has been running since 1985 and is carried out by the Netherlands Institute of Sea Research (NIOZ), in close cooperation with the Netherlands Organization for Applied Scientific Research (TNO). NIOZ performs the biological part of the project, TNO is responsible for the chemical part. The 1985 and 1986 investigations have been reported by MULDER *et al.* (1987,1988), KUIPER *et al.* (1986) and VAN HET GROENEWOUD (1988). This report deals with the results of the biological research, performed in 1987 and 1988. The chemical results are published by VAN HET GROENEWOUD (1990).

The main object of the programme is to detect biological effects and to get insight into the extent of such effects on both a spatial and a temporal scale, to support a scientifically based management concerning offshore mining activities. Besides, the development and standardization of adequate monitoring techniques is of special interest. The investigations concern effects of discharges of both WBM- and OBM-containing material and are performed in areas with different hydrographic characteristics and, consequently, different sediment structures and benthic communities.

From the very beginning the strategy underlying this study has been to sample the macrobenthos on a number of stations along 2 transects projected from

the point where discharge of cuttings with adhering muds had taken place. By determining distribution and composition of the benthic macrofauna insight is gained into the overall spatial effects of pollution around drilling locations (MULDER *et al.*, 1988). This approach was continued in 1987 and 1988. However, a new method was attempted, to reduce the time-consuming work involved in sieving, sorting and identifying of macrofauna from the samples, by making photographic records of the sea bottom *in situ*. Moreover, additional methods were explored to investigate biological effects of the discharge of contaminated drill cuttings in an experimental way, by studying the functioning of macrofauna on contaminated sediment, collected near the drill sites, in indoor incubated 'boxcosms'. The main purpose of these experiments was to arrive at suitable methods for biological effect-assessment and to get insight into dose-effect relationships. This was pursued on the basis of the following underlying questions:

1. Is it possible to keep sediment cores with the original infauna for a longer period in a mesocosm in more or less natural condition?
2. Does the presence of some specimens of a species in contaminated sediments prove the existence of viable populations, insensitive to the discharged contaminants involved?
3. Is it possible to find indicator species, suitable for active biological monitoring? Such species should, with respect to behaviour, activity or percent survival, show a clear response to sediment pollution.
4. Can accumulation of oil-components be demonstrated in the tissue of benthic animals? (This question is dealt with by VAN HET GROENEWOUD, 1990)
5. Which sublethal effects can be observed in the bottom fauna?
6. Are polluted sediments, which are poor in fauna, accessible to recolonization?

In 1987 and 1988 5 surveys were carried out around 3 drilling locations, with different sediment structures and loads of contamination (Fig. 1, Table 1). On all locations OBM had been discharged. On location L4a, situated in the transition zone between sand and silty sediments, short-term effects were studied during 2 routine surveys in 1987, following drilling operations between July and October 1986. The data collected in 1987 can be compared with those obtained during a 'baseline' survey performed in May 1986, when only wells had been drilled with WBM, and a survey in September 1986, which actually took place during the OBM drilling activities. Location K12a, also in the transition zone, has been the object of study since 1985 and was visited for the third and fourth time in

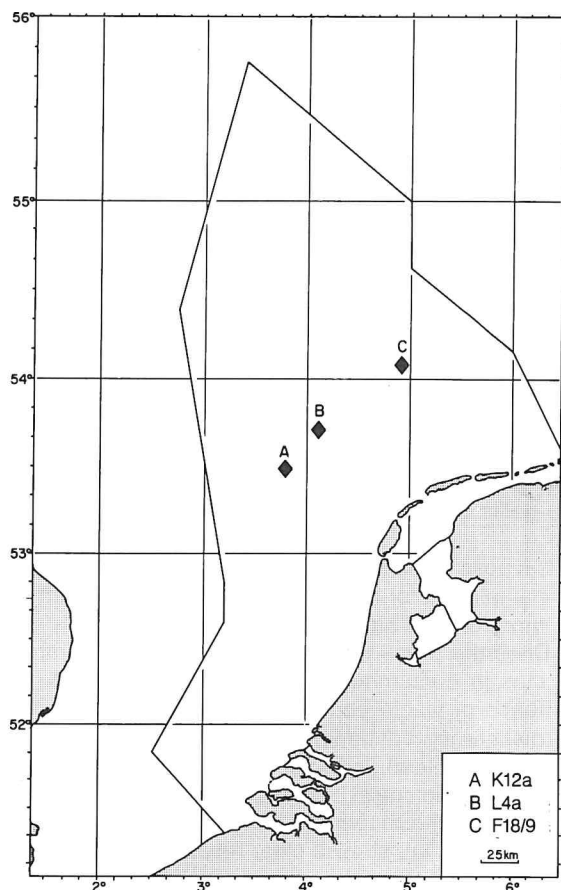


Fig. 1. Positions of drill sites sampled in 1987 and 1988. Solid line: border of the Dutch part of the continental shelf.

1987 and 1988, respectively, to investigate long-term effects. In addition to the routine monitoring program around K12a, a first tentative study was made, using sediment from this location, to investigate biological effects of OBM discharge in an experimental ecosystem. To this end a modest 4 boxcosms were incubated in the laboratory. Finally, for the first time a drilling location was surveyed in the sedimentation area (F18.9). From 3 stations of the sampling grid a number of intact bottom cores was collected for extensive investigations, to explore the potentialities of mesocosms, with respect to an experimental approach of effect studies.

In this report the results of the fieldwork and the indoor incubations will be treated for each location separately. In the discussion different methods are compared and a review is given of the sensitiveness of a number of macrofauna species to discharge of OBM-contaminated cuttings, based on evidence obtained from all 11 surveys performed since 1985.

1.2 ACKNOWLEDGEMENTS

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 Drs. S.A. de Jong (RWS, North Sea Directorate), secretary
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2. METHODS

2.1 FIELD SURVEYS

2.1.1 SAMPLING

Near each drilling location sampling stations were chosen at varying distances along two transects, one running parallel with the residual current and one perpendicular to the first transect, the distance be-

TABLE 1
Locations investigated in 1987 and 1988.

Location	Position	Drilling activities	Area	Survey	Remarks	Report
L4a	53°43'40"N 04°06'15"E	Previous drilling with WBM in Jan. '85; drilling of 2 wells in Aug.-Oct. 1986 with low aromatic OBM; tot. emission: 912 tonnes OBM: 555 tonnes oil: 178 tonnes	Transition zone, fine sand with silt, depth 35 m. Platform present	May '86	'Baseline' (only WBMs discharged)	MULDER <i>et al.</i> , 1988
				Sept. '86	Drilling not yet finished	MULDER <i>et al.</i> , 1988
				Febr. '87		This report
				June '87	Additional photosurvey (Sept. 1987)	This report
K12a	53°28'36.2"N 03°47'19.4"E	5 Wells drilled with diesel and low-tox OBM, between Febr. '83 and Nov. '84; tot. emission: 2278 tonnes. OBM: 1082 tonnes oil: 393 tonnes	Transition zone, fine sand with silt, depth 28 m. Platform present	Sept. '85		MULDER <i>et al.</i> , 1987
				Sept. '86		MULDER <i>et al.</i> , 1988
				Sept. '87	Additional photosurvey	This report
				Sept. '88	4 boxcosms	This report
F18/9	54°06'09.8"N 04°45'25.1"E	1 Well drilled with OBM in May 1987; tot. emission: 1912 tonnes. OBM: 819 tonnes, oil: 283 tonnes	Sedimentation area, silt, depth 42 m. Deserted location	June '88	17 boxcosms (collected Sept. 1988)	This report

tween stations getting smaller in the close vicinity of the platform (Table 2). The outermost stations, at 5 km from the discharge point, were assumed to represent a reference situation, to which possible spatial effects could be related (MULDER *et al.*, 1988).

Samples were collected with a 0.2 m² Van Veen grab, usually 10 per station, but sometimes less within 100 m from the platform for safety reasons. At F18.9, where no platform was present, 8 samples were taken at all stations. From the grab samples

TABLE 2
Survey data and number of collected (=coll.) and analysed (=an.) samples per station; RC=residual current transect, PT=perpendicular transects.

[illegible]

small duplicate cores were collected for chemical and grain size analyses and immediately frozen at -20° until later analysis (see VAN HET GROENEWOUD, 1990). Then the contents of the grab were washed through a sieve (mesh size 1 mm) and the residual macrofauna was preserved in a 6% neutralized formaldehyde solution.

2.1.2 TREATMENT OF SAMPLES IN THE LABORATORY

In the laboratory the samples were stained with Bengal rose and sorted under a stereomicroscope. Then, molluscs, crustaceans, polychaetes and echinoderms were identified and counted on species level. (N.B. In this report the following acronyms are used: POL = Polychaeta, MOL = Mollusca, CRU = Crustacea, ECH = Echinodermata). Remaining taxa were not further identified and only recorded at higher taxonomic levels. Fragments of the animals were not counted, when the head was absent in the sorted material.

Not all samples were analysed. Particularly the material of L4a and K12a was considerably reduced to meet a workable proposition (Table 2). Only for F18.9 nearly all samples were analyzed.

Oil analyses were performed using the GCMS technique (gas chromatograph mass spectrometer). Concentrations of the fractions of alkanes (C_9 - C_{32}), unidentified complex matter (UCM) and 'other components' were quantified. Methods and results are presented in detail by VAN HET GROENEWOUD (1990).

2.1.3 STATISTICAL PROCEDURES

2.1.3.1. INDIVIDUAL SPECIES

From the data obtained during each survey the mean density ($n \cdot m^{-2}$) and the frequency of occurrence of all species in the samples could be derived (Table 25 - 29, appendix). To test whether possible effects on the distribution of individual species were statistically significant, 'logit regression' was used (JONGMAN *et al.*, 1987, chapter 3.3). This method is based on a mathematical model for presence-absence data, which describes the expected response when an explanatory variable changes along a gradient. The expected response here is the presence of at least one specimen of a species in an individual sample, the explanatory variable is the degree of sediment contamination, or instead the distance of the station to the platform. The model may be illustrated by the following theoretical example.

Let us consider a certain species which is susceptible to OBM-contaminants present in the sediment and, in consequence, occurs in lower densities in the vicinity of a drilling location than far off. It seems plausible then that the probability (p) of a species being present in a sample may be described by a sigmoid curve (Fig. 2). The curve satisfies the requirement that $0 \leq p \leq 1$. In a sensitive species p will be low in the vicinity of the platform and higher at the reference station (as illustrated in Fig. 2), whereas in opportunistic species the opposite is expected. Although the response variable can only be

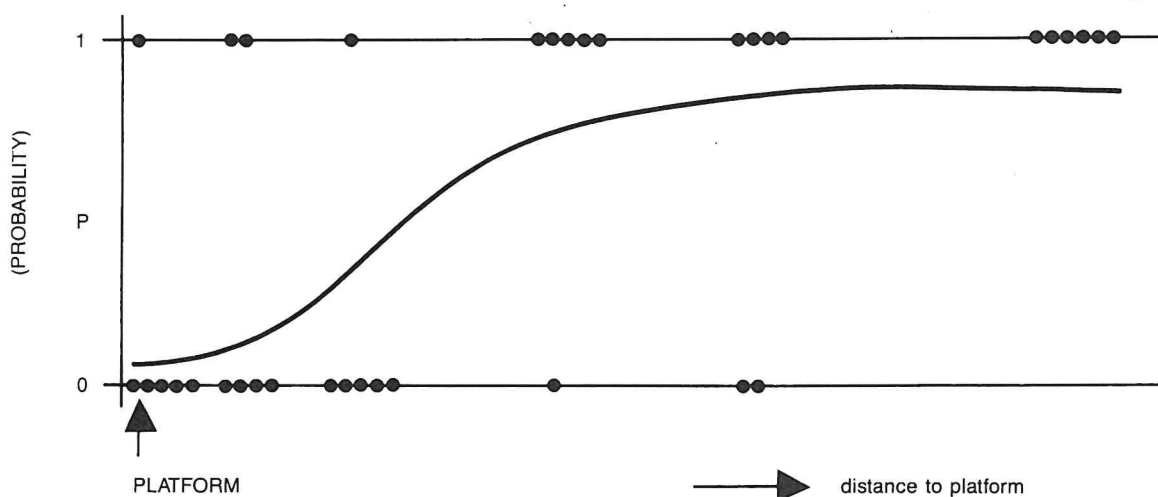


Fig. 2. Theoretical probability curve for the occurrence of a sensitive species in samples taken at increasing distance from a point-source of contamination. Simulated responses (presence or absence) are represented by black dots.

come 1 (species present in a sample) or 0 (species not present), the frequency of observed 1-values on a station will depend on the shape of the s-curve. A general model describing p as a function of the distance (x) to the platform is given by the equation:

$$p = \frac{e^{f(x)}}{1 + e^{f(x)}}$$

in which: $f(x) = b_0 + b_1 \cdot x$

Starting from the maximum likelihood principle, an iterative method can be applied (GENSTAT) to find a best fitting set of parameter values (b_0 and b_1) for $f(x)$. This method provides a set of parameter values for which the probability of the actually observed responses is maximal. A χ^2 test can now be applied of whether b_1 differs significantly from 0, or, in other words, to judge whether a significant gradient is present. For each survey logit regression was applied to those species of which at least 20 specimens were found. For stations at the residual current transect the real distance to the platform was used as the explanatory variable, for stations at the perpendicular transect the distance was multiplied by 1.5, in view of an ellipsoid distribution pattern to be expected around the discharge point (O'REILLY, 1989).

2.1.3.2. MACROBENTHIC COMMUNITY

Another statistical analysis was performed to determine the distance over which effects of pollution can be detected on the total macrobenthic community. This method is based on the mean relative abundance of all species along the surveyed transects. The procedure employed is as follows: For the individual species the mean density is considered on each of the (n) stations. These densities are arranged in order from lowest to highest. Then for each density a rank is substituted, according to well-known non-parametric methods, *i.e.* ranks range from 1 for the lowest density to n for the highest density. If any densities are equal, they are given the average of the tied ranks. When this procedure has been completed for all species, the mean rank, its variance and 95% confidence limits are calculated for each of the stations. Differences between mean ranks can now be tested for statistical significance by ANOVA. In the performance of this procedure only those species were included which had been identified on species level.

2.2 IN SITU PHOTOGRAPHS

Underwater photography was applied in September 1987 around the locations K12a and L4a, using the deep-shelf stereo camera system developed by Lob-siger Associates Ltd. (see WILDISH & LOBSIGER,

1987 or WILDISH *et al.*, 1990). The aim was to test the usefulness of this technique as a tool for monitoring the benthos.

Two cameras were mounted in a rigid frame at a separation of 20 cm. The distance between sediment surface and film was 40 cm. The cameras were loaded with rolls of Ektachrome color film. The field of view for a single camera was 44x66 cm and the separation resulted in a stereo-overlap of 0.2 m² (or nearly 70%). Two electronic strobes were set at an angle of 45° to the camera axis and an underwater video camera completed the system.

At location K12a 5 x 2 photographs were taken on each of 4 stations at the residual current transect, *viz.* 100 m, 250 m, 500 m and 5000 m. On the perpendicular transects photographs were taken at 250 m from the platform. After each set of photographs, the frame was hauled up and lowered again on the seabed at some distance of the previous position. Simultaneously, the benthos was sampled with a 0.2 m² Van Veen grab, to compare both methods and to find out, whether the photographs yield quantitative information on fauna abundance.

At location L4a the same grid of stations was photographed. However, no additional grab sampling was performed.

Sets of color prints were analyzed in the laboratory under a stereoscope. By the 3-D effect differences between holes, mounds and tubes, apparently belonging to different infauna species, became clearly visible. Transparent sheets were used to mark and count them.

2.3 BOXCOSM EXPERIMENTS

2.3.1 COLLECTING BOXCORES AND INCUBATION REGIME

Intact boxcores were collected with a (modified) Scripps boxcorer. The stainless steel boxes (50x50x60 cm) were furnished with a mica-teflon coating, to prevent the sediment from being contaminated with trace metals and to avoid the occurrence of redox potential differences between steel and sediment. The Scripps corer tended to dig about 40 cm deep, thus collecting the major sediment layers inhabited by the benthic infauna. On board the cores were placed in polyester containers or waterproof plywood cases with cooling-water and fixed in sand. The water on top of the cores was regularly changed during the transport to the laboratory. After transport the complete cases were placed in an indoor basin (Fig. 3) and incubated at $\approx 16^\circ\text{C}$. During the period of incubation, the temperature was gradually lowered to $\approx 10^\circ\text{C}$, according to *in situ* temperatures. The water on the cores was continuously replaced with filtered and O₂-saturated water from the Wad-



Fig. 3. Arrangement of the boxcosms in the indoor basin.

den Sea, with salinity varying between 27 and 31‰. Apart from inspections, incubation took place continuously in dark. During the period of incubation all boxes were inspected daily for mortality and activity of test animals and natural infauna. Epibenthic carnivores, like crabs, were removed to minimize mortality by predation. At termination of the experiments from all boxcosms 10 samples of the upper 10 cm sediment were collected with a tube corer (diameter 25 mm) for analysis of contamination by oil components (VAN HET GROENEWOUD, 1990). Then the sediment of the boxcosms was washed through a 1 mm sieve to collect the macrofauna, including the introduced test animals.

2.3.2 K12A: PROGRAM OF EXPERIMENTS

Boxcores were collected on September 23 (1987) at 2 stations on the residual current transect of K12a. The first station was situated ≈ 100 m from the platform, the second (reference) station at 5000 m. On both stations 3 cores were taken. One core was sieved over a 1 mm² mesh screen to determine the composition of the macrofauna at the start of the experiment. The other 2 cores were utilized for indoor incubation.

3 cores were supplied with adult *Echinocardium cordatum* (ECH), a common North Sea dweller of manageable size (≈ 4 cm), to study possible effects of pollution on behaviour, activity and mortality, and, thus, to examine the suitability of this organism as a

standard test object. On 10 November cores 100 m-A and 5000 m-A were stocked with 5 animals and on 7 December core 100 m-B with 10 animals.

In the course of the experiment redox-potential (Eh) has been measured 6 times in the 15 cm top layer of the sediment in cores 100 m-A and 5000 m-B, to obtain a rough measure of the balance between oxygen supply and consumption. To that end a Pt-electrode was utilized, which was calibrated against an Orion double function reference electrode (model 90-02). On 2 occasions duplicate measurements were performed.

The boxcosms were incubated for 5 months. On 21 February (1988) the experiments were terminated.

2.3.3 F 18.9: PROGRAM OF EXPERIMENTS

The boxcosms employed were bottom cores collected on the residual current transect of F 18.9. Based on the degree of pollution observed during the July survey, 3 stations were chosen, at distances of 50 m, 100 m and 5000 m from the discharge point. On 6 and 8 September all stations were first sampled with a Rheineck boxcorer (27x27x60 cm), to determine the benthic fauna composition at the start of the experiment. Per station 10 cores were taken and sieved immediately on deck on a 1 mm mesh screen. The samples were preserved in 6% formalin for later analysis in the laboratory. Then 6 Scripps cores were collected on each of the 50 m and 5000 m stations

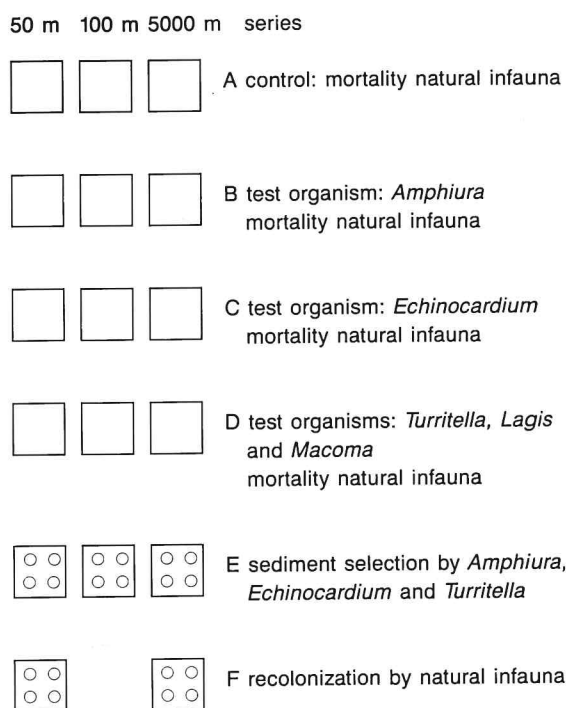


Fig. 4. Boxcosms F 18.9: Schedule of experiments. Test species: *Amphiura filiformis*, *Echinocardium cordatum*, *Turritella communis*, *Lagis koreni* and *Macoma balthica*.

and 5 on the 100 m station.

Series of 3 cores (1 core of each of the 3 stations) were each utilized for a different application (Fig. 4). One core series (A) was incubated without any treatment. On 3 other series adult test animals of different species were introduced. General conditions to which the test species chosen were required to conform are:

1. they should be common in large areas of the North Sea
2. they should be representatives of different higher taxonomic entities
3. the natural longevity of each species is more than one year
4. the animals have a suitable size to handle

Series B was stocked with *Amphiura filiformis* (ECH, ≈ 120 per box) on 26 September, series C with *Echinocardium cordatum* (ECH, 20 per box) on 27 September and series D with *Turritella communis* (MOL, 23 per box), *Lagis koreni* (POL, 27 per box) and *Macoma balthica* (MOL, 44 per box) on 27 September, 3 October and 6 October respectively. The size class of the test animals (only adult specimens were used) was in none of these species naturally present in the sediment, or only in fractional num-

bers. For all species the time was recorded during which the animals burrowed before they finally disappeared in the sediment. Series E was used for an experiment on sediment selection by test animals, in which duplicate cores (diameter 12 cm, depth 35 cm) were exchanged between boxes of all three stations (see Fig. 4). In this way about a fifth of the sediment in each box was replaced by sediment of the other ones. A mixture of three species, viz. *A. filiformis* (≈ 120 specimens), *T. communis* (21 specimens) and juvenile *E. cordatum* (diameter ≈ 2 cm, 30 specimens), was introduced in each box. After termination of the experimental period the animals present in the matrix sediment and in the changed cores were counted separately. An alternative recolonization experiment was performed with the boxcosms of the F-series. This series consisted only of boxes from the 50-m and the 5000-m station. In both boxcosms 4 tubes (diameter 12 cm) were placed in the sediment. The water overlying these sediment enclosures was purged with nitrogen gas for two weeks, to create anaerobic conditions and, thus, to expel all animal life from the cores. Then two of the cores were exchanged between the boxcosms, to study recolonization of the cores by the natural infauna present in the surrounding matrix.

3 RESULTS

3.1 PLATFORM L4A

3.1.1 GENERAL REMARKS

The operational platform L4a is situated in the transition zone between sand and silty sediment (Fig. 1). The location was drilled for the first time in 1985 with WBM. In July 1986 drilling was continued and now OBM were employed (Table 1). The 2 surveys carried out in 1987 were the last in a series of three, following a baseline study in May 1986 (MULDER *et al.* 1988), and were meant to detect short term effects of discharged OBM. During the February 1987 survey, 5 stations were sampled. Due to weather conditions the station nearest to the platform was at about 100 m distance and only 2 samples were taken here. A total number of 30 samples has been analyzed, which yielded 97 identified species. In June 1987 a more extensive program was carried out: 10 stations were visited, among which the platform itself. The analysis of 76 samples has resulted in 111 identified species. Their percentual occurrence in the samples is given in Tables 3 and 4.

3.1.2 SURVEY FEBRUARY 1987 (4 MONTHS AFTER OBM-DRILLING)

In the samples collected during the February survey, *Amphiura filiformis* dominated the macrofauna by

TABLE 3

Data platform L4a, survey Febr.1987. Percentage of occurrence of each species in the total number of analysed samples (30).

POLYCHAETA			
<i>Aphrodita aculeata</i>	20.00	<i>Mya spec. juv.</i>	3.33
<i>Harmothoe lunulata</i>	33.33	<i>Corbula gibba</i>	13.33
<i>Harmothoe longisetis</i>	23.33	<i>Thracia convexa</i>	43.33
<i>Gattyana cirrosa</i>	73.33	<i>Cingula nitida</i>	36.67
<i>Pholoe minuta</i>	93.33	<i>Turritella communis</i>	73.33
<i>Sthenelais limicola</i>	36.67	<i>Cylichna cilindracea</i>	76.67
<i>Eteone longa</i>	10.00	<i>Philine catena</i>	53.33
<i>Eteone lactea</i>	3.33		
<i>Anaitides groenlandica</i>	50.00	CRUSTACEA	
<i>Eumida sanguinea</i>	13.33	<i>Processa parva</i>	3.33
<i>Ophiidromus flexuosus</i>	46.67	<i>Pontophilus trispinosus</i>	3.33
<i>Gyptis capensis</i>	70.00	<i>Pagurus bernhardus</i>	3.33
<i>Synelmis klatti</i>	16.67	<i>Macropipus holsatus</i>	10.00
<i>Autolytus spec.</i>	13.33	<i>Ebalia cranchii</i>	36.67
<i>Nereis longissima</i>	13.33	<i>Corystes cassivelaunus</i>	16.67
<i>Nereis spec. juv.</i>	20.00	<i>Upogebia deltaura</i>	3.33
<i>Nephtys hombergii</i>	93.33	<i>Upogebia spec. juv.</i>	20.00
<i>Glycera rouxii</i>	90.00	<i>Callianassa subterranea</i>	63.33
<i>Glycinde nordmanni</i>	53.33	<i>Callianassa spec. juv.</i>	53.33
<i>Goniada maculata</i>	93.33	<i>Decapoda larven</i>	13.33
<i>Lumbrineris latreilli</i>	100.00	<i>Nebalia bipes</i>	10.00
<i>Lumbrineris fragilis</i>	53.33	<i>Gastrosaccus spinifer</i>	3.33
<i>Driloneris filum</i>	16.67	<i>Mysiden larven</i>	3.33
<i>Scoloplos armiger</i>	6.67	<i>Eudorella truncatula</i>	13.33
<i>Orbinia sertulata</i>	16.67	<i>Ipinoe trispinosa</i>	33.33
<i>Poecilochaetus serpens</i>	3.33	<i>Diastylis bradyi</i>	90.00
<i>Spio filicornis</i>	3.33	<i>Cirolana borealis</i>	10.00
<i>Polydora guillei</i>	3.33	<i>Melita dentata</i>	3.33
<i>Spiophanes kroyeri</i>	3.33	<i>Atylus swammerdami</i>	3.33
<i>Spiophanes bombyx</i>	10.00	<i>Orchomenella nana</i>	40.00
<i>Scolecopsis foliosa</i>	30.00	<i>Sthenothoe marina</i>	6.67
<i>Magelona papillicornis</i>	3.33	<i>Ampelisca brevicornis</i>	13.33
<i>Chaetopterus variopedatus</i>	73.33	<i>Ampelisca tenuicornis</i>	20.00
<i>Tharyx marioni</i>	43.33	<i>Ampelisca spec. juv.</i>	6.67
<i>Chaetozone setosa</i>	80.00	<i>Urothoe poseidonis</i>	3.33
<i>Diplocirrus glaucus</i>	93.33	<i>Bathyporeia elegans</i>	6.67
<i>Scalibregma inflatum</i>	13.33	<i>Bathyporeia tenuipes</i>	3.33
<i>Ophelina acuminata</i>	3.33	<i>Harpinia antennaria</i>	53.33
<i>Capitella capitata</i>	3.33	<i>Perioculodes longimanus</i>	50.00
<i>Notomastus latericeus</i>	46.67	<i>Aora typica</i>	10.00
<i>Heteromastus filiformis</i>	56.67		
<i>Owenia fusiformis</i>	30.00	ECHINODERMATA	
<i>Polycirrus medusa</i>	3.33	<i>Asterias rubens</i>	6.67
<i>Lagis koreni</i>	33.33	<i>Amphiura filiformis</i>	100.00
<i>Ampharete acutifrons</i>	3.33	<i>Amphiura chiajei</i>	63.33
<i>Amphicteis gunneri</i>	10.00	<i>Ophiura texturata</i>	3.33
<i>Sosane gracilis</i>	6.67	<i>Ophiura albida</i>	50.00
<i>Lysilla loveni</i>	36.67	<i>Ophiura spec. juv.</i>	56.67
		<i>Echinocardium cordatum</i>	13.33
MOLLUSCA			
<i>Nucula turgida</i>	63.33	OTHER TAXA	
<i>Thyasira flexuosa</i>	3.33	<i>Nemertinea</i>	100.00
<i>Montacuta ferruginosa</i>	20.00	<i>Turbellaria</i>	53.33
<i>Mysella bidentata</i>	90.00	<i>Phoroniden</i>	76.67
<i>Arctica islandica</i>	33.33	<i>Harp. copepoda</i>	3.33
<i>Acanthocardia echinata</i>	6.67	<i>Oligochaeta</i>	23.33
<i>Dosinia exoleta</i>	3.33	<i>Holothuroidea</i>	23.33
<i>Dosinia lupinus</i>	6.67	<i>Sagitta spec.</i>	3.33
<i>Venus striatula</i>	33.33	<i>Sipunculida</i>	80.00
<i>Mysia undata</i>	6.67	<i>Anthozoa</i>	10.00
<i>Tellina fabula</i>	6.67	<i>Ascidacea</i>	6.67
<i>Abra alba</i>	16.67		
<i>Cultellus pellucidus</i>	3.33		

TABLE 4

Data platform L4a, survey June 1987. Percentage of occurrence of each species in the total number of analysed samples (76).

POLYCHAETA					
<i>Aphrodita aculeata</i>	14.47	<i>Amphiteis gunneri</i>	2.63	<i>Nebalia bipes</i>	5.26
<i>Harmothoe lunulata</i>	9.21	<i>Sosane gracilis</i>	5.26	<i>Schistomysis ornata</i>	5.26
<i>Harmothoe longisetis</i>	27.63	<i>Lysilla loveni</i>	38.16	<i>Eudorella truncatula</i>	30.26
<i>Gattyana cirrosa</i>	88.16	<i>Terebellides stroemi</i>	6.58	<i>Iphinoe trispinosa</i>	5.26
<i>Polynoe kinbergi</i>	22.37	MOLLUSCA		<i>Pseudocuma longicornis</i>	1.32
<i>Pholoe minuta</i>	84.21			<i>Diastylis bradyi</i>	67.11
<i>Sthenelais limicola</i>	27.63	<i>Nucula turgida</i>	50.00	<i>Lamprops fasciata</i>	1.32
<i>Eteone longa</i>	11.84	<i>Modiolus modiolus</i>	1.32	<i>Cirolana borealis</i>	6.58
<i>Eteone lactea</i>	3.95	<i>Thyasira flexuosa</i>	11.84	<i>Ione thoracica</i>	6.58
<i>Eteone flava</i>	5.26	<i>Lepton squamosum</i>	5.26	<i>Orchomenella nana</i>	9.21
<i>Anaitides groenlandica</i>	30.26	<i>Montacuta ferruginosa</i>	17.11	<i>Leucothoe incisa</i>	5.26
<i>Anaitides maculata</i>	3.95	<i>Mysella bidentata</i>	82.89	<i>Metopa spec. juv.</i>	1.32
<i>Eumida sanguinea</i>	7.89	<i>Arctica islandica</i>	48.68	<i>Ampelisca brevicornis</i>	3.95
<i>Ophiodromus flexuosus</i>	38.16	<i>Acanthocardia echinata</i>	2.63	<i>Ampelisca tenuicornis</i>	21.05
<i>Gyptis capensis</i>	25.00	<i>Dosinia lupinus</i>	7.89	<i>Ampelisca spec. juv.</i>	19.74
<i>Synelmis klatti</i>	31.58	<i>Venus striatula</i>	36.84	<i>Urothoe poseidonis</i>	10.53
<i>Autolytus spec.</i>	19.74	<i>Mysia undata</i>	14.47	<i>Bathyporeia elegans</i>	5.26
<i>Nereis longissima</i>	13.16	<i>Tellina fabula</i>	1.32	<i>Bathyporeia tenuipes</i>	3.95
<i>Nereis spec. juv.</i>	35.53	<i>Abra alba</i>	15.79	<i>Harpinia antennaria</i>	43.42
<i>Nephtys hombergii</i>	85.53	<i>Cultellus pellucidus</i>	36.84	<i>Pericardium longimanus</i>	46.05
<i>Nephtys caeca</i>	1.32	<i>Mya arenaria</i>	1.32	<i>Westwoodilla caecula</i>	1.32
<i>Nephtys spec. juv.</i>	7.89	<i>Mya spec. juv.</i>	18.42	<i>Aora typica</i>	2.63
<i>Glycera rousii</i>	59.21	<i>Corbula gibba</i>	18.42	<i>Jassa falcata</i>	5.26
<i>Glycera spec. juv.</i>	44.74	<i>Thracia convexa</i>	39.47	ECHINODERMATA	
<i>Glycinde nordmanni</i>	55.26	<i>Cingula nitida</i>	11.84	<i>Astropecten irregularis</i>	2.63
<i>Goniada maculata</i>	88.16	<i>Turritella communis</i>	72.37	<i>Asterias rubens</i>	5.26
<i>Lumbrineris latreilli</i>	98.68	<i>Natica alderi</i>	5.26	<i>Amphiura filiformis</i>	84.21
<i>Lumbrineris fragilis</i>	51.32	<i>Aporrhais pespelecar</i>	2.63	<i>Amphiura chiajei</i>	42.11
<i>Driloneris filum</i>	7.89	<i>Buccinum undatum</i>	6.58	<i>Ophiura texturata</i>	13.16
<i>Scoloplos armiger</i>	5.26	<i>Cylindrina cylindracea</i>	31.58	<i>Ophiura albida</i>	28.95
<i>Orbinia sertulata</i>	7.89	<i>Philine catena</i>	28.95	<i>Ophiura spec. juv.</i>	50.00
<i>Poecilochaetus serpens</i>	1.32	CRUSTACEA		<i>Echinocardium cordatum</i>	21.05
<i>Spio filicornis</i>	6.58			OTHER TAXA	
<i>Polydora guillei</i>	13.16	<i>Crangon crangon</i>	1.32	<i>Nemertinea</i>	94.74
<i>Spiophanes kroyeri</i>	2.63	<i>Processa parva</i>	1.32	<i>Turbellaria</i>	64.47
<i>Spiophanes bombyx</i>	18.42	<i>Pontophilus trispinosus</i>	2.63	<i>Phoroniden</i>	60.53
<i>Scolecopsis foliosa</i>	19.74	<i>Pagurus bernhardus</i>	7.89	<i>Harp. copepoda</i>	3.95
<i>Magelona allenii</i>	10.53	<i>Macropipus holsatus</i>	2.63	<i>Parasitaire copepoda</i>	10.53
<i>Chaetopterus variopedatus</i>	69.74	<i>Macropipus spec. juv.</i>	2.63	<i>Oligochaeta</i>	18.42
<i>Tharyx marioni</i>	51.32	<i>Ebalia cranchii</i>	25.00	<i>Holothuroidea</i>	15.79
<i>Chaetozone setosa</i>	86.84	<i>Corystes cassivelaunus</i>	6.58	<i>Sagitta spec.</i>	1.32
<i>Diplocirrus glaucus</i>	85.53	<i>Macropodia spec.</i>	1.32	<i>Echiurida</i>	25.00
<i>Scalibregma inflatum</i>	56.58	<i>Upogebia stellata</i>	3.95	<i>Sipunculida</i>	63.16
<i>Ophelina acuminata</i>	13.16	<i>Upogebia deltaura</i>	22.37	<i>Anthozoa</i>	21.05
<i>Capitella capitata</i>	13.16	<i>Upogebia spec. juv.</i>	6.58	<i>Ascidacea</i>	31.58
<i>Notomastus latericeus</i>	63.16	<i>Callianassa subterranea</i>	75.00	<i>Priapulida</i>	7.89
<i>Heteromastus filiformis</i>	21.05	<i>Callianassa spec. juv.</i>	11.84	<i>Arthropoda</i>	1.32
<i>Owenia fusiformis</i>	53.95	<i>Decapoda larven</i>	11.84		
<i>Lagis koreni</i>	6.58				

numbers (Table 25) (Appendix). The species occurred in average densities of $\approx 1000 \text{ ind} \cdot \text{m}^{-2}$ in the area. However, at the 100-m station densities were obviously lower ($35 \cdot \text{m}^{-2}$). A similar trend was observed in the other relatively abundant species

($> 10 \cdot \text{m}^{-2}$): *Pholoe minuta*, *Nephtys hombergii*, *Chaetopterus variopedatus*, *Chaetozone setosa*, *Diplocirrus glaucus*, *Mysella bidentata* and *Turritella communis* all showed decreasing densities at the 100 m station. No indication of such a trend was

TABLE 5

L4a Febr. 1987. List of species showing a significant density gradient (logit regression). Sign of the gradient (+/-) and significance level are indicated. +: Increasing densities off the location; -: Decreasing densities off the location.

	Sign	Signif. level (%)
<i>Heteromastus filiformis</i>	-	0.5
<i>Lysilla loveni</i>	+	0.5
<i>Turritella communis</i>	+	1
<i>Ampelisca tenuicornis</i>	+	0.1
<i>Harpinia antennaria</i>	+	0.1

found in *Goniada maculata*, *Lumbrineris latreilli* and *Diastylis bradyi*. Two species that were absent at the 100-m station, *Lysilla loveni* and *Harpinia antennaria*, showed a conspicuous gradient along the transect to high densities at the 5000-m reference station. Other species did not show a clear gradient, or were too few to detect any such. Moreover, the low number of samples taken at the 100-m station makes apparent differences in abundance of individual species less conclusive. However, the number of species found (19 in 2 samples) is considerably lower than expected, if species richness were similar to that at other stations (61 to 69 in 6 to 10 samples).

Logit regression was applied to 30 species that occurred at least 20 times in the samples. Testing at the 5% significance level, the H_0 hypothesis, that a density gradient was not present, was rejected in 5 species (Table 5). In a series of 30 tests this is hardly more than could be expected, if H_0 were true for all species. However, in all 5 species the gradient was also statistically significant at the 1% level, in 4 species significance was reached at the 0.5% level and 2 species showed significant gradients even at the 0.1% level, which is statistically unlikely to occur, if H_0 were true. In other words, a gradient in macrofaunal densities has been statistically verified, although in only a few species. In 4 species the gradient was positive, *i.e.* densities increasing with increasing distance to the platform, and not only evident by their presence-absence response in the samples, as tested by logit regression, but also by densities observed at each of the stations as described before. It should be noted that statistical significance for a positive gradient was detected by logit regression only in species that showed increasing densities over the whole transect. In none of the species that were absent at the 100-m station, but present in steady abundance between 250 and 5000 m, was statistical significance detected. Undoubtedly, the number of samples collected at the 100-m station was too low to detect statistical significance.

One species, *Heteromastus filiformis*, displayed a negative density gradient. The species was absent at the 5000-m reference station, but present in $\geq 50\%$

of the samples of the other stations.

Mean relative abundance of the whole macrofauna was remarkably low at the 100-m station (Fig. 5). Application of ANOVA resulted in rejection of H_0 , that all stations could represent the same macrofauna composition, even at the 0.1% level. When the data set of the 100-m station were excluded, the same test detected no significant differences between the stations. Consequently, the 100-m station may be concluded to be poor in macrofauna, whereas among the 250 - 5000-m stations no significant differentiation in relative abundance could be found.

3.1.3 SURVEY JUNE 1987 (8 MONTHS AFTER OBM-DRILLING)

In common with the February survey, the June survey to L4a revealed large numbers of *Amphiura filiformis* ($\approx 1000 \cdot m^{-2}$, Table 26). To a lesser extent the fauna in the area was also dominated by *Lumbrineris latreilli* ($\approx 250 \cdot m^{-2}$). *Amphiura*, however was not found at the PI-station and occurred in somewhat lower densities at the 100 m station. *Lumbrineris* only displayed reduced numbers at the PI-station, but was particularly abundant at the 100-m and 250-m stations. This picture, absence or strongly reduced densities right beneath the platform, was observed in most species and is illustrated by the remarkably low number of species found at this station (25 compared to 57 - 71 at the other stations), in spite of the maximum number of 10 samples analyzed.

Nearly all more or less abundant species ($\geq 10 \cdot m^{-2}$) occurred in low numbers at the PI-station, as was clearly observed in *Gattyana cirrosa*, *Pholoë minuta*, *Nephtys hombergi*, *Chaetopterus variopedatus*, *Chaetozone setosa*, *Diplocirrus glaucus*, *Mysella bidentata*, *Turritella communis*, *Callianassa subterranea*, and *Harpinia antennaria*. The

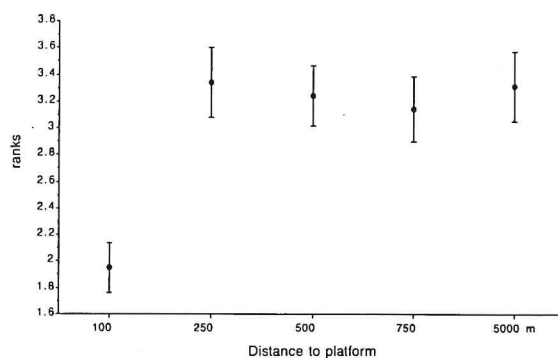


Fig. 5. L4a Febr. 1987: Relative macrofauna abundance (mean ranks and 95% confidence limits).

latter 6 species were also relatively scarce at the 100-m station. Only in *Goniada maculata* no indication of lower abundance near the platform was found. Two species, viz. *Capitella capitata* and *Pagurus bernardus* (a hermit crab, living on top of the sediment), apparently took advantage of the deviant conditions near the platform. Both were found exclusively at the PI-station, and that in fair numbers. Some of the less abundant species seemed to display a clear gradient along the whole residual current transect and the perpendicular transect as well. Such a gradient was most evident in *Polynoe kinbergi*, *Lysilla loveni*, *Montacuta ferruginosa*, *Harpinia antennaria* and *Echinocardium cordatum*.

Logit regression was applied to 41 species, of which at least 20 specimens were found in this survey. At the 5% level 14 species showed a significant response in frequency of occurrence in the samples to distance of the sampling station from the platform (Table 6). In 11 species such a presence-absence gradient was even significant at the 0.1% level. Frequency of occurrence in the samples increased in 11 species with increasing distance to the platform (positive gradients). For most of these species such increase was shown also by their densities, as described above, except for *Spiophanes bombyx* and *Owenia fusiformis*, because both species occurred in numbers lower than 10 ind·m⁻². The negative trend mentioned earlier for 2 species was statistically confirmed by logit regression, and was also detected (5% level) for *Anaitides groenlandica*, partly due to its frequent occurrence at the 100 m station. Most gradients were restricted to the area within 250 m of the platform, but in 5 species, *Polynoe kinbergi*, *Lysilla loveni*, *Montacuta ferruginosa*, *Harpinia antennaria* and *Echinocardium cordatum*, increasing frequency of occurrence in the samples proceeded to ≥ 500 m.

Fig. 6, showing relative abundance of all macro-

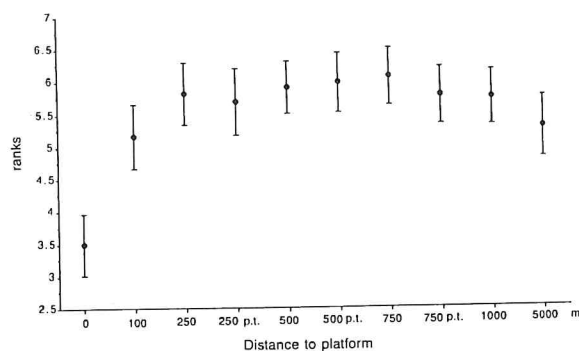


Fig. 6. L4a June 1987: Relative macrofauna abundance (mean ranks and 95% confidence limits).

TABLE 6

L4a June 1987. List of species showing a significant density gradient (logit regression). Sign of the gradient (+/-) and significance level are indicated. +: Increasing densities off the location; -: Decreasing densities off the location.

	Sign	Signif. level (%)
<i>Polynoe kinbergi</i>	+	0.1
<i>Anaitides groenlandica</i>	-	5
<i>Nephtys hombergi</i>	+	0.1
<i>Spiophanes bombyx</i>	+	1
<i>Diplocirrus glaucus</i>	+	0.1
<i>Capitella capitata</i>	-	0.1
<i>Owenia fusiformis</i>	+	0.5
<i>Lysilla loveni</i>	+	0.5
<i>Montacuta ferruginosa</i>	+	0.1
<i>Mysella bidentata</i>	+	0.1
<i>Turritella communis</i>	+	0.1
<i>Pagurus bernhardus</i>	-	0.1
<i>Harpinia antennaria</i>	+	0.1
<i>Amphiura filiformis</i>	+	0.1

fauna species in the area, confirms the general idea of a strongly reduced fauna at the PI-station and a slightly reduced fauna at the 100-m station. The 250-m stations on the residual current and perpendicular transect do not seem to be affected in fauna abundance. The result of application of ANOVA was that the PI-station was significantly (0.1% level) poorer in fauna, whereas the other stations, including the 100-m station, might all be representative of the same parent distribution.

3.1.4 COMPARISON WITH PRECEDING SURVEYS

In the period between May 1986 and June 1987 4 surveys were carried out to the area around L4a, during which 232 samples were taken at 14 different stations. Together these surveys yielded 146 species (identified on species level). The number of species found per survey was rather variable, due to differences in sampling intensity (e.g. compare 122 species in 88 samples from 14 stations in May 1986 to 97 species in 30 samples from 5 stations in February 1987). The development of the species richness of the area should, however, rather be judged by comparing only those stations that were sampled during each survey, i.e. stations 250, 500, 750 and 5000 m, all on the residual current transect. At these stations the following numbers of species were found:

May 1986:	28	samples	yielded	98	species
Sept 1986:	24	„	„	95	„
Febr 1987:	28	„	„	96	„
June 1987:	31	„	„	101	„

These statistics show that the overall species richness of the area has not appreciably changed. As a consequence it is concluded that changes in species

richness on individual stations should not be attributed to overall changes due to natural annual fluctuations.

Still the macrofauna composition seems to have changed. This may be inferred from the differences in abundance of several species displayed by the baseline records of 1986 on the one hand and those of 1987 on the other (Table 7). This table compares only mean densities at stations that were sampled on both, the baseline survey and the February or June survey. The species listed were selected according to the following criteria:

- The highest mean density in one of the surveys is $\geq 1 \text{ ind} \cdot \text{m}^{-2}$
- The difference between lowest and highest abundance within a survey is less than about 1 order of magnitude (except when a gradient is present.)
- The difference between mean densities should be more than a factor 2 (June survey) or 4 (February survey), or $> 100 \text{ ind} \cdot \text{m}^{-2}$. (For June and February different criteria were used, because of the different number of corresponding stations sampled during the baseline study.)

TABLE 7

Platform L4a: comparison of the surveys of 1987 with the baseline survey of 1986. Species showing substantial changes at corresponding stations. Corresponding stations are: May 1986 - Febr 1987: 250, 500, 750 and 5000 m (all res. cur. transect; May 1986 - June 1987: 250, 500, 750, 1000 and 5000 m (res. cur. transect), 250, 500 and 750 m (perp. transect).

	$(n \cdot m^{-2})$		increase(+) / decrease(-) / no change(=)	$(n \cdot m^{-2})$		increase(+) / decrease(-) / no change(=)
	May 1986	Febr 1987		May 1986	June 1987	
<i>Philine catena</i>	0.0	3.8	+	0.0	2.8	+
<i>Scololepis foliosa</i>	0.0	2.1	+	0.0	1.8	+
<i>Scalibregma inflatum</i>	0.0	1.4	+	0.1	10.8	+
<i>Cultellus pellucidus</i>	(0 - 1)		=	0.2	2.7	+
<i>Gattyana cirrosa</i>	2.4	9.7	+	2.3	20.1	+
<i>Chaetopterus variopedatus</i>	1.9	17.4	+	2.3	14.5	+
<i>Perioculodes longimanus</i>	0.8	3.4	+	0.6	3.5	+
<i>Arctica islandica</i>	(0 - 4)		=	1.4	7.1	+
<i>Diplocirrus glaucus</i>	12.3	49.8	+	11.5	53.4	+
<i>Synelmis klatti</i>	(0 - 3)		=	0.7	2.8	+
<i>Lumbrineris latreilli</i>	(70-190)		=	146	240	+
<i>Lysilla loveni</i>	3.4	19.2	+ $\geq 750 \text{ m}$	4.4	25.2	+ $\geq 750 \text{ m}$
	8.0	0.4	- $\leq 500 \text{ m}$	6.7	1.3	- $\leq 500 \text{ m}$
<i>Harpinia antennaria</i>	(6 - 60)		= $\geq 500 \text{ m}$	(6 - 60)		= $\geq 500 \text{ m}$
	22.5	1.0	- 250 m	34.6	0.0	- 250 m
<i>Polynoe kinbergi</i>	5.5	0.0	-	(1 - 20)		= $\leq 750 \text{ m}$
			-	4.3	0.0	$\leq 500 \text{ m}$
<i>Montacuta ferruginosa</i>	(0 - 10)		=	(1 - 10)		= $\geq 750 \text{ m}$
			-	3.8	0.2	$\leq 500 \text{ m}$
<i>Echinocardium cordatum</i>	7.8	1.5	-	(1 - 12)		= $\geq 750 \text{ m}$
			-	5.9	0.4	$\leq 500 \text{ m}$
<i>Heteromastus filiformis</i>	(0 - 12)		=	5.5	2.0	-
<i>Cylichna cylindracea</i>	(4 - 24)		=	17.4	4.0	-
<i>Sthenelais limicola</i>	(0.5 - 5)		=	5.4	1.2	-
<i>Ophiura albida</i>	(2 - 20)		=	12.3	2.5	-
<i>Amphicteis gunneri</i>	(0 - 4)		=	1.1	0.2	-
<i>Amphiura chiajei</i>	(5 - 20)		=	28.3	4.9	-
<i>Terebellides stroemi</i>	4.4	0.0	-	3.5	0.5	-
<i>Lagis koreni</i>	(0.5 - 6)		=	3.6	0.5	-
<i>Upogebia stellata</i>	3.6	0.0	-	4.2	0.3	-
<i>Ampelisca tenuicornis</i>	1.5	17.5	+ 5000 m	(0 - 9)		=
	4.7	0.0	- $\leq 750 \text{ m}$			
<i>Lumbrineris fragilis</i>	0.8	5.1	+	(0 - 8)		=
<i>Ebalia cranchii</i>	0.5	3.2	+	(0 - 4)		=
<i>Spiophanes bombyx</i>	2.4	0.5	-	(0 - 7)		=
<i>Ophelina acuminata</i>	1.4	0.1	-	(0 - 4)		=

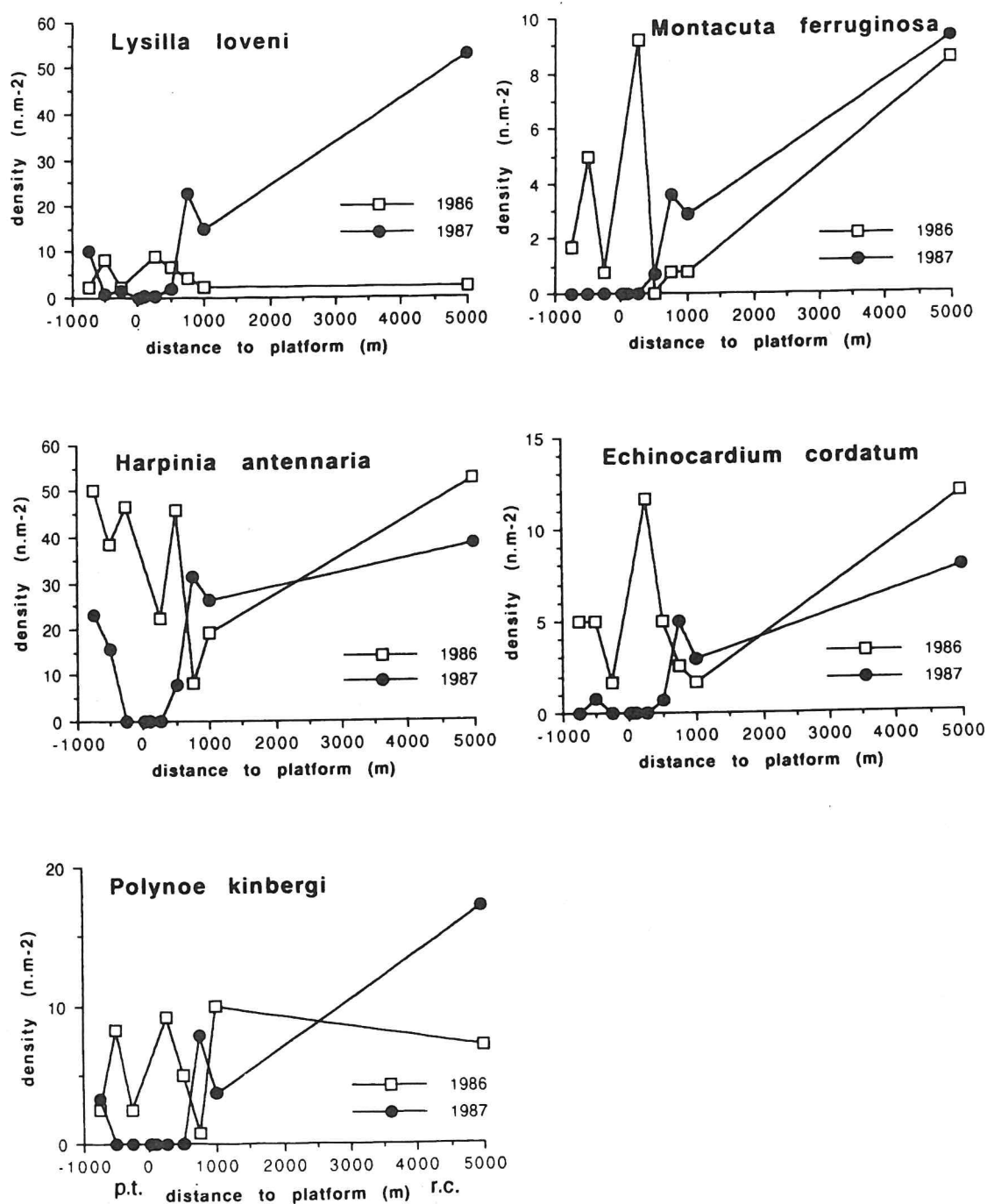


Fig. 7. Platform L4a: Distribution patterns of 5 macrofauna species on the perpendicular transect (p.t.) and residual current transect (r.c.) in May 1986 (before OBM-drilling) and in June 1987 (after OBM-drilling).

The comparison between the baseline data and those of June 1987 is most suitable, since these data sets may be assumed to show hardly any differences due to seasonal variability. Moreover, the number of corresponding stations surveyed in May 1986 and

June 1987 (8) is high compared to those surveyed in May 1986 and February 1987 (4).

Among the species found in June 1987, 12 species showed a substantial increase in the area ≥ 250 m off the platform. In 6 of these species (*Philine cate-*

na, *Scololepis foliosa*, *Scalibregma inflatum*, *Chaetopterus variopedatus*, *Synelmis klatti* and *Lumbrineris latreilli*), the increase was particularly obvious within 1000 m of the platform, although all showed strongly reduced numbers at the platform itself. In 9 species an overall decrease in abundance was observed and in 2 of them (*Sthenelais limicola* and *Lagis koreni*) this decrease manifested itself most clearly within 1000 m. Finally, in 5 species, an evident decrease was observed within 250 m (*Harpinia antennaria*) or 500 m (*Lysilla loveni*, *Polynoe kinbergi*, *Montacuta ferruginosa* and *Echinocardium cordatum*), whereas their densities outside this area appeared to be stable or even strongly increased (*Lysilla loveni*, see Fig. 7).

50% of the observed density changes in June were already indicated by the results of the February survey. For a few species that showed such changes in February (*Ampelisca tenuicornis*, *Lumbrineris fragilis*, *Spiophanes bombyx*, *Ebalia cranchi* and *Ophelina acuminata*), no confirmation was obtained in June. This might possibly be explained by a seasonal effect, e.g. caused by seasonal differences in burrowing depths of these animals.

As in individual species, the development of total macrofauna abundance can be described only by considering those stations that were sampled during each survey (Table 8). Since the macrofauna at L4a was consistently dominated by 2 species (*Amphiura filiformis* and *Lumbrineris latreilli* generally accounted for >50% of the macrofauna), Table 8 shows both absolute total numbers and total numbers without the 2 dominant species. Total fauna abundance in the area ≥ 250 m off the platform appeared to have kept fairly stable between $\approx 1400 - 2400$ ind·m⁻² since the baseline survey of May 1986. When only the non-dominant species are considered, the numbers fluctuated generally between 400 and 700 ind·m⁻² except for September 1986, when high densities were measured. It seems likely, that this is a seasonal effect, since many macrobenthic species spawn during summer. Table 8 does not show any indication of a gradual change in fauna

densities over the transect between 250 and 5000 m. However, to illustrate, the earlier mentioned low fauna densities at the 100-m station in 1987, the corresponding data are additionally given in Table 8.

Considering all observed spatial and temporal trends, the overall short-term biological effects of OBM discharges at L4a may be summarized as follows:

1. Strong effects, in terms of total abundance and species abundance, were observed within 100 m of the platform. The PI-station was very poor in macrofauna: species richness was >50% reduced, nearly all species present occurred in very low densities, 2 opportunistic species (*Capitella capitata* and *Pagurus bernhardus*) were exclusively found at this station (June). At the 100-m station relative macrofauna abundance was significantly reduced in February, but not in June. The fauna composition in June was obviously different from other stations: common species at the stations of ≥ 250 m occurred at the 100-m station either in low densities (*Nephtys hombergi*, *Goniada maculata*, *Glycinde nordmanni*, *Chaetozone setosa*, *Diplocirrus glaucus*, *Owenia fusiformis*, *Mysella bidentata*, *Turritella communis*, *Cylichna cylindracea*, *Callianassa subterranea*, *Amphiura filiformis*) or high densities (*Gattyana cirrosa*, *Anaitides groenlandica*, *Lumbrineris latreilli*, *Perioculodes longimanus*, *Diastylis bradyi*).
2. In the area off ≥ 250 m fauna abundance and species richness have not changed since the baseline survey of May 1986. The fauna composition, however, has changed: a substantial increase in numbers was observed in 12 species, whereas 13 species decreased. Partly these density changes may be due to natural annual fluctuations, but the conditions in the 250-1000 m zone should be considered to have changed, because 50% of these changes were restricted to the area within 250-1000 m off the platform whereas the refer-

TABLE 8

Macrofauna abundance at L4a on 5 stations (residual current transect) sampled in 1986 and 1987. a: total number (n·m⁻²), dominant species included. b: total number (n·m⁻²), dominant species excluded. Dominant species: *Amphiura filiformis* and *Lumbrineris latreilli*.

station	May 1986		Sept 1986		Febr 1987		June 1987	
	a	b	a	b	a	b	a	b
100 m	-	-	-	-	247	117	1313	476
250 m	2387	722	1705	906	1954	563	2205	608
500 m	2023	554	1963	1003	1869	553	1747	544
750 m	1398	440	2703	1432	1936	550	1867	613
5000 m	1643	468	1508	1005	1399	535	1531	704

ence station did not show a corresponding change or even an opposite trend (*Lysilla loveni*). The most obvious changes were observed on the 250-m and 500-m station. In 5 species (*Lysilla loveni*, *Harpinia antennaria*, *Polynoe kinbergi*, *Montacuta ferruginosa* and *Echinocardium cordatum*) this has resulted in evident density gradients along the whole residual current transect as well as the perpendicular transect, which were absent during the baseline survey (Fig. 7).

3.2 PLATFORM K12A

3.2.1 GENERAL REMARKS

The operational platform K12a, situated in an area with fine sandy sediment (Table 1), was visited in 1987 and 1988 for the third and fourth time, respectively, to study possible long-term effects after OBM drilling in 1983 and 1984. In 1987 the analysis of 8 stations (61 samples) yielded 97 species, in 1988 90 species were found in 30 samples from 6 stations. Tables 9 and 10 show the percentage of occurrence of each species in the samples.

3.2.2 SURVEY SEPTEMBER 1987 (3 YEARS AFTER OBM-DRILLING)

Table 27 (appendix), which gives the species composition per station in 1987, clearly shows that the fauna in the area was dominated by huge numbers of juvenile *Echinocardium cordatum* and, to a lesser extent, by *Spiophanes bombyx* and *Nucula turgida*. *Echinocardium* was particularly abundant ≥ 500 m off the platform. The 250-m station at the perpendicular transect revealed lower densities and the species was absent at the Platform station. *Spiophanes* and *Nucula* were abundant at all stations except the PI-station, where both were absent. A similar trend can be observed in the majority of the other species and finds expression in a remarkably low number of species found at the PI-station (16 versus 45-67 at the other stations). Also the total density of individuals ($418 \cdot m^{-2}$) at the PI-station was very low compared with the other stations ($1858-4626 \cdot m^{-2}$). Moreover, the number of 418 is largely accounted for by *Macropipus holsatus*, a few other crabs living on top of the sediment and by some known opportunistic species like *Capitella capitata*. A few species that were still abundant in 1986, viz. *Scalibregma inflatum* and *Lagis koreni*, occurred in strongly diminished densities in the area in 1987. In this respect both species continued a trend, which was observed already between 1985 and 1986.

Possible trends in the distribution of macrofauna were tested by logit regression for 36 species, that occurred in sufficient numbers to meet the criterion

laid down in chapter 2.3. In 21 species the densities showed a significant (5% level) gradient along the transect (Table 11). In 15 species such a gradient was even significant at the 0.1% level. Positive trends, i.e. increasing densities off the platform, occurred 17 times. *Goniada maculata*, *Lumbrineris latreilli*, *Spiophanes bombyx*, *Chaetozone setosa*, *Owenia fusiformis*, *Nucula turgida*, *Natica alderi* and *Echinocardium cordatum* were absent or almost absent at the PI-station, but present in nearly all samples of the other stations. *Montacuta ferruginosa* was only found at the 1000-m and 5000-m stations. In 4 species the trend was negative. *Porcellana longicornis* and *Galathea intermedia* only occurred at the PI-station. Two other species, *Venus striatula* and *Orchomenella nana*, also showed a negative trend, which was, however completely due to their relatively high abundance at the 100-m and 250-m stations, since both were absent at the PI-station. In most of the 15 species in which significant density gradients could not be statistically proved the visual trend was that they were absent or relatively scarce at the PI-station.

Fig. 8, showing the mean relative abundance of all at species level identified macrofauna, confirms the general impression obtained by logit regression. Most species are absent or occur in low numbers at the PI-station, and, therefore, score low in relative abundance. The hypothesis (H_0) that all sample-units originate from the same macrofaunal distribution was tested by ANOVA at the 5%, 1%, 0.5% and 0.1% levels and rejected even at the 0.1% level. When the PI-station is excluded such a test does not reject H_0 . The conclusion may be that the PI-station differs significantly from all other stations, whereas differences between the community structures at the stations between 100 m and 5000 m are too small to consider these stations affected by differing loads of pollution.

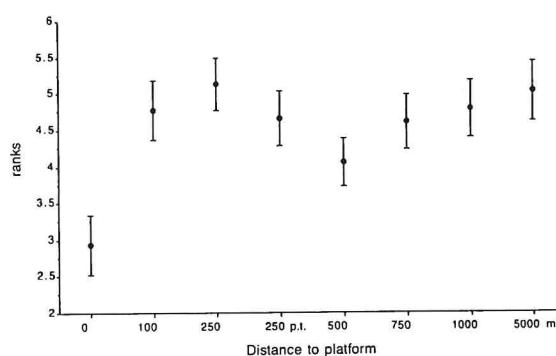


Fig. 8. K12a Sept. 1987: Relative macrofauna abundance (mean ranks and 95% confidence limits).

TABLE 9

Data platform K12a, survey Sept. 1987. Percentage of occurrence of each species in the total number of analysed samples (61).

POLYCHAETA		<i>Cylindrichthys cilindracea</i>	4.92
<i>Aphrodita aculeata</i>	9.84	CRUSTACEA	
<i>Harmothoe lunulata</i>	4.92	<i>Crangon crangon</i>	4.92
<i>Harmothoe longisetis</i>	9.84	<i>Processa parva</i>	14.75
<i>Gattyana cirrosa</i>	1.64	<i>Pontophilus trispinosus</i>	18.03
<i>Sigalion mathildae</i>	3.28	<i>Pagurus bernhardus</i>	11.48
<i>Pholoe minuta</i>	57.38	<i>Porcellana longicornis</i>	6.56
<i>Sthenelais limicola</i>	34.43	<i>Galathea intermedia</i>	6.56
<i>Eteone longa</i>	3.28	<i>Macropipus holsatus</i>	24.59
<i>Anaitides groenlandica</i>	32.79	<i>Macropipus spec. juv.</i>	62.30
<i>Anaitides mucosa</i>	21.31	<i>Ebalia cranchii</i>	24.59
<i>Anaitides maculata</i>	62.30	<i>Atelecyclus spec. juv.</i>	1.64
<i>Eumida sanguinea</i>	11.48	<i>Cancer pagurus</i>	3.28
<i>Ophiodromus flexuosus</i>	47.54	<i>Corystes cassivelaunus</i>	50.82
<i>Gyptis capensis</i>	18.03	<i>Upogebia spec. juv.</i>	85.25
<i>Exogone hebes</i>	3.28	<i>Callianassa spec. juv.</i>	54.10
<i>Nereis longissima</i>	9.84	<i>Decapoda larven</i>	57.38
<i>Nereis spec. juv.</i>	52.46	<i>Schistomysis ornata</i>	1.64
<i>Nephtys hombergii</i>	81.97	<i>Eudorella truncatula</i>	8.20
<i>Nephtys cirrosa</i>	60.66	<i>Ipipinoe trispinosa</i>	18.03
<i>Nephtys caeca</i>	6.56	<i>Pseudocuma longicornis</i>	3.28
<i>Nephtys spec. juv.</i>	8.20	<i>Diastylis bradyi</i>	42.62
<i>Glycera rouxii</i>	21.31	<i>Atylus swammerdami</i>	37.70
<i>Glycera spec. juv.</i>	65.57	<i>Atylus falcatus</i>	1.64
<i>Glycinde nordmanni</i>	21.31	<i>Hippomedon denticulatus</i>	1.64
<i>Goniada maculata</i>	88.52	<i>Orchomenella nana</i>	29.51
<i>Lumbrineris latreilli</i>	90.16	<i>Leucothoe incisa</i>	9.84
<i>Scoloplos armiger</i>	1.64	<i>Metopa spec.</i>	1.64
<i>Poecilochaetus serpens</i>	27.87	<i>Ampelisca brevicornis</i>	14.75
<i>Spio filicornis</i>	29.51	<i>Ampelisca tenuicornis</i>	6.56
<i>Spiophanes bombyx</i>	88.52	<i>Ampelisca spec. juv.</i>	8.20
<i>Scolecopsis bonnieri</i>	18.03	<i>Bathyporeia elegans</i>	1.64
<i>Magelona papillicornis</i>	73.77	<i>Bathyporeia tenuipes</i>	57.38
<i>Chaetozone setosa</i>	86.89	<i>Argissa hamatipes</i>	3.28
<i>Diplocirrus glaucus</i>	14.75	<i>Harpinia antennaria</i>	16.39
<i>Scalibregma inflatum</i>	42.62	<i>Apherusa ovalipes</i>	3.28
<i>Ophelina acuminata</i>	9.84	<i>Pericardodes longimanus</i>	42.62
<i>Capitella capitata</i>	18.03	<i>Jassa falcata</i>	9.84
<i>Notomastus latericeus</i>	6.56	ECHINODERMATA	
<i>Heteromastus filiformis</i>	6.56	<i>Astropecten irregularis</i>	8.20
<i>Owenia fusiformis</i>	83.61	<i>Asterias rubens</i>	18.03
<i>Lanice conchilega</i>	8.20	<i>Amphiura filiformis</i>	26.23
<i>Lagis koreni</i>	29.51	<i>Amphiura chiajei</i>	1.64
<i>Sosane gracilis</i>	1.64	<i>Ophiura texturata</i>	6.56
MOLLUSCA		<i>Ophiura albida</i>	3.28
<i>Nucula turgida</i>	88.52	<i>Ophiura spec. juv.</i>	16.39
<i>Diplodonta rotundata</i>	6.56	<i>Echinocardium cordatum</i>	86.89
<i>Thyasira flexuosa</i>	18.03	<i>Echinocyamus pusillus</i>	14.75
<i>Montacuta ferruginosa</i>	13.11	<i>Psammechinus miliaris</i>	3.28
<i>Mysella bidentata</i>	24.59	OTHER TAXA	
<i>Acanthocardia echinata</i>	45.90	Nemertinea	85.25
<i>Dosinia lupinus</i>	29.51	Nematoda	1.64
<i>Venus striatula</i>	54.10	Hydrozoa	1.64
<i>Mactra corallina</i>	22.95	Turbellaria	22.95
<i>Spisula spec. juv.</i>	1.64	Phoroniden	16.39
<i>Tellina fabula</i>	54.10	Harp. copepoda	54.10
<i>Tellina tenuis</i>	1.64	Oligochaeta	67.21
<i>Abra alba</i>	50.82	<i>Sagitta spec.</i>	6.56
<i>Ensis ensis</i>	1.64	Anthozoa	6.56
<i>Cultellus pellucidus</i>	31.15	Ascidacea	6.56
<i>Cingula nitida</i>	1.64		
<i>Turritella communis</i>	1.64		
<i>Natica alderi</i>	88.52		
<i>Buccinum undatum</i>	3.28		

TABLE 10

Data platform K12a, survey Sept. 1988. Percentage of occurrence of each species in the total number of samples (30).

POLYCHAETA		<i>Tellina fabula</i>	83.33
<i>Aphrodita aculeata</i>	6.67	<i>Abra alba</i>	83.33
<i>Harmothoe longisetis</i>	13.33	<i>Cultellus pellucidus</i>	56.67
<i>Harmothoe spec. juv.</i>	36.67	<i>Mya spec. juv.</i>	10.00
<i>Gattyana cirrosa</i>	3.33	<i>Cingula nitida</i>	3.33
<i>Sigalion mathildae</i>	10.00	<i>Natica alderi</i>	100.00
<i>Pholoe minuta</i>	90.00	<i>Cylichna cilindracea</i>	3.33
<i>Sthenelais limicola</i>	36.67	<i>Philine catena</i>	3.33
<i>Eteone longa</i>	76.67	<i>Philine scabra</i>	6.67
<i>Anaitides groenlandica</i>	83.33	CRUSTACEA	
<i>Anaitides mucosa</i>	100.00	<i>Crangon crangon</i>	6.67
<i>Anaitides maculata</i>	30.00	<i>Processa parva</i>	3.33
<i>Eumida sanguinea</i>	33.33	<i>Pontophilus trispinosus</i>	10.00
<i>Ophiodromus flexuosus</i>	83.33	<i>Pagurus bernhardus</i>	3.33
<i>Gyptis capensis</i>	80.00	<i>Porcellana spec. juv.</i>	3.33
<i>Synelmis klatti</i>	3.33	<i>Galathea spec. juv.</i>	3.33
<i>Exogone hebes</i>	3.33	<i>Macropipus holsatus</i>	30.00
<i>Nereis longissima</i>	23.33	<i>Macropipus spec. juv.</i>	66.67
<i>Nereis spec. juv.</i>	56.67	<i>Ebalia cranchii</i>	20.00
<i>Nephtys hombergii</i>	96.67	<i>Corystes cassivelaunus</i>	56.67
<i>Nephtys cirrosa</i>	43.33	<i>Upogebia spec. juv.</i>	63.33
<i>Nephtys caeca</i>	10.00	<i>Callianassa subterranea</i>	10.00
<i>Nephtys spec. juv.</i>	13.33	<i>Callianassa spec. juv.</i>	83.33
<i>Glycera rouxii</i>	26.67	<i>Decapoda larven</i>	33.33
<i>Glycera alba</i>	3.33	<i>Eudorella truncatula</i>	26.67
<i>Glycera spec. juv.</i>	26.67	<i>Iphinoe trispinosa</i>	3.33
<i>Glycinde nordmanni</i>	73.33	<i>Diastylis bradyi</i>	100.00
<i>Goniada maculata</i>	90.00	<i>Atylus falcatus</i>	13.33
<i>Lumbrineris latreilli</i>	100.00	<i>Orchomenella nana</i>	10.00
<i>Scoloplos armiger</i>	23.33	<i>Leucothoe incisa</i>	20.00
<i>Poecilochaetus serpens</i>	36.67	<i>Ampelisca brevicornis</i>	53.33
<i>Spio filicornis</i>	96.67	<i>Ampelisca tenuicornis</i>	13.33
<i>Spiophanes kroyeri</i>	16.67	<i>Ampelisca spec. juv.</i>	50.00
<i>Spiophanes bombyx</i>	100.00	<i>Bathyporeia tenuipes</i>	3.33
<i>Scolecopsis bonnieri</i>	13.33	<i>Argissa hamatipes</i>	3.33
<i>Magelona papillicornis</i>	100.00	<i>Harpinia antennaria</i>	6.67
<i>Chaetozone setosa</i>	96.67	<i>Pericardium longimanus</i>	20.00
<i>Diplocirrus glaucus</i>	30.00	<i>Synchelidium haplocheles</i>	3.33
<i>Scalibregma inflatum</i>	70.00	<i>Caprella spec.</i>	6.67
<i>Capitella capitata</i>	30.00	ECHINODERMATA	
<i>Notomastus latericeus</i>	20.00	<i>Astropecten irregularis</i>	10.00
<i>Heteromastus filiformis</i>	36.67	<i>Amphiura filiformis</i>	50.00
<i>Owenia fusiformis</i>	90.00	<i>Amphiura chiajei</i>	6.67
<i>Myriochele heeri</i>	26.67	<i>Amphiura texturata</i>	16.67
<i>Lanice conchilega</i>	100.00	<i>Ophiura albida</i>	3.33
<i>Lagis koreni</i>	100.00	<i>Ophiura spec. juv.</i>	83.33
<i>Pectinaria auricoma</i>	10.00	<i>Echinocardium cordatum</i>	100.00
<i>Ampharete finmarchica</i>	6.67	<i>Echinocyamus pusillus</i>	3.33
<i>Sosane gracilis</i>	96.67	OTHER TAXA	
<i>Lysilla loveni</i>	10.00	<i>Nemertinea</i>	100.00
<i>Terebellides stroemi</i>	3.33	<i>Nematoda</i>	3.33
<i>Sabellaria spec.</i>	3.33	<i>Phoroniden</i>	26.67
MOLLUSCA		<i>Harp. copepoda</i>	43.33
<i>Nucula turgida</i>	100.00	<i>Oligochaeta</i>	86.67
<i>Thyasira flexuosa</i>	6.67	<i>Sagitta spec.</i>	40.00
<i>Montacuta ferruginosa</i>	73.33	<i>Sipunculida</i>	3.33
<i>Mysella bidentata</i>	20.00	<i>Actinaria</i>	30.00
<i>Arctica islandica</i>	3.33	<i>Ascidacea</i>	6.67
<i>Acanthocardia echinata</i>	6.67		
<i>Dosinia lupinus</i>	6.67		
<i>Venus striatula</i>	56.67		

TABLE 11

K12a Sept. 1987. List of species showing a significant density gradient (logit regression). Sign of the gradient (+/-) and significance level are indicated. +: Increasing densities off the location; -: Decreasing densities off the location.

	Sign	Signif. level (%)
<i>Pholoe minuta</i>	+	0.1
<i>Sthenelais limicola</i>	+	5
<i>Ophiodromus flexuosus</i>	+	0.1
<i>Nephtys hombergii</i>	+	0.1
<i>Goniada maculata</i>	+	0.1
<i>Lumbrineris latreilli</i>	+	0.1
<i>Spiophanes bombyx</i>	+	0.1
<i>Magelona papillicornis</i>	+	0.1
<i>Chaetozone setosa</i>	+	0.1
<i>Owenia fusiformis</i>	+	0.1
<i>Nucula turgida</i>	+	0.1
<i>Montacuta ferruginosa</i>	+	0.1
<i>Mysella bidentata</i>	+	5
<i>Venus striatula</i>	-	5
<i>Abra alba</i>	+	5
<i>Natica alderi</i>	+	0.1
<i>Porcellana longicornis</i>	-	0.1
<i>Galathea intermedia</i>	-	0.1
<i>Diastylis bradyi</i>	+	5
<i>Orchomenella nana</i>	-	5
<i>Echinocardium cordatum</i>	+	0.1

3.2.3 SURVEY SEPTEMBER 1988 (4 YEARS AFTER OBM-DRILLING)

In 1988 the benthic community in the area was dominated by *Spiophanes bombyx* and, to a lesser extent, by *Lagis koreni* and *Echinocardium cordatum* (Table 28) (Appendix). Juvenile specimens of these three species together accounted for over 70% of the fauna. *Echinocardium* was present at the PI-station, although in low numbers compared to the other stations. *Spiophanes* and *Lagis* occurred at all stations in more or less similar numbers. Densities of both species seem to have recovered to a level comparable to the situation of 1985, when the first survey to K12a took place. In the other, less abundant species differences between stations were generally small and striking density gradients could hardly be observed.

Total fauna densities were in the order of 4000 ind·m⁻² at all stations, which is more or less similar to densities found in preceding years at distances ≥ 250 m off the platform. Also in the total number of species found per station, there was no evidence for declining numbers at the PI-station.

Logit regression, applied to 35 of the most abundant species, resulted, at the 5% level, in significant gradients in 6 species (Table 12). In 3 species such a gradient was significant even at the 0.1% level. All significant gradients displayed positive trends (in-

creasing densities with distance to the platform), but 5 species were present at the PI-station, albeit in low numbers. Only *Montacuta ferruginosa* seemed to be absent at the PI-station, but was found already at the 250-m station. So the area in which this species occurs has expanded since 1987. An opportunistic species like *Capitella capitata* was very abundant in 2 samples of the PI-station, and, consequently, displayed a high density there. However, since the species was present at some other stations too, logit regression revealed no significant gradient.

The mean relative abundance of species illustrates that differences between stations were generally small (Fig. 9). Although most species seemed to be relatively abundant at the 5000 m reference station, mean ranks did not differ significantly from the other stations, as demonstrated by application of ANOVA. From this result it may be inferred that, 4 years after discharge of OBM cuttings, spatial differences in loads of pollution in the area (VAN HET GROENEWOUD, 1990) are not reflected by clear differences in relative macrofauna abundance of the stations sampled.

3.2.4 COMPARISON WITH PRECEDING SURVEYS

Since platform K12a was surveyed in 1985 for the first time, a total number of 200 samples has been analyzed, originating from 10 stations, which has resulted in 130 identified species. Although sampling intensity varied from year to year, the total number of species found per survey was fairly constant between 90 and 100. The following statistics show that the species richness in the area surrounding K12a does not seem to have declined after 1985:

1985: 62 samples from 9 stations yielded 99 species					
1986: 47	"	"	7	"	90 "
1987: 61	"	"	8	"	97 "
1988: 30	"	"	6	"	90 "

TABLE 12

Data K12a, Sept. 1988. List of species showing a significant density gradient (logit regression). Sign of the gradient (+/-) and significance level are indicated. +: Increasing densities off the location; -: Decreasing densities off the location.

	Sign	Sign. level (%)
<i>Pholoe minuta</i>	+	0.1
<i>Ophiodromus flexuosus</i>	+	0.5
<i>Gyptis capensis</i>	+	0.1
<i>Montacuta ferruginosa</i>	+	0.1
<i>Cultellus pellucidus</i>	+	5
<i>Ampelisca brevicornis</i>	+	1

On the contrary, the number of species found in 1988 is high, when taking into account the low number of samples analyzed that year. Indeed the species composition has changed somewhat after 1985: some species seem to have vanished (e.g. *Polycirrus medusa* and *Bathyporeia guilliamsoniana*), whereas others took their place (e.g. *Glycera rousii*, *Myriochele heeri* and *Sosane gracilis*). Most such changes, however, concern species so rarely found, or spatially so patchy distributed that evident temporal trends cannot be detected. Moreover, natural long-term density fluctuations will have a considerable share in observed year to year differences. None of the common (≥ 20 specimens found) species in 1985 were completely absent on corresponding stations in the 1988 survey, or conversely.

Possible long-term trends in macrofauna abundance can only be found by comparing the datasets of those stations that were sampled in each of the 4 surveys. Since total macrofauna abundance is usually largely determined by a few very dominant species, one may consider total numbers of individuals with the dominant species either included or dominant species excluded (Table 13). At the PI-station macrofauna abundance was obviously low in 1985, 1986 and 1987. In 1988, however, all stations, the PI-station included, showed densities similar to those commonly found at the 5000-m (reference) station. This similarity is most distinct when densities are compared without dominant species. Note that the real distance of the PI-station to the discharge point was not exactly the same in all surveys. In 1985, 1986 and 1988 the real distance varied between 50 and 100 m, whereas in 1987 sampling took place from the platform itself. The patchy distribution of oil-contaminated cuttings (VAN HET GROENEWOUD, 1990) and slight aberrations in position finding may thus have biased the sampling results of the PI-station.

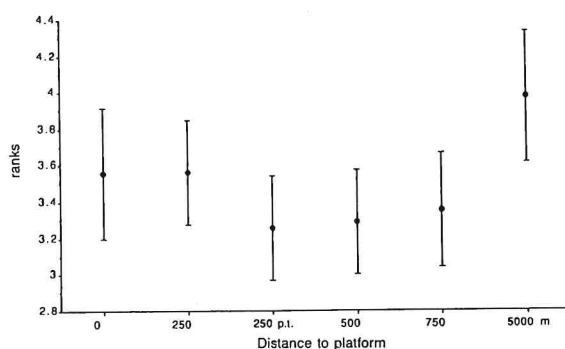


Fig. 9. K12a Sept. 1988: Relative macrofauna abundance (mean ranks and 95% confidence limits).

The apparent recovery of the area might be illustrated by the come-back of *Montacuta ferruginosa* and *Lanice conchilega* on stations within 500 m of the platform (Fig. 10). Both species were rare in this area in the period 1985-1987 and tended to high abundance only at the 5000-m station. Although this picture has not completely disappeared, both penetrated the area near the platform in 1988.

When the overall biological effects found in 1987 and 1988 (and dealt with in this report) are compared with the effects measured in 1985 and 1986 (MULDER *et al.*, 1987, 1988), the results may be summarized as follows:

- 1985: Effects measured up to 750-1000 m off the platform
- 1986: Clear effects measured up to 250 m off the platform
- 1987: Clear effects measured at the platform station
- 1988: Marginal effects measured within 100 m of the platform

TABLE 13

Macrofauna abundance at K12a on 6 stations sampled in 4 consecutive years. r.c. = residual current transect perp. = perpendicular transect. a: total numbers ($n \cdot m^{-2}$), dominant species included b: total numbers ($n \cdot m^{-2}$), dominant species excluded. Dominant species: S.b. = *Spiophanes bombyx*; L.k. = *Lagis koreni*; E.c. = *Echinocardium cordatum*.

station	1985		1986		1987		1988	
	a	b	a	b	a	b	a	b
250 m perp.	3647	808	2589	1142	2197	1723	3873	956
PI-station	1792	580	383	213	418	418	4016	1320
250 m r.c.	3742	819	767	743	4626	1236	4703	1267
500 m r.c.	3439	802	2541	1025	3837	796	4553	1081
750 m r.c.	5046	1060	2650	1016	4144	811	4353	1131
5000 m r.c.	4868	1255	1134	987	4409	1196	4264	1443
Dominant species	S.b. L.k.		L.k.		E.c.		S.b. L.k. E.c.	

These results lead the following conclusions:

1. In the 4 years following drilling activities at platform K12a, spatial effects of discharged cuttings with adhering OBM on the benthic community have steadily decreased from 750 - 1000 m off the platform to < 250 m off the platform.

2. Only at the platform station (≈ 66 m off the discharge point) biological effects were measured in 1988.

3. Also within 100 m of the platform the benthic community seems to have largely recovered.

3.2.5 BOXCOSM EXPERIMENTS - K12A

3.2.5.1 GENERAL REMARKS

In addition to the field surveys to K12a, an exploratory study was made in the period September 1987 - February 1988 to investigate biological effects of discharged OBM in indoor incubated boxcosms. The basic question underlying this study was whether it is possible to keep the benthic community in its natural composition in a small experimental ecosystem for some months and, if so, how biological effects of contamination can be studied in such boxcosms.

From the very beginning there were obvious differences between the cores of the contaminated location and those of the undisturbed reference station. On the 100-m cores black patches were observed apparently representing oil-contaminated sediment. During the experiment, white colonies of *Beggiatoa mirabilis* developed on these patches. *Beggiatoa* is a sulphur bacterium, which commonly occurs in anoxic environments, particularly on decaying organic material (WIESSNER, 1981). Furthermore the surface structure of the cores looked very different. In the reference box-cosms numerous funnels, cones, holes and tubes indicated a rich infauna. At the surface of the contaminated cores such structures, or any other sign of life, were almost absent.

3.2.5.2 SURVIVAL OF THE NATURAL INFAUNA

The incubation of boxcosms under controlled laboratory circumstances has proved that it is possible to keep the infauna in good condition for several months. Table 30 (Appendix) shows that in the cores of the reference (5000-m) station indeed there was a decrease in total numbers of individuals. However, this decrease can almost completely be attributed to mortality among initially abundant juvenile *Echinocardium cordatum* (ECH). During the incubation period several hundreds appeared at the sediment surface and died. To a lesser extent a decrease in numbers of *Spiophanes bombyx* (POL) could also be observed, possibly due to mortality, but their

numbers might have been lower in the experimental cores from the beginning. The other species, all less abundant, maintained themselves very well, which is illustrated by the fact that at the end of the experiment, there was no decrease in the number of species. The species composition of the fauna in the 2 experimental cores and in the core representing the initial situation was very similar: 46% of the total of 35 species found in the 3 cores were present in each of them. The other species were all so scarce that their presence will have been determined mainly by accident.

Different results were obtained in the polluted cores (100-m station). A total of 21 species was found in the 3 cores (Table 30). Among these species *Nucula turgida* (MOL) was abundant in the original field sample and in only one of the experimental cores. In the other one this species was not present and, as a consequence, the total number of individuals was remarkably low. In this core the fauna was dominated by *Capitella capitata* (POL), which in turn

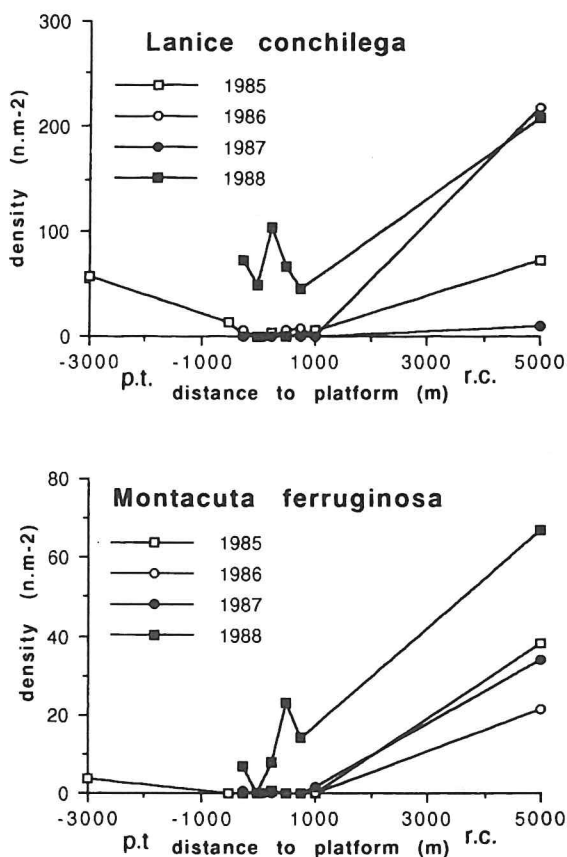


Fig. 10. K12a: Distribution patterns of 2 macrofauna species on the perpendicular transect (p.t.) and residual current transect (r.c.) in 4 consecutive years after drilling with diesel based muds in 1983 and 1984.

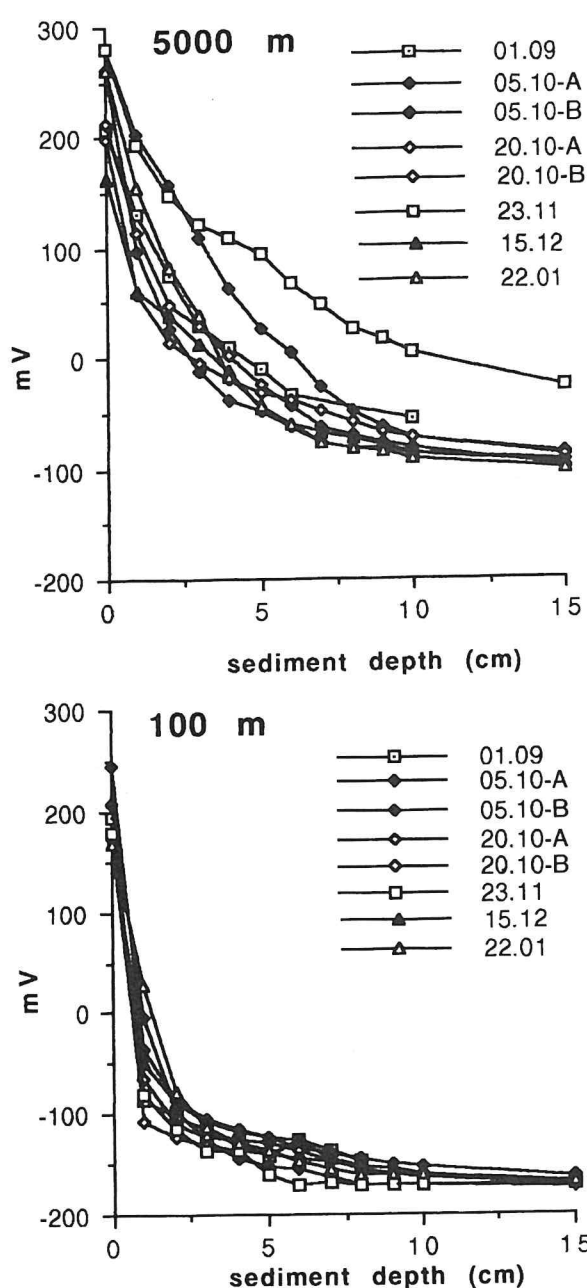


Fig. 11. Boxcosms K12a: Vertical profiles of Eh (mV) in the sediment of 100 m and 5000 m, measured between 1.09.1987 and 22.01.1988.

was absent in the other cores. All other species occurred in very low densities. In both experimental boxcosms the final number of species was lower than in the initial field sample. However, the differences cannot unambiguously be explained by mortality since there was little resemblance in species composition of the 3 cores. Only 2 out of 21 species

were present in all 3 boxes. This may indicate that the fauna is more heterogeneously distributed in the polluted area than at the reference station, possibly due to the observed patchy distribution of oil-based muds.

3.2.5.3 BEHAVIOUR AND SURVIVAL OF *ECHINOCARDIUM CORDATUM*

The experiments with *Echinocardium cordatum* yielded promising results. First the species has shown to thrive, when kept under laboratory conditions in undisturbed boxcosms. When the reference core was stocked with 5 animals, 4 of them dug in within about 10 minutes. The fifth disappeared under the sediment surface after 30 minutes. Only one specimen died: it re-emerged at the surface after 3 days and died 2 days later. It is conceivable that the animal was not in optimal condition from the beginning. The other 4 specimens were not seen again during the incubation period, but at termination of the experiment, they were found again in healthy condition at about 15 cm beneath the sediment surface.

The test animals in the contaminated cores behaved in an obviously less natural way. In core 100 m-A (5 test animals) *Echinocardium* burrowed normally (4 animals disappeared under the sediment surface after 10 minutes, 1 after 1 h), but during the next few days it became clear that their behavioural pattern was disturbed: the animals were continuously migrating right beneath the surface and appeared again and again overground, till finally they stopped burrowing. Four animals did not survive the experimental period. Mortality happened after 13, 47, 78 and 84 days. All animals experienced severe loss of spines, particularly on the ventral side, which may explain why they gradually could not dig in anymore. In core 100 m-B (10 test animals) disturbed functioning of *Echinocardium* was even more evident. Four animals did not burrow deeper than halfway the sediment surface. The other ones migrated several times before they finally disappeared, but only for a short time. Then they were observed again on the sediment, sometimes with traces of oil between the spines and always suffering loss of spines on the ventral side. Not one of the animals survived the experiment. Mortality occurred already after 8 d and was complete after 45 d.

3.2.5.4 REDOX PROFILES

Measurement of redox-potential in the top layers of the sediment may provide a rough qualitative impression of the balance between O_2 -diffusion from the overlying water into the sediment and the oxygen consumption in the sediment, or, in other words, of

TABLE 14

Data location F18/9, survey Sept. 1988. Percentage of occurrence of each species in the total number of samples (107).

POLYCHAETA		<i>Ophelina acuminata</i>	15.89	<i>Upogebia deltaura</i>	5.61
		<i>Capitella capitata</i>	9.35	<i>Upogebia spec. juv.</i>	.93
<i>Aphrodita aculeata</i>	18.69	<i>Notomastus latericeus</i>	58.88	<i>Callianassa subterranea</i>	41.12
<i>Harmothoe lunulata</i>	8.41	<i>Heteromastus filiformis</i>	33.64	<i>Callianassa spec. juv.</i>	14.02
<i>Harmothoe longisetis</i>	19.63	<i>Owenia fusiformis</i>	26.17	<i>Decapoda larven</i>	9.35
<i>Gattyana cirrosa</i>	90.65	<i>Myriochele heeri</i>	7.48	<i>Nebalia bipes</i>	4.67
<i>Polynoe kinbergi</i>	4.67	<i>Lanice conchilega</i>	8.41	<i>Eudorella truncatula</i>	17.76
<i>Pholoe minuta</i>	61.68	<i>Lagis koreni</i>	19.63	<i>Diastylis bradyi</i>	21.50
<i>Sthenelais limicola</i>	14.02	<i>Pectinaria auricoma</i>	3.74	<i>Cirolana borealis</i>	3.74
<i>Eteone longa</i>	5.61	<i>Amphiteis gunneri</i>	.93	<i>Ionethoracica</i>	2.80
<i>Eteone lactea</i>	.93	<i>Sosane gracilis</i>	6.54	<i>Hippomedon denticulatus</i>	1.87
<i>Eteone flava</i>	.93	<i>Lysilla loveni</i>	13.08	<i>Leucothoe spinicarpa</i>	.93
<i>Anatides groenlandica</i>	14.95	<i>Terebellides stroemi</i>	3.74	<i>Leucothoe richardii</i>	.93
<i>Anatides maculata</i>	5.61			<i>Ampelisca brevicornis</i>	7.48
<i>Eumida sanguinea</i>	1.87	MOLLUSCA		<i>Ampelisca tenuicornis</i>	12.15
<i>Ophiodromus flexuosus</i>	42.06			<i>Ampelisca spec. juv.</i>	9.35
<i>Gyptis capensis</i>	10.28	<i>Nucula turgida</i>	60.75	<i>Cheirocratus sundevalli</i>	2.80
<i>Synelmis klatti</i>	25.23	<i>Modiolus modiolus</i>	.93	<i>Bathyporeia tenuipes</i>	.93
<i>Exogone hebes</i>	8.41	<i>Thyasira flexuosa</i>	.93	<i>Harpinia antennaria</i>	41.12
<i>Autolytus spec.</i>	1.87	<i>Lepton squamosum</i>	.93	<i>Perioculodes longimanus</i>	35.51
<i>Nereis longissima</i>	.93	<i>Devonia perrieri</i>	.93	<i>Aoratyptica</i>	2.80
<i>Nereis spec. juv.</i>	3.74	<i>Montacuta ferruginosa</i>	13.08	<i>Lembos longipes</i>	2.80
<i>Nephtys hombergii</i>	68.22	<i>Mysella bidentata</i>	16.82	<i>Caprella spec.</i>	1.87
<i>Nephtys incisa</i>	26.17	<i>Arctica islandica</i>	28.04		
<i>Nephtys cirrosa</i>	3.74	<i>Acanthocardia echinata</i>	.93	ECHINODERMATA	
<i>Nephtys caeca</i>	5.61	<i>Dosinia lupinus</i>	28.97	<i>Astropecten irregularis</i>	2.80
<i>Nephtys longosetosa</i>	.93	<i>Venus striatula</i>	49.53	<i>Asterias rubens</i>	.93
<i>Nephtys spec. juv.</i>	71.96	<i>Mysia undata</i>	5.61	<i>Amphiura filiformis</i>	93.46
<i>Glycera rouxii</i>	62.62	<i>Tellina fabula</i>	.93	<i>Ophiura texturata</i>	24.30
<i>Glycera alba</i>	32.71	<i>Abra alba</i>	84.11	<i>Ophiura albida</i>	28.97
<i>Glycera spec. juv.</i>	86.92	<i>Cultellus pellucidus</i>	40.19	<i>Ophiura spec. juv.</i>	39.25
<i>Glycinde nordmanni</i>	51.40	<i>Mya spec. juv.</i>	1.87	<i>Asteroidea spec. juv.</i>	.93
<i>Goniada maculata</i>	84.11	<i>Hiatella arctica</i>	.93	<i>Echinocardium cordatum</i>	79.44
<i>Lumbrineris latreilli</i>	96.26	<i>Corbula gibba</i>	81.31	<i>Brissopsis lyrifera</i>	1.87
<i>Lumbrineris fragilis</i>	61.68	<i>Thracia convexa</i>	5.61		
<i>Driloneris filum</i>	.93	<i>Cingula nitida</i>	37.38		
<i>Orbinia sertulata</i>	1.87	<i>Turritella communis</i>	28.04	OTHER TAXA	
<i>Paraonis spec.</i>	41.12	<i>Natica alderi</i>	64.49		
<i>Poecilochaetus serpens</i>	2.80	<i>Diaphana minuta</i>	1.87	<i>Nemertinea</i>	92.52
<i>Spio filicornis</i>	18.69	<i>Retusa obtusata</i>	2.80	<i>Hydrozoa</i>	38.32
<i>Polydora pulchra</i>	.93	<i>Cylichna cilindracea</i>	56.07	<i>Turbellaria</i>	14.02
<i>Polydora guillei</i>	5.61	<i>Philine catena</i>	5.61	<i>Phoroniden</i>	46.73
<i>Spiophanes kroyeri</i>	8.41	<i>Philine scabra</i>	.93	<i>Harp. copepoda</i>	18.69
<i>Spiophanes bombyx</i>	59.81			<i>Parasitaire copepoda</i>	45.79
<i>Scolecopsis bonnierii</i>	2.80	CRUSTACEA		<i>Oligochaeta</i>	14.95
<i>Scolecopsis foliosa</i>	.93			<i>Holothuroidea</i>	22.43
<i>Magelona papillicornis</i>	13.08	<i>Processa parva</i>	4.67	<i>Sagitta spec.</i>	6.54
<i>Magelona alleni</i>	17.76	<i>Pontophilus trispinosus</i>	2.80	<i>Echiurida</i>	18.69
<i>Chaetopterus variopedatus</i>	76.64	<i>Porcellana spec. juv.</i>	1.87	<i>Sipunculida</i>	84.11
<i>Tharyx marioni</i>	32.71	<i>Macropipus spec. juv.</i>	.93	<i>Actinaria</i>	1.87
<i>Chaetozone setosa</i>	77.57	<i>Ebalia cranchii</i>	34.58	<i>Ascidia</i>	27.10
<i>Diplocirrus glaucus</i>	49.53	<i>Corystes cassivelaunus</i>	1.87	<i>Foraminiferida</i>	7.48
<i>Scalibregma inflatum</i>	30.84	<i>Upogebia stellata</i>	.93		

a gradient in the state of reduction caused by the oxidative decomposition of organic matter (RUTTNER, 1974). Measurement of Eh has been proposed as a rapid method to assess effects of organic pollution (PEARSON & STANLEY, 1979). In the oxygenated environment at the sediment-water interface Eh is

usually high (+200 to +300 mV; ZOBELL, 1946), whereas in the deeper layers of the sediment, where reducing conditions prevail, this potential tends to turn strongly negative. However, in an absolute sense, the potential is greatly influenced by pH and varies in different kinds of sediment. Practical and

theoretical problems are discussed by HOSTETTLER (1984) and PLANTE *et al.* (1989). Moreover it is not clear how oil contamination of the Pt electrode may affect the measurement. Although Eh measurements are, thus, seldom of quantitative significance and therefore not easy to interpret, a consistent qualitative difference may be noticed between Eh gradients in the polluted core and in the reference core (Fig. 11). In both cores the potential was generally between +150 and +250 mV at the sediment-water interface. In the unpolluted sediment of core 5000-m A Eh declined to negative values between 3 to 7 cm beneath the surface and seemed to stabilize at ≈ -100 mV at a depth of 15 cm. On 23 November an aberrant gradient was observed, possibly caused by sticking the electrode into the tunnel of a benthic inhabitant. In the polluted core 100-m B gradients were always much steeper, with negative Eh values already within 2 cm. At 15 cm depth the potential was always significantly below -150 mV. This steep gradient might indicate a very thin oxygenated top layer, which in turn could be explained by: a. enhanced bacterial activity in superficial sediment layers, or b. decreased O_2 -transport from the overlying water into the sediment as a consequence of reduced bioturbation. In particular the latter factor seems plausible, because of the relatively narrow variation among gradients measured in the contaminated core compared to the reference core. In sediments which are strongly subject to bioturbation, gradients are likely to be much more variable.

3.2.5.5 CONCLUSIONS

1. The large measure of survival of most species in the undisturbed cores indicates the feasibility of long-term effect studies in experimental box-cosms.

2. Adult *Echinocardium cordatum* as a test object is promising:

- The species is common and widespread in the North Sea and, thus, a good representative for the benthic fauna of large parts of the continental shelf
- The species readily survives long-term indoor incubation in undisturbed bottom sediments.
- Because of its relatively robust size, behaviour and activity are easily observed.
- Loss of spines may possibly present a suitable sublethal effect parameter.
- The species responds to unfavourable environmental conditions by emerging from the sediment. This enables the examiner to register mortality in the course of an experiment.

3. Gradients in Eh are likely to be affected in OBM-polluted sediments, but measurements of Eh are difficult to interpret.

3.3 LOCATION F 18.9

3.3.1 SURVEY JUNE 1988 (1 YEAR AFTER OBM-DRILLING)

F 18.9 is a location in the sedimentation area where drilling took place in 1987. After the exploration was terminated, the drilling rig was removed and not replaced by a production platform. Hence, the discharge point had to be traced by means of Decca-positioning. As a consequence, the exact detection of the discharge point will have been biased by inaccuracy of the apparatus: in Decca-positioning a maximum deviation of 50 m should be reckoned with. The positions of the stations visited, expressed as distance (m) to the 'platform', should therefore be considered approximate indications.

Around F 18.9 an actual cross-shaped transect was sampled including 4 250-m and 4 5000-m stations. A total number of 107 analyzed samples from 14 stations resulted in 107 identified species. In Table 14 their percentual occurrence in the samples is summarized.

The fauna in the area was more or less dominated by *Lumbrineris latreilli* and (juvenile) *Amphiura filiformis* (Table 29) (Appendix). Together these species accounted for 10 to 40% of the macrofauna numbers. Particularly *Amphiura*, however, showed obviously lower densities within 750 m of the platform on each of the individual transects. In a majority of the other relatively abundant species ($\geq 10 \cdot m^{-2}$) a similar trend was found. Densities of *Gattyana cirrosa*, *Chaetopterus variopedatus*, *Chaetozone setosa*, *Notomastus latericeus*, *Nucula turgida*, *Cylichna cilindracea*, *Callianassa subterranea* and *Harpinia antennaria* all declined within 750 m of the platform. No clear density response was observed in *Goniada maculata*, *Abra alba*, *Corbula gibba* and (juvenile) *Echinocardium cordatum*. As a result total macrofauna abundance was considerably lower at stations ≤ 500 m ($300-450 \text{ ind} \cdot m^{-2}$) than at stations ≥ 1000 m ($600-1300 \text{ ind} \cdot m^{-2}$, Fig. 12). In this respect the 750-m station was intermediate, having about the same fauna abundance as the 5000-m reference station with lowest density. Within 250 m no further gradual decrease towards the 0-m station could be observed, which might be partly explained by inaccuracies in positioning.

The numerical decrease within 750 m, as displayed by most of the abundant species, is not the only reason why overall macrofauna abundance is substantially reduced within this zone. Among the more scantily distributed species, 27 occurred only ≥ 750 m off the platform, whereas 8 species were only found at stations ≤ 500 m. Consequently the numbers of species found at stations within 500 m were considerably lower (44-54) than at stations out-

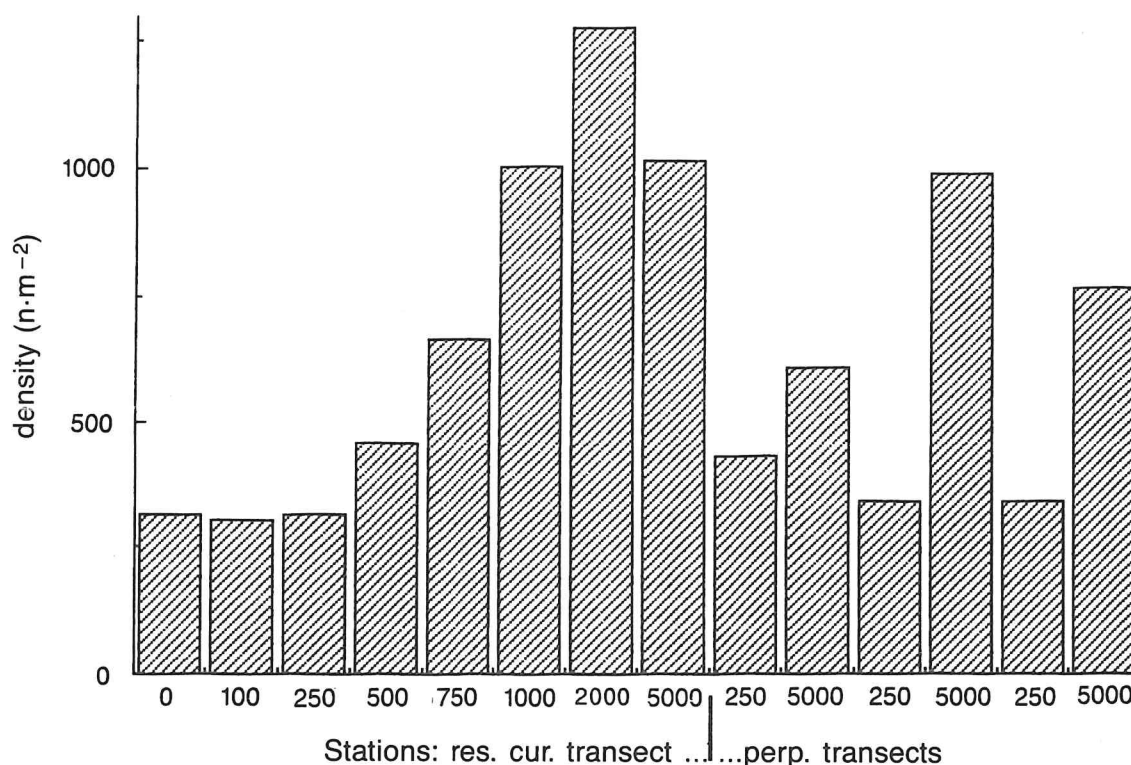


Fig. 12. Macrofauna abundance at F 18.9, June 1988.

side this zone (61-72, Fig. 13), although only 7 samples were analyzed from each of the 2000-m and 5000-m stations (versus 8 from the other stations). As in macrofauna abundance, the 750-m station revealed an intermediate number of species, compared to stations within and outside this distance. Two species, *Capitella capitata* and, to a lesser extent, *Anaitides groenlandica* seemed to profit from the conditions in the vicinity of the platform, as indicated by their relatively high numbers within 250 m.

Logit regression was applied to 46 species of which at least 20 specimens were found (Table 15). The hypothesis (H_0) that frequency of occurrence in the samples was not dependent on distance between sampling station and platform was rejected at the 5% level in 22 species, in favour of the alternative, viz. gradients being significantly present. In 8 species such a gradient was even significant at the 0.1% level. Except for *Anaitides groenlandica* all significant density gradients concerned species that occurred in increasing densities with increasing distance to the platform. Six species, including *Harmothoe longisetis*, *Owenia fusiformis*, *Mysella bidentata*, *Callianassa subterranea*, *Harpinia antennaria* and *Montacuta ferruginosa*, were absent at both the 0-m and 100-m stations, but also at one or more of the 250-m and 500-m stations. *Callianassa* was less frequent at sta-

tions ≤ 1000 m. *Harpinia* was not found at stations ≤ 500 m, occurred 3 times in the 750-m samples and was nearly always present in the samples taken at ≥ 1000 m off the platform. *Montacuta* occurred only at the 5000-m stations and was found there in $\approx 50\%$ of the samples (Fig. 14).

Among the species in which logit regression did not detect a significant gradient, *Tharyx marioni* and *Scalibregma inflatum* were absent at the 0-m and 100-m stations, but they occurred more frequently at the intermediate 750-m and 1000-m station than at the reference stations at 5 km.

Relative macrofauna abundance (Fig. 15) clearly illustrates the overall lower specific densities at all stations ≤ 500 m off the platform. Analysis of variance revealed highly significant differences (0.1% level) in mean ranks of the different stations. Although it is thus concluded that the means are not all equal, ANOVA does not give information on which stations differ from which. Therefore a *Least Significant Difference* test (LSD-test, SOKAL & ROHLF, 1981) was applied to all pairs of means, to detect whether they were significantly different. The result was that among 91 pairs of stations mutually compared, 55 were significantly different at the 5% level (Table 16). The number of 55 rejections of H_0 (i.e. mean ranks of mutually compared stations are equal) is much

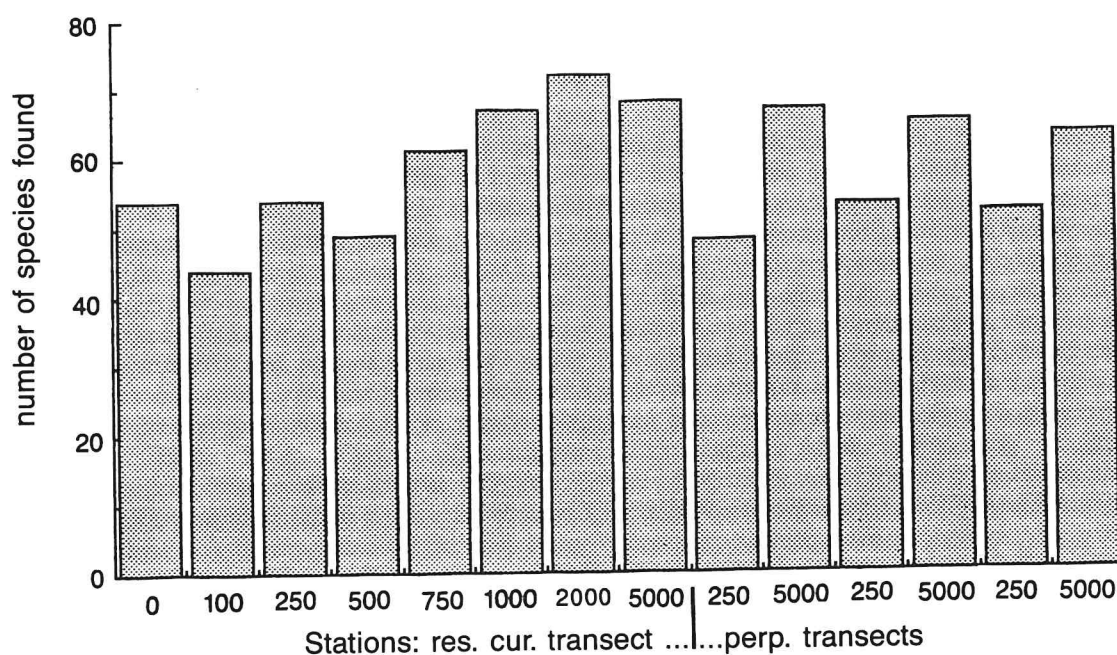


Fig. 13. Species richness at F 18.9, June 1988.

higher than expected, if H_0 were true for all stations, since among 91 tests at the 5% level maximally 8 tests will statistically lead to rejection. This clearly indicates that the majority of the differences detected do not concern Type-1 errors (*i.e.* rejection of H_0 when it is true). Another approach to avoid the effect of too many differences being adjudged significant, due to the number of tests involved in the statistical procedure, is to utilize a significance level of 0.05% for the individual tests ($\approx 5\%$ level divided by the number of tests). Table 16 shows that even at this level 43 differences appeared significant. The statistical result is easily described: Relative macrofauna abundance at stations within 500 m was always significantly lower than at stations ≥ 750 m off the platform. Differences between stations within 500 m were not significant. In the area ≥ 750 m off the platform, the 2000-m station on the residual current transect scored remarkably high in relative abundance. At the 5% level the difference between the 2000-m station and the 750-m station and with one of the 5000-m stations on a perpendicular transect was significant. This might indicate that the 750-m station was intermediate in relative abundance between stations inside and outside.

The results of the survey to F 18.9 may be summarized as follows:

1. The benthic community in the area within 500 m of the platform is obviously affected by discharges of drill cuttings with adhering OBM, which has resulted

in reduced macrofauna abundance, reduced relative abundance and reduced species richness. Although differences between the 750-m station and stations

TABLE 15

F18/9, June 1988. List of species showing a significant density gradient (logit regression). Sign of the gradient (+/-) and significance level are indicated. +: Increasing densities off the location; -: Decreasing densities off the location

	Sign	Signif. level (%)
<i>Harmothoe longisetis</i>	+	0.5
<i>Anaitides groenlandica</i>	-	5
<i>Glycinde nordmanni</i>	+	5
<i>Lumbrineris latreilli</i>	+	5
<i>Lumbrineris fragilis</i>	+	1
<i>Spiophanes bombyx</i>	+	0.1
<i>Chaetopterus variopedatus</i>	+	0.5
<i>Chaetozone setosa</i>	+	0.5
<i>Notomastus latericeus</i>	+	0.1
<i>Heteromastus filiformis</i>	+	0.1
<i>Owenia fusiformis</i>	+	5
<i>Nucula turgida</i>	+	0.1
<i>Montacuta ferruginosa</i>	+	0.1
<i>Mysella bidentata</i>	+	1
<i>Abra alba</i>	+	5
<i>Cingula nitida</i>	+	5
<i>Cylichna cylindracea</i>	+	5
<i>Callianassa subterranea</i>	+	0.1
<i>Diastylis bradyi</i>	+	5
<i>Harpinia antennaria</i>	+	0.1
<i>Amphiura filiformis</i>	+	0.1
<i>Echinocardium cordatum</i>	+	5

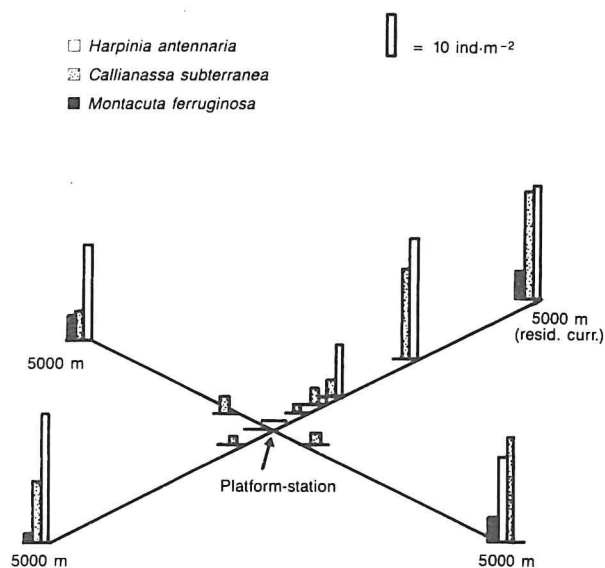


Fig. 14. Densities of 3 macrofauna species on a cross-shaped transect around drilling location F 18.9, June 1988.

farther off were generally not significant, the fauna characteristics of this station seem intermediate, as indicated by its macrofauna abundance, relative abundance and species richness.

2. Within 500 m only slight indications were found of increased effects in the direction of the platform, in terms of reduced densities of more or less abundant species (in some cases leading to absence at the 0-m and 100-m stations).

3. The occurrence of a few highly sensitive species might be affected up to 1000 or 2000 m, as indicated by the distribution patterns displayed by the crustaceans *Harpinia antennaria* and *Callianassa subterranea* and the bivalve shell *Montacuta ferruginosa* (Fig. 14).

4. The high macrofauna abundance at the 2000-m station illustrates how natural variability of the benthic community can interfere in gradient analysis.

3.3.2 BOXCOSM EXPERIMENTS F18.9

3.3.2.1 GENERAL REMARKS

There were obvious differences between the cores of the different stations (Fig. 16). In the undisturbed cores of the 5000-m reference station numerous funnels, cones, holes and tubes in the sediment surface betrayed a rich infauna. Activity of benthic animals was established by the observation of repeated emission of sediment clouds from the holes. Such

activity could be observed during the whole period of incubation.

Almost the same sediment features characterized the intermediate 100-m boxcosms. On 2 cores appeared a few yellow blotches after 2 months, presumably representing small colonies of a sulphur bacteria. This might indicate the presence of oil traces close to the sediment surface.

The boxcosms of the 50-m station looked completely different. The cores were covered with large black patches, clearly representing OBM-contaminated sediment. Already in the first week white and yellow colonies of bacteria developed on these patches. In most cores the white one, identified as the sulphur bacterium *Beggiatoa mirabilis*, predominated and proliferated web-like threads, but particularly in the core of the D-series (Fig. 4), which showed relatively few oil patches, the yellow colonies were extensive. The colonies persisted till the end of the experiment, but microscopic observations no longer revealed viable cells. In the structure of the sediment surface hardly any sign of animal life could be detected: holes were almost absent.

3.3.2.2 SURVIVAL OF THE NATURAL INFAUNA

In the actual field situation at the start of the experiment the Reineck box samples yielded altogether 82 identified species (Table 17). Numbers of species found in individual samples clearly decreased in the vicinity of the drilling location. The total number of species too was also lowest at the 50-m station and highest at the 5000-m reference station. Species which were more or less abundant at the latter station generally tended to occur in lower numbers with decreasing distance to the drilling location (Table 31) (Appendix). A different pattern was found in the gastropod *Philine scabra*, which was particularly abun-

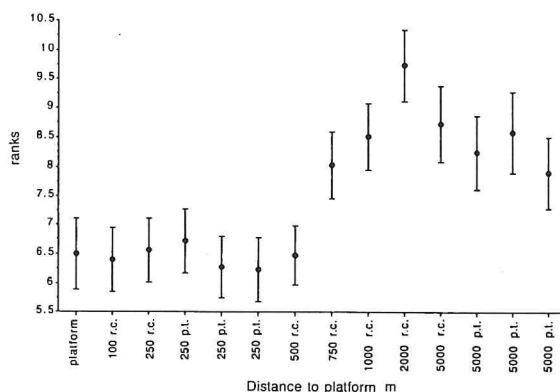


Fig. 15. F 18.9 June 1988: Relative macrofauna abundance (mean ranks and 95% confidence limits).

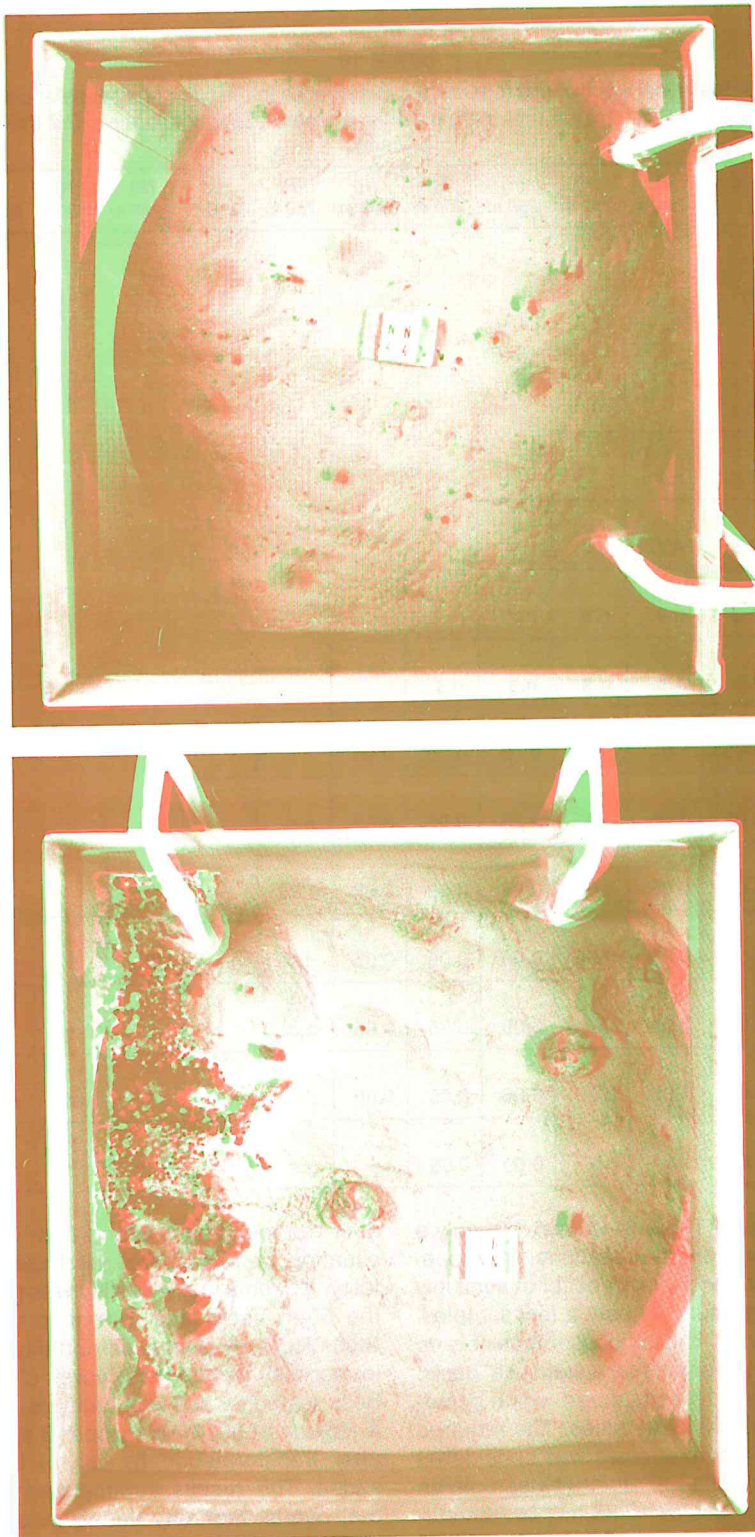


Fig. 16. Boxcosms F 18.9. View on sediment cores from 5000 m (top) and 50 m (bottom) with sea urchins (*Echinocardium cordatum*) on top of the sediment. (Use the 3-D viewer provided on the inside of the back-cover.)

TABLE 16

F18/9, survey June 1988. Statistical significance (LSD-test) of differences in relative macrofauna abundance between sampled stations. (R)= residual current transect; (P)= perpendicular transects. Significance level (%) indicated; (n.s.= not significant).

	0 m	100 m	(R) 250 m	(P) 250 m	(P) 250 m	(P) 250 m	(R) 250 m	(R) 750 m	(R) 1000 m	(R) 2000 m	(R) 5000 m	(P) 5000 m	(P) 5000 m	(P) 5000 m
0 m														
100 m	n.s.													
(R) 250 m	n.s.	n.s.												
(P) 250 m	n.s.	n.s.	n.s.											
(P) 250 m	n.s.	n.s.	n.s.	n.s.										
(P) 250 m	n.s.	n.s.	n.s.	n.s.	n.s.									
(P) 250 m	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.								
(R) 500 m	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.							
(R) 750 m	0.05	0.05	5	5	0.05	0.05	0.05							
(R) 1000 m	0.05	0.05	0.05	0.05	0.05	0.05	0.05	n.s.						
(R) 2000 m	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	5					
(R) 5000 m	0.05	0.05	0.05	0.05	0.05	0.05	0.05	n.s.	n.s.	5				
(P) 5000 m	0.05	0.05	0.05	5	0.05	0.05	0.05	n.s.	n.s.	5	n.s.			
(P) 5000 m	0.05	0.05	0.05	0.05	0.05	0.05	0.05	n.s.	n.s.	5	n.s.	n.s.		
(P) 5000 m	0.05	5	5	5	0.05	0.05	5	n.s.	n.s.	0.05	n.s.	n.s.	n.s.	

dant at the 50-m station. Table 31 shows that only a few species were common at all stations. Most species have a clumped distribution or occur in such low numbers that they are found in only a few samples. In all the latter species it is almost impossible to study mortality in the boxcosms on a statistical basis. Only those species can be considered which occurred in reasonable initial field densities. The required abundance of an individual species was considered to be at least 2 specimens per Rheineck sample on average (or ≈ 7 specimens per 0.25 m^2 , i.e. the surface area of one boxcosm). Only 5 species met this condition at all stations, whereas another 5 were present in such numbers only at 1 or 2 stations (Table 18). Except for *Callianassa subterranea* all these species occurred in lower densities in the boxcosms

after the incubation period than in the original field situation, indicating that most species suffered mortality. It seems that mortality was generally highest in the 50-m cores and lowest in the 5000-m cores. Statistical significance of mortality and of differences in mortality between the cores of the 3 stations has been tested by two-way analysis of variance (SOKAL & ROHLF, 1969) for the upper 5 species of Table 18, after transformation by $\log(n+1)$ to stabilize variances. The results summarized in Table 19 show that overall mortality during incubation was significant at the 5% level in *Lumbrineris latreilli*, *Amphiura filiformis* and *Echinocardium cordatum*, but not in *Gattyana cirrosa* and *Chaetopterus variopedatus*. Differences between numbers found at each station were significant in all species except *Chaetopterus*

TABLE 17

Location F18/9. Boxcosm experiment 1988-1989. Initial fauna abundance of the sediment used in the boxcosms. Numbers of species and individuals in 10 Reineck samples per station.

	number of species	total number of individuals
5000 m	66	899
100 m	55	590
50 m	45	397

variopedatus, i.e. the densities at the 50-m station, derived both from Rheineck cores and boxcosms, were significantly lower than at the 5000-m station. The densities at the 100-m station were intermediate. However, none of the individual species demonstrated an interaction effect, i.e. differences in mortality between boxcosms of the 3 stations were not significant.

The same statistical procedure was applied to the numbers obtained after pooling the counts of the species mentioned above, and after pooling the counts of all species together (Table 19). Both operations revealed a highly significant interaction effect. From this result it may be inferred that although the natural infauna apparently suffered mortality in the boxcosms of all stations, mortality was substantially

higher in those of the polluted 50-m station.

Mortality of the lower 5 species in Table 18 was tested for significance at the 95% confidence level by applying a Mann-Whitney U-test. Mortality appeared significant in *Notomastus latericeus* and *Abra alba* in the 5000-m cores, and in *Philine scabra* in the 100 and 50-m cores.

Although the total fauna will have suffered mortality in the mesocosms, differences in mortality can be discerned between various taxonomic groups (Table 20). Overall high mortality was found in Echinodermata and, to a lesser extent, in Molluscs. Crustaceans seem to represent the most resistant group. For all groups mortality was lowest in the 5000-m cores (with low oil concentrations) and, except for crustaceans, highest in the 50-m cores (with high oil concentrations).

3.3.2.3 BEHAVIOUR OF TEST ANIMALS

Burrowing times of test species are illustrated in Fig. 17. Since the species respond rather differently when liberated in the boxcosms, their behaviour will here be treated separately.

Amphiura (ECH): Most specimens started digging immediately and in all boxes 50% had disappeared in the sediment within 2 to 3 minutes. In the 5000 and 100-m boxes 90% burrowing was reached within 5 to

TABLE 18

Boxcosms F18/9. Mean numbers of individuals per boxcosm ($n=0.25 \text{ m}^{-1}$) of 10 abundant species before (n_A) and after (n_B) incubation. Significance of differences tested with Mann-Whitney U-test. *: significant at the 95% level; n.s.: not significant.

		5000 m	100 m	50 m
<i>Gattyana cirrosa</i>	n_A	24.3	11.6	14.1
	n_B	10.5 n.s.	10.4 n.s.	.7 n.s.
<i>Chaetopterus variopedatus</i>	n_A	21.5	12.0	12.0
	n_B	20.7 n.s.	10.8 n.s.	1.0 n.s.
<i>Lumbrineris latreilli</i>	n_A	31.7	28.5	11.6
	n_B	15.5 n.s.	12.2 n.s.	3.5 n.s.
<i>Amphiura filiformis</i>	n_A	69.0	17.3	15.1
	n_B	7.0 *	2.8 *	.3 *
<i>Echinocardium cordatum</i>	n_A	29.9	32.7	14.8
	n_B	21.2 n.s.	.4 *	.0 *
<i>Notomastus latericeus</i>	n_A	13.4		
	n_B	6.2 *		
<i>Pectinaria auricoma</i>	n_A	10.7		
	n_B	5.2 n.s.		
<i>Abra alba</i>	n_A	11.3		
	n_B	.3 *		
<i>Callianassa subterranea</i>	n_A	13.5		
	n_B	14.5 n.s.		
<i>Philine scabra</i>	n_A		15.8	24.6
	n_B		.8 *	.5 *

TABLE 19

Significance of mortality, of differences in densities between stations and of the interaction effect, i.e. station dependent mortality, tested by analysis of variance (ANOVA).

*: significant at 5 % level; n.s.: not significant.

	difference between mortality interaction stations		
<i>Gattyana cirrosa</i>	*	n.s.	n.s.
<i>Chaetopterus variopedatus</i>	n.s.	n.s.	n.s.
<i>Lumbrineris latreilli</i>	*	*	n.s.
<i>Amphiura filiformis</i>	*	*	n.s.
<i>Echinocardium cordatum</i>	*	*	n.s.
Pooled counts of the above 5 species	*	*	*
Pooled counts of all species together	*	*	*

15 minutes. A few specimens stayed inactive longer, but after 24 h all had disappeared. In the 50-m box a substantial number behaved differently, particularly those, which were put on oil patches. They kept creeping around till they reached fine sediment. Finally, after 24h all specimens had disappeared in this box too. During the incubation period, only once was a specimen observed on the surface. This occurred in the 50-m box. After termination of the experiment most of the surviving animals were found in the upper 15 cm of the sediment.

Echinocardium (ECH): In the 5000 and 100-m boxes the sea urchins generally burrowed within 10 to 20 minutes. A few specimens remained inactive for some hours, but after 8 h all had dug in. In the 5000 m box the animals apparently migrated to rather deep sediment layers, just leaving a small hole at the surface. At the termination of the incubation period they were generally found at ≈ 15 cm depth. In the 100-m box some specimens were always seen just beneath the sediment surface. On the contaminated sediment of the 50-m box the test animals behaved

quite upset. Most of them burrowed and moved over the surface alternately. After 30 min. only 2 had completely dug in and after 2 h still more than 50% were observed on top of the sediment. Five animals never dug in and kept creeping round on a large oil patch. The other specimens were generally observed just beneath the surface and regularly reappeared on the sediment surface after 2 weeks, till finally they stopped burrowing, perhaps as a consequence of severe loss of spines. On the ventral side the loss of spines was on average 40% in dying animals. It seems likely that the deviant behaviour of *Echinocardium* will expose them to enhanced predation by epibenthic and pelagic carnivores.

Turritella (MOL): This gastropod mollusc seems to dwell in the superficial sediment layers and is often seen creeping on top of the sediment. Many of the liberated animals kept moving around on the surface and a minority had burrowed within 4 hours, also in the 5000-m box. It is difficult, therefore, to discern possible effects of sediment pollution on their behaviour. Still the low number of specimens (6) that burrowed within 8 h in the 50-m box (compare 16 and 17 specimens in the 100-m and 5000-m box) might indicate that contamination of the sediment could have retarded their digging activity.

Lagis (POL): This worm lives in a tube just beneath the sediment surface. About 50% of the animals burrowed under (halfway or completely) within 7 to 15 minutes after liberation and 80 to 90% had disappeared after 1 h. In each of the boxes 2 or 3 animals were apparently in a poor condition and did not dig at all, but died within a few days. So far there was hardly any difference between the boxes of different stations. However, only in the 5000-m box the tubes did all disappear completely in the sediment, whereas in the 100 and 50-m boxes most of the animals dug only halfway down into the mud. The animals seemed to prefer the relatively clean top layer and to avoid the deeper contaminated sediment layers. It is not clear whether this phenomenon has to be considered an abnormality. It seems plausible,

TABLE 20

Boxcosms F18/9. Densities ($n \cdot m^{-2}$) of natural benthic infauna, pooled in taxonomic groups, before and after incubation. Percentage mortality in the 5000 m boxcosms and additional mortality in the 100 m and 50 m boxcosms are indicated. Oil contents in parentheses (mg/kg wet-weight)

	5000 m (2)			100 m (9-160)			50 m (100-1270)		
	Start	End	%Mort.	Start	End	Add. mort.	Start	End	Add. mort.
Polychaeta	614	345	44	368	186	5	252	83	23
Mollusca	149	60	60	139	17	28	127	7	35
Crustacea	101	70	31	87	27	38	23	11	19
Echinodermata	401	117	71	237	35	14	158	6	25
Other taxa	86	58	33	69	26	29	52	3	61

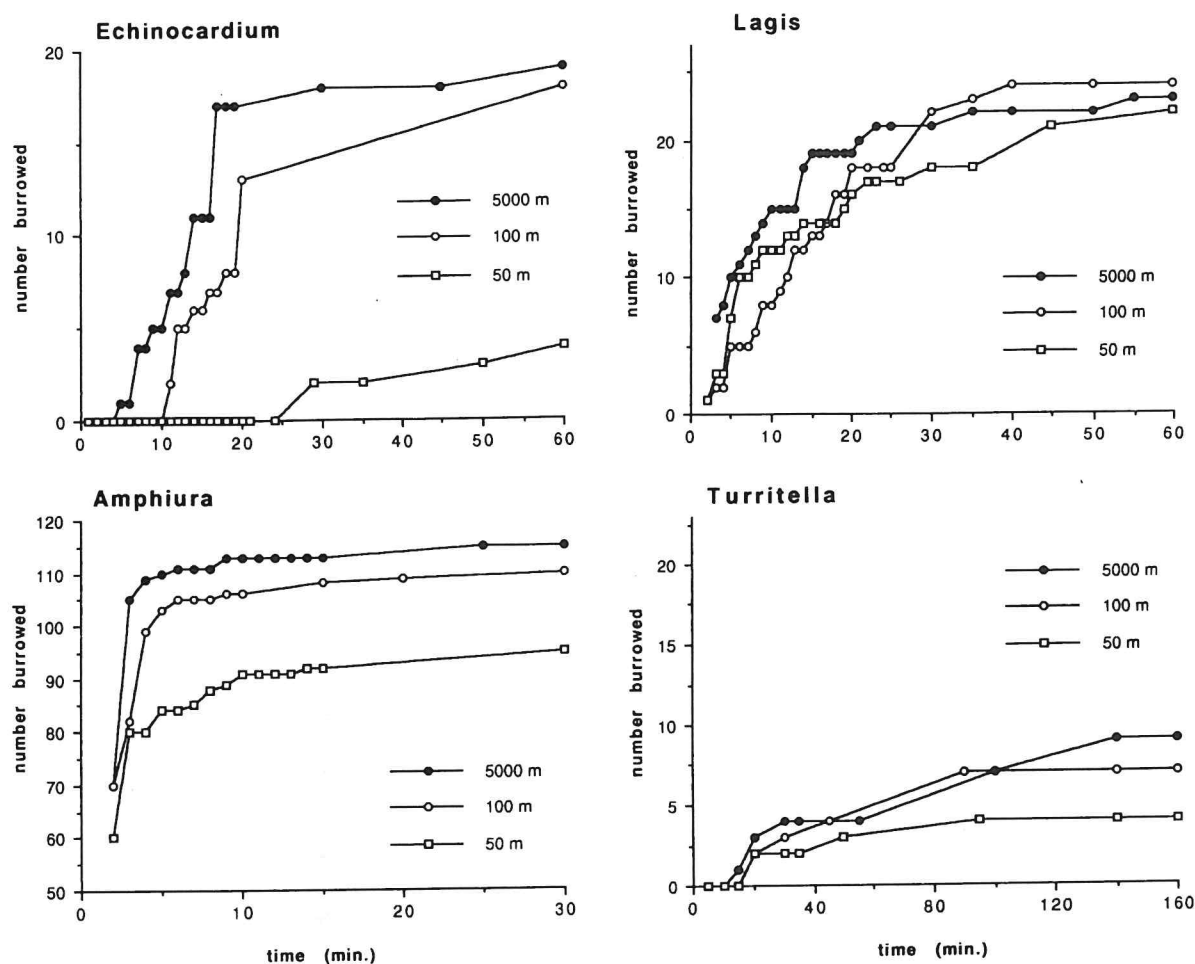


Fig. 17. Boxcosms F 18.9: Burrowing times of 4 test species in sediment from 50 m, 100 m and 5000 m. Numbers of specimens introduced per boxcosm: *Echinocardium cordatum*: 20, *Lagus koreni*: 27, *Amphiura filiformis*: 120, *Turritella communis*: 23.

however, that in the natural field situation animals that live not completely hidden in the sediment are exposed to enhanced predation pressure.

Macoma (MOL): This bivalve shell is very common in the Dutch coastal area, and much used in experimental work. However, in the soft sediment of F

18.9 it did not do very well. Most specimens did not dig in at all, or only after several days. Animals that burrowed under did not show elevated siphons, which would have been evidence of normal behaviour. Differences in behaviour related to sediment contamination were not observed.

TABLE 21

Boxcosms F18/9. Mortality of *Amphiura*, *Echinocardium* and *Lagus* after 3 months of incubation; oil contents in parentheses (mg/kg wet weight).

	initial number	5000 m			100 m			50 m		
		number died	%mort		number died	%mort		number died	%mort	
<i>Amphiura</i>	120	(2)	7	6	(19)	21	18	(1274)	81	68
<i>Echinocardium</i>	20	(2)	0	0	(9)	3	15	(356)	17	85
<i>Lagus</i>	27	(2)	18	66	(161)	24	89	(535)	27	100

TABLE 22

Experiment on sediment selection by test organisms. N_0 : initial number of animals liberated; N_1 : number of animals, which survived the experimental period; mat: number of animals recovered in matrix sediment; 5000, 100 and 50 refer to origin of replaced sediment core.

boxcosm		5000 m				100 m				50 m			
testorganism	N_0	N_1	mat	100	50	N_1	mat	5000	50	N_1	mat	5000	100
<i>Echinocardium</i>	30	14	14			16	11	3	2	8	7		1
<i>Amphiura</i>	120	90	57	18	15	117	92	10	15	89	63	12	14
<i>Turritella</i>	21	19	16	3		21	19	2		21	16	2	3

3.3.2.4 SURVIVAL OF TEST ANIMALS

Over the period of incubation clear differences in percentage survival were found between the test species. *Turritella* appeared a strong species, that survived in the boxcosms of all stations. On the other hand *Macoma* suffered almost total mortality in all boxes. About half of this mortality was confirmed during daily inspections. In this respect there was hardly any difference between the stations. Thus, in both species (*Turritella* and *Macoma*) no effect of OBM- contamination could be found on mortality rates. Mortality was also high in *Lagis* (Table 21). However, in the box of the reference station still 33% survived, whereas in the polluted 50 m box mortality was complete. The most obvious trends in mortality were found in the echinoderms *Echinocardium* and *Amphiura*. Both species survived in the reference cores, suffered slight mortality in the 100-m cores and high mortality in the 50-m cores. In *Amphiura* mortality was confirmed after termination of the experiment, but in *Echinocardium* almost all mortality could be recorded during daily inspections (Fig. 18). 50 % of the animals in the 50-m core died within 3 weeks. The 3 animals which were still alive in this core at the end of the incubation period were in a bad condition and had lost $\approx 40\%$ of their spines on the ventral side.

3.3.2.5 SEDIMENT SELECTION BY TEST ANIMALS

After changing cores between the boxcosms of the 3 stations (series E), the test animals were introduced in the first week of November. All species seemed in good condition and readily burrowed. However, during daily inspections considerable mortality became evident among the subadult *Echinocardium* in all boxes, particularly in the first weeks. In that period 30 to 40% of the animals appeared at the sediment surface and died. As was already experienced upon collection, subadult specimens are much more vulnerable than adults, and handling may easily have a lethal effect. Total mortality and final settlement of the surviving

animals was assessed 2 months later (Table 22). In *Echinocardium* mortality amounted to $\approx 50\%$ in the boxes of the 5000 and 100-m stations and to $\approx 75\%$ in the 50-m box. *Amphiura* did not suffer significant mortality in the 100-m box, but $\approx 25\%$ died both in the 50-m and in the 5000-m box. *Turritella* survived the experimental period for almost 100%.

The numbers of specimens found in each type of sediment in the 3 boxcosms do not support active selection of either sediment type (Table 22). In all boxes most specimens of each species were found in the original matrix, which is to be expected if sediment selection does not play a role, since the surface area covered by this matrix was about 4.5 times as large as the complete area covered by the cores.

3.3.2.6 RECOLONIZATION BY NATURAL INFAUNA

This experiment was set up to investigate the potential usefulness of boxcosms for recolonization

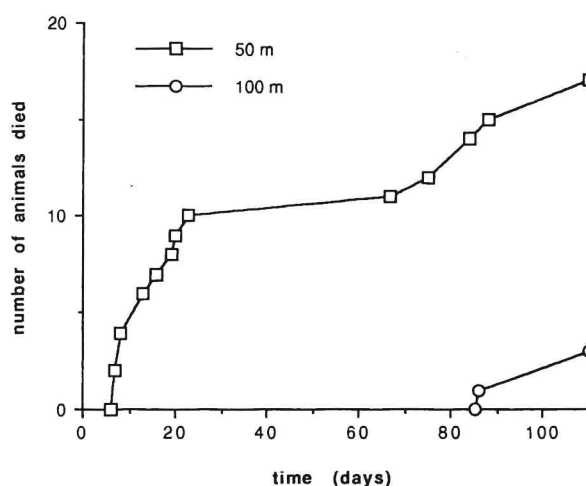


Fig. 18. Boxcosms F 18.9: Mortality in *Echinocardium cordatum* in sedimentcores from 50 m ($356 \text{ mg oil} \cdot \text{kg}^{-1}$ sediment) and 100 m ($9 \text{ mg oil} \cdot \text{kg}^{-1}$ sediment). (N.B.: in the 5000-m core ($2 \text{ mg} \cdot \text{kg}^{-1}$) no mortality occurred).

studies. For this purpose, subcores from a 50-m and a 5000-m boxcosm were interchanged. The experiment failed because of practical difficulties. First, the procedure applied to create anaerobe conditions in the cores before they were exchanged was unsuitable to expel all live infauna from the cores: as Table 23 shows, the 5000-m cores transferred to the sediment matrix of the 50-m boxcosm later revealed 8 specimens of species that only occurred in the 5000-m matrix and not in the 50-m matrix. There is only one plausible explanation for this, viz. these animals have survived the 2 weeks during which the overlying water in the cores was purged with nitrogen gas. The second reason why the experiment failed is that, in view of the natural faunal densities in the sediment matrices, the volume of the transferred sediment cores appeared too small. This prohibited a quantitative assessment of migrations of species between contaminated and clean sediments.

3.4 IN SITU PHOTOGRAPHS

Of stereophotographs collected at K12a, 31 pairs were analyzed. The quality of the photographs was quite perfect. On the sediment surface a few specimens of macrobenthic species were seen, which could be identified to species level (e.g. the mollusc *Natica alderi* and the crab *Corystes cassivelaunus*) or to genus level (e.g. the brittle star *Ophiura* spec.). Numbers of epifauna were, however, too low to compare them reliably with the grab sample counts.

Several holes and tubes indicated the presence of benthic infauna. Holes were recognized as likely belonging to the sea urchin *Echinocardium cordatum* and the crustaceans *Callianassa* and/or *Upogebia* spec., respectively. The polychaetes *Spiophanes bombyx* and *Lanice conchilega* were assumed to be inhabitants of the tubes. However, the photographs

revealed no specimens of these species. By counting all holes and tubes, estimates were obtained of the densities, in which the different species could have occurred.

Very few holes of *Echinocardium* were evident from the photographs taken at the residual current transect, particularly when compared to the numbers visible on the stereo-pairs from the perpendicular transects. This is in contrast to the grab sample results, since *Echinocardium* was present in huge numbers especially on the residual current transect and occurred in much lower densities on the perpendicular transect stations (Table 27) (Appendix). It seems likely that the holes belonged to other infauna than *Echinocardium* and that *Echinocardium* burrows are only now and then visible. This might also explain why *Echinocardium* occurred in the grab samples always in much larger numbers, than counts from the photographs suggested.

For *Spiophanes bombyx* the opposite was true: the photographs showed more tubes than there were living specimens of this species in the grab samples. It seems plausible, that also empty tubes have been counted, since it was not possible to detect from the photographs whether the tubes were occupied or not. There was no correlation between the numbers of tubes counted from the photographs and the numbers of *Spiophanes* found in the grab samples.

Burrow openings belonging to *Callianassa* or *Upogebia*, that were visible on some photographs, do not allow for quantitative estimates of densities in which these species occur, because different funnels may belong to only one living specimen. These species build a branched system of funnels with a varying number of outlets.

From the photographs taken at the 100-m, 250-m and 500-m stations on the residual current transect, patches of oil were evident. On board such patches were also observed in the grab samples.

TABLE 23

Recolonization of changed sediment cores (F-series of boxcosms) by natural infauna. Numbers of individuals found in different sediment compartments are indicated.

	5000 m boxcosm			50 m boxcosm		
	Matrix	5000 m core	50 m core	Matrix	5000 m core	50 m core
Animals which belong to species (27) only found in the 5000 m matrix	117	5	5	-	8	0
Animals which belong to species (3) only found in the 50 m matrix	-	1	0	55	0	8
Animals which belong to species (2) found in both matrices	13	0	0	2	0	0
Animals which belong to species found in neither of the matrices	-	6	0	-	2	0



Fig. 19. L4a June 1987: View on the sediment at 250 m (p.t.). (Use the 3-D viewer provided on the inside of the back-cover.)

Summarizing the stereophotographic results at K12a, it is concluded, that the number of infaunal surface structures are not correlated with the actual number of infauna, which is consistent with the observations of WILDISH & LOBSIGER (1987). Major problems arising in the analysis of the photographs are:

a. The morphological characteristics of holes and tubes offer no distinct key to identify the inhabiting animals.

b. It is not possible to detect, whether tubes are empty or occupied by living animals.

c. Some species build funnel systems with often more than one outlet.

A particular problem in sandy areas, in which platform K12a is situated, is, that the seabed is unstable, due to the prevailing current velocities. This may be the major reason why the presence of organisms in the sediment is not always necessarily indicated by the presence of outlets at the sediment surface. As a consequence, the photographs will generally suggest less infauna, than actually is present.

It is for the latter reason, that also location L4a was visited in September 1987. The idea was, that

stereophotography might yield better results in this area, which is characterized by rather stable fine sediment and a relatively rich infauna. Indeed, the photographs showed a more differentiated pattern of sediment structures, which, at least for some species, might be better to quantify than was possible at K12a. Still, it will be hardly possible to gain overall quantitative information on the fauna composition in terms of species richness and densities of most of the individual species.

Fig. 19 shows a stereo photograph taken at the 500 m station on one of the perpendicular transects. Structures and epifauna specimens, as evident from this photograph, appeared generally less abundant at stations in the vicinity of the platform. In this respect a gradient was detected towards the platform. Quantitatively the camera results could not be tested, since simultaneous grab sampling data are not available. In broad outline the gradient, photographically observed in September 1987, corresponds to the grab sampling results of June 1987. However a quantitative comparison is again not possible, because of the difference in time.

3.5 FIELD DOSE-EFFECT RELATIONSHIPS

So far, the biological effects of sediment contamination around drill sites, as detected during the field surveys, have been described in terms of gradual changes in benthic fauna abundance on spatial and on temporal scales. Observed density changes, on species level as well as on community level, were related to distance of the sampling stations to the discharge point and to time elapsed since actual drilling activities took place. The effects described were considered to be the net result of the distribution of OBM-contaminated cuttings in space and time. Implicitly, it was assumed that the concentration of oil components in the sediment, *i.e.* those originating from the discharged material, was dependent on:

- a. the amount of oil discharged
- b. the distance to the platform
- c. the time elapsed since discharge took place

Although these assumptions seem quite plausible, the question remains to what extent the observed effects can be related to oil concentrations detected in the sediment. Particularly from the management point of view, it is important to know what kind of effects have to be expected at different levels of sediment pollution, *c.q.* at different levels of emission.

Before arriving at the actual comparison of oil data and observed biological effects, it should be noted here that interpretation of the field data in terms of dose-effect relationships is *a priori* subject to major problems, which may be summarized as follows:

- a. Although biological effects are indisputable and

often have been statistically verified, it is in general not possible to quantify such effects consistently and reliably because of differences in fauna composition between locations and natural variability in the abundance of species within sampled transects. We are compelled therefore, to compare oil data and different kinds of effects in a qualitative way. Although the effects that occur are generally not independent of each other, accumulation of observed effects may serve as the most suitable response variable.

- b. Oil concentrations were assessed in pooled subsamples taken from each of 10 van Veen grabs collected per station and, thus, represent an average in which patchiness of the oil distribution is smoothed. Within a series of grab samples, however, the concentrations may be highly variable (*e.g.* DAVIES *et al.*, 1989; VAN HET GROENEWOUD, 1990) and especially the degree of patchiness may largely determine the character of the effects observed.

- c. Routine samples for oil analysis were restricted to the top layer (0-10 cm) of the sediment. Accumulation of contaminants in deeper sediment layers is thus ignored as a possible cause of observed effects.

- d. Character and intensity of biological effects will largely depend on factors like the chemical composition of the discharged muds, grain size of the bottom substrate, the rate of distribution of different contaminants, and the changes taking place in the composition of the oil mixture. At the investigated locations different types of OBM have been used, but since the hydrographical characteristics at L4a, K12a and F18.9 are not the same and the amounts of material discharged vary considerably (Table 1) a specified interpretation of the effects, with respect to the chemical composition of the OBM discharged, is not possible.

- e. Effects measurable at some distance from the discharge point, where oil concentrations are hardly enhanced, might be caused by transport of toxic contaminants through the water.

Considering the above mentioned restrictions in the interpretation of field data, Fig. 20 still illustrates how increasing oil concentrations in the sediment generally result in an accumulation of measurable effects. All effects are described in terms of reduced or enhanced numbers on species level or community level. The criterion utilized to qualify numbers as reduced or enhanced was that these numbers should fit in a significant gradient. At L4a, the location with probably the lowest load of pollution (Table 1), severely enhanced oil concentrations in the sediment were only found within 100 m. At the highest concentration of 5989 mg oil per kg sediment (PI-station, June) all defined effects were observed. At the 100-m station, however, the correlation between oil concentrations and observed effects is complicated: Although in February a lower oil concentration

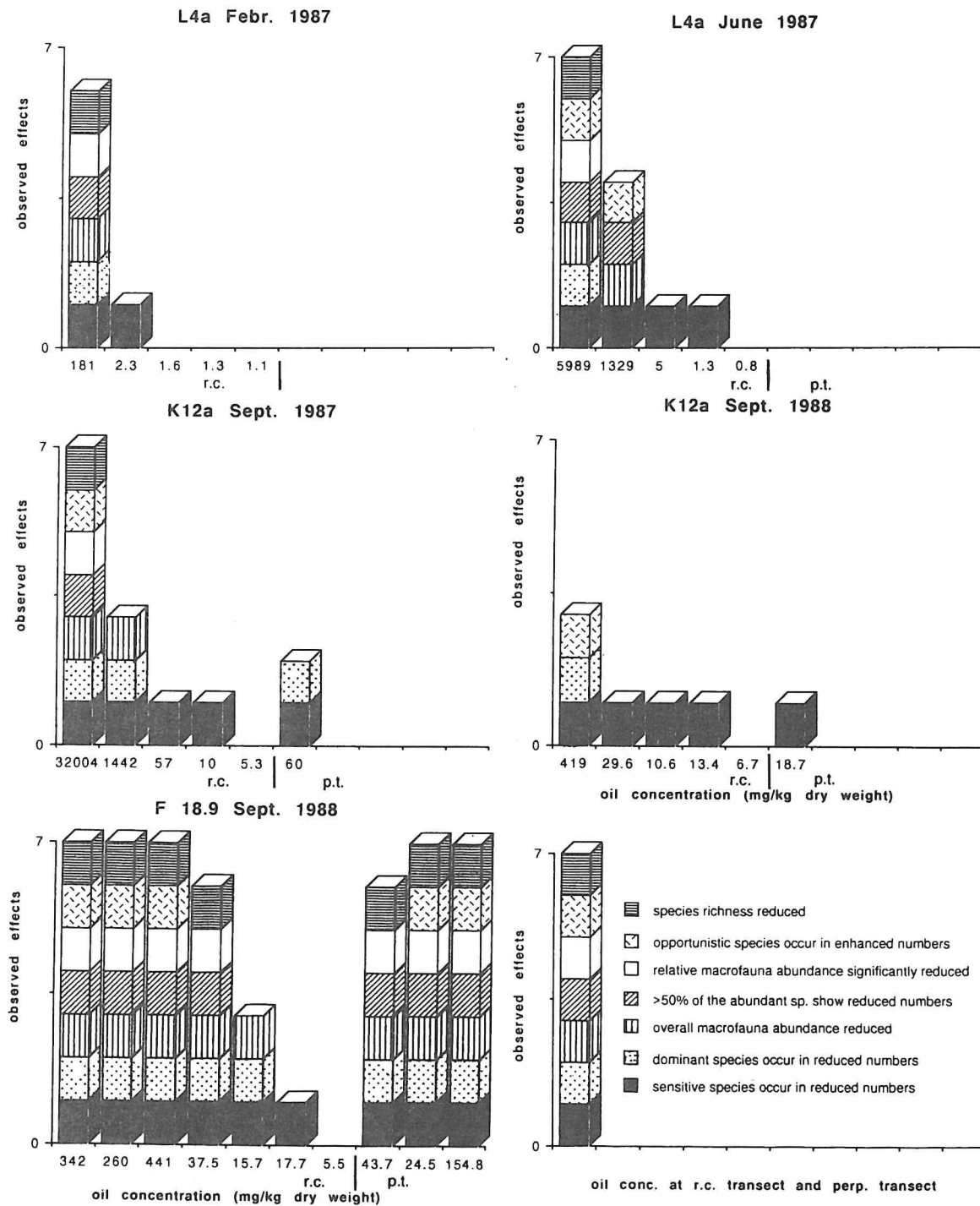


Fig. 20. Observed effects around L4a (4 and 8 months after drilling), K12a (3 and 4 year after drilling) and F 18.9 (1 year after drilling) at varying levels of sediment contamination.

(181 mg·kg⁻¹) was found than in June (1329 mg·kg⁻¹), nearly all effects, except for the occurrence of opportunistic species, were observed in February. In June no effects could be detected in terms of relative abundance, reduced occurrence of dominant species or species richness. Farther off the platform, slight effects, indicated by the absence of some sensitive species, were found at concentrations between 1 and 5 mg/kg.

At K12a an accumulation of all effects could only be detected in 1987 right beneath the Platform, at the very high concentration of 32 000 mg/kg. At some distance from the platform, the concentrations measured (1442 mg/kg in 1987 and 419 mg/kg in 1988) involved considerably fewer (3) effects than in 1986, when in this area at a similar concentration (361 mg/kg, VAN HET GROENEWOUD, 1987) all effects were clearly present (see MULDER *et al.*, 1988). At concentrations between 10 and 60 mg/kg, effects in macrofauna composition were indicated only by reduced numbers of some sensitive species and by the presence of an opportunistic species (at the 250 m p.t. station). The number of effects observed at these concentrations seems low compared to the number of effects observed at similar concentrations at other locations. This might suggest, that the toxicity of the material discharged at K12a has gradually decreased. Weathering and biodegradation could have resulted in a decrease of the fraction of aromatics, which are particularly toxic (*e.g.*, RICE *et al.*, 1978). The occurrence of such a decrease could not be verified, since in the chemical analyses aromatics were not consistently included. However, indications for the occurrence of weathering or biodegradation might be obtained from the fractions of other compounds in the oil mixture, since degradation of different oil compounds will occur at different rates. As a result of weathering, the UCM fraction in the oil tends to increase, whereas within the group of the alkanes a decrease in dominance of the smaller chains should be expected (WOLFE, 1985). The fractions of the larger chains will become relatively more important. Thus, indications for weathering might be obtained from the results of the chemical analyses performed between 1985 and 1988 (KUIPER & VAN HET GROENEWOUD, 1986; VAN HET GROENEWOUD, 1988, 1990). The following UCM fractions (% of total oil) were detected at the residual current transect:

- 1985: 45 and 41% (platform and 250-m station)
- 1986: 4 to 49% (whole transect between 100 and 5000 m, no trend)
- 1987: 8% at the platform and 64 to 80% between 100 and 750 m.
- 1988: 53 to 65 % (platform to 250-m station)

Indeed, the UCM fraction seems to have increased somewhat, but the share of UCM in the total oil concentration appeared extremely variable. This varia-

bility may be explained by several factors:

1. heterogeneity of the oil mixtures in the discharged OBM,
2. spatial differences in degradation rates,
3. sensitivity of the analytical methods applied, which may include an error of $\approx 10\%$ in the detection of the UCM fraction.

Of the alkanes the consecutive fractions C-9 upto C-20 were consistently analysed between 1985 and 1988. Within these fractions no shift in dominance could be found at stations within 250 m from the platform. C-12 generally showed a distinct peak and the fractions of C-11 to C-13 accounted together always for 16 to 80% of the alkanes, without showing any temporal trend. At stations ≥ 500 m, however, these smaller alkanes seemed to have largely disappeared in 1988 (see VAN HET GROENEWOUD, 1990). As a consequence a shift in dominance could be observed towards the larger alkanes in this area.

Summarizing, it is concluded, that the chemical analyses do provide only weak evidence for weathering of the oil in the vicinity (≤ 250 m) of the discharge point, whereas such indications are stronger more far off (≥ 500 m). If weathering does not play an important role, an alternative explanation for the decrease in effects might be that the oil present in the sediment is for the most part enclosed in pockets of cuttings and muds. As a consequence, toxic compounds might have become less available to benthic organisms.

Finally, a remarkably high concentration of 5859 mg/kg, found in 1987 at the 750 m (r.c.) station of K12a, was hardly reflected in the fauna composition at this station. This is most plausibly explained by the presence of some 'tar droplets' in one of the van Veen grabs, identified as originating from the discharged muds (VAN HET GROENEWOUD, 1990), that could have been subsampled by accident. Such a local pollution may hardly be expected to affect the macrofauna. This example of patchiness illustrates that correlations between spatially observed effects and oil data should be interpreted with caution.

An increase in measurable effects at increasing concentrations of oil in the sediment is most clearly illustrated by the observations at F 18.9. Extremely high concentrations were not found at this location, but at 'moderate' levels of 20 to 400 mg/kg most effects could always be detected. Below 20 mg/kg effects seem to decline gradually.

To what extent are effects of sediment contamination predictable? Having in mind the earlier mentioned restrictions in the evaluation of field data, this question might be tackled by summarizing all dose-effect relations observed in the consecutive surveys (Fig. 21). The most sensitive response variable is undoubtedly the abundance of some species that display their susceptibility to oil-derived contaminants

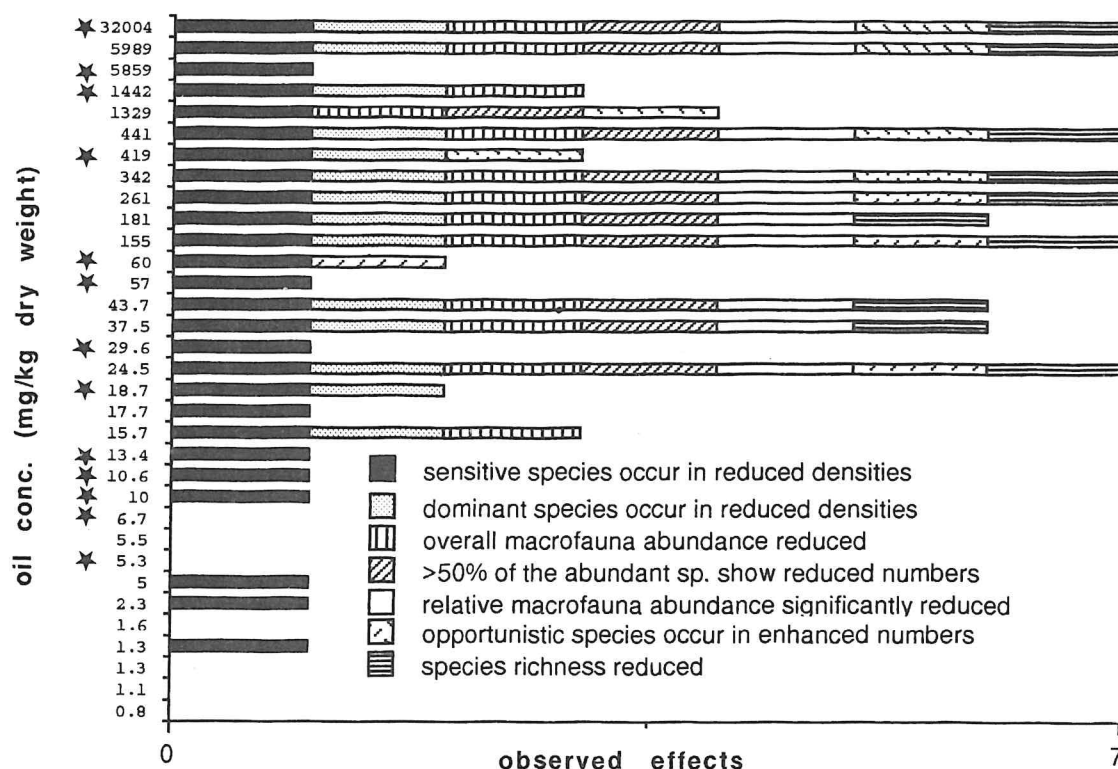


Fig. 21. Summary of observed effects at contamination levels ranging from 0.8 to 32000 mg/kg dry sediment (1987 and 1988). * = more than 2 years after termination of the discharges.

by a gradient in frequency of occurrence over the sampling transect (sensitive species). Reduced densities of sensitive species were observed already at oil concentrations of 1 - 10 mg/kg. However, the criterion utilized to qualify numbers of individuals found as 'reduced', is not unambiguous, since the bending point in a density gradient curve cannot be exactly detected, because of natural variability in the density distribution of species. At concentrations between 10 and 100 mg/kg overall macrofauna abundance, excluding or including dominant species, tends to be significantly reduced. A limited number of species may substantially contribute to this decrease in abundance. The detection of this effect depends on the presence of abundant species in the area of research that are susceptible to moderate contamination of the sediment: *E.g.*, *Lumbrineris latreilli* and *Amphiura filiformis* have both been found as abundant or even dominant species in several surveys; only the latter species, however, responded in terms of reduced abundance to oil concentrations of 10 - 100 mg/kg. At the same level of pollution all defined effects have been established in some cases, including reduced relative macrofauna abundance, reduced species richness and the occur-

rence of opportunistic species. Finally, all these effects are very likely to be found in areas with OBM-pollution levels consistently above 100 mg/kg, at least within 2 years after the material has been discharged. At longer term the biological impact of such concentrations seems to be depressed.

4 DISCUSSION

During the consecutive research projects performed since 1985 on biological effects of drilling activities, a total number of 15 surveys has been carried out at 9 locations on the Dutch continental shelf. The samples of 11 surveys were actually analyzed. Six surveys have been reported by MULDER *et al.* (1987, 1988). The remaining 5 are dealt with in this report. Two surveys concerned platforms where only water-based drilling fluids (WBM) had been utilized and discharged. On all other locations visited, discharged drill cuttings were contaminated with OBM. Summarizing the results of all field surveys it is concluded, that at WBM locations no clear effects have been detected, whereas at OBM locations effects always became manifest by reduced numbers of species or reduced specific densities in the vicinity of the

discharge point. However, the susceptibility of individual species to discharged OBM could not be reliably demonstrated by the data obtained during separate surveys, for reasons of natural variability in distribution patterns and problems involved in statistical verification. The accumulated information however, obtained by pooling the data of 11 surveys, provides much evidence for (a) susceptibility to OBM-discharges displayed by a number of species and (b) the presence of a few opportunistic species in severely contaminated areas. In Table 24-A a number of sensitive species is listed, in Table 24-B some opportunistic species. The species are arranged according to the frequency, in which their susceptibility (or opportunism) was indicated by relatively low (or high) densities near the discharge point during at least 3 surveys. (The qualification 'low (or high) density near the discharge point' was in individual surveys only applied to species of which at least 20 specimens were found during that survey.) Table 24-A shows that evidence of susceptibility to OBM is most obvious in *Montacuta ferruginosa*. During 8 OBM surveys the species was found to be absent or occurred in reduced numbers in the vicinity of the platform, whereas no conflicting observations were made. On the other hand at WBM locations no decrease was observed at the platform. For species listed below *Montacuta* decreasing evidence was obtained for OBM susceptibility. A few species displayed conflicting distribution patterns. E.g., *Nucula turgida* was found in reduced numbers in the vicinity of platforms during 6 OBM surveys, but during 1 survey in enhanced numbers. This example may illustrate that results of individual surveys should be interpreted very cautiously. It should be noted here that the species listed are arranged according to *decreasing evidence* and not to *decreasing susceptibility*! A species like *Nucula turgida* was often absent at platform stations, but abundant already at 250 m stations, whereas e.g. *Lysilla loveni* has displayed gradients over the whole residual current transect, and, therefore, might be considered much more sensitive.

The list of opportunistic species (Table 24-B) is much smaller. Only 2 species showed consistently higher densities in contaminated sediments. *Capitella capitata* is universally known to be abundant under gross organic enrichment, including areas affected by oil pollution (e.g. GRAY, 1982; DAVIES *et al.*, 1984; LEVELL *et al.*, 1989). For *Nereis longissima* the literature does not provide such evidence. In 2 other species the observations were conflicting. There is a plausible explanation for this: It is not only due to the absence of competitors or predators that opportunistic species occur in enhanced numbers in contaminated sediment. An important factor is their tolerance for the specific kind of contamination con-

cerned. If, however, the severity of contamination exceeds a certain critical level, even the densities of opportunistic species may be negatively affected. A species like *Anaitides groenlandica* may show increased abundance under enrichment by organic pollution (see PEARSON *et al.*, 1983) but at K12a (platform, survey 1987) the species was absent, probably due to the extremely high contamination level of $32 \text{ g} \cdot \text{kg}^{-1}$ dry sediment. The highest level of contamination observed during a survey, will largely depend on the distance of the nearest station to the discharge point. Since this distance was rather variable among the different surveys, the presence of opportunistic species will not always be unambiguously established.

Our increased knowledge on sensitive and opportunistic species may contribute substantially to an adequate interpretation of field data. For location L4a, where a relatively small amount of OBM has been discharged, only field data on the macrofauna distribution were collected. Clear effects were observed up to 100 m distance to the platform. Outside this area the faunal composition appeared to have changed compared to the situation before OBM-drilling (baseline study), particularly within 500 m, whereas such changes became less pronounced farther off. This might indicate a causal relationship between level of pollution and severity of changes observed in faunal composition. Indeed, the decrease of some sensitive species like *Harpinia antennaria*, *Montacuta ferruginosa*, *Echinocardium cordatum* and *Lagis koreni* seems to be closely related to a gradient in pollution by OBM. It would be too much to conclude, however, that opportunistic species have reoccupied the habitat of sensitive species in the area: a number of species which appeared susceptible to contaminants in several surveys (e.g. *Scalibregma inflatum*, *Gattyana cirrosa*, *Chaetopterus variopedatus*, *Perioculodes longimanus* and *Diplocirrus glaucus*, see Table 7) actually increased in the area. The change in the faunal composition in the area within 1000 m, additional to the natural change in the whole area might therefore be interpreted as a gradual shift from strongly sensitive species to less sensitive species.

In the area around K12a the macrofauna seems to have largely recovered in 1988, i.e. 4 years after extensive drilling activities, during which high-toxic diesel-based muds were discharged. Even within 100 m only slight effects were observed. This seems quite remarkable since the sediment samples collected looked severely contaminated and were confirmed to be so by the chemical analyses (VAN HET GROENEWOUD, 1990): although contamination levels in 1988 were lower than those found in 1987, they were quite similar to those found in 1986. The apparent recovery of the sediment, however, is most obvi-

TABLE 24

List of common 'sensitive' and 'opportunistic' species, based on 11 surveys (9 OBM and 2 WBM). In this table those species are listed, which, during at least 3 OBM-surveys, were observed to occur in relatively low (high) numbers in the vicinity of the platform. The total number of surveys, in which at least 20 specimens of each species were found, is given after the taxonomic group. The frequency of relative abundances near the platform (low, normal or high) is given for OBM-surveys as well as for WBM-surveys.

A. Sensitive species				Density at PL.		
				low	normal	high
<i>Montacuta ferruginosa</i>	MOLLUSCA	10	WBM		2	
			OBM	8		
<i>Scalibregma inflatum</i>	POLYCHAETA	7	WBM			
			OBM	7		
<i>Pholoë minuta</i>	POLYCHAETA	10	WBM		1	1
			OBM	7	1	
<i>Amphiura filiformis</i>	ECHINODERMATA	9	WBM		2	
			OBM	6	1	
<i>Echinocardium cordatum</i>	ECHINODERMATA	9	WBM		2	
			OBM	6	1	
<i>Mysella bidentata</i>	MOLLUSCA	9	WBM		2	
			OBM	6	1	
<i>Nephtys hombergi</i>	POLYCHAETA	10	WBM		2	
			OBM	6	2	
<i>Lumbrineris latreilli</i>	POLYCHAETA	10	WBM		2	
			OBM	6	2	
<i>Chaetozone setosa</i>	POLYCHAETA	11	WBM		2	
			OBM	6	3	
<i>Owenia fusiformis</i>	POLYCHAETA	10	WBM		2	
			OBM	6	1	1
<i>Nucula turgida</i>	MOLLUSCA	9	WBM		1	
			OBM	6	1	1
<i>Gattyana cirrosa</i>	POLYCHAETA	7	WBM		2	
			OBM	5		
<i>Harpinia antennaria</i>	CRUSTACEA	7	WBM		2	
			OBM	5		
<i>Lagis koreni</i>	POLYCHAETA	8	WBM		2	
			OBM	5	1	
<i>Glycinde nordmanni</i>	POLYCHAETA	10	WBM		2	
			OBM	5	3	
<i>Cylichna cilindracea</i>	MOLLUSCA	6	WBM		2	
			OBM	4		
<i>Harmothoë longisetis</i>	POLYCHAETA	5	WBM		1	
			OBM	4		
<i>Callianassa subterranea</i>	CRUSTACEA	6	WBM		1	
			OBM	4	1	
<i>Magelona papillicornis</i>	POLYCHAETA	5	WBM			
			OBM	4	1	
<i>Tellina fabula</i>	MOLLUSCA	5	WBM			
			OBM	4	1	
<i>Natica alderi</i>	MOLLUSCA	6	WBM			
			OBM	4	2	
<i>Spiophanes bombyx</i>	POLYCHAETA	10	WBM		1	1
			OBM	4	4	
<i>Ophiodromus flexuosus</i>	POLYCHAETA	8	WBM		2	
			OBM	4	1	1
<i>Notomastus latericeus</i>	POLYCHAETA	7	WBM	1	1	
			OBM	4		1
<i>Lumbrineris fragilis</i>	POLYCHAETA	5	WBM		2	
			OBM	3		
<i>Amphiura chiajei</i>	ECHINODERMATA	4	WBM		1	
			OBM	3		
<i>Leucothoë incisa</i>	CRUSTACEA	3	WBM			
			OBM	3		

Table 24 continued.

A. Sensitive species				low	Density at PL.	
					normal	high
<i>Chaetopterus variopedatus</i>	POLYCHAETA	6	WBM		2	
			OBM	3	1	
<i>Tharyx marioni</i>	POLYCHAETA	6	WBM		2	
			OBM	3	1	
<i>Ophiura albida</i>	ECHINODERMATA	6	WBM		2	
			OBM	3	1	
<i>Gyptis capensis</i>	POLYCHAETA	5	WBM		1	
			OBM	3	1	
<i>Lanice conchilega</i>	POLYCHAETA	4	WBM			
			OBM	3	1	
<i>Perioculodes longimanus</i>	CRUSTACEA	5	WBM		2	
			OBM	3	1	
<i>Diplocirrus glaucus</i>	POLYCHAETA	7	WBM		3	
			OBM	3	2	
<i>Abra alba</i>	MOLLUSCA	9	WBM		4	
			OBM	3	1	1
<i>Turritella communis</i>	MOLLUSCA	6	WBM		1	
			OBM	3	1	
<i>Sthenelais limicola</i>	POLYCHAETA	6	WBM		1	
			OBM	3		2

B. Opportunistic species				low	Density at PL.	
					normal	high
<i>Nereis longissima</i>	POLYCHAETA	4	WBM			
			OBM			4
<i>Capitella capitata</i>	POLYCHAETA	4	WBM			
			OBM			4
<i>Spio filicornis</i>	POLYCHAETA	7	WBM			
			OBM	1	3	3
<i>Anaitides groenlandica</i>	POLYCHAETA	8	WBM			
			OBM	1	4	3

ously indicated by the presence (in 1988) of several sensitive species that have reoccupied the area: *Spiophanes bombyx* and *Lagis koreni* occurred in large numbers, even within 100 m of the platform *Echinocardium cordatum* and *Lanice conchilega* were found also within this distance, although in reduced numbers, and a very sensitive species like *Montacuta ferruginosa*, which in 1986 and 1987 occurred almost exclusively at the 5000-m reference station, was found already at the 250-m station. As pointed out in chapter 3.5, the observed long-term recolonization of the area in the vicinity of the platform indicates either a decrease of the toxicity of the discharged muds by weathering or biodegradation, or a decrease in the availability of toxic compounds. Although the initial toxicity of diesel-contaminated cuttings may be high compared to low-aromatic OBM, the rate of biodegradation of toxic diesel contaminants might be faster (see e.g. DIXON, 1987; BAKKE *et al.*, 1989-b). It is also conceivable, however, that redistribution of contaminated cuttings

may have resulted in a more patchy distribution. Therefore field surveys have to be continued to follow and verify the environmental recovery at K12a.

The location F 18.9, where drilling of 1 well was attended by a relatively large OBM discharge, was surveyed 1 year after drilling. Faunal disturbance was clearly detected up to 500 m off the discharge point. Most probably due to inaccuracy in positioning, a short-range gradient in sediment contamination or biological effects was hardly observed within 500 m. The uniformity of effects observed within this area, most clearly illustrated by the mean relative abundance of macrofauna species (Fig. 15), was in good correspondence with the rather narrow range of oil concentrations detected (35 - 450 mg/kg sediment). At the 750-m and 1000-m (r.c.) stations, slightly enhanced oil concentrations seemed particularly to affect the distribution of some strongly sensitive species: all 3 species represented in Fig. 14 showed their susceptibility to OBM during several surveys.

Application of logit regression has provided a

suitable statistical method for the verification of gradients in the abundance of individual species. Still the sensitivity of the method is not quite clear. On the one hand the number of strongly significant outcomes was relatively high: 56% of 68 gradients that were significant at the 5% level appeared also significant at the 0.1% level. On the other hand some apparent gradients were not confirmed by logit regression. This can probably be explained by the logarithmic scale of the sampling grit, in which presence or absence of a species in a single sample may strongly influence the statistical outcome. A logarithmic transformation of the explanatory variable (distance to discharge point), before the response curve is fitted, might be considered, but needs a theoretical basis.

Relative macrofauna abundance has shown to be a useful effect parameter. Although a handicap of the parameter may be that its attributed value is always relative and depends on the number of stations sampled, the method has several advantages:

a. it provides an illustrative graphic presentation of an overall shift in faunal abundance, which is also visually observed during field surveys by the examiner who is sorting macrofauna from bottom samples collected over a transect with a gradient in pollution; b. differences in mean relative abundance between stations are statistically verifiable; c. it may serve as an alternative to traditional diversity indices. In contrast to such indices, all species have an equal share in the computation of mean relative abundance. As a consequence, its attributed value is not disproportionately affected by accidental patches of individual species. The earlier applied Shannon-Wiener index (MULDER *et al.*, 1987, 1988) has shown to be very sensitive for the abundance of only one dominant species, and should therefore be interpreted very cautiously.

Biological field monitoring provides information on the structure of the benthic fauna in terms of macrofauna abundance and species richness. On the basis of instantaneous samples, the composition of the benthic fauna in a disturbed area can be compared with that at reference stations. Thus, insight is obtained in spatial as well as temporal effects of discharges of contaminated cuttings along a gradient. However, as pointed out in chapter 3.5, field data are difficult to interpret quantitatively in terms of dose-effect relationships. Moreover, the question remains how OBM-discharges affect settlement, behaviour and mortality of different species and to what extent it leads to sublethal effects. To answer these questions, the functioning of macrofauna was studied in experimental boxcosms. Experimental research on effects of drilling fluids on macrobenthos is not new. Till now, however, methods applied mostly concerned observations on settlement and mortality of

organisms on artificially contaminated sediments (*e.g.* DIXON, 1987; BAKKE *et al.*, 1989a, b; MORTON & MONTGOMERY, 1989). The main advantage of such an approach is the feasibility of dosage control, providing the opportunity of studying real dose-effect relationships. In contrast, the present boxcosm experiments were based on a design of intact sediment cores including the discharged cuttings. This approach was chosen because in the natural situation the cuttings are distributed in the sediment in a way that is difficult to simulate in the laboratory. In the field the sediment is first covered by a layer of discharged cuttings, resulting in suffocation of the infauna (DAVIES *et al.*, 1984), but subsequently the cuttings will be buried by sedimentation from the water column. The superficial sediment layer might be recolonized. Dependent on the thickness of the polluted stratum, even recolonization of deep sediment layers might be possible. Intact sediment cores were therefore considered to represent the most suitable substratum to explore the possibilities of experimental investigations with test organisms.

In the reference cores (5000 m) most of the natural infauna species appeared readily to survive the indoor incubations for several months. Indeed, faunal abundance at the termination of the incubation was somewhat lower than in the initial situation, which, however, was to be expected since mortality (*e.g.* by predation) was not compensated for by recruitment of newly settled individuals, due to the experimental design. On the other hand, in the contaminated cores, particularly in those of the 50-m station, with highest oil concentrations, mortality was substantially enhanced among all taxonomic groups. This may indicate that the presence of species in contaminated sediment does not necessarily prove their resistance and that the viability of these populations is depressed. Hence, it might be hypothesized, that in the actual field situation, the presence of at least part of the fauna may be the result of continuous settlement of pelagic larvae of benthic species, but that the mean life-span of these animals might be reduced. A similar conclusion may be derived from the observations on the transferred test organisms, *viz.* *Echinocardium cordatum*, *Amphiura filiformis* and *Lagis koreni*. All showed higher mortality in the contaminated cores than in the control. Most evident was the response in *Echinocardium*, both by mortality and by sublethal effects (loss of spines and burrowing behaviour). *Echinocardium* may therefore be considered an appropriate test organism in experimental effect studies.

The results of the boxcosm experiments do not yet allow a reliable interpretation in terms of doses and effects, since all experiments were singular and performed on only 3 concentrations. Duplicate experiments are needed to verify to what extent the results

are reproducible. However, boxcosms have proved to provide an excellent opportunity for experimental dose-effect studies.

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APPENDIX

Table 25. Data platform L4a, survey February 1987.
 Residual current transect.
 Mean densities (n.m⁻²).
 Tot. number of ind. per m² per station.
 Number of identified species.
 Number of samples () in which species are present.

Distance to platform (m)	100	250	500	750	5000
Number of analysed samples	2	10	6	6	6
POLYCHAETA					
Aphrodita aculeata	--	3.0 (5)	--	--	.8 (1)
Harmothoe lunulata	--	2.0 (4)	1.7 (2)	2.5 (3)	.8 (1)
Harmothoe longisetis	--	.5 (1)	2.5 (3)	3.3 (2)	.8 (1)
Gattyana cirrosa	--	7.0 (8)	10.0 (4)	13.3 (5)	8.3 (5)
Pholoe minuta	2.5 (1)	114.5 (10)	73.3 (6)	33.3 (6)	21.7 (5)
Sthenelais limicola	--	1.5 (3)	3.3 (3)	.8 (1)	4.2 (4)
Eteone longa	--	1.0 (2)	--	.8 (1)	--
Eteone lactea	--	.5 (1)	--	--	--
Anaitides groenlandica	7.5 (1)	4.5 (5)	5.8 (5)	.8 (1)	3.3 (3)
Eumida sanguinea	--	.5 (1)	--	1.7 (1)	2.5 (2)
Ophiodromus flexuosus	--	4.0 (6)	3.3 (3)	3.3 (3)	1.7 (2)
Gyptis capensis	--	5.0 (7)	5.0 (5)	5.0 (5)	5.0 (4)
Syneimis klatti	--	2.5 (4)	.8 (1)	--	--
Autolytus spec.	--	1.5 (2)	--	1.7 (2)	--
Nereis longissima	--	1.0 (2)	.8 (1)	.8 (1)	--
Nereis spec. juv.	2.5 (1)	.5 (1)	2.5 (1)	1.7 (2)	.8 (1)
Nephtys hombergii	7.5 (1)	16.5 (10)	23.3 (6)	19.2 (6)	14.2 (5)
Glycera capitata	--	--	--	--	--
Glycera rousii	5.0 (1)	9.5 (10)	5.8 (4)	5.0 (6)	9.2 (6)
Glycinde nordmanni	--	5.0 (5)	5.8 (4)	4.2 (2)	8.3 (5)
Goniada maculata	12.5 (1)	21.0 (10)	16.7 (6)	19.2 (6)	12.5 (5)
Lumbrineris latreilli	95.0 (2)	188.5 (10)	135.0 (6)	144.2 (6)	94.2 (6)
Lumbrineris fragilis	--	6.0 (7)	5.0 (3)	4.2 (3)	5.0 (3)
Driloneris filum	--	1.5 (3)	.8 (1)	--	.8 (1)
Scoloplos armiger	--	--	--	1.7 (2)	--
Orbinia sertulata	--	1.0 (2)	--	1.7 (2)	.8 (1)
Poecilochaetus serpens	--	--	--	--	.8 (1)
Spio filicornis	--	1.0 (1)	--	--	--
Polydora guillei	--	.5 (1)	--	--	--
Spiophanes kroyeri	--	--	--	--	.8 (1)
Spiophanes bombyx	--	.5 (1)	.8 (1)	.8 (1)	--
Scolecopsis foliosa	--	2.5 (4)	3.3 (3)	.8 (1)	1.7 (1)
Magelona papillicornis	--	--	--	.8 (1)	--
Chaetopterus variopedatus	--	17.0 (8)	25.8 (5)	21.7 (5)	5.0 (4)
Tharyx marioni	--	2.5 (5)	2.5 (2)	4.2 (3)	5.0 (3)
Chaetozone setosa	--	17.0 (8)	22.5 (6)	8.3 (4)	13.3 (6)
Diplocirrus glaucus	5.0 (1)	66.5 (10)	80.0 (6)	64.2 (5)	48.3 (6)
Scalibregma inflatum	--	2.0 (2)	--	1.7 (1)	1.7 (1)
Ophelina acuminata	--	.5 (1)	--	--	--
Capitella capitata	--	1.5 (1)	--	--	--
Notomastus latericeus	--	6.5 (6)	3.3 (2)	6.7 (4)	3.3 (2)
Heteromastus filiformis	2.5 (1)	6.5 (6)	5.8 (5)	4.2 (5)	--
Owenia fusiformis	--	1.0 (1)	3.3 (3)	3.3 (3)	2.5 (2)
Polycirrus medusa	--	--	--	.8 (1)	--
Lagis koreni	--	.5 (1)	.8 (1)	5.0 (4)	3.3 (4)
Ampharete acutifrons	--	--	.8 (1)	--	--
Amphicteis gunneri	--	--	--	.8 (1)	3.3 (2)
Sosane gracilis	--	--	--	.8 (1)	1.7 (1)
Lysilla loveni	--	--	.8 (1)	5.0 (5)	33.3 (5)
MOLLUSCA					
Nucula turgida	--	3.5 (5)	19.2 (6)	7.5 (4)	8.3 (4)
Thyasira flexuosa	--	--	.8 (1)	--	--
Montacuta ferruginosa	--	--	1.7 (2)	3.3 (2)	1.7 (2)

Table 25 continued.

Distance to platform (m)	100	250	500	750	5000
<i>Mysella bidentata</i>	--	133.5 (10)	75.0 (6)	142.5 (6)	65.0 (5)
<i>Arctica islandica</i>	--	2.0 (3)	2.5 (2)	2.5 (2)	3.3 (3)
<i>Acanthocardia echinata</i>	--	--	.8 (1)	--	.8 (1)
<i>Dosinia exoleta</i>	--	--	.8 (1)	--	--
<i>Dosinia lupinus</i>	--	--	--	.8 (1)	.8 (1)
<i>Venus striatula</i>	5.0 (2)	1.0 (2)	2.5 (2)	1.7 (2)	2.5 (2)
<i>Mysia undata</i>	--	.5 (1)	.8 (1)	--	--
<i>Tellina fabula</i>	--	--	--	--	2.5 (2)
<i>Abra alba</i>	--	--	--	.8 (1)	5.0 (4)
<i>Cultellus pellucidus</i>	--	--	--	--	.8 (1)
<i>Mya spec. juv.</i>	--	--	--	--	.8 (1)
<i>Corbula gibba</i>	--	--	.8 (1)	1.7 (2)	.8 (1)
<i>Thracia convexa</i>	--	5.5 (6)	3.3 (2)	.8 (1)	5.0 (4)
<i>Cingula nitida</i>	--	15.0 (5)	.8 (1)	1.7 (2)	3.3 (3)
<i>Turritella communis</i>	2.5 (1)	5.5 (5)	21.7 (5)	19.2 (5)	29.2 (6)
<i>Cylichna cylindracea</i>	2.5 (1)	21.5 (9)	7.5 (4)	15.8 (5)	4.2 (4)
<i>Philine catena</i>	2.5 (1)	8.5 (9)	3.3 (3)	1.7 (1)	1.7 (2)

CRUSTACEA

<i>Processa parva</i>	--	.5 (1)	--	--	--
<i>Pontophilus trispinosus</i>	2.5 (1)	--	--	--	--
<i>Pagurus bernhardus</i>	--	--	--	--	.8 (1)
<i>Macropipus holsatus</i>	--	1.0 (2)	.8 (1)	--	--
<i>Ebalia cranchii</i>	--	4.5 (5)	6.7 (4)	.8 (1)	.8 (1)
<i>Corystes cassivelaunus</i>	--	--	.8 (1)	.8 (1)	2.5 (3)
<i>Upogebia deltaura</i>	--	.5 (1)	--	--	--
<i>Upogebia spec. juv.</i>	--	.5 (1)	1.7 (2)	.8 (1)	5.0 (2)
<i>Callianassa subterranea</i>	2.5 (1)	5.0 (7)	6.7 (4)	15.0 (5)	5.8 (2)
<i>Callianassa spec. juv.</i>	2.5 (1)	.5 (1)	6.7 (3)	8.3 (5)	25.8 (6)
<i>Decapoda larven</i>	--	1.5 (3)	--	--	.8 (1)
<i>Nebalia bipes</i>	--	1.0 (2)	--	1.7 (1)	--
<i>Gastrosaccus spinifer</i>	--	.5 (1)	--	--	--
<i>Mysiden larven</i>	--	.5 (1)	--	--	--
<i>Eudorella truncatula</i>	--	.5 (1)	--	.8 (1)	2.5 (2)
<i>Iphinoe trispinosa</i>	10.0 (2)	3.0 (5)	--	--	3.3 (3)
<i>Diastylis bradyi</i>	17.5 (2)	50.5 (9)	5.0 (5)	9.2 (5)	30.8 (6)
<i>Cirolana borealis</i>	--	1.0 (2)	.8 (1)	--	--
<i>Melita dentata</i>	--	--	--	--	.8 (1)
<i>Atylus swammerdami</i>	--	--	--	.8 (1)	--
<i>Orchomenella nana</i>	2.5 (1)	2.5 (5)	1.7 (2)	3.3 (3)	.8 (1)
<i>Sthenothoe marina</i>	--	.5 (1)	.8 (1)	--	--
<i>Ampelisca brevicornis</i>	--	--	--	--	5.0 (4)
<i>Ampelisca tenuicornis</i>	--	--	--	--	17.5 (6)
<i>Ampelisca spec. juv.</i>	--	.5 (1)	--	--	.8 (1)
<i>Urothoe poseidonis</i>	--	--	.8 (1)	--	--
<i>Bathyporeia elegans</i>	--	--	1.7 (1)	.8 (1)	--
<i>Bathyporeia tenuipes</i>	--	--	--	--	.8 (1)
<i>Harpinia antennaria</i>	--	1.0 (2)	15.0 (5)	5.8 (3)	25.8 (6)
<i>Periculodes longimanus</i>	2.5 (1)	4.5 (5)	2.5 (3)	2.5 (3)	4.2 (3)
<i>Aora typica</i>	--	.5 (1)	1.7 (1)	--	1.7 (1)

ECHINODERMATA

<i>Asterias rubens</i>	--	2.5 (2)	--	--	--
<i>Amphiura filiformis</i>	35.0 (2)	1202.0 (10)	1181.7 (6)	1241.7 (6)	770.0 (6)
<i>Amphiura chiajei</i>	--	11.0 (7)	5.8 (4)	15.8 (6)	7.5 (2)
<i>Ophiura texturata</i>	--	.5 (1)	--	--	--
<i>Ophiura albida</i>	--	4.0 (6)	5.0 (4)	1.7 (1)	6.7 (4)
<i>Ophiura spec. juv.</i>	--	7.5 (8)	3.3 (3)	.8 (1)	9.2 (5)
<i>Echinocardium cordatum</i>	--	--	1.7 (2)	--	4.2 (2)

Table 25 continued.

Distance to platform (m)	100	250	500	750	5000
OTHER TAXA					
Nemertinea	P	P	P	P	P
Turbellaria	2.5 (1)	7.5 (7)	4.2 (3)	1.7 (2)	4.2 (3)
Phoroniden	P	P	P	P	P
Harp. copepoda	2.5 (1)	--	--	--	--
Oligochaeta	P	P	P	P	P
Holothuroidea	--	.5 (1)	2.5 (2)	3.3 (3)	.8 (1)
Sagitta spec.	--	.5 (1)	--	--	--
Sipunculida	5.0 (1)	14.0 (9)	13.3 (5)	15.8 (6)	4.2 (3)
Anthozoa	--	1.0 (2)	--	--	.8 (1)
Ascidacea	--	--	--	.8 (1)	.8 (1)
Tot. no. of ind. (n.m ⁻²)	246.5	1954.0	1869.3	1935.5	1399.3
No. of identified species	19	69	61	62	67
P= present, not counted					

Table 26. Data platform L4a, survey June 1987.

Residual current transect.

Mean densities (n.m⁻²).Tot. number of ind. per m² per station.

Number of identified species.

Number of samples () in which species are present.

Distance to platform (m)	5000	1000	750	500	250	100
Nr. of analysed samples	7	7	7	7	10	10
POLYCHAETA						
Aphrodita aculeata	--	1.4 (2)	.7 (1)	.7 (1)	1.0 (2)	--
Harmothoe lunulata	.7 (1)	.7 (1)	.7 (1)	1.4 (1)	--	--
Harmothoe longisetis	1.4 (2)	4.3 (5)	1.4 (2)	4.3 (2)	1.0 (2)	3.0 (4)
Gattyana cirrosa	11.4 (6)	17.9 (6)	20.7 (7)	25.0 (7)	14.0 (10)	46.0 (10)
Polynoe kinbergi	17.1 (6)	3.6 (4)	7.9 (5)	--	--	--
Pholoe minuta	48.6 (7)	62.1 (7)	33.6 (6)	44.3 (7)	86.0 (10)	45.5 (9)
Sthenelais limicola	1.4 (2)	.7 (1)	1.4 (2)	2.9 (4)	1.5 (3)	1.0 (2)
Eteone longa	--	2.1 (3)	.7 (1)	--	1.0 (2)	--
Eteone lactea	--	--	--	--	.5 (1)	.5 (1)
Eteone flava	--	--	--	.7 (1)	--	--
Anaitides groenlandica	.7 (1)	2.1 (2)	--	.7 (1)	1.5 (3)	18.0 (9)
Anaitides maculata	--	--	--	--	--	1.0 (2)
Eumida sanguinea	--	--	--	--	.5 (1)	--
Ophiodromus flexuosus	4.3 (4)	3.6 (4)	5.7 (4)	2.9 (3)	2.0 (4)	.5 (1)
Gyptis capensis	1.4 (2)	2.1 (3)	2.1 (3)	1.4 (2)	.5 (1)	.5 (1)
Synelmis klatti	.7 (1)	3.6 (4)	1.4 (2)	4.3 (4)	--	1.5 (3)
Autolytus spec.	.7 (1)	2.9 (4)	.7 (1)	3.6 (4)	--	.5 (1)
Nereis longissima	--	.7 (1)	--	5.0 (3)	.5 (1)	--
Nereis spec. juv.	1.4 (2)	2.9 (4)	.7 (1)	1.4 (2)	2.0 (3)	4.0 (6)
Nephtys hombergii	15.7 (7)	20.0 (7)	20.7 (7)	13.6 (7)	8.5 (9)	8.0 (9)
Nephtys caeca	--	--	--	--	--	--
Nephtys spec. juv.	1.4 (1)	2.1 (2)	--	--	--	--
Glycera rouxii	3.6 (4)	5.7 (6)	6.4 (6)	6.4 (5)	5.0 (6)	6.0 (6)
Glycera spec. juv.	2.1 (3)	1.4 (2)	1.4 (1)	1.4 (2)	8.5 (7)	6.5 (6)
Glycinde nordmanni	3.6 (3)	8.6 (7)	8.6 (6)	5.0 (5)	5.5 (6)	2.5 (4)
Goniada maculata	15.7 (6)	10.0 (7)	13.6 (6)	12.1 (6)	13.5 (8)	6.5 (9)
Lumbrineris latreilli	157.1 (7)	202.1 (7)	214.3 (7)	195.0 (7)	316.5 (10)	343.0 (10)
Lumbrineris fragilis	2.1 (3)	3.6 (5)	3.6 (3)	6.4 (6)	7.0 (7)	4.0 (3)
Driloneris filum	--	.7 (1)	1.4 (2)	--	--	.5 (1)
Scoloplos armiger	--	.7 (1)	--	.7 (1)	--	--
Orbinia sertulata	--	--	--	1.4 (2)	--	.5 (1)
Poecilochaetus serpens	.7 (1)	--	--	--	--	--
Spio filicornis	--	--	1.4 (2)	--	--	2.0 (2)
Polydora guillei	--	1.4 (1)	3.6 (2)	2.9 (3)	1.0 (1)	--
Spiophanes kroyeri	.7 (1)	.7 (1)	--	--	--	--
Spiophanes bombyx	5.7 (4)	1.4 (2)	1.4 (1)	1.4 (2)	--	.5 (1)
Scolecopsis foliosa	--	1.4 (2)	.7 (1)	2.1 (2)	2.5 (4)	.5 (1)
Magelona allenii	.7 (1)	--	.7 (1)	--	.5 (1)	1.0 (2)
Chaetopterus variopedatus	.7 (1)	15.7 (7)	21.4 (7)	17.9 (6)	9.5 (8)	11.5 (6)
Tharyx marioni	1.4 (2)	8.6 (5)	9.3 (6)	5.0 (4)	4.0 (5)	2.0 (3)
Chaetozona setosa	10.7 (6)	37.9 (7)	35.7 (7)	31.4 (7)	30.5 (10)	10.5 (7)
Diplocirrus glaucus	48.6 (7)	63.6 (7)	73.6 (7)	52.1 (7)	74.5 (10)	8.5 (7)
Scalibregma inflatum	2.1 (2)	2.1 (3)	6.4 (4)	5.0 (5)	24.5 (10)	17.5 (7)
Ophelina acuminata	--	2.1 (2)	1.4 (2)	2.1 (2)	.5 (1)	--
Capitella capitata	--	--	--	--	--	--
Notomastus latericeus	5.7 (3)	6.4 (6)	4.3 (5)	6.4 (6)	7.5 (7)	6.5 (7)
Heteromastus filiformis	1.4 (1)	1.4 (2)	2.1 (1)	--	1.5 (3)	1.0 (2)
Owenia fusiformis	5.7 (6)	3.6 (4)	5.7 (6)	5.7 (4)	4.0 (6)	2.0 (2)
Lagis koreni	1.4 (2)	--	--	.7 (1)	--	--
Amphicteis gunneri	--	--	--	.7 (1)	--	--
Sosane gracilis	.7 (1)	.7 (1)	--	--	--	--
Lysilla loveni	52.9 (6)	15.0 (6)	22.9 (5)	2.1 (3)	.5 (1)	.5 (1)
Terebellides stroemi	--	--	--	--	--	--

Table 26. Data platform L4a, survey June 1987.
 Perpendicular transect.
 Mean densities (n.m⁻²).
 Tot. number of ind. per m² per station.
 Number of identified species.
 Number of samples () in which species are present.

Distance to platform (m)	0(PL)	250	500	750
Nr. of analysed samples	10	6	6	6
POLYCHAETA				
Aphrodita aculeata	--	2.5 (2)	--	2.5 (3)
Harmothoe lunulata	--	.8 (1)	--	2.5 (2)
Harmothoe longisetis	--	1.7 (1)	.8 (1)	2.5 (2)
Gattyana cirrosa	2.0 (4)	25.0 (6)	28.3 (6)	19.2 (5)
Polynoe kinbergi	--	--	--	3.3 (2)
Pholoe minuta	.5 (1)	40.0 (6)	40.0 (6)	42.5 (5)
Sthenelais limicola	3.5 (5)	--	.8 (1)	.8 (1)
Eteone longa	--	2.5 (2)	--	.8 (1)
Eteone lactea	--	--	.8 (1)	--
Eteone flava	--	.8 (1)	--	1.7 (2)
Anaitides groenlandica	3.5 (6)	--	.8 (1)	--
Anaitides maculata	.5 (1)	--	--	--
Eumida sanguinea	1.5 (2)	.8 (1)	.8 (1)	.8 (1)
Ophiodromus flexuosus	--	1.7 (1)	8.3 (5)	5.8 (3)
Gyptis capensis	.5 (1)	3.3 (2)	1.7 (2)	2.5 (2)
Synelmis klatti	.5 (1)	6.7 (4)	3.3 (3)	2.5 (2)
Autolytus spec.	.5 (1)	--	1.7 (2)	.8 (1)
Nereis longissima	.5 (1)	--	3.3 (2)	1.7 (2)
Nereis spec. juv.	--	5.0 (5)	2.5 (3)	.8 (1)
Nephtys hombergii	.5 (1)	13.3 (6)	12.5 (6)	10.0 (6)
Nephtys caeca	--	--	--	.8 (1)
Nephtys spec. juv.	1.0 (2)	--	--	.8 (1)
Glycera rouxii	--	6.7 (4)	5.8 (4)	3.3 (4)
Glycera spec. juv.	4.0 (6)	3.3 (3)	2.5 (2)	1.7 (2)
Glycinde nordmanni	--	9.2 (6)	6.7 (4)	3.3 (1)
Goniada maculata	8.0 (8)	8.3 (5)	20.0 (6)	12.5 (6)
Lumbrineris latreilli	22.0 (9)	323.3 (6)	298.3 (6)	213.3 (6)
Lumbrineris fragilis	--	3.3 (3)	7.5 (6)	3.3 (3)
Driloneris filum	--	.8 (1)	.8 (1)	--
Scoloplos armiger	--	.8 (1)	.8 (1)	--
Orbinia sertulata	--	1.7 (1)	.8 (1)	.8 (1)
Poecilochaetus serpens	--	--	--	--
Spio filicornis	.5 (1)	--	--	--
Polydora guillei	--	--	2.5 (1)	1.7 (2)
Spiophanes kroyeri	--	--	--	--
Spiophanes bombyx	--	.8 (1)	1.7 (1)	2.5 (2)
Scoelepis foliosa	--	3.3 (2)	2.5 (2)	1.7 (1)
Magelona allenii	--	.8 (1)	1.7 (2)	--
Chaetopterus variopedatus	--	23.3 (6)	20.8 (6)	16.7 (6)
Tharyx marioni	--	5.0 (4)	9.2 (5)	7.5 (5)
Chaetozone setosa	5.5 (5)	20.0 (6)	28.3 (6)	31.7 (5)
Diplocirrus glaucus	3.5 (3)	12.5 (6)	48.3 (6)	54.2 (5)
Scalibregma inflatum	--	35.8 (6)	8.3 (4)	2.5 (2)
Ophelina acuminata	--	.8 (1)	.8 (1)	.8 (1)
Capitella capitata	29.0 (10)	--	--	--
Notomastus latericeus	--	7.5 (4)	21.7 (6)	6.7 (4)
Heteromastus filiformis	--	1.7 (2)	5.8 (3)	2.5 (2)
Owenia fusiformis	--	6.7 (5)	3.3 (2)	5.8 (6)
Lagis koreni	--	--	1.7 (2)	--
Amphicteis gunneri	--	--	.8 (1)	--
Sosane gracilis	--	--	.8 (1)	.8 (1)
Lysilla loveni	--	1.7 (1)	.8 (1)	10.0 (5)
Terebellides stroemi	--	.8 (1)	--	3.3 (4)

Table 26 continued.

Distance to platform (m)	5000	1000	750	500	250	100
MOLLUSCA						
<i>Nucula turgida</i>	10.0 (3)	5.7 (5)	8.6 (4)	7.9 (3)	7.5 (7)	5.0 (5)
<i>Modiolus modiolus</i>	--	--	--	--	--	.5 (1)
<i>Thyasira flexuosa</i>	--	.7 (1)	--	.7 (1)	1.5 (2)	1.5 (3)
<i>Lepton squamosum</i>	--	--	1.4 (1)	--	1.0 (2)	--
<i>Montacuta ferruginosa</i>	9.3 (5)	2.9 (3)	3.6 (4)	.7 (1)	--	--
<i>Mysella bidentata</i>	219.3 (7)	95.7 (7)	131.4 (7)	93.6 (7)	132.0 (10)	72.5 (7)
<i>Arctica islandica</i>	9.3 (5)	8.6 (4)	9.3 (6)	12.9 (6)	3.0 (2)	9.0 (7)
<i>Acanthocardia echinata</i>	--	--	.7 (1)	--	.5 (1)	--
<i>Dosinia lupinus</i>	--	.7 (1)	1.4 (1)	.7 (1)	--	.5 (1)
<i>Venus striatula</i>	5.0 (5)	2.1 (2)	.7 (1)	2.9 (4)	1.0 (2)	9.0 (9)
<i>Mysia undata</i>	.7 (1)	.7 (1)	2.1 (3)	.7 (1)	2.0 (4)	--
<i>Tellina fabula</i>	--	--	--	--	--	--
<i>Abra alba</i>	.7 (1)	.7 (1)	--	1.4 (2)	.5 (1)	8.0 (4)
<i>Cultellus pellucidus</i>	7.1 (5)	6.4 (4)	2.9 (3)	.7 (1)	3.0 (5)	8.5 (8)
<i>Mya arenaria</i>	1.4 (1)	--	--	--	--	--
<i>Mya spec. juv.</i>	2.9 (4)	.7 (1)	1.4 (2)	.7 (1)	--	1.0 (2)
<i>Corbula gibba</i>	2.1 (2)	--	2.1 (3)	.7 (1)	3.5 (5)	--
<i>Thracia convexa</i>	--	2.9 (4)	4.3 (5)	3.6 (4)	4.0 (5)	2.0 (3)
<i>Cingula nitida</i>	1.4 (1)	1.4 (1)	.7 (1)	2.1 (2)	3.0 (3)	--
<i>Turritella communis</i>	32.9 (7)	22.1 (7)	14.3 (7)	17.9 (7)	19.0 (10)	1.5 (3)
<i>Natica alderi</i>	--	--	.7 (1)	--	1.0 (2)	1.0 (1)
<i>Aporrhais pespelecani</i>	--	--	--	.7 (1)	--	--
<i>Buccinum undatum</i>	--	--	.7 (1)	--	--	.5 (1)
<i>Cylichna cilindracea</i>	5.0 (4)	6.4 (4)	2.9 (1)	2.9 (1)	6.5 (5)	1.0 (1)
<i>Philine catena</i>	--	--	2.9 (3)	2.1 (3)	8.5 (7)	3.5 (4)
CRUSTACEA						
<i>Crangon crangon</i>	.7 (1)	--	--	--	--	--
<i>Processa parva</i>	--	--	--	.7 (1)	--	--
<i>Pontophilus trispinosus</i>	--	--	.7 (1)	--	--	.5 (1)
<i>Pagurus bernhardus</i>	--	--	--	--	--	--
<i>Macropipus holsatus</i>	--	--	--	--	.5 (1)	--
<i>Macropipus spec. juv.</i>	--	--	--	--	--	1.0 (2)
<i>Ebalia cranchii</i>	.7 (1)	--	1.4 (2)	1.4 (2)	3.5 (4)	3.5 (4)
<i>Corystes cassivelaunus</i>	.7 (1)	--	--	1.4 (1)	--	--
<i>Macropodia spec.</i>	--	--	--	--	--	--
<i>Upogebia stellata</i>	--	1.4 (2)	--	--	--	--
<i>Upogebia deltaura</i>	--	1.4 (1)	2.9 (4)	3.6 (4)	2.5 (4)	--
<i>Upogebia spec. juv.</i>	.7 (1)	--	.7 (1)	--	--	--
<i>Callianassa subterranea</i>	4.3 (3)	22.9 (7)	25.7 (7)	36.4 (7)	14.0 (10)	4.5 (5)
<i>Callianassa spec. juv.</i>	5.0 (5)	2.1 (2)	2.1 (1)	--	--	.5 (1)
<i>Decapoda larven</i>	--	.7 (1)	1.4 (2)	--	.5 (1)	--
<i>Nebalia bipes</i>	--	.7 (1)	--	--	.5 (1)	.5 (1)
<i>Schistomysis ornata</i>	--	--	.7 (1)	.7 (1)	--	--
<i>Eudorella truncatula</i>	2.1 (2)	7.9 (5)	1.4 (2)	1.4 (2)	2.5 (4)	5.0 (6)
<i>Iphinoe trispinosa</i>	.7 (1)	--	.7 (1)	--	--	.5 (1)
<i>Pseudocuma longicornis</i>	--	--	--	--	.5 (1)	--
<i>Diastylis bradyi</i>	5.7 (5)	2.1 (3)	5.0 (5)	7.9 (5)	11.5 (9)	33.5 (9)
<i>Lamprops fasciata</i>	--	.7 (1)	--	--	--	--
<i>Cirolana borealis</i>	--	--	--	--	1.5 (2)	--
<i>Ione thoracica</i>	.7 (1)	.7 (1)	--	--	--	--
<i>Orchomenella nana</i>	--	1.4 (2)	.7 (1)	--	--	.5 (1)
<i>Leucothoe incisa</i>	--	--	--	.7 (1)	--	--
<i>Metopa spec. juv.</i>	--	--	--	--	--	.5 (1)
<i>Ampelisca brevicornis</i>	--	--	--	--	.5 (1)	.5 (1)
<i>Ampelisca tenuicornis</i>	2.1 (2)	--	.7 (1)	.7 (1)	--	3.0 (4)
<i>Ampelisca spec. juv.</i>	7.1 (5)	.7 (1)	2.9 (4)	--	1.0 (2)	.5 (1)
<i>Urothoe poseidonis</i>	--	3.6 (2)	7.1 (5)	--	--	--
<i>Bathyporeia elegans</i>	--	2.1 (2)	1.4 (2)	--	--	--
<i>Bathyporeia tenuipes</i>	--	--	1.4 (1)	.7 (1)	--	--
<i>Harpinia antennaria</i>	38.6 (6)	26.4 (7)	31.4 (7)	7.9 (2)	--	--

Table 26 continued.
Distance to platform (m)

	0(PL)	250	500	750
MOLLUSCA				
<i>Nucula turgida</i>	--	5.0 (2)	5.8 (4)	6.7 (5)
<i>Modiolus modiolus</i>	--	--	--	--
<i>Thyasira flexuosa</i>	--	--	.8 (1)	.8 (1)
<i>Lepton squamosum</i>	--	--	--	.8 (1)
<i>Montacuta ferruginosa</i>	--	--	--	--
<i>Mysella bidentata</i>	--	172.5 (6)	156.7 (6)	126.7 (6)
<i>Arctica islandica</i>	--	3.3 (2)	2.5 (2)	7.5 (3)
<i>Acanthocardia echinata</i>	--	--	--	--
<i>Dosinia lupinus</i>	--	--	.8 (1)	.8 (1)
<i>Venus striatula</i>	--	2.5 (2)	.8 (1)	1.7 (2)
<i>Mysia undata</i>	--	--	.8 (1)	--
<i>Tellina fabula</i>	--	--	.8 (1)	--
<i>Abra alba</i>	1.5 (2)	--	--	.8 (1)
<i>Cultellus pellucidus</i>	--	--	--	1.7 (2)
<i>Mya arenaria</i>	--	--	--	--
<i>Mya spec. juv.</i>	--	.8 (1)	2.5 (3)	--
<i>Corbula gibba</i>	--	1.7 (2)	.8 (1)	--
<i>Thracia convexa</i>	--	5.8 (4)	3.3 (3)	1.7 (2)
<i>Cingula nitida</i>	--	--	.8 (1)	--
<i>Turritella communis</i>	--	6.7 (5)	14.2 (5)	7.5 (4)
<i>Natica alderi</i>	--	--	--	--
<i>Aporrhais pespelecari</i>	--	.8 (1)	--	--
<i>Buccinum undatum</i>	1.5 (3)	--	--	--
<i>Cylichna cylindracea</i>	--	1.7 (2)	5.8 (5)	.8 (1)
<i>Philine catena</i>	--	9.2 (4)	--	.8 (1)
CRUSTACEA				
<i>Crangon crangon</i>	--	--	--	--
<i>Processa parva</i>	--	--	--	--
<i>Pontophilus trispinosus</i>	--	--	--	--
<i>Pagurus bernhardus</i>	7.5 (6)	--	--	--
<i>Macropipus holsatus</i>	--	--	--	.8 (1)
<i>Macropipus spec. juv.</i>	--	--	--	--
<i>Ebalia cranchii</i>	--	.8 (1)	2.5 (3)	1.7 (2)
<i>Corystes cassivelaunus</i>	1.0 (2)	--	--	.8 (1)
<i>Macropodia spec.</i>	--	--	.8 (1)	--
<i>Upogebia stellata</i>	--	--	--	.8 (1)
<i>Upogebia deltaura</i>	--	--	3.3 (3)	.8 (1)
<i>Upogebia spec. juv.</i>	.5 (1)	--	--	1.7 (2)
<i>Callianassa subterranea</i>	--	19.2 (6)	37.5 (6)	40.0 (6)
<i>Callianassa spec. juv.</i>	--	--	--	--
<i>Decapoda larven</i>	1.5 (2)	--	2.5 (3)	--
<i>Nebalia bipes</i>	--	.8 (1)	--	--
<i>Schistomysis ornata</i>	.5 (1)	--	1.7 (1)	--
<i>Eudorella truncatula</i>	--	--	1.7 (2)	--
<i>Iphinoe trispinosa</i>	--	.8 (1)	--	--
<i>Pseudocuma longicornis</i>	--	--	--	--
<i>Diastylis bradyi</i>	.5 (1)	8.3 (4)	12.5 (5)	9.2 (5)
<i>Lamprops fasciata</i>	--	--	--	--
<i>Cirolana borealis</i>	--	1.7 (2)	.8 (1)	--
<i>Ione thoracica</i>	--	--	1.7 (2)	.8 (1)
<i>Orchomenella nana</i>	--	1.7 (2)	--	.8 (1)
<i>Leucothoe incisa</i>	--	1.7 (1)	--	1.7 (2)
<i>Metopa spec. juv.</i>	--	--	--	--
<i>Ampelisca brevicornis</i>	--	--	--	.8 (1)
<i>Ampelisca tenuicornis</i>	--	2.5 (2)	2.5 (2)	4.2 (4)
<i>Ampelisca spec. juv.</i>	--	1.7 (1)	.8 (1)	--
<i>Urothoe poseidonis</i>	--	--	.8 (1)	--
<i>Bathyporeia elegans</i>	--	--	--	--
<i>Bathyporeia tenuipes</i>	--	--	--	.8 (1)
<i>Harpinia antennaria</i>	--	--	15.8 (6)	23.3 (5)

Table 26 continued.

Distance to platform (m)	5000	1000	750	500	250	100
<i>Perioculodes longimanus</i>	3.6 (4)	2.9 (4)	2.1 (3)	4.3 (4)	5.0 (6)	10.5 (7)
<i>Westwoodilla caecula</i>	--	--	--	--	.5 (1)	--
<i>Aora typica</i>	.7 (1)	1.4 (1)	--	--	--	--
<i>Jassa falcata</i>	--	--	--	--	--	1.5 (1)

ECHINODERMATA

<i>Astropecten irregularis</i>	--	--	--	.7 (1)	.5 (1)	--
<i>Asterias rubens</i>	--	--	--	--	.5 (1)	--
<i>Amphiura filiformis</i>	670.7 (7)	1027.9 (7)	1013.6 (7)	1008.6 (7)	1280.5 (10)	494.0 (8)
<i>Amphiura chiajei</i>	3.6 (2)	5.7 (4)	2.1 (2)	6.4 (4)	7.0 (6)	7.5 (4)
<i>Ophiura texturata</i>	1.4 (2)	.7 (1)	1.4 (1)	2.9 (3)	1.5 (2)	--
<i>Ophiura albida</i>	1.4 (2)	.7 (1)	1.4 (1)	1.4 (2)	4.0 (3)	1.0 (2)
<i>Ophiura spec. juv.</i>	5.7 (4)	1.4 (2)	1.4 (2)	4.3 (4)	8.5 (8)	6.0 (5)
<i>Echinocardium cordatum</i>	7.9 (7)	2.9 (3)	5.0 (4)	.7 (1)	--	--

OTHER TAXA

<i>Nemertinea</i>	P (7)	P (7)	P (7)	P (7)	P (10)	P (10)
<i>Turbellaria</i>	5.0 (4)	8.6 (5)	7.9 (6)	10.0 (6)	8.0 (7)	11.5 (9)
<i>Phoroniden</i>	P (6)	P (3)	P (5)	P (4)	P (9)	P (4)
<i>Harp. copepoda</i>	--	--	--	.7 (1)	--	.5 (1)
<i>Parasitaire copepoda</i>	.7 (1)	2.1 (2)	--	.7 (1)	--	.5 (1)
<i>Oligochaeta</i>	P	P (4)	P (2)	P (2)	P (2)	P
<i>Holothuroidea</i>	2.1 (1)	1.4 (1)	2.1 (3)	1.4 (1)	1.5 (2)	.5 (1)
<i>Sagitta spec.</i>	--	.7 (1)	--	--	--	--
<i>Echiurida</i>	2.1 (2)	2.1 (2)	1.4 (2)	.7 (1)	.5 (1)	25.0 (8)
<i>Sipunculida</i>	12.9 (5)	5.7 (3)	5.7 (4)	7.1 (7)	10.0 (8)	5.0 (5)
<i>Anthozoa</i>	.7 (1)	.7 (1)	--	.7 (1)	1.5 (3)	--
<i>Ascidacea</i>	3.6 (4)	2.9 (2)	2.9 (2)	2.9 (3)	2.0 (1)	4.5 (5)
<i>Priapulida</i>	2.1 (2)	--	.7 (1)	--	1.0 (2)	--
<i>Arthropoda</i>	--	--	--	--	--	--

Tot. nr. of ind. (n.m ⁻²)	1531.3	1830.0	1867.3	1747.0	2204.5	1313.0
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Nr. of identified species	61	68	71	70	64	61
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P= present, not counted

Table 26 continued.

Distance to platform (m)	0(PL)	250	500	750
<i>Perioculodes longimanus</i>	--	5.0 (3)	1.7 (1)	3.3 (3)
<i>Westwoodilla caecula</i>	--	--	--	--
<i>Aora typica</i>	--	--	--	--
<i>Jassa falcata</i>	1.5 (3)	--	--	--
ECHINODERMATA				
<i>Astropecten irregularis</i>	--	--	--	--
<i>Asterias rubens</i>	3.0 (3)	--	--	--
<i>Amphiura filiformis</i>	--	1161.7 (6)	1190.0 (6)	1162.5 (6)
<i>Amphiura chiajei</i>	--	6.7 (5)	5.8 (3)	1.7 (2)
<i>Ophiura texturata</i>	--	--	.8 (1)	--
<i>Ophiura albida</i>	.5 (1)	5.8 (5)	1.7 (1)	3.3 (4)
<i>Ophiura spec. juv.</i>	--	11.7 (6)	3.3 (4)	3.3 (3)
<i>Echinocardium cordatum</i>	--	--	.8 (1)	--
OTHER TAXA				
Nemertinea	P (6)	P (6)	P (6)	P (6)
Turbellaria	--	11.7 (6)	9.2 (4)	5.0 (2)
Phoroniden	P	P (6)	P (4)	P (5)
Harp. copepoda	--	--	--	.8 (1)
Parasitaire copepoda	--	.8 (1)	3.3 (2)	--
Oligochaeta	P	P (2)	P (1)	P (1)
Holothuroidea	--	--	--	2.5 (3)
Sagitta spec.	--	--	--	--
Echiurida	--	.8 (1)	--	1.7 (2)
Sipunculida	--	11.7 (6)	16.7 (5)	15.8 (5)
Anthozoa	3.0 (5)	--	3.3 (3)	1.7 (2)
Ascidacea	--	.8 (1)	7.5 (4)	2.5 (2)
Priapulida	--	--	--	1.7 (1)
Arthropoda	--	.8 (1)	--	--
Tot. nr. of ind. (n.m ⁻²)	110.0	2049.5	2133.2	1941.2
Nr. of identified species	25	57	65	68

P=present, not counted.

Table 27. Data platform K12a, survey Sept. 1987.
 RC= residual current transect; PT= perpendicular transect.
 Mean densities (n.m⁻²).
 Tot. number of ind. per m² per station.
 Number of identified species.
 Number of samples () in which species are present.

Distance to platform (m)	250 PT	0 (PL)	100 RC	250 RC
Nr. of analysed samples	10	7	10	10
POLYCHAETA				
Aphrodita aculeata	.5 (1)	--	.5 (1)	.5 (1)
Harmothoe lunulata	--	--	--	--
Harmothoe longisetis	.5 (1)	--	.5 (1)	1.0 (2)
Gattyana cirrosa	--	--	--	--
Sigalion mathildae	--	--	--	--
Pholoe minuta	1.0 (2)	--	1.5 (2)	28.5 (10)
Sthenelais limicola	2.0 (3)	--	1.0 (2)	2.0 (2)
Eteone longa	--	--	.5 (1)	--
Anaitides groenlandica	.5 (1)	--	4.5 (5)	7.5 (8)
Anaitides mucosa	3.5 (6)	--	1.0 (1)	.5 (1)
Anaitides maculata	10.5 (8)	--	11.5 (9)	9.5 (8)
Eumida sanguinea	--	--	.5 (1)	.5 (1)
Ophiodromus flexuosus	2.5 (4)	--	.5 (1)	3.0 (4)
Gyptis capensis	--	--	--	.5 (1)
Exogone hebes	--	--	--	--
Nereis longissima	--	--	.5 (1)	2.0 (4)
Nereis spec. juv.	3.5 (5)	.7 (1)	7.0 (7)	7.0 (7)
Nephtys hombergii	30.0 (10)	.7 (1)	12.0 (7)	24.0 (9)
Nephtys cirrosa	9.5 (10)	.7 (1)	4.0 (5)	3.5 (4)
Nephtys caeca	--	--	1.0 (2)	--
Nephtys spec. juv.	--	--	--	--
Glycera rouxii	.5 (1)	.7 (1)	5.5 (6)	1.5 (2)
Glycera spec. juv.	7.0 (6)	--	5.5 (6)	9.5 (9)
Glycinde nordmanni	1.5 (3)	--	.5 (1)	2.5 (4)
Goniada maculata	25.5 (10)	--	27.5 (10)	35.0 (10)
Lumbrineris latreilli	38.0 (10)	1.4 (1)	49.5 (10)	96.5 (10)
Scoloplos armiger	--	--	--	--
Poecilochaetus serpens	1.0 (2)	--	--	1.5 (3)
Spio filicornis	6.0 (7)	--	1.5 (2)	1.5 (3)
Spiophanes bombyx	684.0 (10)	--	380.5 (10)	369.0 (10)
Scolecopsis bonnieri	2.0 (3)	--	--	--
Magelona papillicornis	18.0 (10)	--	3.0 (3)	11.5 (9)
Chaetozone setosa	54.0 (10)	--	34.5 (10)	38.0 (10)
Diplocirrus glaucus	1.0 (2)	--	--	2.0 (3)
Scalibregma inflatum	2.0 (3)	--	9.0 (7)	7.5 (7)
Ophelina acuminata	.5 (1)	--	--	--
Capitella capitata	1.0 (2)	15.0 (4)	--	--
Notomastus latericeus	--	--	1.0 (2)	.5 (1)
Heteromastus filiformis	.5 (1)	--	.5 (1)	3.0 (2)
Owenia fusiformis	9.5 (8)	--	9.5 (9)	25.5 (10)
Lanice conchilega	--	--	--	--
Lagis koreni	3.5 (5)	--	5.5 (7)	3.0 (4)
Sosane gracilis	--	--	--	--
MOLLUSCA				
Nucula turgida	623.0 (10)	--	1062.0 (10)	368.0 (10)
Diplodonta rotundata	.5 (1)	--	.5 (1)	.5 (1)
Thyasira flexuosa	.5 (1)	--	--	2.5 (5)
Montacuta ferruginosa	--	--	--	--
Myssella bidentata	--	--	.5 (1)	.5 (1)
Acanthocardia echinata	2.5 (4)	--	2.5 (4)	2.5 (4)
Dosinia lupinus	.5 (1)	--	4.0 (5)	3.0 (6)
Venus striatula	10.0 (7)	--	12.0 (9)	8.5 (8)

Table 27. Data platform K12a, survey Sept. 1987.

RC= residual current transect.

Mean densities (n.m⁻²).Tot. number of ind. per m² per station.

Number of identified species.

Number of samples () in which species are present.

Distance to platform (m)	500 RC	750 RC	1000 RC	5000 RC
Nr. of analysed samples	6	6	6	6
POLYCHAETA				
Aphrodita aculeata	1.7 (2)	--	--	.8 (1)
Harmothoe lunulata	--	--	--	3.3 (3)
Harmothoe longisetis	--	.8 (1)	.8 (1)	--
Gattyana cirrosa	--	--	--	.8 (1)
Sigalion mathildae	--	.8 (1)	.8 (1)	--
Pholoe minuta	15.8 (4)	16.7 (5)	10.0 (6)	41.7 (6)
Sthenelais limicola	.8 (1)	5.0 (4)	7.5 (5)	5.8 (4)
Eteone longa	--	1.7 (1)	--	--
Anaitides groenlandica	.8 (1)	--	1.7 (2)	4.2 (3)
Anaitides mucosa	.8 (1)	1.7 (2)	.8 (1)	.8 (1)
Anaitides maculata	1.7 (1)	5.0 (4)	4.2 (4)	5.8 (4)
Eumida sanguinea	--	.8 (1)	--	5.8 (4)
Ophiodromus flexuosus	3.3 (3)	16.7 (5)	22.5 (6)	15.0 (6)
Gyptis capensis	--	3.3 (2)	4.2 (4)	3.3 (4)
Exogone hebes	--	--	--	1.7 (2)
Nereis longissima	--	--	--	.8 (1)
Nereis spec. juv.	6.7 (4)	2.5 (3)	1.7 (2)	4.2 (3)
Nephtys hombergii	24.2 (5)	35.8 (6)	41.7 (6)	42.5 (6)
Nephtys cirrosa	1.7 (1)	13.3 (6)	8.3 (5)	9.2 (5)
Nephtys caeca	--	.8 (1)	.8 (1)	--
Nephtys spec. juv.	3.3 (1)	5.8 (3)	--	.8 (1)
Glycera rouxii	.8 (1)	--	1.7 (1)	.8 (1)
Glycera spec. juv.	6.7 (5)	5.0 (4)	9.2 (6)	5.8 (4)
Glycinde nordmanni	2.5 (2)	1.7 (2)	--	.8 (1)
Goniada maculata	16.7 (6)	15.0 (6)	24.2 (6)	18.3 (6)
Lumbrineris latreilli	30.8 (6)	63.3 (6)	43.3 (6)	85.8 (6)
Scoloplos armiger	--	--	--	.8 (1)
Poecilochaetus serpens	1.7 (2)	3.3 (4)	1.7 (2)	5.0 (4)
Spio filicornis	--	2.5 (1)	5.8 (3)	1.7 (2)
Spiophanes bombyx	265.8 (6)	162.5 (6)	165.8 (6)	420.8 (6)
Scolecopsis bonnieri	--	2.5 (3)	3.3 (3)	1.7 (2)
Magelona papillicornis	21.7 (5)	45.8 (6)	58.3 (6)	43.3 (6)
Chaetozone setosa	25.0 (6)	85.0 (6)	58.3 (6)	14.2 (5)
Diplocirrus glaucus	--	.8 (1)	.8 (1)	1.7 (2)
Scalibregma inflatum	5.8 (4)	5.8 (3)	.8 (1)	.8 (1)
Ophelina acuminata	--	.8 (1)	1.7 (2)	1.7 (2)
Capitella capitata	--	7.5 (3)	3.3 (2)	--
Notomastus latericeus	.8 (1)	--	--	--
Heteromastus filiformis	--	--	--	--
Owenia fusiformis	40.8 (6)	22.5 (6)	25.8 (6)	81.7 (6)
Lanice conchilega	--	--	--	10.0 (5)
Lagis koreni	.8 (1)	--	--	.8 (1)
Sosane gracilis	--	--	--	.8 (1)
MOLLUSCA				
Nucula turgida	180.8 (6)	143.3 (6)	110.8 (6)	165.0 (6)
Diplodonta rotundata	--	.8 (1)	--	--
Thyasira flexuosa	1.7 (2)	--	1.7 (2)	1.7 (1)
Montacuta ferruginosa	--	--	1.7 (2)	34.2 (6)
Mysella bidentata	5.8 (4)	1.7 (2)	7.5 (4)	3.3 (3)
Acanthocardia echinata	8.3 (5)	3.3 (4)	6.7 (4)	4.2 (3)
Dosinia lupinus	2.5 (3)	.8 (1)	--	1.7 (2)
Venus striatula	2.5 (2)	5.8 (4)	1.7 (2)	.8 (1)

Table 27 continued.

Distance to platform (m)	250 PT	0 (PL)	100 RC	250 RC
<i>Macra corallina</i>	1.5 (2)	--	1.5 (2)	.5 (1)
<i>Spisula spec. juv.</i>	--	--	--	.5 (1)
<i>Tellina fabula</i>	7.5 (8)	--	1.5 (2)	6.0 (5)
<i>Tellina tenuis</i>	--	--	--	2.0 (1)
<i>Abra alba</i>	3.0 (6)	--	2.0 (3)	2.5 (4)
<i>Ensis ensis</i>	--	--	.5 (1)	--
<i>Cultellus pellucidus</i>	1.0 (2)	--	8.0 (7)	3.0 (3)
<i>Cingula nitida</i>	--	--	--	.5 (1)
<i>Turritella communis</i>	--	--	--	--
<i>Natica alderi</i>	51.0 (10)	--	27.5 (10)	38.0 (10)
<i>Buccinum undatum</i>	.5 (1)	--	--	--
<i>Cylichna cylindracea</i>	1.5 (2)	--	--	.5 (1)

CRUSTACEA

<i>Crangon crangon</i>	--	--	--	.5 (1)
<i>Processa parva</i>	--	--	.5 (1)	1.0 (1)
<i>Pontophilus trispinosus</i>	1.0 (1)	12.1 (3)	2.5 (3)	1.5 (2)
<i>Pagurus bernhardus</i>	.5 (1)	.7 (1)	2.5 (4)	1.5 (1)
<i>Porcellana longicornis</i>	--	47.1 (4)	--	--
<i>Galathea intermedia</i>	--	23.6 (4)	--	--
<i>Macropipus holsatus</i>	1.5 (2)	261.4 (7)	.5 (1)	--
<i>Macropipus spec. juv.</i>	3.0 (4)	--	8.0 (8)	5.5 (7)
<i>Ebalia cranchii</i>	3.5 (5)	.7 (1)	2.0 (3)	1.5 (2)
<i>Atelecyclyus spec. juv.</i>	--	1.4 (1)	--	--
<i>Cancer pagurus</i>	--	2.1 (2)	--	--
<i>Corystes cassivelaunus</i>	9.5 (8)	--	15.5 (10)	7.5 (7)
<i>Upogebia spec. juv.</i>	4.0 (6)	17.9 (4)	21.5 (10)	20.5 (10)
<i>Callinassa spec. juv.</i>	2.0 (3)	--	3.5 (5)	5.5 (7)
<i>Decapoda larven</i>	10.0 (9)	4.3 (2)	6.5 (8)	3.5 (4)
<i>Schistomysis ornata</i>	--	--	--	.5 (1)
<i>Eudorella truncatula</i>	--	--	--	.5 (1)
<i>Iphinoe trispinosa</i>	.5 (1)	--	2.5 (4)	.5 (1)
<i>Pseudocuma longicornis</i>	--	--	.5 (1)	--
<i>Diastylis bradyi</i>	2.0 (2)	1.4 (2)	2.5 (3)	3.5 (6)
<i>Atylus swammerdami</i>	5.0 (5)	--	7.5 (7)	4.5 (5)
<i>Atylus falcatus</i>	--	1.4 (1)	--	--
<i>Hippomedon denticulatus</i>	.5 (1)	--	--	--
<i>Orchomenella nana</i>	2.0 (4)	--	5.0 (5)	1.5 (3)
<i>Leucothoe incisa</i>	--	--	--	--
<i>Metopa spec.</i>	--	1.4 (1)	--	--
<i>Ampelisca brevicornis</i>	--	--	3.0 (4)	2.0 (4)
<i>Ampelisca tenuicornis</i>	--	--	--	--
<i>Ampelisca spec. juv.</i>	--	--	1.0 (2)	.5 (1)
<i>Bathyporeia elegans</i>	.5 (1)	--	--	--
<i>Bathyporeia tenuipes</i>	36.5 (10)	--	25.0 (10)	5.5 (5)
<i>Argissa hamatipes</i>	--	--	--	.5 (1)
<i>Harpinia antennaria</i>	--	--	--	.5 (1)
<i>Apherusa ovalipes</i>	1.5 (1)	--	--	.5 (1)
<i>Perioculodes longimanus</i>	7.0 (9)	--	4.0 (5)	2.5 (4)
<i>Jassa falcata</i>	--	10.7 (6)	--	--

ECHINODERMATA

<i>Astropecten irregularis</i>	2.5 (4)	--	--	.5 (1)
<i>Asterias rubens</i>	--	6.4 (3)	1.0 (1)	2.0 (4)
<i>Amphiura filiformis</i>	--	--	2.0 (3)	2.5 (4)
<i>Amphiura chiajei</i>	--	--	--	--
<i>Ophiura texturata</i>	.5 (1)	--	2.0 (2)	--
<i>Ophiura albida</i>	--	--	1.0 (1)	1.0 (1)
<i>Ophiura spec. juv.</i>	2.0 (2)	1.4 (1)	2.0 (4)	2.0 (3)
<i>Echinocardium cordatum</i>	473.5 (10)	--	20.5 (9)	3399.5 (10)
<i>Echinocyamus pusillus</i>	2.0 (4)	--	1.0 (2)	1.5 (3)
<i>Psammechinus miliaris</i>	--	2.1 (2)	--	--

Table 27 continued.

Distance to platform (m)	500 RC	750 RC	1000 RC	5000 RC
<i>Mactra corallina</i>	1.7 (2)	.8 (1)	1.7 (2)	4.2 (4)
<i>Spisula spec. juv.</i>	--	--	--	--
<i>Tellina fabula</i>	4.2 (2)	20.0 (6)	19.2 (6)	10.0 (4)
<i>Tellina tenuis</i>	--	--	--	--
<i>Abra alba</i>	24.2 (6)	4.2 (3)	4.2 (4)	10.0 (5)
<i>Ensis ensis</i>	--	--	--	--
<i>Cultellus pellucidus</i>	.8 (1)	5.0 (5)	.8 (1)	--
<i>Cingula nitida</i>	--	--	--	--
<i>Turritella communis</i>	--	1.7 (1)	--	--
<i>Natica alderi</i>	18.3 (6)	27.5 (6)	18.3 (6)	31.7 (6)
<i>Buccinum undatum</i>	--	--	.8 (1)	--
<i>Cylichna cilindracea</i>	--	--	--	--

CRUSTACEA

<i>Crangon crangon</i>	--	--	.8 (1)	1.7 (1)
<i>Processa parva</i>	.8 (1)	1.7 (2)	3.3 (3)	.8 (1)
<i>Pontophilus trispinosus</i>	.8 (1)	--	--	.8 (1)
<i>Pagurus bernhardus</i>	--	--	--	--
<i>Porcellana longicornis</i>	--	--	--	--
<i>Galathea intermedia</i>	--	--	--	--
<i>Macropipus holsatus</i>	.8 (1)	--	--	8.3 (4)
<i>Macropipus spec. juv.</i>	8.3 (6)	5.8 (4)	10.0 (6)	5.0 (3)
<i>Ebalia cranchii</i>	--	.8 (1)	3.3 (2)	.8 (1)
<i>Atelecyclus spec. juv.</i>	--	--	--	--
<i>Cancer pagurus</i>	--	--	--	--
<i>Corystes cassivelaunus</i>	--	3.3 (3)	1.7 (1)	1.7 (2)
<i>Upogebia spec. juv.</i>	6.7 (5)	11.7 (5)	12.5 (6)	15.0 (6)
<i>Callinassa spec. juv.</i>	5.8 (3)	5.8 (4)	10.0 (6)	7.5 (5)
<i>Decapoda larven</i>	5.0 (3)	7.5 (5)	2.5 (3)	1.7 (1)
<i>Schistomysis ornata</i>	--	--	--	--
<i>Eudorella truncatula</i>	3.3 (2)	--	.8 (1)	.8 (1)
<i>Iphinoe trispinosa</i>	2.5 (2)	.8 (1)	1.7 (2)	--
<i>Pseudocuma longicornis</i>	--	--	.8 (1)	--
<i>Diastylis bradyi</i>	2.5 (3)	1.7 (2)	2.5 (3)	9.2 (5)
<i>Atylus swammerdami</i>	2.5 (2)	1.7 (2)	--	1.7 (2)
<i>Atylus falcatus</i>	--	--	--	--
<i>Hippomedon denticulatus</i>	--	--	--	--
<i>Orchomenella nana</i>	.8 (1)	.8 (1)	2.5 (3)	.8 (1)
<i>Leucothoe incisa</i>	--	3.3 (3)	.8 (1)	1.7 (2)
<i>Metopa spec.</i>	--	--	--	--
<i>Ampelisca brevicornis</i>	1.7 (1)	--	--	--
<i>Ampelisca tenuicornis</i>	--	.8 (1)	.8 (1)	1.7 (2)
<i>Ampelisca spec. juv.</i>	--	--	--	4.2 (2)
<i>Bathyporeia elegans</i>	--	--	--	--
<i>Bathyporeia tenuipes</i>	--	6.7 (4)	14.2 (6)	--
<i>Argissa hamatipes</i>	--	--	.8 (1)	--
<i>Harpinia antennaria</i>	--	.8 (1)	1.7 (2)	8.3 (6)
<i>Apherusa ovalipes</i>	--	--	--	--
<i>Perioculodes longimanus</i>	2.5 (3)	.8 (1)	9.2 (4)	--
<i>Jassa falcata</i>	--	--	--	--

ECHINODERMATA

<i>Astropecten irregularis</i>	--	--	--	--
<i>Asterias rubens</i>	1.7 (1)	.8 (1)	--	.8 (1)
<i>Amphiura filiformis</i>	2.5 (3)	.8 (1)	2.5 (2)	5.0 (3)
<i>Amphiura chiajei</i>	--	.8 (1)	--	--
<i>Ophiura texturata</i>	--	--	--	.8 (1)
<i>Ophiura albida</i>	--	--	--	--
<i>Ophiura spec. juv.</i>	--	--	--	--
<i>Echinocardium cordatum</i>	3041.7 (6)	3332.5 (6)	2796.7 (6)	3212.5 (6)
<i>Echinocyamus pusillus</i>	--	--	--	--
<i>Psammechinus miliaris</i>	--	--	--	--

Table 27 continued.

Distance to platform (m)	250 PT	0 (PL)	100 RC	250 RC
OTHER TAXA				
Nemertinea	P (9)	--	P (10)	P (9)
Nematoda	--	1.4 (1)	--	--
Hydrozoa	--	--	--	--
Turbellaria	.5 (1)	--	3.0 (6)	2.5 (4)
Phoroniden	--	--	--	--
Harp. copepoda	2.0 (1)	1.4 (2)	7.0 (8)	5.5 (6)
Oligochaeta	P (8)	--	P (9)	P (8)
Sagitta spec.	.5 (1)	--	2.0 (3)	--
Anthozoa	.5 (1)	--	--	.5 (1)
Ascidacea	--	--	--	--
Tot. nr. of ind. (n.m ⁻²)	2197	418	1858	4626
Nr. of identified species	58	16	58	67
P=present, not counted				

Table 27 continued.

Distance to platform (m)	500 RC	750 RC	1000 RC	5000 RC
OTHER TAXA				
Nemertinea	P (6)	P (6)	P (6)	P (6)
Nematoda	--	--	--	--
Hydrozoa	--	--	--	-- (1)
Turbellaria	--	.8 (1)	.8 (1)	.8 (1)
Phoroniden	P (1)	P (3)	P (3)	P (3)
Harp. copepoda	14.2 (4)	5.0 (3)	9.2 (4)	6.7 (5)
Oligochaeta	P (4)	P (5)	P (6)	P (1)
Sagitta spec.	--	--	--	--
Anthozoa	--	--	2.5 (2)	--
Ascidacea	1.7 (2)	--	.8 (1)	.8 (1)
Tot. nr. of ind. (n.m ⁻²)	3837	4144	3577	4409
Nr. of identified species	45	55	55	60
P=present, not counted				

Table 28. Data platform K12a, survey Sept. 1988.

RC= residual current transect; PT= perpendicular transect.

Mean densities (n.m⁻²).Tot. number of ind. per m² per station.

Number of identified species.

Number of samples () in which species are present.

Distance to platform (m)	0 (PL)	250 RC	500 RC	750 RC	5000 RC	250 PT
Nr. of analysed samples	5	5	5	5	5	5
POLYCHAETA						
<i>Aphrodita aculeata</i>	1.0 (1)	--	--	--	1.0 (1)	--
<i>Harmothoe longisetis</i>	--	--	--	1.0 (1)	1.0 (1)	2.0 (2)
<i>Harmothoe spec. juv.</i>	--	8.0 (3)	4.0 (2)	1.0 (1)	22.0 (5)	--
<i>Gattyana cirrosa</i>	--	--	--	--	1.0 (1)	--
<i>Sigalion mathildae</i>	--	--	--	1.0 (1)	3.0 (2)	--
<i>Pholoe minuta</i>	14.0 (2)	94.0 (5)	129.0 (5)	128.0 (5)	70.0 (5)	44.0 (5)
<i>Sthenelais limicola</i>	10.0 (4)	3.0 (3)	1.0 (1)	--	1.0 (1)	3.0 (2)
<i>Eteone longa</i>	9.0 (4)	16.0 (4)	5.0 (4)	5.0 (4)	15.0 (3)	7.0 (4)
<i>Anaitides groenlandica</i>	10.0 (4)	9.0 (4)	6.0 (4)	7.0 (4)	22.0 (5)	6.0 (4)
<i>Anaitides mucosa</i>	22.0 (5)	29.0 (5)	25.0 (5)	25.0 (5)	26.0 (5)	17.0 (5)
<i>Anaitides maculata</i>	2.0 (2)	1.0 (1)	--	2.0 (1)	3.0 (3)	3.0 (2)
<i>Eumida sanguinea</i>	--	2.0 (2)	2.0 (2)	--	30.0 (5)	1.0 (1)
<i>Ophiodromus flexuosus</i>	3.0 (2)	11.0 (4)	29.0 (5)	37.0 (5)	18.0 (5)	13.0 (4)
<i>Gyptis capensis</i>	3.0 (1)	8.0 (4)	13.0 (5)	19.0 (5)	8.0 (5)	8.0 (4)
<i>Synelmis klatti</i>	--	--	1.0 (1)	--	--	--
<i>Exogone hebes</i>	--	--	--	--	1.0 (1)	--
<i>Nereis longissima</i>	12.0 (2)	1.0 (1)	--	2.0 (1)	2.0 (1)	2.0 (2)
<i>Nereis spec. juv.</i>	12.0 (3)	7.0 (4)	6.0 (3)	1.0 (1)	22.0 (4)	3.0 (2)
<i>Nephtys hombergii</i>	38.0 (4)	53.0 (5)	61.0 (5)	45.0 (5)	60.0 (5)	60.0 (5)
<i>Nephtys cirrosa</i>	4.0 (3)	5.0 (2)	7.0 (3)	6.0 (2)	1.0 (1)	3.0 (2)
<i>Nephtys caeca</i>	--	--	1.0 (1)	--	1.0 (1)	2.0 (1)
<i>Nephtys spec. juv.</i>	--	1.0 (1)	--	1.0 (1)	6.0 (2)	--
<i>Glycera rouxii</i>	3.0 (2)	2.0 (2)	--	3.0 (2)	3.0 (2)	--
<i>Glycera alba</i>	1.0 (1)	--	--	--	--	--
<i>Glycera spec. juv.</i>	8.0 (4)	--	1.0 (1)	1.0 (1)	1.0 (1)	1.0 (1)
<i>Glycinde nordmanni</i>	5.0 (2)	8.0 (5)	6.0 (4)	8.0 (3)	4.0 (4)	9.0 (4)
<i>Goniada maculata</i>	21.0 (4)	11.0 (5)	14.0 (4)	23.0 (5)	14.0 (4)	13.0 (5)
<i>Lumbrineris latreilli</i>	77.0 (5)	77.0 (5)	94.0 (5)	93.0 (5)	191.0 (5)	93.0 (5)
<i>Scoloplos armiger</i>	1.0 (1)	1.0 (1)	1.0 (1)	--	4.0 (3)	1.0 (1)
<i>Poecilochaetus serpens</i>	1.0 (1)	4.0 (2)	3.0 (3)	1.0 (1)	2.0 (2)	2.0 (2)
<i>Spio filicornis</i>	75.0 (5)	65.0 (5)	30.0 (5)	16.0 (5)	30.0 (4)	31.0 (5)
<i>Spiophanes kroyeri</i>	1.0 (1)	2.0 (2)	1.0 (1)	1.0 (1)	--	--
<i>Spiophanes bombyx</i>	2081.0 (5)	2261.0 (5)	2140.0 (5)	1791.0 (5)	1466.0 (5)	1719.0 (5)
<i>Scolecopsis bonnierii</i>	3.0 (3)	--	--	--	1.0 (1)	--
<i>Magelona papillicornis</i>	107.0 (5)	110.0 (5)	83.0 (5)	65.0 (5)	81.0 (5)	102.0 (5)
<i>Chaetozone setosa</i>	31.0 (5)	35.0 (5)	28.0 (5)	33.0 (5)	14.0 (4)	24.0 (5)
<i>Diplocirrus glaucus</i>	2.0 (2)	1.0 (1)	1.0 (1)	2.0 (2)	5.0 (3)	--
<i>Scalibregma inflatum</i>	5.0 (3)	15.0 (5)	16.0 (5)	13.0 (3)	11.0 (2)	7.0 (3)
<i>Capitella capitata</i>	89.0 (2)	5.0 (1)	5.0 (3)	6.0 (3)	--	--
<i>Notomastus latericeus</i>	2.0 (2)	--	--	3.0 (1)	1.0 (1)	2.0 (2)
<i>Heteromastus filiformis</i>	11.0 (3)	4.0 (1)	3.0 (2)	1.0 (1)	9.0 (3)	1.0 (1)
<i>Owenia fusiformis</i>	11.0 (4)	12.0 (4)	19.0 (5)	18.0 (5)	20.0 (4)	14.0 (5)
<i>Myriochele heeri</i>	1.0 (1)	2.0 (2)	1.0 (1)	1.0 (1)	1.0 (1)	3.0 (2)
<i>Lanice conchilega</i>	49.0 (5)	104.0 (5)	66.0 (5)	45.0 (5)	208.0 (5)	73.0 (5)
<i>Lagis koreni</i>	521.0 (5)	481.0 (5)	465.0 (5)	453.0 (5)	925.0 (5)	278.0 (5)
<i>Pectinaria auricoma</i>	--	2.0 (2)	1.0 (1)	--	--	--
<i>Ampharete finmarchica</i>	--	2.0 (1)	--	--	--	3.0 (1)
<i>Sosane gracilis</i>	6.0 (5)	11.0 (5)	21.0 (5)	17.0 (5)	20.0 (5)	8.0 (4)
<i>Lysilla loveni</i>	3.0 (2)	--	--	--	1.0 (1)	--
<i>Terebellides stroemi</i>	1.0 (1)	--	--	--	--	--
<i>Sabellaria spec.</i>	--	--	--	--	1.0 (1)	--

Table 28 continued.

Distance to platform (m)	0 (PL)	250 RC	500 RC	750 RC	5000 RC	250 PT
MOLLUSCA						
<i>Nucula turgida</i>	394.0 (5)	293.0 (5)	149.0 (5)	201.0 (5)	160.0 (5)	168.0 (5)
<i>Thyasira flexuosa</i>	--	1.0 (1)	--	--	1.0 (1)	--
<i>Montacuta ferruginosa</i>	--	8.0 (4)	23.0 (4)	14.0 (5)	67.0 (5)	7.0 (4)
<i>Mysella bidentata</i>	--	4.0 (3)	2.0 (2)	--	1.0 (1)	--
<i>Arctica islandica</i>	--	--	--	--	1.0 (1)	--
<i>Acanthocardia echinata</i>	1.0 (1)	--	--	--	--	1.0 (1)
<i>Dosinia lupinus</i>	1.0 (1)	--	--	--	--	1.0 (1)
<i>Venus striatula</i>	5.0 (3)	4.0 (4)	6.0 (4)	3.0 (2)	1.0 (1)	4.0 (3)
<i>Tellina fabula</i>	21.0 (4)	14.0 (5)	16.0 (5)	5.0 (3)	29.0 (4)	21.0 (4)
<i>Abra alba</i>	14.0 (3)	19.0 (4)	27.0 (5)	21.0 (5)	5.0 (3)	20.0 (5)
<i>Cultellus pellucidus</i>	8.0 (3)	5.0 (2)	4.0 (3)	1.0 (1)	7.0 (5)	5.0 (3)
<i>Mya spec. juv.</i>	--	2.0 (2)	--	1.0 (1)	--	--
<i>Cingula nitida</i>	--	--	--	--	1.0 (1)	--
<i>Natica alderi</i>	26.0 (5)	31.0 (5)	30.0 (5)	28.0 (5)	39.0 (5)	33.0 (5)
<i>Cylichna cylindracea</i>	--	--	--	--	1.0 (1)	--
<i>Philine catena</i>	1.0 (1)	--	--	--	--	--
<i>Philine scabra</i>	1.0 (1)	--	--	1.0 (1)	--	--
CRUSTACEA						
<i>Crangon crangon</i>	--	1.0 (1)	--	--	1.0 (1)	--
<i>Processa parva</i>	--	--	--	--	1.0 (1)	--
<i>Pontophilus trispinosus</i>	1.0 (1)	--	1.0 (1)	1.0 (1)	--	--
<i>Pagurus bernhardus</i>	1.0 (1)	--	--	--	--	--
<i>Porcellana spec. juv.</i>	--	--	--	1.0 (1)	--	--
<i>Galathea spec. juv.</i>	--	1.0 (1)	--	--	--	--
<i>Macropipus holsatus</i>	1.0 (1)	--	4.0 (3)	2.0 (1)	5.0 (2)	5.0 (2)
<i>Macropipus spec. juv.</i>	9.0 (5)	3.0 (3)	7.0 (3)	4.0 (4)	7.0 (2)	7.0 (3)
<i>Ebalia cranchii</i>	3.0 (2)	1.0 (1)	--	1.0 (1)	3.0 (2)	--
<i>Corystes cassivelaunus</i>	4.0 (3)	5.0 (3)	1.0 (1)	3.0 (3)	6.0 (4)	4.0 (3)
<i>Upogebia spec. juv.</i>	15.0 (4)	6.0 (3)	7.0 (3)	5.0 (3)	2.0 (2)	9.0 (4)
<i>Callinassa subterranea</i>	2.0 (1)	2.0 (1)	--	1.0 (1)	--	--
<i>Callinassa spec. juv.</i>	7.0 (4)	14.0 (4)	27.0 (5)	18.0 (4)	33.0 (5)	11.0 (3)
<i>Decapoda larven</i>	1.0 (1)	--	3.0 (3)	1.0 (1)	3.0 (3)	2.0 (2)
<i>Eudorella truncatula</i>	1.0 (1)	2.0 (2)	2.0 (2)	1.0 (1)	2.0 (1)	1.0 (1)
<i>Iphinoe trispinosa</i>	--	--	--	--	--	1.0 (1)
<i>Diastylis bradyi</i>	93.0 (5)	80.0 (5)	61.0 (5)	156.0 (5)	45.0 (5)	60.0 (5)
<i>Atylus falcatus</i>	2.0 (1)	1.0 (1)	--	--	--	3.0 (2)
<i>Orchomenella nana</i>	--	4.0 (2)	--	1.0 (1)	--	--
<i>Leucothoe incisa</i>	--	--	1.0 (1)	--	5.0 (4)	1.0 (1)
<i>Ampelisca brevicornis</i>	4.0 (3)	3.0 (2)	2.0 (2)	4.0 (3)	7.0 (5)	1.0 (1)
<i>Ampelisca tenuicornis</i>	--	--	--	1.0 (1)	5.0 (2)	2.0 (1)
<i>Ampelisca spec. juv.</i>	3.0 (3)	5.0 (3)	4.0 (3)	4.0 (2)	8.0 (3)	1.0 (1)
<i>Bathyporeia tenuipes</i>	--	--	--	1.0 (1)	--	--
<i>Argissa hamatipes</i>	--	--	--	1.0 (1)	--	--
<i>Harpinia antennaria</i>	--	2.0 (2)	--	--	--	--
<i>Perioculodes longimanus</i>	1.0 (1)	1.0 (1)	1.0 (1)	--	4.0 (2)	1.0 (1)
<i>Synchelidium haplochele</i>	--	--	--	1.0 (1)	--	--
<i>Caprella spec.</i>	--	--	--	1.0 (1)	1.0 (1)	--
ECHINODERMATA						
<i>Astropecten irregularis</i>	1.0 (1)	--	--	1.0 (1)	--	1.0 (1)
<i>Amphiura filiformis</i>	1.0 (1)	2.0 (2)	7.0 (3)	4.0 (3)	11.0 (4)	2.0 (2)
<i>Amphiura chiajei</i>	--	--	--	--	1.0 (1)	1.0 (1)
<i>Ophiura texturata</i>	2.0 (1)	2.0 (2)	--	--	1.0 (1)	1.0 (1)
<i>Ophiura albida</i>	--	--	--	1.0 (1)	--	--
<i>Ophiura spec. juv.</i>	32.0 (4)	19.0 (5)	6.0 (3)	4.0 (3)	30.0 (5)	16.0 (5)
<i>Echinocardium cordatum</i>	94.0 (5)	694.0 (5)	867.0 (5)	978.0 (5)	430.0 (5)	920.0 (5)
<i>Echinocyamus pusillus</i>	1.0 (1)	--	--	--	--	--

Table 28 continued.

Distance to platform (m)	0 (PL)	250 RC	500 RC	750 RC	5000 RC	250 PT
OTHER TAXA						
Nemertinea	P (5)	P (5)	P (5)	P (5)	P (5)	P (5)
Nematoda	--	2.0 (1)	--	--	--	--
Phoroniden	--	--	P (2)	P (1)	P (4)	P (1)
Harp. copepoda	3.0 (1)	6.0 (2)	4.0 (4)	3.0 (2)	2.0 (2)	2.0 (2)
Oligochaeta	P (3)	P (5)	P (5)	P (5)	P (3)	P (5)
Sagitta spec.	1.0 (1)	3.0 (3)	1.0 (1)	--	5.0 (4)	3.0 (3)
Sipunculida	--	--	--	--	1.0 (1)	--
Actinaria	5.0 (3)	1.0 (1)	--	4.0 (3)	3.0 (2)	--
Ascidacea	--	--	--	--	2.0 (2)	--
Tot. nr. of ind. (n.m ⁻²).	4016	4703	4553	4353	4264	3873
Nr. of identified species	63	57	49	56	65	55
P=present, not counted						

Table 29. Data location F18/9 (abandoned), survey June 1988.
 Residual current transect.
 Mean densities (n.m⁻²).
 Tot. number of ind. per m² per station.
 Number of identified species.
 Number of samples () in which species are present.

Distance to platform (m)	0	100	250	500	750	1000	2000
Nr. of analysed samples	8	8	8	8	8	8	8
POLYCHAETA							
<i>Aphrodita aculeata</i>	.6 (1)	--	.6 (1)	1.2 (2)	1.2 (2)	1.9 (3)	5.0 (4)
<i>Harmothoe lunulata</i>	--	--	--	--	.6 (1)	--	.7 (1)
<i>Harmothoe longisetis</i>	--	--	--	--	1.2 (1)	1.2 (2)	2.9 (3)
<i>Gattyana cirrosa</i>	31.9 (6)	10.0 (7)	26.2 (8)	66.3 (8)	68.1 (7)	59.4 (7)	71.4 (7)
<i>Polynoe kinbergi</i>	--	--	--	--	--	--	--
<i>Pholoe minuta</i>	5.0 (3)	3.8 (4)	8.8 (6)	5.6 (5)	5.6 (6)	15.6 (6)	12.1 (7)
<i>Sthenelais limicola</i>	--	1.9 (2)	--	--	1.9 (2)	1.9 (2)	.7 (1)
<i>Eteone longa</i>	5.0 (2)	--	--	--	--	.6 (1)	--
<i>Eteone lactea</i>	--	--	--	.6 (1)	--	--	--
<i>Eteone flava</i>	--	--	--	--	--	--	--
<i>Anaitides groenlandica</i>	10.6 (7)	1.2 (2)	1.2 (1)	.6 (1)	--	--	2.1 (1)
<i>Anaitides maculata</i>	.6 (1)	--	1.2 (1)	.6 (1)	.6 (1)	--	.7 (1)
<i>Eumida sanguinea</i>	.6 (1)	--	.6 (1)	--	--	--	--
<i>Ophiodromus flexuosus</i>	1.2 (2)	--	1.2 (2)	6.3 (6)	6.3 (5)	3.1 (4)	3.6 (3)
<i>Gyptis capensis</i>	--	.6 (1)	--	--	1.2 (2)	1.9 (3)	2.1 (2)
<i>Synelmis klatti</i>	1.2 (2)	.6 (1)	3.1 (4)	1.2 (2)	.6 (1)	1.2 (2)	1.4 (2)
<i>Exogone hebes</i>	.6 (1)	--	.6 (1)	.6 (1)	--	--	2.1 (3)
<i>Autolytus spec.</i>	--	--	--	--	--	--	--
<i>Nereis longissima</i>	--	--	--	--	--	--	.7 (1)
<i>Nereis spec. juv.</i>	--	--	.6 (1)	--	1.2 (2)	--	--
<i>Nephtys hombergii</i>	1.2 (1)	2.5 (3)	8.8 (5)	6.3 (5)	12.5 (6)	7.5 (6)	7.9 (6)
<i>Nephtys incisa</i>	.6 (1)	--	1.2 (2)	1.2 (2)	1.2 (2)	--	.7 (1)
<i>Nephtys cirrosa</i>	.6 (1)	.6 (1)	--	--	--	--	1.4 (2)
<i>Nephtys caeca</i>	--	--	.6 (1)	--	--	.6 (1)	.7 (1)
<i>Nephtys longosetosa</i>	--	--	--	--	--	.6 (1)	--
<i>Nephtys spec. juv.</i>	3.8 (5)	8.1 (5)	7.5 (5)	5.6 (5)	10.0 (7)	13.1 (8)	17.9 (6)
<i>Glycera rouxii</i>	2.5 (2)	5.0 (4)	5.6 (5)	13.7 (7)	3.8 (3)	8.8 (7)	15.0 (7)
<i>Glycera alba</i>	--	--	--	1.9 (2)	3.8 (4)	1.9 (2)	5.7 (5)
<i>Glycera spec. juv.</i>	10.6 (5)	9.4 (6)	6.9 (6)	7.5 (6)	18.8 (7)	38.7 (8)	32.9 (7)
<i>Glycinde nordmanni</i>	3.1 (2)	5.0 (5)	1.9 (3)	3.1 (4)	4.4 (5)	11.2 (8)	6.4 (4)
<i>Goniada maculata</i>	6.3 (5)	11.9 (6)	5.6 (5)	6.9 (6)	10.6 (8)	19.4 (8)	17.1 (7)
<i>Lumbrineris latreilli</i>	30.6 (7)	68.8 (8)	49.4 (6)	93.8 (8)	72.5 (7)	198.7 (8)	170.7 (7)
<i>Lumbrineris fragilis</i>	1.2 (2)	3.8 (4)	1.9 (3)	3.8 (4)	13.1 (4)	5.0 (5)	10.0 (6)
<i>Driloneris filum</i>	--	--	--	.6 (1)	--	--	--
<i>Orbinia sertulata</i>	--	--	--	--	.6 (1)	--	.7 (1)
<i>Paraonis spec.</i>	--	--	1.2 (2)	1.9 (3)	3.1 (5)	4.4 (5)	10.7 (3)
<i>Poecilochaetus serpens</i>	--	--	--	--	--	--	.7 (1)
<i>Spio filicornis</i>	1.2 (2)	2.5 (3)	4.4 (4)	--	1.2 (2)	1.2 (1)	--
<i>Polydora guillei</i>	--	--	--	--	--	.6 (1)	--
<i>Polydora pulchra</i>	--	--	--	--	--	--	--
<i>Spiophanes kroyeri</i>	--	--	--	--	--	3.1 (4)	.7 (1)
<i>Spiophanes bombyx</i>	5.6 (5)	8.1 (6)	6.3 (4)	1.2 (2)	2.5 (3)	5.0 (5)	5.0 (5)
<i>Scolecopsis bonnierii</i>	.6 (1)	.6 (1)	--	--	--	--	--
<i>Scolecopsis foliosa</i>	--	--	--	--	--	--	--
<i>Magelona papillicornis</i>	.6 (1)	1.9 (2)	.6 (1)	--	1.2 (1)	2.5 (3)	.7 (1)
<i>Magelona alleni</i>	--	--	.6 (1)	.6 (1)	3.1 (3)	3.1 (5)	2.1 (2)
<i>Chaetopterus variopedatus</i>	18.8 (5)	3.8 (2)	16.9 (7)	53.8 (8)	90.0 (8)	98.7 (7)	89.3 (7)
<i>Tharyx marioni</i>	--	--	--	.6 (1)	6.3 (5)	6.9 (5)	5.0 (4)
<i>Chaetozone setosa</i>	3.1 (4)	3.8 (4)	3.8 (4)	6.3 (5)	19.4 (7)	39.4 (8)	60.7 (7)
<i>Diplocirrus glaucus</i>	.6 (1)	4.4 (5)	1.2 (2)	2.5 (3)	4.4 (5)	13.7 (7)	18.6 (7)
<i>Scalibregma inflatum</i>	--	--	.6 (1)	--	5.0 (5)	13.7 (7)	13.6 (6)
<i>Ophelina acuminata</i>	2.5 (3)	--	1.9 (3)	1.2 (1)	--	.6 (1)	.7 (1)
<i>Capitella capitata</i>	1.9 (1)	.6 (1)	1.2 (2)	1.2 (1)	--	.6 (1)	--
<i>Notomastus latericeus</i>	3.8 (3)	1.2 (1)	3.8 (3)	16.2 (6)	25.0 (7)	16.2 (8)	27.9 (6)

Table 29. Data location F18/9 (abandoned), survey June 1988.
 RC= residual current transect; PT= perpendicular transects.
 Mean densities (n.m⁻²).
 Tot. number of ind. per m² per station.
 Number of identified species.
 Number of samples () in which species are present.

Distance to platform (m)	5000 RC	250 PT	5000 PT	250 PT	5000 PT	250 PT	5000 PT
Nr. of analysed samples	7	8	7	8	7	8	7
POLYCHAETA							
<i>Aphrodita aculeata</i>	.7 (1)	.6 (1)	.7 (1)	1.2 (2)	--	--	1.4 (2)
<i>Harmothoe lunulata</i>	--	1.9 (3)	1.4 (2)	--	.7 (1)	--	.7 (1)
<i>Harmothoe longisetis</i>	2.1 (3)	--	2.1 (3)	.6 (1)	2.1 (3)	1.9 (3)	2.1 (2)
<i>Gattyana cirrosa</i>	69.3 (7)	15.6 (8)	19.3 (6)	25.0 (6)	74.3 (7)	42.5 (6)	97.1 (7)
<i>Polynoe kinbergi</i>	--	--	1.4 (2)	--	2.1 (2)	--	.7 (1)
<i>Pholoe minuta</i>	5.7 (4)	1.9 (3)	5.7 (4)	3.8 (5)	12.9 (6)	4.4 (4)	3.6 (3)
<i>Sthenelais limicola</i>	--	--	1.4 (2)	1.2 (2)	--	1.2 (2)	1.4 (2)
<i>Eteone longa</i>	.7 (1)	.6 (1)	--	--	--	.6 (1)	--
<i>Eteone lactea</i>	--	--	--	--	--	--	--
<i>Eteone flava</i>	--	.6 (1)	--	--	--	--	--
<i>Anaitides groenlandica</i>	.7 (1)	--	--	--	--	1.2 (2)	.7 (1)
<i>Anaitides maculata</i>	--	--	--	--	--	--	1.4 (1)
<i>Eumida sanguinea</i>	--	--	--	--	--	--	--
<i>Ophiodromus flexuosus</i>	8.6 (4)	1.9 (3)	2.1 (2)	4.4 (5)	5.7 (5)	1.9 (3)	1.4 (1)
<i>Gyptis capensis</i>	.7 (1)	--	.7 (1)	--	--	.6 (1)	--
<i>Syneimis klatti</i>	2.9 (3)	--	2.9 (3)	.6 (1)	2.1 (3)	1.2 (1)	1.4 (2)
<i>Exogone hebes</i>	--	--	--	.6 (1)	--	.6 (1)	.7 (1)
<i>Autolytus spec.</i>	.7 (1)	--	.7 (1)	--	--	--	--
<i>Nereis longissima</i>	--	--	--	--	--	--	--
<i>Nereis spec. juv.</i>	--	--	--	--	--	.6 (1)	--
<i>Nephtys hombergii</i>	6.4 (5)	11.2 (8)	5.0 (4)	8.1 (6)	5.0 (5)	7.5 (7)	9.3 (6)
<i>Nephtys incisa</i>	7.1 (5)	4.4 (5)	--	.6 (1)	2.1 (3)	2.5 (3)	5.7 (3)
<i>Nephtys cirrosa</i>	--	--	--	--	--	--	--
<i>Nephtys caeca</i>	--	--	.7 (1)	.6 (1)	--	--	.7 (1)
<i>Nephtys longosetosa</i>	--	--	--	--	--	--	--
<i>Nephtys spec. juv.</i>	10.7 (6)	11.2 (6)	2.1 (2)	5.0 (5)	6.4 (6)	8.1 (6)	5.7 (5)
<i>Glycera rousii</i>	10.0 (6)	8.8 (5)	5.7 (5)	2.5 (3)	12.9 (7)	3.1 (3)	3.6 (3)
<i>Glycera alba</i>	2.1 (3)	2.5 (3)	--	3.8 (3)	9.3 (6)	3.8 (3)	5.7 (4)
<i>Glycera spec. juv.</i>	35.7 (7)	16.2 (7)	12.1 (6)	21.2 (8)	32.1 (7)	10.0 (6)	40.7 (7)
<i>Glycinde nordmanni</i>	6.4 (6)	1.9 (3)	7.1 (6)	--	2.1 (2)	1.2 (2)	5.7 (5)
<i>Goniada maculata</i>	11.4 (6)	10.6 (6)	8.6 (6)	12.5 (8)	6.4 (4)	18.1 (8)	10.7 (7)
<i>Lumbrineris latreilli</i>	88.6 (7)	78.1 (8)	106.4 (7)	83.1 (8)	115.7 (7)	65.0 (8)	55.7 (7)
<i>Lumbrineris fragilis</i>	7.9 (7)	3.1 (4)	5.7 (5)	6.3 (6)	8.6 (5)	5.0 (5)	5.7 (6)
<i>Driloneris filum</i>	--	--	--	--	--	--	--
<i>Orbinia sertulata</i>	--	--	--	--	--	--	--
<i>Paraonis spec.</i>	4.3 (4)	2.5 (3)	3.6 (4)	1.2 (2)	5.7 (6)	1.9 (2)	7.1 (5)
<i>Poecilochaetus serpens</i>	--	--	1.4 (2)	--	--	--	--
<i>Spio filicornis</i>	.7 (1)	--	.7 (1)	--	.7 (1)	1.9 (3)	1.4 (2)
<i>Polydora guillei</i>	1.4 (1)	--	2.1 (1)	--	.7 (1)	--	2.9 (2)
<i>Polydora pulchra</i>	--	--	--	--	.7 (1)	--	--
<i>Spiophanes kroyeri</i>	.7 (1)	--	--	.6 (1)	.7 (1)	--	1.4 (1)
<i>Spiophanes bombyx</i>	8.6 (6)	3.1 (5)	15.0 (7)	1.9 (2)	9.3 (5)	1.9 (3)	5.0 (6)
<i>Scoletepis bonnieri</i>	--	--	--	--	.7 (1)	--	--
<i>Scoletepis foliosa</i>	--	--	--	.6 (1)	--	--	--
<i>Magelona papillicornis</i>	--	.6 (1)	1.4 (2)	.6 (1)	.7 (1)	--	--
<i>Magelona allenii</i>	2.9 (2)	--	--	.6 (1)	--	2.5 (4)	--
<i>Chaetopterus variopedatus</i>	105.7 (7)	8.1 (4)	15.0 (5)	13.1 (3)	98.6 (7)	41.2 (5)	143.6 (7)
<i>Tharyx marioni</i>	10.7 (5)	5.6 (5)	.7 (1)	1.2 (2)	7.1 (6)	--	1.4 (1)
<i>Chaetozone setosa</i>	55.0 (6)	21.2 (7)	7.9 (6)	18.1 (6)	34.3 (7)	5.0 (5)	30.7 (7)
<i>Diplocirrus glaucus</i>	2.1 (2)	3.1 (5)	2.9 (3)	4.4 (4)	2.9 (3)	1.9 (3)	2.9 (3)
<i>Scalibregma inflatum</i>	3.6 (2)	1.2 (1)	2.1 (3)	1.2 (2)	2.1 (3)	.6 (1)	2.1 (2)
<i>Ophelina acuminata</i>	.7 (1)	1.2 (2)	2.1 (3)	.6 (1)	--	.6 (1)	--
<i>Capitella capitata</i>	--	--	--	1.2 (2)	--	1.9 (2)	--
<i>Notomastus latericeus</i>	30.7 (7)	--	9.3 (5)	1.2 (2)	53.6 (6)	11.9 (4)	61.4 (5)

Table 29 continued.

Distance to platform (m)	0	100	250	500	750	1000	2000
<i>Heteromastus filiformis</i>	3.1 (2)	2.5 (2)	1.2 (2)	--	1.9 (2)	1.2 (2)	12.1 (5)
<i>Owenia fusiformis</i>	--	--	--	1.2 (1)	1.9 (3)	3.8 (5)	1.4 (2)
<i>Myriochele heeri</i>	--	--	--	--	--	--	.7 (1)
<i>Lanice conchilega</i>	1.2 (2)	--	1.2 (1)	--	1.2 (2)	1.2 (2)	1.4 (2)
<i>Lagis koreni</i>	.6 (1)	--	2.5 (4)	--	3.1 (3)	1.2 (2)	2.9 (3)
<i>Pectinaria auricoma</i>	--	--	--	--	--	--	.7 (1)
<i>Lysilla loveni</i>	--	--	.6 (1)	--	.6 (1)	--	2.9 (3)
<i>Terebellides stroemi</i>	--	--	--	--	--	--	--
<i>Amphicteis gunneri</i>	--	--	--	--	--	--	--
<i>Sosane gracilis</i>	--	--	--	--	--	--	--

MOLLUSCA

<i>Nucula turgida</i>	1.2 (2)	4.4 (5)	3.1 (4)	6.9 (6)	8.8 (6)	22.5 (6)	13.6 (6)
<i>Modiolus modiolus</i>	--	--	--	--	--	--	--
<i>Thyasira flexuosa</i>	--	--	--	--	.6 (1)	--	--
<i>Lepton squamosum</i>	--	--	--	--	--	--	.7 (1)
<i>Devonia perrieri</i>	--	--	--	--	--	--	--
<i>Montacuta ferruginosa</i>	--	--	--	--	--	--	--
<i>Mysella bidentata</i>	--	--	--	--	--	3.1 (2)	.7 (1)
<i>Arctica islandica</i>	2.5 (3)	2.5 (3)	--	3.8 (4)	1.9 (1)	2.5 (4)	7.9 (4)
<i>Acanthocardia echinata</i>	--	--	--	--	--	--	--
<i>Dosinia lupinus</i>	3.1 (1)	8.1 (7)	1.2 (2)	--	1.2 (2)	2.5 (4)	4.3 (4)
<i>Venus striatula</i>	3.8 (4)	5.6 (4)	5.6 (5)	3.1 (5)	2.5 (3)	3.1 (3)	4.3 (4)
<i>Tellina fabula</i>	--	--	--	--	--	--	--
<i>Mysia undata</i>	--	--	--	--	--	--	.7 (1)
<i>Abra alba</i>	20.0 (7)	10.6 (8)	6.3 (6)	2.5 (4)	11.2 (7)	17.5 (7)	17.9 (6)
<i>Cultellus pellucidus</i>	1.2 (2)	5.0 (5)	--	.6 (1)	3.1 (4)	3.8 (4)	5.0 (5)
<i>Mya spec. juv.</i>	--	--	--	1.2 (2)	--	--	--
<i>Hiatella arctica</i>	--	--	--	--	--	--	.7 (1)
<i>Corbula gibba</i>	11.2 (6)	20.6 (7)	16.2 (6)	14.4 (7)	30.0 (8)	16.9 (8)	29.3 (7)
<i>Thracia convexa</i>	--	--	.6 (1)	--	1.2 (1)	.6 (1)	.7 (1)
<i>Cingula nitida</i>	3.8 (2)	1.2 (1)	.6 (1)	6.3 (3)	2.5 (3)	3.8 (4)	20.0 (5)
<i>Turritella communis</i>	.6 (1)	3.1 (3)	1.9 (2)	3.8 (3)	3.1 (3)	2.5 (4)	3.6 (2)
<i>Natica alderi</i>	6.3 (4)	6.3 (7)	8.8 (6)	5.6 (5)	6.9 (8)	5.0 (4)	12.1 (7)
<i>Diaphana minuta</i>	--	--	--	--	.6 (1)	.6 (1)	--
<i>Retusa obtusata</i>	--	--	.6 (1)	--	--	--	--
<i>Cylichna cylindracea</i>	.6 (1)	1.2 (1)	2.5 (4)	6.9 (7)	8.1 (6)	13.7 (7)	19.3 (7)
<i>Philine catena</i>	.6 (1)	--	--	1.9 (3)	--	--	.7 (1)
<i>Philine scabra</i>	--	--	--	--	--	--	--

CRUSTACEA

<i>Processa parva</i>	.6 (1)	--	--	--	--	.6 (1)	--
<i>Pontophilus trispinosus</i>	--	.6 (1)	--	--	--	--	--
<i>Macropipus spec. juv.</i>	--	--	.6 (1)	--	--	--	--
<i>Ebalia cranchii</i>	2.5 (4)	1.2 (2)	2.5 (3)	5.6 (5)	1.2 (2)	1.9 (3)	1.4 (2)
<i>Corystes cassivelaunus</i>	--	--	--	--	1.2 (2)	--	--
<i>Porcellana spec. juv.</i>	--	--	--	--	--	--	--
<i>Upogebia stellata</i>	--	--	--	--	--	--	--
<i>Upogebia deltaura</i>	--	--	--	--	--	--	--
<i>Upogebia spec. juv.</i>	--	--	--	--	--	.6 (1)	--
<i>Callianassa subterranea</i>	--	--	--	1.9 (3)	3.8 (2)	3.8 (2)	21.4 (7)
<i>Callianassa spec. juv.</i>	--	--	--	--	2.5 (3)	10.0 (5)	2.9 (2)
<i>Decapoda larven</i>	1.2 (2)	--	--	.6 (1)	--	--	--
<i>Nebalia bipes</i>	.6 (1)	--	.6 (1)	--	4.4 (1)	--	--
<i>Eudorella truncatula</i>	1.2 (2)	1.2 (1)	1.9 (3)	.6 (1)	1.9 (3)	1.2 (1)	2.1 (3)
<i>Diastylis bradyi</i>	1.2 (2)	1.9 (2)	.6 (1)	.6 (1)	.6 (1)	.6 (1)	1.4 (2)
<i>Cirolana borealis</i>	--	--	--	--	--	.6 (1)	.7 (1)
<i>Ione thoracica</i>	--	--	--	--	--	.6 (1)	1.4 (1)
<i>Hippomedon denticulatus</i>	.6 (1)	--	--	--	--	--	.7 (1)
<i>Leucothoe spinicarpa</i>	--	--	--	--	--	.6 (1)	--
<i>Leucothoe richardii</i>	--	--	--	--	--	--	--

Table 29 continued.

Distance to platform (m)	5000 RC	250 PT	5000 PT	250 PT	5000 PT	250 PT	5000 PT
<i>Heteromastus filiformis</i>	8.6 (4)	--	2.1 (3)	--	5.7 (6)	2.5 (4)	3.6 (4)
<i>Owenia fusiformis</i>	2.1 (3)	1.9 (2)	2.1 (2)	2.5 (4)	2.9 (4)	--	1.4 (2)
<i>Myriochele heeri</i>	.7 (1)	1.2 (2)	1.4 (2)	.6 (1)	.7 (1)	--	--
<i>Lanice conchilega</i>	--	--	--	--	--	--	--
<i>Lagis koreni</i>	2.1 (3)	--	.7 (1)	--	2.9 (2)	.6 (1)	.7 (1)
<i>Pectinaria auricoma</i>	.7 (1)	--	.7 (1)	--	.7 (1)	--	--
<i>Lysilla loveni</i>	2.9 (4)	--	2.1 (2)	--	2.9 (2)	--	.7 (1)
<i>Terebellides stroemi</i>	.7 (1)	--	--	--	1.4 (1)	--	1.4 (2)
<i>Amphicteis gunneri</i>	.7 (1)	--	--	--	--	--	--
<i>Sosane gracilis</i>	3.6 (4)	--	.7 (1)	--	1.4 (2)	--	--

MOLLUSCA

<i>Nucula turgida</i>	19.3 (6)	1.9 (2)	19.3 (7)	2.5 (3)	9.3 (6)	.6 (1)	6.4 (5)
<i>Modiolus modiolus</i>	--	--	--	.6 (1)	--	--	--
<i>Thyasira flexuosa</i>	--	--	--	--	--	--	--
<i>Lepton squamosum</i>	--	--	--	--	--	--	--
<i>Devonia perrieri</i>	--	--	--	--	--	--	.7 (1)
<i>Montacuta ferruginosa</i>	6.4 (5)	--	5.7 (3)	--	5.7 (4)	--	2.1 (2)
<i>Mysella bidentata</i>	.7 (1)	.6 (1)	6.4 (6)	--	7.9 (5)	--	2.9 (2)
<i>Arctica islandica</i>	2.1 (3)	.6 (1)	5.7 (4)	1.9 (2)	--	.6 (1)	--
<i>Acanthocardia echinata</i>	--	--	.7 (1)	--	--	--	--
<i>Dosinia lupinus</i>	.7 (1)	2.5 (2)	1.4 (2)	3.8 (4)	.7 (1)	--	.7 (1)
<i>Venus striatula</i>	2.1 (3)	3.8 (5)	13.6 (6)	3.1 (3)	2.1 (2)	3.1 (4)	2.9 (2)
<i>Tellina fabula</i>	--	--	.7 (1)	--	--	--	--
<i>Mysia undata</i>	--	--	.7 (1)	--	2.1 (3)	.6 (1)	--
<i>Abra alba</i>	30.7 (7)	18.1 (7)	42.9 (7)	2.5 (4)	11.4 (7)	6.9 (7)	17.1 (6)
<i>Cultellus pellucidus</i>	1.4 (2)	3.8 (5)	5.7 (5)	.6 (1)	6.4 (5)	1.9 (3)	.7 (1)
<i>Mya spec. juv.</i>	--	--	--	--	--	--	--
<i>Hiatella arctica</i>	--	--	--	--	--	--	--
<i>Corbula gibba</i>	10.7 (6)	18.8 (8)	4.3 (6)	14.4 (6)	5.7 (4)	4.4 (3)	7.9 (5)
<i>Thracia convexa</i>	--	--	--	--	.7 (1)	--	.7 (1)
<i>Cingula nitida</i>	18.6 (6)	7.5 (5)	2.9 (4)	--	5.0 (3)	--	2.9 (3)
<i>Turritella communis</i>	.7 (1)	--	2.9 (3)	.6 (1)	4.3 (4)	.6 (1)	1.4 (2)
<i>Natica alderi</i>	4.3 (4)	5.0 (5)	5.7 (6)	3.8 (4)	2.9 (3)	3.8 (4)	2.1 (2)
<i>Diaphana minuta</i>	--	--	--	--	--	--	--
<i>Retusa obtusata</i>	--	--	--	.6 (1)	--	.6 (1)	--
<i>Cylindrina cylindracea</i>	27.9 (7)	6.3 (3)	7.1 (4)	3.8 (3)	5.0 (4)	1.9 (1)	8.6 (5)
<i>Philine catena</i>	--	--	--	--	.7 (1)	--	--
<i>Philine scabra</i>	.7 (1)	--	--	--	--	--	--

CRUSTACEA

<i>Processa parva</i>	--	--	--	.6 (1)	--	1.2 (1)	.7 (1)
<i>Pontophilus trispinosus</i>	--	--	--	--	--	.6 (1)	.7 (1)
<i>Macropipus spec. juv.</i>	--	--	--	--	--	--	--
<i>Ebalia cranchii</i>	7.9 (4)	3.1 (4)	1.4 (1)	.6 (1)	2.1 (3)	.6 (1)	1.4 (2)
<i>Corystes cassivelaunus</i>	--	--	--	--	--	--	--
<i>Porcellana spec. juv.</i>	.7 (1)	--	--	--	--	--	.7 (1)
<i>Upogebia stellata</i>	--	--	--	--	.7 (1)	--	--
<i>Upogebia deltaura</i>	2.1 (3)	.6 (1)	.7 (1)	--	.7 (1)	--	--
<i>Upogebia spec. juv.</i>	--	--	--	--	--	--	--
<i>Callianassa subterranea</i>	26.4 (6)	3.8 (4)	6.4 (5)	2.5 (2)	26.4 (6)	1.9 (2)	15.0 (5)
<i>Callianassa spec. juv.</i>	2.1 (1)	--	--	--	7.1 (3)	--	2.1 (1)
<i>Decapoda larven</i>	--	7.5 (6)	--	--	--	.6 (1)	--
<i>Nebalia bipes</i>	4.3 (1)	.6 (1)	--	--	--	--	--
<i>Eudorella truncatula</i>	--	2.5 (2)	.7 (1)	--	.7 (1)	.6 (1)	--
<i>Diastylis bradyi</i>	2.1 (3)	1.2 (1)	2.1 (3)	.6 (1)	2.9 (4)	--	.7 (1)
<i>Cirolana borealis</i>	--	--	--	1.2 (2)	--	--	--
<i>Ione thoracica</i>	--	.6 (1)	--	--	--	--	--
<i>Hippomedon denticulatus</i>	--	--	--	--	--	--	--
<i>Leucothoe spinicarpa</i>	--	--	--	--	--	--	--
<i>Leucothoe richardii</i>	.7 (1)	--	--	--	--	--	--

Table 29 continued.
Distance to platform (m)

	0	100	250	500	750	1000	2000
<i>Ampelisca brevicornis</i>	--	--	.6 (1)	.6 (1)	1.2 (2)	1.2 (2)	--
<i>Ampelisca tenuicornis</i>	1.2 (2)	.6 (1)	.6 (1)	--	.6 (1)	--	.7 (1)
<i>Ampelisca spec. juv.</i>	--	--	--	--	--	.6 (1)	1.4 (2)
<i>Cheirocratus sundevalli</i>	--	--	--	--	--	--	--
<i>Bathyporeia tenuipes</i>	--	--	--	--	--	--	--
<i>Harpinia antennaria</i>	--	--	--	--	1.9 (3)	13.1 (8)	27.1 (7)
<i>Perioculodes longimanus</i>	1.9 (3)	3.1 (4)	2.5 (3)	2.5 (3)	2.5 (4)	3.1 (4)	--
<i>Aora typica</i>	--	--	--	--	--	.6 (1)	--
<i>Lembos longipes</i>	--	--	--	--	.6 (1)	--	--
<i>Caprella spec.</i>	--	--	--	--	--	--	1.4 (2)

ECHINODERMATA

<i>Astropecten irregularis</i>	--	--	--	--	1.2 (1)	.6 (1)	--
<i>Asterias rubens</i>	--	--	--	--	--	--	--
<i>Amphiura filiformis</i>	6.9 (4)	19.4 (8)	10.6 (7)	32.5 (8)	61.2 (8)	153.7 (8)	307.9 (7)
<i>Ophiura texturata</i>	.6 (1)	1.9 (2)	1.2 (2)	.6 (1)	1.2 (1)	1.2 (1)	2.9 (3)
<i>Ophiura albida</i>	--	1.9 (3)	.6 (1)	3.1 (5)	6.3 (5)	1.9 (1)	2.9 (3)
<i>Ophiura spec. juv.</i>	.6 (1)	--	1.2 (2)	2.5 (3)	5.0 (3)	10.6 (6)	7.9 (6)
<i>Asteroidea spec. juv.</i>	--	--	--	--	--	--	--
<i>Echinocardium cordatum</i>	59.4	27.5	15.0 (6)	2.5 (4)	36.9 (7)	30.0 (8)	29.3 (7)
<i>Brissopsis lyrifera</i>	--	--	--	--	--	--	--

OTHER TAXA

Nemertinea	--	--	P (8)	P (7)	P (6)	P (8)	P (7)
Hydrozoa	P (8)	P (8)	P (4)	P (4)	P (3)	P (3)	P (4)
Turbellaria	.6	.6	1.9 (2)	.6 (1)	--	.6 (1)	.7 (1)
Phoroniden	P (1)	P (1)	P (2)	P (1)	P (5)	P (5)	P (5)
Harp. copepoda	4.4	1.2	1.2 (2)	1.2 (2)	1.2 (2)	.6 (1)	1.4 (1)
Parasitaire copepoda	.6 (5)	-- (2)	1.9 (2)	8.8 (5)	15.6 (5)	18.1 (6)	22.1 (5)
Oligochaeta	P (1)	--	P (1)	--	P (2)	P (3)	P (3)
Holothuroidea	--	--	--	--	1.9 (3)	3.1 (4)	3.6 (3)
Sagitta spec.	.6	.6	--	--	--	1.2 (2)	--
Echiurida	3.1 (1)	1.2 (1)	3.1 (2)	.6 (1)	.6 (1)	--	--
Sipunculida	12.5 (4)	10.6 (2)	38.1 (6)	27.5 (7)	25.0 (7)	53.8 (8)	66.4 (7)
Actinaria	--	--	--	--	.6 (1)	--	--
Ascidia	--	.6	.6 (1)	--	3.8 (3)	.6 (1)	.7 (1)
Foraminiferida	--	--	--	--	1.9 (3)	--	--

Tot. nr. of ind. (n.m⁻²) 317.2 305.3 314.5 457.2 660.8 1004.5 1277.2
 Nr. of identified species 54 44 54 49 61 67 72

P=present, not counted

Table 29 continued.

Distance to platform (m)	5000 RC	250 PT	5000 PT	250 PT	5000 PT	250 PT	5000 PT
<i>Ampelisca brevicornis</i>	--	--	.7 (1)	--	--	.6 (1)	--
<i>Ampelisca tenuicornis</i>	1.4 (2)	--	--	--	1.4 (2)	--	2.1 (3)
<i>Ampelisca spec. juv.</i>	1.4 (2)	--	2.1 (2)	--	2.1 (2)	--	.7 (1)
<i>Cheirocratus sundeavalli</i>	--	--	.7 (1)	--	2.1 (2)	--	--
<i>Bathyporeia tenuipes</i>	--	--	--	--	--	.6 (1)	--
<i>Harpinia antennaria</i>	27.9 (7)	--	22.9 (6)	--	21.4 (6)	--	32.1 (7)
<i>Perioculodes longimanus</i>	5.0 (3)	3.1 (3)	6.4 (4)	3.1 (4)	--	--	3.6 (3)
<i>Aora typica</i>	--	--	--	--	1.4 (2)	--	--
<i>Lembos longipes</i>	.7 (1)	--	--	--	--	--	.7 (1)
<i>Caprella spec.</i>	--	--	--	--	--	--	--

ECHINODERMATA

<i>Astropecten irregularis</i>	--	--	--	--	--	.6 (1)	--
<i>Asterias rubens</i>	--	--	.7 (1)	--	--	--	--
<i>Amphiura filiformis</i>	183.6 (7)	66.9 (8)	95.0 (7)	36.2 (8)	158.6 (7)	16.2 (6)	56.4 (7)
<i>Ophiura texturata</i>	1.4 (2)	3.8 (5)	2.9 (3)	.6 (1)	5.0 (3)	--	2.1 (1)
<i>Ophiura albida</i>	.7 (1)	1.2 (2)	.7 (1)	1.2 (2)	2.1 (2)	2.5 (3)	2.1 (2)
<i>Ophiura spec. juv.</i>	2.1 (3)	1.9 (2)	7.9 (5)	2.5 (4)	1.4 (2)	3.8 (4)	.7 (1)
<i>Asteroidea spec. juv.</i>	--	--	--	--	--	--	--
<i>Echinocardium cordatum</i>	17.9 (7)	16.9 (6)	10.7 (5)	1.9 (3)	30.7 (7)	5.0 (3)	15.0 (7)
<i>Brissopsis lyrifera</i>	1.4 (2)	--	--	--	--	--	--

OTHER TAXA

<i>Nemertinea</i>	P (7)	P (8)	P (7)	P (8)	P (6)	P (5)	P (6)
<i>Hydrozoa</i>	P (2)	P (4)	P (1)	P (4)	P (2)	P (3)	P (3)
<i>Turbellaria</i>	.7 (1)	2.5 (4)	--	--	1.4 (2)	--	.7 (1)
<i>Phoroniden</i>	P (4)	P (5)	P (3)	P (2)	P (5)	P (7)	P (6)
<i>Harp. copepoda</i>	.7 (1)	.6 (1)	--	.6 (1)	--	1.2 (2)	--
<i>Parasitaire copepoda</i>	10.7 (6)	.6 (1)	.7 (1)	2.5 (1)	19.3 (7)	3.8 (2)	24.3 (7)
<i>Oligochaeta</i>	P (2)	P (2)	--	P (2)	--	--	P (1)
<i>Holothuroidea</i>	2.9 (3)	1.9 (2)	2.9 (3)	.6 (1)	1.4 (2)	1.2 (2)	2.1 (1)
<i>Sagitta spec.</i>	.7 (1)	.6 (1)	--	--	.7 (1)	--	--
<i>Echiurida</i>	1.4 (2)	4.4 (3)	1.4 (2)	1.9 (1)	4.3 (1)	.6 (1)	--
<i>Sipunculida</i>	61.4 (7)	16.2 (7)	42.1 (7)	16.2 (7)	98.6 (7)	18.1 (5)	35.0 (6)
<i>Actinaria</i>	--	--	--	--	.7 (1)	--	--
<i>Ascidia</i>	2.1 (2)	2.5 (4)	2.9 (4)	1.2 (2)	5.0 (4)	1.9 (3)	2.9 (3)
<i>Foraminiferida</i>	.7 (1)	.6 (1)	--	1.2 (2)	.7 (1)	--	--

Tot. nr. of ind. (n.m⁻²) 1015.0 433.9 603.9 343.4 987.1 340.4 764.1
 Nr. of identified species 68 48 67 53 65 52 63

P=present, not counted

Table 30. Boxcosms K12a, natural infauna.
Numbers of individuals per box (0.25 m^{-2}) at the start of the incubation period (Sept.1987) and at the end (Febr. 1988).

	5000 m			100 m		
	start	end		start	end	
	A	B		A	B	
POLYCHAETA						
Harmothoe lunulata	1	2	1	--	--	--
Gattyana cirrosa	1	--	--	--	--	--
Pholoe minuta	1	--	--	--	--	--
Eteone longa	--	--	--	--	--	1
Gyptis capensis	--	3	--	--	--	--
Nereis longissima	1	3	3	1	--	4
Nephtys hombergii	9	2	4	3	1	--
Glycera rouxii	--	--	--	1	1	--
Glycera spec. juv.	--	--	--	--	--	1
Goniada maculata	--	1	1	2	--	--
Lumbrineris latreilli	5	5	10	6	2	--
Poecilochaetus serpens	--	1	--	--	--	--
Spiophanes bombyx	43	13	6	--	--	--
Scolecopsis bonnierii	--	--	--	1	--	--
Magelona papillicornis	1	--	--	--	--	--
Chaetozona setosa	1	--	--	--	--	--
Capitella capitata	--	--	--	--	--	38
Owenia fusiformis	22	18	9	--	--	--
Lanice conchilega	4	5	4	--	--	--
Lagis koreni	--	--	1	--	--	--
MOLLUSCA						
Nucula turgida	30	54	32	185	245	--
Montacuta ferruginosa	13	10	1	--	--	--
Myrella bidentata	--	2	--	--	--	--
Acanthocardia echinata	--	--	--	1	--	--
Dosinia lupinus	--	--	--	--	1	--
Venus striatula	1	--	--	1	5	--
Tellina fabula	1	1	1	--	--	--
Abra alba	14	1	1	1	--	--
Cultellus pellucidus	--	--	--	1	--	--
Natica alderi	12	4	6	6	7	2
Buccinum undatum	--	--	--	--	--	1
CRUSTACEA						
Crangon crangon	--	--	3	--	--	--
Processa parva	--	2	8	--	--	--
Pagurus bernhardus	--	--	--	--	--	1
Macropipus holsatus	7	3	4	--	--	--
Ebalia cranchii	--	--	1	2	1	--
Corystes cassivelaunus	--	--	1	3	2	--
Callinassa subterranea	2	7	4	--	--	--
Ampelisca brevicornis	--	--	1	--	--	--
Harpinia antennaria	--	1	1	--	--	--
ECHINODERMATA						
Amphiura filiformis	1	1	--	--	--	--
Echinocardium cordatum	343	95	63	--	--	--
OTHER TAXA						
Nemertinea	--	P	P	P	P	P
Phoronidea	P	P	P	--	--	--
Sipunculida	1	--	--	--	--	--
Tot. number of ind.	514	234	166	214	265	48
Nr. of identified species	21	22	23	14	9	7
P = present, not counted						

Table 31. Boxcosms F18/9, natural infauna.
 Mean numbers of individuals per 0.25 m² (=surface of one boxcosm) at
 the start of the incubation period (Sept. 1988) and at the end (Febr. 1989).

	5000 m		100 m		50 m	
	start	end	start	end	start	end
POLYCHAETA						
Aphrodita aculeata	--	--	0.4	0.2	--	--
Harmothoe lunulata	--	--	--	--	--	0.2
Harmothoe longisetis	--	--	--	0.2	--	--
Gattyana cirrosa	24.3	10.5	11.6	10.4	14.1	0.7
Polynoe kinbergi	0.4	0.3	--	--	--	--
Pholoe minuta	1.1	0.7	--	0.8	0.7	--
Sthenelais limicola	0.7	--	0.4	--	--	--
Anaitides groenlandica	--	--	0.4	--	--	--
Anaitides maculata	--	--	0.4	--	--	--
Ophiodromus flexuosus	2.5	0.3	0.7	--	0.4	--
Gyptis capensis	--	--	1.4	0.4	0.4	--
Synelmis klatti	2.5	1.8	2.1	2.0	1.4	1.0
Autolytus spec.	--	--	--	--	0.4	--
Nereis longissima	0.4	0.5	1.4	0.6	0.4	0.2
Nereis spec. juv.	--	--	0.4	--	--	--
Nephtys hombergii	4.2	1.2	1.8	1.4	2.8	0.7
Nephtys incisa	0.4	1.8	1.8	3.0	0.7	1.3
Nephtys caeca	--	0.3	--	0.2	--	--
Nephtys spec. juv.	1.1	0.5	--	--	0.7	--
Glycera rouxii	2.1	1.7	6.0	1.8	1.8	0.2
Glycera alba	1.1	2.5	0.4	1.4	0.7	0.3
Glycera spec. juv.	4.2	3.5	2.5	2.4	4.2	--
Glycinde nordmanni	2.5	2.3	--	0.4	--	--
Goniada maculata	3.5	0.7	1.8	0.4	0.7	0.2
Lumbrineris latreilli	31.7	15.5	28.5	12.2	11.6	3.5
Lumbrineris fragilis	0.7	1.3	0.7	1.4	1.4	--
Driloneris filum	--	--	--	0.2	--	--
Scoloplos armiger	--	--	--	--	--	--
Orbinia sertulata	--	0.2	--	--	--	--
Paraonis gracilis	0.4	0.7	--	0.4	0.4	--
Spio filicornis	0.4	--	--	--	--	--
Polydora guillei	3.9	1.5	0.4	--	--	--
Spiophanes kroyeri	0.4	--	0.4	--	--	--
Spiophanes bombyx	2.5	0.5	2.1	0.4	0.4	--
Scolecopsis foliosa	0.4	0.3	0.4	0.2	0.7	--
Magelona papillicornis	--	--	--	--	--	--
Magelona allenii	--	--	0.4	--	0.4	--
Chaetopterus variopedatus	21.5	20.7	12.0	10.8	12.0	1.0
Tharyx marioni	--	--	--	0.2	0.4	--
Chaetozone setosa	3.9	0.3	1.8	0.6	--	0.2
Diplocirrus glaucus	2.8	0.5	--	1.0	1.8	--
Scalibregma inflatum	2.5	--	3.2	--	0.4	--
Ophelina acuminata	1.1	0.2	--	--	--	--
Capitella capitata	0.7	--	--	0.2	--	10.8
Notomastus latericeus	13.4	6.2	4.9	0.4	2.1	0.4
Heteromastus filiformis	0.7	0.7	--	--	--	--
Owenia fusiformis	1.4	1.0	1.1	0.4	0.7	0.2
Myriochele heeri	--	0.2	--	--	--	--
Lanice conchilega	0.7	--	--	--	0.4	--
Lagis koreni	2.5	0.2	--	--	1.4	--
Pectinaria auricoma	10.7	5.2	1.8	1.0	--	--
Pectinaria belgica	--	0.2	--	--	--	--
Amphicteis gunneri	--	--	--	0.2	--	--
Sosane gracilis	0.7	0.2	1.4	--	--	--
Lysilla loveni	0.4	0.2	--	--	--	--
Terebellides stroemi	--	0.3	--	0.6	--	--

Table 31 continued.

	5000 m		100 m		50 m	
	start	end	start	end	start	end
MOLLUSCA						
<i>Nucula turgida</i>	2.1	1.8	1.8	0.4	--	--
<i>Lepton squamosum</i>	1.1	--	--	--	--	--
<i>Montacuta ferruginosa</i>	0.7	2.2	--	0.6	--	--
<i>Myrella bidentata</i>	0.4	0.5	0.4	--	--	--
<i>Arctica islandica</i>	0.4	0.3	0.4	--	1.1	--
<i>Acanthocardia echinata</i>	2.5	--	1.8	--	0.7	--
<i>Dosinia lupinus</i>	0.7	--	--	--	1.8	0.2
<i>Venus striatula</i>	--	--	0.4	0.6	1.1	--
<i>Mysia undata</i>	--	--	0.4	--	0.4	--
<i>Mactra corallina</i>	0.4	--	--	--	--	--
<i>Spisula spec. juv.</i>	--	--	--	--	0.4	--
<i>Abra alba</i>	11.3	0.3	6.3	0.2	--	0.2
<i>Cultellus pellucidus</i>	2.8	0.2	2.8	--	0.7	--
<i>Mya truncata</i>	--	--	--	0.2	--	--
<i>Corbula gibba</i>	1.8	2.5	1.1	1.4	0.7	0.2
<i>Thracia convexa</i>	2.5	0.5	0.4	--	0.4	--
<i>Cingula nitida</i>	2.1	2.2	2.8	0.2	--	--
<i>Turritella communis</i>	2.5	0.2	--	0.4	--	0.2
<i>Natica alderi</i>	1.8	0.5	0.7	0.4	--	0.5
<i>Cylichna cylindracea</i>	2.1	0.7	--	--	--	--
<i>Philine scabra</i>	2.5	3.0	15.8	0.8	24.6	0.5
CRUSTACEA						
<i>Processa parva</i>	1.4	0.3	1.1	0.4	--	0.3
<i>Pontophilus trispinosus</i>	--	--	0.4	--	--	0.2
<i>Porcellana longicornis</i>	0.4	--	--	--	--	--
<i>Macropipus holsatus</i>	0.4	--	0.4	--	--	--
<i>Macropipus spec. juv.</i>	1.1	--	1.8	--	1.8	--
<i>Ebalia cranchii</i>	--	0.2	1.4	0.2	0.7	0.2
<i>Corystes cassivelaunus</i>	--	0.2	--	--	0.4	--
<i>Upogebia stellata</i>	--	--	--	0.4	--	--
<i>Upogebia deltaura</i>	--	1.2	--	0.4	--	--
<i>Upogebia spec. juv.</i>	1.1	0.2	2.5	--	0.4	--
<i>Callianassa subterranea</i>	14.4	14.5	6.7	6.2	0.4	0.5
<i>Callianassa spec. juv.</i>	0.7	0.5	1.8	0.2	--	--
<i>Nebalia bipes</i>	--	--	--	--	--	0.3
<i>Gastrosaccus spinifer</i>	0.4	--	--	--	--	--
<i>Schistomysis ornata</i>	--	0.2	--	--	--	--
<i>Eudorella truncatula</i>	--	--	--	0.2	--	--
<i>Diastylis bradyi</i>	0.4	--	1.1	--	0.7	--
<i>Cirolana borealis</i>	--	--	0.4	--	--	--
<i>Ione thoracica</i>	0.7	0.2	0.7	--	--	--
<i>Orchomenella nana</i>	--	--	--	--	0.4	--
<i>Ampelisca brevicornis</i>	1.1	--	2.1	--	0.4	--
<i>Ampelisca tenuicornis</i>	0.4	--	0.4	--	0.7	--
<i>Ampelisca spec. juv.</i>	--	--	1.4	--	--	--
<i>Urothoe poseidonis</i>	--	--	--	--	--	--
<i>Harpinia antennaria</i>	2.5	0.2	--	--	--	--
<i>Aora typica</i>	0.4	--	--	--	--	--
<i>Lembos longipes</i>	0.4	--	--	--	--	--
ECHINODERMATA						
<i>Astropecten irregularis</i>	--	--	1.4	0.2	3.2	0.2
<i>Amphiura filiformis</i>	69.0	7.0	17.3	2.8	15.1	0.3
<i>Ophiura texturata</i>	--	--	0.4	--	0.4	--
<i>Ophiura albida</i>	1.1	--	--	--	--	--
<i>Ophiura spec. juv.</i>	0.4	0.8	7.4	7.2	6.0	1.0
<i>Echinocardium cordatum</i>	29.9	21.2	32.7	0.4	14.8	--
<i>Brissopsis lyrifera</i>	--	0.3	--	--	--	--

