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O-92187

ZEEPIPE Ready For Operation

Environmental monitoring of the discharge of inhibited seawater at Sleipner, January - March 1993

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Abstract: The Zeepipe Ready For Operation program involved the discharge of some 1.5 mill. m^3 of sea water inhibited with Na-bisulphite and glutaraldehyde at Sleipner. The discharges which took place during January and March 1993, were subject to environmental monitoring at sea performed by NIVA. The extremely bad weather conditions during the monitoring periods were favourable for dispersion of the plume, but highly unfavourable for monitoring. The discharge plume was frequently detected, mostly at mid-depth. The plume was not detected more than 200 m from the discharge point. The overall biological impact from the discharges may be considered as being small. Chemical analyses of water samples collected near the discharge showed no inhibitor concentrations above detection limit, and no oxygen reduction. Screening toxicity tests and tests on primary production on the water samples did however show some impact. Analyses of samples from the pipeline showed low sulphite values, and glutaraldehyde values in the range 3 - 35 ppm.

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Zeepipe Ready For Operation

Environmental monitoring

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the discharge of inhibited sea water

at Sleipner

January-March 1993

FINAL REPORT to STATOIL
August 4 1993

NIVA
The Norwegian Institute for Water Research

Cover photo :
Standby vessel at Sleipner in January 1993. The Riser platform is behind the floating "Polycastle" in front.

Preface

The gas pipeline ZEEPIPE connects the Sleipner field in the northern North Sea to the receiving terminal in Zeebrügge, Belgium. In connection with preparations and start-up (RFO; Ready For Operation), large quantities of chemically treated sea water were to be discharged from the pipeline at the Sleipner field. The operator STATOIL was responsible for conducting an environmental monitoring, in order to document the level of effects in the marine environment.

NIVA, The Norwegian Institute for Water Research, was contracted by STATOIL to organise and perform the monitoring the following winter. The performance of the program involved many scientific disciplines, and many research scientists and assistants at NIVA. The frequent contacts on formal and practical aspects with STATOIL were through STATOIL representatives Terje Kleppe and Synnøve Jacobsen. Terje Kleppe also participated on the two monitoring cruises, in January and March 1993.

The following scientific personnel at NIVA were directly involved in the monitoring:
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Thanks are due to all participants. We are also indebted to the captain H. Ferøy and his crew of R/V "Håkon Mosby" who maintained patience and excellent seamanship throughout the cruising periods, which happened to have highly unfavourable weather most of the time. Thanks also to Dr. Henrik Søyland at the HOV Centre in Bergen who provided current and wave prognoses.

Bergen/Oslo 4 August 1993

Lars G. Golmen
Project manager

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Executive summary

Three discharges, one of 300.000 m^3 and two of approximately 600,000 m^3 each of inhibited sea water were consecutively discharged at the Sleipner field from the 810 km Zeepipe pipeline that connects Sleipner to Zeebrügge in Belgium. The first two discharges took place during a 4 weeks period starting on 28 December 1992. The last discharge took place during the period 12-26 March 1993. The discharge point was located ca 2 m above the sea bottom, 1,500 m NE of the Sleipner Riser platform. The inhibitor chemicals used were glutaraldehyde (biocide) and Na-bisulphite (oxygen scavenger).

A programme was specially designed to monitor environmental effects from the discharges. On behalf of STATOIL, NIVA, the Norwegian Institute for Water Research performed this monitoring, which took place during two separate cruise periods. The first period was scheduled to cover the last eight days of the first discharge plus the first eight days of the second that followed with essentially no time break. The third discharge was similarly scheduled to be monitored for eight days.

The weather and wave conditions during the discharge period in January were the worst encountered in the North Sea for 30 years or more. Winds never were below gail force, and wind speeds of 80-100 knots were frequently reported. Wave heights of 6-10 m were the normal, with 15 m peaks or higher frequently reported. Also the 2nd cruise in March had unnormally bad weather. These conditions severely restricted the monitoring, which had to take place during short time windows within each cruise period.

The discharge location was easily detected by the vessels echo sounder. A small "cloud" emerged from the discharge at ca 4-5 m above the sea bottom. Also during the first encounter, a dark plume was visible at the sea surface right above the discharge. That surface signature was due to some additional water in the discharge, that was fresh water originating from Kårstø trough the Sleipner condensate pipeline. The visible track of the discharge water was soon lost, and it was never detected visually again.

Theoretical considerations (plume modelling) indicated that dilution factors of ca 100 or more would be expected in the near field of the discharge. This modelling did not take into account the vigorous effect on mixing by the surface waves, which may have speeded up the dispersion process significantly.

Vertical profiles of salinity, temperature, fluorescence and turbidity were frequently taken near the discharge, and at reference stations some km off. During both monitoring periods, the water column was essentially homogeneous. In January, the salinity difference between surface and bottom was only a few thousands parts of a per-mille. Thus there was never any significant stratification or surface layer that might affect the vertical dispersion of the plume.

The discharge plume was detected several times at mid-depth. Also some stations showed signs of surface anomalies in salinity and optical parameters due to the plume. The signatures represented salinity anomalies on the order of 0.05 ppt or less, relative to the ambient salinity of ca 35 ppt. This corresponds to dilution factors of 100 or more. The monitoring that was accomplished, did show both sub-surface and surface signatures of the plume.

The salinity of the discharge water was the dominating factor to control the buoyancy of the rising plume. The temperature inside the pipeline was expected to be adjusted to the ambient (bottom) temperature. Salinities of the discharged water varied, according to the previous oceanographic conditions at the intake location in Zeebrügge. This variability was reflected in the measurements made at the intake, as well as on the samples taken directly from the pipeline at Sleipner. The range was from 27 ppt or lower to above 33 ppt. The higher saltinities would theoretically give a sub-surface plume, while the more brackish water would make the plume rise to the surface, according to the model calculations. Four samples of discharge water were collected directly from the pipeline at Sleipner. These represented water from all three discharges. The results showed that all discharges had lower sulphite values than the expected 30 ppm. The first discharge (which represented the oldest water of the

three) seemed to be completely depleted of sulphite, with some H_2S detected. The last two discharges had on the order of 1-3 ppm sulphite. Glutaraldehyde concentrations were in the range 25-35 ppm for the last two discharges, while the first had only 3.5 ppm.

Tests for biodegradability showed that a fraction of the 1st discharge was readily degradable. A major fraction, however, showed some resistance towards biodegradation. The 2nd discharge showed that the organic substances in the test water were readily degradable at low concentrations (2-5 ppm carbon). This was also the case for the 3rd discharge, for concentrations < 5 ppm carbon. The sensivity (EC_{50}) of the test organisms (acute toxicity tests) was between 0.1 and 0.3 ppm glutaraldehyde.

The optical measurements and CTD-casts could only detect the discharge on stations closer than 200 m from the discharge point. The plume was mainly detected between 40 and 60 m. Chemical analysis of sulphite and glutaraldehyde of water samples by photometry never showed values above the detection limit of 0.1 - 0.2 ppm. Extensive sampling of oxygen in the water column was undertaken, in order to detect any oxygen-depleted patches due to the remaining sulphite. No anomalously low oxygen values were detected neither in the plume nor above/below.

A sub-set of the same samples were subject to inspections of phytoplankton communities and tests for primary production (March monitoring only). Algae concentrations were very low (< 0.2 µg chorophyll-a/l) in January, while March had significant, but still low concentrations (0.4-0.5 µg chlorophyll-a/l). The results for primary production did show reductions that must be due to impact from the discharge water. Also inspection of zooplankton from net hauls indicated some increased mortality in the vicinity of the discharge. These samples, however, were taken under rather rough conditions that might have added extra mortality by mechanical stress during sampling.

Toxicity screening tests on water samples using *Skeletonema costatum* were performed on board. These did show reduction in algal growth rate for some samples that were collected within 100-200 m from the discharge location. The measured reduction were maximum 78%, which corresponds to an estimated glutaraldehyde concentration of 0.1-0.3 ppm, i.e. around the detection limit for the photometric method.

It can be concluded that neither the discharge plume nor any toxic effect could be detected further away than 200 meters from the discharge point. The area of impact was probably less than 0.1 km^2. The biological impact within this area may be considered small.

Results from the monitoring indicate that both the screening test and the primary production experiments were more sensitive than the photometric method in detecting chemical impact. The toxic effects could also theoretically be due to other substances than those analysed for. These might be certain residual components from the biodegradation. As a suggestion for future monitoring operations, the field screening test as well as primary production experiments should be included. As the Zeepipe monitoring did not benefit from the use of additional tracers such as rhodamine-B dye to trace the plume, the use of a high-resolution CTD, and fluorescence and optics in-situ measuring instruments is a must. Also the change from a regularly spaced station grid to a more strategically selected grid according to prevailing currents improves the monitoring. These factors seems to be the experience from the Zeepipe monitoring project, even though the weather conditions made the operations deviate heavily from ideal working conditions.

1. Introduction

A brief overview of the background for the monitoring project, and a description of the discharge and the surrounding North Sea environment is given in this chapter.

1.1 The Zeepipe project

The Zeepipe Transportation System is developed to deliver gas from the Sleipner and later the Troll fields to continental Europe. Fully developed the pipeline will be approximately 1,300 km long, with terminal connection in Zeebrügge, Belgium (Fig. 1.1). The length of the line from Sleipner to Zeebrügge is 810 km, and it has a diameter of 40 inches (1 m).

1.2 The discharges

The pipeline was filled and flushed three times with chemically treated (coastal) water from Zeebrügge. The first discharge was only 1/2 pipe full (ca 300.000 m^3), while the two last ones were complete pipe fills of 600.000 m^3. The discharges exited through an upward directed nozzle ca 2 m above the seabed, which is at approximately 80 meters depth. The discharge point was located 1,500 m north east of the Sleipner Riser platform, at position 58^O 22.64' N, 001^O 55.61' E. Discharges took place during three periods. Number one and two during 28 December 1992 to 26 January 1993, and the last during 12 - 26 March.

Each discharge was supposed to take about 16 days with continuous pumping. With a pipeline volume of 600,000 m^3, the expected mean flux rate was 1,600 m^3/s (0.44 m^3/s). There was some delay in the schedule for the 1st discharge period, while the discharge in March went approximately as scheduled.

The chemicals used in the pipeline were
- Oxygen scavenger (NAT C111 sodium bisulphite), 285 mg/l (285 ppm),
- biocide (NAT B882 glutaraldehyde) 100 mg/l (100 ppm),

where the initial concentrations are indicated.

Estimated concentrations during discharges were 30 ppm and 30-50 ppm respectively. The estimated reduction in concentration would be due to consumption and biodegradability in the pipeline.

Possible negative environmental impact in the receiving waters by the residual chemicals was the main objective for performing the monitoring study. The discharged water was expected to rapidly dilute while rising to the sea surface. Some theoretical considerations before the monitoring started indicated surface concentrations on the order of 0.2 ppm, and further dilution to below 0.1 ppb some 1-2 km downstream (CMS 1991).

Initial toxicity testing (EC50) of the aldehyde showed ca 0.4 ppm as a limiting concentration. As surface concentrations at Sleipner were expected to be below this value (CMS 1991), possible impacts probably would be limited to the water column just above the discharge.

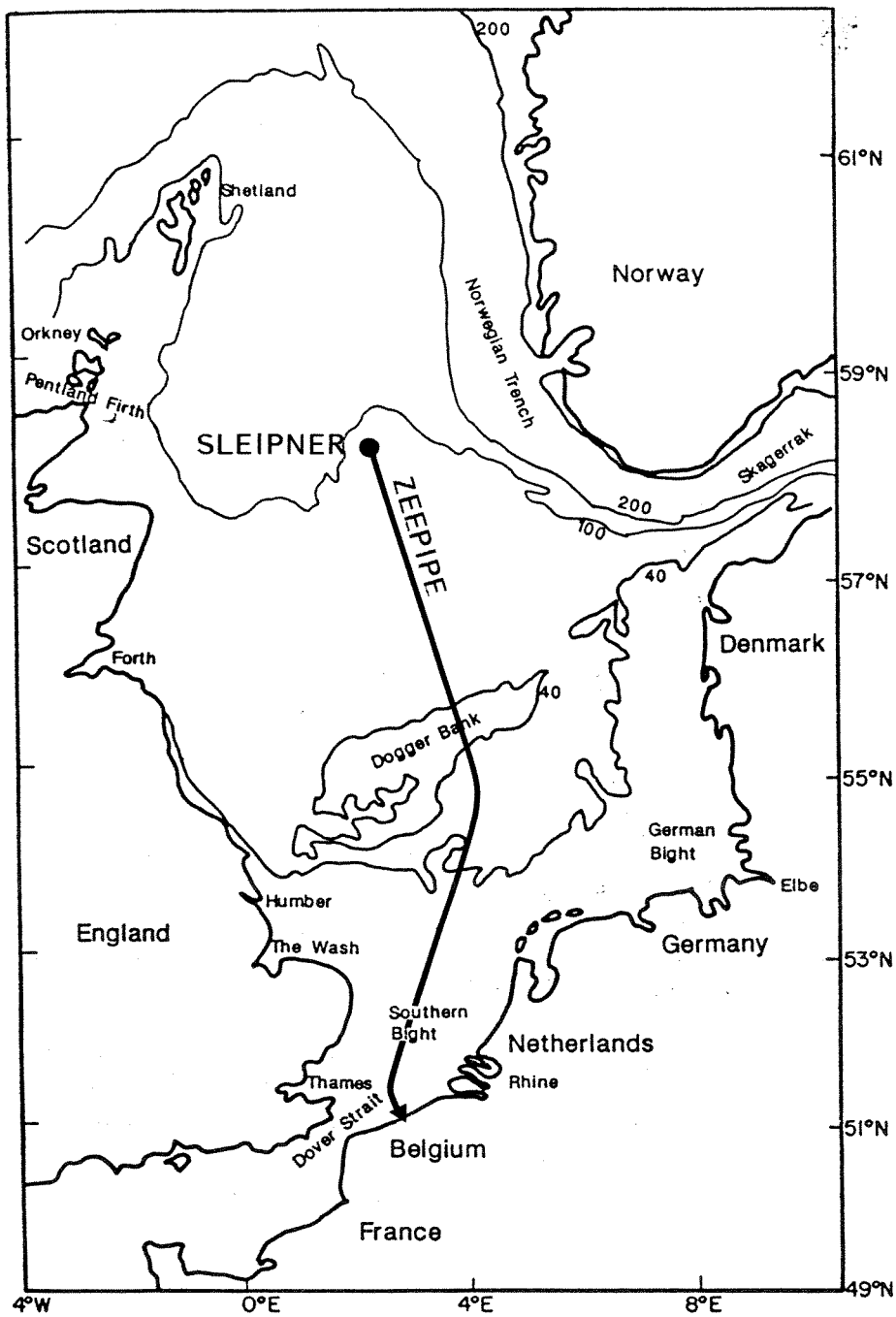


Figure 1.1. North Sea extent, bathymetry and nomenclature, with the Zeepipe indicated. Map from Hutnance (1991).

1.3 General oceanographic conditions at Sleipner

Hydrography

The Sleipner field as situated in the northern North Sea lies in an area where impact from various water masses can be expected. According to Hutnance (1991) and Lee (1980) the most important are North Atlantic Water with high salinity and Skagerrak Water (low salinity, wide annual temperature range). The Sleipner region lies away from typical frontal areas found closer to the coasts, where variations (time/space) are much larger (Otto et. al. 1990).

Fig. 1.2 shows the average surface and bottom salinity in the different regions of the North Sea. In the Sleipner area the average salinity in winter is slightly above 35.0 ppt, with only weak stratification. Minor deviations from the mean values are expected to occur, but generally the salinity stratification at Sleipner is weak.

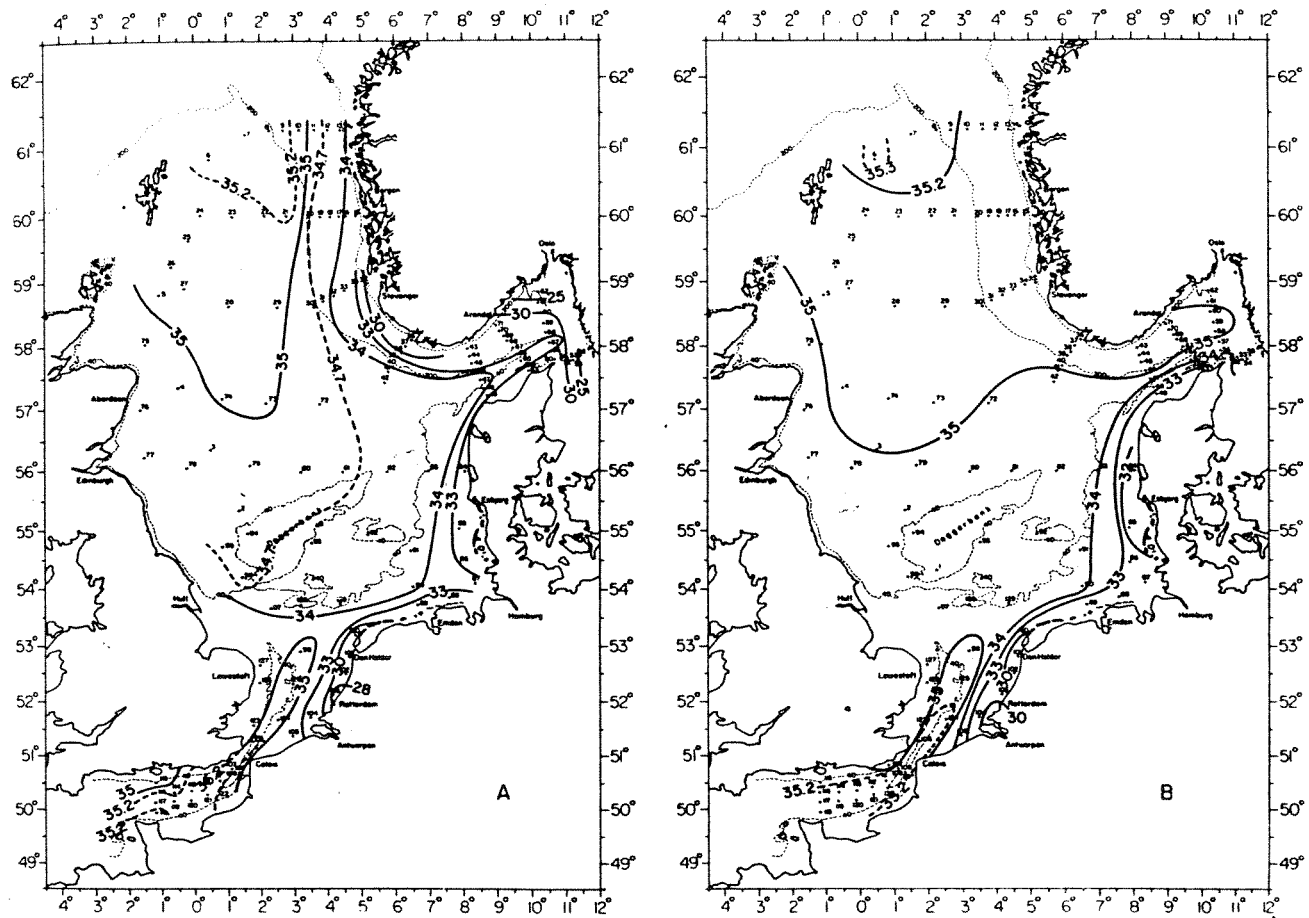
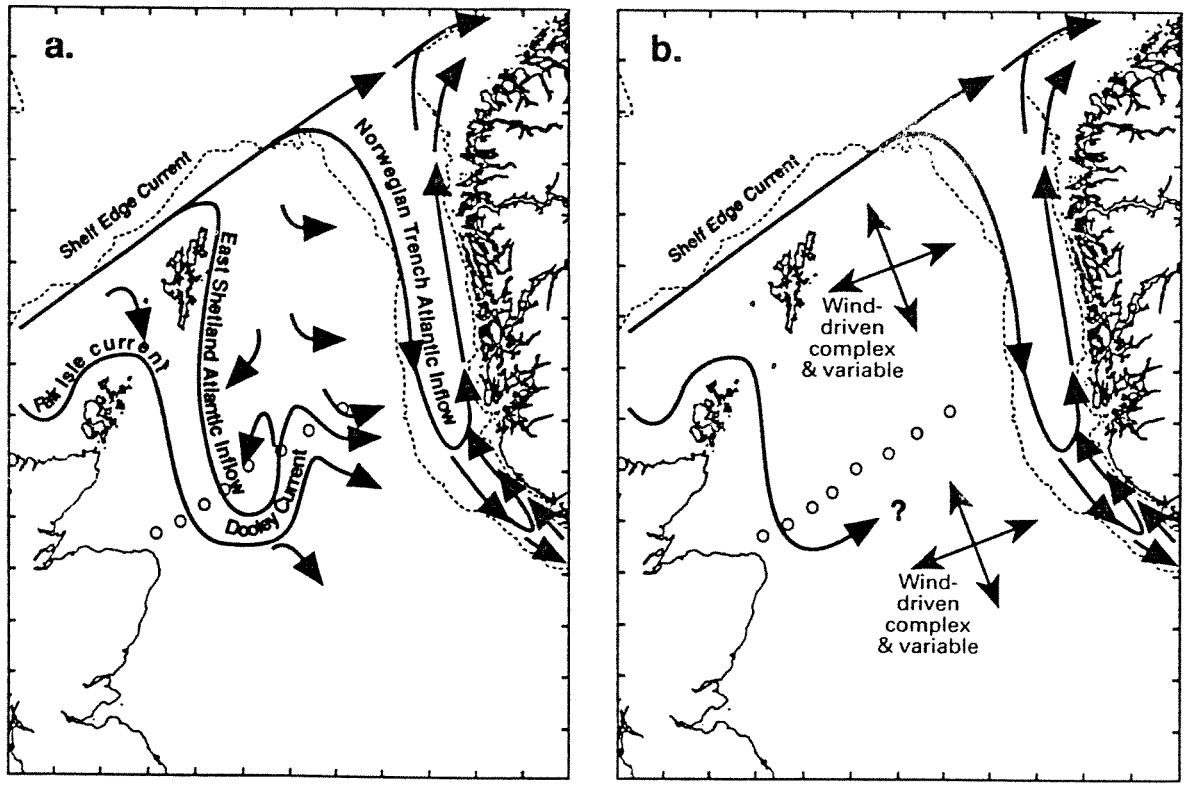


Figure 1.2. Surface salinity (A) and bottom salinity (B) in the North Sea in January. From Hutnance (1991).

Some temperature stratification may even occur during winter. In general one can expect surface temperatures around 6^{o}C (Hutnance 1991), and slightly higher bottom temperatures. The interannual variations are about 0.75^{o}C (RMS value).

Circulation

The currents around Sleipner are determined by wind, tides and large-scale pressure gradients (e.g. from meteorological highs/lows). Thus short term as well as long term variations in currents must be expected, and generally the Sleipner region has currents of varying direction and magnitude. Current measurements at Sleipner are scarce. The region can at times be expected to be influenced by the eastward flowing "Dooley" current (Dooley 1974, Svendsen et. al. 1991), which also is variable (Fig. 1.3). Note Dooleys question mark in the Sleipner area!



Charts showing the conceptual models of the circulation of the northern North Sea: (a) as derived by Turrell (1992) using the results of the Autumn Circulation Experiment (ACE); and (b) as derived by Dooley (1974).

Figure 1.3. Map of the circulation in the northern North Sea. From Turrell (1992).

The tidal height amplitude at Sleipner is about 0.5 m. The mean tidal current (spring tides) is on the order 0.2 - 0.3 m/s (Hutnance 1991).

Maximum estimated storm surge currents are ca 0.5 m/s (Flather 1987). The wind-induced currents probably have a significant NE-ward component, due to the frequently occurring SW wind during winter. This also is reflected in numerical simulations of oil spills, which often show a NE-ward drift (Anon, 1980).

1.4. Previous investigations on discharges

Company CMS in Oslo performed a preliminary, theoretical study on the discharge at Sleipner (CMS 1991). They concluded that the discharge water would rise to the surface, with a dilution factor of 200-700. Best conditions for dilution would be achieved with a deep (near bottom) discharge. Concentrations of chemicals upon surfacing were expected to be in the range 0.1 - 0.5 ppm. Downstream concentrations would rapidly decrease, to expected levels in the range 0.03 - 0.5 ppb.

Earlier, in 1984-1985, a number of reports were issued to STATOIL, related to discharges containing chemically treated water during testing and start-up of the Statpipe system in the autumn of 1984. The discharges were at different platforms, and had different configurations; surface or submerged. Continuous addition of highly visible rhodamine-B dye into the discharge made detection of the plumes

much easier than during the Zeepipe RFO in 1993, where dye was not used.

An experiment at the Statfjord field (NW of Bergen) dealt with a near-bottom (z=-147 m) discharge (IMR 1984a). The water of 1st part of the discharge was of oceanic origin. The buoyant plume rose to max. 50 m depth, before being carried away by currents. Some rhodamine was detected in the water column. Highest measured in-situ concentration represented a 1000-fold dilution of discharge water ca 600 m downstream. It shall be noted that from the discharge consisting of coastal water no rhodamine was detected. Net hauls indicated some increased mortality between potentially exposed small zooplankton (no data available to actually document true concentrations of chemicals at stations were mortality was indicated).

A second survey in August 1984 was also reported on (IMR 1984b). Rhodamine-B dye showed rapid dilution of the initial 100 ppm concentration. However, neither discharge depth, nor water flux numbers are given in the report, so experience is of limited value in the present context. The discharge contained Biocide, corrosion inhibitor, oxygen scavenger and rhodamine-B. Corrosion inhibitor, which is very toxic, was not used during the present Zeepipe RFO in 1992-93.

IMR (1984c) similarly reported on water samples of rhodamine at Ekofisk, taken 1 week after the cease of discharge in early September 1984. Near-bottom samples showed the surprising result of small, but significant levels even after 1 week period. Significant concentrations were found down to ca 20 m depth, due to vertical mixing and/or convection. No exact water flux was given. The plume was clearly visible, and dye traces prevailed for several tidal cycles. Dilution factors were however, large, on the order of 1000 near (ca 100 m from) the discharge point. Examination of zooplankton exposed in the recipient showed no mortality.

In March-April 1985 tracking of discharges at 16/11-S and 2/4-S (Ekofisk) was performed (IMR 1985). Discharge depths were not given, except stated as "sub-surface". Rhodamine was clearly seen at the surface several hundred meters downstream. No fish or zooplankton mortality was detected. Chlorophyll values were generally low, making evaluation of possible effects of primary production difficult.

2. The Monitoring Programme

2.1 Sampling philosophy

Sampling periods
According to the requirements from SFT, all three discharges were to be monitored. As each discharge was expected to last as long as about 16 days, it was agreed to sample only one half part of each discharge. This ment sampling during the last half of 1st discharge, 1st half of 2nd discharge and during 8 days of 3rd discharge. In this way sampling through ca 8 days for each discharge was achieved.

Sampling stations
In stead of running extra separate cruises before each discharge to sample reference stations, it was agreed that reference stations could be taken during the discharge periods, at sufficient distance from the discharge to rule out any possibility of far zone impacts. Initial suggestions by SFT were to perform sampling at fixed and pre-decided positions symmetrically distributed around the discharge. Also sampling depths were suggested to be pre-decided, with 4-5 depths at each station evenly distributed between bottom and surface.

It was already noted from previous investigations (conf. chapter 1) that the concentrations of chemicals in the recipient would be very low, so that detection of the plume even quite close to the discharge location might be difficult (CMS 1991). There was a great possibility of frequently, if not always missing the plume remnants when sampling at the initially proposed grid. Some of the previous comparable studies which used fixed station grid found no evidence of biological impact at all. Therefore it was agreed to apply another more flexible sampling strategy. This was to first detect the plume (if possible at all), and thereafter collect samples in the plume and above/below.

The new strategy took into account actual current and hydrographic conditions, which were expected to vary with time. This required physical measurements with sophisticated on-board instruments. Based on these measurements, model calculations of plume dilution & dispersion was to be undertaken frequently on board.

In order to achieve the best possible accuracy of model calculations, data on the actual salinity (density) of the discharge water (i.e. intake water at Zeebrügge some time before) should also be provided.

2.2 Physical monitoring and sampling

2.2.1 The Vessel
The research vessel "Håkon Mosby" (Fig. 2.1) of University of Bergen was hired for the monitoring operation. This vessel is equipped with state of the art technology for offshore oceanographic surveys, and has adequate deck gear to handle most equipment. Her length is 47.5 m, and the displacement is 950 tons. Maximum speed is about 14 knots. The crew counts 9 persons, with additional cabin space for 14 scientists.

Figure 2.1. R/V "Håkon Mosby" was used for the monitoring at Sleipner.

2.2.2 Positioning

The position for the discharge was given by STATOIL, and it was immediately located with the echo sounder upon 1st arrival. For some hours it was also visible on the sea surface as anomalously dark water. This was due to discharging of fresh water from the Sleipner condensate pipeline going on at that time. The plume was never visible (by eye) again. The Vessel had an integrated navigation system, with GPS/SPS (Global Positioning System/Standard Positioning System), which without differential mode operation presently (1993) has an accuracy of 20-30 m or better relative to WGS84 datum (Gooding 1990) in the area. Spatial resolution is an order of magnitude better (LaChapelle et. al. 1992).

2.2.3 Hydrography

Continuous depth profiles of salinity (conductivity) and temperature were simultaneously recorded digitally from the Neil Brown CTD unit (NBIS 1982) with the highest obtainable resolution and accuracy (better than +/- 0.003 ppt and +/- 0.001 deg C respectively). Salinity values are based on the PSS78 scale (Lewis and Perkin 1978). Plots (T-S profiles) and data listings were made in real-time in the computer lab. The profile data were then immediately available for comparisons, and for input to plume modelling on computer.

2.2.4 Currents

Throughout the sampling periods, ocean currents were measured in order to find the drift direction of the plume. The main instrument for this purpose was the ship mounted, four-beam 150 kHz ADCP (Acoustic Doppler Current Profiler) of RD Instruments (RDI 1989). This instrument gives at specified time intervals (e.g. each 5 minutes) a (plotted) current velocity (speed & direction) profile from near

surface to the sea bottom. In the shallow range of 80-100 m in the Sleipner field area, the ADCP worked in the bottom lock mode, and thus measured absolute (relative to sea bottom) current velocity (New 1992). The ADCP measures and compensates for the ships pitch and roll.

During 1st cruise the ADCP was not functioning properly. In stead, current was measured with an acoustic current meter of mark Simtronix UCM-40. The instrument was kept bottom moored for some time, at constant depth by a sub-surface float. Via a long cable data were transferred and read in real-time modus on board.

Forecasts on (surface) currents and wave heights were regularly received by from the HOV-Centre in Bergen by facsimile.

2.2.5 Meteorology

Meteorological conditions were partly evaluated from the Vessels own met. station. Weather-prognoses were received regularly via facsimile from the Norwegian Meteorological Institute and from the British Meteorological Office in Reading.

2.2.6 Chlorophyll-fluorescence

Determination of the vertical distribution of phytoplankton measured as the specific chlorophyll-a fluorescence at 685 nm was carried out with a Variosens *in situ* fluorimeter. This instrument was also used for determination of particle scattering (turbidity) with blue light (430 nm). Due to some instrument failure on the depth sensor and interference from the ships power supply the instrument was only used for a limited number of stations. The number of fluorescence-casts could be reduced since the chlorophyll-a concentration (phytoplankton) was low during the two cruises and the other optical profiling instrument (light beam attenuation) would have detected any chlorophyll-a layer. This also saved time on the stations which was important under the severe weather conditions during the two cruises.

2.2.7 Light beam attenuation

Light beam attenuation (transmission) was measured *in situ* for detection and monitoring of the discharge from the pipe. This method determines the attenuation of light due to particles and dissolved substances in the water masses. Two instruments were used measuring in the bluegreen (480 nm) and red (660 nm) part of the spectrum giving light beam attenuation coefficients of c480 (m^{-1}) and c660 (m^{-1}). The c480-coefficient was determined with a Martec transmission meter with 100 cm light path and c660 with an Q-instrument transmission meter with 50 cm light path. The measurements covered the whole water column down to the bottom except for the Martec instrument in March were discrete depths had to be used due to depth sensor failure.

2.3 Chemical and biological sampling

2.3.1 Water samples from the pipeline

One water sample from each discharge was collected by the staff on board the platform, and transferred on-shore with helicopter. These samples, which contained undiluted water from the pipeline just before discharging were a few days later subject to toxicity tests and tests for biodegradation in NIVAs laboratories in Oslo. For each sample a 5 l plastic container was used. The container was placed in a refrigeration box (kept dark and cool) for further transport on-shore shortly after collection.

2.3.2 Water sampling from the Vessel

The sampling on stations was done with a General Oceanics rosette sampler connected to the Neil Brown CTD. It provided a secure and accurate sampling procedure also in the frequent cases of bad weather, although wave heights exceeding ca 5 m prevented sampling. Generally hydrographic profiling (S,T,D) was done first, while continuously lowering the CTD. Water sampling was then done when retrieving the CTD.

The rosette held five 5 litre Niskin bottles. The release of each bottle was triggered from the lab when the desired depth was obtained. The depth was read from the CTD deck unit inside the lab. Simultaneous values of sea temperature and conductivity/salinity were also read from the CTD deck unit.

Upon retrieval of the rosette/CTD on deck, bottles were either transferred to the wet lab for collecting of samples, or water was withdrawn from the bottles while mounted on the CTD.

Water for determination of sulphite and oxygen was immediately withdrawn and transferred to glass vessels, prior to the addition of preserving chemicals (Winkler method for oxygen).

2.3.3 Biological sampling

Sampling of zooplankton was done with a double Juday plankton net, with adequate mesh size (180 µm) by vertical hauls on stations. It was attempted to keep the haul speed at ca. 0.2 m/s, in order to avoid plankton being physically damaged. This was of course difficult under the prevailing conditions.

Samples were subject to species identification, counting and sorting of living and dead immediately after the hauls.

Phytoplankton water samples were collected and conserved with formaline and lugol, and prepared for transfer to NIVAs laboratories in Bergen for microscope identification and counting.

2.4 Chemical and biological analyses and tests

Chemical analyses were performed partly in NIVAs on-shore laboratories and partly on board the Vessel. Except for the field screening test the algal toxicity and degradability tests was performed on-shore.

2.4.1 Glutaraldehyde

The analysis for glutaraldehyde was carried out by a photometric method using phenol and sulphuric acid. The method uses 20 % phenol in ethanol and 96 % sulphuric acid, which forms a yellow colour complex with absorbance maximum at 482 nm. The determination was performed on board on a Hitachi spectrophotometer (U-1100), except for the pipeline samples. The sensitivity of the method in natural water samples by using a 20 mm cuvette was in the range between 0,1 - 0,2 mg/l, due to contribution from particles or dissolved material. This sensivity is slightly higher than for pure sea

water, and a practical detection limit was set to 0.2 mg/l. The water samples were generally analysed the same day as sampled, but during bad weather conditions the samples were stored cool and analysed at the latest the day after sampling.

2.4.2 Chlorophyll-a and primary production

Chlorophyll-a was determined by a monochromatic spectrophotometric method according to the Norwegian Standard (NS4767). This method uses 100 % methanol as extraction reagent. Water samples were filtered on board on glass fibre filters (GFF) stored deep frozen until analysis at NIVA on a Perkin Elmer Lambda-5 spectrophotometer by using a 10 cm semimicro cuvette (volume 5 ml). This gives a sensitivity of 0.1 µg/l chlorophyll-a with 1 litre water sample. The absorption spectra of the crude methanol extract were inspected for severe degradation of the chlorophyll by running a complete pigment spectrum.

Primary production was determined with the standard ^{14}C-method (Gargas, 1975, Steemann-Nielsen, 1952). Water samples (50 ml) from two depth on each station were spiked with ^{14}C and incubated using an incubator holding an constant temperature and fixed light intensity. All samples were incubated for two hours. The water was filtered and deep frozen until counting on shore. The production versus light (PI-curve) was calculated.

2.4.3 Oxygen

Oxygen was determined onboard and follows the classical procedures as given by e.g. Bjerrum (1904), with modifications (Grasshoff et al., 1983).

2.4.4 Turbidity and total suspended sediments

As a control and verification of the *in situ* measurements of light beam attenuation and scattering, some water samples were also analysed for turbidity and total suspended sediments. The turbidity analyses were performed on a Hach turbidimeter (mod. 2100A) on board ship. The values are expressed in Formazin Turbidity Units (FTU).

Analyses of total suspended sediment were carried out by filtering (on board) 100-200 ml on pre weight 0.4 µm Nucleopore filters, rinsed with distilled water and weighted on a Sartorius micro balance back in the laboratory. The detection limit with minimum 100 ml water sample is 0.1 mg/l.

2.4.5 Sulphite analysis

A colour reagent called Dr. Langes testkit (Dr. Lange LCW 054, Berlin) was used to determine the sulphite concentration. The colour reagent forms a yellow coloured complex with SO_2, and the absorption of the complex is measured spectrophotometrically. Water samples were siphoned into oxygen bottles and kept cold and dark until analyses less than two hours after sampling. A 10 ml subsample was added 5 droplets of reagent A and 2 droplets of reagent B of the test kit. After 3 minutes incubation (maximum 10 minutes) the sample was sucked into the syringe and filtered through the Millipore filter into the cuvette (5 cm) and immediately measured in a Hitachi (U-1100) spectrophotometer at 435 nm.

The concentration of sulphite in the samples were calculated against a set of standard solutions measured photometrically. The standard solution for di-natrium sulphite is very reactive with oxygen. It is therefore important to titrate the solution to get an accurate concentration. An acetic acid solution of iod/iodide and di-natrium sulphite was titrated with natrium tiosulfat and starch solution. Water from the reference stations was used as blank samples for subtracting background values. The detection limit was 0,1 mg/l SO_2.

2.4.6 Field screening toxicity tests

Toxicity tests of water samples in the field were carried out on 96-wells micro-plates. The water samples were spiked with plant nutrients corresponding to 10 % Z8 (Staub, 1961) and inoculated with *Skeletonema costatum* from a semi-continuous culture kept under ca. 100 µE $m^{-2}s^{-1}$

continuous illumination at 20 °C. A control culture was prepared by adding the same amount of inoculum of *S. costatum* to sea water from a reference station with 10 % Z8. 0.25 ml portions of the inoculated water sample and the control culture were transferred to 6 wells on a micro plate. The micro plates were incubated for 24 hours. The chlorophyll fluorescence in the wells was measured at the start and after 24 hours incubation, using a Millipore Cytofluor 2300. The average growth rate in the incubation period was calculated from the increase of fluorescence.

2.4.7 Algal toxicity tests

The tests were carried out in accordance with ISO/DIS 10253, Marine algal toxicity test. The water sample was spiked with plant nutrients to the same concentrations as in the ISO marine culture medium and a dilution series of the sample in this medium was prepared. The test solutions were inoculated with approx. $5 \cdot 10^6$ cells/l of an exponentially growing culture of *Skeletonema costatum*. The cultures were incubated on a shaking table at 20 °C under 70 µE $m^{-2}s^{-1}$ continuous illumination. The cell density was measured with a Coulter Multisizer after 24, 48 and 72 hours, and the growth rate for the period 0-72 hours was calculated. The growth rate at each concentration (as percentage of control growth rate) was plotted against sample concentration. A concentration/response curve was fitted to the points by linear regression of probits against log concentration. The EC_{50}-value, i.e. the concentration where the growth rate of *Skeletonema* was reduced by 50%, was derived from the response curve.

2.4.8 Degradability test

Biodegradation was followed by using a modified respirometric method (NIVA method L4) adapted for sea water. The method is a modified version of the OECD 301 F (manometric respirometry) based on Guideline 306: "Biodegradability in Sea water". Due to very high toxicity in two samples (samples from 2nd and 3rd discharge) a closed bottle method in sea water was also used.

The respirometric method is suitable for test substances in the concentration range of 10 to 60 mg/l (ppm) DOC, but have shown to give acceptable results also at 5 mg/l DOC.

Natural sea water was collected outside NIVAs research station, Drøbak, at 40 m depth, and stored for 2 days at room temperature for conditioning. The sea water was enriched in nutrient salts and mineral elements, and then used to dilute the samples. Micro-organisms already present in the sea water were used as test organisms.

The degradation was monitored during periods lasting 28 to 40 days.

The biodegradability of the test compound was based on oxygen consumed expressed as percentage of theoretical oxygen demand (ThOD), calculated from the formula of the compound. Biological oxygen demand (BOD) was used as the main test criterion, supplemented by DOC analysis. The theoretical oxygen demand (ThOD) was calculated from the chemical formula of glutaraldehyde, assuming that all dissolved carbon measured was derived from this compound. Reduction in dissolved organic carbon (DOC) is normally used to evaluate the biodegradability. Analysis of DOC in sea water at low concentration gives unreliable values, which is the case for these tests.

The test medium was stirred continuously in closed bottles during incubation, and the evolution of consumption of oxygen was determined from the change in gas pressure in the sample bottles. The manometer readings were calibrated against oxygen electrode readings at the end of test. The intermittent BOD-values were derived from the level of manometer reading during incubation.

Consumption of oxygen was calculated in each test flask based on the volume of liquid and gas phase in each bottle. The concentration of dissolved oxygen at the beginning and end of incubation was measured by use of an oxygen electrode instrument.

The closed bottle method (OECD 301 D) was used as a supplementary test to overcome the problem of high toxicity in two of the samples. This test method is recommended for compounds at a concentration

of 2-5 mg/l. The test-medium and condition were the same as in the respirometric test. BOD was measured by oxygen electrode.

2.4.9 Acute toxicity test using the marine copepod *Acartia tonsa.*

The toxicity test using *Acartia tonsa* - is based on ISO proposal Water quality - Determination of acute lethal toxicity to marine copepods (Copepoda, Crustacea).

The test is used to determine which concentration of a given chemical will give acute lethal toxicity to 50 % of the test organisms after 48 hours. This concentration is called LC_{50}.

Five test concentrations are normally used. 20 organisms are used for each test concentration. The animals are added to test chambers containing sea water holding a salinity of 3.2 %, after adding the actual chemical to be tested, a pH of 8.1 ± 0.2, and an oxygen concentration of > 90 %. Incubation temperature is 20 ± 2°C.

After 48 hours the numbers of living and dead animals are quantified. Immediately after counting, the pH and oxygen concentrations are measured.

The LC_{50}-value are calculated using a probit-analysis programme (NIVAs computer program: rur-test). Results from the test are reported on standard forms, see appendix.

2.5 Weather conditions

The weather conditions during first sampling period represented the worst experienced in 30 years. During the first 8 days, wind speed was never under gail force. Wind speeds up to 80-100 knots (gusts) were frequently reported from the platforms. Measured wave heights were as large as 25 m at Sleipner.

Under these conditions there was a general shutdown of production on many platforms in the North Sea. The Sleipner Riser Platform and the nearby semisubmersible "Polycastle" were frequently disconnected. Towards the end of the scheduled monitoring period, conditions improved somewhat. But the prognosted time windows given for possible sampling were narrow.

The discharge operation was not hampered by these severe conditions. Conditions for dispersion of the plume was probably optimum. But scientific sampling of course was impossible most of the time. Max. wave heights of more than 4-5 m (corresponding to a time average of ca 3 m in the records of Fig. 2.2) restricted sampling. As can be seen from the next section, only two short rounds of sampling were achieved during the 1st cruise.

The second cruise in March had somewhat better conditions. The first half of the period allowed for some sampling. However, the weather conditions worsened after a while, and activities were suspended, as the next section explains.

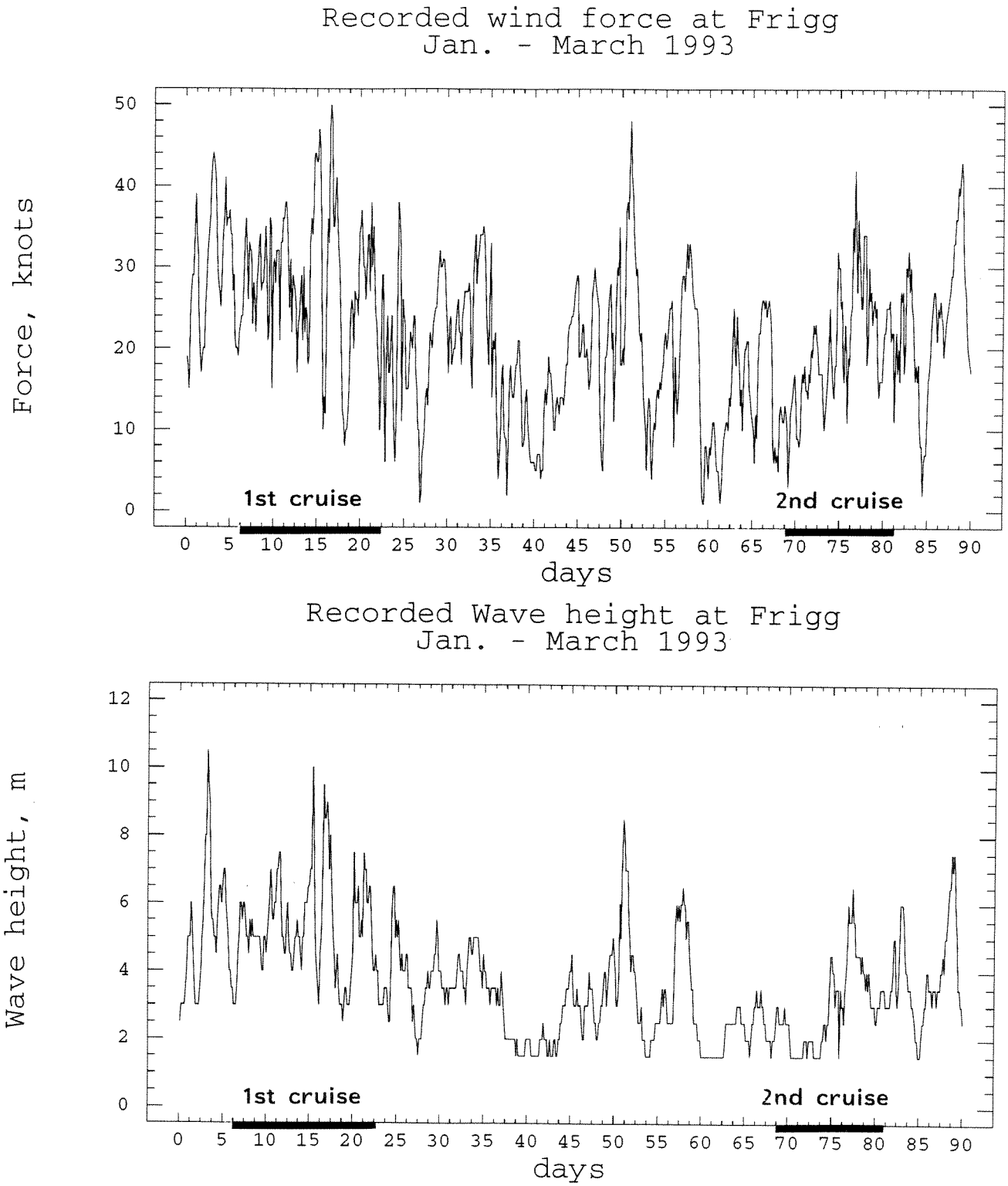


Figure 2.2. Observed wind speed and wave heights at the Frigg field, January-March 1993. Data represent time averages, so that peak values are not shown. These at times exceeded averaged values by 100%. Data from the Metr. Inst. in Oslo.

2.6 Sampling and stations, 1st cruise

The first cruise was ment to cover last 8 days of 1st discharge, and 1st 8 days of 2nd discharge. After some delay for the 1st discharge the Vessel departed from Bergen 6 January 1993 at 1500 hrs. The course was set for the Sleipner field. Halfway, the weather, the wave conditions and forecasts made sampling essentially impossible. The Vessel then returned, and called at port in Stavanger to await the weather situation. This descrition of the start of the cruise reflects what happened also during most of the remaining scheduled monitoring in January, which turned out to be significantly hampered due to extremely bad weather.

1st round of sampling, 14 January
The forecasts on Thuesday 12 January indicated a 1-2 day cease in wind. The Vessel then left port on Wednesday 13 January at 0800 hrs. Steaming to Sleipner was slow in the first hours, due to opposing wind and waves.

The discharge location was reached at 0900 hrs 14 January. The conditions were too bad for sampling, with >50 knot winds, and 8-10 m peak waves. Water was collected, however, with buckets (surface samples), and via the Vessels sea water intake at 4 m depth (not cooling water).

Initial sampling on 14 January was performed as follows:

0920 UTC, in the surface plume proper, which was clearly visible
0950 UTC, 2.7 km downstream, NE of the discharge
1127 UTC, in the surface plume proper, 2nd time
1145 UTC, 600 m upstream of the discharge, in SW direction
1250 UTC, 2 km upstream of the discharge, in SW direction
1610 UTC, in the surface plume proper, 3rd time

Additional monitoring of sea water salinity and temperature was performed in running water from the Vessels sea water intake. The Vessels scheduled track was interrupted at times due to on-going pipeline inspection from another vessel.

In the evening, 14 January, winds calmed to approx. 20 knots, and regular casts were possible. Due to the short time window to be foreseen for sampling between storms, one had to make priority for certain parameters. This included focus on the downstream area of the discharge.

Sampling and measurements were done at 8 positions in the vicinity of the discharge according to Table 2.1.

Table 2.1. Sampling through the evening of 14 January.

Sta #	Pos N	Pos E	Time UTC	Activities
1	58^{O} 22.64'	01^{O} 55.60'	1850-	CTD to bottom, & samples at 5 depths
2	58^{O} 23.04'	01^{O} 54.76'	2000-	CTD to bottom, samples at 5 depths
3	58^{O} 22.68'	01^{O} 55.68'	2110-	profile of transmission
4	58^{O} 22.70'	01^{O} 55.64'	2130-	2 transmission profiles
5	58^{O} 22.60'	01^{O} 55.59'	2145-	CTD to bottom, transm, samples at 5 depths
6	58^{O} 22.64'	01^{O} 55.90'	2215-	Transmission measurements
7	58^{O} 22.87'	01^{O} 55.90'	2245-	CTD to bottom, transm., samples from 5 depths
8	58^{O} 24.63'	02^{O} 05.43'	2330-	CTD to bottom, transm., samples from 5 depths.

Pitch and roll especially made photometric measurements difficult or at best uncertain. Also tox-testing on aldehyde was difficult to perform under the prevailing wave conditions.

The forecasted increase of wind speed started around midnight, between 14 and 15 January. The Vessel steamed to Stavanger, to await cease of wind, and to perform water analyses.

2nd round of sampling, 19 January.
On Monday, 18 January, the weather forecast indicated conditions satisfactory for sampling on Thuesday, and possibly on Wednesday. Monday morning still had very strong wind. At 1600 hrs the Vessel left port in Stavanger, at 20-30 knot winds. Sleipner was reached at 0800 hrs on Thuesday 19 January, and sampling started immediately, according to Table 2.2.

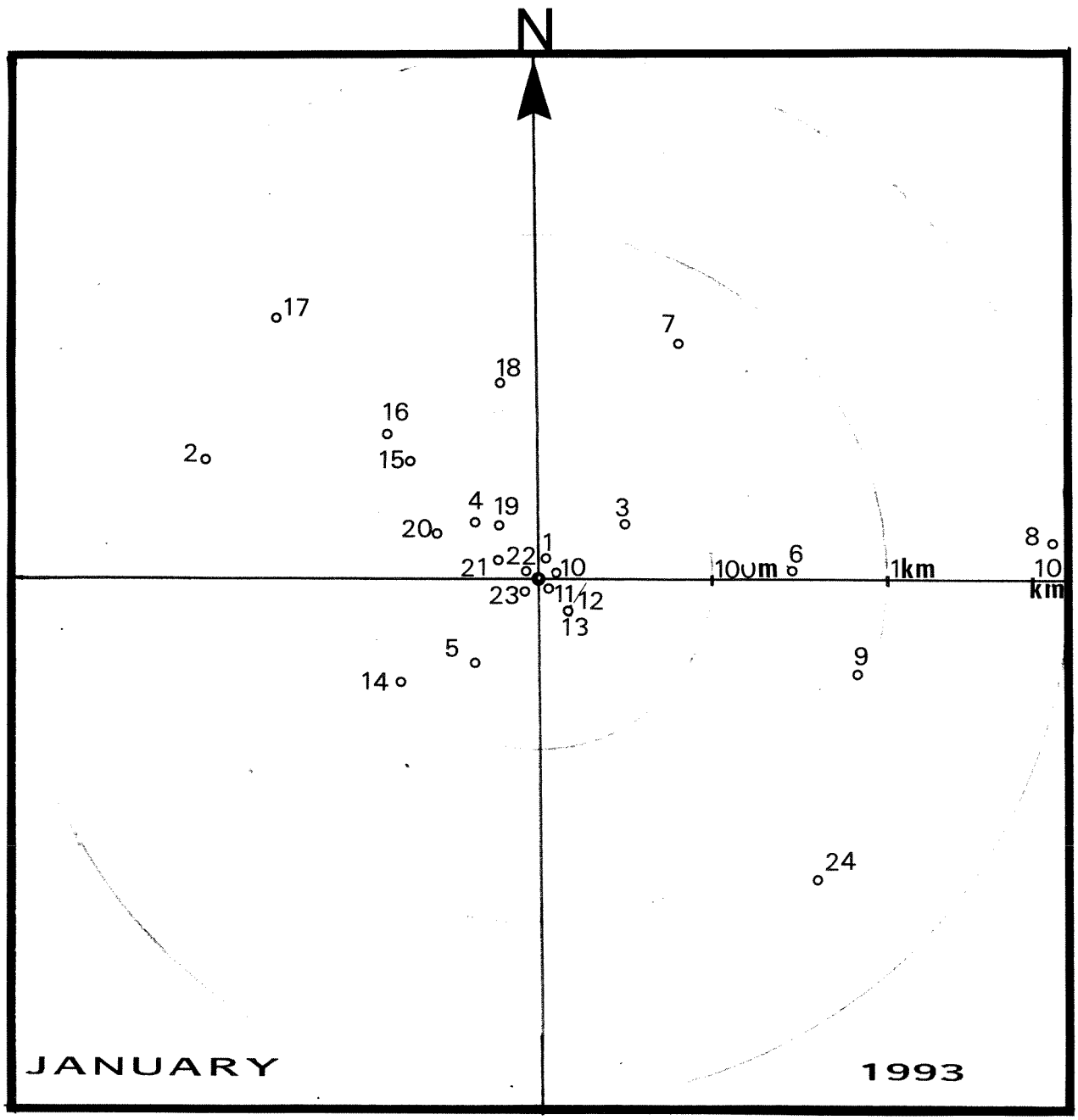


Figure 2.3. Station map, January 1993.

Also this second period of sampling was focused on the downstream region of the discharge, which was towards west-north-west. Surface currents were in the same direction as currents at depth. Fig. 2.3. shows a map of stations.

Table 2.2. Activities 2nd round of sampling, 1st cruise.

Sta #	Pos N	Pos E	Time UTC	Activities
9	58°22.40'	01°56.26'	0720	CTD
10	58°22.64'	01°55.60'	0735	Transmission
11	58°22.64'	01°55.66'	0815	Transmission
12	58°22.64'	01°55.60'	0823	CTD, water s,
13	58°22.60	01°55.52'	0922	CTD, water s, transm
14	55°22.60'	01°55.51'	1100	CTD, water s, transm
15	55°22.65'	01°55.45'	1300	CTD, water s
16	58°22.66'	01°55.40'	1400	CTD, water s, transm
17	58°23.05'	01°54.72'	1455	CTD, transm
18	58°22.67'	01°55.44'	1600	CTD, transm
19	58°22.64'	01°55.50'	1630	CTD
20	58°22.63'	01°55.48'	1730	CTD, water s, transm, nethaul
21	58°22.61'	01°55.46'	1820	CTD
22	58°22.61'	01°55.52'	1840	CTD, transm
23	58°22.62'	01°55.53'	1920	CTD, water s, transm
24	58°21.71'	01°57.55'	2137	CTD, water s, transm

2.7 Sampling and stations, 2nd cruise.

The third and last discharge operation of Zeepipe took place during the period 12 - 26 March 1993.

During part of the discharge period, monitoring & sampling at the discharge location was performed.

The cruise schedule and main activities are presented in Tables 2.3 and 2.4. Station positions are shown in the map, Fig. 2.4.

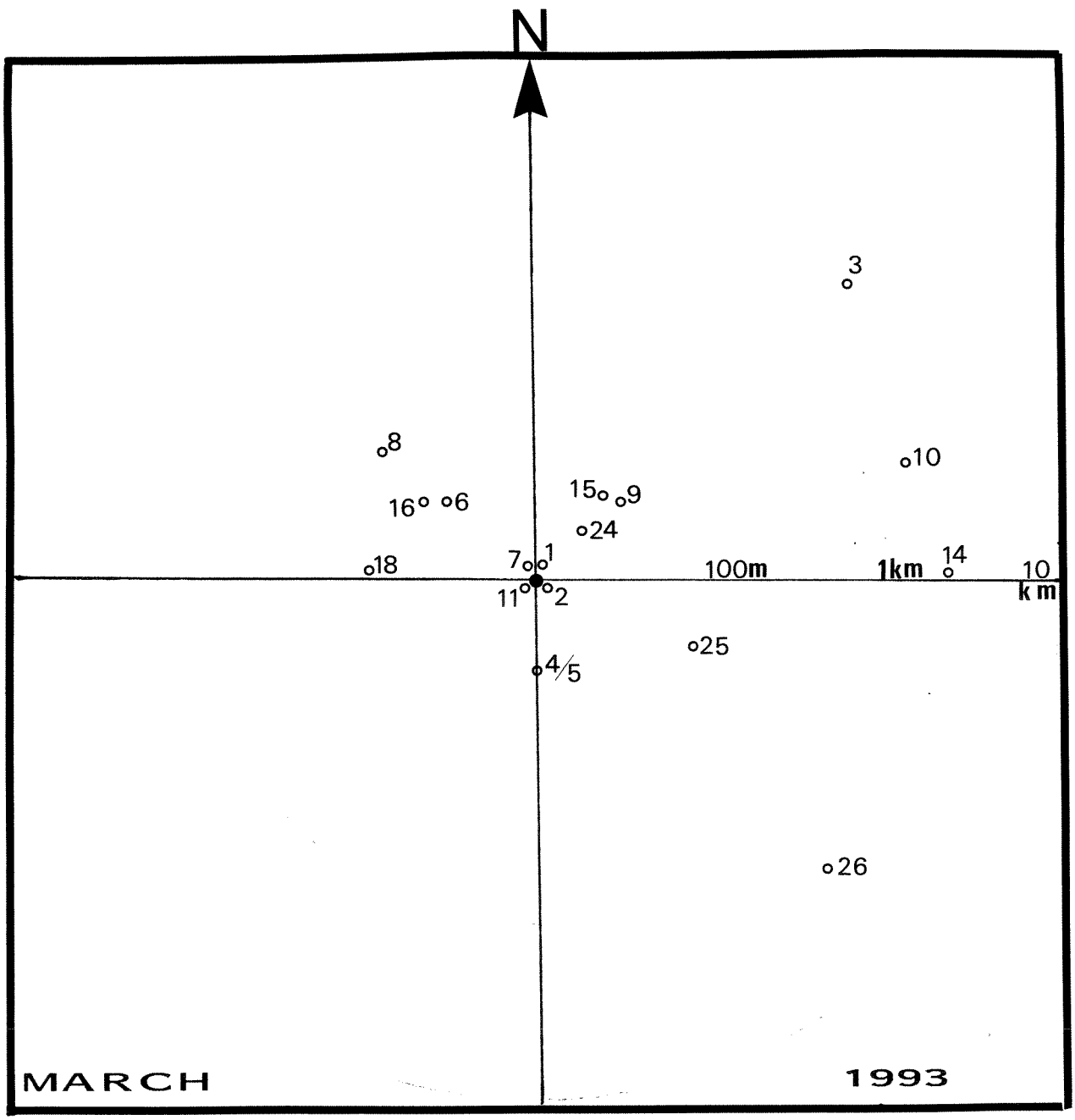


Figure 2.4. Station map, March 1993.

Table 2.3. Activities 2nd cruise (time: local time).

Day, March 1993	Main activity	Sampling	Remarks
Monday, 15	Preparations in Bergen		Loading stuff
Thuesday, 16	Mob. boat, departure from Bergen		Arr. Haugesund 2330 Hrs. Gail warning for Sleipner. Waiting for better forecasts
Wednesday, 17	Departure from Haugesund 0900 Hrs. 2300 Hrs arr. Sleipner.	Stations # 1 and 2	4-6 m waves when steaming to Sleipner. Logging sea surface temp. & Sal. + ADCP current
Thursday, 18	Night: Logging ADCP and searching with EK500 38 kHz echo sounder. Morning: sampling	Stations # 3-5, incl. net haul & water samples	Last station at 1300 Hrs. Wind increasing to Beaufort 9-10. 1800 Hrs: 70 knots (gust). Sampling impossible
Friday, 19	Sampling. Logging ADCP. Logging sea surface T-S.	Station # 6 at 0900 Hrs	Night time: Storm & 6-8 m waves. Slight decrease in the morning. Gale warning for next 2 days. Returning to Haugesund 1200 Hrs.
Saturday, 20	No sampling		0100 Hrs arr. Haugesund. Analysis and biol. testing of samples.
Sunday, 21	Logging ADCP and sea surface T-S. Start sampling at 2000 Hrs	Stations # 7 - 10	Dep. Haugesund. Steaming to Sleipner under modest conditions. Arr. -Sleipner at 1900 Hrs.
Monday, 22	Sampling. Net hauls. Towing of CTD near surface. Logging ADCP	Stations # 11 -23	Satisfactory ("90%") conditions for sampling & analysis.
Thuesday, 23	Sampling. logging ADCP. Analysis of samples.	Stations # 24 - 26	Sampling till 1400 Hrs. wind increasing to Beaufort 8. Gail warning (Bf 8-9) for Sleipner next 2 days. Decision made to end sampling programme.
Wednesday, 24	Steaming to Bergen. Logging ADCP & ss T-S.		NW Wind, Bf 9. Arr. Bergen 1300 Hrs. Start Demob. of boat.
Thursday, 25	Demob. Boat. Summary meeting		Packing of goods & equipment. END sampling cruise.

Table 2.4. Sampling at Sleipner, 2nd cruise, March 1993.

Station #	Time, GMT	Location rel. to disch.	CTD/ hydr	Water sampl.	Transm M Transm Q Fluor-V	Fyto-net Zoo-net	Chemical sampl/analyses					
							Sulph	Aldeh	O2	Fyto	Inkub	Tox
1	0317 2225	at disch	X		M							
2	0317 2250	--"--	X									
3	0318 0718	1600 m NE	X	X	Q, V, M	Z,F	X	X	X	X	X	X
4/5	0318 1000	50 m S	X	X	Q, V, M	F	X	X	X	X	X	X
6	0319 0823	50 m NW	X	X	Q, V, M		X	X	X	X	X	X
7	0321 2015	at disch	X	X	Q, V, M	Z		X	X	X		X
8	0321 2055	130 m NW	X	X	Q, M			X	X			X
9	0321 2155	50 m NE	X	X	Q, M			X	X			X
10	0321 2319	2 km E-NE	X	X	Q, V, M	Z,F			X	X		X
11	0322 0814	at disch	X	X	Q, V, M	Z,F	X	X	X	X		X
12	0322 0943	Towing CTD	X		Q							
13	0322 1016	---"---	X									
14	0322 1202	3.3 km E	X	X	Q, V, M	Z,F	X	X	X	X		
15	0322 1415	50 m NE	X	X	Q, V, M	Z	X	X	X	X		X
16	0322 1540	70 m NW	X	X	Q	Z	X	X	X	X		X
17	0322 1730	100 m W	X		Q							
18	0322 1817	100 m SW	X									
19/23	0322 1837	Towing CTD	X		Q							
24	0323 0830	30 m NE	X	X	Q, V, M	F,Z	X	X	X	X	X	X
25	0323 1001	100m E-SE	X	X		Z	X	X	X	X		X
26	0323 1204	3.5 km SE	X	X	Q		X	X	X	X	X	X

M: Martec Transmission, 480 nm Q: Q.instrument, Transmission 660 nm V: Variosens, Clorophyll fluorescens

3. Main findings

3.1 Samples from the pipeline

3.1.1 Chemical analysis

Chemical analysis from the pipeline samples were analysed shortly (a few days) after sampling. Results for sulphite from 3rd discharge may be too low as the bottle containing the water sample was sub sampled from the day before sulphite was analysed. An extra analysis was performed on a sample from 1st discharge.

Table 3.1. Chemical analysis from samples collected on the platform, directly from the pipeline. Salinity values are calculated from the chlorinity.

Discharge #	Sample date	Sulphite mg/l	Glutaraldehyde mg/l	Sulphide mg/l	Chlorinity ppt	Salinity ppt
1st, extra	30 December -92	2.2*	50.1*	nm	20.9	33.54
1st	14 January -93	0.12	3.5	18.33	19.7	31.62
2nd	19 January -93	2.87	35.1	nd	17.7	28.41
3rd	22 March -93	0.83	24.7	nd	16.9	27.12

* Analysed on board ship 13 January 1993.
nd: precipitation containing sulphide was observed, but the amount of sulphide was below the detection limit (0.10 mg/l) for the method used to analyse sulphide (NS 4735).
nm: Not measured.

3.1.2 Laboratory tests on pipeline samples

Standard toxicity tests were run on three pipeline samples. Results in appendix 1 to 9 are given as response in different dilution's of the sample. Results presented in Table 3.2 show concentrations of glutaraldehyde in the test vessels based on the results from the chemical analysis (Table 3.1), and the calculated concentration corresponding to the 50 % response concentrations for *S. costatum* and *A. tonsa* respectively, assuming that glutaraldehyde is the only toxic component in the pipeline sample.

Tests for biodegradability showed that a fraction of the 1st discharge was readily degradable. A major fraction, however, showed some resistance towards bio-oxidation (appendix 7). The 2nd discharge (appendix 8) showed that the organic substances in the test water were readily degradable at low concentrations (2-5 ppm C). This was also the case for the 3rd discharge, for concentrations < 5 ppm C (appendix 9).

Table 3.2. Calculated responses in tests based on chemical analysis. Test forms are enclosed in appendix 1-9. EC_{50} = effect concentration for 50 % reduction in the growth rate. LC_{50} = lethal concentration for 50 % reduction in the number of organisms. Actual concentration of glutaraldehyde (mg/l) after dilution are shown.

Discharge #	Sample date, 1993	Glutaralde-hyde mg/l	EC_{50} S. costatum	LC_{50} A. tonsa	Degradability
1st	14 January	3.5	(87% *1) 3.0	(>100%*4) > 3.5	Degradable *7
2nd	19 January	35.1	(0.82% *2) 0.29	(2.9%*5) 1.0	DWD *8
3rd	22 March	24.7	(0.55% *3) 0.14	(3.5%*6) 0.86	DWD *9

*1 - *9: appendix 1 to 9 in report.
DWD: Degradable when diluted.

3.2 Hydrography

The use of the CTD instrument to measure hydrographic profiles offered the possibility to measure under more severe conditions than what could be done with other sampling. Also the CTD with its high resolution capabilities was expected to be a powerful tool for detecting salinity anomalies in the water column that could be due to the discharge plume.

When selecting station positions, reference was made to the available current measurements (ref. para. 2.1.1.), so that the upstream-downstream direction could be determined. At times the ADCP current data showed a reversal of direction with depth. It was then still attempted to sample downstream/ upstream relative to the discharge after determining the depth of the plume.

3.2.1 1st and 2nd discharges

None of the 5 profiles that were possible to obtain during the 1st round of sampling (14 January) showed any sign of salinity anomalies. The water column was completely mixed, with high salinities, ranging from 35.185 to 35.195, and temperatures between 7 and 7.15^{O}C. The extremely well-mixed column (only a few parts of a thousand in salinity difference between surface and bottom) must be due to the very severe weather conditions prior to sampling (frequently 15-20 m waves). This was also demonstrated by the water samples which contained fine sand even at the sea surface. Fig. 3.1a shows the salinity profile for station 1, which was taken at the discharge point (+/-30 m).

During the second round of sampling (19 January), conditions had changed slightly, with salinities in the range 35.16-35.19, and temperatures in the range 6.8-7.0 ^{O}C. Fig. 3.1b shows the profile for station 24 taken 3.5 km SE of the discharge as a reference station. Still a remarkable well-mixed situation prevailed.

During 1st round of sampling, no anomalies were detected by the CTD, that could be due to discharge water. As discussed elsewhere, some stations did show evidence for some impact. As the ship drifted somewhat between the different profiling and sampling activities on station, the CTD profiles might have missed what was detected by other instruments and/or samples.

During the 2nd round (19 January), anomalies that most probably was due to discharge water were detected several times. Fig. 3.2a-c presents three such profiles, for stations 15, 16 and 23. The profiles show a layer of somewhat less saline water (delta-S = 0.02 - 0.035 ppt) at 40-60 m depth. These stations also had more or less strong optical anomalies at corresponding depths (para. 3.3).

3.2.2 3rd discharge, March 1993

Typical winter time conditions still prevailed during the period of the March monitoring, although the water column was somewhat more stratified than in January. Typical salinity values were in the range 34.95 - 35.05 ppt. Temperatures ranged between 6.0 and 6.3 ^{O}C. Figs. 3.3a,b show vertical profiles of salinity for station 3, 18 March and station 26 on 23 March, i.e. at the beginning and end of the monitoring. These stations were taken 2-4 km away from the discharge location, and served as reference stations. A pycnocline (vertical density gradient) is seen at a depth of about 50 m on 18 March, increasing to ca 65 m on station 26. The upper layer turned slightly (0.05 ppm) less saline during the period between stations.

Fig. 3.3c shows the salinity profile at station 4, taken ca 50 m S of the discharge location. Anomalies of 0.04 - 0.05 ppt occurred at 25-40 m depth. Anomaly was also detected in the optical measurements.

3.2.3 Dilution and dispersion

Modelling of the discharge by use of NIVAs plume model "JETMIX" (Fan and Brooks 1969, Bjerkeng and Lesjo 1973) was undertaken on board based on available information. An important and somewhat uncertain factor was the salinity (i.e. density) of the discharge water. The lower the salinity, the shallower the expected neutral buoyant layer in which the discharge water would disperse horizontally. As already seen from Table 3.1, the salinities ranged between 27.1 and 33.5 ppt for the samples analysed on shore, after the monitoring cruises. These numbers, which probably anyway do not reflect the full salinity range, were not available during the cruises.

Some data on salinities that were made available from Zeebrügge, indicated that salinities from 18 ppt to above 33 ppt could be expected in the discharge. The chlorinity measurements made by NIVA on the samples from the pipeline indicated that values tended to be in the higher fraction of the indicated range. Tests of the the plume model showed that for the expected range of salinities (densities), the plume would rise to the surface (0-20 m depth) for the lower salinities. For salinities of 32-33 ppt or higher, the plume would not come to the surface, but reach its neutral level around 20-40 m depth.

As was observed, this depth range frequently showed some form of anomalies in the profiles. Also, if frequent surface impact would occur, one would also expect some visible trace of the discharge water, originally of coastal origin. This was only seen once (14 January), while another flow of fresh water was added to the discharge.

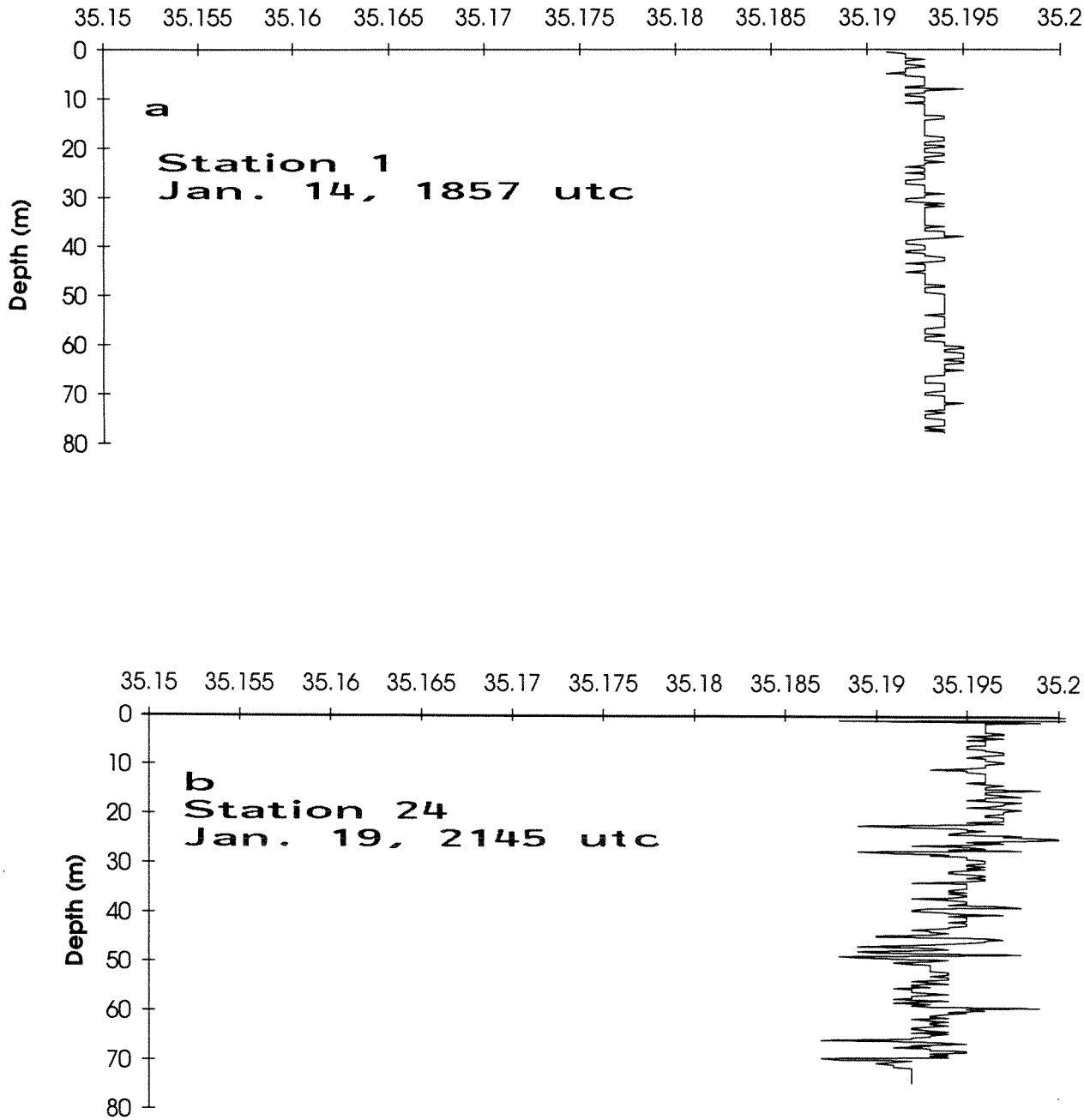


Figure 3.1a-b. Salinity profiles from 1st cruise.

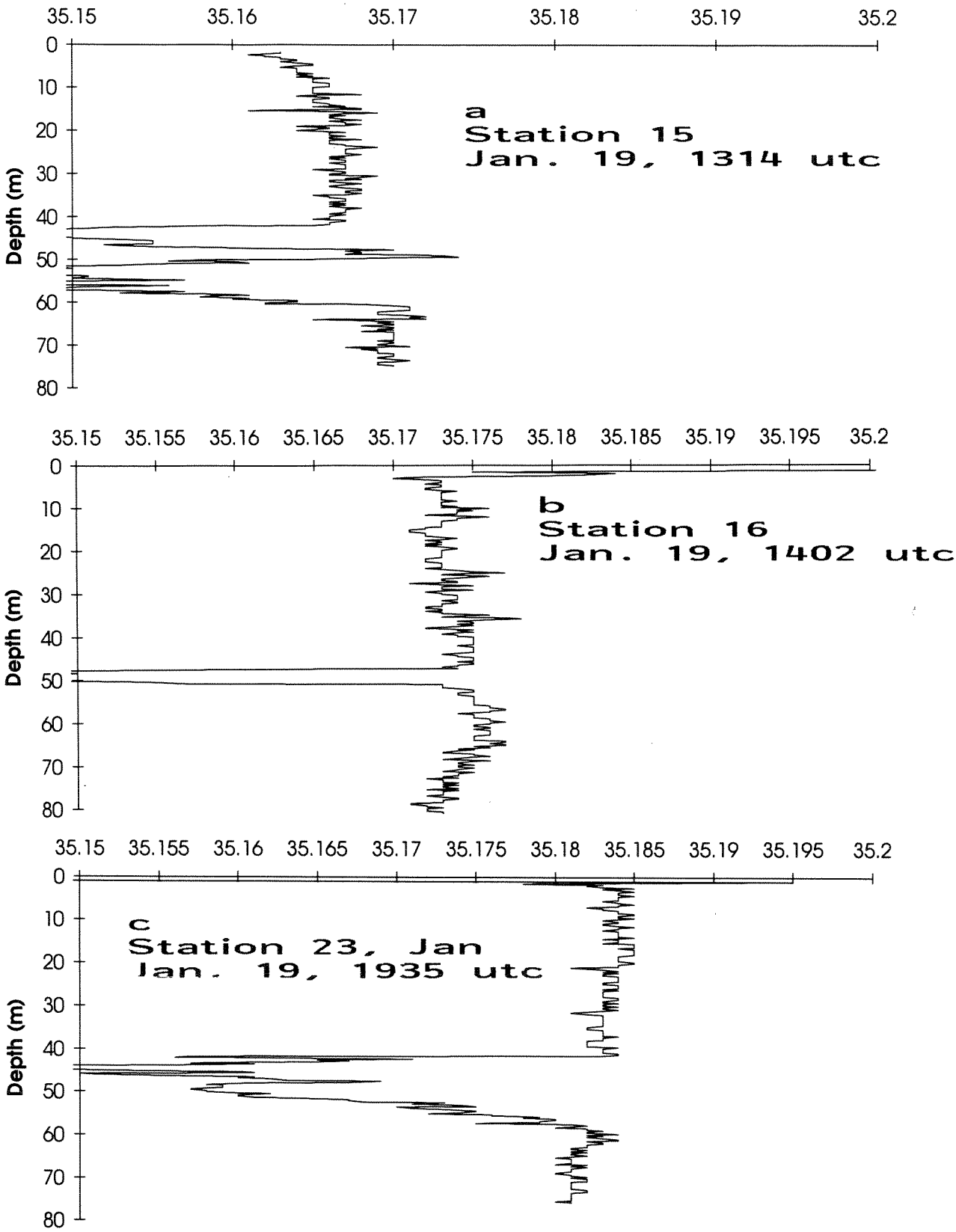


Figure 3.2a-c. Salinity profiles from 1st cruise showing anomalies due to the discharge.

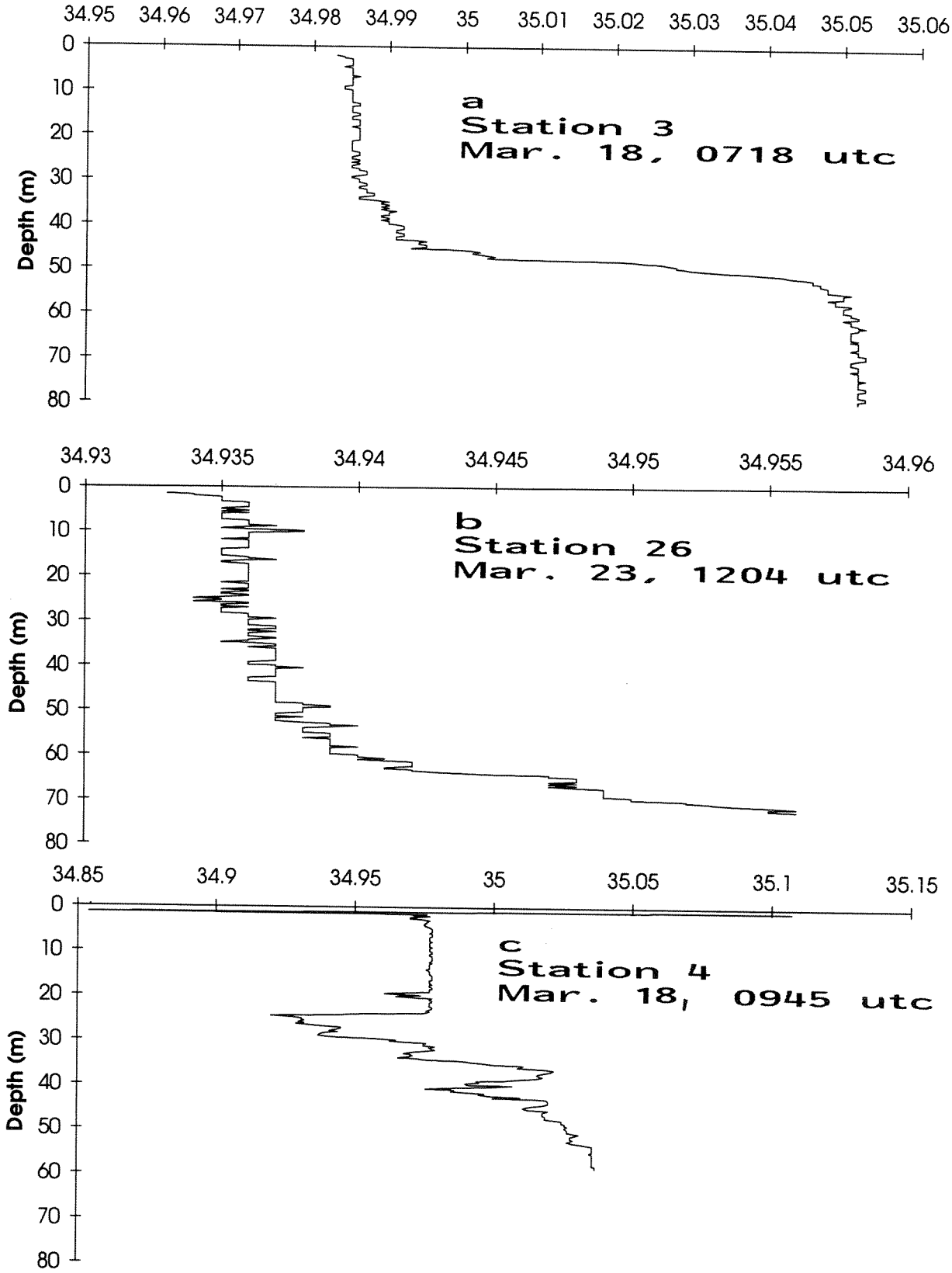


Figure 3.3a-c. Salinity profiles from the March cruise. Stations 3 and 26 are reference stations. Station 4 shows some impact from the discharge.

3.3 Optical measurements.

The January situation.

Light beam attenuation (c480) was measured on all stations, but only on a few locations close to the discharge where it possible to detect any plume (discharge). Figure 3.4 shows the vertical distribution of c480 (m^{-1}) from station 23 where some toxic effects were determined (conf. para 3.6.4). The discharge anomaly is seen at 40 to 50 meter depth. Also station 1 had some effect but here only traces of the discharge can be seen in the profile (Figure 3.5). Higher values are also seen in the surface, but this can be due to air bubbles mixed into the surface waters (no surface anomaly in the CTD profile, Fig. 3.1.a). The same surface signal was also seen on the reference station 8, Fig. 3.6. In January significant detection of the discharge was recorded on station 1, 10-15, 19 and 23.

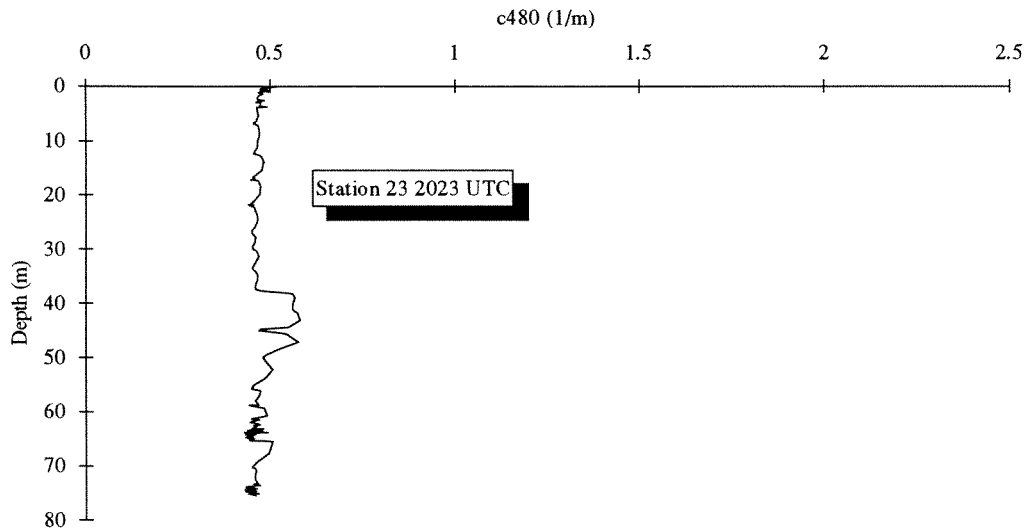


Figure 3.4. Light beam attenuation (c480) on station 23 (2027 UTC) on 19 January, 1993.

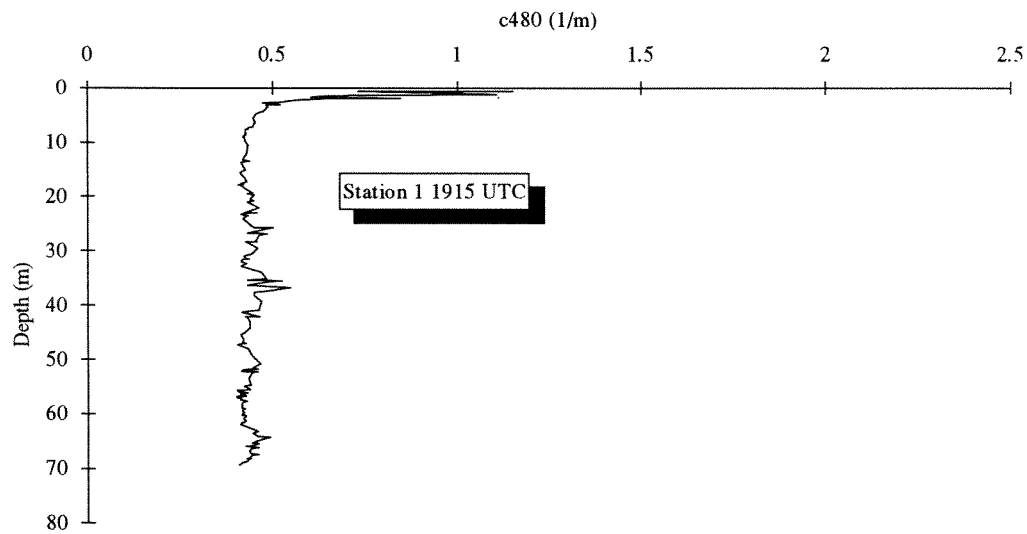


Figure 3.5. Light beam attenuation (c480) on station 1 (1915 UTC) on 14 January, 1993.

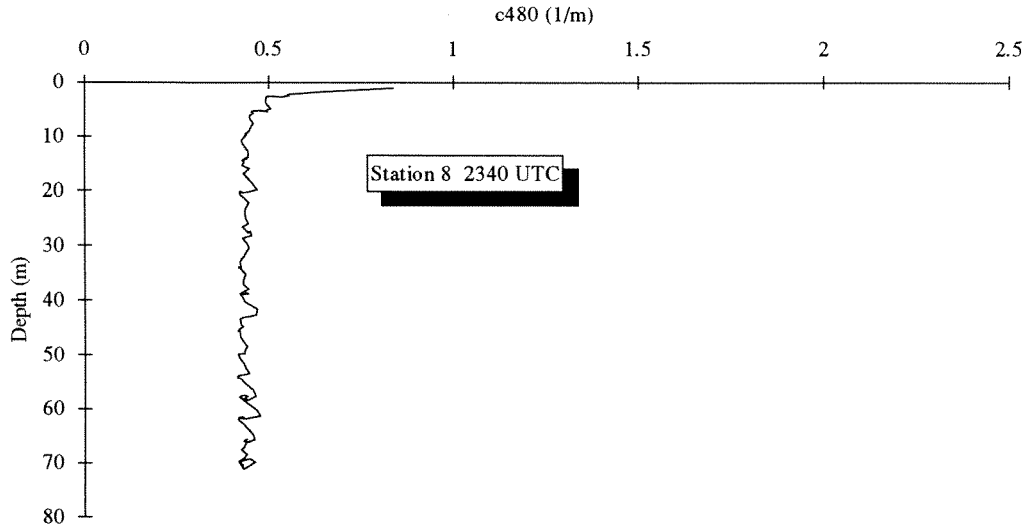


Figure 3.6. Light beam attenuation (c480) on station 8 (2340 UTC) on 14 January, 1993.

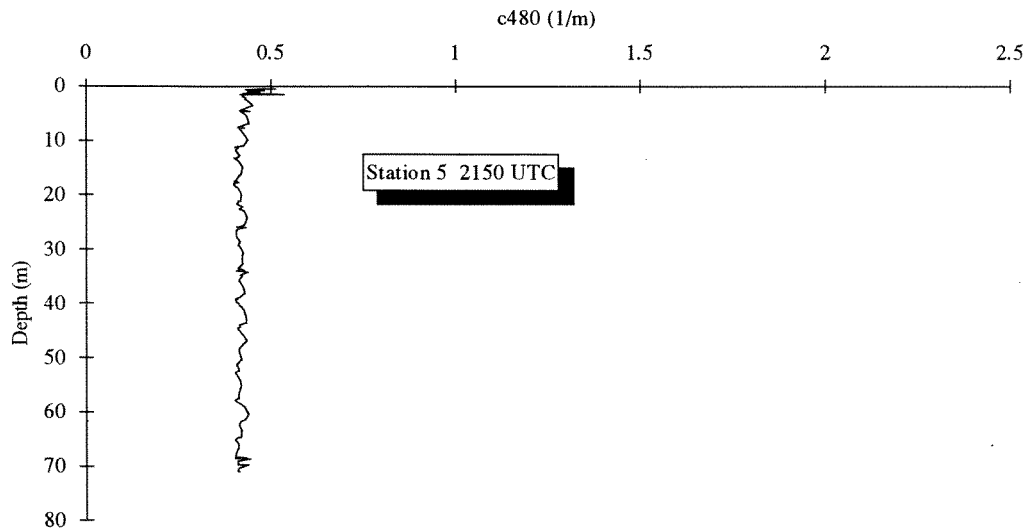


Figure 3.7. Light beam attenuation (c480) on station 5 (2150 UTC) on 14 January, 1993.

The particle concentration measured as turbidity was generally high in the whole area and it is likely that bottom sediments were mixed into the whole water column. Figure 3.8 shows the turbidity in the water samples.

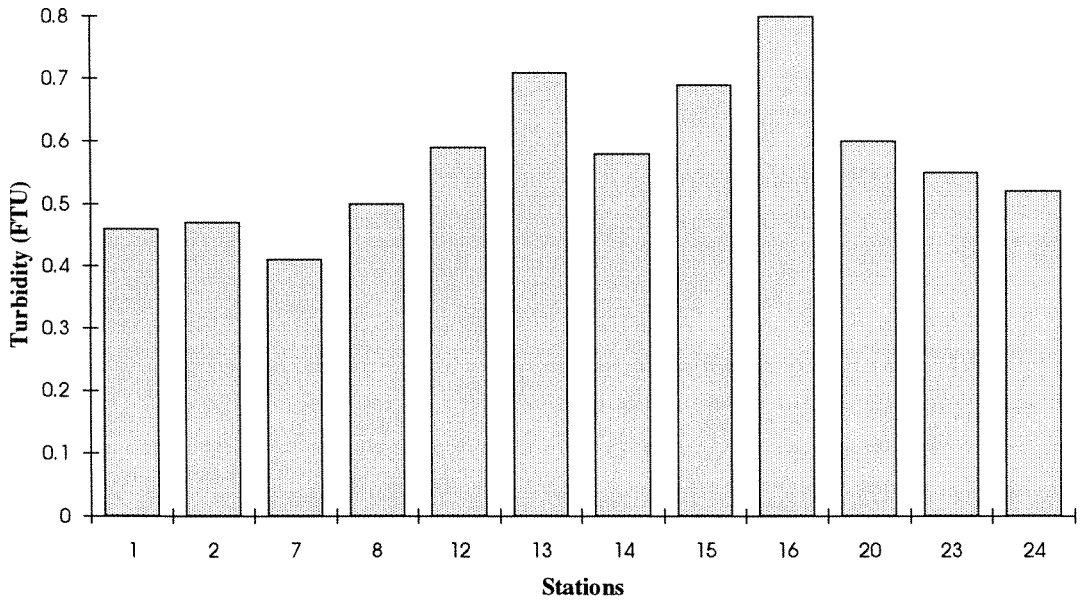


Figure 3.8. Mean concentration (five water samples) of turbidity (FTU) from some of the stations in January.

The concentrations of chlorophyll-a were also very low, between the detection limit (< 0,1µg/l) and 0,2 µg/l. Figure 3.9 shows the situation for the January cruise.

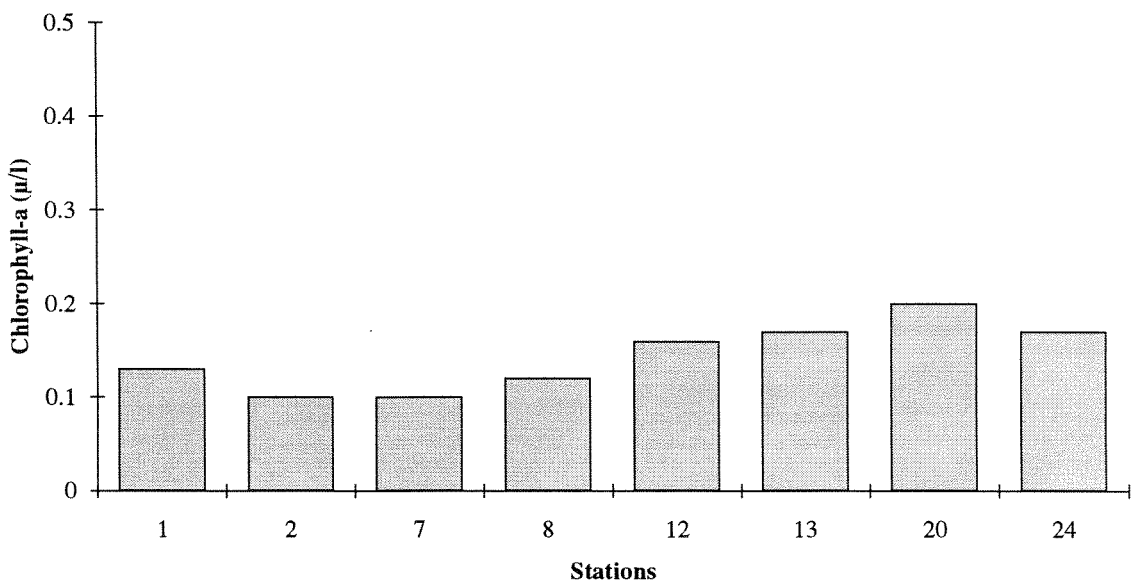


Figure 3.9. Mean concentration of chlorophyll-a (five samples) on some of the stations in January.

The March situation

Transmission (c660) was measured on most of the stations in March as well as one situation during towing of the CTD. Figures 3.10 and 3.11 show the plume on 2 of the stations near (50 m from) the discharge. In March the discharge was detected at station 5, 6 and 7.

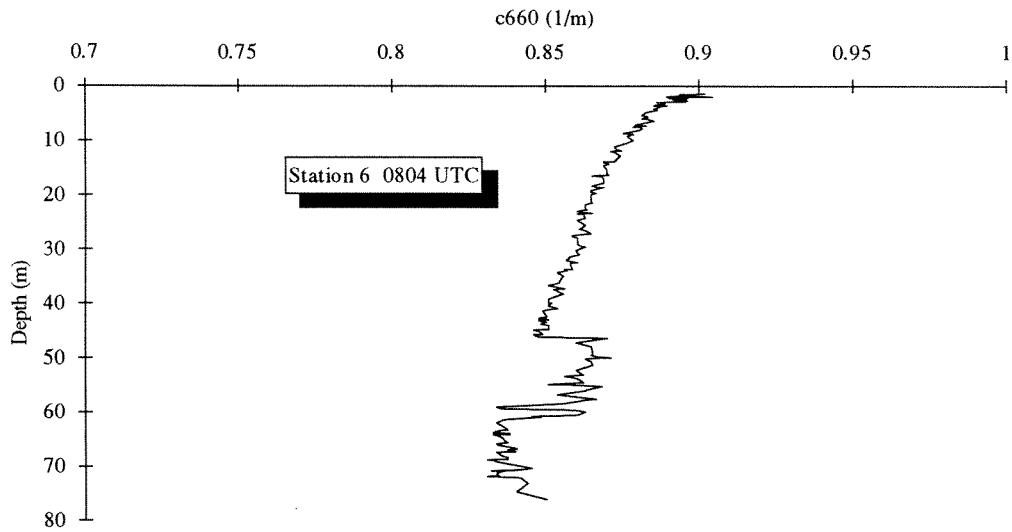


Figure 3.10. Light beam attenuation (c660) on station 6 (0804 UTC) on 19 March, 1993.

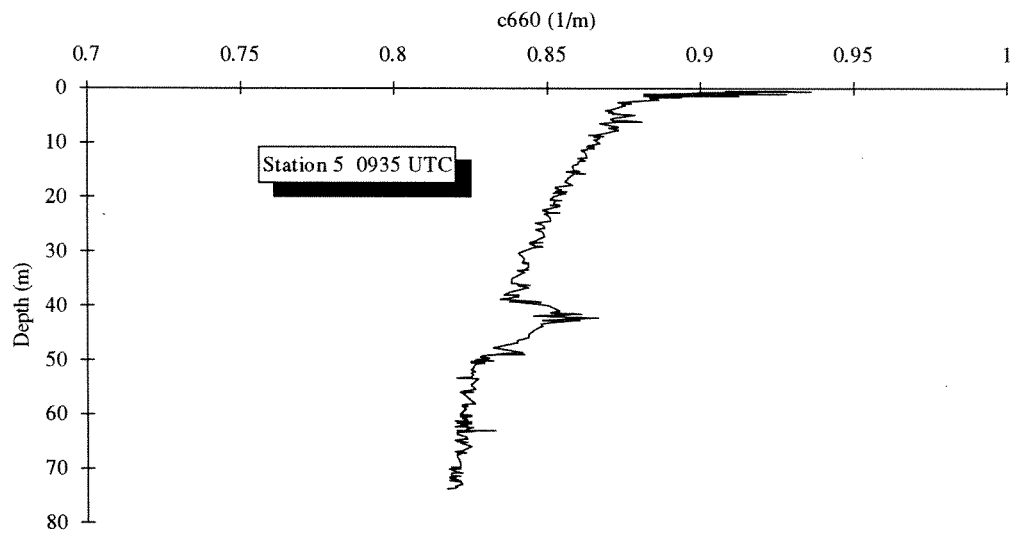


Figure 3.11. Light beam attenuation (c660) on station 5 (0935 UTC) on 18 March, 1993.

There was also a general increase in c660 towards the surface, but this trend was also found for the reference stations 14 (Figure 3.12) and 10 (Figure 3.13) taken 3,3 and 2 km from the discharge.

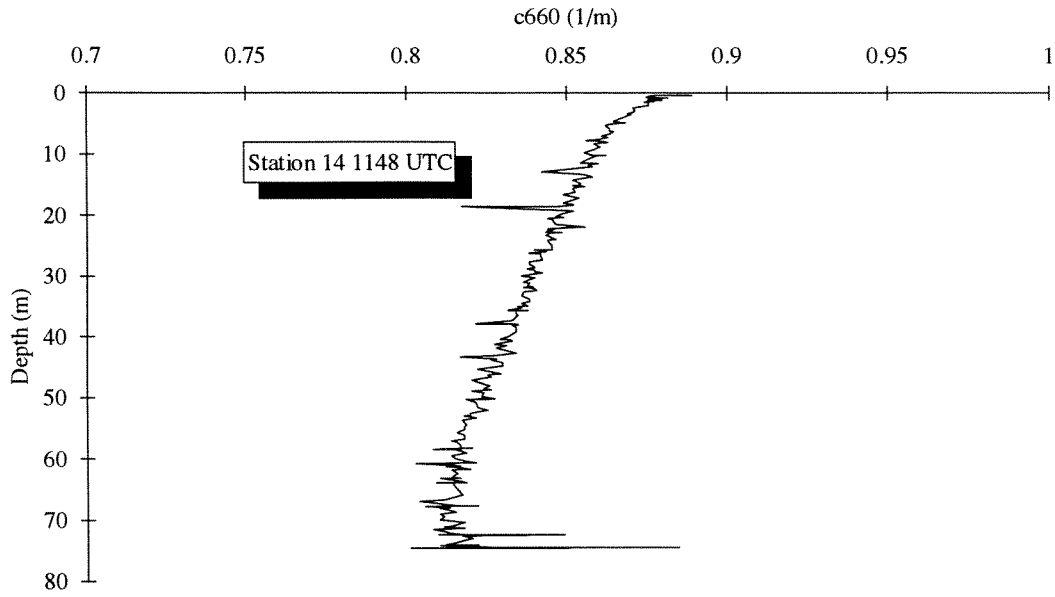


Figure 3.12. Light beam attenuation (c660) on station 14 (1148 UTC) on 22 March, 1993.

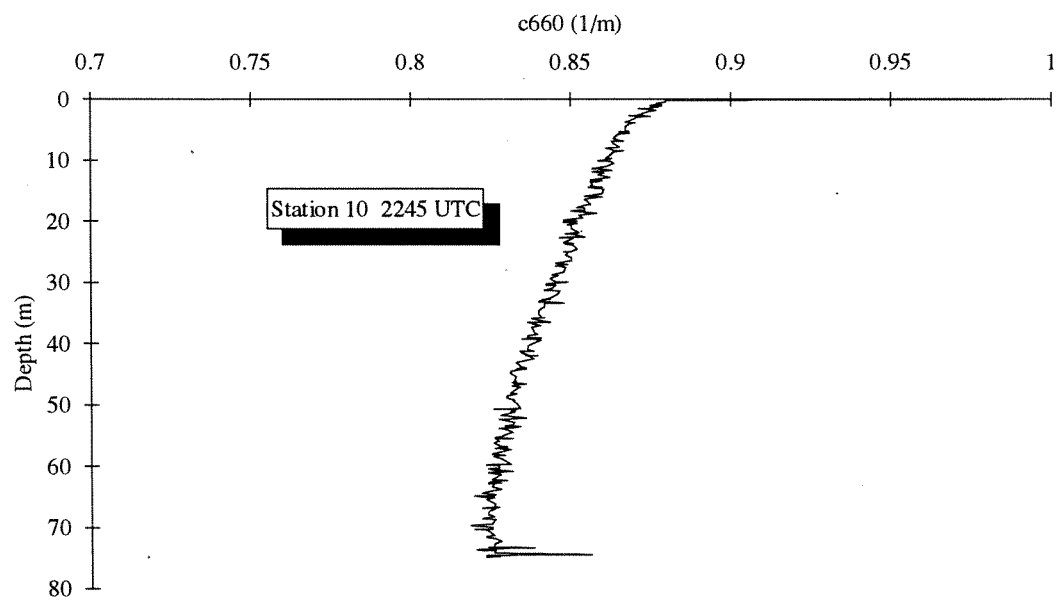


Figure 3.13. Light beam attenuation (c660) on station 10 (2245 UTC) on 21 March, 1993.

Turbidity values of the water samples from March are shown in Figure 3.14. The variation between the stations was small and the concentration slightly lower than in January. Chlorophyll-a concentration (Figure 3.15) had increased slightly from 0.2 µg/l in January to 0.4-0.5 µg/l in March.

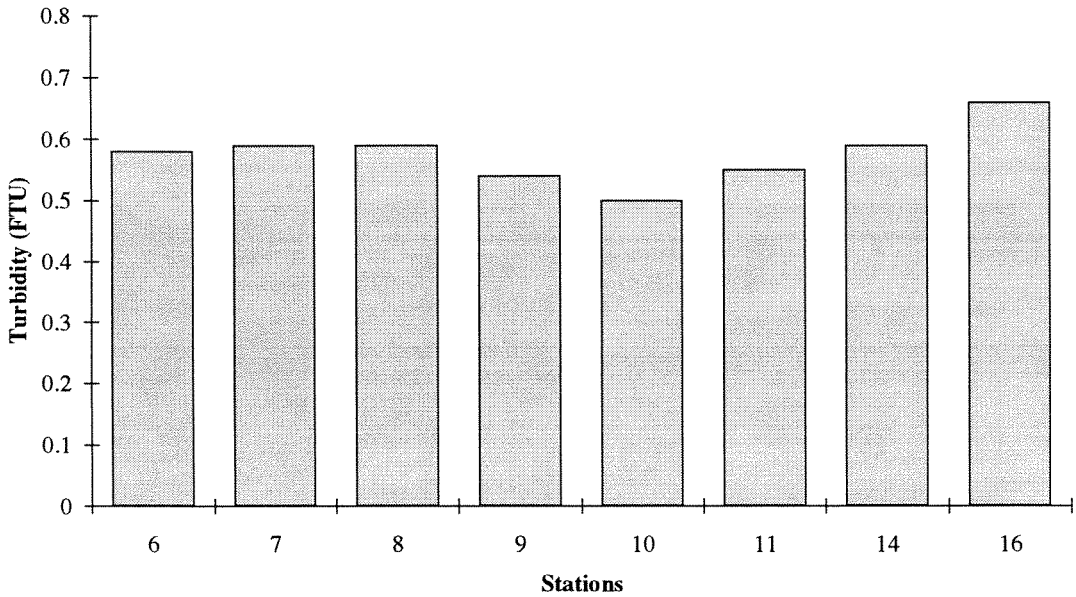


Figure 3.14. Mean concentration of turbidity (FTU) (four water samples) from some of the stations in March.

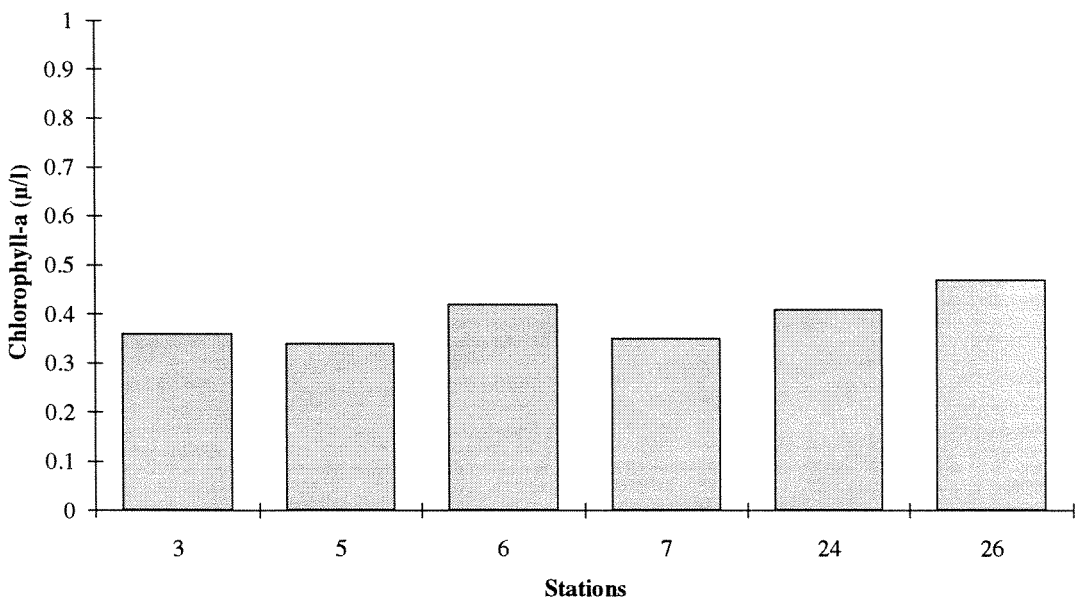


Figure 3.15. Mean concentration of chlorophyll-a (four samples) on some of the stations in March.

3.4 Zooplankton

Sampling of zooplankton was severely hampered by the weather and wave conditions. In order to evaluate possible mortality, samples have to be investigated and sorted under stereo microscope immediately after sampling, before organisms start to die. Such inspections will naturally be difficult to perform when the ship heaves and rolls, which was the case all the time at sea.

1st cruise
During the January cruise sampling of zooplankton was given a low priority, partly due to the risk of destroying the net and/or organisms possibly present, and partly due to the higher priority made for other sampling. Test samples showed that the zooplankton biomass was very low at that time, making further investigations for mortality irrelevant anyway.

2nd cruise
During the 2nd cruise, several samples were recovered, although conditions were far from ideal. The heave of the ship still caused irregular, and at times high hauling speed, which in itself may cause some (mechanical) stress to organisms.

Hauls were taken from 20 m to surface, as plankton concentrations in deeper layers were low or zero.

Station 3, 03-18, morning (reference)
Some mortality counted. The heavy sea (wave height ca 6 m) made selection of nauplii impossible. The observed mortality most probably was caused by the heavy weather.

Station 7, 03-21, evening.
Ca 2 m wave height. Plenty of small pieces of wood and paint (from pipeline, platforms or paint from the ships hull?). Ca 30% of plankton alive just after sampling. Almost all nauplii were dead. After 1/2 hour almost all organisms had passed away. As an attempt to reduce mortality rate by oxygen loss and warming in lab, some part of the sample was kept cool, and supplied with new sea water. This had no effect on mortality rate.

Station 10, 03-21, evening (reference)
Ca 2-3 m wave height. Significant concentrations of plankton probably due to vertical upward migration at night. 1/4 of sample was further investigated and sorted. Ca 60% of plankton alive just after sampling. Only a few nauplii were dead. Low mortality rate during 1-2 hours of inspection. Seemingly better conditions than on previous station 7.

Station 11, 03-22, morning.
Ca 2-3 m wave height. Ca 50% dead in sample. Plankton in better condition than at station 7, but worse than on 10.

Station 14, 03-22, noon.
Ca 3-4 m wave height. Conditions essentially as on previous station 11.

Station 15, 03-22, early afternoon.
Ca 4-5 m wave height. Results essentially as for station 14. The sorted living fraction was lost due to sudden heavy roll! This fraction contained *Oithona spp*, and nauplii, plus some *Calanus Finmarcicus, Acartia sp* and trochopore larvae.

Station 16, 03-22, afternoon.
Ca 4-5 m wave height. Ca 90 % dead in sample.

Station 24, 03-23, morning.
Ca 6-7 m waves. Few plankton. Mostly dead.

Station 25, 03-23, morning.
Ca 6-7 m waves, increasing. High mortality.

The severe conditions especially when last stations were taken, may severely have affected the sampling. Thus any deductions on mortality due to the discharge components should be done with precaution.

3.5 Phytoplankton

Species composition

January
The winter population was characterised by very low biomass and few species. Since the cell numbers of the different species were low, near the detection limit, sporadic registrations were more or less the rule. It is therefore difficult to draw any conclusion at the species level. Calculation of mean values for each station (Table 1) show the highest value for station 8, the reference station. The mean cell number for station 1 is nearly 12% lower than the reference station. Detailed results are given i Appendix 10.

Table 1. Mean values in cells/l, based on all organisms and all depth.

Station number	1	8	14	20
Mean cell number	962.120	1.089.240	1.053.850	1.056.268
% reduction from reference	11.7	ref.	3.2	3.0

March
The phytoplankton population was still dominated by small flagellates, and the biomass was low (see Appendix 11).

The three stations that were worked up with respect to species composition, stations 3 (reference), 5 and 6, showed small differences except for the upper depth (10 m) at station 6, where total cell numbers were more than 20% lower than for corresponding depth at the reference station (2 m). The shallowest depths at these two stations have a 8 m difference.

3.6 Analyses during monitoring

3.6.1 Sulphite

January
Sulphite was measured for most stations of which water was sampled. These were the following stations: 1, 2, 7, 8, 13, 15 and 16.

No sulphite was detected for any depth in any of the stations measured. The detection limit for this analysis are between 0.05 to 0.1 mg per litre.

March
Sulphite was measured for most stations of which water was sampled. These were the following stations: 3, 5, 6, 11, 14, 15, 16, 24 and 25.

No sulphite was detected for any depth in any of the stations measured.

3.6.2 Chemical analyses of glutaraldehyde

Glutaraldehyde was analysed on both pipeline samples and water samples collected in January and March. In January 59 samples from 12 normal stations and 6 surface samples were analysed. For all the samples glutaraldehyde was below the detection limit of 0.2 mg/l (appendix 13).

In March glutaraldehyde were analysed on 14 stations and total of 56 samples. No significant concentration of glutaraldehyde could be detected (appendix 13).

3.6.3 Oxygen

Oxygen samples were collected, conserved and titrated on board shortly after sampling according to the Winkler method. The main objective for collecting these samples was to detect, if possible any patches of water depleted in oxygen due to reaction with sulphite from the discharge.

Results from the analyses are shown in tables, Appendix 12. Fig. 3.16 shows the results graphically, one frame for each cruise. Oxygen levels were high, and always above 94% saturation. January had systematically somewhat lower values (2-4% lower in saturation) than March. No anomalously low values were observed.

The results for chemical analysis of the pipeline samples (para. 3.1) showed sulphite concentrations less than 3 ppm, which is far lower than the expected ca 30 ppm. These low exit concentrations may explain the lack of negative oxygen value anomalies in the water samples.

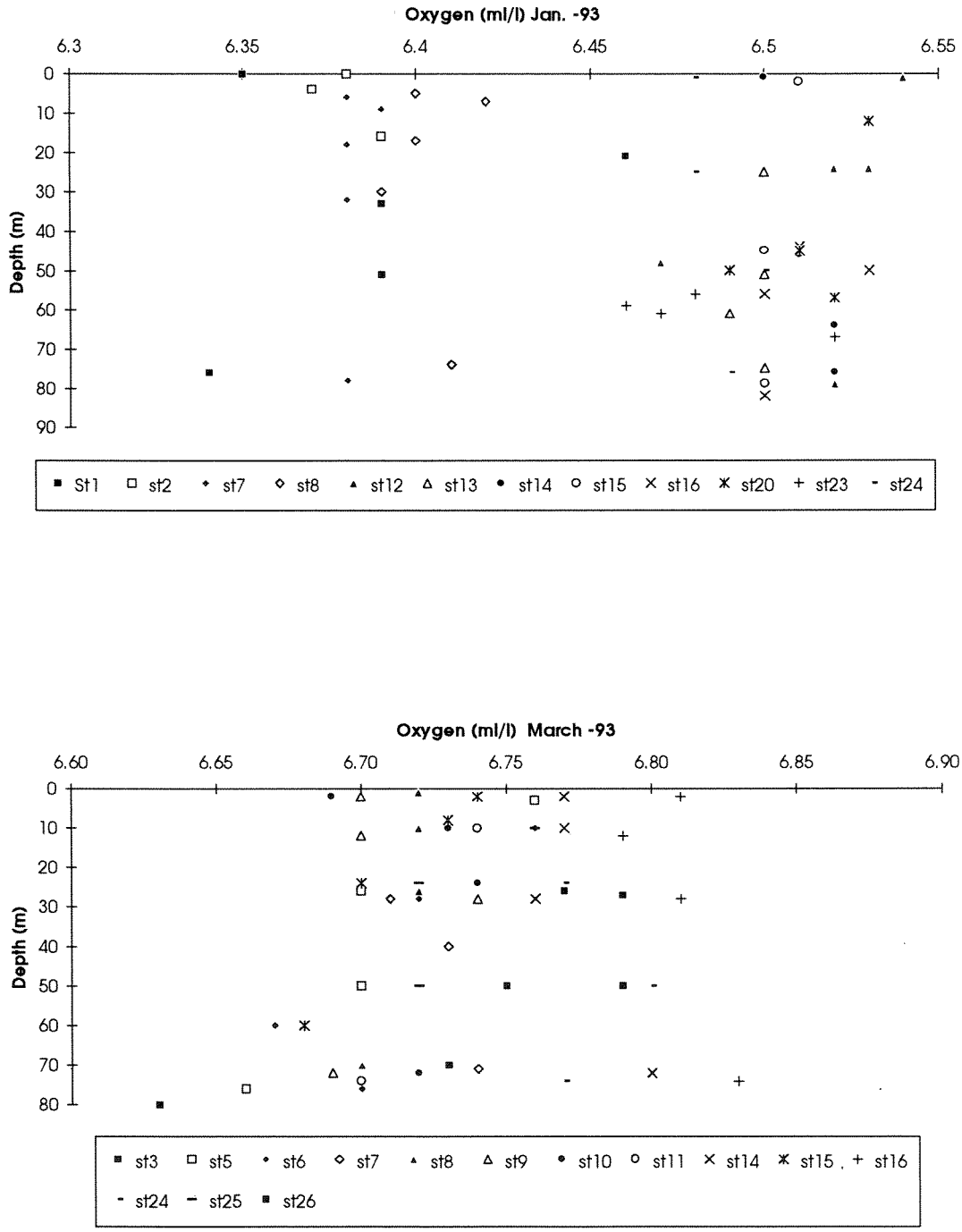


Figure 3.16. Oxygen values from water samples in January (upper frame) and March 1993. Data in Appendix 12.

3.6.4 Field screening tests

January cruise

During the January cruise water samples were tested (screening test) using *S. costatum.* Water was collected at five depths from twelve stations. From three stations only surface water was sampled.

S. costatum growth rates for each station were compared with growth rates at the reference station. Significant reduction (student's t-Test, paired two-samples assuming equal variances) in growth rate was observed on station 1, all depths, and station 23, depths: 56, 59, 61, 67. Significant reduction in growth rate was also found for station 14 (64 and 76 m) and station 20 (50 m).

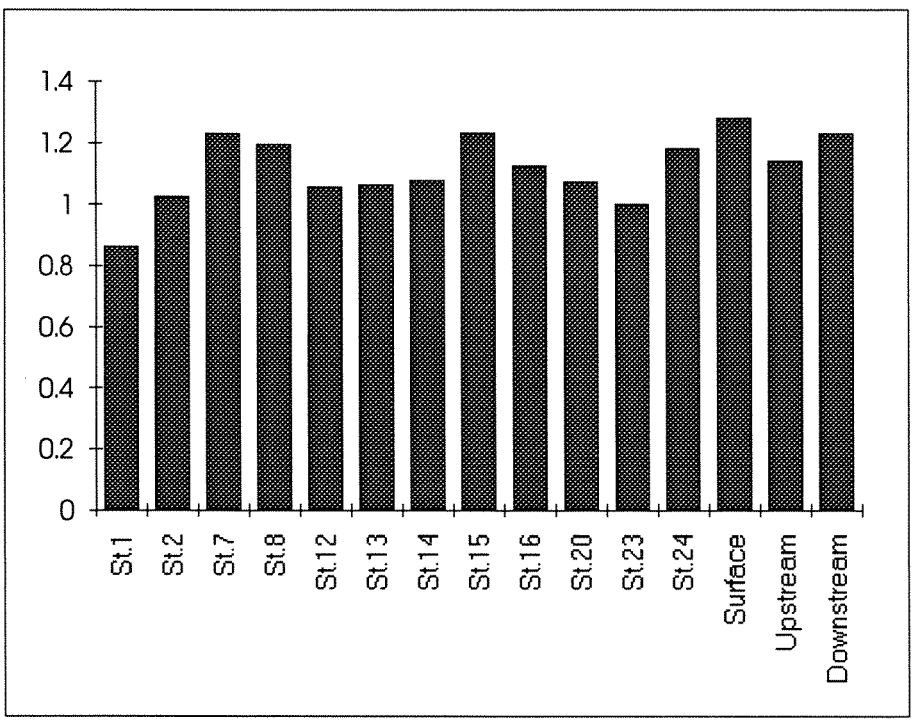


Figure 3.17. Algal growth rate, January cruise. Each station is represented by mean value for five depths. Bar named surface is bucket sample from visible plume.

March cruise

During the March cruise water samples from fourteen stations each for four depths were tested by screening test using *S. costatum.*

Significant reduction (student's t-Test, paired two-samples assuming equal variances) in growth rate was observed for station 5 and 6.

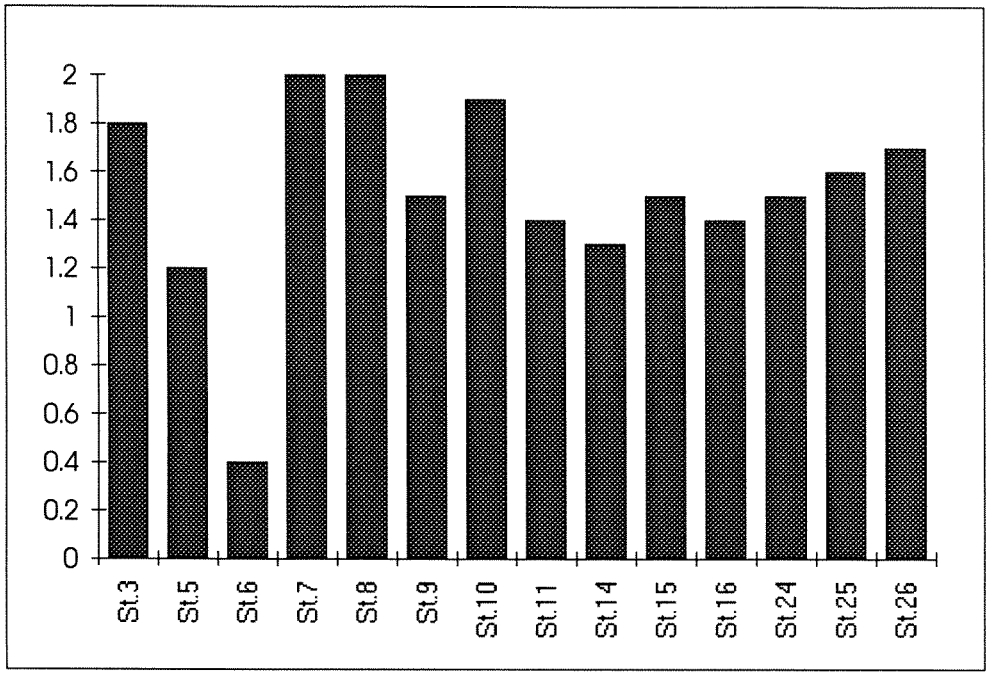
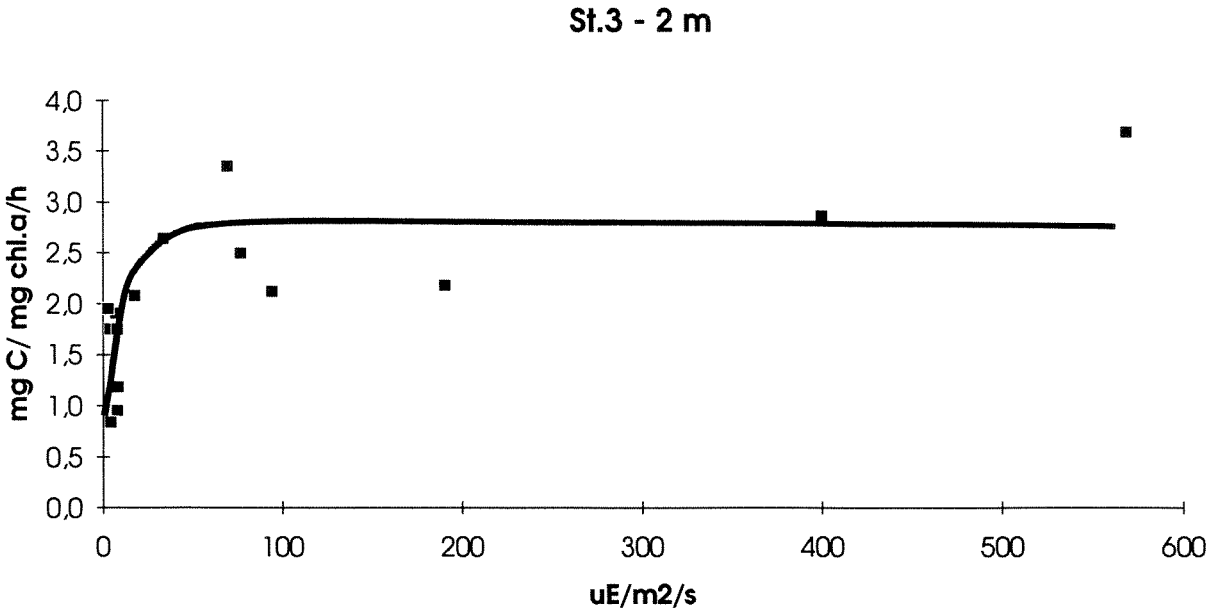


Figure 3.18. Algal growth rate, March cruise. Each station is represented by mean value for five depths.

3.6.5 Primary production

Primary production in March.
The results of measurements of primary production (P, mgC/mg Chl-a/h) versus irradiance (I, µE/m2/s) at five stations and two depths at each station are shown in Fig. 3.19. Some of the spots don't fit well, but low algal biomass often makes curve fitting difficoult. Therefore, the curves are drawn out of experience.



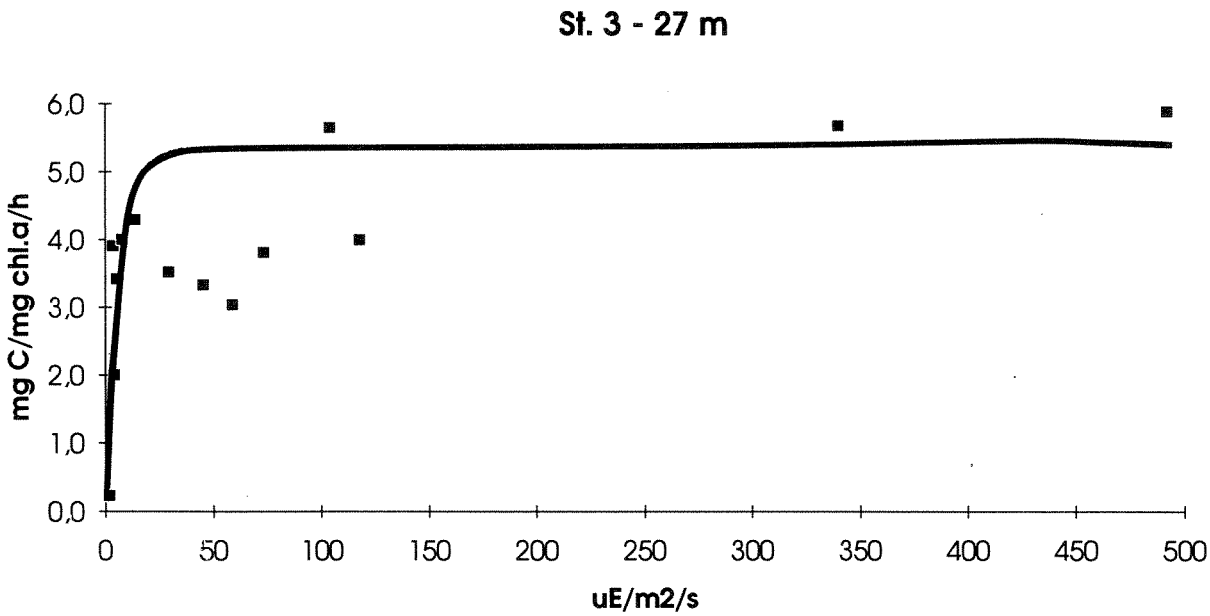
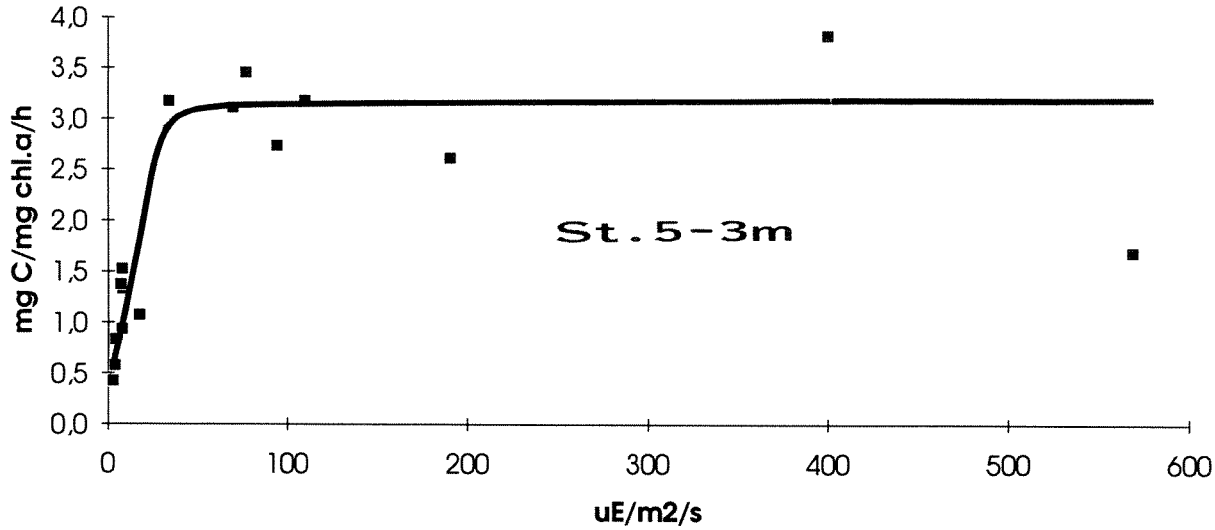


Figure 3.19a. Primary production versus irradiance at station 3, for 2 m and 27 m.

Looking at the photosynthetic efficiency (how efficient the algae utilise low irradiances) and the photosynthetic capacity (the maximum light-saturated rate of photosynthesis) there is no clear difference between the stations.



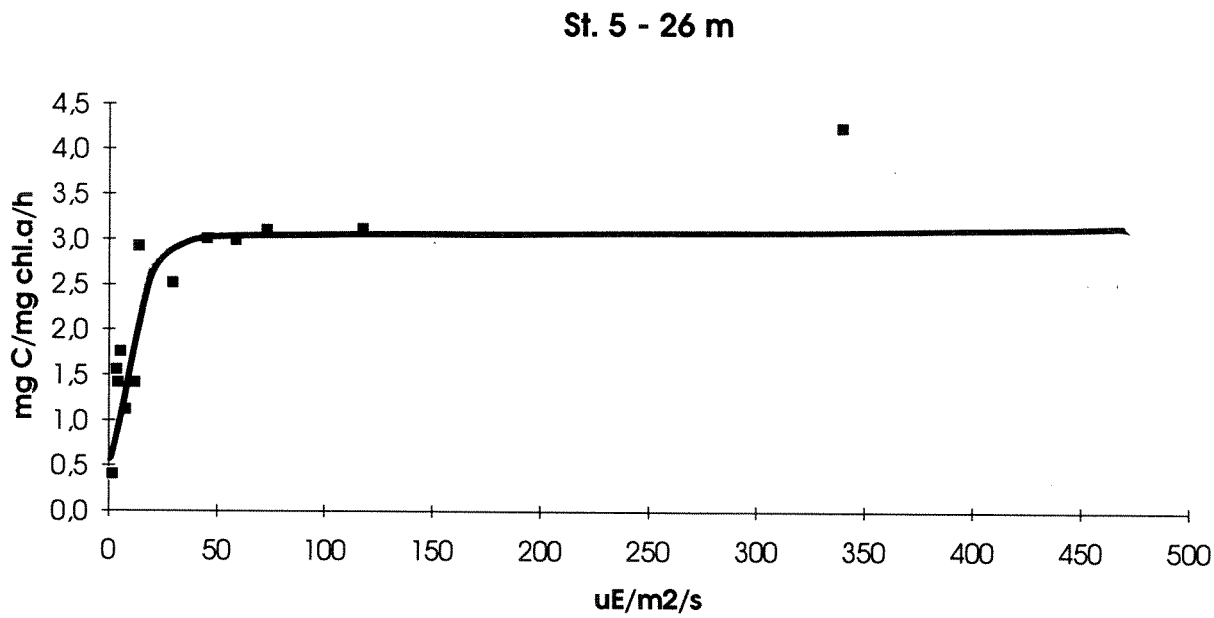
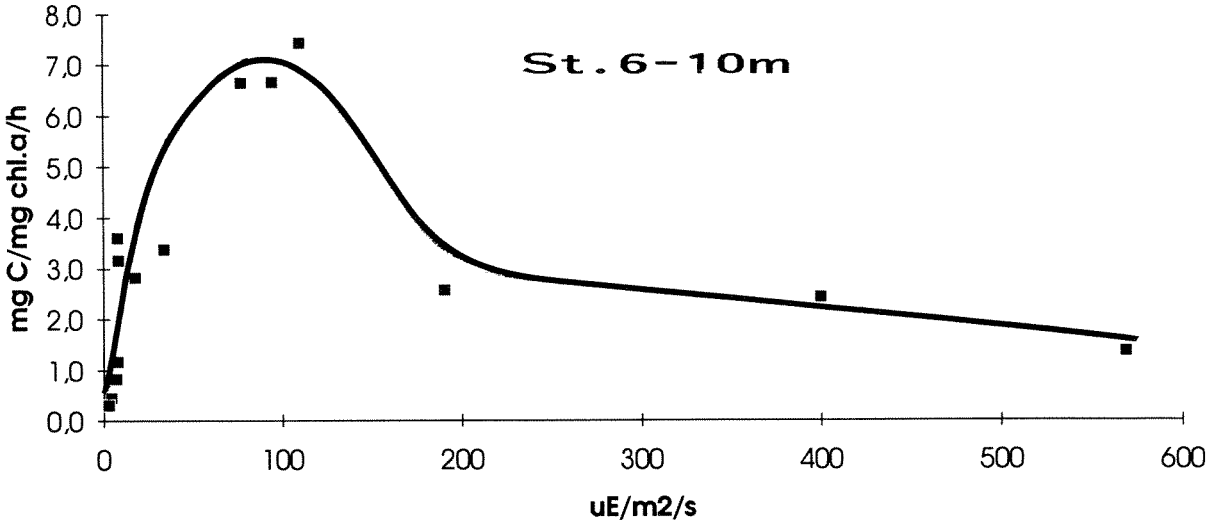


Figure 3.19b. Primary production versus irradiance at station 5, for 3 m and 26 m.

However, the P vs I curves at both depths at station 6 have different shapes than the curves at all the other stations. At station 6 light inhibition starts at about 90 µE m^{-2} s^{-1} at 10 m and at about 75 µ E m^{-2} s^{-1} at 28 m (Fig. 3.19c). This station was influenced of discharge water from the pipeline according to other data. Therefore, we believe that the planktonic algae in one way or another were influenced by the discharge water, resulting in depression in photosynthetic rate (photo inhibition).



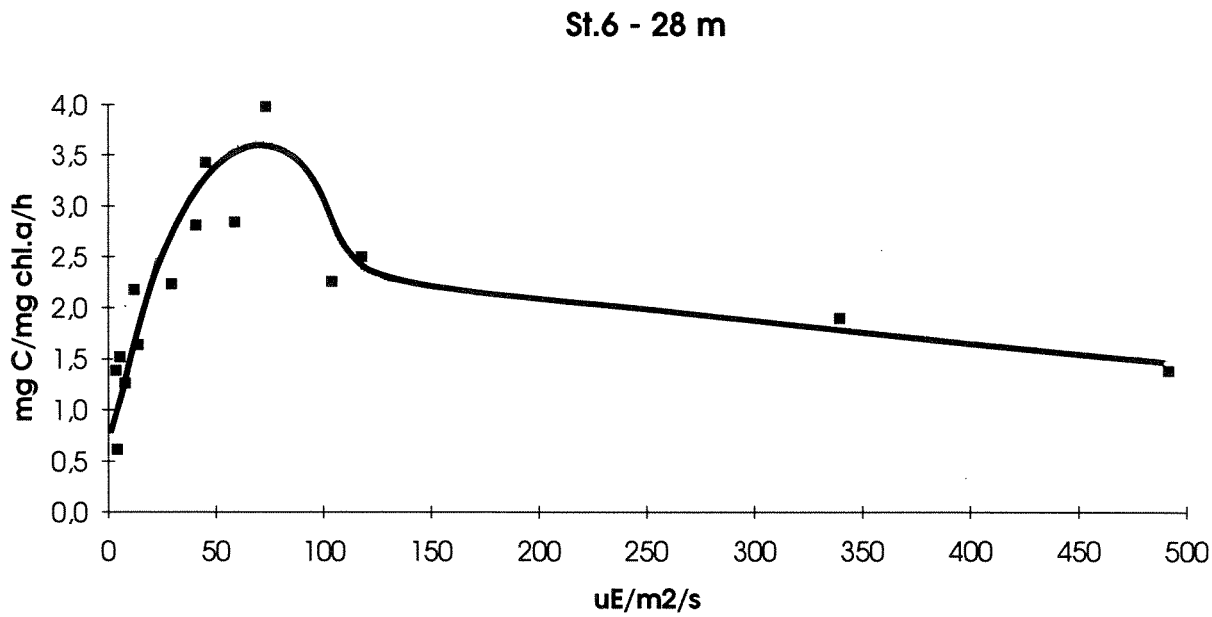


Figure 3.19c. Primary production versus irradiance at station 6, for 10 m and 28 m.

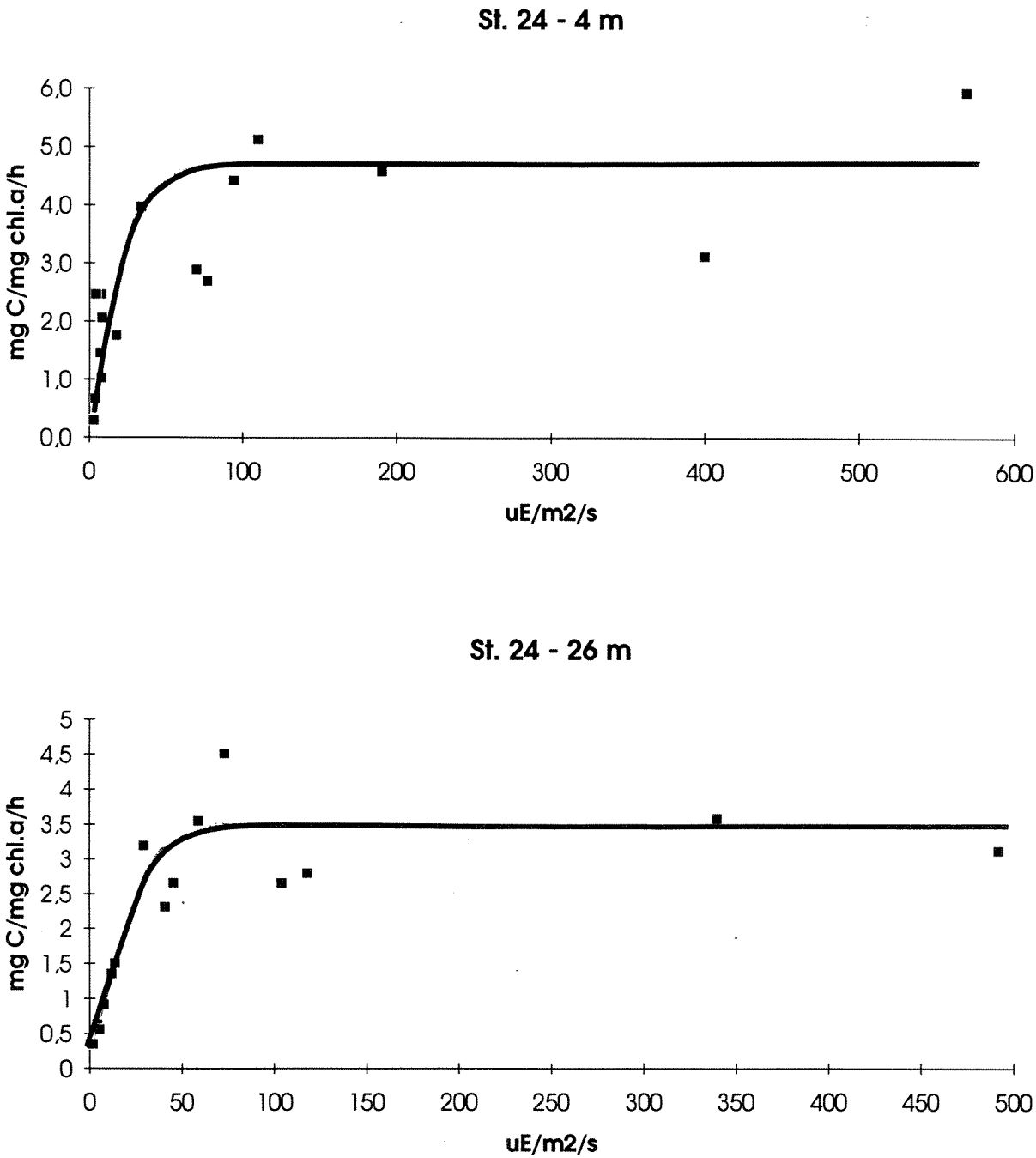


Figure 3.19d. Primary production versus irradiance at station 24, for 4 m and 26 m.

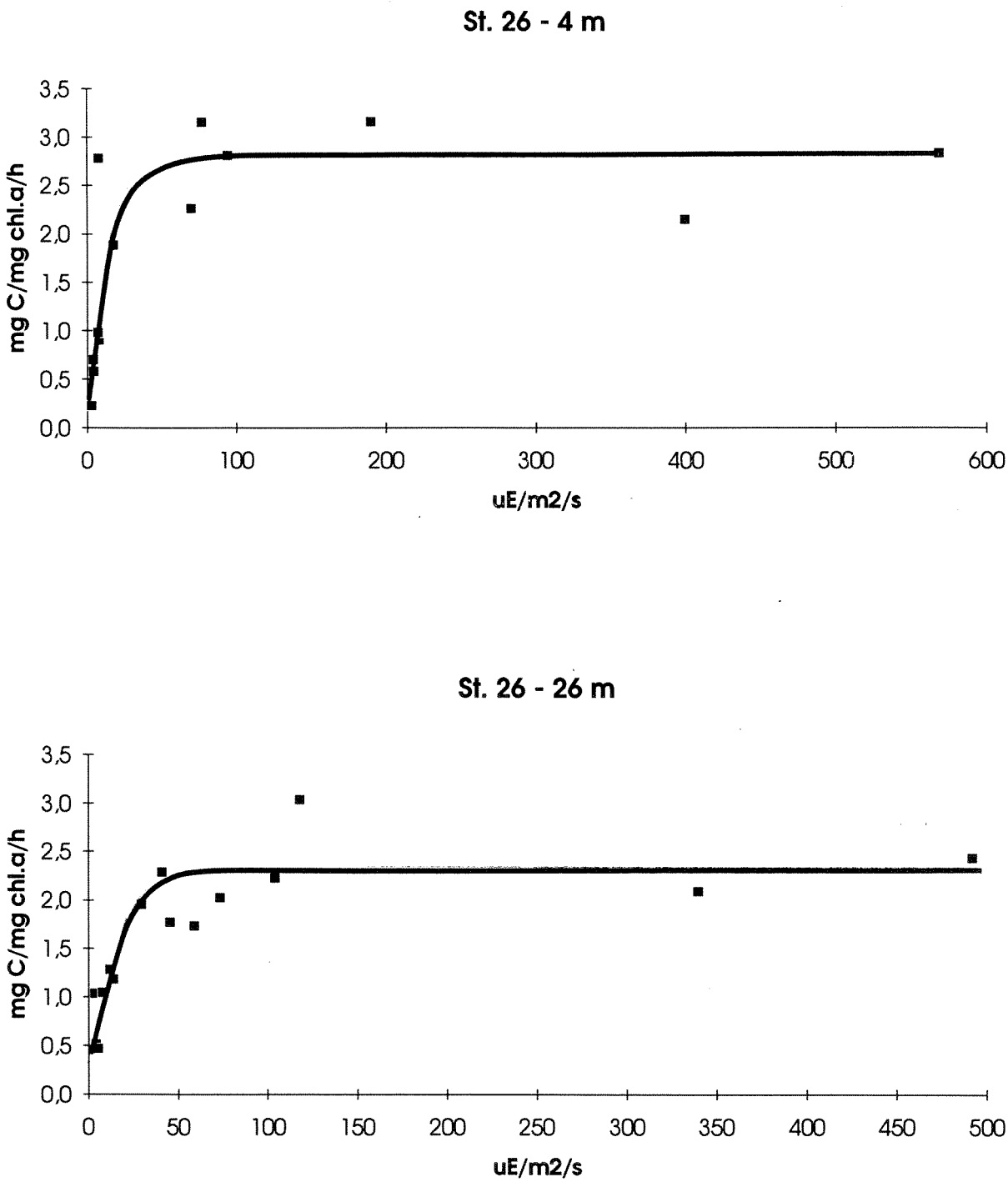


Figure 3.19e. Primary production versus irradiance at station 26, for 4 m and 26 m.

4. Discussion

The discharges of water at the Sleipner field from the Zeepipe pipeline took place during two periods in winter and early spring of 1993.

The prevailing weather conditions may be considered being optimum for dispersion of the discharge water. Winds seldom were below gail force, and wave heights generally were in the range 5-6 m to 10-15 m with even higher peaks encountered during the discharge periods. Although the monitoring was severely hampered by the weather conditions, the number of stations covered (more than 50) approached the number that was scheduled based on reasonable working conditions (4-5 stations/day). The sampling, however, had to be run intensively during the few time windows that were available.

The exact position of the discharge was provided by STATOIL. It was easily detected by the echo sounder. A "cloud" of particles and/or small bubbles could be seen some 5 m above the bottom. When first approaching the location in January, the plume was readily seen as a dark anomaly at the sea surface. This plume, however was also containing some other water, which originated from Kårstø according to information from STATOIL. This extra fresh water added extra buoyancy to the discharge, making it rise to the surface rapidly.

Later, the plume was never detected visually. It was expected that the Zeepipe discharge water, which derived from the coast near Zeebrügge in Belgium, would give some visible colour signal if the plume came to the surface. The four samples that were collected directly from the line on the platform did show a yellowish colour. The lack of surface detection indicates that the plume did not reach the surface all the time. Additional plume modelling showed that for salinities exceeding 32 ppt, the plume would level off somewhere between 20 and 40 meters depth. Such high salinities were reported several times from the intake at Zeebrügge, and was also measured in the sample from the first discharge (33.5 ppt).

The four samples that were brought on shore for analysis and bio-testing, showed that the sulphite (oxygen scavenger) concentrations were an order of magnitude lower than expected. Glutaraldehyde concentrations were in the range 3-35 ppm, of which the higher number is close to the expected level. The first discharge might even have been depleted of sulphite. Some hydrogen sulphide was measured in the first (extra) sample.

The plume model calculations indicated dilution factors of about 70-100 or larger at the time the plume would reach its neutral buoyant depth. The initially rather low level of chemicals (especially in the first discharge) would mean that maximum concentrations in the near-field would be on the order of 0.35 ppm or less for aldehyde. This is slightly above the detection limit for the spectrophotometric method employed in the analyses. The size of the computed minimum dilution factor would be representative for a thin layer only. The plume modelling does not take into account the effect of waves, which most of the time must have added extra turbulence and helped the dispersion, even at depth.

The hydrographic profiles did measure salinity anomalies that must be due to the discharge water. These anomalies were small, on the order of 0.05 ppt or less relative to the ambient values. If one estimates discharge salinities of about 30 ppt, this means a dilution of 100 or more, which is in relatively good accordance with the initial plume model calculations. The optical measurements often confirmed the salinity anomalies.

The high expected dilution factors even in the near field of the discharge do supplement the fact that no water sample analyses did show any concentrations above detection limits. For sulphite, the theoretical effect in the recipient could be a depletion of oxygen in the near-field. Numerous oxygen samples did not document any such effect to any significant level. Oxygen concentrations were always close to 100% saturation.

The algal tests on primary production, and also the zooplankton samples, did show some indications of toxic effects. As suggested below, these might be due to chemical residuals other than the glutaraldehyde (degradation products). The high carbon contents in the samples collected from the pipeline may indicate the presence of such constituents.

Assuming that the toxicity of the samples was caused by glutaraldehyde only, the effect of glutaraldehyde on the growth of *S. costatum* could be detected down to 0.07 mg/l, and 50 % growth inhibition was between 0.1 and 0.3 mg/l. As the EC_{50} for the first sample from the plume was at least 10 times higher, this may indicate a combined toxic effect in the two next samples due to chemical by-products from the pipeline.

The detection limit of the chemical analysis of glutaraldehyde is approximately 0.2 mg/l in sea water. Due to higher sensitivity for the biological tests, compared to the chemical tests it may be possible to detect effects on algal growth due to low concentrations of glutaraldehyde without being able to detect glutaraldehyde by chemical analysis. An other possibility giving higher sensitivity when using biologic tests is that degradation products will not be quantified using specific chemical analysing methods, but the algae may respond.

A fast screening test for field testing was chosen to test potential toxic water samples onboard the M/S Håkon Mosby. The test organism chosen for the screening test was the diatom *Skeletonema costatum.* Our results indicate that we were able to detect toxic effects on the algal growth rate in water samples containing chemicals below the detection limit for the chemical analysis, or we observed toxic effects due to degradation products of the chemicals. Toxic effects were observed for five stations, plus two single depths for two other stations during the January cruise, and for two stations during the March cruise.

During the January cruise the growth reduction effect on *S. costatum* was maximum 30 %, indicating a maximum concentration of 0.1 to 0.15 mg/l glutaraldehyde near the plume, calculated from the toxicity tests.

During the March cruise the maximum concentration of glutaraldehyde might have been somewhat higher, as a 78 % growth rate reduction of the *S. costatum* was observed for one station near the plume. This could indicate a glutaraldehyde concentration of between 0.1 to 0.3 mg/l close to the plume, calculated from the toxicity tests. We were not able to detect glutaraldehyde quantitatively from the same water sample which may be a indication of a secondary toxic effect due to degradation products.

References

Anon, 1980: Environmental investigations of the North Sea in the vicinity of the Ekofisk Oil Field 21 May 1977 - 30 May 1988. Hazelton Environmental Services, U.K.

Bjerkeng, B. and A. Lesjo, 1973: Mixing of a jet into a stratified environment. Rep. No. O-126/2, NIVA, Oslo.

Bjerrum, N., 1904. On the Determination of Oxygen in Sea Water. Medd. Komm. Havunders. København Serie Hydr. Bd. I, No. 5, p. 2-13.

CMS 1991: Discharge of chemicals from Zeepipe, phase 1 pipeline. Rep. Co-operating Marine Scientists, Oslo, 19 pp.

Dooley, H.D. 1974: Hypothesis concerning the circulation of the northern North Sea. J. Cons. int. Expl. Mer, Vol 36, 54-61.

Fan, L-N and H. Brooks 1969: Numerical solutions of turbulent buoyant jet problems. Rep. No. KH-R-18, Calif. Inst. of Technology, U.S.A.

Flather, R.A., 1987: Estimates of extreme conditions in tide and surge using a numerical model of the Northwest European continental shelf. Coast. Shelf Science, Vol. 24, pp 69-93.

Gargas, E. 1975. (Ed). A manual for phytoplankton production studies in the Baltic. Baltic marine Biologist Publ. No. 2. Water Quality Institute, Hørsholm, Denmark

Gooding, N.R.L. 1990: The Navigational Chart and Marine Positioning in the 1990s. Marine Geodesy, Vol. 14, 197-203.

Grasshoff, K., M. Ehrhardt and K. Kremling, 1983. Methods of Seawater Analysis. Verlag Chemie GmBH, Weinheim, Germany, 419 pp.

Hutnance, J.M. 1991: Physical Oceanography of the North Sea. Journ. Ocean & Shoreline Management, Vol. 16, pp 199-231.

IMR 1984a: Monitoring and sampling of disposed seawater with corrosion inhibitors. Rep. I. Preliminary manuscript, Institute for Marine Research, Bergen, ca 25 pp.

IMR 1984b: Monitoring and sampling of disposed seawater with corrosion inhibitors, Rep. III. Rep. No. BKO 8402, Institute for Marine Research, Bergen, 7 pp.

IMR 1984c: Monitoring and sampling of disposed seawater with corrosion inhibitors. Rep. IV. Monitoring of discharge at Ekofisk 25 September - 1 October 1984. Rep. No. BKO 8403, Institute for Marine Research, Bergen, 5 pp.

IMR 1985: Monitoring and sampling of disposed seawater with corrosion inhibitors, Rep. I. Rep. Institute for Marine Research, Bergen, ca 100 pp.

LaChapelle, G., P. Kielland and M. Casey (1992): GPS for Marine Navigation and Hydrography. Int. Hydr. Review, 43-69.

Lee, A.J. 1980: North sea: physical oceanography. In The Nort-West European Shelf seas: The Sea Bed and the Sea in Motion. Vol. II, Ed. Banner, Collins & Massie, Elsevier, Amsterdam, 550 p.

Lewis, E.L. and R.G. Perkin (1978): Salinity: Its Definition and Calculation. Journal of Geophysical Research 83, No C1, 466 - 478.

NBIS 1982: Mark IIIB Conductivity, Temperature, Depth Profiler Underwater Unit. Manual 00100. Neil Brown Instrument systems, Inc, U.S.A.

New, A.L. 1992: Factors affecting the quality of shipboard acoustic Doppler current profiler data. Deep Sea Res., Vol. 39, No. 11/12, 1985-1996.

Otto, L., J.T.F. Zimmerman G.K. Furnes, M. Mork, R. Sætre and G. Becker 1990: Review of the Physical Oceanography of the North Sea. Netherl. Journ. of Sea Research, Vol. 26, pp 161-238.

RDI 1989: Acoustic Doppler Current Profilers. Principles of operation: A practical primer. RD Instruments, San diego, CA, 42p.

Staub. R. (1961): Ernärungsphysiologische Untersuchungen an der planktischen Blaualge Oscillatoria rubescens D.C. Schweiz. Z. Hydrol. 23: 82-198.

Steemann-Nielsen, E. 1952. The use of radio active carbon (^{14}C) for masureing organic production in the sea. J. Fish. Res. Bd. Can. 36: 152-157.

Svendsen, E., R. Sætre and M. Mork 1991: Features of the northern North Sea circulation. Cont. Shelf Res. Vol 11, No 5, 493-508.

Turrell, W.R. 1992: The East Shetland Atlantic Inflow. ICES Mar. Sci. Symp. 195, 127-143.

Appendix

NIVA

TEST REPORT

Norwegian Institute for Water Research
P.O. Box 69 Korsvoll
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Phone: +47 22 18 51 00
Fax: +47 22 18 52 00

Marine Algal growth inhibition test ISO/DIS 10253

Test sample: **Statoil 14.01.93** **Lab. code:** **B049/1**

Test details:

Test organism:	*Skeletonema costatum* NIVA BAC 1
Test endpoint:	Growth rate, average from start to 72 hours
Stock culture	Semi-continuous cultivation in natural sea water with 10% Z8 growth medium (Staub 1961)
Start date:	25.01, 31.01 and 16.02.93
Concentrations:	0.18, 0.32, 0.56, 1.0, 1.8, 3.2, 5.6, 10, 18, 32 %
Test medium:	ISO 10253 with Fe reduced to 16.5 µg/l, Zn: 15 µg/l, NaEDTA: 100 µg/l. Natural sea water, salinity 34 g/l, from 40m in Outer Oslo Fjord
Incubator:	Reciprocal shaker
Culture flasks:	100 ml flat bottom flasks with 50 ml medium
Light:	70 µE m^2 s^{-1}, continous from daylight-type fluorescent tubes
Temperature:	20±0.5 °C
pH in controls:	Start: 8.1-8.2 End: 8.8.9-9.0
pH at highest concentration:	Start: 7.9 End: 8.2
Cell density measurement:	Coulter Multisizer
Calculation of EC_{50} *	Manual from concentration/response plot (fig. 2)
Calculation of NOEC **	t-test

Results: Cell density at each measuring point, the calculated area under growth curve and growth rate in each flask is shown on the attached data sheet. Mean values for each treatment (and controls) at the bottom. Growth curves for each concentration are shown in figure 1. The concentration/response plot is shown in figure 2.

End point	Unit	EC_{50}	95% conf. int.	EC_{10}	95% conf. int.	NOEC
Growth rate	%	87	-	65	-	56

Comments:

Tested by: Randi Romstad
Randi Romstad

Responsible for test: Torsten Källqvist
Torsten Källqvist

* EC_{50} = The highest concentration giving 50% reduction of test endpoint as compared to controls.
** NOEC = Highest tested concentration without significant effect on test endpoint.

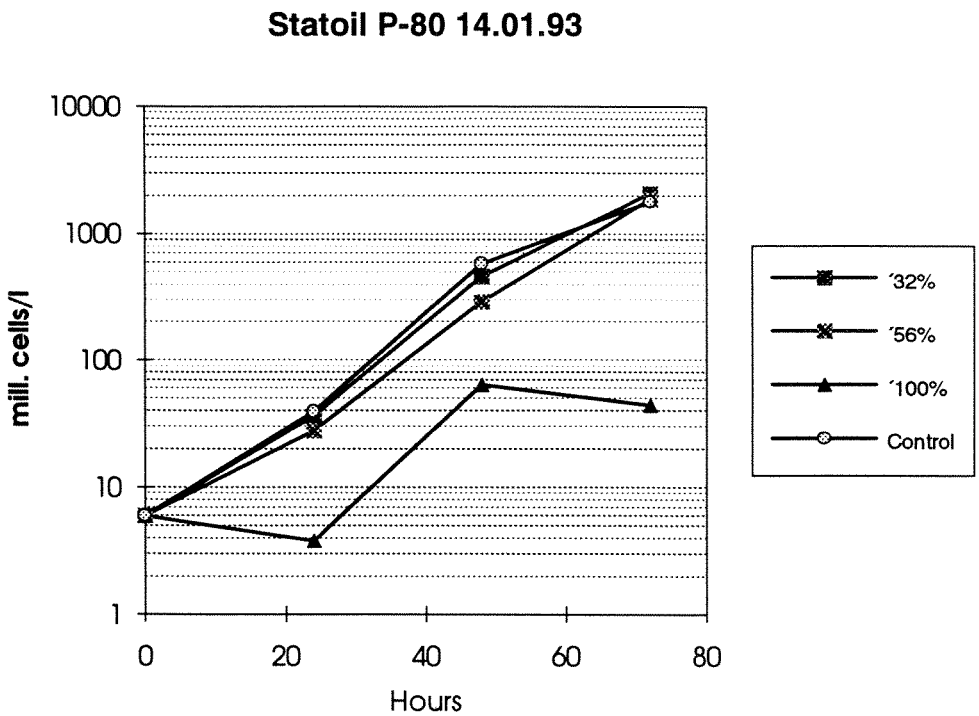

Fig. 1. Growth curves for *Skeletonema costatum* at different concentrations of Statoil P-80 14.01.93.

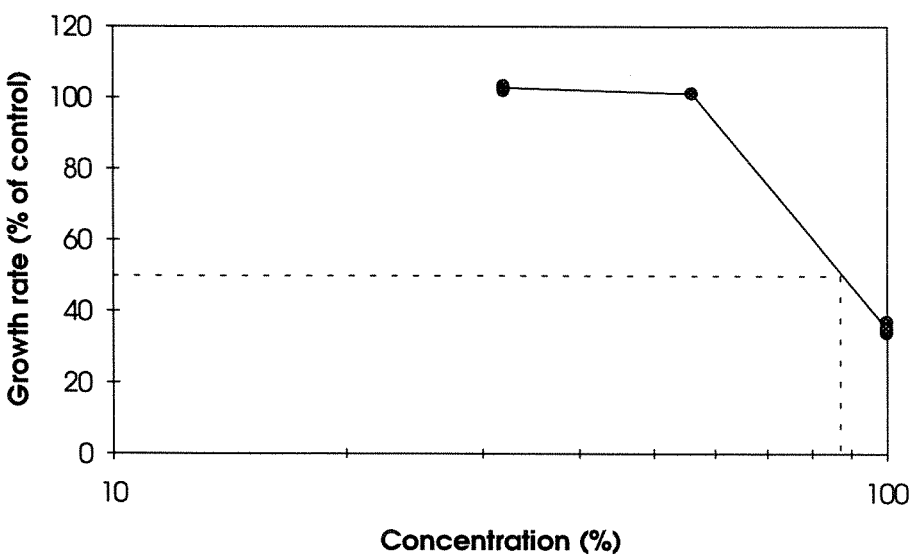

Fig. 2. Effect of Statoil P-80 14.01.93 on growth rate of *Skeletonema costatum.*

References:

ISO/DIS 10253 : Water quality - Marine algal growth inhibition test

Staub. R. (1961): Ernärungsphysiologische Untersuchungen an der planktischen Blaualge *Oscillatoria rubescens* D.C. Schweiz. Z. Hydrol. 23: 82-198.

TEST:>> ISO
COMPOUND >>>> Statoil P-80 14.01.93
TEST ALGA >>>> *Skeletonema costatum*
INOCULUM >>>> 5.9 mill. cells/l

Date >> 21.1.93
Lab. code >>>>> B049/1
Medium> ISO

	Hours:	Day 1 24 mill/l	Day 2 48 mill/l	Day 3 72 mill./l	Area	Area %	G. rate	G. rate%
Cons. 1	´32%	35	438	2083	35994	101	1.96	103
		36	442	2030	35478	99	1.95	102
		38	486	2071	37074	104	1.95	103
Cons. 2	´56%	29	286	1819	29034	81	1.91	101
		27	277	1826	28854	81	1.91	101
		27	300	1907	30378	85	1.93	101
Cons. 3	´100%	4.2	58	40	1619	5	0.64	34
		4.3	67	48	1933	5	0.70	37
		2.9	67	44	1852	5	0.67	35
Cons. 4								
Cons. 5								
Cons. 6								
Cons. 7								
Control		43	664	1599	35802	100	1.87	98
		44	643	1816	37926	106	1.91	101
		37	583	1716	35118	98	1.89	100
		42	584	1938	37926	106	1.93	102
		32	441	1784	32406	91	1.90	100
		38	563	1753	35106	98	1.90	100

MEAN VALUES

´32%	Mv:	36.33	455.33	2061.33	36182	101.31	1.95	102.72
	St. d.	*1.25*	*21.75*	*22.69*	*665*	*1.86*	*0.00*	*0.19*
´56%	Mv.	27.67	287.67	1850.67	29422	82.38	1.92	100.83
	St. d.	*0.94*	*9.46*	*39.94*	*680*	*1.90*	*0.01*	*0.38*
´100%	Mv.	3.80	64.00	44.00	1801	5.04	0.67	35.20
	St. d.	*0.64*	*4.24*	*3.27*	*133*	*0.37*	*0.02*	*1.31*
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
Control	Mv.	39.33	579.67	1767.67	35714	100.00	1.90	100.00
	St. d.	*4.15*	*71.48*	*102.43*	*1891*	*5.30*	*0.02*	*1.02*

Appendix 2

TEST REPORT

Norwegian Institute for Water Research
P.O. Box 69 Korsvoll
N-0808 Oslo Norway
Phone: +47 22 18 51 00
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Marine Algal growth inhibition test ISO/DIS 10253

Test sample: **Statoil 19.01.93** **Lab. code:** **B049/2**

Test details:

Test organism:	*Skeletonema costatum* NIVA BAC 1
Test endpoint:	Growth rate, average from start to 72 hours
Stock culture	Semi-continuous cultivation in natural sea water with 10% Z8 growth medium (Staub 1961)
Start date:	25.01, 31.01 and 16.02.93
Concentrations:	0.18, 0.32, 0.56, 1.0, 1.8, 3.2, 5.6, 10, 18, 32 %
Test medium:	ISO 10253 with Fe reduced to 16.5 µg/l, Zn: 15 µg/l, NaEDTA: 100 µg/l. Natural sea water, salinity 34 g/l, from 40m in Outer Oslo Fjord
Incubator:	Reciprocal shaker
Culture flasks:	100 ml flat bottom flasks with 50 ml medium
Light:	70 µE m^2 s^{-1}, continous from daylight-type fluorescent tubes
Temperature:	20±0.5 °C
pH in controls:	Start: 8.1-8.2 End: 8.9-9.0
pH at highest concentration:	Start: 7.9 End: 8.2
Cell density measurement:	Coulter Multisizer
Calculation of EC_{50} *	Probit transformation and linear regression of probit values against log concentration
Calculation of NOEC **	t-test

Results: Cell density at each measuring point, the calculated area under growth curve and growth rate in each flask is shown on the attached data sheet. Mean values for each treatment (and controls) at the bottom. Growth curves for each concentration are shown in figure 1. The concentration/response plot is shown in figure 2.

End point	Unit	EC_{50}	95% conf. int.	EC_{10}	95% conf. int.	NOEC
Growth rate	%	0.82	0.66 - 1.0	0.33	0.28 - 0.38	<0.18

Comments:

Tested by: Randi Romstad Responsible for test: Torsten Källqvist

Randi Romstad

Torsten Källqvist

* EC_{50} = The highest concentration giving 50% reduction of test endpoint as compared to controls.

** NOEC = Highest tested concentration without significant effect on test endpoint.

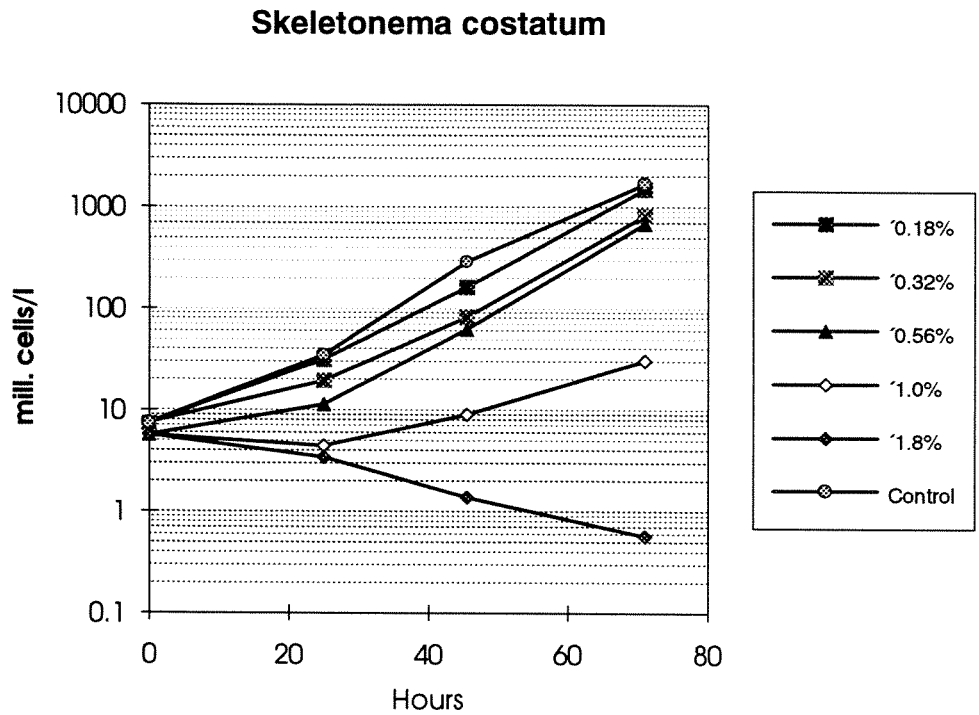

Fig. 1. Growth curves for *Skeletonema costatum* at different concentrations of Statoil 19.01.93

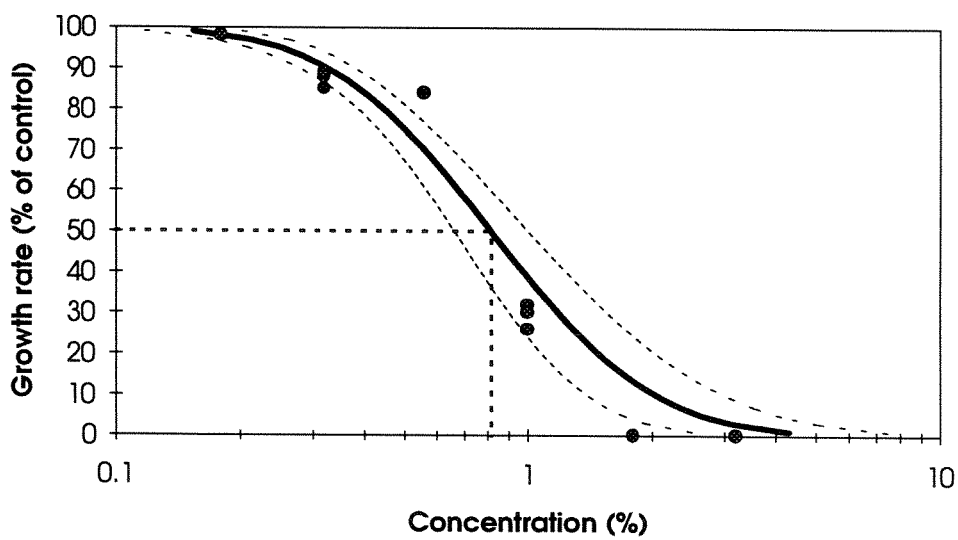

Fig. 2. Effect of Statoil 19.01.93 on growth rate of *Skeletonema costatum.*

References:

ISO/DIS 10253 : Water quality - Marine algal growth inhibition test

Staub. R. (1961): Ernärungsphysiologische Untersuchungen an der planktischen Blaualge *Oscillatoria rubescens* D.C. Schweiz. Z. Hydrol. 23: 82-198.

TEST:>> ISO/DIS 10253 **Date >>** 25.01.93
COMPOUND >>>> Statoil 19.01.93 **Lab. code >>>>>** B049/2
TEST ALGA >>>> *Skeletonema costatum* **Medium>** ISO
INOCULUM >>>> 6.2 mill. cells/l

	Hours:	Day 1 24 mill/l	Day 2 50.5 mill/l	Day 3 73 mill./l	Area	Area %	G. rate	G. rate%
Cons. 1	´5.6%	5.2	1.7	2.3	-179	0	-0.33	-18
		4.2	2.1	1.2	-207	-1	-0.54	-29
		3.8	2.6	2.8	-187	0	-0.26	-14
Cons. 2	´10%	3.2	1.7	1.1	-243	-1	-0.57	-31
		2.8	1.4	1.2	-260	-1	-0.54	-29
		2.7	1.2	0.9	-271	-1	-0.63	-35
Cons. 3	´18%	4.5	4.2	3.6	-121	0	-0.18	-10
		3.5	3.7	3.3	-162	0	-0.21	-11
		4.6	3.7	3.3	-134	0	-0.21	-11
Cons. 4	´32%	5.9	4.5	4.2	-72	0	-0.13	-7
		5.7	6.3	5.6	-17	0	-0.03	-2
		7.4	5.3	5	-5	0	-0.07	-4
Cons. 5								
Cons. 6								
Cons. 7								
Control		50	633	1368	31783	84	1.77	97
		56	831	1675	40239	107	1.84	100
		57	816	1530	38266	101	1.81	99
		45	645	1712	35821	95	1.85	101
		49	822	1929	42699	113	1.89	103
		47	685	1766	37459	99	1.86	101

MEAN VALUES

´5.6%	Mv:	4.40	2.13	2.10	-191	-0.51	-0.38	-20.46
	St. d.	*0.59*	*0.37*	*0.67*	*12*	*0.03*	*0.12*	*6.48*
´10%	Mv.	2.90	1.43	1.07	-258	-0.68	-0.58	-31.63
	St. d.	*0.22*	*0.21*	*0.12*	*11*	*0.03*	*0.04*	*2.16*
´18%	Mv.	4.20	3.87	3.40	-139	-0.37	-0.20	-10.77
	St. d.	*0.50*	*0.24*	*0.14*	*17*	*0.05*	*0.01*	*0.73*
´32%	Mv.	6.33	5.37	4.93	-31	-0.08	-0.08	-4.21
	St. d.	*0.76*	*0.74*	*0.57*	*29*	*0.08*	*0.04*	*2.12*
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
Control	Mv.	50.67	738.67	1663.33	37711	100.00	1.84	100.00
	St. d.	*4.42*	*85.90*	*177.31*	*3424*	*9.08*	*0.04*	*1.95*

TEST:>> ISO/DIS 10253 **Date >>** 31.1.93
COMPOUND >>>> Statoil 19.01.93 **Lab. code >>>>>** B049/2
TEST ALGA >>>> *Skeletonema costatum* **Medium>** ISO
INOCULUM >>>> 5.7 mill. cells/l

	Hours:	**Day 1** 24 mill/l	**Day 2** 48 mill/l	**Day 3** 71 mill./l	**Area**	**Area %**	**G. rate**	**G. rate%**
Cons. 1	´0.56%	11	59	667	8985	36	1.61	84
		12	62	685	9286	37	1.62	84
		11	63	659	8987	36	1.61	84
Cons. 2	´1.0%	4.4	10	35	407	2	0.61	32
		4.4	10	31	361	1	0.57	30
		4.5	6.9	25	221	1	0.50	26
Cons. 3	´1.8%	3.5	1.7	0.7	-204	-1	-0.71	-37
		3.5	1.3	0.8	-213	-1	-0.66	-35
		3.3	1.1	0.2	-229	-1	-1.13	-59
Cons. 4	´3.2%	1.9	1.2	0.2	-260	-1	-1.13	-59
		2.2	1.1	0.2	-255	-1	-1.13	-59
		1.9	1.4	0.2	-256	-1	-1.13	-59
Cons. 5								
Cons. 6								
Cons. 7								
Control		29	225	1678	24944	100	1.92	100
		27	205	1584	23345	94	1.90	99
		33	249	1748	26409	106	1.94	101

MEAN VALUES

´0.56%	Mv:	11.33	61.33	670.33	9086	36.49	1.61	83.94
	St. d.	*0.47*	*1.70*	*10.87*	*142*	*0.57*	*0.01*	*0.28*
´1.0%	Mv.	4.43	8.97	30.33	330	1.32	0.56	29.27
	St. d.	*0.05*	*1.46*	*4.11*	*79*	*0.32*	*0.05*	*2.45*
´1.8%	Mv.	3.43	1.37	0.57	-215	-0.86	-0.84	-43.50
	St. d.	*0.09*	*0.25*	*0.26*	*10*	*0.04*	*0.21*	*10.99*
´3.2%	Mv.	2.00	1.23	0.20	-257	-1.03	-1.13	-58.98
	St. d.	*0.14*	*0.12*	*0.00*	*2*	*0.01*	*#NUM!*	*0.00*
Control	Mv.	29.67	226.33	1670.00	24900	100.00	1.92	100.00
	St. d.	*2.49*	*17.99*	*67.19*	*1251*	*5.03*	*0.01*	*0.71*

TEST:>> ISO/DIS 10253 **Date >>** 16.2.93
COMPOUND >>>> Statoil 19.01.93 **Lab. code >>>>>** B049/2
TEST ALGA >>>> *Skeletonema costatum* **Medium>** ISO
INOCULUM >>>> 7.4 mill. cells/l

	Hours:	**Day 1** 25 mill/l	**Day 2** 45.5 mill/l	**Day 3** 71 mill./l	**Area**	**Area %**	**G. rate**	**G. rate%**
Cons. 1	´0.18%	31	165	1460	22682	81	1.79	98
		32	157	1502	23057	82	1.80	98
		31	161	1463	22629	81	1.79	98
Cons. 2	´0.32%	20	82	851	12758	46	1.60	88
		18	78	716	10900	39	1.55	85
		20	84	888	13276	47	1.62	89
Cons. 3								
Cons. 4								
Cons. 5								
Cons. 6								
Cons. 7								
Control		35	290	1603	27472	98	1.82	99
		34	299	1561	27120	97	1.81	99
		35	288	1719	28905	103	1.84	101
		33	270	1604	26979	96	1.82	100
		35	298	1688	28739	103	1.84	100
		35	286	1714	28795	103	1.84	101

MEAN VALUES

´0.18%	Mv:	31.33	161.00	1475.00	22789	81.39	1.79	97.96
	St. d.	*0.47*	*3.27*	*19.13*	*190*	*0.68*	*0.00*	*0.24*
´0.32%	Mv.	19.33	81.33	818.33	12311	43.97	1.59	86.98
	St. d.	*0.94*	*2.49*	*73.92*	*1020*	*3.64*	*0.03*	*1.72*
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
0.00	Mv.							
	St. d.							
Control	Mv.	34.50	288.50	1648.17	28002	100.00	1.83	100.00
	St. d.	*0.76*	*9.59*	*61.27*	*826*	*2.95*	*0.01*	*0.69*

Appendix 3

TEST REPORT

Norwegian Institute for Water Research
P.O. Box 69 Korsvoll
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Phone: +47 22 18 51 00
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Marine Algal growth inhibition test ISO/DIS 10253

Test compound: Statoil 22.03.93 **Lab. code: B049/3**

Test details:

Test organism:	*Skeletonema costatum* NIVA BAC 1
Test endpoint:	Growth rate, average from start to 72 hours
Stock culture	Semi-continuous cultivation in natural sea water with 10% Z8 growth medium (Staub 1961)
Start date:	30.3. 1993
Concentrations:	0.10, 0.18, 0.32, 0.56, 1.0, 1.8, 3.2 %
Preparation of solutions	
Test medium:	ISO 10253 with Fe reduced to 16.5 µg/l, Zn: 15 µg/l, NaEDTA: 100 µg/l. Natural sea water, salinity 34 g/l, from 40m in Outer Oslo Fjord
Incubator:	Reciprocal shaker
Culture flasks:	100 ml flat bottom flasks with 50 ml medium
Light:	70 µE m^{-2} s^{-1}, continous from daylight-type fluorescent tubes
Temperature:	20.5 ± 0.5 °C
pH in controls:	Start: 8.1 End: 8.9
pH at highest concentration:	Start: 8.2 End: 8.2
Cell density measurement:	Coulter Multisizer
Calculation of EC_{50} *	Probit transformation and linear regression of probit values against log concentration
Calculation of NOEC **	t-test

Results: Cell density at each measuring point, the calculated area under growth curve and growth rate in each flask is shown on the attached data sheet. Mean values for each treatment (and controls) at the bottom. Growth curves for each concentration are shown in figure 1. The concentration/response plot is shown in figure 2.

End point	Unit	EC_{50}	95% conf. int.	EC_{10}	95% conf. int.	NOEC
Growth rate	%	0.55	0.47 - 0.66	0.33	0.27 - 0.39	0.18

Comments:

Tested by: Randi Romstad Responsible for test: Torsten Källqvist

Randi Romstad

Torsten Källqvist

* EC_{50} = The highest concentration giving 50% reduction of test endpoint as compared to controls.
** NOEC = Highest tested concentration without significant effect on test endpoint.

NIVA

ANALYSIS AND RESULTS:

Test period: Mars. 25. to May 4. 1993

Test compound: Statoil Zee-pipe 22. 03. 93 **Lab. code:** **B049/3**

Concentrations: 10 % in respirometric test.

Analyticals results:
Calculations of DOC values mg/l at 10 % concentration of sample.

Medium	Bottle code	Initial 0 day	End 40 days
Inoculum	C1	1,4	1,5
"	C2	1,2	1,8
"	Cmv.	**1,3**	**1,65**
Sample	A1	5,3	1,9
"	A2	5,5	1,8
"	Amv.	**5,4**	**1,85**
Corrected values		4,1	0,20
DOC-reduction after 40 days of degradation			**95 %**

Figure 1
BOD curve in respirometric test
Conc. 10 %

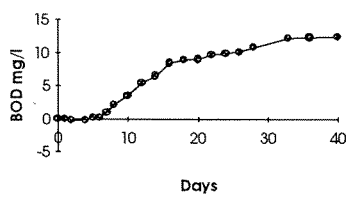


Figure 2
BOD curve in closed bottle test
Conc. 5 %

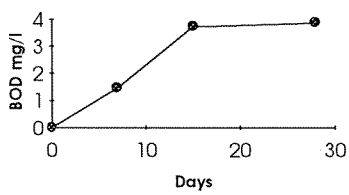
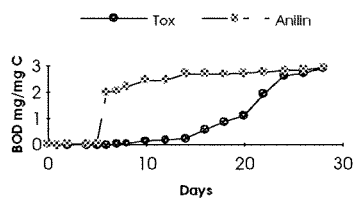


Figure 3
BOD in toxicty control Conc. 10 %
Respirometric test



Comments:
Oxygen consumption was inhibited by toxic substances in the first part of the test period. This is clearely shown in fig. 3. In the toxicity test the consumption of oxygen was depressed by the toxicant up to 20 days of incubation. The test period was prolonged to 40 days, because concumption of oxygen was not stagnated at the time of 28 days.
In the closed bottle test (CBT) no toxic effect was observed at a concentration of 5 % of test sample as shown in fig. 2. However, a very high elimination of DOC was measured at 10 %, indicating that organic substances in the sample are readily biodegradable at low concentration.

Analytical measurements:
The intermittent BOD-values were derived from the level of manometer reading during incubation. The manometer readings were calibrated against oxygen electrode readings after 28 days.

Dissolved oxygen was determined by a WTW OXI 2000 oxygen instrument in each test flasks before and after incubation. Dissolved organic carbon in the test medium was analyzed on Dohrmann DC 190 after combustion at 680 °C, with platinum as catalyzer (TC/TOC analyzer).
NO_3-N concentration was analyzed according NS 4745 (Autoanalyzer Method).

REFERENCE:
1. ISO/DIS 9408 Water Quality- Evaluation in a aqueous medium of the "ultimate" biodegradability of organic compounds- Method by determining the oxygen demand in closed respirometer.
2. OECD Test guideline 301 Manometric Respirometry. Adopted July 17th 1992.
Room document no. 16, Annex 4. Biodegradability in Seawater. Ocotober 1990

TEST:>> ISO 10253 **Date >>** 30.03.93
COMPOUND >>>> Statoil 22.03.93 **Lab. code >>>>>** B049/3
TEST ALGA >>>> *Skeletonema costatum* **Medium>** ISO
INOCULUM >>>> 5.6 mill. cells/l

	Hours:	Day 1 24.5 mill/l	Day 2 48 mill/l	Day 3 72 mill./l	Area	Area %	G. rate	G. rate%
Cons. 1	0.1 %	37	393	1383	26483	96	1.84	101
		40	410	1297	25927	94	1.82	100
		13	84	978	13708	50	1.72	95
Cons. 2	0.18 %	33	324	1300	23752	86	1.82	100
		30	274	1197	21257	77	1.79	98
		34	285	1195	21590	78	1.79	98
Cons. 3	0.32 %	29	146	991	15721	57	1.73	95
		27	131	1021	15677	57	1.74	95
		29	142	980	15494	56	1.72	95
Cons. 4	0.56 %	15	49	203	3625	13	1.20	66
		17	50	229	4009	14	1.24	68
		14	43	189	3291	12	1.17	64
Cons. 5	1.0 %	8.7	8.4	9.9	193	1	0.19	10
		5.2	6.2	7.1	23	0	0.08	4
		7.2	5.6	5.8	41	0	0.01	1
Cons. 6	1.8 %	4	3.9	2.1	-121	0	-0.33	-18
		5.2	3.4	2.1	-104	0	-0.33	-18
		4.8	4.7	2.9	-73	0	-0.22	-12
Cons. 7	3.2 %	4.8	3	1.6	-129	0	-0.42	-23
		3.5	4.3	2.2	-122	0	-0.31	-17
		4.5	4.1	3	-93	0	-0.21	-11
Control		41	326	1171	22444	81	1.78	98
		43	515	1458	30425	110	1.85	102
		39	557	1462	31374	113	1.85	102
		43	446	1366	27682	100	1.83	101
		39	472	1200	26211	95	1.79	98
		43	513	1262	28025	101	1.81	99

MEAN VALUES

0.1 %	Mv:	30.00	295.67	1219.33	22039	79.58	1.79	98.42
	St. d.	*12.08*	*149.83*	*174.22*	*5895*	*21.29*	*0.05*	*2.76*
0.18 %	Mv.	32.33	294.33	1230.67	22200	80.16	1.80	98.78
	St. d.	*1.70*	*21.45*	*49.03*	*1106*	*3.99*	*0.01*	*0.72*
0.32 %	Mv.	28.33	139.67	997.33	15630	56.44	1.73	94.94
	St. d.	*0.94*	*6.34*	*17.33*	*98*	*0.35*	*0.01*	*0.32*
0.56 %	Mv.	15.33	47.33	207.00	3642	13.15	1.20	66.08
	St. d.	*1.25*	*3.09*	*16.57*	*293*	*1.06*	*0.03*	*1.45*
1.0 %	Mv.	7.03	6.73	7.60	85	0.31	0.09	5.14
	St. d.	*1.43*	*1.20*	*1.71*	*76*	*0.27*	*0.07*	*4.04*
1.8 %	Mv.	4.67	4.00	2.37	-99	-0.36	-0.29	-16.00
	St. d.	*0.50*	*0.54*	*0.38*	*19.79*	*0.07*	*0.05*	*2.79*
3.2 %	Mv.	4.27	3.80	2.27	-115	-0.41	-0.31	-17.17
	St. d.	*0.56*	*0.57*	*0.57*	*15.48*	*0.06*	*0.09*	*4.70*
Control	Mv.	41.33	471.50	1319.83	27694	100.00	1.82	100.00
	St. d.	*1.80*	*73.88*	*116.40*	*2912*	*10.51*	*0.03*	*1.62*

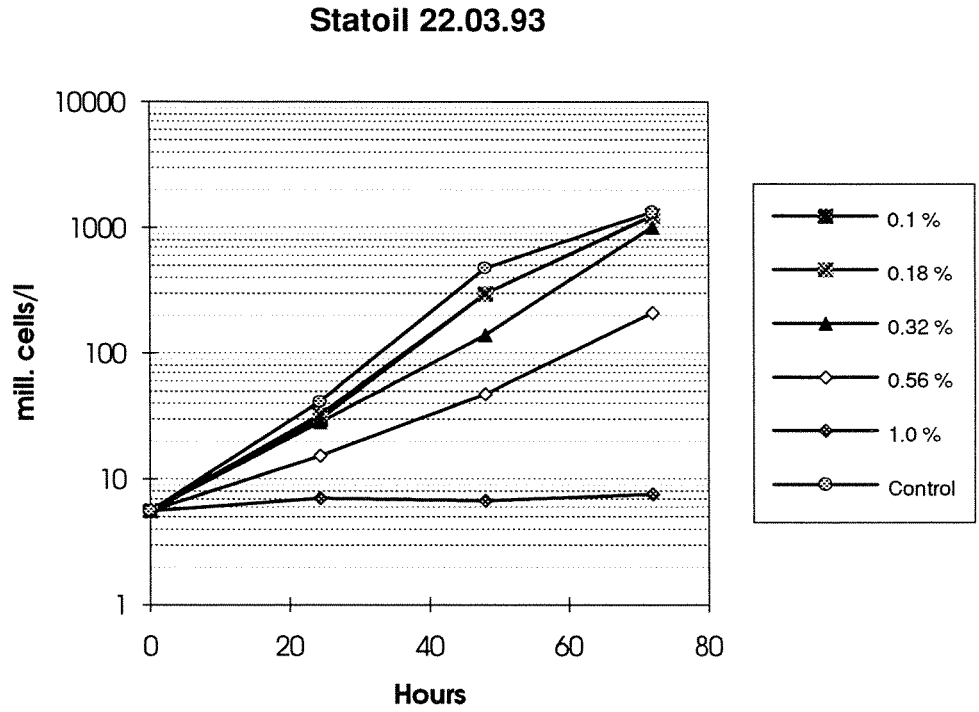


Fig. 1. Growth curves for *Skeletonema costatum* at different concentrations of Statoil 22.03.93

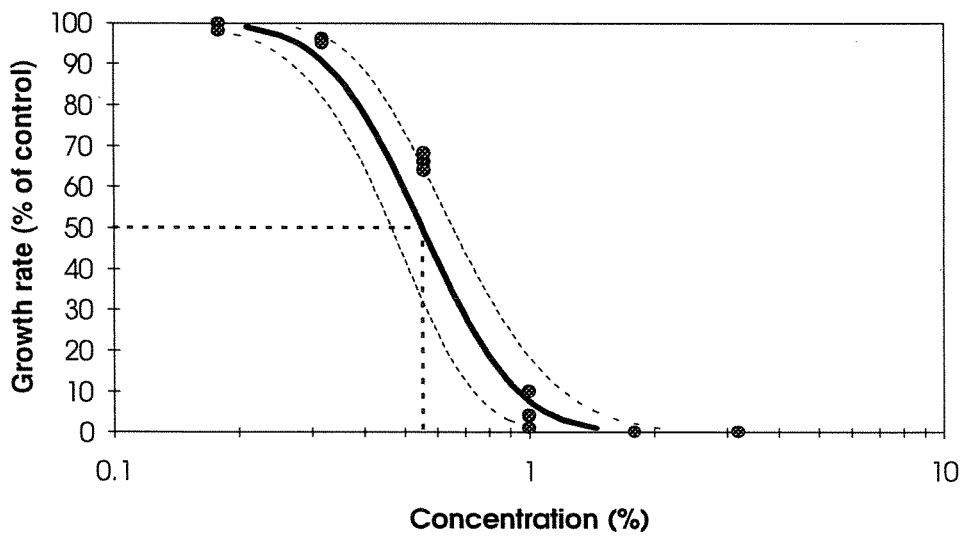


Fig. 2. Effect of Statoil 22.03.93 on growth rate of *Skeletonema costatum.*

References:

ISO/DIS 10253 : Water quality - Marine algal growth inhibition test

Staub. R. (1961): Ernärungsphysiologische Untersuchungen an der planktischen Blaualge *Oscillatoria rubescens* D.C. Schweiz. Z. Hydrol. 23: 82-198.

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Appendix 4

TEST REPORT

Acute toxicity
Acartia tonsa

Test method: ISO TC147 SC5 WG2 draft proposal: Water-Quality - Determination of acute lethal toxicity to marine copepods (Copepoda,Crustacea)

Test substance	Statoil P-80, 14.01.93.
Laboratory code	B049/1
Test organism	*Acartia tonsa*, Origin: Havforskningslaboratoriet, Helsingør. Grown in stock culture in natural sea water, with *Rhodomonas baltica* as food.
Development stage	Copepodite, age 6-8 days
Test period	27-99.1.93
Dilution water	Sea water from the Oslo fjord, 40m at Solbergstrand. Salinity adjusted to 32 ‰
Test concentrations	32, 56 and 100 %
No. of units/conc.	4
Temperature	20° C
pH in control	Start: 8.03 End: 8.18
pH at highest conc.	Start: 8.07 End: 8.41
Dissolved O_2 (48 h)	Control: 100% Highest test concentration: 100%
Calculation of LC_{50}*	Probit analysis (SNV Probit)

Results

Time	Cons. unit	LC_{50}	95% Conf. int.	LC_{20}	0% Effect	100% Effect
48 h	%	> 100	-	> 100	32	> 100

Comments: LC_{50} could not be calculated as mortality in 100 % testwater was 16 %.

Responsible for test: T. Källqvist

* LC_{50} = Concentrations which causes 50% lethality of test organisms.

Table1. Effect of P-80, 14.01.93. on survival of Acartia tonsa

Concentration of sample % of total	Mortality of Acartia tonsa %
0	4.4
32	7.7
56	11.5
100	16.0

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TEST REPORT

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Acute toxicity
Acartia tonsa

Test method: ISO TC147 SC5 WG2 draft proposal: Water-Quality - Determination of acute lethal toxicity to marine copepods (Copepoda,Crustacea)

Test substance	Statoil 19.01.93.
Laboratory code	B049/2
Test organism	*Acartia tonsa*, Origin: Havforskningslaboratoriet, Helsingør. Grown in stock culture in natural sea water, with *Rhodomonas baltica* as food.
Development stage	Copepodite, age 6-8 days
Test period	17-19.2.93
Dilution water	Sea water from the Oslo fjord, 40m at Solbergstrand. Salinity adjusted to 32 ‰
Test concentrations	1, 5.6, 10, 32 and 100 %
No. of units/conc.	4
Temperature	20° C
pH in control	Start: 8.03 End: 8.18
pH at highest conc.	Start: 7.80 End: 8.14
Dissolved O_2 (48 h)	Control: 100% Highest test concentration: 100%
Calculation of LC_{50}*	Probit analysis (SNV Probit)

Results

Time	Cons. unit	LC_{50}	95% Conf. int.	LC_{20}	0% Effect	100% Effect
48 h	%	2.9	2.2 - 3.8	08	< 1	5.6

Comments:

Responsible for test: T. Källqvist

* LC_{50} = Concentrations which causes 50% lethality of test organisms.

Table1. Effect of sample labelled 19.01.93. on survival of Acartia tonsa

Concentration of sample % of total	Mortality of Acartia tonsa %
0	4.2
1	9.5
5.6	96
10	100
32	100
100	100

TEST REPORT

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Acute toxicity
Acartia tonsa

Test method: ISO TC147 SC5 WG2 draft proposal: Water-Quality - Determination of acute lethal toxicity to marine copepods (Copepoda,Crustacea)

Test substance	Statoil SLR 22/3-93.
Laboratory code	B049/3
Test organism	*Acartia tonsa*, Origin: Havforskningslaboratoriet, Helsingør. Grown in stock culture in natural sea water, with *Rhodomonas baltica* as food.
Development stage	Copepodite, age 6-8 days
Test period	29-31.03.93
Dilution water	Sea water from the Oslo fjord, 40m at Solbergstrand. Salinity adjusted to 32 ‰
Test concentrations	1, 1.8, 3.2, 5.6, 10, 32, 50 and 100 %
No. of units/conc.	4
Temperature	20° C
pH in control	Start: 8.02 End: 8.09
pH at highest conc.	Start: 8.07 End: 8.02
Dissolved O_2 (48 h)	Control: 99 % Highest test concentration: 99 %
Calculation of LC_{50}*	Probit analysis (SNV Probit)

Results

Time	Cons. unit	LC_{50}	95% Conf. int.	LC_{10}	0% Effect	100% Effect
48 h	%	3.5	3.0 - 4.2	1.1	< 1	> 5.6

Comments: % mortality of A. tonsa presented in Table 1.

Responsible for test: T. Källqvist

* LC_{50} = Concentrations which causes 50% lethality of test organisms.

Table1. Effect of sample labelled 22.03.93. on survival of Acartia tonsa

Concentration of sample % of total	Mortality of Acartia tonsa %
0	96
1	100
1.8	82
3.2	52
5.6	14
10	0
50	0
100	0

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Appendix 7

TEST REPORT

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Biodegradability test
OECD 301 F, ISO/DIS 9408

Test compound: Statoil Zee-pipe 14. 01. 93 **Lab. code:** **B049/1**

Test details:

Apparatus: Manometric respirometer, WTW 2001

Method: OECD 301 F, modified for biodegradability in seawater (NIVA L4).

Solution: Standard salts were added to the sample. Ammonia: 1.3 mg/l N

Inoculum: Natural seawater from 40 m depth in the Oslofjord was stored for 2 days at room temperature for conditioning, and then filtered through 0.45 µ membrane filters. The material collected on the filters was resuspended in seawater and used as inoculum.
Bacterial counts in the test medium $2 \cdot 10^4$ CFU/ml

Incubation: Temperature: 20 ± 1 °C . Duration: 28 days.

pH: Start 8,0 End: 8,8

Reference: Aniline, 20 mg C/L. Lag-phase: 6 days

Aniline Biodegradation: DOC-reduction of aniline after 14 days: 90 %.

Toxicity - control: No inhibition or degradation delay was observed in a mixture of aniline and the product at the concentration applied.

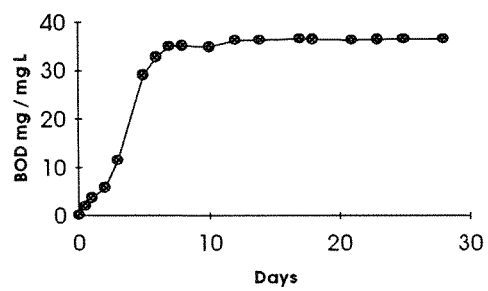
Test period: Jan. 21. to Feb. 18. 1993

Preparation of sample:
The sample water was fortified with nutrient salts and mineral elements and inoculated.
Duplicate flasks were prepared at 50 % and at 98 % (undiluted) concentration.

Results:

Compound	Test conc.	BOD_{28}	DOC_0	DOC_{28}	DOC-red.
Zee-pipe 14.01. 1993	Undiluted	36 mg/l	10.7 mg/l	6.7 mg/l	37 %

BOD-curve:



Conclusion:

A fraction of the organic material is readily biodegradable, however, the maine part is more resistent toward biooxidation under the condition tested.

Oslo, June 25. 1993

Tested by: Harry Efraimsen
Harry Efraimsen

Research manager: Torsten Källqvist
Torsten Källqvist

NIVA

Norwegian Institute for Water Research

ANALYSIS AND RESULTS:

Test period: Jan. 21. to Feb. 18. 1993

Test compound: Statoil. Zee-pipe 14.1.93 **Lab. code:** **B049/1**

Concentrations: 50 and 98 %

Analyticals results:

Calculations of DOC values mg/l in "undiluted sample".

Medium	Bottle code	Initial 0 day	End 28 days
Inoculum	C1	1,2	1,56
"	C2	1,19	1,34
"	Cmv.	**1,195**	**1,45**
Sample	A1	12,0	7,96
"	A2	11,8	8,41
"	Amv.	**11,9**	**8,19**
Corrected values		10,705	6,74
DOC-reduction after 28 days of degradation			**37 %**

Comments:
A relatively high oxygen consumption rate was recorded within the first 7 days of incubation, then a plateau was established. The stagnation of consumption shows that the rest of the organic compounds are more resistant toward biooxidation. This is also supported by the DOC elimination during incubation No nitrification was recorded.

Analytical measurements:
The intermittent BOD-values were derived from the level of manometer reading during incubation. The manometer readings were calibrated against oxygen electrode readings after 28 days.

Dissolved oxygen was determined by a WTW OXI 2000 oxygen instrument in each test flasks before and after incubation. Dissolved organic carbon in the test medium was analyzed on Dohrmann DC 190 after combustion at 680 °C, with platinum as catalyzer (TC/TOC analyzer).
NO_3-N concentration was analyzed according NS 4745 (Autoanalyzer Method).

REFERENCE:
1. ISO/DIS 9408 Water Quality- Evaluation in a aqueous medium of the "ultimate" biodegradability of organic compounds- Method by determining the oxygen demand in closed respirometer.
2. OECD Test guideline 301 Manometric Respirometry. Adopted July 17th 1992.
Room document no. 16, Annex 4. Biodegradability in Seawater. Ocotober 1990

TEST REPORT

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Biodegradability test
OECD 301 F, ISO/DIS 9408

Test compound: Statoil. Zee-pipe 19. 01. 93 **Lab. code:** **B049/2**

Test details:

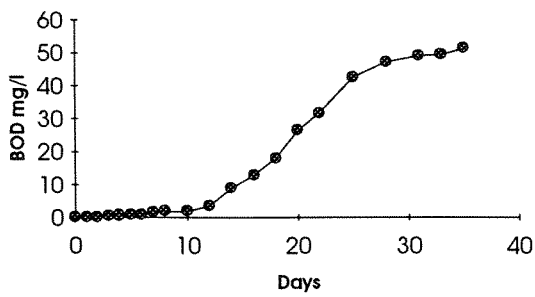
Apparatus:	Manometric respirometer, WTW 2001
Method:	OECD 301 F, modified for biodegradability in seawater (NIVA L4).
Solution:	Standard salts were added to the sample. Ammonia: 1.3 mg/l N
Dilution water:	Natural seawater from 40 m depth in the Oslofjord, stored for 2 days at room temperature for conditioning.
Inoculum:	Microorganisms present in the seawater. Bacterial counts in the test medium $1.3 \cdot 10^4$ CFU/ml
Incubation:	Temperature: 20 ± 1 °C . Duration: 28 days.
pH:	Start 7.8 End: 8.4
Reference:	Aniline, 20 mg C/L. Lag-phase: 6 days
Aniline	Biodegradation: DOC-reduction of aniline after 14 days: 90 %.
Toxicity - control:	A significant delay and depression of oxygen consumption was observed in the mixture of aniline and the sample at 10 and 25 % concentration. Higher dilution of the test sample did not solve the problem. No toxicity was observed in a slosed bottle test at 5 % concentration.
Test period:	Jan. 28. to Mars 4. 1993

Preparation of sample:
Duplicate flasks were prepared at 10 % and at 25 % concentration.

Results: Calculated in undiluted sample.

Compound	Test conc.	BOD_{35}	DOC_0	DOC_{35}	DOC-red.
Zee-pipe 19.01. 1993	25 %	56 mg/l	37.8 mg/l	10.4 mg/l	73 %

BOD-curve:



Conclusion:

Organic substances in test water are shown to be readily biodegradable at low concentration, (2-5 mg/l carbon).

Oslo, June 25. 1993

Tested by: Harry Efraimsen
Harry Efraimsen

Research manager: Torsten Källqvist
Torsten Källqvist

NIVA
Norwegian Institute for Water Research

ANALYSIS AND RESULTS:

Test period: Jan. 28. to Mars 4. 1993

Test compound: Statoil. Zee-pipe 19. 01. 93 **Lab. code:** **B049/2**

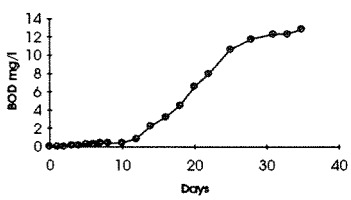
Concentrations: 10 and 25 %

Analyticals results:

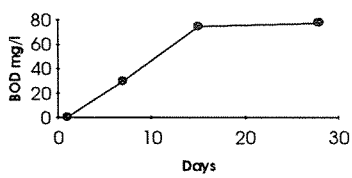
Calculations of DOC values mg/l at 25 % concentration of sample.

Medium	Bottle	Initial 0 day	End 35 days
Inoculum	C1	1,2	1,5
"	C2	1,19	1,34
"	Cmv.	**1,195**	**1,42**
Sample	A1	10,8	4,12
"	A2	10,5	3,9
"	Amv.	**10,7**	**4,01**
Corrected values		9,455	2,59
DOC-reduction after 35 days of degradation			**73 %**

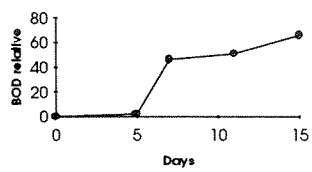
BOD curve in respirometric test
Conc. 25 %



BOD curve in closed bottle test
Conc. 5 %



BOD in toxicty control
Conc. 5 %



Comments:
Oxygen consumption was inhibited by toxic substances causing a lag phase of approx. 10 days at a concentration of 25 % of sample. Further dilution gave unreliable results in the respirometer test. A closed bottle test (CBT) conducted at 5 % overcome the effect of toxicity, indicating that the substances are readily biodegradable at low concentration.
The DOC elimination also indicates that organic substances in the sample are readily biodegradable when diluted below toxic concentration.

Analytical measurements:
The intermittent BOD-values were derived from the level of manometer reading during incubation. The manometer readings were calibrated against oxygen electrode readings after 28 days.

Dissolved oxygen was determined by a WTW OXI 2000 oxygen instrument in each test flasks before and after incubation. Dissolved organic carbon in the test medium was analyzed on Dohrmann DC 190 after combustion at 680 °C, with platinum as catalyzer (TC/TOC analyzer).
NO_3-N concentration was analyzed according NS 4745 (Autoanalyzer Method).

REFERENCE:
1. ISO/DIS 9408 Water Quality- Evaluation in a aqueous medium of the "ultimate" biodegradability of organic compounds- Method by determining the oxygen demand in closed respirometer.
2. OECD Test guideline 301 Manometric Respirometry. Adopted July 17th 1992.
Room document no. 16, Annex 4. Biodegradability in Seawater. Ocotober 1990

Appendix 9

TEST REPORT

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Biodegradability test
OECD 301 F, ISO/DIS 9408

Test compound: Statoil Zee-pipe 22. 03. 93 **Lab. code:** **B049/3**

Test details:

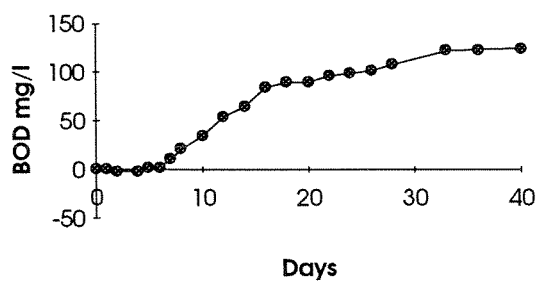
Apparatus:	Manometric respirometer, WTW 2001
Method and Solution:	OECD 301 F, modified for biodegradability in seawater (NIVA L4). Standard salts were added to the sample. Ammonia: 1.3 mg/l N
Dilution water:	Natural seawater from 40 m depth in the Oslofjord, stored for 3 days at room temperature for conditioning.
Inoculum:	Microorganisms present in the dilution water. Bacterial counts in the test medium $2.0 \cdot 10^4$ CFU/ml
Incubation:	Temperature: 20 ± 1 °C . Duration: 28 days.
pH:	Start 8.0 End: 8,4
Reference:	Aniline, 20 mg C/L. Lag-phase: 7 days
Aniline	Biodegradation: DOC-reduction of aniline after 14 days: 93 %.
Toxicity - control:	A significant delay and depression of oxygen consumption was recorded in the mixture of aniline and the sample at the concentration applied. An intensive consumption appeared between 20 to 26 days, indicating an adaption of bacteria.
Test period:	Mars. 25. to May 4. 1993

Preparation of sample:
Duplicate flasks were prepared at 10 % concentration.

Results: Calculated in undiluted sample.

Compound	Test conc.	BOD_{40}	DOC_0	DOC_{40}	DOC-red.
Zee-pipe 22.03. 1993	10 %	125 mg/l	41 mg/l	2 mg/l	95 %

BOD-curve:



Conclusion:

Organic substances in test sample are shown to be readily biodegradable at concentration lower then 5 mg/l carbon.

Oslo, June 25. 1993

Tested by: Harry Efraimsen
Harry Efraimsen

Research manager:
Torsten Källqvist

ANALYSIS AND RESULTS:

Test period: Mars. 25. to May 4. 1993

Test compound: Statoil Zee-pipe 22. 03. 93 **Lab. code:** **B049/3**

Concentrations: 10 % in respirometric test.

Analyticals results:
Calculations of DOC values mg/l at 10 % concentration of sample.

Medium	Bottle code	Initial 0 day	End 40 days
Inoculum	C1	1,4	1,5
"	C2	1,2	1,8
"	Cmv.	**1,3**	**1,65**
Sample	A1	5,3	1,9
"	A2	5,5	1,8
"	Amv.	**5,4**	**1,85**
Corrected values		4,1	0,20
DOC-reduction after 40 days of degradation			**95 %**

Figure 1
BOD curve in respirometric test
Conc. 10 %

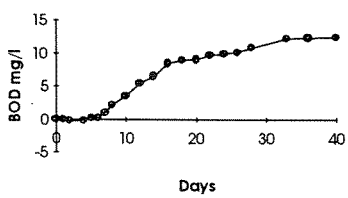


Figure 2
BOD curve in closed bottle test
Conc. 5 %

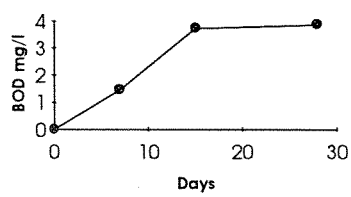
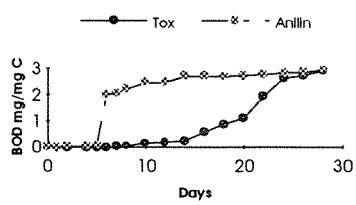


Figure 3
BOD in toxicty control Conc. 10 %
Respirometric test



Comments:
Oxygen consumption was inhibited by toxic substances in the first part of the test period. This is clearely shown in fig. 3. In the toxicity test the consumption of oxygen was depressed by the toxicant up to 20 days of incubation. The test period was prolonged to 40 days, because concumption of oxygen was not stagnated at the time of 28 days.
In the closed bottle test (CBT) no toxic effect was observed at a concentration of 5 % of test sample as shown in fig. 2. However, a very high elimination of DOC was measured at 10 %, indicating that organic substances in the sample are readily biodegradable at low concentration.

Analytical measurements:
The intermittent BOD-values were derived from the level of manometer reading during incubation. The manometer readings were calibrated against oxygen electrode readings after 28 days.

Dissolved oxygen was determined by a WTW OXI 2000 oxygen instrument in each test flasks before and after incubation. Dissolved organic carbon in the test medium was analyzed on Dohrmann DC 190 after combustion at 680 °C, with platinum as catalyzer (TC/TOC analyzer).
NO_3-N concentration was analyzed according NS 4745 (Autoanalyzer Method).

REFERENCE:
1. ISO/DIS 9408 Water Quality- Evaluation in a aqueous medium of the "ultimate" biodegradability of organic compounds- Method by determining the oxygen demand in closed respirometer.
2. OECD Test guideline 301 Manometric Respirometry. Adopted July 17th 1992.
Room document no. 16, Annex 4. Biodegradability in Seawater. Ocotober 1990

Fytoplankton analyses 1st cruise

Station	1	1	1	1	1
Date	93.01.14	93.01.14.	93.01.14	93.01.14	93.01.14
Depth in metres	76	51	31	21	0
Cellcounts are given in cells/litre					
CRYPTOPHYCEAE					
Cryptomonas cf. acuta	2.200	22.200		13.300	4.700
cf. Hemiselmis		4.400		35.600	9.400
Leucocryptos marina	6.700		4.400	8.900	11.700
cf. Plagioselmis sp.	13.300	17.800	4.400	4.400	21.100
DINOPHYCEAE					
Amphidinium sp.1 20-30 µm	100				
A. spp	100				
Gymnodinium elongatum				200	
Gyrodinium aureolum	100		200		200
G. grenlandicum			4.400	4.400	4.700
Heterocapsa niei		200			
Unidentified thecate 10-20 µm	2.200				
Unidentified athecate <10 µm	17.800	26.700	48.900	44.500	28.100
" " 10-20 µm	20.000	8.900	22.200	35.600	28.100
" " 20-30 µm	400	200	200	600	
" " > 30 µm	100	400	200	200	
PRYMNESIOPHYCEAE					
Chrysochromulina spp. < 5 µm			4.400		9.400
C. spp. 5-10 µm		8.900		4.400	
CHRYSOPHYCEAE					
Dictyocha speculum	100				100
cf. Pseudopedinella pyriformis					
BACILLARIOPHYCEAE					
Amphiprora sp.			400		
Chaetoceros sp. Phaeoceros			200		
Coscinodiscus spp.					
Gyrosigma/Pleurosigma	100				
Leptocylindrus danicus					
Melosira sulcata	300		2.200		2.800
Nitzschia closterium/longissima	200				
Nitzscha closterium f.					
Nitzschia spp.	1.000	1.200	800	1.000	
Rhizosolenia imbricata var. shrubsolei					
Thalassiosira spp.			400	200	
Unidentified centric diatoms <10 µm		4.400			
" " 10-20 µm	100	4.400			
" " 20-30 µm	100				
" " > 30 µm					

Station	1	1	1	1	1
Date	93.01.14	93.01.14.	93.01.14	93.01.14	93.01.14
Depth in metres	76	51	31	21	0
Cellcounts are given in cells/litre					
BACILLARIOPHYCEAE continues					
Unidentified pennate <10 µm	2.200			4.400	
" " 10-20 µm					2.300
" " 20-30 µm					
" " >30 µm	400	600	200	1.000	
PRASINOPHYCEAE					
Pyramimonas sp.					
NOT CLASSIFIED					
Unidentified flagellates <5 µm	249.000	302.400	284.600	346.900	262.100
" " 5-10 µm	44.500	8.900	26.700	8.900	18.700
" " 10-20 µm					4.700
" " 20-30 µm				200	
Unidentified without flagella <5 µm	382.400	453.600	400.200	480.300	646.000
" " 5-10 µm	53.400	53.400	97.800	53.400	37.400
cf. Telonema subtilis			8.900	17.800	
Unidentified choanoflagellates	2.200		8.900	13.300	
Unidentified ciliates	600	200	400	200	
TOTAL CELLNUMBERS	799.600	918.800	921.000	1.079.700	1.091.500

Station	8	8	8	8	8
Date	93.01.14	93.01.14.	93.01.14	93.01.14	93.01.14
Depth in metres	74	30	17	7	5
Cellcounts are given in cells/litre					
CRYPTOPHYCEAE					
Cryptomonas cf. acuta	4.400	8.900			
cf. Hemiselmis	8.900	13.300	8.900	17.800	17.800
Leucocryptos marina	4.400	4.400	4.400	8.900	8.900
cf. Plagioselmis sp.	13.300	13.300	22.200	4.400	13.300
DINOPHYCEAE					
Amphidinium sp.1 20-30 µm	200		200		
A. spp					
Gymnodinium elongatum					
Gyrodinium aureolum			200	200	
G. grenlandicum	8.900			4.400	
Heterocapsa niei					
Unidentified thecate 10-20 µm					
Unidentified athecate <10 µm	40.000	26.700	22.200	40.000	13.300
" " 10-20 µm	8.900	31.129	26.700	8.900	22.200
" " 20-30 µm	200	800	600	400	200
" " > 30 µm				200	
PRYMNESIOPHYCEAE					
Chrysochromulina spp. <5 µm					
C. spp. 5-10 µm					
CHRYSOPHYCEAE					
Dictyocha speculum				200	
cf. Pseudopedinella pyriformis					
BACILLARIOPHYCEAE					
Amphiprora sp.	200			200	
Chaetoceros sp. Phaeoceros			200		
Coscinodiscus spp.					
Gyrosigma/Pleurosigma		200		400	100
Leptocylindrus danicus					
Melosira sulcata					2.200
Nitzschia closterium/longissima	600		200		
Nitzscha closterium f.		4.400		4.400	
Nitzschia spp.	600	600	200	1.200	200
Rhizosolenia imbricata var. shrubsolei		200			200
Thalassiosira spp.					
Unidentified centric diatoms <10 µm		4.400			
" " 10-20 µm				200	
" " 20-30 µm	800	200	600		
" " > 30 µm					

Station	8	8	8	8	8
Date	93.01.14	93.01.14.	93.01.14	93.01.14	93.01.14
Depth in metres	74	30	17	7	5
Cellcounts are given in cells/litre					
BACILLARIOPHYCEAE continues					
Unidentified pennate <10 µm				4.400	
" " 10-20 µm				400	
" " 20-30 µm			200		
" " >30 µm	800	1.000	1.600	1.200	600
PRASINOPHYCEAE					
Pyramimonas sp.					
NOT CLASSIFIED					
Unidentified flagellates <5 µm	364.700	346.900	284.600	364.700	249.000
" " 5-10 µm	8.900	17.800	17.800	17.800	17.800
" " 10-20 µm					
" " 20-30 µm					
Unidentified without flagella <5 µm	871.600	587.000	498.000	640.400	453.600
" " 5-10 µm	44.500	62.300	26.700	53.400	17.800
cf. Telonema subtilis	4.400		4.400		
Unidentified choanoflagellates	4.400	4.400		8.900	4.400
Unidentified ciliates	800	600	1000	400	100
TOTAL CELLNUMBERS	1.391.500	1.128.529	920.900	1.183.400	821.700

Station	14	14	14	14
Date	93.01.19	93.01.19	93.01.19	93.01.19
Depth in metres	76	64	46	1
Cellcounts are given in cells/litre				
CRYPTOPHYCEAE				
Cryptomonas cf. acuta	8.900	22.200	13.300	13.300
cf. Hemiselmis	8.900	17.800	13.300	4.400
Leucocryptos marina			4.400	
cf. Plagioselmis sp.	8.900	22.200	26.700	40.000
DINOPHYCEAE				
Amphidinium sp.1 20-30 µm				200
A. spp	200			200
Gymnodinium elongatum				
Gyrodinium aureolum				200
G. grenlandicum		4.400		4.400
Heterocapsa niei				
Unidentified thecate 10-20 µm				
Unidentified athecate <10 µm	8.900	22.200	13.300	13.300
" " 10-20 µm	26.700	13.300	17.800	26.700
" " 20-30 µm	200	200		1.200
" " > 30 µm		200		600
PRYMNESIOPHYCEAE				
Chrysochromulina spp. <5 µm			4.400	
C. spp. 5-10 µm				
CHRYSOPHYCEAE				
Dictyocha speculum				
cf. Pseudopedinella pyriformis	8.900			
BACILLARIOPHYCEAE				
Amphiprora sp.			200	200
Chaetoceros sp. Phaeoceros				
Coscinodiscus spp.			200	
Gyrosigma/Pleurosigma				
Leptocylindrus danicus			400	
Melosira sulcata				
Nitzschia closterium/longissima	200			
Nitzscha closterium f.		8.900	13.300	
Nitzschia spp.	1400	400	200	400
Rhizosolenia imbricata var. shrubsolei				
Thalassiosira spp.				200
Unidentified centric diatoms <10 µm	4.400		4.400	
" " 10-20 µm				
" " 20-30 µm				
" " > 30 µm				

Station	14	14	14	14
Date	93.01.19	93.01.19	93.01.19	93.01.19
Depth in metres	76	64	46	1
Cellcounts are given in cells/litre				
BACILLARIOPHYCEAE continues				
Unidentified pennate <10 µm				
" " 10-20 µm				
" " 20-30 µm				
" " >30 µm	2.400	1.600	1.600	2.000
PRASINOPHYCEAE				
Pyramimonas sp.	4.400			
NOT CLASSIFIED				
Unidentified flagellates <5 µm	249.000	231.200	231.200	409.100
" " 5-10 µm	17.800	8.900	17.800	17.800
" " 10-20 µm				
" " 20-30 µm				
Unidentified without flagella <5 µm	329.100	747.100	507.000	853.800
" " 5-10 µm	35.600	35.600	44.500	8.900
cf. Telonema subtilis	13.300		4.400	
Unidentified choanoflagellates	13.300	8.900		8.900
Unidentified ciliates	1.000	1.200	600	800
TOTAL CELLNUMBERS	743.500	1.146.300	919.000	1.406.600

Station		20	20	20	20
Date		93.01.19	93.01.19	93.01.19	93.01.19
Depth in metres		57	50	45	12
Cellcounts are given in cells/litre					
CRYPTOPHYCEAE					
Cryptomonas cf. acuta		8.900	8.900		400
cf. Hemiselmis		4.400	8.900	4.400	17.800
Leucocryptos marina		4.400		4.400	400
cf. Plagioselmis sp.		44.470	17.800	26.700	13.300
DINOPHYCEAE					
Amphidinium sp.1	20-30 µm	200	200		200
A. spp					
Gymnodinium elongatum					400
Gyrodinium aureolum					
G. grenlandicum		8.900			
Heterocapsa niei					200
Unidentified thecate	10-20 µm				400
Unidentified athecate	<10 µm	22.200	26.700	13.300	13.300
" "	10-20 µm	44.500	26.700	8.900	22.200
" "	20-30 µm	1.000	800	800	200
" "	> 30 µm		200		200
PRYMNESIOPHYCEAE					
Chrysochromulina spp.	<5 µm	4.400			
C. spp.	5-10 µm				
CHRYSOPHYCEAE					
Dictyocha speculum					
cf. Pseudopedinella pyriformis			4.400		
BACILLARIOPHYCEAE					
Amphiprora sp.					400
Chaetoceros sp. Phaeoceros				200	
Coscinodiscus spp.		200			
Gyrosigma/Pleurosigma				600	
Leptocylindrus danicus		400			
Melosira sulcata		800			
Nitzschia closterium/longissima			200		
Nitzscha closterium f.					
Nitzschia spp.		1.000	800	200	800
Rhizosolenia imbricata var. shrubsolei					200
Thalassiosira spp.					
Unidentified centric diatoms	<10 µm				
" "	10-20 µm	400	600	600	
" "	20-30 µm		200	600	
" "	> 30 µm				

Station	20	20	20	20
Date	93.01.19	93.01.19	93.01.19	93.01.19
Depth in metres	57	50	45	12
Cellcounts are given in cells/litre				
BACILLARIOPHYCEAE continues				
Unidentified pennate <10 µm				
" " 10-20 µm	400			
" " 20-30 µm	400	200	400	
" " >30 µm	1.200	1.200	2.600	1.800
PRASINOPHYCEAE				
Pyramimonas sp.				
NOT CLASSIFIED				
Unidentified flagellates <5 µm	231.200	266.800	222.400	142.300
" " 5-10 µm	17.800	35.600	8.900	8.900
" " 10-20 µm			4.400	
" " 20-30 µm				
Unidentified without flagella <5 µm	836.000	595.900	667.100	747.100
" " 5-10 µm	17.800	4.400	4.400	4.400
cf. Telonema subtilis			8.900	
Unidentified choanoflagellates	4.400	8.900		4.400
Unidentified ciliates		800		400
TOTAL CELLNUMBERS	1.255.370	1.010.200	979.800	979.700

Appendix 11

Phytoplankton analyses, 2nd cruise.

Station	3	3	5	5	6	6
Date	93.03.18	93.03.18	93.03.18	93.03.18	93.03.19	93.03.19
Depth in metres	27	2	26	3	27	10
Cellcounts are given in cells/litre						
CRYPTOPHYCEAE						
Cryptomonas cf. acuta	8.700	26.000	17.300	17.300	20.200	20.200
cf. Hemiselmis	5.800	11.500	5.800			2.900
Leucocryptos marina	400				400	
cf. Plagioselmis sp.	323.000	288.400	265.400	173.000	242.300	115.400
DINOPHYCEAE						
Gonyaulax sp.		200				
"Gymnodinium lohmannii"	400	400		200		
Gyrodinium aureolum	200	400				
Katodinium rotundatum	2.900	11.500	11.500	5.800	2.900	
Oxytoxum sp.1		100		400	800	200
Protoperidinium bipes		1.000				
Torodinium robustum		100	200			
Unidentified athecate sp.1	28.800	34.600	26.000	46.100	20.200	28.800
" " <10 µm	11.500	34.600		5.800	14.400	11.500
" " 10-20 µm	26.000	34.600	31.700	43.300	20.200	17.300
" " 20-30 µm	600	400	2.900	2.900		
" " > 30 µm	200			200		400
Unidentified thecate 10-20 µm	8.700	200	2.900	2.900		2.900
" " 20-30 µm						200
" " > 30 µm				200		
PRYMNESIOPHYCEAE						
Chrysochromulina spp. < 5 µm		2.900	8.700	11.500	11.500	5.800
C. spp. 5-10 µm	17.300	2.900	14.400	11.500	11.500	5.800
Dicrateria/Imantonia sp.	173.000	265.400	334.600	311.500	184.600	109.600
Emiliania huxleyi	63.400	92.300	57.700	28.800	20.200	46.100
Phaeocystis sp.		300			1.600	
CHRYSOPHYCEAE						
Dictyocha speculum	400	200		200		
cf. Olisthodiscus luteus		2.900	2.900			
BACILLARIOPHYCEAE						
Arcocellulus cornuservis		11.500				
Bacillaria paradoxa					1.600	
Chaetoceros sp. Phaeoceros		200				
C. sp. Hyalochaete		200	400		600	600
Nitzschia closterium/longissima	1.200	2.000	1.800	1.800	3.000	3.800
Pseudonitzschia pseudodelicatissima	10.400	20.200	14.400	25.400	20.000	24.800
P. seriata	1.000	500	800			
Skeletonema costatum	1.000	3.100	1.800	1.800	2.200	2.600
Thalassionema nitzschioides		200				

Station	3	3	5	5	6	6
Date	93.03.18	93.03.18	93.03.18	93.03.18	93.03.19	93.03.19
Depth in metres	27	2	26	3	27	10
Cellcounts are given in cells/litre						
BACILLARIOPHYCEAE continue						
Thalassiosira "gravida"	1.000	600		600	600	2.000
T. nordenskioeldii		100				
T.sp.	200	300	200	200	1.400	600
Unidentified centric diatom 10 µm						2.900
Unidentified pennate diatom	400	600		1.400	400	2.400
PRASINOPHYCEAE						
Pyramimonas sp. 1	43.300	28.800	14.400	11.500	5.800	23.100
P. sp. 2	14.400	11.500	8.700	14.400	5.800	5.800
EUGLENOPHYCEAE						
Unidentified euglenophyceae		2.900	2.900			
NOT CLASSIFIED						
Unidentified flagellates < 5 µm	265.400	323.000	161.500	196.100	230.700	115.400
" " 5-10 µm	80.800	92.300	57.700	5.800	63.400	80.600
Unidentified without flagella < 5 µm	4.038.000	4.430.200	4.730.000	5.030.100	4.707.100	2.977.000
" " 5-10 µm	115.400	196.100	69.200	69.200	115.370	138.400
cf. Telonema subtilis	23.100	80.800	23.100	14.400	17.300	8.700
Unidentified choanoflagellates	5.800	11.500		2.900	5.700	2.900
TOTAL CELLNUMBERS	5.272.700	6.027.500	5.868.900	6.037.200	5.731.770	3.758.700

APPENDIX ZEEPIPE MONITORING **JANUARY** 1993

Oxygen values and derived variables from water samples

#STAT -	DEPT	###	S	#	T	#	SIG	#o2(ml/l)	#SATUR#	O2(%)	AOU(ml/l)
st1	, 0.	(m):	35.19		7.10		27.55	6.35	6.74	94.3	.39
st1	, 21.	(m):	35.19		7.10		27.55	6.46	6.74	95.9	.28
st1	, 31.	(m):	35.19		7.10		27.55	6.39	6.74	94.9	.35
st1	, 51.	(m):	35.19		7.10		27.55	6.39	6.74	94.9	.35
st1	, 76.	(m):	35.19		7.10		27.55	6.34	6.74	94.1	.40
st2	, 0.	(m):	35.19		7.10		27.55	6.38	6.74	94.7	.36
st2	, 4.	(m):	35.19		7.10		27.55	6.37	6.74	94.6	.37
st2	, 16.	(m):	35.19		7.10		27.55	6.39	6.74	94.9	.35
st2	, 31.	(m):	35.19		7.10		27.55	6.78	6.74	100.7	-.04
st2	, 74.	(m):	35.19		7.10		27.55		6.74		
st7	, 6.	(m):	35.19		7.10		27.55	6.38	6.74	94.7	.36
st7	, 9.	(m):	35.19		7.10		27.55	6.39	6.74	94.9	.35
st7	, 18.	(m):	35.19		7.10		27.55	6.38	6.74	94.7	.36
st7	, 32.	(m):	35.19		7.10		27.55	6.38	6.74	94.7	.36
st7	, 78.	(m):	35.19		7.10		27.55	6.38	6.74	94.7	.36
st8	, 5.	(m):	35.19		7.10		27.55	6.40	6.74	95.0	.34
st8	, 7.	(m):	35.19		7.10		27.55	6.42	6.74	95.3	.32
st8	, 17.	(m):	35.19		7.10		27.55	6.40	6.74	95.0	.34
st8	, 30.	(m):	35.19		7.10		27.55	6.39	6.74	94.9	.35
st8	, 74.	(m):	35.19		7.10		27.55	6.41	6.74	95.2	.33
st12	, 1.	(m):	35.18		6.90		27.57	6.54	6.77	96.6	.23
st12	, 24.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st12	, 24.	(m):	35.18		6.90		27.57	6.53	6.77	96.5	.24
st12	, 48.	(m):	35.18		6.90		27.57	6.47	6.77	95.6	.30
st12	, 79.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st13	, 25.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st13	, 51.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st13	, 51.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st13	, 61.	(m):	35.18		6.90		27.57	6.49	6.77	95.9	.28
st13	, 75.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st14	, 1.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st14	, 46.	(m):	35.18		6.90		27.57	6.51	6.77	96.2	.26
st14	, 64.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st14	, 76.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st15	, 2.	(m):	35.18		6.90		27.57	6.51	6.77	96.2	.26
st15	, 45.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st15	, 56.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st15	, 79.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st16	, 44.	(m):	35.18		6.90		27.57	6.51	6.77	96.2	.26
st16	, 50.	(m):	35.18		6.90		27.57	6.53	6.77	96.5	.24
st16	, 56.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st16	, 82.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st20	, 12.	(m):	35.18		6.90		27.57	6.53	6.77	96.5	.24
st20	, 45.	(m):	35.18		6.90		27.57	6.51	6.77	96.2	.26
st20	, 50.	(m):	35.18		6.90		27.57	6.49	6.77	95.9	.28
st20	, 57.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st23	, 56.	(m):	35.18		6.90		27.57	6.48	6.77	95.7	.29
st23	, 59.	(m):	35.18		6.90		27.57	6.46	6.77	95.5	.31
st23	, 61.	(m):	35.18		6.90		27.57	6.47	6.77	95.6	.30
st23	, 67.	(m):	35.18		6.90		27.57	6.52	6.77	96.3	.25
st24	, 1.	(m):	35.18		6.90		27.57	6.48	6.77	95.7	.29
st24	, 25.	(m):	35.18		6.90		27.57	6.48	6.77	95.7	.29
st24	, 50.	(m):	35.18		6.90		27.57	6.50	6.77	96.0	.27
st24	, 76.	(m):	35.18		6.90		27.57	6.49	6.77	95.9	.28

APPENDIX Continued ZEEPIPE MONITORING MARCH 1993

Oxygen values and derived variables from water samples

# STAT - DEPT ###	S #	T #	SIG	#o2(ml/l)	#SATUR#	O2(%)	#AOU(ml/l)
Sta 3 , 2. (m):	34.98	6.23	27.51	6.81	6.88	98.9	.07
Sta 3 , 27. (m):	34.99	6.24	27.51	6.79	6.88	98.7	.09
Sta 3 , 50. (m):	35.04	6.15	27.57	6.75	6.89	97.9	.14
Sta 3 , 80. (m):	35.06	6.16	27.58	6.63	6.89	96.2	.26
Sta 5 , 3. (m):	34.99	6.22	27.51	6.76	6.89	98.2	.13
Sta 5 , 26. (m):	34.99	6.22	27.52	6.70	6.89	97.3	.19
Sta 5 , 50. (m):	35.02	6.17	27.54	6.70	6.89	97.2	.19
Sta 5 , 76. (m):	35.05	6.14	27.57	6.66	6.89	96.6	.23
Sta 6 , 10. (m):	34.99	6.15	27.52	6.76	6.90	98.0	.14
Sta 6 , 28. (m):	34.99	6.15	27.52	6.72	6.90	97.4	.18
Sta 6 , 60. (m):	34.99	6.15	27.52	6.67	6.90	96.7	.23
Sta 6 , 76. (m):	34.99	6.16	27.53	6.70	6.90	97.2	.20
Sta 7 , 2. (m):	34.99	6.20	27.52	6.77	6.89	98.3	.12
Sta 7 , 28. (m):	34.99	6.21	27.52	6.71	6.89	97.4	.18
Sta 7 , 40. (m):	34.99	6.20	27.52	6.73	6.89	97.7	.16
Sta 7 , 71. (m):	35.00	6.18	27.53	6.74	6.89	97.8	.15
Sta 8 , 1. (m):	35.00	6.18	27.53	6.72	6.89	97.5	.17
Sta 8 , 10. (m):	35.00	6.19	27.53	6.72	6.89	97.5	.17
Sta 8 , 26. (m):	35.00	6.19	27.53	6.72	6.89	97.5	.17
Sta 8 , 70. (m):	35.00	6.14	27.54	6.70	6.90	97.2	.20
Sta 9 , 2. (m):	34.97	6.14	27.51	6.70	6.90	97.1	.20
Sta 9 , 12. (m):	35.00	6.15	27.53	6.70	6.90	97.2	.20
Sta 9 , 28. (m):	36.00	6.15	28.32	6.74	6.85	98.4	.11
Sta 9 , 72. (m):	35.00	6.15	27.53	6.69	6.90	97.0	.21
Sta 10 , 2. (m):	35.00	6.20	27.53	6.69	6.89	97.1	.20
Sta 10 , 10. (m):	35.00	6.20	27.53	6.73	6.89	97.7	.16
Sta 10 , 24. (m):	35.00	6.20	27.53	6.74	6.89	97.9	.15
Sta 10 , 72. (m):	35.00	6.18	27.53	6.72	6.89	97.5	.17
Sta 11 , 2. (m):	34.96	6.24	27.49	6.74	6.88	97.9	.14
Sta 11 , 10. (m):	34.96	6.23	27.49	6.74	6.88	97.9	.14
Sta 11 , 24. (m):	34.97	6.23	27.49	7.12	6.88	103.4	-.24
Sta 11 , 74. (m):	34.96	6.15	27.50	6.70	6.90	97.1	.20
Sta 14 , 2. (m):	34.97	6.24	27.49	6.77	6.88	98.4	.11
Sta 14 , 10. (m):	34.97	6.24	27.50	6.77	6.88	98.4	.11
Sta 14 , 28. (m):	34.97	6.22	27.50	6.76	6.89	98.2	.13
Sta 14 , 72. (m):	34.98	6.15	27.52	6.80	6.90	98.6	.10
Sta 15 , 2. (m):	34.95	6.23	27.48	6.74	6.89	97.9	.15
Sta 15 , 8. (m):	34.95	6.22	27.49	6.73	6.89	97.7	.16
Sta 15 , 24. (m):	34.95	6.22	27.49	6.70	6.89	97.3	.19
Sta 15 , 60. (m):	34.97	6.18	27.50	6.68	6.89	96.9	.21
Sta 16 , 2. (m):	34.88	6.21	27.43	6.81	6.89	98.8	.08
Sta 16 , 12. (m):	34.95	6.21	27.49	6.79	6.89	98.6	.10
Sta 16 , 28. (m):	34.95	6.21	27.48	6.81	6.89	98.9	.08
Sta 16 , 74. (m):	34.97	6.16	27.51	6.83	6.90	99.0	.07
Sta 24 , 4. (m):	34.94	6.16	27.48	6.96	6.90	100.9	-.06
Sta 24 , 26. (m):	34.94	6.16	27.48	6.77	6.90	98.2	.13
Sta 24 , 50. (m):	34.94	6.16	27.48	6.80	6.90	98.6	.10
Sta 24 , 74. (m):	34.96	6.16	27.50	6.77	6.90	98.2	.13
Sta 25 , 10. (m):	34.94	6.16	27.48	6.76	6.90	98.0	.14
Sta 25 , 24. (m):	34.94	6.16	27.48	6.72	6.90	97.4	.18
Sta 25 , 50. (m):	34.94	6.16	27.48	6.72	6.90	97.4	.18
Sta 26 , 4. (m):	34.94	6.15	27.48	6.51	6.90	94.4	.39
Sta 26 , 26. (m):	34.94	6.15	27.48	6.77	6.90	98.1	.13
Sta 26 , 50. (m):	34.94	6.15	27.49	6.79	6.90	98.4	.11
Sta 26 , 70. (m):	34.95	6.15	27.50	6.73	6.90	97.6	.17

Appendix 13

Results of glutaraldehyde, turbidity, total suspended sediments and chlorophyll-a.						
Station	**Date**	**Depth**	**G. aldehyde**	**Turb**	**TSM**	**Kla**
		m	**mg/l**	**FTU**	**mg/l**	**ug/l**
Surface samples in January						
0920 UTC	14/01/93	0	<0.2	0.7		
0950 UTC	14/01/93	0	<0.2	0.73		
1127 UTC	14/01/93	0	<0.2	0.69		
1145 UTC	14/01/93	0	<0.2	0.7		
1250 UTC	14/01/93	0	<0.2	0.52		
1610 UTC	14/01/93	0	<0.2	0.9	1.29	
Regular station in January						
St. 1	14/01/93	0	<0.2	0.49		0.13
	14/01/93	21	<0.2	0.45		0.11
	14/01/93	31	<0.2	0.51		0.12
	14/01/93	51	<0.2	0.4		0.16
	14/01/93	76	<0.2	0.45	0.89	0.12
St. 2	14/01/93	0	<0.2	0.45		0.14
	14/01/93	4	<0.2	0.33		0.08
	14/01/93	16	<0.2	0.6		0.06
	14/01/93	31	<0.2	0.32		0.07
	14/01/93	74	<0.2	0.65	0.81	0.17
St. 7	14/01/93	6	<0.2	0.5		0.06
	14/01/93	9	<0.2	0.49		0.13
	14/01/93	18	<0.2	0.33		0.13
	14/01/93	32	<0.2	0.35		0.12
	14/01/93	78	<0.2	0.4	0.6	0.05
St. 8	14/01/93	5	<0.2	0.5		0.13
	14/01/93	7	<0.2	0.52		0.14
	14/01/93	17	<0.2	0.48		0.11
	14/01/93	30	<0.2	0.55		0.13
	14/01/93	74	<0.2	0.45	1.44	0.10
St.12	19/01/93	1	<0.2	0.75		0.18
	19/01/93	24	<0.2	0.52		0.16
	19/01/93	48	<0.2	0.57		0.16
	19/01/93	79	<0.2	0.51		0.12
St.13	19/01/93	25	<0.2	0.83		0.23
	19/01/93	51	<0.2	0.77		0.13
	19/01/93	61	<0.2	0.65		0.17
	19/01/93	75	<0.2	0.57		0.13
St.14	19/01/93	1	<0.2	0.76		
	19/01/93	46	<0.2	0.56		
	19/01/93	64	<0.2	0.58		
	19/01/93	76	<0.2	0.41		
St.15	19/01/93	2	<0.2	0.91	1.11	
	19/01/93	45	<0.2	0.58	0.79	
	19/01/93	56	<0.2	0.75	0.71	
	19/01/93	79	<0.2	0.5	0.79	

St.16	19/01/93	44	<0.2	1.2		
	19/01/93	50	<0.2	0.58		
	19/01/93	56	<0.2	0.68		
	19/01/93	82	<0.2	0.73		
St.20	19/01/93	12	<0.2	0.75		0.20
	19/01/93	45	<0.2	0.6		0.14
	19/01/93	50	<0.2	0.52		0.19
	19/01/93	57	<0.2	0.52		0.27
St.23	19/01/93	56	<0.2	0.57		
	19/01/93	59	<0.2	0.52		
	19/01/93	61	<0.2	0.57		
	19/01/93	67	<0.2	0.55		
St.24	19/01/93	1	<0.2	0.53	0.83	0.18
	19/01/93	25	<0.2	0.57		0.14
	19/01/93	50	<0.2	0.45		0.19
	19/01/93	76	<0.2	0.53	0.81	0.17
Regular station in March						
3	18/03/93	2	<0.2			0.27
	18/03/93	27	<0.2			0.27
	18/03/93	50	<0.2			0.42
	18/03/93	80	<0.2			0.49
5	18/03/93	3	<0.2			0.23
	18/03/93	26	<0.2			0.29
	18/03/93	50	<0.2			0.36
	18/03/93	76	<0.2			0.47
6	19/03/93	10	<0.2	0.8		0.44
	19/03/93	28	<0.2	0.44		0.35
	19/03/93	60	<0.2	0.63		0.44
	19/03/93	76	<0.2	0.45		0.43
7	21/03/93	2	<0.2	0.9		0.39
	21/03/93	28	<0.2	0.52		0.33
	21/03/93	40	<0.2	0.34		0.32
	21/03/93	71	<0.2			
8	21/03/93	1	<0.2	0.6		
	21/03/93	10	<0.2	0.5		
	21/03/93	26	<0.2	0.62		
	21/03/93	70	<0.2	0.62		
9	21/03/93	2	<0.2	0.78		
	21/03/93	12	<0.2	0.49		
	21/03/93	28	<0.2	0.45		
	21/03/93	72	<0.2	0.45		
10	21/03/93	2	<0.2	0.7		
	21/03/93	10	<0.2	0.44		
	21/03/93	24	<0.2	0.39		
	21/03/93	72	<0.2	0.47		
11	22/03/93	2	<0.2	0.54	0.52	
	22/03/93	10	<0.2	0.62	0.42	
	22/03/93	24	<0.2	0.58	0.61	
	22/03/93	74	<0.2	0.45	0.67	
14	22/03/93	2	<0.2	0.64	0.86	
	22/03/93	10	<0.2	0.65	0.53	
	22/03/93	28	<0.2	0.52	0.48	
	22/03/93	72	<0.2	0.55	0.72	

15	22/03/93	2	<0.2			
	22/03/93	8	<0.2			
	22/03/93	24	<0.2			
	22/03/93	60	<0.2			
16	22/03/93	2	<0.2	0.54	1.36	
	22/03/93	12	<0.2	0.53	1.61	
	22/03/93	28	<0.2	0.55	0.82	
	22/03/93	74	<0.2	0.56	0.74	
24	23/03/93	4	<0.2			0.35
	23/03/93	26	<0.2			0.42
	23/03/93	50	<0.2	0.54		0.43
	23/03/93	74	<0.2	0.47	0.51	0.42
25	23/03/93	10	<0.2			
	23/03/93	24	<0.2			
	23/03/93	50	<0.2			
26	23/03/93	4	<0.2			0.42
	23/03/93	26	<0.2			0.43
	23/03/93	50	<0.2			0.49
	23/03/93	70	<0.2	0.43	1.14	0.52

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