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RAPPORTER OG MELDINGER
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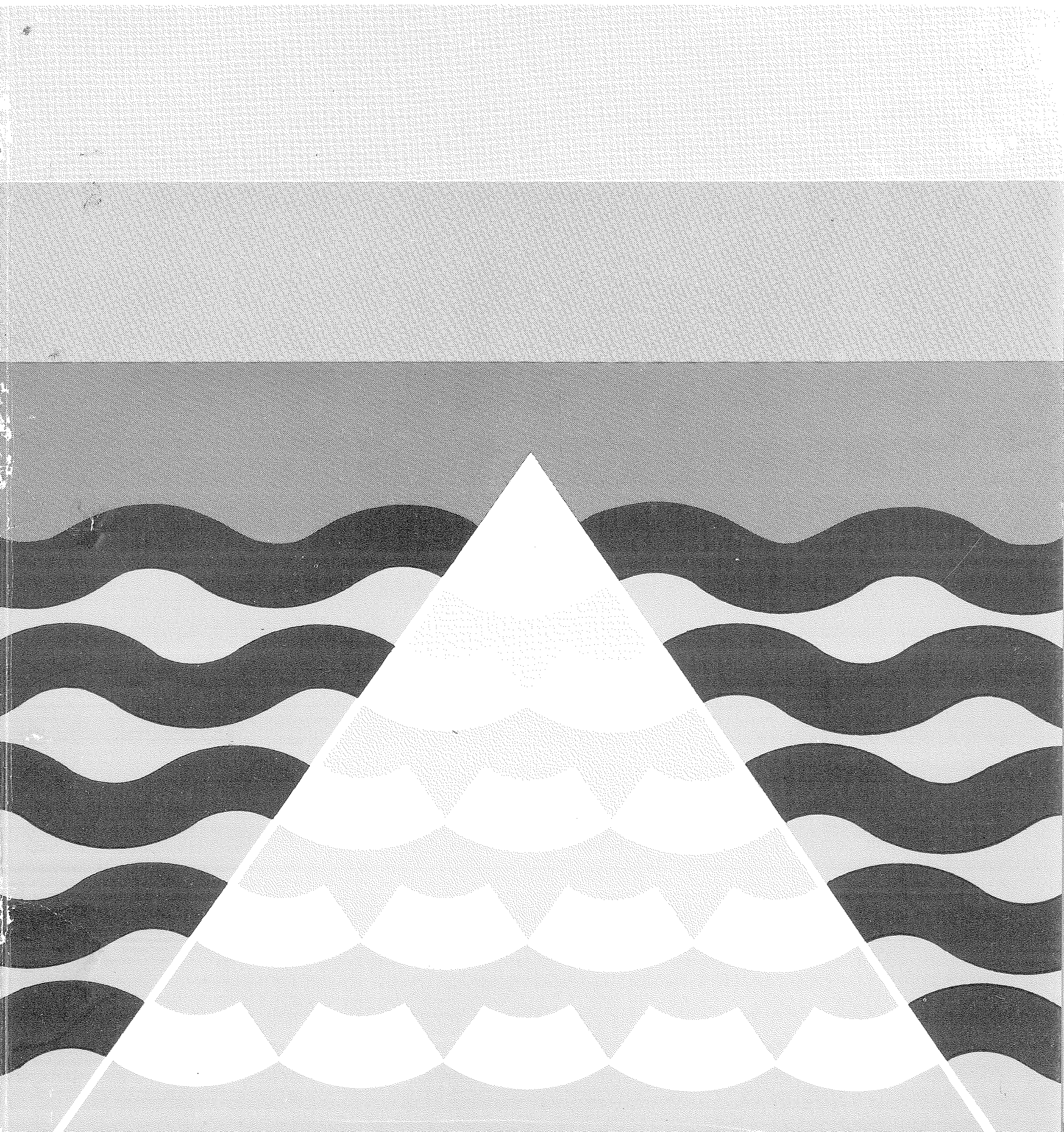

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THE BRAVO BLOW OUT

A report on marine research activities April 23 to May 5 1977
including some preliminar results

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PREFACE

The present report is based on the observations made by KNM "Sleipner", R/V "G.O. Sars" and R/V "Johan Hjort" during the first 10 days following the "blow-out" at Ekofisk Bravo. The Institute of Marine Research expresses their thanks to the officers and crew on KNM "Sleipner" (as well as on their own research vessels) for the willing manner in which they undertook the additional spell of duty this task involved. Thanks are also due to the staffs and crew on R/V "Corella", R/V "Dana" and R/V "Explorer" for their readyness to participate with coordinated programs.

CONTENT

INTRODUCTION

On Friday night April 22 a "blow-out" started at the oil production platform Bravo, situated at 56°33'N, 03°12,2'E within the Ekofisk area in the North Sea. The blow out resulted in uncontrolled discharges of crude oil through the open pipe 20 m above sea surface at an estimated rate of 3-4000 tons per day. The oil mixed with about 50% gas held a temperature of about 75°C at escape and was blown another 30 m into the air and sprayed over the sea surface. Depending on wind forces and the movement of surface waters during the following days the resulting oil slick attained varying shapes, patches of about 1 cm thick oil slicks interchanging with areas of thin film and streamers of oil.

Ekofisk crude oil is light-flowing and spreads rapidly on the sea surface. It has a high content of volatile aromatic hydrocarbons which also are known to contain the more toxic compounds to living marine resources. Chemical dispersion of the oil into the sea would increase the availability of these compounds to the living resources. Since these were most exposed and no coastal interests seemed to be immediately threatened, it was recommended to leave the oil drifting on the surface, thus also to benefit maximally from the evaporation of the volatile toxic compounds. The authorities decided on such a procedure and to use all available mechanical means to recover as much as possible of the oil

The blow-out lasted $7\frac{1}{2}$ days until an expert team after several attempts succeeded in capping the well at 1105 April 30. The remaining oil slick estimated to some 13-15000 tons had then spread over an area of about 4000 km^2 interrupted with areas of seemingly unpolluted waters.

The North Sea houses fish resources of greatest importance to the coastal states, and not least to Norway itself. International fisheries in this area amount to about 3 mill. tons per year devided on a number of species as exemplified by Table 1. These resources reproduce at different spawning sites spread over the entire area, some of which also are situated around the Ekofisk field. This applies for example to the very important mackerel resources where Ekofisk is centered in the middle of its usual spawning area.

Table 1. Species and catches in the North Sea and Skagerrak, 1975. (Data from ICES Working Groups).

Species	Total	Norway
Saithe	271 148	16 547
Herring	365 209	35 879
Mackerel	317 800	241 533
Norway pout	559 600	218 900
Sand eel	424 800	54 000
Cod	219 976	3 957
Haddock	190 118	10 293
Whiting	168 099	13 355
Plaice	124 193	19
Sole	18 761	0
Blue whiting	41 000	41 000
Total	2.371.704	635.483

Several of the fishes are spring spawners and spawning is timed to the vernal development in the plankton. During winter and early spring poor stratification in the waters and the lack of light result in a poor plankton production. Stratification will normally commence in April as the result of solar radiation, and a typical spring bloom of phytoplankton sets off. It is followed by spawning and rapid developments in the zooplankton. Eggs and nauplii of copepods, especially Calanus finmarchicus constitute the most important food for the fish larvae, and their abundance is a prerequisite for success in fish reproduction. For the mature fishes also krill are important and abundant feed organisms in this area.

When the blow-out became known on Saturday morning of April 23 scientists of the Institute of Marine Research met to discuss the situation and prepared a research program for immidate application.

It was foreseen that the blow out might imply serious negative consequences to the fish resources in the area and it would be the task of the scientists to describe possible effects and inform the authorities accordingly. Additionally, the situation obviously gave an unique opportunity to study different scientific aspects of oil behaviour and fate in the marine environment.

The program contained the following elements:

1. To describe the occurrence and distribution of living resources, with emphasis on the plankton including fish eggs and larvae. These organisms living mainly in the surface layers of the sea would be most exposed. They are also known to contain the elements of the marine biomass more sensitive to oil pollution, where possible effects might be traced.

2. To describe the distribution of ongoing fisheries in the area threatened by the oil spill and the fish resources on which they were based.

3. To record possible irregulatities in mortality and development of plankton and fish larvae.

4. To obtain samples for chemical analysis of the horizontal and vertical distribution of petroleum hydrocarbons in the sea water.

5. To obtain samples of fish and plankton for chemical analysis on sorbed petroleum hydrocarbons.

6. To study the environmental effects on oil on the sea surface (weathering). Oil samples representing varying ages after discharge to be collected at different distances from the source and to be analysed on relative hydrocarbon composition.

7. To study microbial degradation by culturing and enumerating oil degrading bacteria and fungi.

8. Hydrographical standard program and currents, waves and drift recording using buoys and remote sensing.

The complex research program required the use of the adequately equipped research vessels of the institute, "G. O. Sars" and "Johan Hjort". However, they were not readily available, the first being docked in Bergen for repair work and the other being in northern waters on programmed research activities. It was decided to interrupt these activities and as soon as possible prepare both ships for the programme at the scene of the blow-out. Awaiting this and as an intermediate arrangement, the Norwegian Navy agreed to put the corvette KNM "Sleipner" to our disposal from April 23 to 26, and in this way a scientific team succeeded to go to the scene within 24 hours after the blow-out had started. R/V "G. O. Sars" and R/V "Johan Hjort" were ready to leave Bergen April 26, with additional members of the team. All together 28 scientists and technicians participated. Among these were guests from other national laboratories and a Danish scientist appointed by the Danish Environmental department.

A rectangle of about 60 x 70 nautical miles (Fig. 1) including both the polluted and non polluted waters was selected to be covered by the research vessels. The selection was based on previous knowledge of the hydrography of the area and information obtained on the formation and drift of the oil slick (Fig.2). Within this area a smaller square of 30 times 30 nautical miles was selected for more intensified investigations. KNM "Sleipner" had the previous days operated a more flexible research program within this latter area where observations were concentrated along the borders of the oil slick. (Fig. 3).

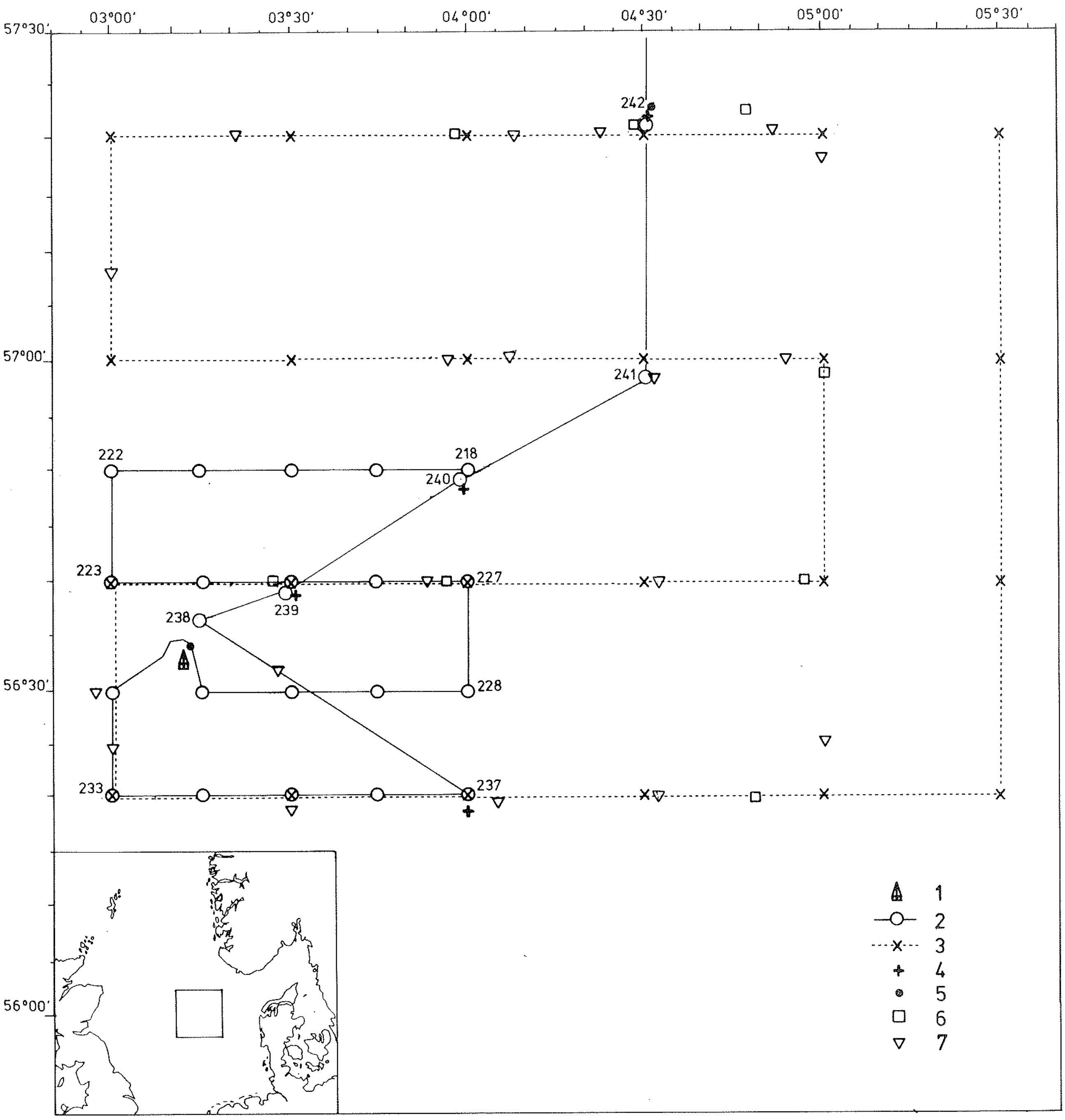

Fig. 1 Station grid systems for R/V"G. O. Sars" and R/V "Johan Hjort". Symbols: 1: Bravo platform, 2: "G. O. Sars" stations, 3: "Johan Hjort" stations, 4: Current meter moorings, 5: Telemetric buoys, 6: Bottom trawl stations, 7: Pelagic trawl stations.

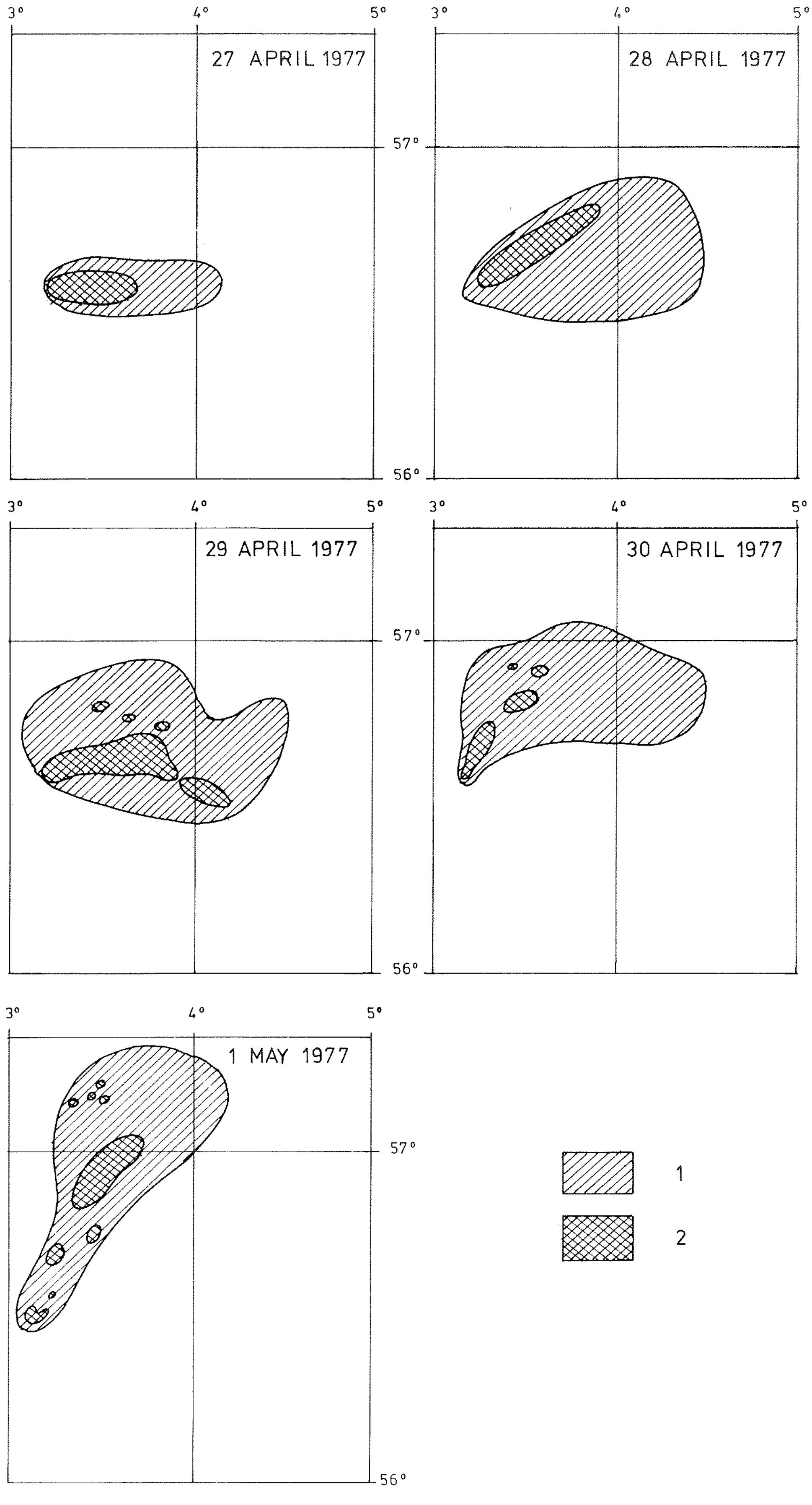

Fig. 2 The distribution of oil in the area based upon information from the Continental Shelf Institute, Trondheim.

1: Blue shine and streamers.

2: Dense slicks and lumps.

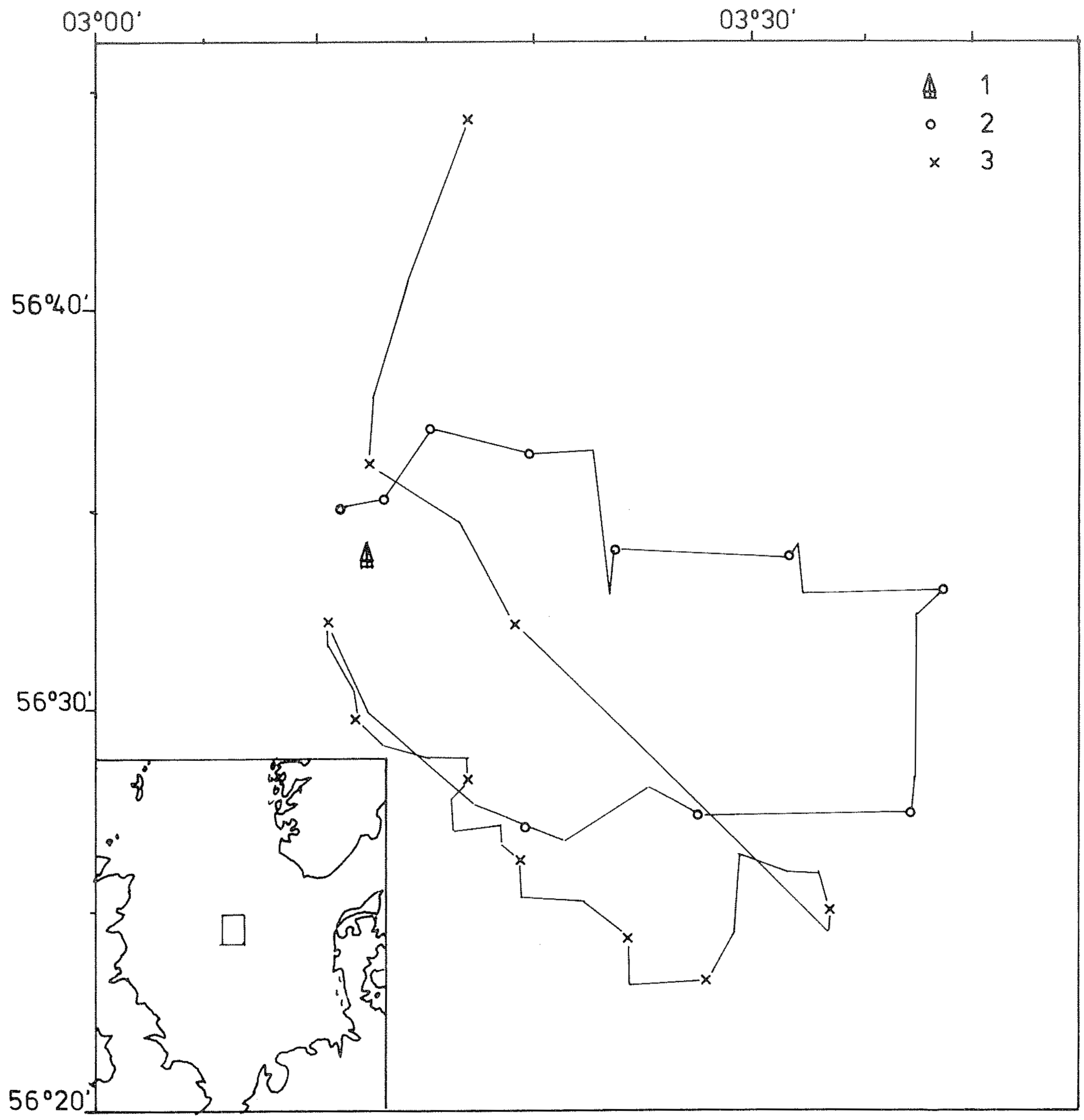

Fig. 3 Station map for KNM "Sleipner", Symbols:
1: Bravo platform, 2: Stations Sunday 24.4.,
3: Stations Monday 25.4.

The British R/V "Corella" from Lowestoft participated in the chemical and biological program sampling within the same grid system. Twice daily joint reports on findings were prepared and communicated to the Norwegian authorities and the Rescue Central in Stavanger. Later the Danish R/V "Dania" and the Scottish R/V "Explorer" participated together with R/V "Johan Hjort", with coordinated observations and in this way made it possible to continue the series of information. Additional programs on effect studies was also including by R/V "Explorer".

The field program is not yet completed, and R/V "G. O. Sars" is programmed for a second cruise to the area on May 10 and for the following 6 days. Also German scientists have announced their participation with a research vessel.

A final evaluation of the effects of the oil spill has to await the completion of these programs and the analytical work. The following is a report on the cruise activities including preliminar results of the analytical work from the Norwegian research programs, prepared for participating colleagues as well as for the authorities. The sub programs on hydrography and microbiology were conducted in cooperation with representatives from the Continental Shelf Institute and the Institute of Technical Biochemistry, both in Trondheim.

HYDROGRAPHY

Methods: The hydrographical stations are shown on Fig. 1 A CTD sonde was used to record salinity and temperature versus depth onboard R/V "G. O. Sars". Nansen casts at standard depths were used onboard R/V "Johan Hjort" to obtain samples for salinity determinations and temperature.

Recording current meters were moored at the positions indicated in the figure. Two of the current meter moorings were collected after one week, the other two will be collected in a month.

The data from the current meters will be used to recalibrate prediction models used during the oil spill and to supplement the basis for description of the hydrographic conditions in the area.

Two drift buoys were put out to measure the wind drift, the first 1.1 nautical mile east of Bravo and one in the position 57°22'N 04°31'E. The signals transmitted from the buoys is picked up by the NIMBUS 6 satelite in order to establish the position of the buoys. The drift is recorded at the NASA center and the observations will be used in the models mentioned above.

Results: The hydrographic condition is characterized by four distinct water masses. A core of cold water occurred between 10 meter depth and the bottom in the center part of the investigated area. The temperature of the core was close to 5°C and the salinity slightly below 34,8°/oo. (Fig. 4, 5, 6 and 7). This water mass was probably locally formed by winter cooling and indicates an eddy.

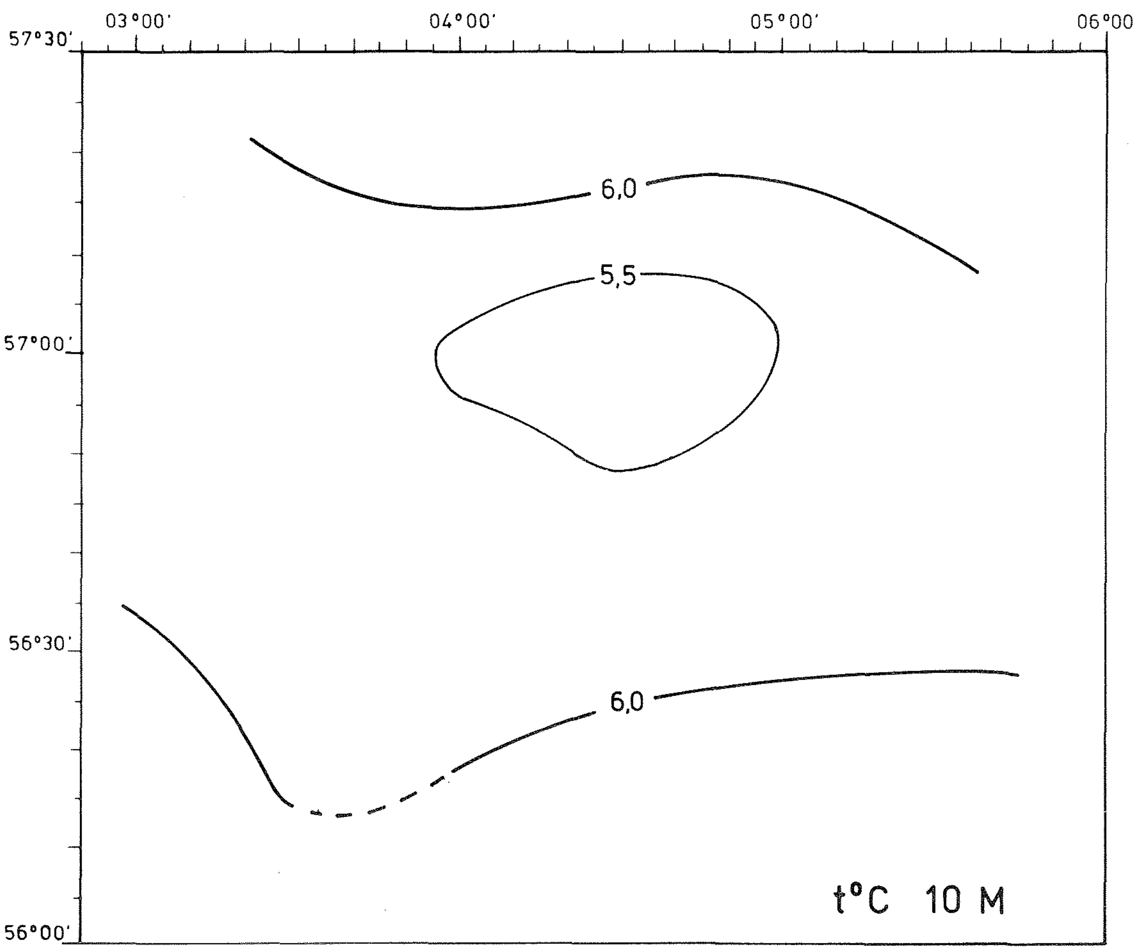

Fig. 4 Temperature, t°C, at 10 meter depth, April 27 - 1 May.

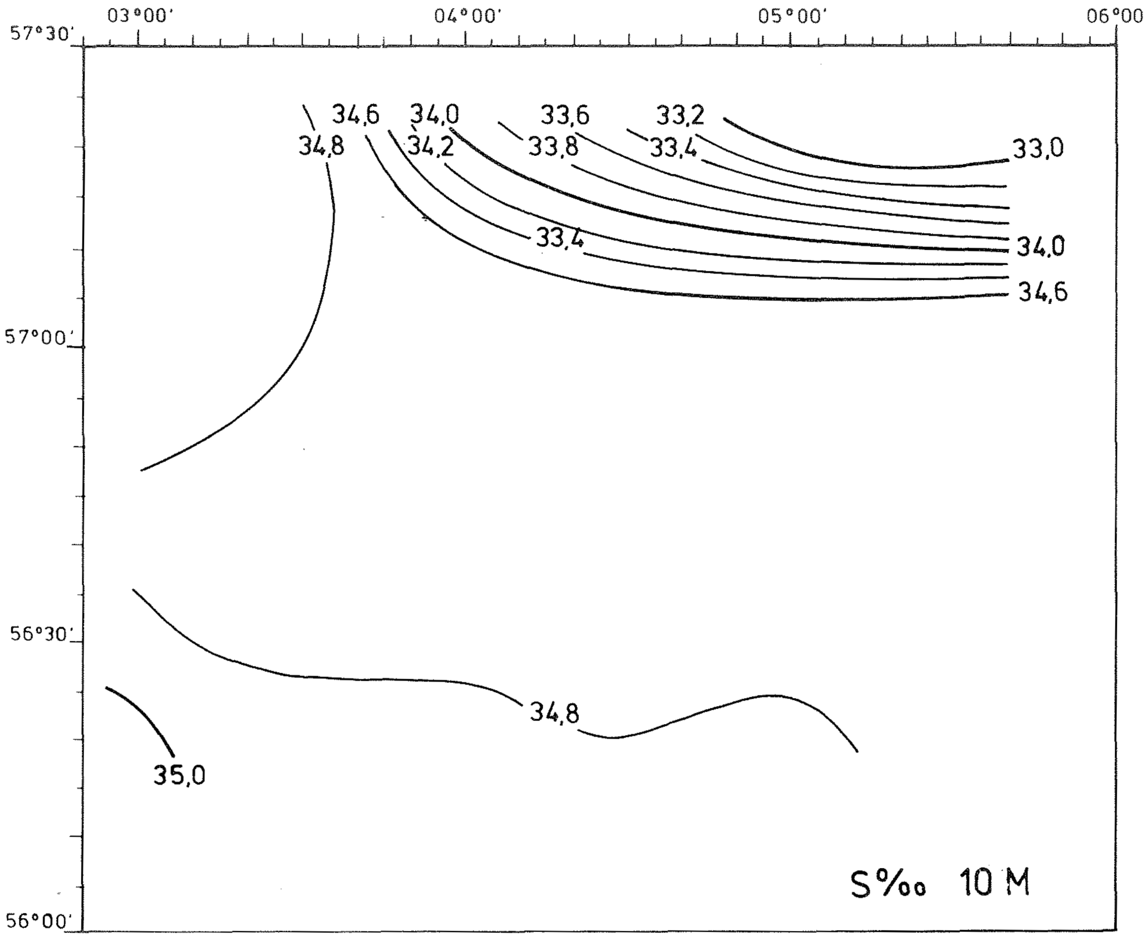

Fig. 5 Salinity S $^{o}/oo$, at 10 meter depth, 27 April - 1 May.

The character of the water masses towards the south-western corner of the grid approaches that of North Atlantic water, e.g. high salinity and high temperature. (Fig. 6 and 7). This high temperature is due to warmer water being brought into the investigated area by advection.

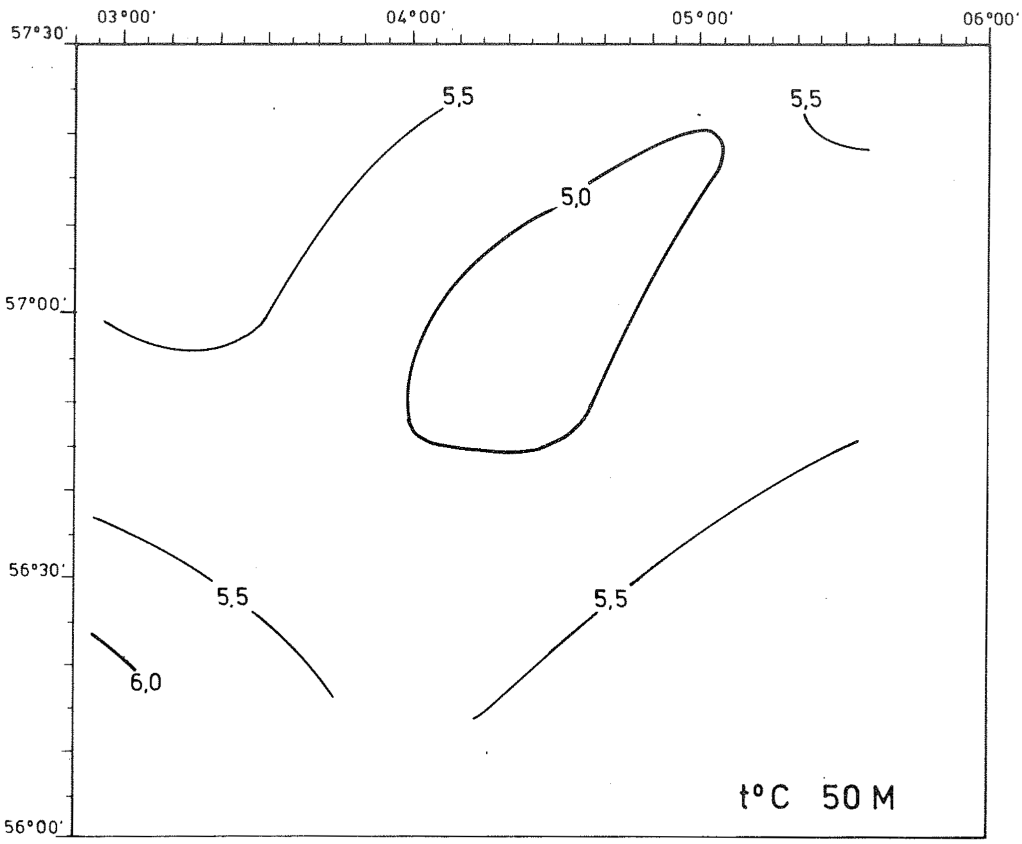

Fig. 6 Temperature, t°C, at 50 meter depth, 27 April - 1 May.

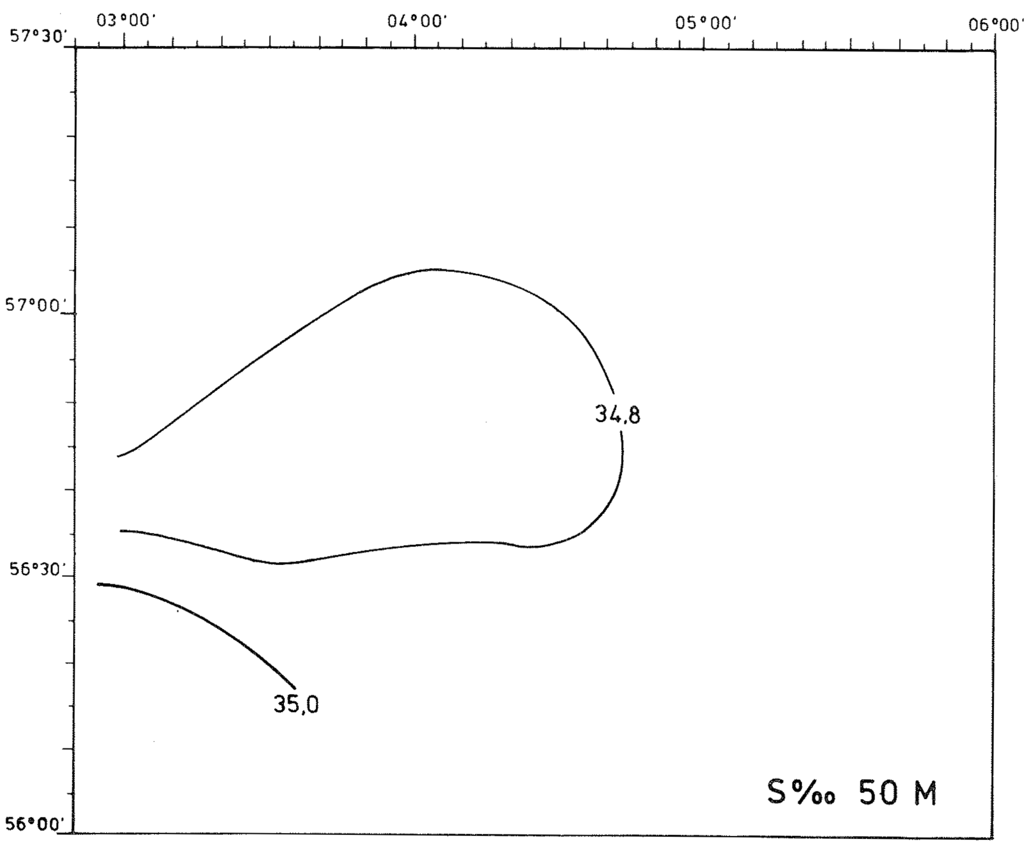

Fig. 7 Salinity, S°/oo, at 50 m depth, 27 April - 1 May.

In the northern part a subsurface water body was found which according to a t-S analysis must havehad a different origin from the two others.

Above this water, especially in the eastern part, a 10 m thick typical coastal water mass was layered with salinity well below 34, 0°/oo. (Fig. 7) The temperature was relatively high, above 6°C, probably due to atmospheric heating. (Fig. 6).

The water masses were vertically nearly homogeniuous except for the northern part of the investigated area.

The sea surface temperature in the investigated area was approximately 1°C below the mean value for this time of the year.

CHEMICAL INVESTIGATIONS ON PETROLEUM HYDROCARBONS

The investigations were devided into three categories:

1. The distribution of petroleum hydrocarbons in relation to meteorological and oceanographical parameters, and in relation to the mode of appearance of oil on the surface. The main emphasis was placed on the horizontal distribution by collecting water samples from 1 m depth at most stations. In addition, a few samples from 10 - 30 cm depth were taken from a lifeboat in the close vicinity to Bravo under a slick of oil. (Fig. 8). On certain locations water was sampled from both 1 m and 5 m to get some knowledge of the vertical distribution of petroleum hydrocarbons. A few samples were filtered by sucktion through a Whatman GF/C filter for evaluation of the way the oil is associated with the water, either dissolved or particulate.

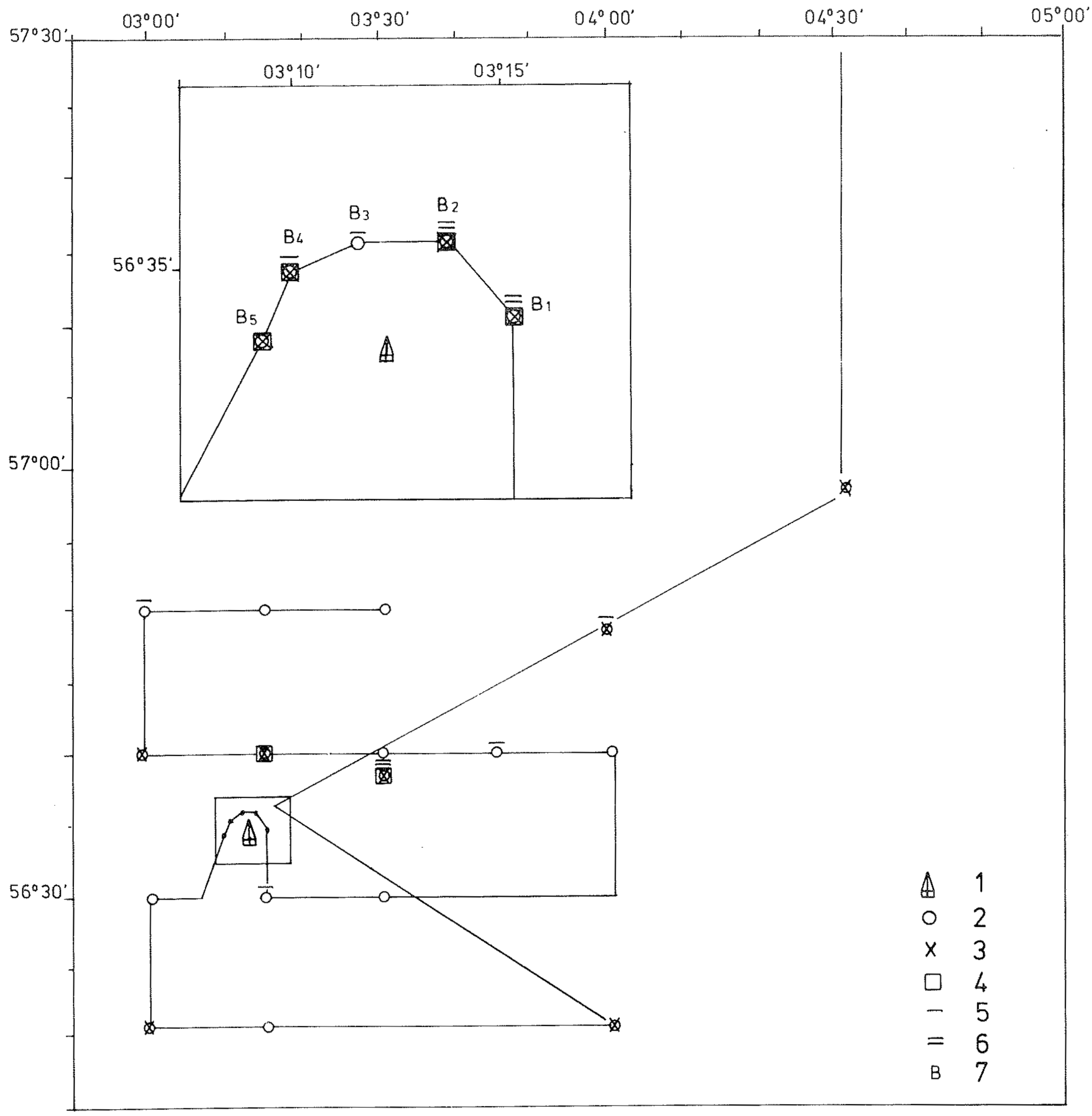

Fig. 8 Map of stations where water was sampled for analysis of petroleum hydrocarbons. Symbols: 1: Bravo platform, 2: Sample taken from 1 m depth, 3: Sample taken from 5 m depth, 4: Samples from 1 and 5 m were filtered, 5: Oil film on surface, 6: Oil globules or slicks on surface, 7: Additional microbiological sampling stations.

2. Oil from the surface, appearing either as film, globules or slicks of water-in-oil emulsion, was sampled for investigation of the weathering effects on the spilled oil and also for identification purposes.

3. Various species of fish and krill, caught by trawl under the oil slick, were frozen for later analysis for content of petroleum hydrocarbons.

Methods: Water samples were collected in 3 l bottles. These were lowered empty and stoppered to the appropriate depth, 1 or 5 m. The stopper was removed by pulling a string, and the bottle was retrieved when full, after 20 - 30 seconds. On KNM "Sleipner" and R/V "G. O. Sars" the water was extracted immediately with column-distilled dichloromethane. The water samples from R/V "Johan Hjort" were stored in the sample bottles after addition of 25 ml dichloromethane to prevent microbial activity, and extracted upon return to the institute.

The extracts were dried with sodium sulfate and analysed by gas chromatography in two different ways:

1. Total hydrocarbons. These were assessed on a packed column with a flame ionisation detector by comparison of the total area of the chromatograms with the area of chromatograms of known amounts of the oil from the sea surface close to the Bravo platform.

2. Selected aromatics. For this purpose a capillary column with a computerized mass spectrometer as detector was used. The mass spectrometer was tuned to detect naphtalenes, phenanthrenes and dibenzothiophenes, considered to be characteristic of petroleum pollution and to belong to the more poisonous components in crude oil. The quantification was achieved by addition of fluorene and anthracene as internal standards.

For analysis of oil samples from the surface, water was first removed by addition of sodium sulfate and/or centrifugation. The oil was dissolved in dichloromethane and chromatographed on the packed column with flame ionisation detector. With respect to the total area of the chromatograms and the height of the normal C_{23} alkane peak, the chromatograms were compared with chromatograms of Ekofisk crude oil. In this manner the relative disappearance of the more volatile components could be estimated.

Results: Of a total of approximately 100 samples collected on the three cruises about 40 have been analysed for total hydrocarbons, among these the majority of the KNM "Sleipner" samples, and about 15 have been analysed for selected aromatics. From these results a few trends have emerged: Significant amounts of total hydrocarbons i. e. 100 µg/l or more, were only detected in samples from water with visible oil on the surface. The oil concentration reached in some cases more than 300 µg/l. The amounts of oil in the water seem to be roughly proportional to the amount of oil on the surface, suggesting that the oil is present in the water as oil-in-water emulsion. This is further substantiated by the resemblance of the chromatograms of the dichloromethane extracts with chromatograms of oil samples from the surface. On the locations with this relatively high concentration of oil in the water no significant difference between 1 and 5 m could be detected. The selected aromatics accounted for approximately 2 - 3% of the total hydrocarbon content. On the stations where no oil could be observed on the surface, i.e. most of the KNM "Sleipner" stations, the water samples contained much less extractable organic material and no petroleum hydrocarbons were appearant on the packed column chromatograms. However, in these cases the analysis of the selected aromatics, not yet carried out, has to be made for confirmation of the presence of petroleum hydrocarbons.

The analysis of the oil samples revealed an increasing disapperance of the more volatile components with increasing distance from the Bravo-platform. Oil sampled on May 1 had lost more than 50% of its original components. Based on other relevant investigations, it is assumed that the majority had evaporated. A sample collected May 2. showed disappearance of more than 60%, but this figure should be confirmed by further analysis.

A more than one year old sample of Ekofisk crude oil was used as reference oil in the above investigations since samples of the Bravo B 14 well oil was not available. A check will later be made against a sample from the Bravo well.

OIL-DEGRADING BACTERIA

Bacteria, and to some extent fungi, are the only groups of organisms which have any significant capability to degrade and mineralise hydrocarbons. They therefore play an important part with respect to the self-cleaning capacity of waters in which oil spills have occurred.

Microbial transformations of toxic oil components also prevents an extensive accumulation of these potentially harmful chemicals, as would normally be the results of a stepwise, concentrative transfer of unmetabolisable compounds via members of the marine food chains.

The microbiological experiments performed during this expedition were designed for the general purpose of strengthening the basic knowledge concerning this cleaning potential, and more specifically, to obtain a present status of the bacterial activity in this area during the "blow out" as compared with levels obtained earlier under "normal" circumstances.

Table 2 shows the stations where bacteriological sampling and enumeration were performed.

Table 2. Stations where bacteriological sampling and enumeration were performed.

Station number	Sampling depth 0 m	5 m	10 m
218	+	+	+
220	+	+	+
222	+	+	+
223	+	+	+
225	+	+	+
227	+	+	+
228	+	+	+
230	+	+	+
231	+		
B 1	+	+	+
B 2	+		
B 3	+	+	+
B 4	+		
B 5	+	+	+
232	+	+	+
233	+	+	+
235	+	+	+
237	+	+	+
238	+		
239	+	+	+
240	+	+	+
241	+	+	+

Methods: The main experiments and their purpose can be summarized as follows: Enumeration was made of hydrocarbon degrading bacteria in water samples taken at different horizontal distances from the oil leak. This is done to obtain a distance/bacterial countprofile which is to be correlated with chemical analyses of oil components in corresponding water samples. The results when available later may give information as to the optimal hydrocarbon concentration for bacterial growth under otherwise normal conditions with respect to temperature, nitrogen and phosphorous etc. The results will also possibly indicate a maximum oil concentration, above which the different oil components have an inhibitory effect on microorganisms, with the result that the bacterial number and thereby the cleaning capacity will decline.

Enumeration was also made of hydrocarbon degrading bacteria in water samples from varying depths. These results are also going to be correlated with a series of chemical and physical parameters, and will give information about the bacterial activity in water layers that have different contents of hydrocarbons and oxygen.

Water samples were collected from varying depths (Niskin sampler for 5 - 20 m samples, bucket for surface (0 m) sample). Dilution series (1/1 to $1/10^6$) from each sample were set up, and 1 ml of each dilution was filtred through a membrane filter (0.45 μg pore diam., Selectron). The membrane filters were placed in Petri dishes on top of cellulose pads soaked in growth medium (sea water containing additional phosphate (0.002%), ammonia (0.005%), tris HCl (0.01%) and a mixture of oil components; C_{14}-, $C_{16}$and C_{18}-alkanes plus "weathered" oil in equal amounts (0.1%), pH 7.2).

The Petri dishes were incubated at 10°C.

Results: The number of bacteria in the original water sample will be deduced from the number of bacterial colonies that develop on the surface of the membrane filter after an incubation period of one to three weeks.

PHYTOPLANKTON AND PRIMARY PRODUCTION INVESTIGATIONS

Methods: Samples for determination of phytoplankton standing stock and primary production were obtained from 0, 5, 10, 20 and 30 meters depth levels at each hydrographic station.

Surface water was sampled at every station for determination of particle size frecuencies distribution and for phytoplankton species composition.

An attempt at a rapid estimation of possible oil effects on phytoplankton photosynthesis was carried out at each station in surface and 5 meters samples. At selected stations the experiment was also carried out on 10, 20 and 30 meters depth samples. The method is based on the relative increase of in vivo chlorophyll fluorescence after blocking the photosynthesis electron transport with a herbicide (DCMU),[x] the computed values being used as an index of the physiological state of a phytoplankton population.

Seawater samples for nutrients analysis were obtained at each hydrographic station from 0, 5, 10, 20 and 30 meters depth levels.

At 22 stations surface samples were obtained for determination of phytoplankton standing stock and primary production rates for three differents group sizes (total, smaller than 30 microns and smaller than 5 microns).

Surface samples from 22 stations and 5 and 10 meters samples from 6 stations were obtained for determination of radioactive glucose uptake as an indication of heterotrophic activity.

Secchi depth was determined at every station during the day. Underwater irradiance measurements were made at four stations with a quantameter.

An experiment was carried out with natural water from surface and 15 meters depth in order to evaluate possible long-time effects of oil on natural phytoplankton populations.

[x] 3-(3.4-dichlorophenyl)-1.1-dimethylurea

During the cruise with KNM "Sleipner" phytoplankton observations were made only on surface samples.

Continuous measurements: Continuous recordings of incident solar radiation, in vivo chlorophyll fluorescence and relative concentration of particles were made during the whole cruise.

Results: The standing stock of phytoplankton was relatively low (from 0.55 to 3.78 mg chlorophyll a/m^3 with an average of 4.96 mg/m^3). The phytoplankton was rather uniformly distributed over the whole investigated area with some patches of higher concentrations changing locations in the sequential surveys, obviously caused by physical transport of water masses (Fig. 9).

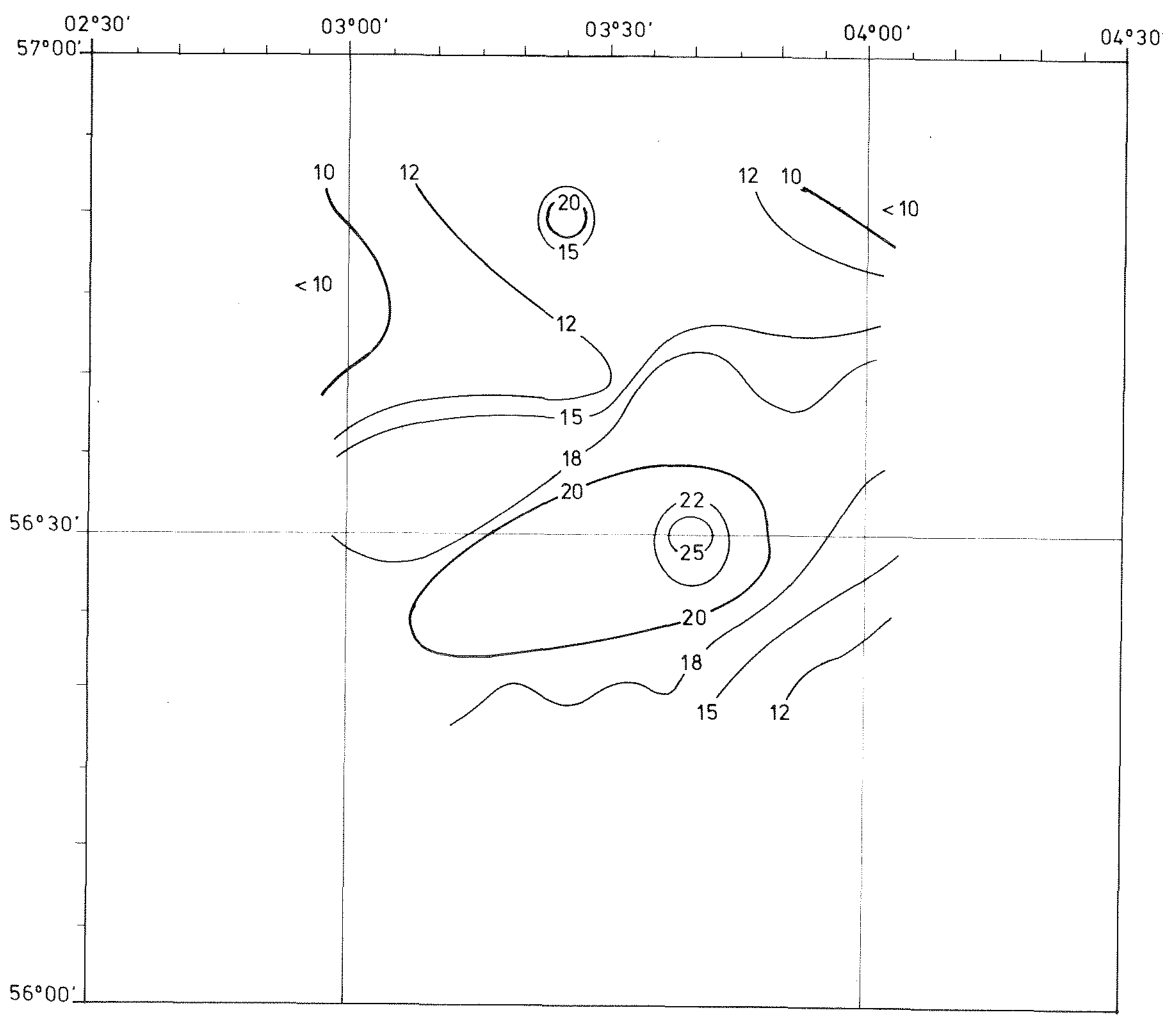

Fig. 9 Horizontal distribution of in vivo chlorophyll fluorescence. 27 April - 1 May. Relative values.

The vertical distribution of phytoplankton standing stock was also uniform from surface to about 20 m depth and from there on decreasing rapidly to 30 meter.

Large diatoms were dominating, especially Rhizosolenia alata Chaetoceros convolutus and Thalassiosira sp.

Primary production rates per unit of light followed mainly the same pattern as phytoplankton standing stock and was in general medium high and consequently delayed as to the normal for this time of the year (from 6.0 to 42.0 $\mu g\ C/m^3/10^{17}$ quanta/cm^2/hour with an average value of 16.0).

Normally during the spring bloom in the North Sea phytoplankton standing stocks exceed 10 - 15 mg chlorophyll a/m^3 and production rates are higher than 25 - 30 $\mu g\ C/m^3/10^{17}$ quanta/cm^2/hour).

Production indices showed also uniform values over the entire area with exception of a small segment extending about 10 nautical miles to the east from Ekofisk where relatively lower production indices were found at the surface. (Fig. 10).

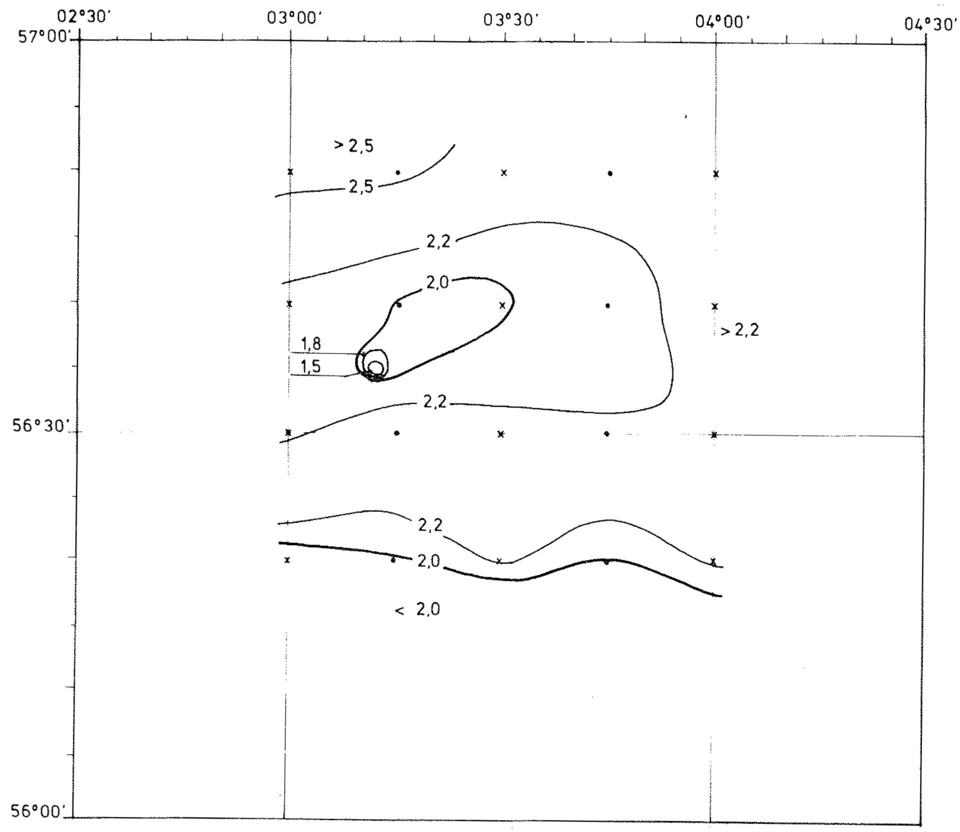

Fig. 10 Production indices at the surface 27 April - 1 May. Relative values.

Nutrients concentrations (nitrate, phosphate and silicate) were generally medium low, especially within the patches with higher chlorophyll a concentrations, but had not yet reached the extremely low concentrations limiting phytoplankton growth. Vertically the nutrients were evenly distributed at all stations.

These preliminary results indicate that the spring bloom of phytoplankton had startet, but with a rather medium growth rate. The stability of the water masses was generally low resulting in convections from surface to bottom and this situation explains why the standing stock of phytoplankton was kept rather low. The phytoplankton horizontal distribution was strongly related to the hydrographical conditions of the different water masses. In the whole, the situation indicates an early stage in the typical spring development of phytoplankton.

The relatively low production indices at the surface near Ekofisk were possibly due to the presence of oil-slicks since ecological conditions otherwise were not significantly different from the rest of the area.

ZOOPLANKTON, FISH EGGS AND LARVAE

Methods: Plankton samples were taken vertically at each station with a Juday net (36 cm) from 50 m to the surface, with a Clarke-Bumpus plankton sampler from 40 m to 0 m 4 minutes at each 10 m step, and with a neuston net (Otter surface sampler) which was towed over a distance of 1 nautical mile. The samples taken by KNM "Sleipner" were collected only with the neuston net. All samples were microscopically examined immediately after collection for identification and enumeration of fish eggs and larvae. Zooplankton concentrations were determined by displacement volume. Krill was also recorded by an EK 120 scientific echo-sounder.

Results: Zooplankton in the area was dominated by krill which was sometimes recorded by echo sounder in dense pelagic patches at depths of 25-50 m. The patches could easily be mistaken for schools of pelagic fish, but trawl sampling identified the recordings as being krill. Fig. 11, 12 and 13 shows the distribution of plankton, (mostly krill) recorded by echo sounder.

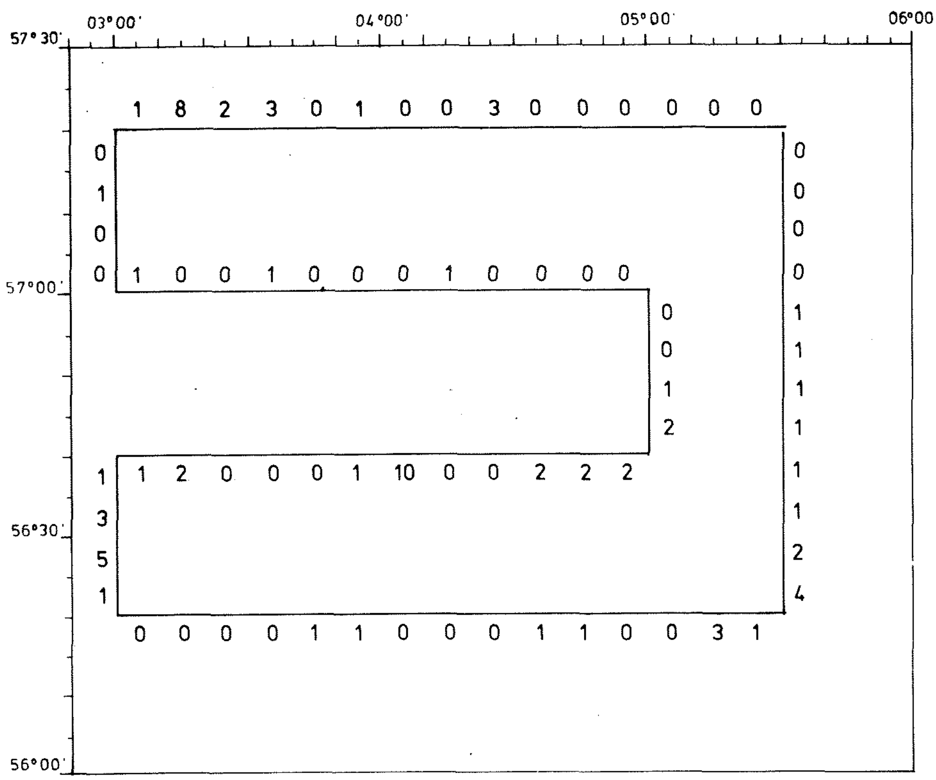

Fig. 11. Distribution of planktonic scatters, mainly krill, (integrated echo intensity) 27 April - 1 May (R/V "Johan Hjort").

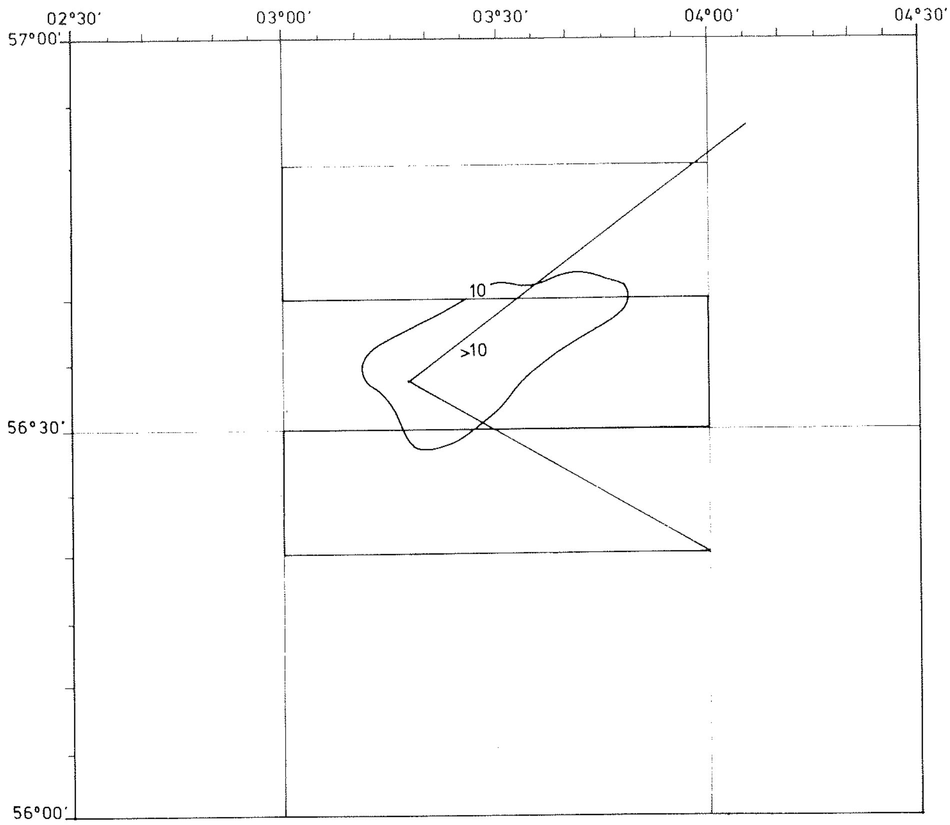

Fig. 12. Distribution of planktonic scatters, mainly krill, (integrated echo intensity) (R/V "G. O. Sars").

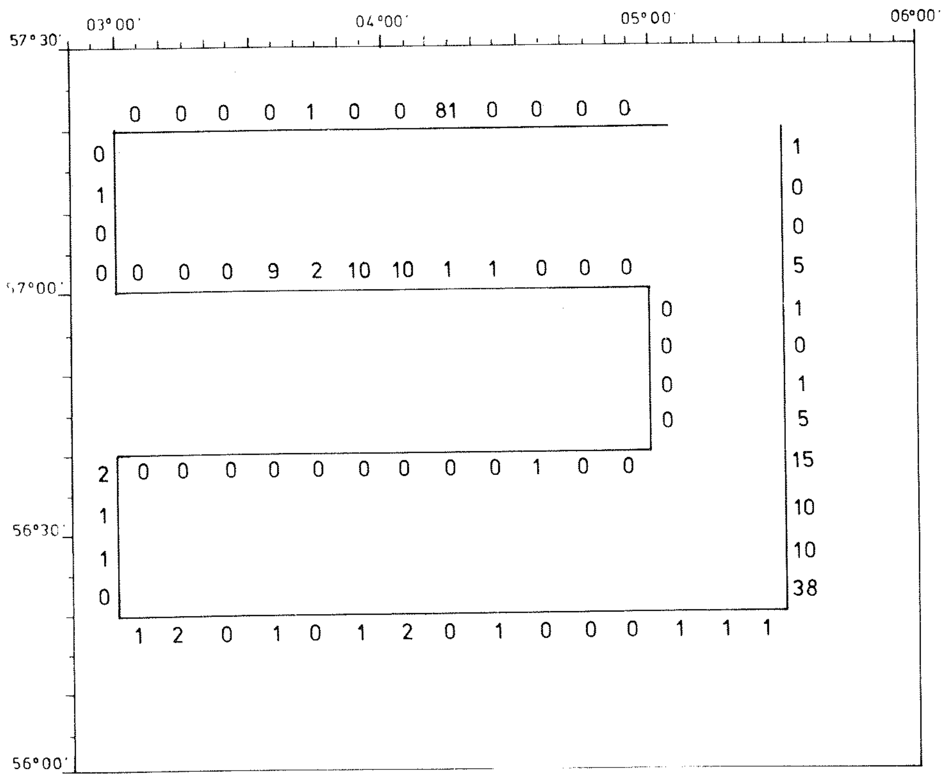

Fig. 13. Distribution of planktonic scatters, mainly krill, (integrated echo intensity) 1 May - 4 May. (R/V "Johan Hjort")

Differences in catching efficiencies by the Clarke-Bumpus samplers at day and night stations makes the samples unsuited for quantitative comparisons. This is because krill, which constitute the bulk of plankton caught at night, avoid the net during daytime. However, the plankton biomass during the two surveys was found in general to be low, probably because the zooplankton bloom was still in its early stages of development.

Fish eggs were also thinly distributed, except for a denser distribution north to north-east of the Bravo platform (Fig. 14). The fish eggs were identified as those of long rough dab and Gadoids, probably whiting, haddock and cod. Eggs of dab and plaice were also found in some of the plankton samples.

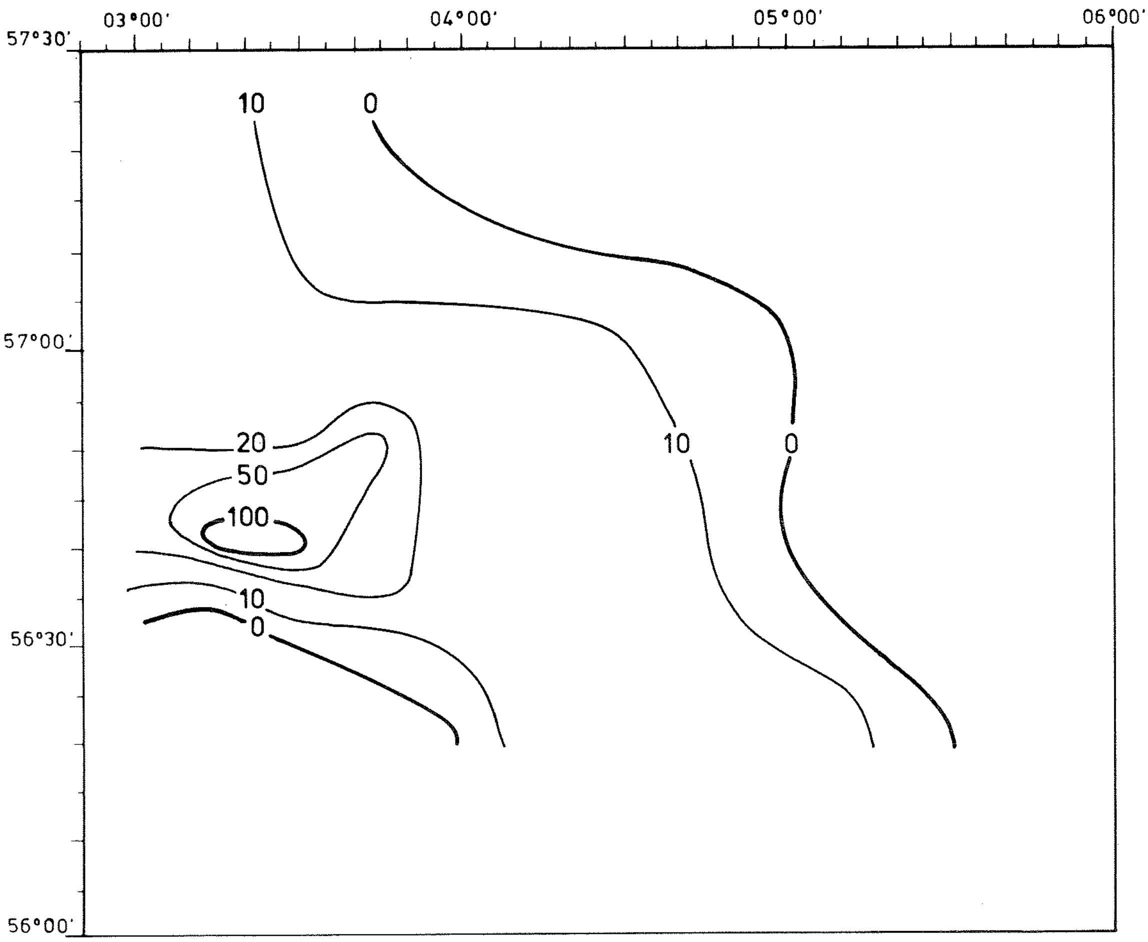

Fig. 14. Fish eggs in numbers/m^2 surface (Juday net 50 - 0 m). April 27 to May 1.

Except for one locality centered about 10 nautical miles north of platform Bravo where a maximum of 100 eggs/m^2 was found, the concentrations were usually less than 20 eggs/m^2. During the second survey the highest egg densities were found further to the north-east (Fig. 15). The concentration of fish eggs in the area

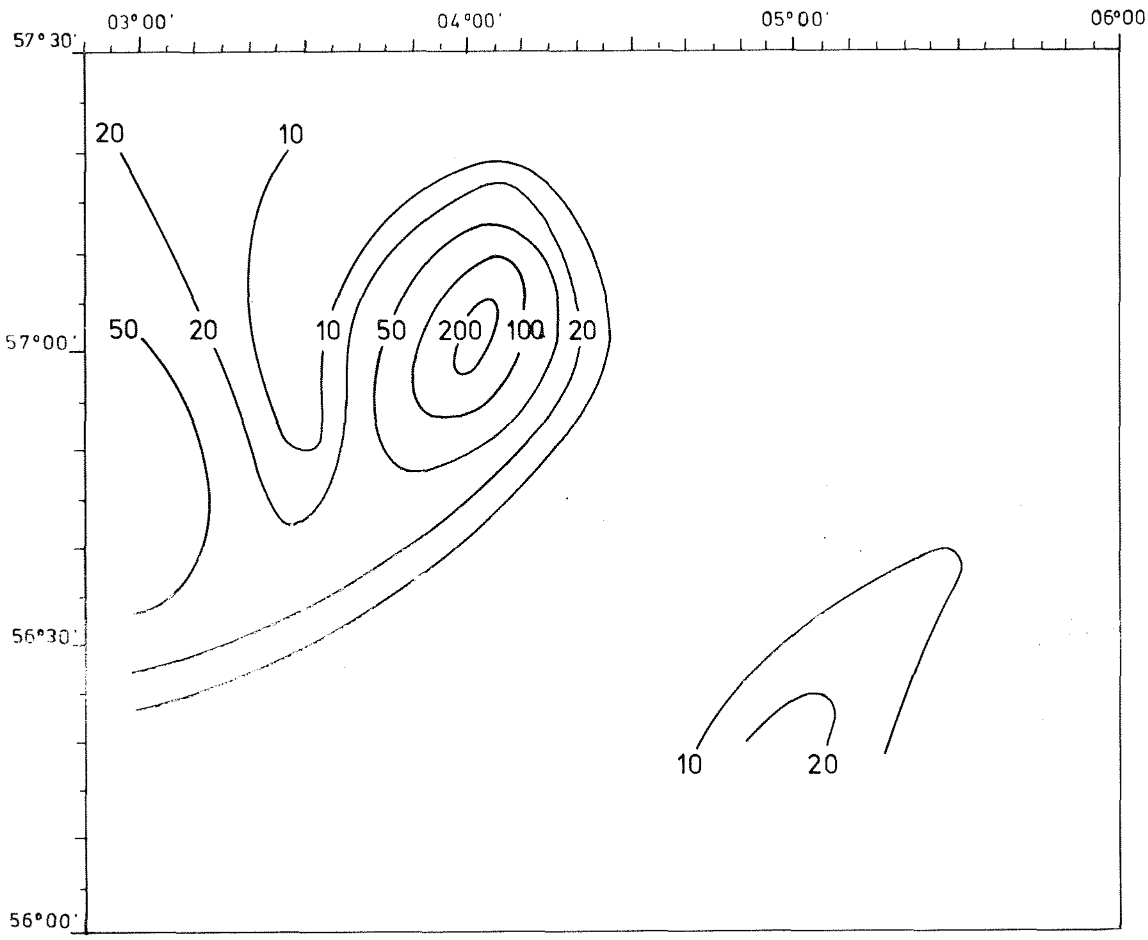

Fig. 15. Fish eggs in numbers/m^2 surface (Juday net 50 - 0 m). Mayl1 to May 5.

was obviously low, but this can partly be explained by the long spawning periods of the species found (4 - 8 months). Mackerel however, which spawn later in the same area, has a spawning period of less than two months (June- July), and concentrations of more than 300 mackerel eggs/m^2 are then quite usual.

A few sand eel larvae were caught at the southernmost stations, as were some catfish larvae in the north-western area. Apart from their scarcity, the larvae are also difficult to sample representatively with the plankton samplers used because of their own mobility (avoidance), a fact which has presumably affected the sampling.

A few dead fish eggs and copepods were observed in surface plankton samples collected in an area where there was much oil on the surface (sts 230 and 231).

FISH

Methods: Echo sounder EK 50, EK 120 and sonar was applied continuously on both research vessels. The EK 50 was equipped with an integrator, which integrated signals at intervals of 25 meter.

Depending on the type and intensity of echo signals pelagic - and bottom trawls were used to identify the fish recordings. Trawling was also undertaken to measure the fish abundance in the upper 10 meters and close to the bottom.

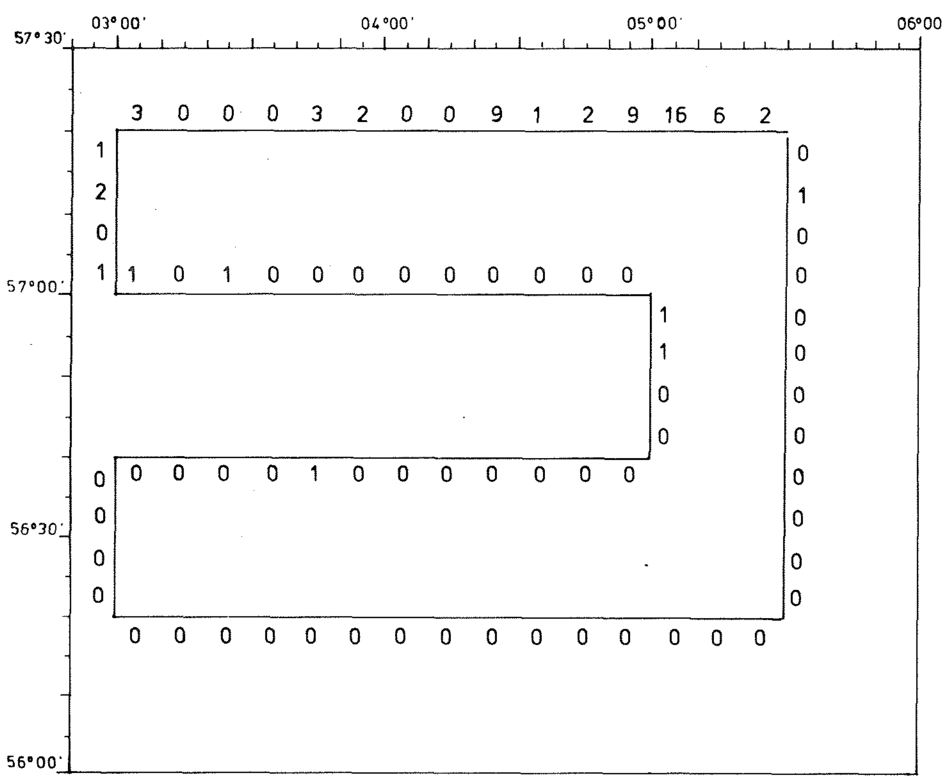

Fig. 16. Distribution of demersal fish (integrated echo intensity) 27 April to 1 May. (R/V "Johan Hjort").

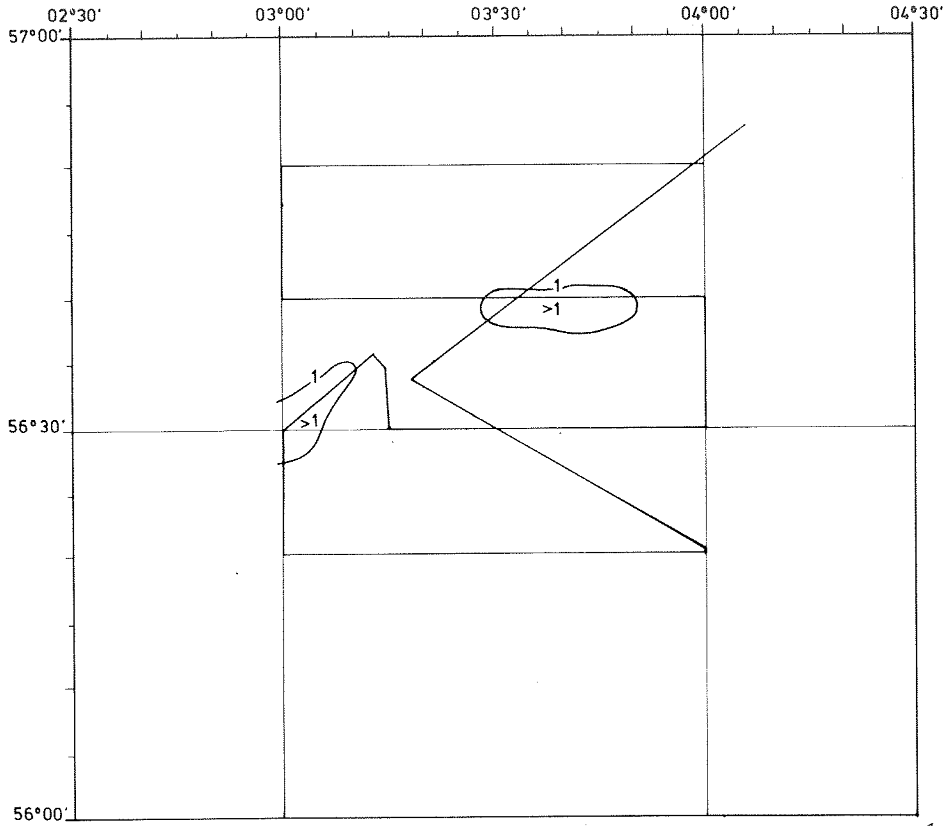

Fig. 17. Distribution of demersal fish (integrated echo intensity) (R/V "G. O. Sars").

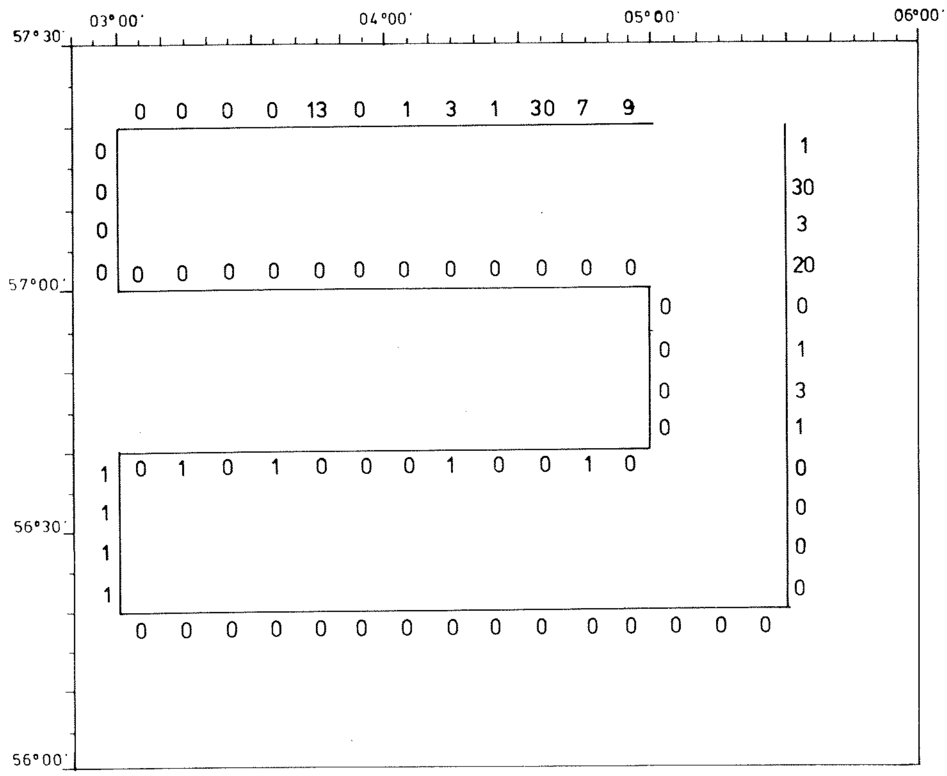

Fig. 18 Distribution of demersal fish (integrated echo intensity) 1 May - 4 May (R/V "Johan Hjort").

Fig. 16, 17 and 18 show the distribution of demersal fish. Results from trawl catches are shown in Fig. 19 and 20, Table 3 and 4. in the main part of the area the occurence of demersal fish was insignificant during both cruises, with the exception of some haddock, whiting and sand-eel in the northern part. In this area several foreign fishing vessels were observed.

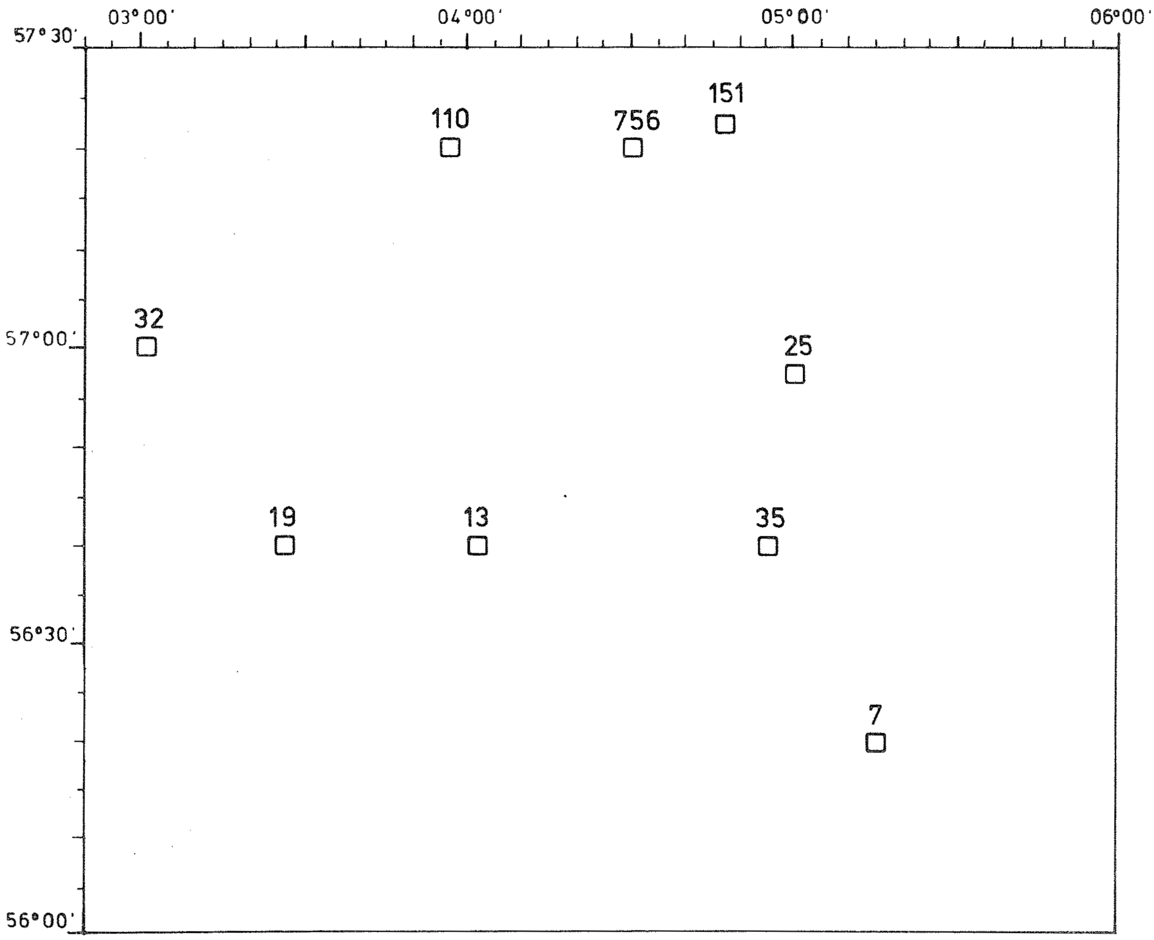

Fig. 19. Total catch (kilogram per hour trawling) in bottom trawl.

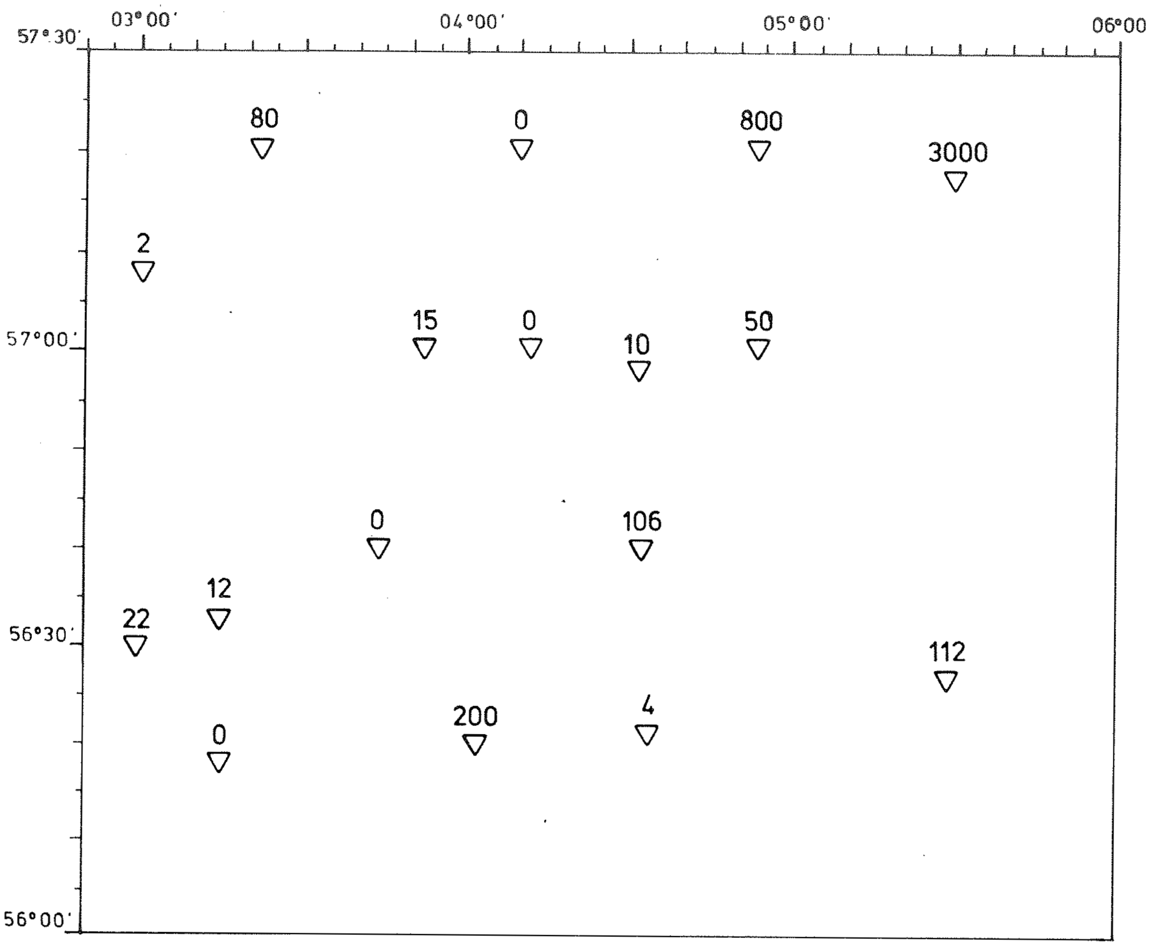

Fig. 20. Catches of 0-group herring (number per hour trawling) in pelagic trawl.

Table 3. Bottom trawl catches, numbers per trawl hour.

Species	Tr. st. 79	Tr. st. 81	Tr. st. 84	Tr. st. 85	Tr. st. 88	Tr. st. 91	Tr. st. 95	Tr. st. 97
Cod	4	-	2	2	2	-	18	-
Haddock	-	52	18	2	-	286	16	46
Whiting	4	12	6	14	2	124	8	50
Dab	72	20	58	50	96	-	2	62
Long rough dab	12	12	12	16	30	2	2	8
Plaice	2	-	-	-	2	-	2	4
Lemon sole	-	-	-	-	-	-	2	-
Sandeel	5192	290	-	-	-	2	-	-
Catfish	2	2	4	2	-	-	2	-
Gurnard	-	2	10	10	6	8	-	-
Thornback Ray	-	2	-	-	-	-	2	-
Gobius larvae	-	-	-	40	46	-	-	6
Sprat	-	-	-	-	2	-	-	-
Catfish larvae	-	-	-	-	-	-	-	2
Kg. pr. hour	110.0	32.4	34.8	12.8	6.8	151.25	25.0	18.6

Table 4. Pelagic trawl catches, numbers of fish larvae and kilogram krill per trawl hour.

Larvae	Tr. st. 78	Tr. st. 80	Tr. st. 82	Tr. st. 83	Tr. st. 86	Tr. st. 87	Tr. st. 89	Tr. st. 90	Tr. st. 92	Tr. st. 93	Tr. st. 94	Tr. st. 96	Tr. st. 98
Herring	800	80	15	50	22	200	112	3000	-	2	-	106	4
Long rough dab	2	-	-	-	-	-	-	-	-	-	-	-	-
Sandeel	2	-	-	-	2	-	84	2	-	-	-	-	-
Catfish	-	-	-	28	8	12	2	2	-	2	2	-	2
Gobius sp.	-	-	-	-	10	30	10	-	-	20	6	66	2
Norway pout	-	-	-	-	-	-	8	-	-	-	-	-	-
Lumpenus sp.	-	-	-	-	-	-	20	20	-	-	-	-	-
Krill	Litt	40 kg	10 kg	-	-	-	-	-	1000	-	100	-	10
Fishing depth	0-20	0-40	0-15	0-20	0-20	0-15	0-15	0-20	0-25	0-20	0-30	0-15	0-20

The composition of the bottom trawl catches shown in Table reveals that haddock, sand flounder, long rough dab and whiting dominated.

Pelagic fishes were not observed by the R/V "Johan Hjort" neither on sonar nor by echo sounder. The echo sounder observations made by R/V "G. O. Sars" showed only insignificant amounts of pelagic fishes. Pelagic trawling just below the sea surface showed that 0-group herring was scattered more or less all over the surveyed area (Fig. 20).

CONCLUDING REMARKS

The preliminary findings at this stage of the investigations can be summarized as follows:

The hydrographical data demonstrate that the temperature of the watermasses in the surface layers were below the normal for this time of the year. No vertical gradients were observed in the watercolumn except for a limited area in the north eastern part of the grid system, where a significant transition layer existed between 10 and 20 meters.

The hydrographical situation was reflected in the biological development, which could be described as an early spring stage. The primary production had with minor exceptions, barely begun and the stock of plankton was small. There were few fish eggs in the area, and those found consisted mainly of long rough dab and cod fishes (whiting, haddock and cod), mixed occasionally with eggs of dab and plaice. In an area 6 nautical miles north-northeast of Bravo a maximum density of about 100 eggs per m^2 was found. During the second coverage of the area this maximum had moved north-eastwards.

A few sandeel larvae was found in the sourthern part of the surveyed area and a few cat fish larvae in the northern part. The variations observed in the occurrence and amounts of plankton as well as in the primary production rates may mainly be attributed to different physical conditions in the actual water masses.

The total biomass of fish resources as recorded by echo sounders was very low and these findings were further confirmed by the poor catches obtained by pelagic and bottom trawls. The main fish resource in the area was 0-group herring scattered more or less all over the entire area. Sandeel was only found at a few stations. There were insignificant amounts of mackerel present. Any gathering and spawning of these species would not be expected until the temperature rises to about 10 ^{o}C.

The results so far available of the chemical analysis of hydrocarbons in sea water samples from 1 and 5 meters depth show low values (considerably less than 1 mg per liter), even in the immediate vicinity of visible oil on the surface. These levels are below those usually observed to have acute lethal effects on the sensitive stages of fish in laboratory tests. Although sublethal effects cannot be excluded, the low concentrations of hydrocarbons combined with the scarce availability of sensitive resources makes it unlikely that serious effects on the production of fish resources have occurred. It is evident that several factors account for the low aromatic contents in the sea: the high temperature in the oil at discharge, and the winds and surface spreading which caused rapid evaporation of the volatile and most toxic components. The instable condition of the watermasses probably resulted in effective dilution of the part that became dissolved and dispersed.

No direct damage was observed on organisms, except in a small area stretching about 10 nautical miles eastwards from platform Bravo where some dead fish eggs and planktonorganisms were found. The primary production indices showed a corresponding decline and indicated an inhibition in the primary production system.

An extensive follow-up programme of field studies and analyses will be conducted to enable further evaluations of the fate of the oil spill and its effects on the environment and the fishery resources.

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