NORTH SEA PROJECT CD-ROM

BROCHURE

Description of the NERC North Sea Project

Background

The North Sea is an important resource shared by many nations with a wide range of potentially conflicting activities. Effective management requires an improved scientific understanding of the sea, incorporated in computer based models able to predict the impact of man's activities and, for example, climatic changes under various scenarios. The NERC North Sea Project addresses this need in respect of physical properties, mobile sediments and a wide range of dissolved and particulate constituents in the water.

The Project evolved from a NERC review of shelf sea research, which identified the need for a concerted multidisciplinary study of circulation, transport and production. Ideas were developed through a working group and a workshop of UK marine scientists, with the result that the project was adopted by NERC as their first Marine Sciences Community Research Project to run from 1987 to 1992. A scientific steering group was appointed and £780k assigned to a Special Topic. The Project was hosted by the Proudman Oceanographic Laboratory, Birkenhead, and involved over 200 scientists and support staff from NERC and other Government funded laboratories as well as seven universities and polytechnics.

This UK observational programme has been complemented by Danish and Norwegian surveys in more northern waters. Further collaboration is also ongoing through the International Council for the Exploration of the Sea (ICES) and other scientific organisations in Germany, Holland, Belgium and France.

Including support of the work at the four NERC marine laboratories and the associated work of the MAFF Fisheries Laboratory and university scientists, the full economic cost of the project exceeded £15M over the five years.

Aims

The ultimate aim of the NERC North Sea Project was the development of a suite of prognostic water quality models to aid management of the North Sea. Such models are complex since they involve many inter-related physical, chemical, biological and sedimentological processes. However, the foundations for such a study already existed since the dominant physical processes such as waves, tides and surges which underpin the other processes were quite well understood. The distributions

of the chemical, biological and sedimentological parameters were reasonably well known and the quantification of the rates of their reactions were beginning to be estimated. To progress towards water quality models, three intermediate objectives were pursued in parallel:

i) production of a 3 dimensional transport model for any conservative passive constituent, incorporating improved representations of the necessary physics - hydrodynamics and dispersion,

ii) identifying and quantifying non-conservative processes - sources and sinks determining the cycling and fate of individual constituents,

iii) defining a complete seasonal cycle as a data base for all the observational studies needed to formulate, drive and test models.

The North Sea Project Data Sampling Strategy

To ensure sufficient resolution of the seasonal cycle 15 cruises each lasting 12 days and following the same track, were repeated monthly measuring many physical, chemical, biological and sedimentological parameters. Seasonal changes dominate events within the North Sea (i.e. winter storms, spring floods, summer sunshine) and understanding the effects of these phenomena is essential for the development of water quality models.

Physical processes such as storms, waves and stratification underpin and often control the rates of chemical, biological and sedimentological processes. The physical scales and characteristics of, for example, the sea bed topography, sediment distribution and the nature of estuaries helped to determine the sampling strategy.

The first survey cruise took place in August 1988, the intention being to ensure a calm beginning to the survey and to enable the autumnal overturn to be measured twice. The 30 day approximate repeat period tied the survey to the spring/neap cycle with the aim of visiting each position along the track at approximately the same stage in the cycle. To improve temporal resolution a few points could be visited twice on each circuit. The survey track was constrained by the 12 day duration to about 2000 nautical miles confining the survey to the southern North Sea and imposing a compromise between spatial coverage and resolution. In the event of bad weather two triangles of total length 500 nautical miles could be omitted from any cruise without seriously affecting the spatial coverage round the boundary. Although it was more likely that time would be lost in the winter months this was offset to some extent due to the water column being more mixed and offshore gradients weaker, necessitating a less dense sampling coverage.

The track selected covered the summer stratified waters of the north and the homogeneous waters in the Southern Bight in about equal lengths together with their separating frontal band from Flamborough Head to Dogger Bank, the Friesian Islands and the German Bight. Waters influenced by river discharge, especially along the continental coast, were also covered as were the different water masses - oceanic via the Channel and the northern North Sea, British coastal and continental coastal. Particular regard was paid to the major estuaries of the Tyne,

Tees, Humber, Thames, Rhine, Meuse, Lake Ijessel, Ems, Weser and Elbe, each the source of an individual mix of contaminants and collectively of great importance.

Alternating with the survey cruises were process study cruises which investigated some particular aspect of the science of the North Sea. The process cruises fell into six main categories: fronts (nearshore, circulation and mixing), sandwaves and sandbanks, plume (Humber, Wash, Thames and Rhine), resuspension, air-sea exchange, productivity and blooms. In addition to the main data collection period (August 1988 - October 1989), a series of cruises took place between October 1989 and October 1990 which followed up this work. Process studies relating to blooms, plumes (Humber, Wash, Rhine), sandwaves and the flux of contaminants through the Dover Strait were carried out as well two 'survey' cruises.

North Sea Project Data Management

An essential aspect of the North Sea Project was the assembly of a North Sea data set containing all the good quality data collected during the project. Data collected during the project were managed by the British Oceanographic Data Centre (BODC), concentrating primarily on the survey cruise data. Managing the data included working up and quality controlling the data coming from the shipboard computer system. This work was carried out in close collaboration with the principal investigators responsible for collecting the data. Effort was concentrated on three major data sets associated with survey and process study cruises. They were worked up on a cruise by cruise basis.

The data management problems posed by the data collection exercise were twofold. First there was a requirement to work up and quality control a large diverse data set to the highest possible standards but under strict time constraints. Secondly there was the requirement to bring together the data into a coherent data base so that the relationships between individual components of the data set might be readily examined.

The conventional practice where scientists take data from a cruise, work it up and then submit it to a data centre did not hold great promise due to the number of scientists from different laboratories participating in each cruise. For example, responsibility for calibration and quality control of the CTD sensors was divided between two NERC institutes and two university departments. The result would have been massive duplication of software development effort and a great danger of inconsistencies creeping into the data set which the data centre would have had difficulty in resolving.

The solution adopted was to centralise the data processing at BODC liaising as closely as possible with the participating scientists. Effort was concentrated on the three major data sets associated with the survey and process study cruises - the CTD database, the samples database and the underway database. High throughput systems utilising the available main-frame resources and graphics workstation technology were put together to despike and calibrate the underway and CTD data. As a consequence a usable underway data set and a fully worked up CTD data set were available within 4 months of the completion of the data collection phase.

Once worked up the data were brought together into a coherent data base. A relational schema was devised and implemented under the Oracle RDBMS. Due to physical constraints the data base was restricted to CTD and sample data.. Other data types (e.g. moored instruments, shipborne ADCP data, river input, supporting meteorological data sets) were compiled into supporting databases.

On March 1st 1990 the database was made available over the UK academic network (JANET) to scientists participating in the project. The database may either be interrogated interactively using SQL query language or by means of retrieval programs including graphical presentation software.

The data collected during the observational phase of the North Sea Project comprises one of the most detailed sets of observations ever undertaken in any shallow shelf sea.

North Sea Project Modelling

Modelling was integral to the success of the Project and was carried out at two levels, among the participants at their own laboratories and more centrally at the Proudman Oceanographic Laboratory. A 2 dimensional general purpose model was distributed within the Project and applied to studies of temperature, salinity, plumes, fish larvae dispersion, oxygen, nutrients and metals. This enabled simple comparisons to be made between computed and actual measurements thus suggesting important non-conservative processes taking place. At the same time the more complex 3 dimensional models were being developed and tested at the Proudman Laboratory. A model framework now exists that allows for the modular design of these more sophisticated models. Any physical, biological or chemical process can now be incorporated provided certain simple constraints are adhered to. Although the North Sea Project has officially ended many of the areas of research especially in the field of modelling will be continued either as NERC laboratory projects or in the wider Community Research Projects.

The North Sea Project Measurements

The Survey

RRS Challenger followed the 12 day 1800 nautical mile track (Figure 1) sampling more than 100 stations in each of the 15 months (Figure 2). The survey cruise numbers and dates are given in the table below.

North Sea Project Survey Cruise timetable for RRS Challenger, April 1988 - October 1989

Cruise No.	Dates
28/1988	29 Apr - 15 May
33/1988	04 Aug - 16 Aug
35/1988	03 Sep - 15 Sep
37/1988	02 Oct - 14 Oct
39/1988	01 Nov - 13 Nov
41/1988	01 Dec - 13 Dec
43/1989	30 Dec - 12 Jan
45/1989	28 Jan - 10 Feb
47/1989	27 Feb - 12 Mar
49/1989	29 Mar - 10 Apr
51/1989	27 Apr - 09 May
53/1989	26 May - 07 Jun
55/1989	24 Jun - 07 Jul
57/1989	24 Jul - 06 Aug
59/1989	23 Aug - 04 Sep
61/1989	21 Sep - 03 Oct

The CTD profiles from the stations and underway sampling at 30 second intervals (a total of 500,000 data cycles) provided three dimensional distributions of conductivity (for salinity), temperature, depth, dissolved oxygen, transmittance (for suspended sediment concentration), fluorescence (for chlorophyll) and irradiance.

Water bottle samples were collected on almost all CTD casts, usually with bottles being fired at the bottom, middle and top of a cast. Many different parameters were measured from these water samples. In order to calibrate the CTD sensors, temperatures were obtained from reversing thermometers, salinity determinations and dissolved oxygen measurements were made. Spectrophotometric chlorophyll and phaeopigment determinations were carried out, the chlorophyll values for a cruise were used to calibrate the CTD fluorometer. Sediment content was determined and the values used to calibrate the transmissometer.

Nutrients (nitrate, nitrite, silicate, phosphate and ammonium) were determined from water bottle samples using an autoanalyser.

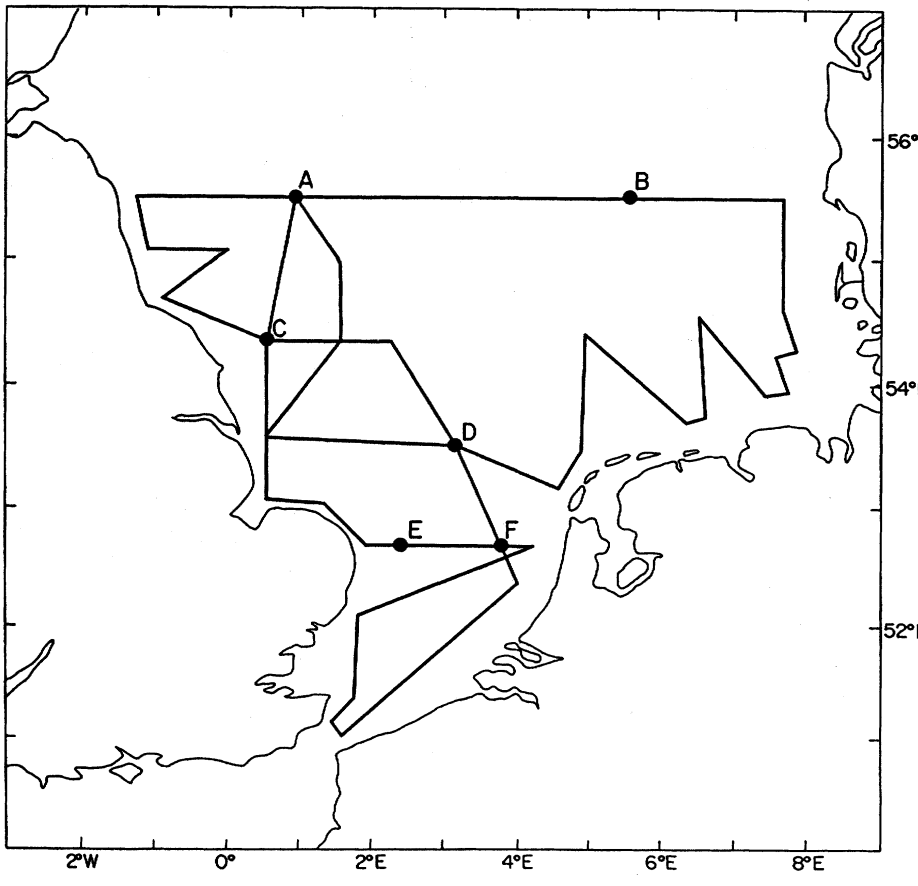


Figure 1. North Sea Survey cruise track

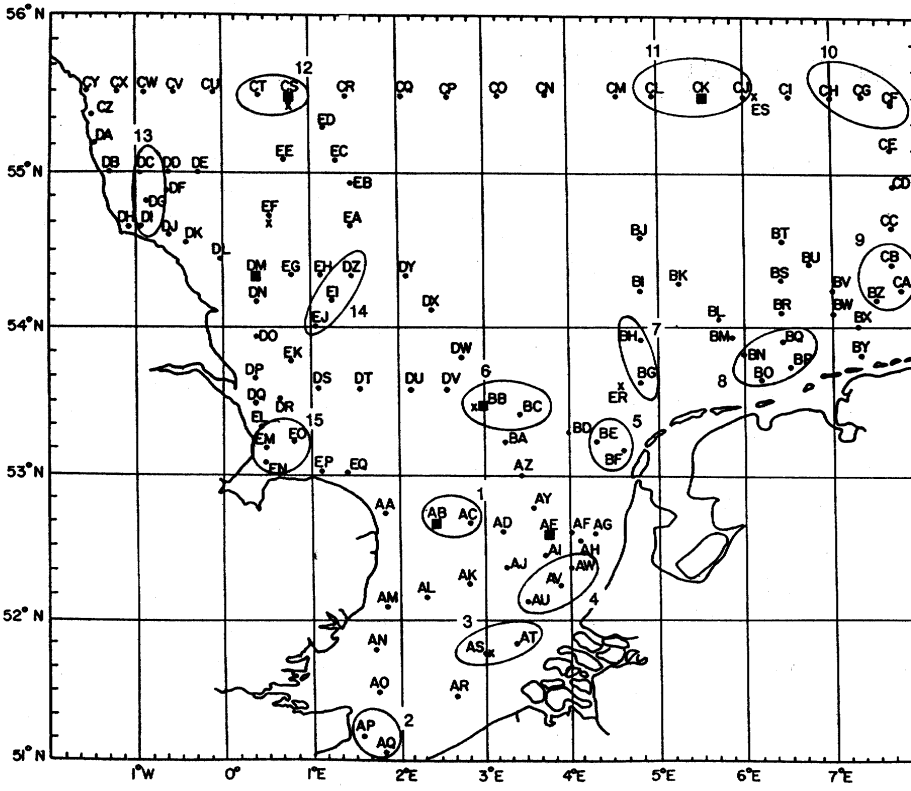


Figure 2. North Sea Survey station positions plus mooring sites, coring sites and key areas of phytoplankton study

On eight of the survey cruises (between February and October 1989) measurements were made of dimethyl sulphide (DMS) and its cellular precursor, dimethyl sulphoniopropionate (DMSP). These determinations were carried out using gas chromatography. In addition to the DMS measurements, low molecular weight halocarbons have been determined.

Dissolved and particulate trace metals (Mn, Cu, Pb, Zn, Cd, Co, Ni, Fe, Hg, As, Al) were measured on survey cruises during May 1988, August 1988, January 1989 and May 1989.

Primary productivity was investigated on each survey cruise, the uptake of ^{14}C being measured in an on-deck incubator. Water bottle samples from a pre-dawn CTD cast were taken from six depths (usually 1, 3, 7, 15, 20 and 30m) instead of the more usual top, middle and bottom samples. Triplicate samples were then incubated at six simulated depths for a 24 hour period.

During the survey cruises a water sample was collected for microscopic analysis of phytoplankton numbers and species composition at every other CTD station. The area covered by the survey cruises was split into fifteen representative regions (Figure 2) and one or two samples falling within each area analyzed for each survey cruise.

Zooplankton samples were taken at half the stations on all but one of the survey cruises by the Netherlands Institute for Sea Research.

The air-sea interaction components of the North Sea survey comprised four experiments measuring organic particles, inorganic (trace metal) particles, large airborne particles and rainfall.

Benthic processes were investigated with sediment cores taken on eight survey cruises at six sites (Figure 2) of varied character, three being in the area of summer stratification. Oxygen uptake and sulphate reduction rates were measured to investigate aerobic and anaerobic microbial activity; also fluxes and profiles of nutrients, sedimentary characteristics, organic matter, water content, particle size and temperature. The oxygen content in the overlying water was also measured.

Current profiles were recorded at 10 minute intervals (with 4m bin size) underway by the shipborne ADCP (Acoustic Doppler Current Profiler) on all survey cruises.

Six current meter stations (Figure 2) were maintained over the fifteen month survey period. Instruments were recovered and redeployed on each of the survey cruises. Three of the moorings (B, E and F) were made up of Aanderaa and S4 current meters, while the other three (A, C and D) were bottom mounted ADCPs. In addition, at four sites (A, B, C and D), moored thermistor chains were deployed during the stratification season. Recording fluorometers were also deployed at sites A and E between February and May 1989. Data recovery from the moorings was about 80%.

Process Studies

In between the survey cruises, a process study cruise looked at some particular aspect of the science of the North Sea. The process cruises fall into six main categories, although there is some overlap between the data collected and the processes studied. Figure 3 shows the process study cruise areas. For most process study cruises surface underway data, CTD casts and water bottle samples were taken, in the same way as on the survey cruises. However, although all the sensors for the survey cruises were available, not all were calibrated for the process study cruises.

The process study categories are detailed below and a brief synopsis of each process study follows:

Cruise	Dates	Process
34/1988	18 Aug-01 Sep	Fronts - nearshore
36/1988	16 Sep-30 Sep	Fronts - mixing
56/1989	08 Jul-22 Jul	Fronts - circulation
58/1989	07 Aug-21 Aug	Fronts - mixing
38/1988	24 Oct-31 Oct	Sandwaves
40/1988	15 Nov-29 Nov	Sandbanks
42/1988	15 Dec-29 Dec	Plumes/Sandbanks
46/1989	12 Feb-26 Feb	Plumes/Sandwaves
44/1989	13 Jan-27 Jan	Resuspension
52/1989	11 May-24 May	Resuspension
60/1989	06 Sep-19 Sep	Resuspension
48/1989	13 Mar-27 Mar	Air/sea exchanges
62/1989	05 Oct-19 Oct	Air/sea exchanges
50/1989	12 Apr-25 Apr	Blooms/chemistry
54/1989	09 Jun-22 Jun	Production

Fronts (nearshore, mixing, circulation)

The three fronts studies all concerned the front extending from the region of Flamborough Head offshore between summer stratified water to the north and well mixed water to the south. The associated local circulation and distinctive

dispersion, notably by eddies exchanging material across the front, are important to North Sea transports of all water-borne constituents. In collaboration with MAFF, moorings were laid and CTD, ADCP and SeaSoar surveys carried out to define the dynamical fields for model testing and interpretation. Near shore HF radar gave synoptic coverage of large scale and eddy contributions to transport. Further offshore drogue tracks and the spreading of released Rhodamine B was used both to assess circulation and horizontal and vertical mixing.

Sandwaves & Sandbanks

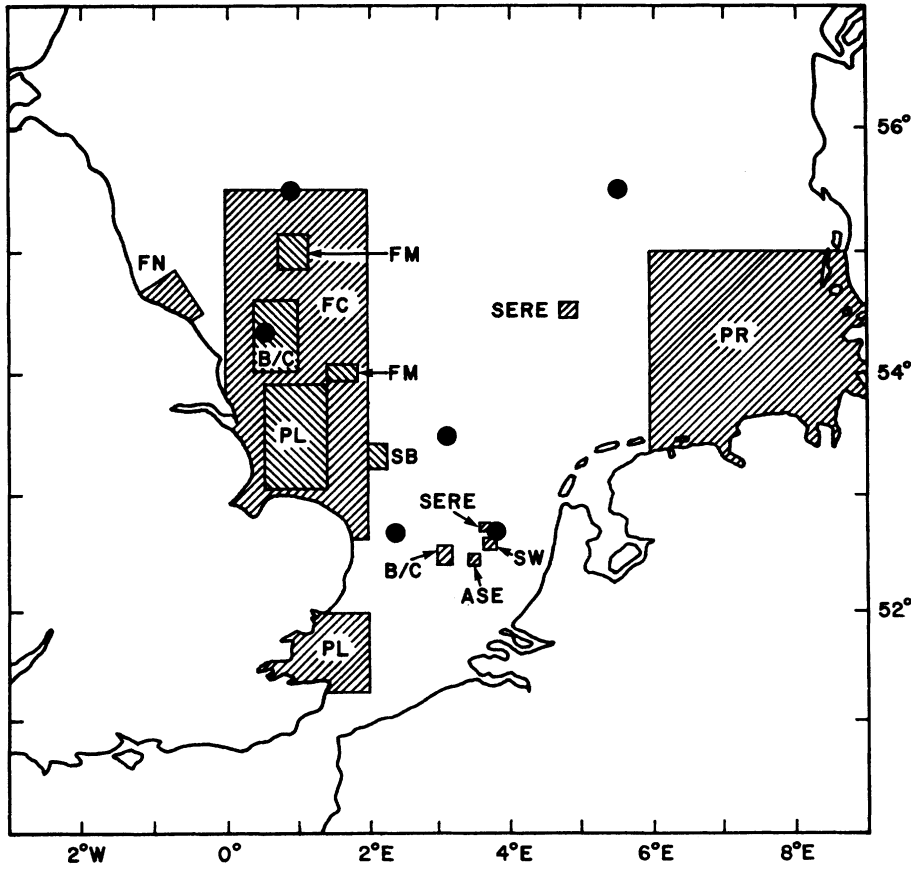
Sandwave fields cover at least 15000 km^2 of the Southern Bight of the North Sea. Drag coefficients based on measured pressure gradients were recorded and sea bed photography used to test bedload prediction formulae. The sand covering much of the southern North Sea is mobile forming banks that are interleaved with mud. Current meter moorings placed either side of a bank were used to estimate its associated circulation and contribution to dispersion. A 3 dimensional model using wave-current interaction enhancing the bed stress is being applied to fine grid (~100m) bathymetry and is being tested using detailed measurements of near-bed currents and turbulence obtained from the STABLE (Sediment Transport And Boundary Layer Equipment) rig.

Plumes (Humber & Thames)

Estuaries are important boundary sources of some metals and nutrients in the North Sea and distinctive dispersions in their plumes such as the Humber, Wash and Thames outflow, require special study. Specific objectives included the definition of the spatial and temporal characteristics of the Humber/Wash and Thames by repetitive sampling for selected conservative and non-conservative constituents around a grid enclosing the plume, determination of the transport pathways for non-conservative constituents in relation to suspended particle/water exchanges and the characterisation of nutrient and metal transfer across the sediment/water interface. These latter two were carried out through controlled experiments on-board ship. Nutrient flows are being correlated with river flows using all available data. A 2 dimensional hydrodynamic model is being used to calculate nutrient fluxes and mass balances.

Resuspension

The ratio of particulate to dissolved material which is so important to water quality is affected by resuspension which, in turn, depends on the character of the sea bed, biological influences, tidal currents, wind, waves and seasonal stratification. The objectives of the three resuspension cruises were to make time series observations of physical, sedimentological and biological properties of the sediment, suspended particle material and water at two sites in the North Sea, using a variety of moored instruments, CTD/water bottle casts, pumped sampling and sediment grabs and box cores. The two sites were: (1) northern site (N), 54° 35'N 4° 50'E, 45m depth, muddy sand, seasonally stratified water column, and (2) southern site (S), 52° 40'N, 3° 40'E, 27m depth, sand, permanently well-mixed water column.



FN	Fronts - nearshore	SERE	Sediment resuspension
FC	Fronts - circulation	PL	Plumes
FM	Fronts - mixing	ASE	Air-sea exchange
SW	Sandwaves	B/C	Blooms/chemistry
SB	Sandbanks	PR	Production

Figure 3. Process cruise locations

Air-sea exchanges

Air-sea exchange rates are important for determining the budgets of carbon dioxide, oxygen and some metals held within the sea. The primary aims of these cruises were to measure the rate of gas exchange across the sea surface as a function of wind and sea conditions by the release of volatile tracers into the water column, to investigate the rates of dispersion and advection due to tidal and residual currents by means of the same tracer release and to investigate the biological sources of oxygen, methane, dimethyl sulphide and a suite of halocarbons in the coherent body of water marked by the tracers, with a view to obtaining budgets.

Primary productivity

Primary productivity in the Irish Sea is comparable to that of the North Sea but fewer fish larvae survive. Fish larvae were sampled, CTD profiles established the physical conditions likely to favour their survival and phytoplankton productivity and zooplankton distributions were determined. These data are now being compared with earlier Irish Sea data. This process study cruise aimed to measure primary productivity and relate it to physical conditions, light, nutrients and organic fluxes. Also, the horizontal and vertical distribution and behaviour of zooplankton was studied in relation to hydrographic conditions and primary production.

Blooms/Chemistry

This study examined the effects of developing phytoplankton blooms on water chemistry. Time series measurements using drogued buoys (primary productivity, dimethyl sulphide and vertical fluxes) were all recorded on a diatom bloom off the North Yorkshire coast and a Phaeocystis bloom in the Southern Bight. The primary aims were to investigate gross and net primary production during bloom conditions and to examine the relationships between primary productivity and biogeochemical cycling of certain trace metals and biogenic trace gases.

Cruises with North Sea Project interest in 1990

Eight follow-up cruises have taken place during 1990 including two 'survey' cruises and six process study cruises - the latter covering the following areas of interest: blooms, plumes (Humber, Wash, Rhine), sandwaves and flux of contaminants through the Dover Strait - as shown below.

Additional cruises with a North Sea interest since October 1989

Cruise No.	Dates	Cruise Interest
62A/1989	23 Oct-03 Nov	Blooms
64/1990	03 Apr-03 May	Blooms
65/1990	06 May-17 May	Humber Plume
66A/1990	20 May-31 May	Survey
66B/1990	03 Jun-18 Jun	Contaminants through Dover Strait
69/1990	26 Jul-07 Aug	Resuspension/Plumes
72A/1990	20 Sep-02 Oct	Survey
72B/1990	04 Oct-06 Oct	Sandwaves/STABLE
72C/1990	06 Oct-19 Oct	Rhine plume

Blooms - Challenger 62A and 64

The main aims were to measure concentrations and spatial distributions of major nutrients and their influence on the formation of phytoplankton blooms, to study the historical record of eutrophication using sediment cores, to investigate the distributions of chlorophyll and particulate organic carbon and nitrogen, to study primary and bacterial productivity and to investigate the influence of benthic macrofauna on the resuspension of particulate matter.

Plumes/Resuspension - Challenger 65 and 69

These cruises continued the work of Challenger 42 and 46. Four circuits were made of the Humber plume grid on both cruises. In addition a shortened transect was completed on CH65 and a transect of the Thames plume was made on CH69. The two resuspension sites were also visited on both cruises.

Survey cruises - Challenger 66A and 72A

These cruises carried out the usual survey measurements (i.e. surface underway, CTD and water bottle samples). Shipborne ADCP measurements were recorded on Challenger 72A, but the instrument failed on Challenger 66A, so no data were recorded.

Flux of contaminants through the Dover Straits - Challenger 66B

This cruise formed part of a study to measure the flow of contaminants entering the North Sea over a complete year. Shore based HF Radar stations, deployed from May 1990 to May 1991, measured sea surface currents over most of the Strait. A mooring in mid-channel, instrumented with a sea floor ADCP, transmissometer and current meter, was also maintained for one year. During the cruise surface underway data, CTD data and water bottle samples were taken and shipborne ADCP measurements were also made.

Sand waves - Challenger 72B

Challenger 72B visited the southern sandwave site. Two pressure sensor tide gauges were deployed; these were recovered during the following cruise (CH72C) and obtained 12 days' data. In addition a waverider and a current meter rig were deployed and recovered after 24 hours. Ship's radar photography was carried out concurrently with the waverider deployment. Shipborne ADCP measurements were made through-out the cruise.

Rhine plume - Challenger 72C

This formed the second half of a pilot study of the region of the North Sea which is directly influenced by the Rhine discharge. The primary aim was to obtain time series data from a mooring array in the Rhine plume (deployed by CH72A) in order to investigate the variability of the water column stratification and its influence on primary productivity and sediment resuspension.

Background Measurements

Additional background data were assembled including satellite imagery (AVHRR), river discharge, the UK Meteorological Office atmospheric model output, wave model ouput, POL storm surge model products (tide and surge elevations, depth mean currents) and calculated of monthly 3 dimensional distributions of temperature and salinity.

Introduction to the CD-ROM and its Supporting Software

Concepts behind the CD-ROM

The North Sea Project CD-ROM is first and foremost an electronic publication of the data collected during the project. Like other CD-ROMs in circulation it is accompanied by visualisation software which allows graphical images to be displayed on a PC.

However, this is just one facet of the product. Much of the data on the CD-ROM are stored in flat ASCII files. The pathnames and structures of these files are fully documented in this manual. Consequently, the CD-ROM may also be regarded as a very large floppy disk from which data may be loaded into the user's home system.

Compared to modern magnetic disks, CD-ROM readers are very slow devices. Some of the data files, particularly the underway files and satellite images, are quite large and consequently reading through them may take a long time.

However, the software interfaces have been designed in such a way that no part of the file pathname is assumed. Consequently, users are actively encouraged to copy heavily used data from the CD-ROM onto their hard disks which will give a marked increase in performance.

The data files used by the display and retrieval programs must be copied following certain rules and detailed instructions are included in the software documentation. However, any of the flat ASCII files, such as the 'kit form' database included on the CD-ROM may be copied to any other device without restriction on directory structure or naming convention.