Pergamon

Marine Pollution Bulletin Vol. 38, No. 7, pp. 525–530, 1999

Printed in Great Britain

PII: S0025-326X(99)00004-1

0025-326X/99 $ – see front matter

VIEWPOINT

Managing the Environmental Effects of the Norwegian Oil and Gas Industry: From Conflict to Consensus

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In the early days of exploitation of the oil resources on Norway's continental shelf there was little control over environmental impacts. The oil companies expected effects of their activities to be found to a 1 km radius round platforms. In the late 1980s data started appearing that suggested that effects were over much larger areas. These findings were disputed but subsequent studies showed that a more realistic figure of the area affected was a 3 km radius giving roughly 10 times the area predicted by the companies. The Norwegian authorities reacted by imposing restrictions on discharges of oil-based drilling cuttings and since 1993 oil-based drilling mud or cuttings have not been intentionally discharged to sea on the Norwegian shelf. In 1996 Norway changed its offshore monitoring from field based monitoring of sediments to a regional monitoring of both sediments and the water column. The change makes it possible to obtain a better overview of the environmental conditions, at the same time it also reduces costs for the operators.

One of the most unfortunate scientific predictions ever made was that of the Norwegian Geological Survey who in 1958 in a report to the Norwegian foreign department stated, "one can exclude the possibility that coal, oil or sulphur can be found on the Norwegian continental shelf". Fortunately for the economy of Norway this prediction was wrong and Norway is now the world's fourth largest oil and gas exporter.

Phillips was the first company to seek permission to explore for oil in 1962. In 1965 the permission was granted (Table 1) and two days before Christmas in 1969 oil was found at the Ekofisk field and the oil adventure had begun. At first exploration was restricted to South of latitude 62°N. The first permission for drilling North of this latitude was given in 1980. Last year a new phase began with exploration at depths of 1500 m in the Vøring plateau, much different from the ca. 70 m at Ekofisk.

Exploratory drilling involves use of a number of chemicals, including lubricating oils and the use of fluid material, so called drilling muds composed of barium, but since it is derived from natural deposits it comprises a number of additional elements notably small amounts of other heavy metals. In the mid to late 1970s the use of oil based drilling muds increased rapidly due to their technical superiority over water based muds when drilling difficult and non-vertical wells. In the early days of exploration, the material reaching the surface (drilling muds which could not be recycled and drilling cuttings), were discharged into the sea. In the early 1960s it was felt that the composition and amounts of these wastes were unlikely to lead to detrimental environmental effects. For the Ekofisk field Phillips in 1968, produced in an Environmental Impact Assessment (EIA). This was presented to the relevant Norwegian authority the Norwegian Pollution Control Authority, (Statens forurensningstilsyn SFT), and predicted that they expected the species diversity of the benthic organisms inhabiting the seabed to be affected to a maximum of a 1 km radius from the drilling platform. Extensive discharge of oil based muds on cuttings to the North Sea bottom occurred from 1965. In 1985 the Paris Commission Working Group on Oil Pollution (Paris Commission, 1985) compiled a list of "agreed facts" on the impact of oil based muds. They concluded that the effects on benthic organisms in general was confined to less than 1 km from the discharge source, and with a few exceptional cases reaching to 2 km. Fig. 1 shows the development of the oil industry in Norway and the discharges up to 1993 showing a decrease in the later period.

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TABLE 1

History of the Norwegian gas and oil industry.

1962	Phillips applies to do geological survey
1963	21st June Norway declares that undersea resources belong to the Sttate
1965	278 blocks released South of latitude 62°N
1969	23rd December Phillips finds Ekofisk field
1970	Tor and West Ekofisk discovered
1971	4th August first oil shipped
1973	Statfjord field found, one of world's largest
1977	2200 Friday 22nd April Bravo "blow-out"
1980	"Alexander Kielland" platform capsizes 123 die
1980	Drilling North of 62°N permitted
1986	Troll field gas sold for £50,000 million
1989	30th March First oil shipped directly to Norway
1998	Exploration on Vøring Plateau at 1500 m depth

Development of Environmental Control Procedures

From 1973 the Norwegian authorities required all the companies exploring on the continental shelf to submit annual reports on the environmental conditions in the areas being explored. The companies engaged a variety of consulting companies to do this work. The requirement for monitoring associated with the operator's activity is given in relation to their discharge permit. The first monitoring was done at Ekofisk in 1973. At Statfjord the first monitoring (chemistry) was done in 1978. At that time SFT received these reports, but they were not reviewed or analysed.

In the mid-1970s Norway established a new research programme Forskningsprogram om Havforurensning, FoH, (the Research Programme on Marine Pollution) where the oil industry came into focus. With the establishment of FoH and with a new strategy for the overseeing of the environmental aspects of the oil industry at SFT, expert review of the annual reports began in the mid-1980s. An initial analysis of the data from several surveys at the Statfjord field (Reiersen *et al.*, 1988) suggested that the biological effects were over much greater areas than that predicted in the companies EIAs. This paper received an extremely hostile reception from the oil companies and when printed (without the authors knowledge), had a disclaimer added to the first page suggesting that the results were not to be trusted!

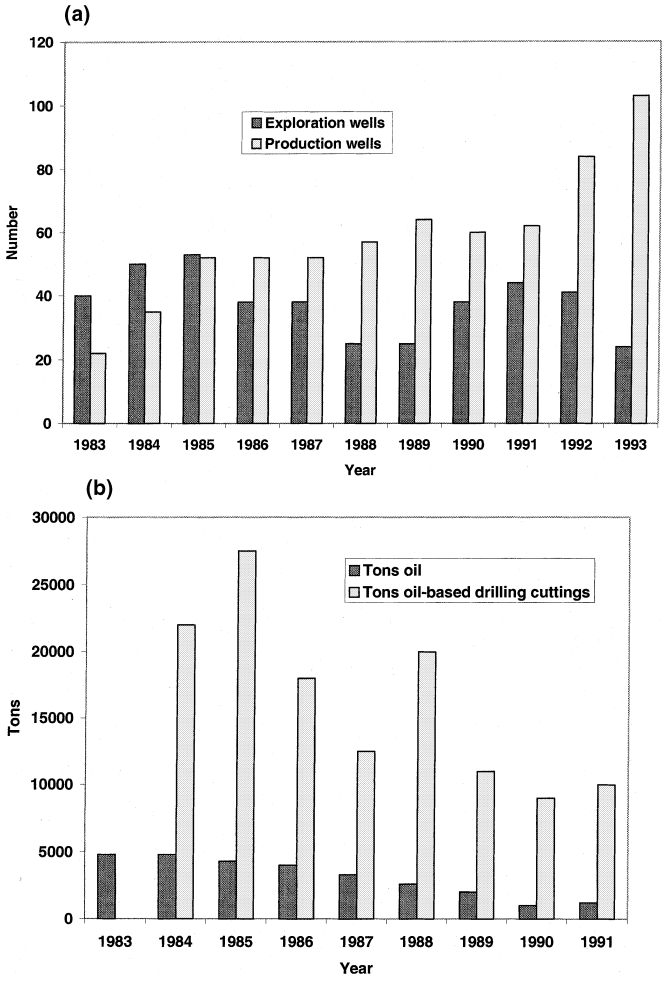

Fig. 1 Development of the Norwegian oil industry: (a) showing number of exploration and production wells and (b) discharges of oil and drilling cuttings.

TABLE 2

Development of environmental programme.

1970–1985	Annual reports submitted by companies to The Norwegian Pollution Control Authority (SFT)
1985	Expert group established (2 biologists 2 chemists) to review reports
1988	Official guidelines for monitoring methods established and adopted by OSPARCOM
1990	Norwegian guidelines made mandatory for Norwegian offshore monitoring
1993	Regulations which prohibit discharge oil-contaminated drill cuttings on the continental shelf enter into force
1997	Revised Norwegian guidelines published

TABLE 3

Monitoring programme established in 1989.

A fixed network of stations is established at each field on 4 radii (at 0°, 90°, 180° and 270°) and at logarithmically increasing distances (250, 500, 1000, 2000 and 4000 m) from the structure
For all fields during drilling: annual chemical surveys covering sediment particle size, heavy metals and hydrocarbons, once every 3 years biological surveys of sediment-living macrofauna
For oil fields during production: as during drilling
For gas fields during production: surveys once every 6 years

Further analyses of the monitoring reports showed that quality control left much to be desired. In the worst case a survey had revealed more than 300 species of benthic organisms whereas a re-survey of the same area 5 years later reported only 26. Pollution was not the cause, quality control was simply non-existent. Similar examples were found with the chemical analyses. SFT responded by setting up an expert group in 1986 with the primary objective of assessing the quality of the reports. Simultaneously an initiative was made by SFT to establish common guidelines as to how the monitoring should be done. Sampling methods for both biology and chemistry were standardised as were analysis methods, (including statistical). The Guidelines were developed by the expert group based on two-day scientific workshop held in 1987, and were subsequently discussed in an open forum with the oil companies. The Guidelines were largely based on the best practices already used by the scientific community and the oil companies. In 1988 the Guidelines were adopted for general application, by the Paris Commission, and in 1990 they were made mandatory for monitoring around Norwegian fields (Table 2).

The basic outline of the monitoring programme that was established in 1989 is shown in Table 3. Figure 2 shows a typical sampling design. In addition a reference station is required 10 km away. One important aspect of the Norwegian system is that once the reports are received by SFT they are in the public domain and open to scrutiny by interested scientists, the green movement or members of the public. The cost of the annual surveys required by Norwegian legislation is estimated at NOK 1.6 million per field (ca. £130,000).

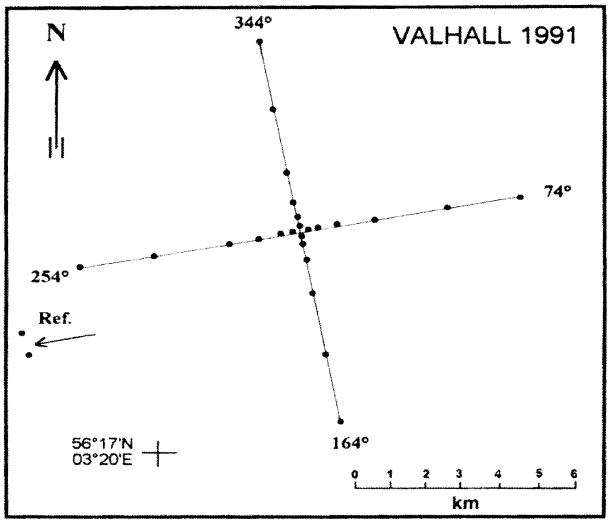

Fig. 2 Typical sampling design.

Reassessment of Environmental Effects

By use of the expert group SFT had established annual reviews of all the reports submitted as well as the production of annual summary reports on the environmental condition around the Norwegian offshore installations. At that time new statistical methods for examining effects on benthic organisms had been developed and were being applied. Gray *et al.* (1990) published an analysis of the Ekofisk data submitted to SFT. It was clearly apparent to the expert group that effects on the benthos covered much larger areas than that predicted in the mid-1960s by the oil companies, (3 km^2 at each drilling or production platform where drilling muds and cuttings were discharged) and by the "agreed facts" of the Working Group of the Paris Commission (1985). Data from several surveys, Bakke *et al.* (1990) and Davies *et al.* (1998) also found that some of the more common benthic invertebrates around North Sea oil and gas fields were reduced in abundance at oil concentrations which could be expected as far out as 10 km or more from the drilling discharge points, thus, supporting the conclusions from Reiersen *et al.*

(1988) that the biological effects were over much greater areas that predicted in the companies EIAs. Gray *et al.* (1990) findings aroused controversy since it was argued, notably by the oil companies and by the British environmental authorities, that no effects on fish or fish food had been found. The effects were merely on "worms and snails".

The response of the Norwegian authorities was that the effects were unacceptable because they covered ca. 10 times the area predicted by the oil companies' EIAs. This is an important aspect that is not generally appreciated. The criterion used by the authorities is that what is tested is compliance with the prediction by the EIA of the area affected. If instead one asks the question, "Are there effects on fish or food for fish?" then the one cannot use the monitoring data obtained but have to make value judgments as to whether organisms not actually monitored are likely to be affected. Since value judgments are subjective then there is room for constant argument. Testing for compliance with environmental criteria should not be left to subjective appraisal. Thus, it is essential that EIAs make quantitative predictions which can then be tested using objective statistical methods.

Finding that the effects were greater than predicted in the EIA, the Norwegian authorities in 1991 applied legislation. This permitted the maximum amounts of oil to be discharged with cuttings at 60 g kg^{-1} up to 1 January 1993, and after 1 January 1993 intentional discharge of oil-contaminated cuttings was prohibited on the Norwegian continental shelf.

That this legislation was justified became apparent after Olsgard and Gray (1995) analysed much of the data then available on the effects of oil and gas exploration on the Norwegian continental shelf. They found that the Ekofisk result of effects on benthic organisms to a radius of 3 km (i.e., ca. 30 km^2) at a single field was a general. Figure 3 shows the historical development of effects at the Gyda field (1987 was the baseline survey). Three years later effects were marked and after 6 years effects were found to an area similar to that at Ekofisk.

The regulations on discharges of oil-based drilling muds and cuttings in the Norwegian sector by 1993 led to the operators investing in new technology. The technologies included reinjection down bore holes, retaining material and disposing on shore, development of new drilling procedures, as well as introducing synthetic drilling fluids (based on esters, ethers, olefins, etc.) with comparable technical performance to that of oil based mud. Since 1993 there has been a rapidly increasing use of these synthetic muds in the Norwegian sector, under licenses given by SFT.

Now that water-based and later generation synthetic drilling fluids are used effects are much less extensive than with oil-based fluids. Figure 4 shows a survey at the Tordis field conducted in 1995 (Gjøs *et al.*, 1996). Drilling took place between 1987 and 1989 and the area has received Barite 4054 tonnes, Novadril (polyalpha-olefin-based) 160 tonnes, Finagreen (ester based) 2.6 tonnes and the following accidental spills: Ethylene glycol 1500, 1, Novadril fluid 7.3 tonnes, oil 1.4 tonnes. Figure 4 shows that the area extent of effects some 6 years after discharge began is far less than at Gyda, for example, and even those affected areas have high numbers of species and show at most very slight effects. Thus the legislation and follow up by the companies has led to a dramatic reduction in pollution levels.

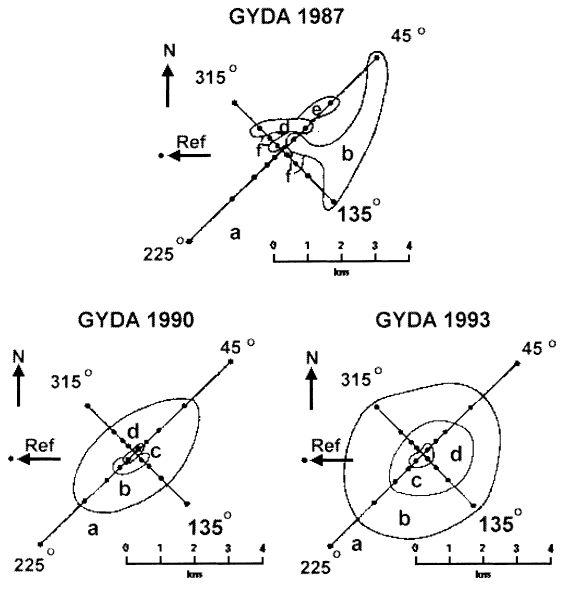

Fig. 3 Development of effects of pollution on benthos at Gyda oil field.

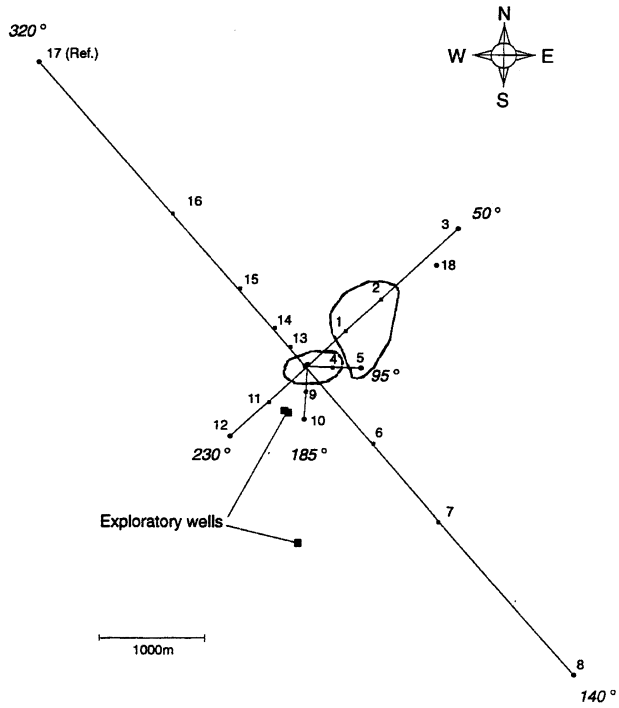

Fig. 4 Area of effects of non-oil based drilling muds: Tordis field 1996.

The monitoring system required each company to investigate each field. As new marginal fields were developed the sampling design for close fields led to overlap of sampling stations. Often different consultant companies were involved in adjacent surveys that were costly and led to inefficient analysis as methods although similar (as required by the Guidelines) were not identical. There were still differences in quality of the reports submitted. Since control stations were 10 km away these were often not appropriate as controls having different depths and sediment types or were influenced by new neighbouring fields. An increased number of fields and changes in the discharge situations led the Expert group to recommend to SFT that the Guidelines, although working well and giving reliable data, had become obsolete regarding sampling design and strategy. Revision was needed and regional monitoring including both sediment and the water column was established.

Regional Monitoring Introduced in 1995

The whole of the Norwegian continental shelf is devided into 11 regions (Fig. 5). Only regions I–VI have oil exploration or production at the moment. Monitoring is now required at a regional level rather than by each company investigating only its own sites. Each regional survey is done by one single consulting company. The oil companies, through their national organisation (OLF) develop the proposal and agree on joint financing. The proposal is then put up for tender and the consultants bid for the contract. Since the requirements are for large surveys only two consulting companies now have the resources and have national accreditation and are prequalified to submit tenders. Both are highly regarded, both by the companies and the experts who review their reports.

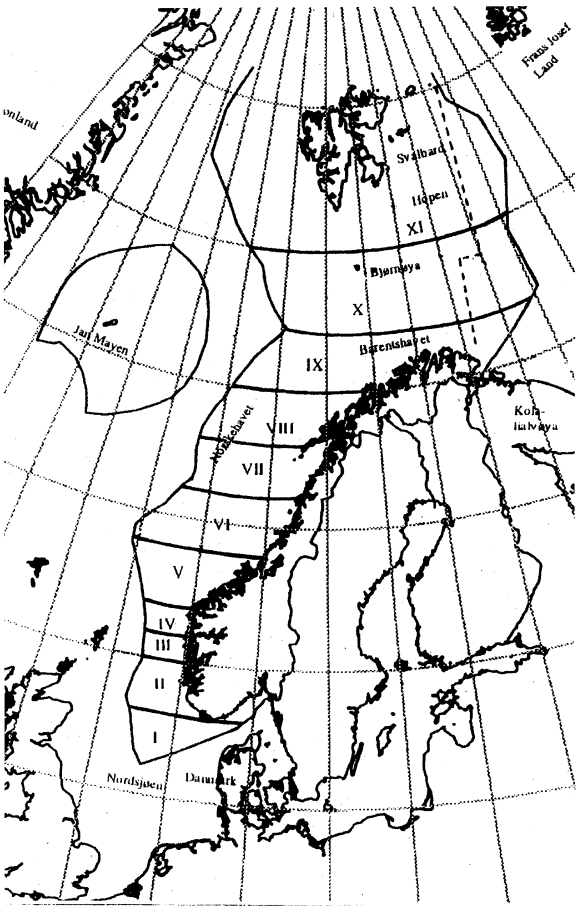

Fig. 5 Regional monitoring programme started in 1995.

The sampling sites cover all the oil fields and in addition a number of general reference sites are included. The purpose of these is to provide data for long-term changes such as those included by climate change.

Each year two regions are covered so that within 3 years the whole continental shelf from 56° to 68° is covered, which is the area which has been drilled to the end of 1998. The first whole shelf survey has been completed and we are beginning the second cycle.

The new monitoring systems makes it possible to know the environmental effects of the offshore activities on a regional basis. On the other hand the companies are pleased with the new monitoring system since they save on average NOK 15 million per company per year with a co-ordinated and more efficient system. Equipment is purchased centrally and standard containers are now available with the gear needed stored centrally. With fewer companies involved it is far easier to examine trends in distribution patterns of fauna across the whole shelf and this provides knowledge of zoogeography and long-term changes which were not possible previously.

The new regional monitoring has thus led to excellent collaboration between the authorities, oil companies, scientists and consultants and shows that the scepticism of the 1960s has changed to a fruitful and profitable liaison which has led to protection of the marine environment and a mutually beneficial data collecting system.

We thank the Norwegian and foreign oil companies that are partners in OLF for allowing us to use the data obtained and to Akvaplan-Niva and Det norske Veritas for their co-operation when reanalysing some of their data.

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