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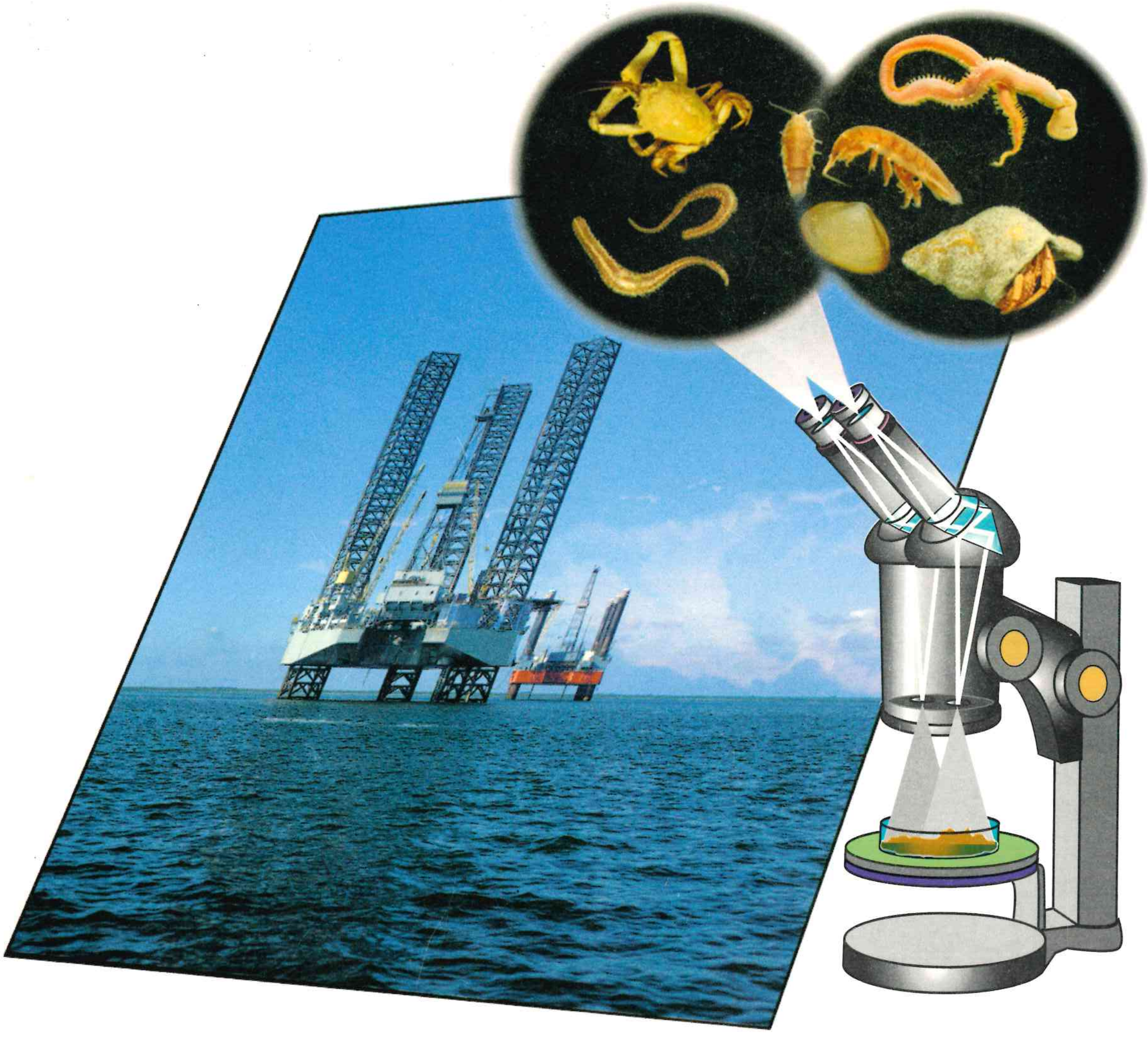

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NETHERLANDS INSTITUTE FOR SEA RESEARCH

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SUMMARY AND CONCLUSIONS

In 1991 and 1992, a 2-phase field monitoring programme has been carried out, aimed to assess possible environmental effects of discharges of drill cuttings drilled with water based muds (WBM). The study was performed at a single well site in the Dutch sector of the North Sea. The location (L3-3) is situated in the Frisian Front area. This area is characterized by a rich macrofauna community. The drilling of this exploration well with WBM (a spud mud and a salt saturated polymer mud) took place at L3-3 in July/August 1991 and all cuttings were dumped on the sea-bed. The first phase of monitoring started 2 months later with a benthic sampling programme around the location. The results of that survey (presented in a preceding report) indicated that, at the short term, there were no adverse effects of the dumpings on the benthic community. Even at a station as close as 25 m from the former discharge site, where suffocation of the macrofauna due to burial by cuttings was anticipated, no significant effect was detected and only small amounts of cuttings were observed at that station. It was postulated, however, that the period elapsed between termination of the discharges and the survey might have been too short to detect subtle biological effects and that a possible response of benthic fauna species on sediment disturbance could occur with some time-lag. Therefore a follow-up survey was organized, to verify the absence of effects at the longer term. This survey was carried out one year later and the results are given in this report.

The major conclusion of the present study is that, also at the longer term, adverse effects on the benthic community around the location were not observed. The occurrence of some possible sublethal effects can not be excluded, but apparently there were no detectable consequences for the macrofauna composition. Just like during the first survey, the fauna composition was homogeneous in the area and even in the immediate vicinity of the former discharge site (at 25 m) the fauna composition did not show any indication of environmental disturbance. At first sight, this finding seemed surprising since most WBM studies known from literature seem to have revealed at least more or less localized effects, generally within 100 m from well sites. It is argued, however, that in most cases such effects could not be attributed with certainty to the WBM discharged. Particularly at multiwell sites the effect of burial may play an important role, whereas the presence of oil components in the sediment has obscured the cause of observed effects at several locations of study.

The results and conclusions of the WBM study in the Frisian Front area may be summarized as follows:

1. During the 1991 survey at L3-3, 2 months after dumping of WBM cuttings, adverse effects on the benthic community were not observed.

2. The 1992 survey at L3-3, 1 year after dumping of WBM cuttings, also revealed no adverse effects on the benthic community, not even at a distance as close as 25 m from the former discharge site.

3. The results suggest that dumping of cuttings drilled with WBM with a chemical composition like used at L3-3 has no detectable effect on the benthic community.

4. The results of this study reinforce conclusions from earlier field studies dealing with OBM related cutting discharges, that the presence of oil in discharged drilling wastes should be considered as a major source of toxic components and environmental disturbance and as responsible for the associated biological effects observed at OBM locations.

SAMENVATTING EN CONCLUSIES

In 1991 en 1992 is in twee fasen veldonderzoek uitgevoerd, teneinde eventuele biologische effekten vast te stellen van lozing van WBM-boorgruis (WBM = water based muds = boorspoeling op waterbasis). De studie werd verricht bij een boorlokatie (L3-3) op het Friese-Front, een faunistisch rijk gebied in de Nederlandse sector van de Noordzee. In augustus 1991 vond hier een exploratieboring plaats, die geheel werd uitgevoerd met WBM. Als spoelingen werden gebruikt een 'spud mud' en een 'salt saturated polymer mud'. Al het boorgruis met aanhangende boorspoeling werd ter plaatse op de zeebodem geloosd. De eerste fase van het onderzoek ging 2 maanden na de boring in met een benthische survey rond de lokatie. De resultaten van die survey (welke al eerder zijn gerapporteerd) duidden er op dat zich op de korte termijn geen negatieve effekten van de lozingen voordeden op de benthische levensgemeenschap. Zelfs op een station op maar 25 m van het voormalige lozingspunt, waar bij voorbaat rekening was gehouden met eventuele verstikking van de macrofauna als gevolg van bedelving onder boorgruis, werd geen signifikant effekt vastgesteld en boorgruis werd hier ook maar in geringe hoeveelheden waargenomen. Gesteld werd echter dat de survey wellicht te kort na beëindiging van de lozing had plaats gevonden om subtiele biologische effekten te kunnen aantonen en dat bepaalde soorten wellicht pas na langere tijd een signifikante respons zouden kunnen vertonen. Daarom is een vervolg-survey uitgevoerd, teneinde het uitblijven van effekten op de langere termijn te verifiëren. Deze survey vond een jaar later plaats en de resultaten ervan worden in dit rapport gepresenteerd.

De belangrijkste conclusie van de voorliggende studie is dat ook op de langere termijn geen effekten op de benthische levensgemeenschap bij de lokatie werden waargenomen. Het optreden van eventuele sublethale effekten kan niet worden uitgesloten, maar kennelijk waren die niet van dien aard, dat dit waarneembare gevolgen had voor de samenstelling van de macrofauna. Net als tijdens de eerste survey was de samenstelling van de fauna homogeen in het gebied en zelfs in de direkte omgeving van het voormalige lozingspunt (op 25 m afstand) was er geen enkel teken dat wees op verstoring van het benthisch milieu. Op het eerste gezicht leek dit een verrassende uitkomst, omdat uit de literatuur bekende WBM-studies bijna altijd tenminste min of meer plaatselijke effekten lijken te hebben aangetoond, in het algemeen binnen een straal van 100 m van lokaties. In de discussie wordt echter betoogd dat dergelijke effekten in de meeste gevallen niet met zekerheid aan de WBM-lozing konden worden toegeschreven. Met name op lokaties waar meerdere boringen zijn verricht kan een bedelvingseffekt een belangrijke rol spelen, terwijl in veel gevallen de waargenomen effekten ook toegeschreven zouden kunnen worden aan verhoogde olieconcentraties in het sediment.

De resultaten en conclusies van de WBM-studie op het Friese Front kunnen als volgt worden samengevat:

1. Op basis van de survey die bij L3-3 in 1991 werd uitgevoerd, 2 maanden na de lozing van WBM-houdend boorgruis, konden geen effekten op de benthische levensgemeenschap worden aangetoond.

2. Ook uit de survey die in 1992 bij L3-3 plaats vond, één jaar na lozing van WBM-houdend boorgruis, blijken geen effekten op de benthische levensgemeenschap, zelfs niet op een afstand van maar 25 m van het voormalige lozingspunt.

3. De resultaten wijzen er op dat lozing van boorgruis met een samenstelling als die welke op L3-3 is gebruikt geen meetbaar effekt heeft op de samenstelling van de bodemfauna.

4. De resultaten van deze studie geven steun aan de overtuiging, die voortkomt uit vroegere veldstudies bij lokaties waar olie-(OBM-)houdend boorgruis was geloosd, namelijk dat de aanwezigheid van olie in geloosd boorgruis gezien moet worden als de belangrijkste bron van toxische componenten en milieuverstoring, en als verantwoordelijk voor de biologische effekten zoals die op OBM-lokaties zijn waargenomen.

1 INTRODUCTION

1.1 GENERAL PART

In the beginning of the 1990's, regulations with respect to the discharges of waste material of drilling activities in the North Sea have become much more rigid. In parts of the Dutch sector, the so-called Environmental Zone (ZEVENBOOM *et al.*, 1992), dumping of drill cuttings contaminated with oil due to the use of oil based drilling muds (OBM) was forbidden from April 1992 and a complete ban on dumping of OBM cuttings in the Dutch sector was introduced in January 1993. Discharges of formation solids on the seabed are only allowed now if they are drilled with drilling fluids based on water (water based muds = WBM). Therefore, if oil companies prefer to use OBM after all, they are obliged to bring the contaminated drill cuttings to land. Because of the high costs associated with storage and transport of the material to land, the relative use of WBM has increased and OBM is only used in those situations where WBM fail to perform the drilling process, *e.g.* in deviated wells.

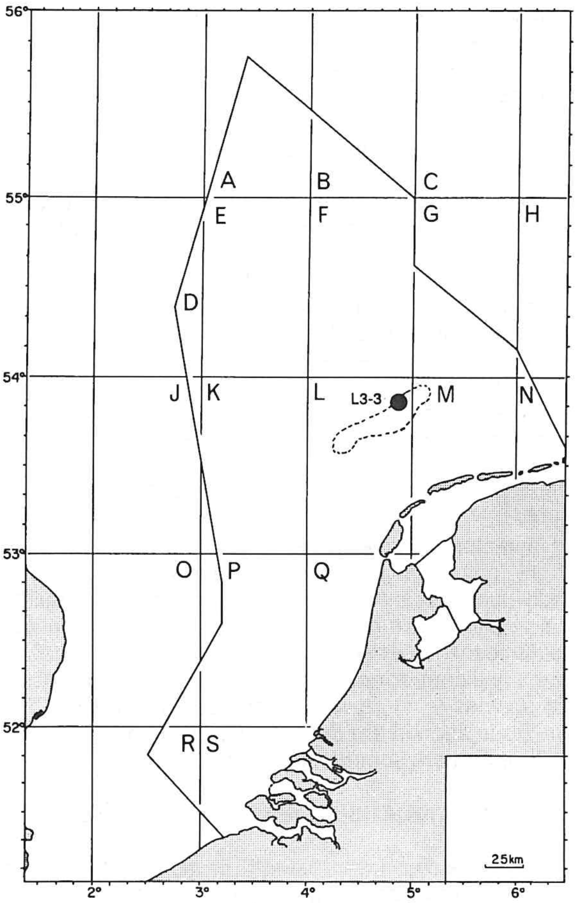

Fig. 1. Position of well site L3-3 in the Dutch sector of the North Sea. Broken line: boundary of the Frisian Front.

Discharges of drill cuttings contaminated with residuals of WBM still take place at a large scale. Nevertheless, little is known about the possible environmental effects of these discharges or, in particular, about the impact on the benthic ecosystem around well sites. WBM consist of a complex mixture of basic substances like barite and/or bentonite, salt, starch etc., to which usually a number of other components are added in small amounts. Although most of the substances applied are not known as toxic or threatening to the (marine) environment (ANONYMOUS, 1992), the discharges might constitute a significant source of disturbance for the benthic community, in particular because of the large quantities of WBM that reach the seabed in this way and which can amount to several hundreds of tonnes dry weight per drilling.

An important question in particular is whether disturbance stretches beyond the small area around the very discharge site, where several species are expected to die from suffocation, merely due to the fact that they are buried under a layer of cuttings. The present study is the second of a 2-phase field monitoring programme aimed to assess possible effects of WBM cutting discharges. The study was performed well over one year after completion of an exploratory drilling in the Frisian Front area in the Dutch sector of the North Sea.

The location of study was L3-3, at 53°51'44.6" N and 4°53'40.2" E (Fig. 1). At this location an exploration well was drilled in the summer of 1991. During drilling only WBM were used, a spud mud for the top-hole and a salt saturated polymer mud for the deeper sections. All drill cuttings were dumped through a chute which extended to a depth of 5 meters above the seabed. The composition of the material discharged is listed in Table 1. The last discharges took place in the end of August 1991. The first phase of the monitoring programme started in October 1991, about 2 months after termination of the discharges. A field survey was carried out around the location to detect possible short-term effects of the discharges on the benthic community. The main conclusion of this study (reported by DAAN & MULDER, 1993) was that 'in the area investigated, including 14 stations from 25 to 5000 m from the discharge site, adverse effects on the benthic community were not observed'. A very weak indication of disturbed sediment conditions was only obtained by the presence of a few specimens of the opportunist polychaete species *Capitella capitata* within 75 m from the discharge site, but this indication was too weak to decide that there was a measurable biological effect of the discharges. It was postulated, however, that the period elapsed between termination of the discharges and the survey might have been too short to detect subtle biological effects. The time could have been too short for sensitive species to dis-

TABLE 1
Amounts and composition of mud and cuttings discharged at L3-3.

drilled material (dry weight):	
sand	354 t
shale	447 t
chalk	13 t
anhydrite	6 t
salt	35 t
WBM	1607 m^3
idem - dry weight (tonnes)	749 t
barite (Bariumsulphate)	470 t
bentonite (clay)	88 t
starch (carboxymethyl cellulose)	18 t
caustic soda (NaOH)	4 t
Salt (NaCl)	163 t
Ferro-lignosulphonate (chrome-free)	0.525 t
Polysaccharid	1.5 t
Polyanionic cellulosic polymer	3.3 t
detergent	0.168 t
Acrylamide/Na-acrylate copolymer (PHPA)	0.145 t
Anionic surfactants (isopropyl alcohol)	0.042 t
Ammonium bisulphite solution	0.116 t
wood shavings and such	0.5 t

play a significant (lethal) response and for opportunistic species to colonize disturbed sediment in significant numbers. Therefore, it was considered necessary to carry out a follow-up survey to verify the absence of adverse effects at the longer term. This second survey was conducted in November 1992, i.e. 1 year after the first one. The results of this survey are presented in this report.

1.2 ACKNOWLEDGEMENTS

The 2-phase monitoring programme was initiated in 1991 by Mobil Producing Netherlands Inc. and Nederlandse Aardolie Maatschappij B.V. We wish to thank especially F.J. op ten Noort, A.J. van Pesch (both Mobil), J.M. Marquenie and J. Verburgh for their interest and the discussions we had about planning the second phase of the project. The present study was performed under contract with the Netherlands Oil and Gas Exploration and Production Association (NOGEPA) and we thank K. Mess for his cooperation. The fieldwork was carried out on board of the R.V. 'Pelagia' and we are grateful to captain and crew for their assistance. J. van der Hoek sorted the samples. Finally, thanks are due to M. van Arkel for his organising assistance.

2 METHODS

2.1 POSITIONING AND SAMPLING

The field survey was carried out in the last 2 weeks of November 1992 on board of the R.V. 'Pelagia'. Since well site L3-3 is an abandoned location, its position had to be traced by an accurate positioning technique. To that end the ship was equipped with DGPS. Side scan sonar apparatus was also installed, but weather conditions were too bad (windforce 7-8 BF) to make sound records and to find the leg imprints of the rig.

Sampling stations were the same as during the first survey of 1991, *i.e.* 14 stations along a cross-shaped transect centered around the discharge site, the main axis running parallel with the residual current direction (Fig. 2). The outermost stations, at 5 km from the discharge site, were assumed to represent a reference situation.

Bottom samples were collected with a 0.16 m^2 Van Veen grab, 8 samples per station. The contents of each grab were washed through a sieve (mesh size 1 mm) and numbers of sea urchins (*Echinocardium cordatum*, specimens >1 cm) were counted immediately. Then, all macrofauna retained on the sieve was preserved in a 6% neutralized formaldehyde solution. Additionally, about 20 samples were taken in the immediate vicinity of the discharge site, to see if there were still cuttings present in the sediment.

These samples were not preserved.

2.2 LABORATORY ANALYSIS

In the laboratory a selection of the macrofauna samples was stained with Bengal rose and sorted using a magnifier. Then molluscs, crustaceans, polychaetes and echinoderms were identified under a stereomicroscope and counted on species level. Remaining taxa were not further identified and only recorded at higher taxonomic levels. When specimens were broken by handling, only heads were counted. Not all samples were analysed. In Fig. 2 those stations are indicated of which 6 samples each were analysed.

2.3 STATISTICAL PROCEDURES

In samples collected over a gradient in disturbance there may be a gradual change in the abundance of individual species over the sampled transect. Statistical analyses are required to obtain objective criteria to decide whether such changes in faunal abundance are significant or not. Such analyses were performed on species level as well as on community level. The methods applied are described in detail by DAAN *et al.* (1990) and are summarized below.

2.3.1 INDIVIDUAL SPECIES (LOGIT REGRESSION)

Logit regression (see JONGMAN *et al.*, 1987) is based on a mathematical model for presence-absence data of individual species in samples collected along a transect with a gradient in pollution. The basic idea is that, if the disturbance involved affects the chance of survival of a certain species, the frequency of occur-

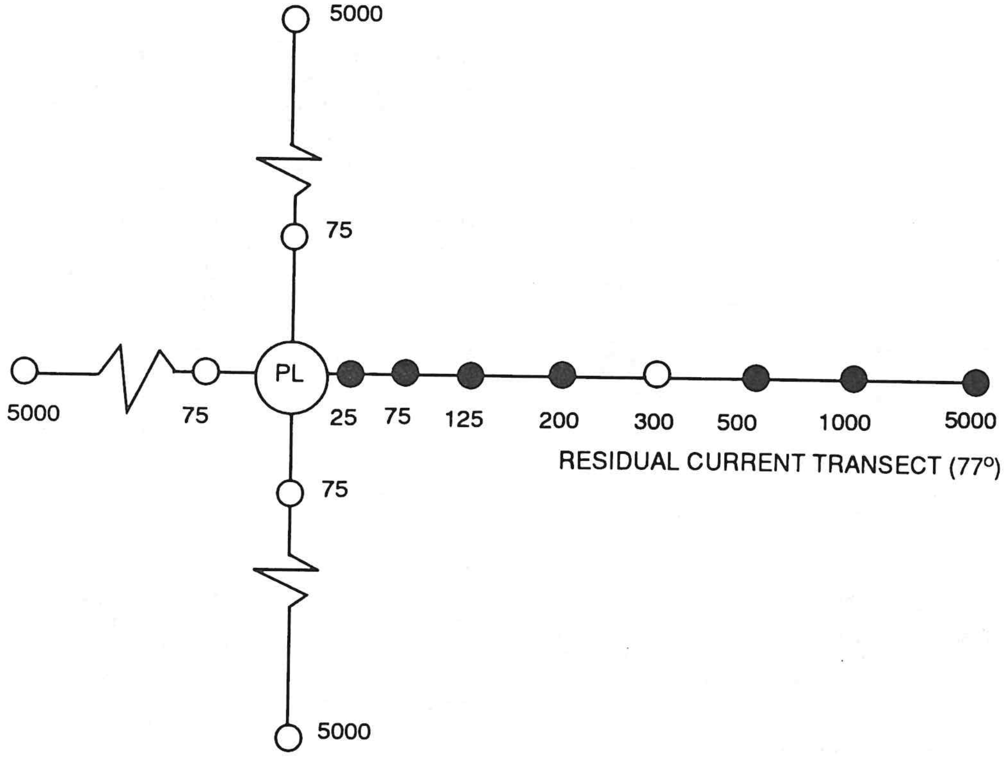

Fig. 2. Positions of the sampling stations (distance to platform in m). The solid circles represent the stations of which a complete fauna analysis was performed.

rence of this species will increase or decrease along the transect. In other words, the probability (p) that a species is present in a sample will change along the transect. Logit regression provides a test to decide either that p increases or decreases significantly with distance to the discharge site or that p just fluctuates at random. Logit regression was applied to those species of which at least 20 specimens were found.

2.3.2 MACROBENTHIC COMMUNITY (RELATIVE ABUNDANCE)

This method provides a measure of the mean relative abundance of all identified species at each station, compared to the other stations around a location. For example, if at a certain station most species occur in lower numbers than at other stations, the relative macrofauna abundance at this station will be attributed a low value. The computation of relative abundance is based on a ranking procedure. For all of the individual species the mean density is considered at each of n investigated stations. Per species a rank is attributed to each of the stations: the rank is 1 for the station with the lowest abundance and n for the station with the highest abundance. When this procedure is completed for all species a mean rank can be calculated for each station. Differences in mean ranks between stations were tested for significance by applying analysis of variance.

3 RESULTS

3.1 ON BOARD COUNTINGS OF *ECHINOCARDIUM CORDATUM*

During fieldwork, the numbers of urchins (*Echinocardium cordatum*, specimens >1 cm) were counted in all samples. The numbers were low at all stations (Fig. 3). Converted numbers per m^2 revealed average densities of 0.9 individuals·m^{-2}, which is substantially lower than in the preceding year, when densities were found to be 2.5 ind·m^{-2} on average (DAAN & MULDER, 1993). A possible decrease in population densities is not likely to be explained as a long-term effect of the WBM cutting discharges, because the numbers were also low at all 5000 m reference stations and Fig. 3 gives no indication of a spatial gradient in population abundance along the sampled transects. A more plausible explanation for the difference between numbers of *E. cordatum* found in 1991 and 1992 can be found in the difference in timing of sampling. The 1992 survey was carried out 7 weeks later in the season than the 1991 survey and from own observations there are indications that *E. cordatum* moves into

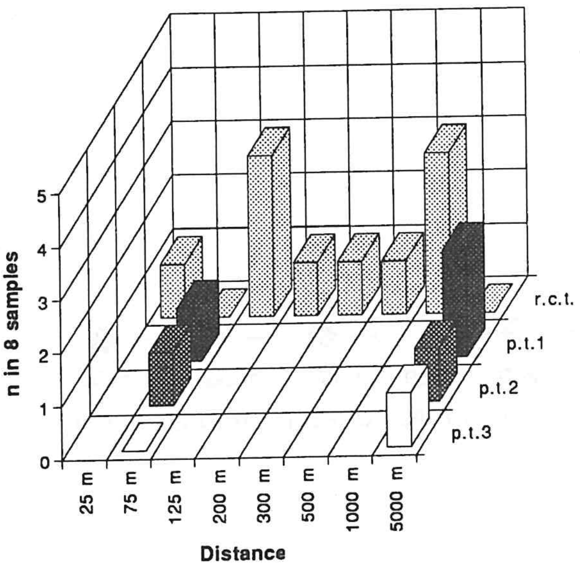

Fig. 3. Spatial abundance pattern of *Echinocardium cordatum* (number of specimens >1 cm in 8 samples (=1.3 m^2)). r.c.t. = residual current transect; p.t. = perpendicular transect.

deeper sediment layers as the winter comes nearer and the water temperature falls. Hence, particularly in 1992, the deeper living animals could have been missed during sampling, because the Van Veen grab collects quantitative samples only from the upper 15-20 cm layer of the sediment. Another explanation which can not be ruled out is that the difference in mean abundance reflects a natural fluctuation in abundance between years. Anyhow, the distribution pattern of *E. cordatum* in 1992 does not suggest that the species is affected in its abundance by the WBM cutting discharges at L3-3.

3.2 GENERAL FAUNA DESCRIPTION

The macrofauna analyses of the samples collected along the residual current transect yielded 97 identified species. In Table 2 their percentual occurrence in the samples is summarized. The original data are listed in Table 5 (Appendix). Just like in 1991 the fauna was dominated by the echinoderm *Amphiura filiformis* (27% of all individuals) and to a lesser extent by the mollusc *Mysella bidentata* (10% of all individuals). The latter species is living as a commensal of *A. filiformis*. At all stations, including the 5000 m reference sites, both species were less abundant than in 1991. Fig. 4 shows that these dominant species did not show a sign of a gradient in abundance along the sampled transect. The curves illustrate a marked similarity between the abundance patterns of both species, which is likely to be explained by their commensal relationship. Other species that were consistently present in all samples were the polychaetes *Pholoe minuta* and *Lumbrineris latreilli*, the crustacean *Callianassa subterranea* and specimens of *Sipunculida*. None of them showed a relation between density and distance to the discharge site (see Table 5, Appendix).

The total macrofauna abundance at the stations investigated fluctuated within a narrow range of 920 to 1260 ind·m^{-2} and did not show a spatial gradient (Fig. 5). The numerical abundance was substantially lower than in 1991, largely due to the decreased abundances of the dominant species (*A. filiformis* and *M. bidentata*). As a result of the decrease of these species the large fluctuations in total macrofauna abundance as found in 1991 were considerably reduced in 1992. Fig. 5 may also illustrate that the decrease in fauna abundance was not consistently smaller or larger at stations close to the discharge site than at stations at larger distance.

The number of identified species at each station was between 55 (5000 m) and 67 (1000 m), which is slightly lower than in 1991 (62-74 species per station) (Fig. 6A). Still, the numbers of species per station were in a similar range as the numbers of species found at reference sites in the area in previous studies (see MULDER *et al.*, 1988; DAAN *et al.*, 1990, 1991, 1992). Fig. 6B, illustrating the total number of species and the mean number of species per sample at each station, shows that there is no indication of a gradual shift in species richness along the sampled transect.

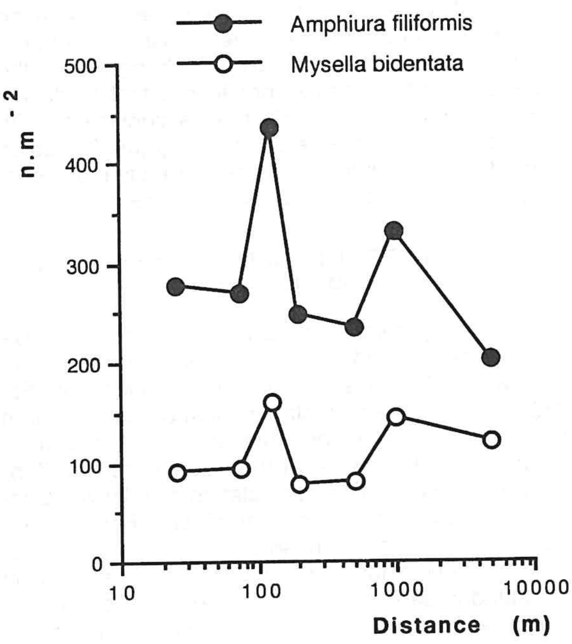

Fig. 4. Spatial abundance pattern of the 2 dominant species along the residual current transect.

TABLE 2

The benthic fauna at L3-3, Nov. 1992. Percentage of occurrence of each species in the total number of analysed samples (42).

POLYCHAETA		*Scalibregma inflatum*	24	*Ebalia cranchii*	2
		Ophelina acuminata	17	*Corystes cassivelaunus*	2
Aphrodita aculeata	2	*Capitella capitata*	2	*Nephrops norvegicus*	2
Harmothoe lunulata	31	*Mediomastus gracilis*	45	*Upogebia stellatata*	5
Harmothoe longisetis	14	*Notomastus latericeus*	60	*Upogebia deltaura*	29
Gattyana cirrosa	45	*Owenia fusiformis*	90	*Upogebia* spec. juv.	10
Sigalion mathildae	2	*Myriochele oculata*	38	*Callianassa subterranea*	100
Pholoe minuta	100	*Lanice conchilega*	17	*Nebalia bipes*	7
Sthenelais limicola	60	*Lagis koreni*	31	*Iphinoe trispinosa*	2
Eteone lactea	5	*Pectinaria auricoma*	26	*Diastylis bradyi*	17
Anaitides mucosa	2	*Ampharete finmarchica*	5	*Ione thoracica*	43
Anaitides maculata	5	*Sosane gracilis*	12	*Atylus falcatus*	5
Ophiodromus flexuosus	45	*Eupolymnia nebulosa*	2	*Leucothoe incisa*	2
Gyptis capensis	43	*Lysilla loveni*	7	*Ampelisca brevicornis*	5
Synelmis klatti	2	*Terebellides stroemi*	10	*Ampelisca tenuicornis*	26
Exogone hebes	10			*Harpinia antennaria*	55
Nereis longissima	40	**MOLLUSCA**		*Aora typica*	12
Nephtys hombergii	29			*Photis longicaudata*	2
Nephtys incisa	48	*Nucula turgida*	98		
Nephtys longosetosa	10	*Lepton squamosum*	2	**ECHINODERMATA**	
Nephtys spec. juv.	31	*Devonia perrieri*	12		
Glycera capitata	2	*Montacuta ferruginosa*	2	*Amphiura filiformis*	100
Glycera rouxii	71	*Mysella bidentata*	100	*Amphiura chiajei*	83
Glycera alba	2	*Arctica islandica*	2	*Ophiura texturata*	5
Glycera spec. juv.	31	*Acanthocardia echinata*	2	*Ophiura albida*	26
Glycinde nordmanni	14	*Dosinia lupinus*	2	*Ophiura* spec. juv.	29
Goniada maculata	86	*Venus striatula*	64	*Echinocardium cordatum*	12
Lumbrineris latreilli	100	*Spisula* spec. juv.	67	*Echinocardium cordatum* juv.	52
Lumbrineris fragilis	52	*Abra tenuis*	14	*Cucumaria elongata*	31
Orbinia sertulata	5	*Abra alba*	40	*Cucumaria frondosa*	43
Paraonis gracilis	43	*Abra nitida*	57		
Paraonis fulgens	2	*Mya truncata*	5	**OTHER TAXA**	
Poecilochaetus serpens	12	*Corbula gibba*	79		
Spio filicornis	2	*Thracia convexa*	33	Nemertinea	81
Polydora guillei	10	*Onoba vitrea*	93	Turbellaria	19
Spiophanes kroyeri	2	*Turritella communis*	57	Phoroniden	81
Spiophanes bombyx	43	*Natica alderi*	98	Harp. copepoda	2
Magelona papillicornis	5	*Cylichna cilindracea*	50	Oligochaeta	12
Chaetopterus variopedatus	64			Holothuroidea	5
Tharyx marioni	7	**CRUSTACEA**		Echiurida	12
Chaetozone setosa	2			Sipunculida	100
Diplocirrus glaucus	17	*Processa parva*	17	Anthozoa	2

3.3 PRESENCE-ABSENCE DATA: LOGIT REGRESSION

Possible gradients in the abundance patterns of individual species were statistically tested by logit regression, which is based on presence-absence data of species in the samples. For each species the hypothesis H_0 is tested, that there is no gradient in frequency of occurrence in the samples, against the alternative hypothesis H_1 that a gradient is significant. The test was performed only for those species of which at least 20 specimens were found. Table 3 shows that of 35 species tested only one species (the polychaete *Lumbrineris fragilis*) seemed to display a significant (5% level) gradient. Since the sign of the gradient was positive (higher frequency of occurrence away from the location), this might indicate that *L. fragilis* suffered from the WBM cutting dumpings and

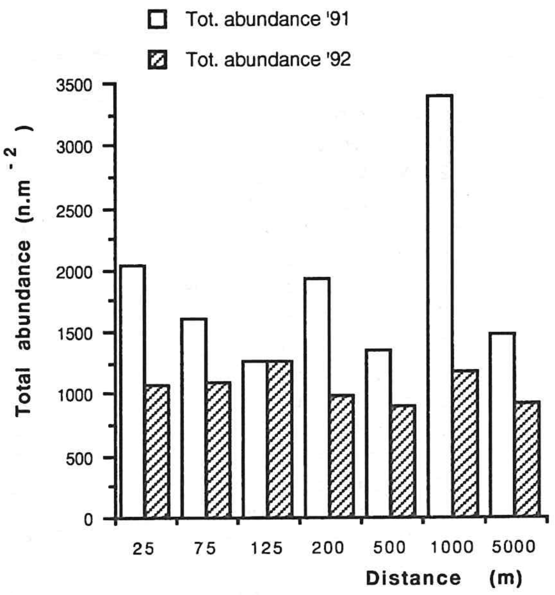

Fig. 5. Total macrofauna abundance along the residual current transect (surveys '91 and '92).

decreased in abundance in the area close to the well site. In view of the number of tests, however, the chance of finding 1 or more significant results is 83% when H_0 is true for all species. In other words, accepting the significance as a rejection of H_0 would imply an enormous risk of making a statistical Type-I error, *i.e.* rejection of H_0 when it is true. Only if 5 or more significant results were found, it would be statistically correct to decide that at least one gradient was significant. Hence, it is concluded that logit regression did not reveal significant gradients in individual species.

3.4 RELATIVE MACROFAUNA ABUNDANCE

In Fig. 7 a plot is given of the relative macrofauna abundance, calculated as the mean rank of each station for all identified species. The figure shows that the mean rank is close to 4 for all stations at the residual current transect, which can be expected in a situation where the abundances of individual species are distributed at random over the 7 stations investigated. Only if one station has consistently higher (or consistently lower) abundances of each species it would be attributed a significantly higher (or lower) rank. However, analysis of variance confirmed that there were no significant differences in mean ranks between stations.

3.5 ABUNDANCE PATTERNS OF OBM-SENSITIVE AND OPPORTUNISTIC SPECIES

In earlier studies, dealing with the effects of OBM cutting discharges, a number of species have been found to be very sensitive to these discharges. Those species were absent, or occurred in reduced abundance in the vicinity of well sites. A few other species

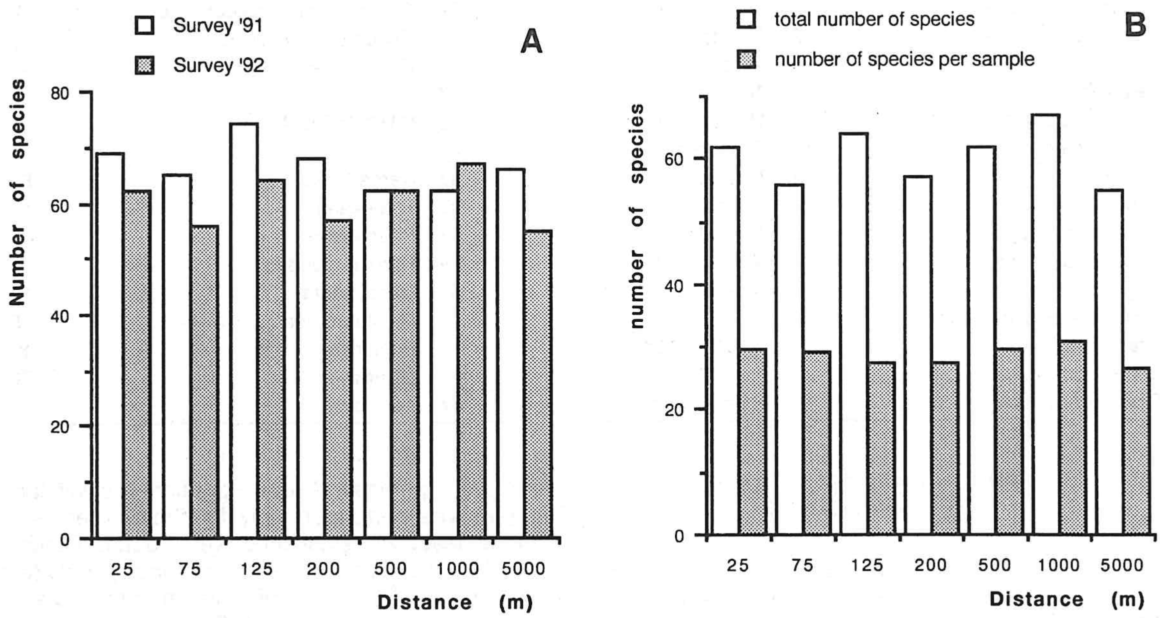

Fig. 6. A. Number of identified species per station (in 6 samples), residual current transect (surveys '91 and '92).
B. Number of identified species per station (in 6 samples) and the mean number of species per sample (residual current transect).

(opportunists) appeared to take profit from the disturbance involved and did occur in elevated numbers particularly in the most contaminated area close to discharge sites. Table 4 shows to what extent these species displayed a gradient in abundance that could be indicative of sediment pollution at L3-3. Among those species of which at least 20 specimens were found, only one OBM-sensitive species (the mollusc *Abra alba*) tended to a gradual shift in abundance along the sampled transect. However, in contrast to OBM locations high numbers were found particularly within 125 m and lower numbers at the stations that lie 200 m or more from the discharge site. Hence,

TABLE 3

Location L3-3, survey '92: List of species for which gradients in frequency of occurrence were tested by logit regression. Sign of the gradient (+/-) and significance level are indicated: + =increasing frequency of occurrence away from the location; - =decreasing frequency of occurrence away from the location; 0 =no gradient.

	sign	*sign. level (%)*
Gattyana cirrosa	+	n.s.
Pholoe minuta	0	-
Sthenelais limicola	-	n.s.
Ophiodromus flexuosus	-	n.s.
Gyptis capensis	-	n.s.
Nereis longissima	+	n.s.
Nephtys incisa	-	n.s.
Glycera rouxii	-	n.s.
Goniada maculata	+	n.s.
Lumbrineris latreilli	0	-
Lumbrineris fragilis	+	5
Paraonis gracilis	-	n.s.
Spiophanes bombyx	+	n.s.
Chaetopterus variopedatus	+	n.s.
Mediomastus gracilis	-	n.s.
Notomastus latericeus	-	n.s.
Owenia fusiformis	-	n.s.
Myriochele oculata	+	n.s.
Lagis koreni	+	n.s.
Nucula turgida	+	n.s.
Mysella bidentata	0	-
Venus striatula	-	n.s.
Abra alba	-	n.s.
Abra nitida	+	n.s.
Corbula gibba	+	n.s.
Onoba vitrea	+	n.s.
Turritella communis	+	n.s.
Natica alderi	+	n.s.
Cylichna cilindracea	-	n.s.
Callianassa subterranea	0	-
Ione thoracica	+	n.s.
Harpinia antennaria	-	n.s.
Amphiura filiformis	0	-
Amphiura chiajei	-	n.s.
Cucumaria frondosa	+	n.s.

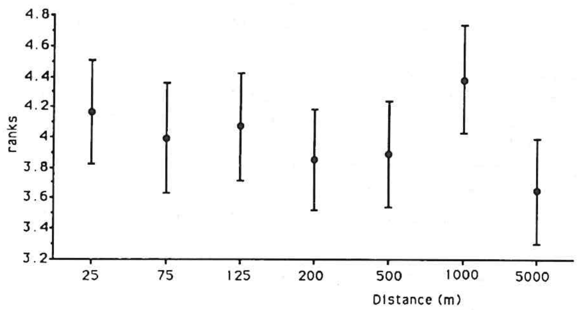

Fig. 7. Pattern of relative macrofauna abundance along the residual current transect. Centre points are mean ranks and vertical bars give 95% confidence limits

there is no reason to consider this shift in abundance as an effect of the dumpings at L3-3. A more plausible explanation seems that there has been settlement of spatfall of *A. alba*, which accidentally found its way to the seabed close to the well site. This is supported by our observation that most of the specimens found were juveniles.

A gradual shift in abundance along the sampled transect, which in the preceding year seemed to occur in the polychaete *Scalibregma inflatum*, has completely disappeared in 1992. Among the opportunistic species, the presence of *Capitella capitata* (in 1991 found at 25 m and 75 m) was assessed only at 25 m, where 1 specimen was found. Although this species is highly indicative of sediment contamination, its extremely low abundance does not point at seriously disturbed sediment conditions.

4 DISCUSSION

The major conclusion of the present study is that adverse effects of WBM cutting discharges on the benthic community at L3-3 were not observed. This supports the provisional conclusion of the first survey of 1991 (see DAAN & MULDER, 1993), that dumping of WBM cuttings with a composition like used at this location has no significant environmental impact. Of course, the occurrence of minor (sublethal) effects can not be completely excluded, but apparently such effects were not so severe that there were detectable consequences for the composition of the benthic fauna. Just like during the first survey the fauna was homogeneous in the area and even at a station as close as 25 m from the former point of discharge the assemblage was not different from that outside the area where physical smothering was *a priori* considered negligible. Although several authors suggest that the severity and spatial extent of the effects of WBM cutting dumpings are less than of those following OBM cutting discharges (*e.g.* DAVIES *et al.*, 1984; DICKS *et al.*, 1986), this finding may seem surprising, since most studies seem to have revealed at least

TABLE 4

Location L3-3, survey '92: Evaluation of the abundance patterns of 37 species sensitive to OBM contamination and 4 opportunistic species.
+ = tendency for higher abundance away from the platform
- = tendency for lower abundance away from the platform
0 = no tendency for a spatial gradient
(?) = total number of specimens found < 20
(Note that the qualifications are based on the abundance patterns of the individual species and not on presence-absence data as used in logit regression.

A. Species sensitive to OBM contamination	
Montacuta ferruginosa	0 (?)
Scalibregma inflatum	0 (?)
Pholoe minuta	0
Amphiura filiformis	0
Echinocardium cordatum	0 (?)
Mysella bidentata	0
Nephtys hombergi	0 (?)
Lumbrineris latreilli	0
Chaetozone setosa	0 (?)
Owenia fusiformis	0
Nucula turgida	0
Gattyana cirrosa	0
Harpinia antennaria	0
Lagis koreni	0
Glycinde nordmanni	0 (?)
Cylichna cilindracea	0
Harmothoe longisetis	0
Callianassa subterranea	0
Magelona papillicornis	0 (?)
Tellina fabula	species not found
Natica alderi	0
Spiophanes bombyx	0
Ophiodromus flexuosus	0
Notomastus latericeus	0
Lumbrineris fragilis	0
Amphiura chiajei	0
Leucothoe incisa	0 (?)
Chaetopterus variopedatus	0
Tharyx marioni	0 (?)
Ophiura albida	0 (?)
Gyptis capensis	0
Lanice conchilega	0 (?)
Perioculodes longimanus	species not found
Diplocirrus glaucus	0 (?)
Abra alba	-
Turritella communis	0
Sthenelais limicola	0
B. Opportunist species	
Nereis longissima	0
Capitella capitata	- (?)
Spio filicornis	0 (?)
Anaitides groenlandica	species not found

more or less localized effects. Unfortunately, a thorough comparison with other WBM studies is hampered by the fact that there are only few published data easily accessible. The majority of macrobenthic surveys around oil and gas installations, including those around WBM sites, were presented as limited circulation reports (see *e.g.* LEVELL, 1987; LEVELL *et al.*, 1989) and review literature generally focuses on OBM and pays little attention to WBM. Nevertheless some published information is available, to which the results of the present survey can be compared.

The field investigation most comparable to the L3-3 study was the one performed around an exploratory drill site on the Mid-Atlantic Outer Continental Shelf (M-A OCS), east of New Jersey, located in 120 m of water (GILLMOR *et al.*, 1985). The research programme included also a post-drilling survey conducted immediately after completion of drilling and a follow-up survey one year later. The authors concluded that an affected area could be identified in the immediate vicinity of the well site (within a radius of about 100 m) which was distinguished from the surrounding area particularly by very low numbers of the brittle star *Amphiloplus macilentus* during both surveys. However, their data suggested clear signs of recovery of the macrofauna in the vicinity of the well, with recolonisation of most species within 1 year. The authors noted that physical alterations to surficial sediments persisted at least one year, owing to the low-energy nature of the benthic environment at the deep-water site concerned, and that initial burial of the infauna could have contributed to the effects observed. In this respect the situation was different at L3-3, where drilled clay cuttings were observed on the sediment only during the first survey within a very small radius of ≤25 m from the point of discharge. During the second survey no trace of cuttings was recovered, possibly due to suspension of the clay which is likely to go much faster in the relatively shallow (≈45 m) water at L3-3. This could explain why there was hardly any spatial effect of burial at L3-3. This explanation is in correspondence with NEFF (1987) who stated that in high-energy environments little mud and cuttings accumulate and impacts on the benthos are minimal and of short duration, whereas in low-energy environments more material accumulates, subsequently leading to reductions in abundance of some benthic species. However, there was also one marked difference between the chemical composition of the muds discharged at L3-3 and at the M-A OCS location. Of the major drilling fluid ingredients used in WBM, only sodium hydroxide and (ferro-) chrome lignosulphonate can be considered moderately toxic (NEFF, 1987). Exactly of these components there has been limited or no use at L3-3: Of NaOH only 4 tonnes were discharged whereas the small amount of lignosulphonate used (0.5 t) was free of chromium. In contrast, the muds used at the M-A OCS location contained 50 tonnes of NaOH, whereas a similar amount of chrome lignosuphonate was discharged. Therefore, a difference in toxicity of the materials dumped at both locations can not be excluded and might possibly explain why (limited) effects did occur at the M-A OCS site and were not observed at L3-3.

NEFF *et al.* (1989) who worked on Georges Bank, east of Massachusetts, investigated possible impacts of cutting discharges around 2 exploratory well sites at Georges Bank, at one of which only WBM had been used. The authors observed that the number of species and diversity dropped sharply during drilling at the station nearest to the well site, but increased again shortly after completion of drilling and remained at the high predrilling level after that. They stated that, if the changes observed were related to drilling, the impact was transitory and their overall conclusion was that no changes were detected in the benthic community that could be attributed to drilling activities. It should be noted, however, that they sampled a very coarse meshed sampling grid and the station nearest to the well site was lying 'within 200 m' from that site. Therefore, they may have missed some possible effects in the immediate vicinity of the point of discharge.

In the North Sea, HARTLEY & FERBRACHE (1983) investigated the Forties Oilfield (≈100 miles east of Scotland, in 100-125 m water depth), where 80 wells were drilled, in every case with WBM. From their results they concluded that the associated discharges presented relatively few biological effects and that there were only some very localized (biological) effects in the immediate vicinity of the platforms. The occurrence of localized effects was assessed on the basis of a few small sediment cores occasionally taken close to one of the platforms, but no areas of biological effect around installations could be delineated on the basis of their main survey programme. It should be noted, however, that this programme was based on a very coarse meshed sampling grid, with stations not closer than about 500 m from the platforms. Hence, they will have missed the areas where major effects are most likely to occur. Particularly in an intensively exploited oilfield like the Forties, where per platform on average 20 wells were drilled (which will have resulted in a total discharge in the order of 20000 tonnes of cuttings per platform), the effect of burial of the macrofauna is probably not restricted to very limited areas beneath the platforms. Moreover, the scale of sediment disturbance around the Forties platforms, may also have given advantage to opportunists or quickly colonizing pioneer species (see EAGLE & REES, 1973). For that reason, but also because of the fact that the samples in which 'localized' effects were observed, appeared to be contaminated with substantially elevated hydrocarbon levels, it is not clear to what extent the WBM contributed to these effects.

In the Beatrice oilfield, which lies12 miles east of North Scotland, ADDY *et al.* (1984) carried out a survey after 13 wells were drilled with WBM. They concluded that biological effects were marked at stations ≤115 m from the platform, comparatively weak at 250 m and undetectable at 750 m from the platform. However, at those stations where they found effects, hydrocarbon levels, in particular aliphatics, were elevated compared to background, so there is no certainty that the effects observed should be attributed to the WBM discharged.

A summary of more recent surveys in the UK sector, carried out since 1987 and including some WBM sites, was given by ANONYMOUS (1991). About North Sea WBM sites no concrete information could be presented. However, from the results of 3 post-drilling surveys around mining installations in the Morecambe Bay (Irish Sea), where only WBM were used, it was concluded that the benthos was unaffected beyond 200 m. A more detailed delineation of the affected zone was not given.

In the Dutch sector MULDER *et al.* (1988) investigated WBM location F18.8 in the Oystergrounds 2 months after drilling an exploratory well and location L4a (west of the Frisian Front) 1 year after WBM drilling. These surveys did not reveal any effect on the macrobenthic community, neither on fauna abundance, species richness or diversity nor on individual species. However, for F18.8 the station nearest to the abandoned well site was planned at 50-100 m (residual current direction), but the research vessel was positioned by Decca, so a considerable discrepancy between the planned sampling position and the real sampling position (possibly exceeding 100 m) should be reckoned with. In the case of L4a (platform present) the station nearest to the platform was lying at 250 m, so the presence of localized effects closer to the platform may have been overlooked.

One other WBM study has been performed in the Dutch sector. Simultaneously with the first survey at L3-3, a survey was carried out at location L6-3 in the Frisian Front area, 2 months after drilling an exploratory well, where only material from the well section drilled with WBM was discharged (DAAN & MULDER, 1993). At this location significant effects were observed up to 75 m from the discharge site, where suffocation of the fauna due to burial by cuttings could be definitely excluded. However, in this case slightly elevated concentrations of OBM base oil were detected in the sediment around the discharge site. For that reason it was concluded that there was no convincing evidence that the effects observed should be attributed to the WBM cutting discharges at L6-3.

Summarizing the results of the studies mentioned above, it is concluded that effects related to WBM drillings have never been observed beyond 250 m from installations and, more usually, were localized within a zone of about 100 m radius. Moreover, in most cases observed effects could not be attributed with certainty to the WBM discharged. Particularly the background presence of oil components in the sediment has often obscured the cause of observed effects. Viewed in that light, the present study at L3-3 seems to have met the requirements for a reliable detection of possible effects of discharged WBM, since the sampling stations were concentrated within a narrow area around the discharge site and the absence of oil in the sediment was verified. The fact that no effects were observed at this WBM location strongly indicates that the presence of oil in discharged drilling wastes should be considered as a major source of toxic components and environmental disturbance and as responsible for the associated biological effects observed at OBM locations.

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APPENDIX

Table 5. Data location L3-3, survey Nov. 1992.
Mean densities (n.m-2)
Number of samples ( ) in which species are present.
Tot. number of ind. per m2 per station.
Number of identified species.

Distance to platform	25 m	75 m	125 m	200 m	500 m	1000 m	5000 m
Number of analysed samples	6	6	6	6	6	6	6
POLYCHAETA							
Aphrodita aculeata			1.0 (1)				
Harmothoe lunulata	4.2 (3)	1.0 (1)	4.2 (3)	2.1 (2)	4.2 (2)	1.0 (1)	1.0 (1)
Harmothoe longisetis		2.1 (2)	1.0 (1)		1.0 (1)	0.0	2.1 (2)
Gattyana cirrosa	2.1 (2)	6.3 (2)	7.3 (4)	6.3 (4)	1.0 (1)	3.1 (2)	4.2 (4)
Sigalion mathildae				1.0 (1)			
Pholoe minuta	68.8 (6)	37.5 (6)	80.2 (6)	75.0 (6)	49.0 (6)	44.8 (6)	39.6 (6)
Sthenelais limicola	8.3 (3)	5.2 (5)	5.2 (2)	3.1 (2)	12.5 (5)	6.3 (5)	4.2 (3)
Eteone lactea						2.1 (2)	
Anaitides mucosa			1.0 (1)				
Anaitides maculata					1.0 (1)		1.0 (1)
Ophiodromus flexuosus	2.1 (1)	2.1 (2)	9.4 (5)	2.1 (2)	4.2 (3)	4.2 (4)	3.1 (2)
Gyptis capensis	7.3 (4)	4.2 (2)	6.3 (4)	3.1 (3)	1.0 (1)	5.2 (3)	1.0 (1)
Synelmis klatti				1.0 (1)			
Exogone hebes	2.1 (2)		2.1 (2)				
Nereis longissima	5.2 (3)	2.1 (2)	2.1 (2)	2.1 (2)	5.2 (4)	1.0 (1)	3.1 (3)
Nephtys hombergii	5.2 (3)		1.0 (1)	2.1 (2)	5.2 (3)	2.1 (2)	1.0 (1)
Nephtys incisa	6.3 (4)	7.3 (4)	4.2 (3)	4.2 (2)	1.0 (1)	4.2 (3)	6.3 (3)
Nephtys longosetosa		1.0 (1)	1.0 (1)			1.0 (1)	1.0 (1)
Nephtys spec. juv.	8.3 (3)	5.2 (3)	2.1 (1)	3.1 (2)	1.0 (1)	2.1 (2)	1.0 (1)
Glycera capitata		1.0 (1)					
Glycera rouxii	6.3 (4)	9.4 (5)	7.3 (3)	5.2 (4)	7.3 (5)	10.4 (5)	4.2 (4)
Glycera alba							1.0 (1)
Glycera spec. juv.	1.0 (1)	3.1 (2)	9.4 (5)		1.0 (1)	2.1 (2)	3.1 (2)
Glycinde nordmanni		1.0 (1)	1.0 (1)	1.0 (1)	1.0 (1)	2.1 (2)	
Goniada maculata	35.4 (6)	14.6 (3)	22.9 (5)	30.2 (5)	17.7 (6)	28.1 (6)	26.0 (5)
Lumbrineris latreilli	108.3 (6)	71.9 (6)	85.4 (6)	108.3 (6)	69.8 (6)	77.1 (6)	27.1 (6)
Lumbrineris fragilis	5.2 (2)	3.1 (2)	3.1 (2)	3.1 (1)	9.4 (5)	11.5 (5)	6.3 (5)
Orbinia sertulata					2.1 (2)		
Paraonis gracilis	9.4 (4)	7.3 (3)	4.2 (2)	1.0 (1)	2.1 (2)	8.3 (4)	4.2 (2)
Paraonis fulgens						4.2 (1)	
Poecilochaetus serpens	1.0 (1)				1.0 (1)	1.0 (1)	2.1 (2)
Spio filicornis				1.0 (1)			
Polydora guillei			1.0 (1)	1.0 (1)		2.1 (2)	
Spiophanes kroyeri						1.0 (1)	
Spiophanes bombyx	2.1 (1)	6.3 (4)	3.1 (2)	3.1 (3)	8.3 (3)	1.0 (1)	4.2 (4)
Magelona papillicornis		1.0 (1)	1.0 (1)				
Chaetopt. variopedatus	4.1 (2)	11.5 (5)	10.4 (3)	7.3 (5)	5.2 (4)	6.3 (3)	6.3 (5)

Table 5. continued.

Distance to platform	25 m	75 m	125 m	200 m	500 m	1000 m	5000 m
Number of analysed samples	6	6	6	6	6	6	6
Tharyx marioni	1.0 (1)	1.0 (1)	1.0 (1)				
Chaetozone setosa	1.0 (1)						
Diplocirrus glaucus	1.0 (1)	1.0 (1)		4.2 (2)	1.0 (1)	1.0 (1)	1.0 (1)
Scalibregma inflatum	3.1 (2)		1.0 (1)	3.1 (2)	2.1 (2)	3.1 (2)	3.1 (1)
Ophelina acuminata			1.0 (1)	2.1 (2)		6.3 (4)	
Capitella capitata	1.0 (1)						
Mediomastus gracilis	3.1 (3)	10.4 (4)	8.3 (3)	8.3 (4)	1.0 (1)	4.2 (3)	1.0 (1)
Notomastus latericeus	9.4 (5)	3.1 (3)	4.2 (3)	6.3 (4)	6.3 (4)	11.5 (4)	2.1 (2)
Owenia fusiformis	18.8 (5)	25.0 (6)	13.5 (6)	12.5 (4)	14.6 (6)	24.0 (6)	16.7 (5)
Myriochele oculata	2.1 (2)	1.0 (1)	1.0 (1)	3.1 (2)	3.1 (3)	5.2 (4)	6.3 (3)
Lanice conchilega	4.2 (4)			3.1 (2)	1.0 (1)		
Lagis koreni	3.1 (2)	2.1 (2)	2.1 (2)	7.3 (1)	4.2 (2)	4.2 (2)	3.1 (2)
Pectinaria auricoma	2.1 (2)	1.0 (1)	3.1 (1)	3.1 (2)	2.1 (1)	1.0 (1)	4.2 (3)
Ampharete finmarchica					1.0 (1)		1.0 (1)
Sosane gracilis	1.0 (1)	1.0 (1)	1.0 (1)		1.0 (1)	1.0 (1)	
Eupolymnia nebulosa					1.0 (1)		
Lysilla loveni	1.0 (1)			1.0 (1)		1.0 (1)	
Terebellides stroemi		1.0 (1)	2.1 (1)			2.1 (2)	
MOLLUSCA							
Nucula turgida	46.9 (6)	32.3 (6)	8.3 (5)	40.6 (6)	43.8 (6)	51.0 (6)	31.3 (6)
Lepton squamosum			1.0 (1)				
Devonia perrieri	1.0 (1)		1.0 (1)		1.0 (1)	1.0 (1)	1.0 (1)
Montacuta ferruginosa						2.1 (1)	
Mysella bidentata	89.6 (6)	93.8 (6)	161.5 (6)	78.1 (6)	79.2 (6)	144.8 (6)	120.8 (6)
Arctica islandica	1.0 (1)						
Acanthocardia echinata				2.1 (1)			
Dosinia lupinus					1.0 (1)		
Venus striatula	6.3 (3)	9.4 (5)	2.1 (2)	15.6 (6)	13.5 (4)	12.5 (5)	3.1 (2)
Spisula spec. juv.	9.4 (5)	11.5 (4)	7.3 (3)	12.5 (4)	11.5 (5)	7.3 (4)	9.4 (3)
Abra tenuis	1.0 (1)	2.1 (2)	1.0 (1)			1.0 (1)	1.0 (1)
Abra alba	20.8 (5)	9.4 (3)	1.0 (1)	2.1 (1)	8.3 (4)	2.1 (2)	1.0 (1)
Abra nitida	3.1 (3)	2.1 (2)	3.1 (2)	13.5 (5)	2.1 (2)	18.8 (6)	17.7 (4)
Mya truncata		1.0 (1)					1.0 (1)
Corbula gibba	7.3 (4)	10.4 (5)	7.3 (5)	17.7 (5)	19.8 (4)	9.4 (5)	14.6 (5)
Thracia convexa	2.1 (2)	3.1 (3)	2.1 (2)	1.0 (1)	1.0 (1)	3.1 (3)	3.1 (2)
Onoba vitrea	60.4 (6)	128.1 (6)	84.4 (6)	26.0 (4)	21.9 (6)	75.0 (5)	111.5 (6)
Turritella communis	4.2 (1)	18.8 (5)	3.1 (2)	7.3 (4)	8.3 (6)	3.1 (2)	5.2 (4)
Natica alderi	55.2 (5)	75.0 (6)	65.6 (6)	60.4 (6)	46.9 (6)	57.3 (6)	47.9 (6)
Cylichna cilindracea	10.4 (4)	8.4 (5)	2.1 (2)	4.2 (3)	7.3 (4)	1.0 (1)	2.1 (2)

Table 5. continued.

Distance to platform	25 m	75 m	125 m	200 m	500 m	1000 m	5000 m
Number of analysed samples	6	6	6	6	6	6	6
CRUSTACEA							
Processa parva	2.1 (1)		8.3 (2)	1.0 (1)	1.0 (1)		4.2 (2)
Ebalia cranchii				1.0 (1)			
Corystes cassivelaunus					1.0 (1)		
Nephrops norvegicus		1.0 (1)					
Upogebia stellatata			1.0 (1)		2.1 (1)		
Upogebia deltaura	3.1 (3)	3.1 (3)			4.2 (3)	3.1 (2)	2.1 (1)
Upogebia spec. juv.				3.1 (2)	2.1 (2)		
Callianassa subterranea	62.5 (6)	89.6 (6)	87.5 (6)	80.2 (6)	75.0 (6)	94.8 (6)	92.7 (6)
Nebalia bipes	1.0 (1)		2.1 (1)			1.0 (1)	
Iphinoe trispinosa						1.0 (1)	
Diastylis bradyi		4.2 (2)	1.0 (1)	1.0 (1)	3.1 (2)	1.0 (1)	
Ione thoracica	2.1 (1)	5.2 (3)	6.3 (2)	7.3 (4)	5.2 (3)	3.1 (2)	7.3 (3)
Atylus falcatus						1.0 (1)	1.0 (1)
Leucothoe incisa	1.0 (1)						
Ampelisca brevicornis					1.0 (1)		1.0 (1)
Ampelisca tenuicornis	1.0 (1)	1.0 (1)	2.1 (2)	1.0 (1)	2.1 (2)	7.3 (4)	
Harpinia antennaria	10.4 (5)	9.4 (4)	2.1 (2)	6.3 (3)	6.3 (4)	7.3 (3)	3.1 (2)
Aora typica	1.0 (1)	9.4 (2)	1.0 (1)			6.3 (1)	
Photis longicaudata						1.0 (1)	
ECHINODERMATA							
Amphiura filiformis	278.1 (6)	270.9 (6)	436.5 (6)	247.9 (6)	234.4 (6)	332.3 (6)	204.2 (6)
Amphiura chiajei	16.7 (5)	21.9 (6)	14.6 (6)	18.8 (4)	13.5 (5)	17.7 (4)	11.5 (5)
Ophiura texturata	1.0 (1)					1.0 (1)	
Ophiura albida	2.1 (2)	1.0 (1)	4.2 (3)	2.1 (2)	2.1 (2)	1.0 (1)	
Ophiura spec. juv.	1.0 (1)	3.1 (3)	2.1 (2)	1.0 (1)	5.2 (2)	1.0 (1)	3.1 (2)
Echinocardium cordatum	1.0 (1)		3.1 (1)	1.0 (1)	1.0 (1)	1.0 (1)	
E. cordatum juv.	18.8 (6)	3.1 (2)	4.2 (2)	4.2 (2)	5.2 (3)	3.1 (3)	6.3 (4)
Cucumaria elongata	3.1 (3)	2.1 (2)	1.0 (1)	2.1 (2)	1.0 (1)	1.0 (1)	5.2 (3)
Cucumaria frondosa	5.2 (3)	6.3 (3)	7.3 (4)	3.1 (3)	3.1 (1)	1.0 (1)	3.1 (3)

Table 5. continued.

Distance to platform	25 m	75 m	125 m	200 m	500 m	1000 m	5000 m
Number of analysed samples	6	6	6	6	6	6	6
OTHER TAXA							
Nemertinea	p (6)	p (6)	p (4)	p (5)	p (5)	p (4)	p (4)
Turbellaria	1.0 (1)		2.1 (2)		2.1 (2)	2.1 (2)	1.0 (1)
Phoroniden	p (4)	p (5)	p (5)	p (5)	p (5)	p (6)	p (4)
Harp. copepoda					1.0 (1)		
Oligochaeta			1.0 (1)	5.2 (2)	2.1 (1)		1.0 (1)
Holothuroidea	1.0 (1)				2.1 (1)		
Echiurida	2.1 (1)	2.1 (2)		1.0 (1)		1.0 (1)	
Sipunculida	29.1 (6)	28.1 (6)	45.8 (6)	30.2 (6)	29.2 (6)	39.6 (6)	32.3 (6)
Anthozoa							1.0 (1)
Tot. nr. of individuals	1075	1100	1263.0	995.3	896.4	1185	919.3
Nr. of identified species	62	56	64	57	62	67	55

p= present, not counted

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