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Impact of Oil Installations on the North Sea Environment
Impact des installations pétroliféres sur l'environnement de la Mer du Nord
Der Einfluss von Oelförderungsanlagen auf die Nordsee-Umwelt

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SUMMARY
It is generally believed that oil installations negatively effect the environment up to areas of around 3 km^2. Such effects are measured on the benthic animal communities which have been found to be sensitive to environmental impacts. Using new analysis techniques (hydrocarbon contens in the sediment) it can be shown that the areas effected are up to a 3 km radius at the Ekofisk field, giving an area effected of 27 km^2. The new technique is based on differences in sensitivity between species. These findings have led to changes in legislation on discharges and improvements in environmental conditions can already be measured.

Impact des installations pétrolifères sur l'environnement de la Mer du Nord

Résumé
On considère généralement que les installations pétrolifères ont une influence négative sur l'environnement dans une zone de 3 km2. De tels effets peuvent être mesurés sur une certaine faune qui réagit de façon très sensible à ces impacts de l'environnement. En utilisant de nouvelles techniques d'analyse (contenu hydrocarboné dans les sédiments), il apparait que les zones affectées du champ pétrolifère de Ekofisk ont un rayon de 3 km, ce qui donne une zone affectée de 27 km2. La nouvelle technique est basée sur des différences de sensibilité entre les espèces marines. Ces découvertes ont conduit à changer la législation sur les dépôts et les décharges. Des améliorations sensibles ont déjà été mesurées dans l'environnement de certaines installations.

Der Einfluss von Oelförderungsanlagen auf die Nordsee-Umwelt

Zusammenfassung
Es wird generell die Meinung vertreten, dass Oelförderungsanlagen die Umwelt in Gebieten von bis zu 3 Quadratkilometern negativ beeinflussen. Auswirkungen auf die Meeresbodenfauna können gemessen werden , da sie sehr sensibel auf diese Umwelteinflüsse reagiert. Durch neue Analysetechniken (Kohlenwasserstoffgehalt in den Sedimenten) kann gezeigt werden, dass die beeinträchtigten Gebiete des Oelfeldes von Ekofisk einen Radius von 3 Kilometern haben; das ergibt ein betroffenes Gebiet von 27 Quadratkilometern. Die neue Technik basiert auf den Empfindlichkeitsunterschieden zwischen den Tierarten. Diese Entdeckung hat zu einer Aenderung der Gesetzgebung über Oeleinleitungen geführt, und Verbesserungen im Zustand der Umwelt sind bereits messbar.

The Impact of Oil Installations on the North Sea Environment.

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Introduction

In relation to oil pollution public opinion is strongly motivated against oil spills and their effects. The dramatic pictures of the "Amoco Cadiz" accident, the Port Valdez pollution and recently the tragic Persian Gulf incident focusses public awareness on oil pollution. Yet the public is strongly affected by visual images and reacts to these. Pollutant effects which cannot be seen or smelt are often more serious yet pass unnoticed by the press and general public. Thus there is little or no public interest or pressure to influence environmental legislation concerning the production of oil and gas, since effects are below the sea surface on the sediments and organisms inhabiting sediments. Here it is the scientist that must act as guardian of the environment on behalf of the public by obtaining data which allow an objective assessment of the extent of damage. This data can then be used by the appropriate environmental authorities to inact legislation, should it be required.

Based on surveys conducted largely by oil companies and their consultants, it is a widely held view that the impact of oil activities on the benthic fauna in the North Sea extends only to a 1 km radius from the installation, [1]. However, data reported to the Norwegian State Pollution Board (Statens forurensningstilsyn, SFT) as part of the obligatory monitoring undertaken by oil companies within the Norwegian sector suggested that effects could be measured as far out as 5 km from one platform, [2]. Much controversy was generated by presentation of this data, with the counter-claim being made that the effects observed were merely due to natural variations and were not due to oil-related activities, [3], [4]. The controversy even generated an editorial preface to the paper where the data was first presented! [2].

In Norway SFT has the responsibility of safeguarding the marine environment from unnecessary pollution and can impose regulations on oil companies if the environmental effects warrant such action. It is clearly necessary that any impositions or restrictions of activities are based on sound analyses of the data reported. The reporting procedures themseves have been analysed in detail and a set of guidelines developed by Norway was adopted at the Paris Commission in 1988. The guidelines have been used for three years and this paper reports on the experience gained and on further evidence that the effects of oil activities on the benthic fauna confirm the suggestions put forward by Reiersen et al. [2].

This paper reviews the latest data available for the Norwegian sector of the North Sea and shows that effects are much greater than is generally accepted.

Methods

Monitoring of the conditions around oil and gas platforms in the Norwegian sector of the North Sea is obligatory, with annual chemical monitoring and biological surveys conducted every 3 years (6 years for gas platforms). The data from these reports was used to assess effects at a well-studied field, Ekofisk and then to obtain general characteristics over all fields.

Sampling is usually done by taking 5 replicate benthic grab samples at a grid of stations arranged as radii, logaritmically spaced from the central installation. Fig 1 shows the sampling grid for Ekofisk sampled in 1987 with the central complex and a new production head the 2/4B complex. The reference site was located 30 km away.

The sample grid axes are determined by the dominant current directions. Additonal grab samples are taken at each site for physico-chemical analyses, including heavy metal and oil hydrocarbon analyses. The benthic fauna were extracted by sieving the organisms on 1mm diameter pore sieves and counting and identifying the organisms retained, (see Gray et al [5] for more details).

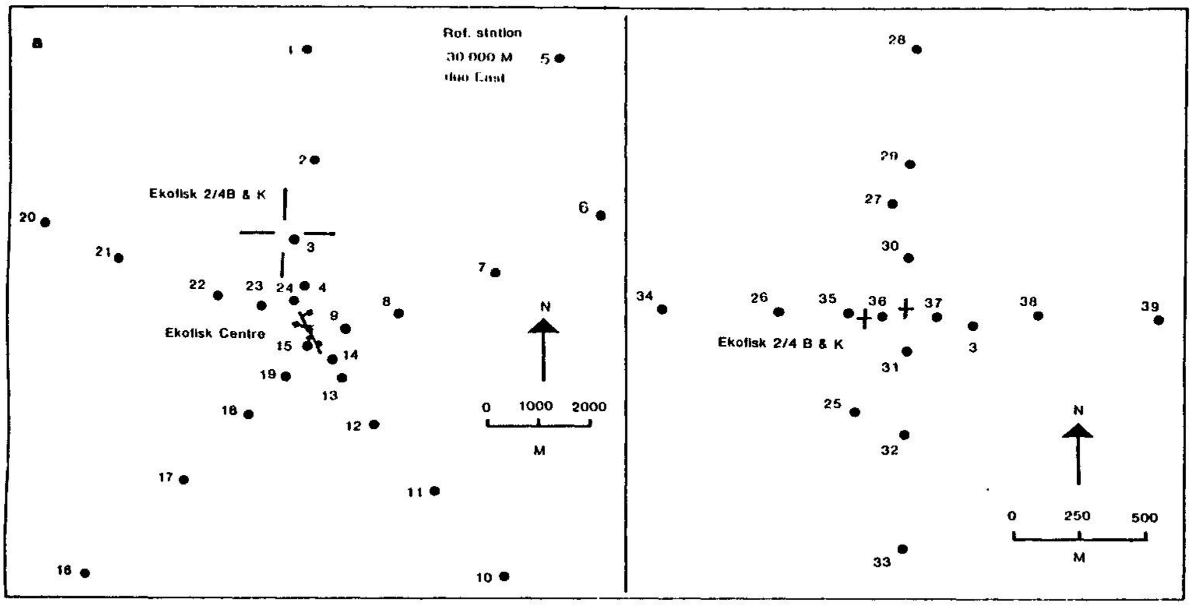

Fig 1. Location of sampling sites at Ekofisk, North Sea, July 1987, from Gray et al [5].

A matrix of numbers of individual organisms of each taxon per site was composed and a variety of statistical analyses methods used. The analyses methods which showed the most sensitivity were multivariate analyses using classification and multi-dimensional scaling ordination. From such analyses groups of sites were identified where changes could be related to influence of oil-related activities. Another statistical analysis technique was used to identify the species that were responsible for the site groupings. Changes in abundances of these species indicate the initial responses of the benthic communities to pollution. (Gray et al [5] should be consulted for details of the analyses used).

Thus a number of species were identified at the Ekofisk field which were suggested as being highly sensitive to oil and/or a tracer of oil-based drilling muds, the barium content of the sediment, (see Reiersen et al. [2] for correlations between total hydrocarbon content of sediment and barium content). In order to test the hypothesis that abundances of these species were responding to oil-related activities. The abundance patterns of the species were plotted against total hydrocarbon and barium content of sediment measured at the same stations over all fields, (except Ekofisk) included in the 1987-1989 surveys. Zero abundance values, i.e. where the species is not present in a sample, were excluded from the analyses.

Results

Fig 2 shows data on the multivariate analyses of the species/site matrix. The MDS ordination (fig 2b) shows that there is a gradient from site group A to D. These groups are plotted against the sample sites (fig 3) and show that the gradient is centred with the D group of sites close to the installation.

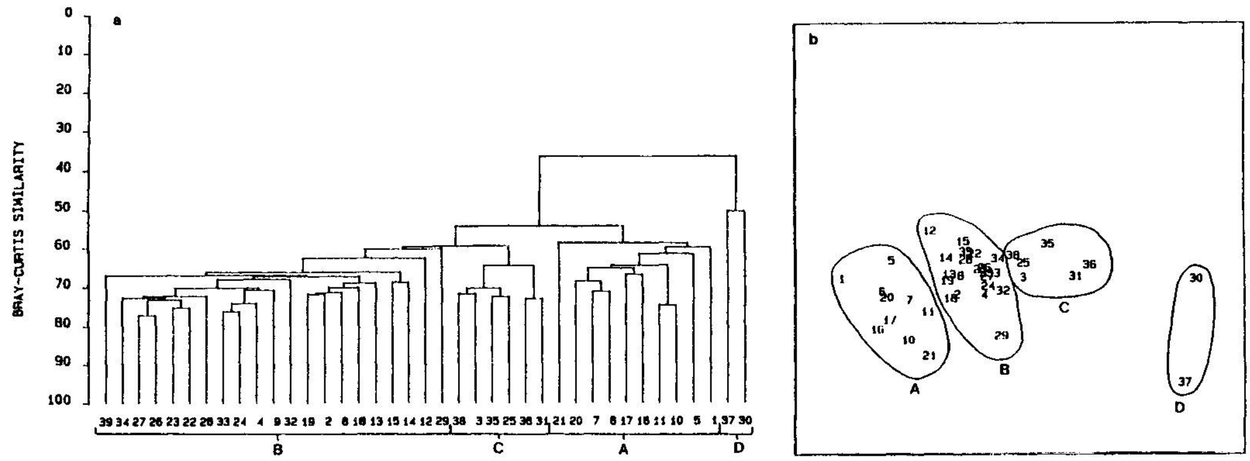

Fig 2. Multivariate analyses of Ekofisk data. (a) Classification analysis; (b) Multidimensional scaling analysis. Numbers refer to site groups and letters to groups of stations separated at 62% dissimilarity level, except for group D separated at 50% level, (from Gray et al [5]).

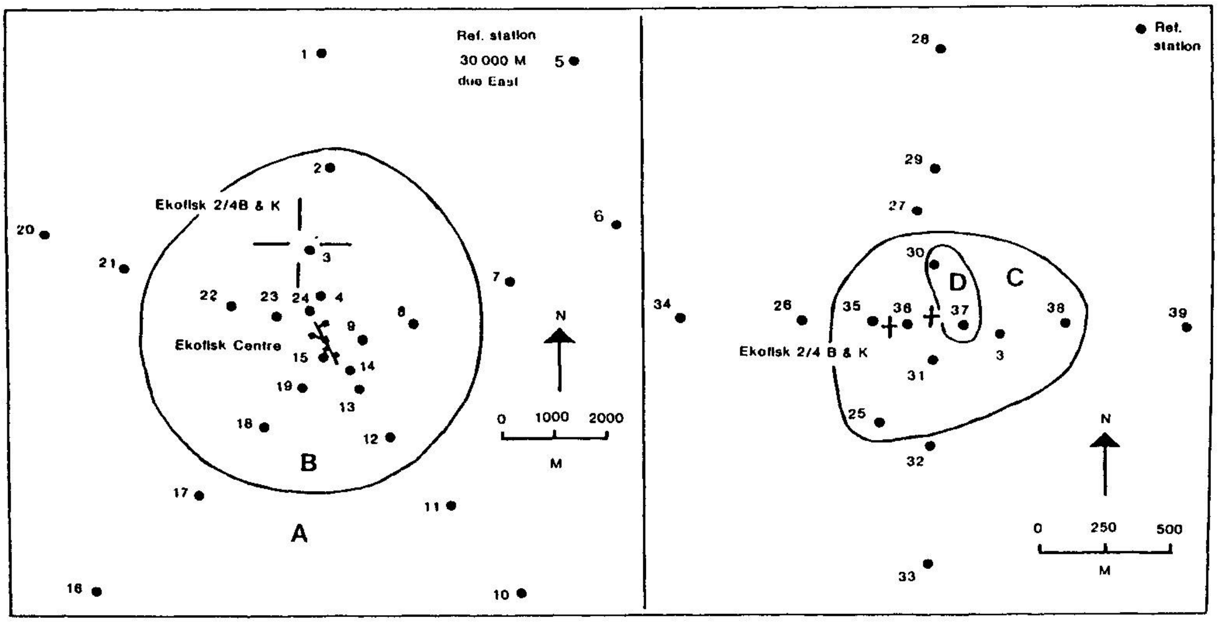

Fig 3. Plots of groups from multivariate analyses on orginal sites. Letters refer to groups from classification analysis (fig 2a), (from Gray et al [5]).

That the gradient is related to oil-related activities can be seen from Fig 4. Fig 4 shows data on total hydrocarbon concentrations (THC), barium content and % of mud (<63 μm particles). In the drilling process barite is used and is discharged with drilling muds and is thus a potential tracer of oil-related activities.

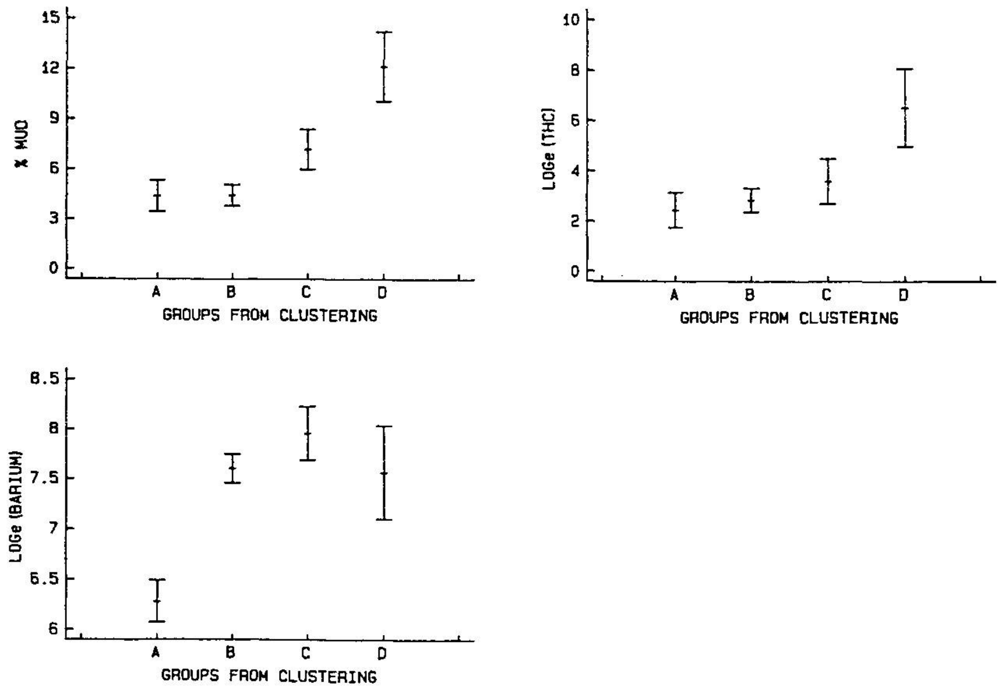

Fig 4. Plots of environmental factors against site groups from classification analysis (fig 2a), (from Gray et al [5]).

There is a clear relationship between species groups and these parameters. Site group C has significantly higher % mud than groups A and B although the level of THC is not higher. For THC there is a gradient from the unpolluted site group A with background levels to the grossly polluted D sites with significantly higher THC levels. Site group A has significantly lower barium content than site groups B,C and D and the levels are comparable to background. So group A sites are regarded as unpolluted, group B just polluted and D gossly polluted with C intermediate between B and D.

The data for the species were found to fall into four distinct patterns. Fig 5 shows data for the bivalve Abra (cf prismatica). Fig 5 (a) shows that there is a gradual decline in abundance starting at a Log_{10} THC level of 1.2 (15.84 ppm). There is a statistically significant difference between abundances at THC concentrations between 37 an 100 ppm and below 15 ppm. No Abra were found at concentrations higher than 400 ppm. Abra showed a similar gradual decline in numbers with barium content (fig 5 b) beginning at concentrations over 200ppm, but only at concentrations above 700 ppm were the abundances significantly different from those at background level.

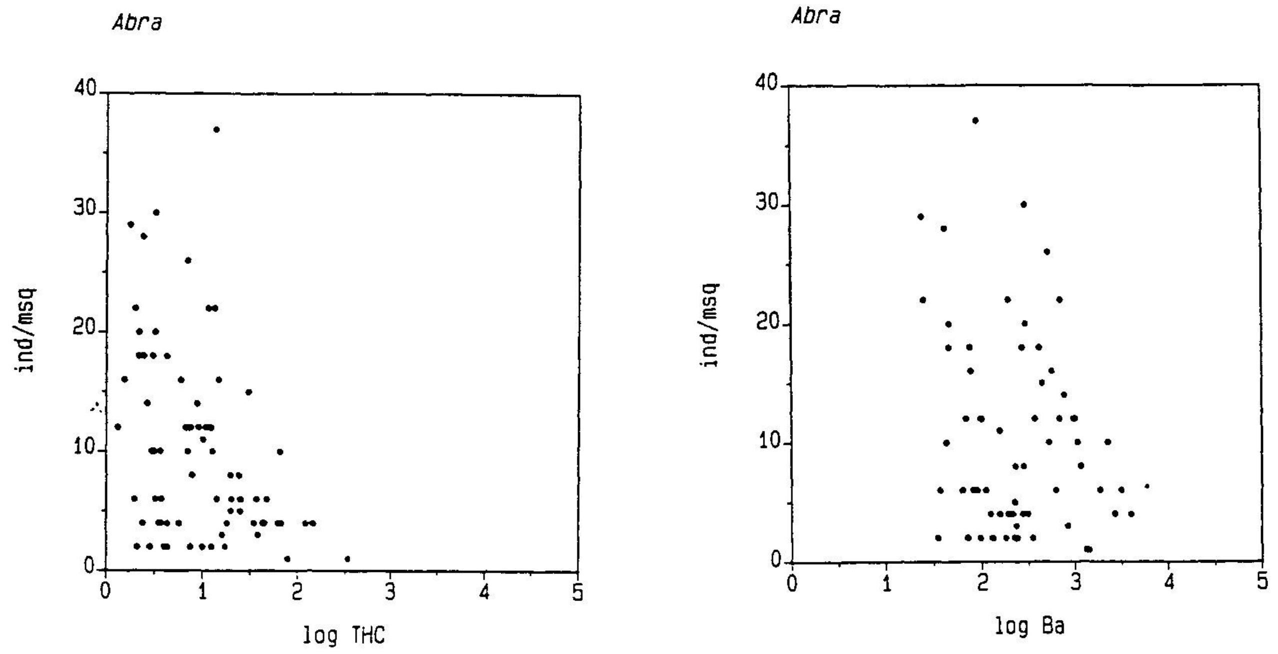

Fig 5 Abundances of Abra cf prismatica at Valhall, Gullfaks, Oseberg and Ula oilfields, N.Sea. a) total hydrocarbon content (THC) of sediment, ppm b) barium content of sediment, ppm.

An almost identical pattern occurs for the cumacean Eudorellopsis deformis with a reduction in abundance begining at 10 ppm THC, but due to high variance within classes the changes are not statistically significant. A dramatic ansd statistically significant increase in abundance occurs at barium levels over 250 ppm and a significant decrease again over 2000 ppm.

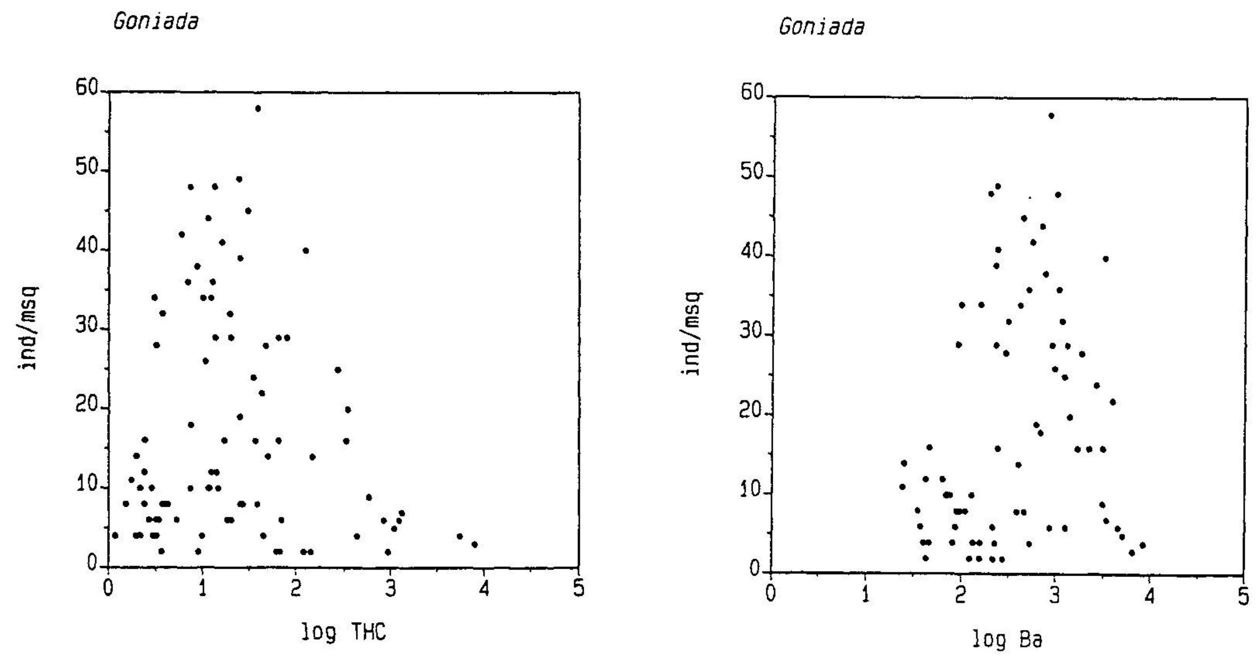

Fig 6 Abundances of Gonidada maculata at Valhall, Gullfaks, Oseberg and Ula oilfields, N.Sea. a) total hydrocarbon content of sediment, ppm b) barium content of sediment, ppm.

The polychaete Goniada maculata shows a slightly different pattern (fig 6 a) with first a significant increase in abundance from background THC levels and then a significant decrease in abundance over 100 ppm THC. G. maculata shows a similar response to barium as to THC (fig 6 b) with a significant increase in abundance from background levels of barium (300 ppm) up to 1000 ppm barium followed by a decrease in abundance.

Nephthys longosetosa (not shown) shows a closely similar pattern to G.maculata with maximum abundances at 10 ppm THC. A decline in abundance occurs at THC concentrations above 10 ppm. For barium N. longosetosa shows maximal abundances at 1000 ppm, and a steep decline in abundance with increasing barium concentrations. The maximal abundance at 1000 ppm barium is significantly different from abundances at higher and lower barium content.

A species that has often been suggested as an indicator of organic enrichment is the polychaete Chaetozone setosa, [6],[7]. Fig 7 shows that with this species there is a large increase in abundance at THC concentrations above 10 ppm but there is no decline in abundance at higher concentrations as with Abra and G. maculata. Abundances over THC concentrations of 700 ppm are significantly different from those below 10 ppm. The response to barium is similar to that to THC with an increase in abundance at concentrations over 500 ppm and maximum abundances at concentrations over 6000 ppm with no decline in numbers. The increase in abundance is however, gradual and variances within barium classes are high so that there is no statistically significant difference between abundances at highest and lowest barium content.

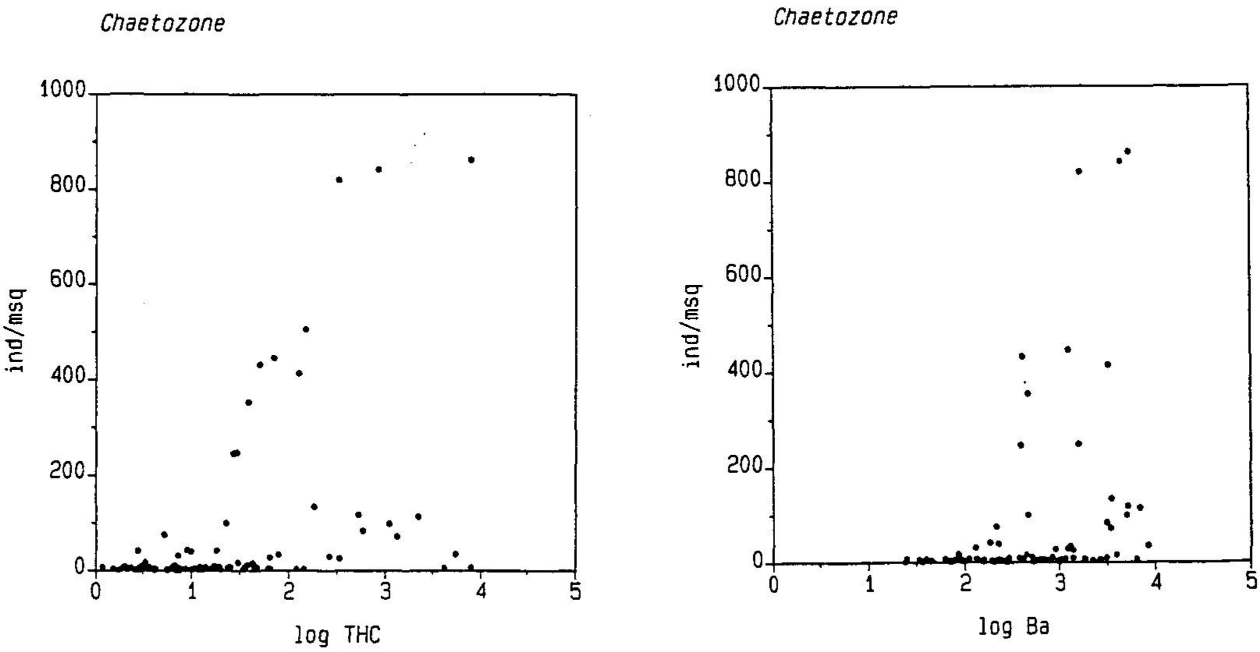

Fig 7 Abundances of Chaetozone setosa at Valhall, Gullfaks, Oseberg and Ula fields, N. Sea. a) total hydrocarbon content (THC) of sediment, ppm b) barium content of sediment, ppm.

Another commonly recommended indicator species for organic enrichment is the polychaete Capitella capitata. Here C. capitata showed a large increase in abundance beginning only at over 300 ppm THC and rising continuously with maximal abundances occurring at THC concentrations of almost 10,000 ppm. Abundances at the highest THC concentration are significantly different from at all other concentrations. So far from being useful as an indicator species C. capitata is merely an indicator of grossly polluted conditions.

The polychaete Aonides pauchibranchiata shows a decrease in abundance from a THC of 10 ppm with total absence over 100 ppm THC but shows no clear response to barium with neither an increase at concentrations over backgound nor a decrease at concentrations of up to 1000 ppm. Due to high variance within classes (THC and barium) there are no statistically significant differences between highest and lowest abundance classes.

Table 1 shows the concentrations of total hydrocarbons (THC) measured in the sediment at selected fields.

Table 1
Concentrations of total hydrocarbons (THC) in sediment at outer stations at the Statfjord oilfield.
(concentrations mg kg^{-1} dry weight)

m dist.	1979	1980	1981	1982	1984	1985	1986	1987	1988	1989
A 2500	15.3	16.3	12.3	10.2	30.1	31.4	45.8	58.9	18.2	41.9
5000	-	<1.0	4.6	3.2	21.2	18.3	22.2	36.8	15.5	9.7
7000	-	-	-	-	-	-	-	41.7	-	-
10000	1.2	2.0	0.8	2.0	-	-	-	-	7.5	-
15000	-	-	-	-	-	-	-	-	7.7	-
B 2500	-	-	1.0	3.3	17.5	7.9	27.6	30.0	19.5	13.6
5000	-	-	-	1.7	9.4	21.6	13.6	8.6	9.8	5.8
7000	-	-	-	-	-	-	-	13.8	-	-
12000	-	-	-	-	-	-	-	28.5	14.5	-
15000	-	-	-	-	-	-	-	-	10.5	-
C2500	-	-	<1.0	1.4	5.5	-	51.8	86.6	17.0	28.8
5000	-	-	-	<1.0	3.5	-	23.7	8.5	17.0	6.6
7000	-	-	-	-	-	-	1.6	13.7	-	-
10000	-	-	-	-	-	-	-	-	3.2	5.0
15000	-	-	-	-	-	-	-	-	2.8	-

The data show that the area affected is largest where discharges are highest. Table 1 shows clearly that background levels for the Norwegian sector of the N.Sea are in the range 2-5 ppm. Values that are above 10 ppm are judged, by the laboratories analysing the hydrocarbon data, to be significantly contaminated. Background values for barium content were more difficult to obtain but were between 100-200 ppm.

Table 1 also shows that as discharge declines so does the THC at the outermost stations. For example at Statfjord B and C at 5000m values declined dramatically within one year from 1986 and from 1987 to 1988 at A and continued to decline at A,B and C to 1989.

Discussion

There is no doubt that overall community structure of the benthic fauna is affected by oil activities out to at least 3 km at Ekofisk in 1987, (Fig 3). The differences between the two outer groups of stations (unpolluted A and just polluted B) is due to changes in abundance patterns of a relatively small number out of the total of over 400 species found. Whether such species respond generally to oil-related activities was tested by posing the hypothesis that the distribution pattern of these species should be similar at other oil fields within the Norwegian sector.

Figs 5-7 showed that the first effects of increased THC began at concentrations above 10 ppm for most of the species studied. For barium a conservative lower limit for effects is 500 ppm. Above THC of 10 ppm and barium content of 500 ppm the initial response was an increase in abundance, but with the exception of Chaetozone and Capitella, the response turns to a negative effect with a reduction in numbers at THC above 100 ppm and barium levels above 1000 ppm. Whether or not the response to THC and barium are independent or simply represent responses to the same gradient remains to be studied. Only A. pauchibranchiata shows a response to THC which is different to the response to barium.

The lowest threshold of response was 10 ppm THC and for the Statfjord field (Table 1) the distance from the platforms that such concentrations were found was 7000-12000m (Statfjord). Similar findings have been found for the Valhall field [7]. In the absence of any measures to control discharges of oil then one can expect significant changes in the species composition of benthic communities out to 10000m and perhaps beyond. Thus the suggestion in Reiersen et al [3], that effects of oil-related activities at the Statfjord C field out to 5,000m could be related to such activities, which was hotly disputed at the time, appear to be confirmed from the present data.

However, the introduction of more stringent regulations controlling discharges leads to rapid improvement in conditions, which can be measured after only one year. New regulations for discharge of oil contaminated cuttings were introduced from 1988 by SFT. The operators were asked to reduce the use and discharge of oil-based muds. The effects of this change in policy can be seen both in the reduction in total tons discharged and on concentrations measured in the sediment at the outermost stations. Despite the increased number of wells drilled discharges were reduced by nearly 50%. In 1989 cuttings from three wells were taken ashore and amounts of oil-based drilling muds severely reduced at others. The figures clearly show that stricter regulations have had a positive effect on the environment. It is unlikely therefore, that the effects on the fauna at levels down to 10 ppm found with use of new analysis techniques [5] will extend out to 10000m or beyond.

From January 1st 1991 the discharge of oil-based muds will be banned in the Norwegian sector of the N.Sea. Exceptions will be allowed for existing fields with a transition period up to January 1st 1993 and where for geological or safety reasons it can be documented that use of oil-based drilling muds are necessary.

The Norwegian experience can be summarised as the imposition of tighter guidelines for monitoring has led to more reliable data on environmental conditions around oil fields. The, now, high quality of the data obtained by the oil companies has allowed new techniques of biological effects assessment to be applied. These techniques show effects at THC levels down to 10 ppm. This in turn has led to tightening of the legislation on discharge from oil platforms in the Norwegian sector. With imposition of the new legislation rapid improvement of environmental conditions has been observed at stations distant from the platforms. Thus rather than a conflict between environmental control authorities and the oil companies, a mutually benefical state has been reached where the oil companies conduct state-of-the-art monitoring which the SFT then can ensure that unacceptable environmental damage will not occur. Whilst the general public has not been involved in this debate, (nor for that matter have the "green" movements) it does demonstrate the positive interaction that can be generated between environmental control agencies and environmental research aimed at measuring the earliest effects of degradtion of the environment.

References.

1. DAVIES, J.M., ADDY, J.M., BLACKMAN,R., BLANCHARD, J.R., MOORE, D.C., SOMERVILLE, H.J., WHITEHEAD, A., WILKINSON, T., Environmental effects of oil based drilling mud cuttings. Mar. Pollut. Bull., 15, 363-370, 1984.

2. REIERSEN, L-O., GRAY, J.S., PALMORK, K.H., LANGE, R. Monitoring in the vicinity of oil and gas platforms; results from the norwegian sector of the North Sea and recommended methods for forthcoming surveillance. In Drilling Wastes (F.R.Engelhardt, J.P. Ray, A.H. Gillam Eds.) Elsevier Applied Science, 91-117, 1989.

3. ENGELHARDT, F.R., RAY, J.P., Environmental Politics. Mar. Poll. Bull. 20, 41-42 1989.

4. GRAY, J.S. A reply to Engelhardt and Ray. Mar. Poll. Bull. 20, 42, 1989.

5. GRAY, J.S., CLARKE, K.R., WARWICK, R.M., HOBBS, G., Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. Mar. Ecol. Progr. Ser. 66, 285-299, 1990.

6. PEARSON, T.H. & ROSENBERG.R. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. mar. biol. A. Rev. 16, 229-311, 1978.

7. PEARSON, T.H. GRAY, J.S. & JOHANNESSEN,P. Objective selection of sensitive species indicative of pollution-induced change in benthic communities.2. Data analyses. Mar. Ecol. Progr. Ser. 12, 237-255, 1983.