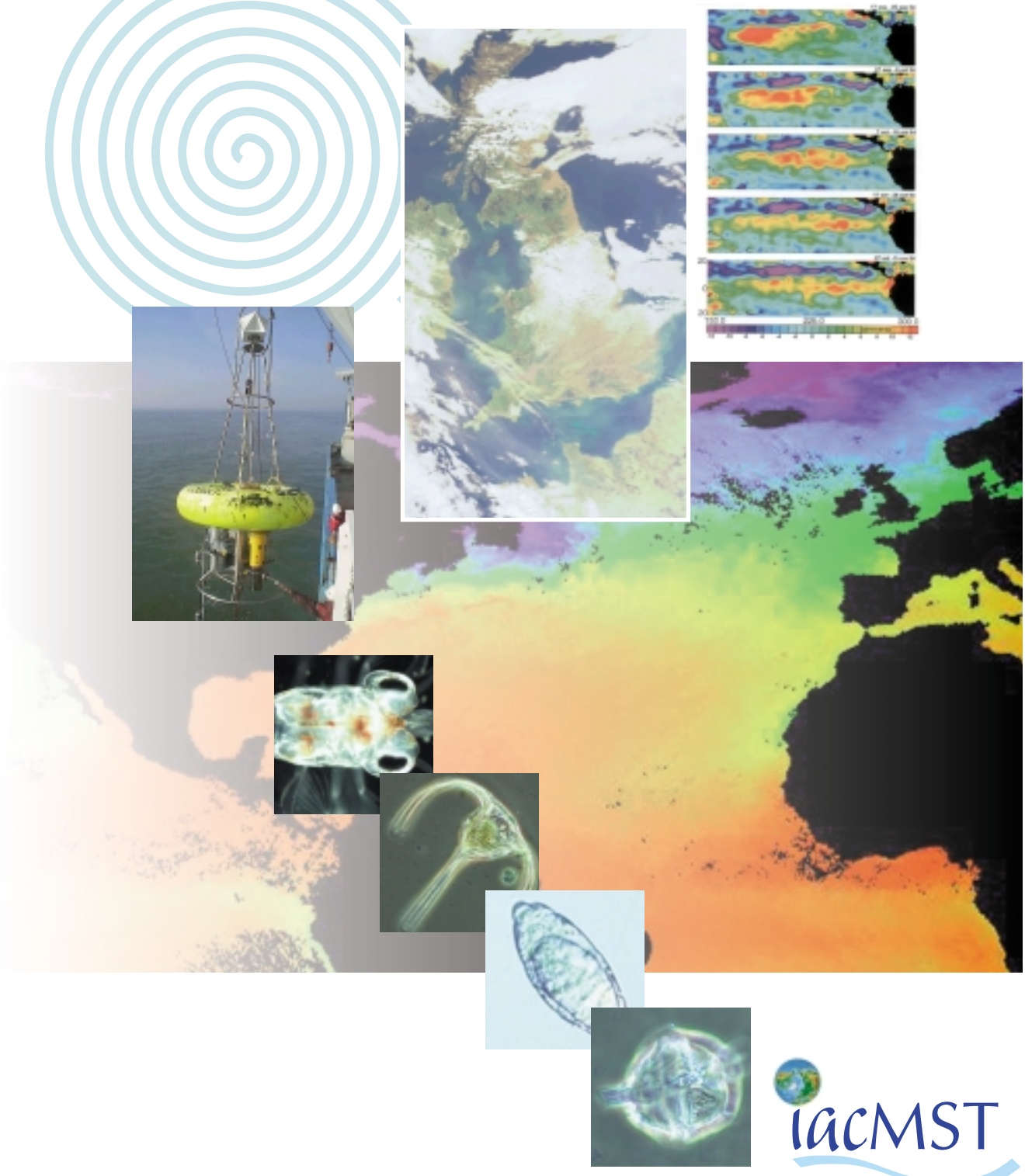
Review of Current UK Marine Observations in relation to present and future needs

Prepared for IACMST
by Dr J E Portmann



IACMST

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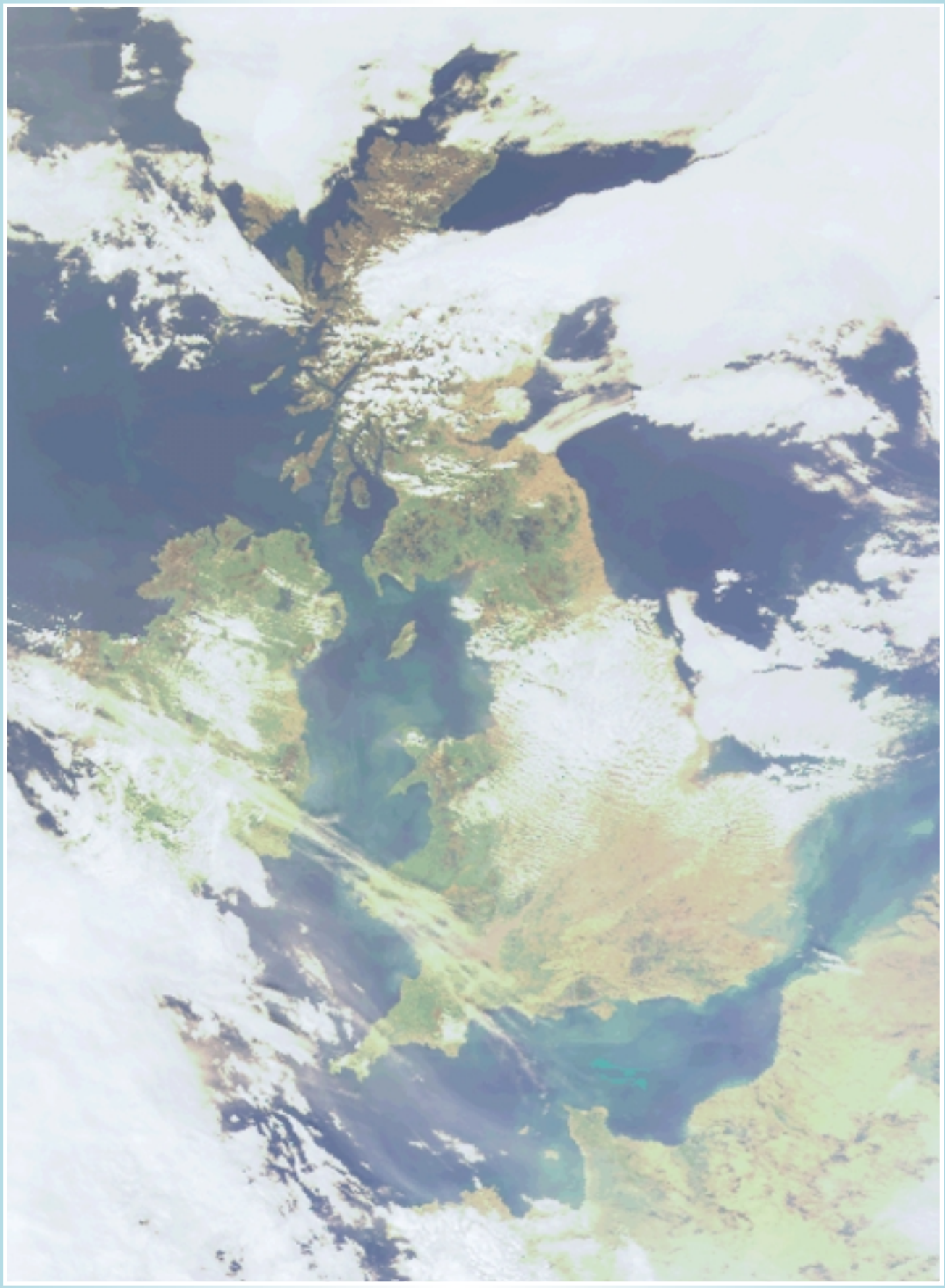

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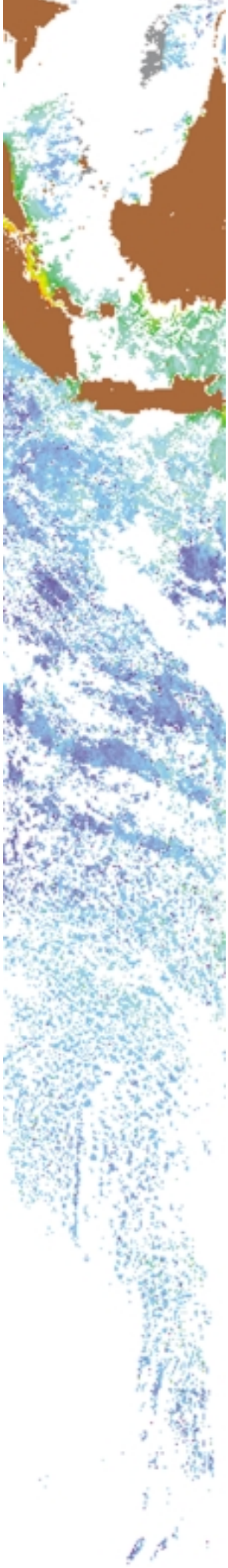
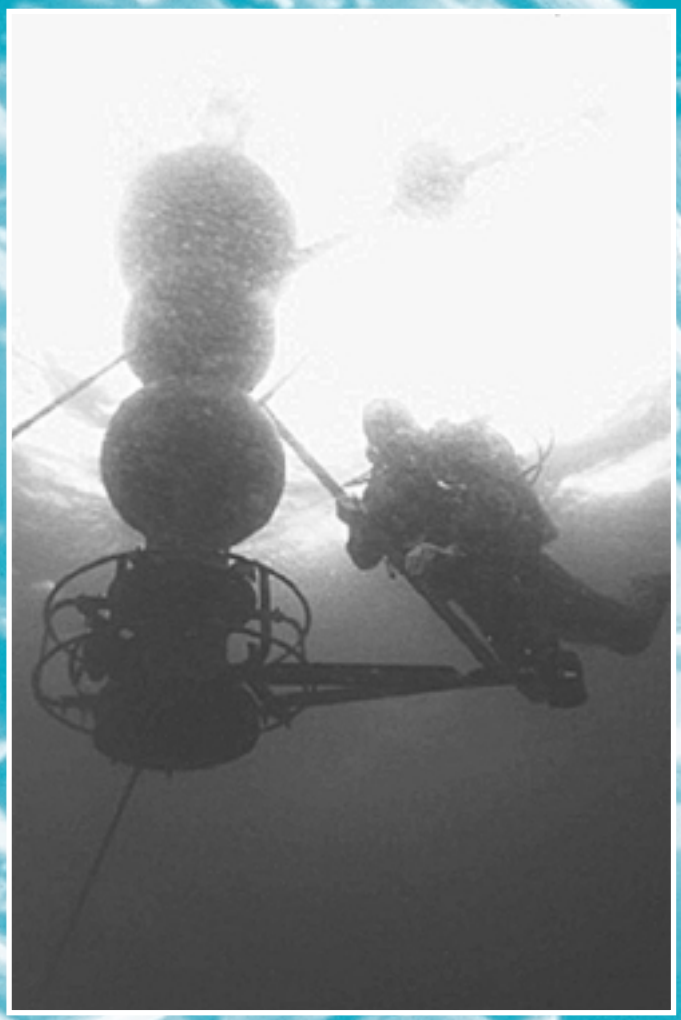


opposite page:
SeaWiFS composite of the UK,
received by the Dundee Satellite Receiving Station
and processed by Plymouth Marine Laboratory
Data courtesy of the NASA SeaWiFS Project and Orbital Sciences Corporation



Executive Summary

The purpose of this Review was to assess what marine observations are currently being made, where, when and why and by which organisations. Recognising the wide range of reasons for making marine observations, the focus of the Review is observations of a longer-term nature i.e. those aimed at assessing the long-term status of the marine environment. The Review does not deal with observations of marine environmental quality in terms of contaminants and effects as this work has already been reviewed and is co-ordinated by the Marine Pollution Monitoring Management Group (MPMMG) under the National Marine Monitoring Programme (NMMP).

The overall objective of the Review was to identify any major overlaps or gaps and to examine whether better use can be made of the existing resources and data obtained. The Review was undertaken on the basis of returns to an initial simple questionnaire, some of the responses being followed up by visits. Use was also made of the IACMST Inventory of Marine Observations, a recently completed review of long-term monitoring observations funded by NERC and two compilations of monitoring programmes produced by the Environment Agency and by MPMMG.

The Review includes an assessment of the possible problems of data comparability between organisations. It also considers the adequacy of the observations taken in relation to the organisations' immediate purposes and, more importantly, their ambitions for the future taking account of their own and others' observational capabilities. The conclusion drawn from this part of the Review is that although a considerable number of observations are made by a range of organisations there is a lack of awareness of each others' programmes and little co-ordination.

Inevitably therefore data which are collected, as well as the resultant information, are under-utilised. Accordingly the Review considers how observations are utilised now and how they could be used in the future. This part of the Review draws upon discussions with some of the organisations involved. It concludes that there has been a slow decline in observational capacity, with several existing observations under threat of cessation and some previous observations already either discontinued or now being made only intermittently. It also highlights the fact that many organisations are keen to access data and information obtained by others but find various obstacles to achieving this. Most notable of these being the practice of charging for data or information and the fact that funding for marine observations is steadily falling in real terms.

left: Moored optical data buoy PlyMBODy's optical sensors being cleaned by Plymouth Marine Laboratory divers

The Review concludes by identifying four basic objectives or aims viz. the desirability of having observations for more parameters at existing routine observation sites, the need to secure the continuation or restoration of observations with a long history, the desirability of having more, simple, observations at more sites and the desirability of establishing a Marine Environmental Change Network to parallel the existing terrestrial and freshwater system. Perhaps most importantly it is concluded that achievement of these objectives need not involve major additional funding. The major requirement is for the organisations concerned to agree on what data and data products they collectively require and to work as partners in achieving their mutual objectives.

If they can agree to do this it ought to be possible, with only limited additional funding, to extend the existing programmes through co-ordination and sharing of resources and to meet the four identified aims. In short the existing programmes provide a sound basis for an overall marine observations programme capable of meeting future forecasting needs and identifying changes in the marine environment. However, any significant reduction in effort would seriously reduce such capabilities and, in the light of the greater degree of uncertainty, invoke the need for greater precautionary measures. These measures would almost certainly cost less if the necessary scientific understanding and predictive abilities had been developed. These dangers can be avoided and good long-term records can be maintained and better predictive capabilities can be developed with minimum additional observation costs, provided appropriate co-operation between the key organisations can be arranged. This will require some revision to current working arrangements between organisations but, given the necessary steer and authorisation, there is clear evidence that they would be ready to co-operate. The various mechanisms by which this co-operation can be achieved should be investigated.

Introduction

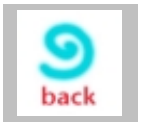
This Review has been undertaken on behalf of IACMST under the guidance of its Global Ocean Observing System Action Group (GOOSAG). The basic remit was to establish an up to date picture of what marine observations are being made, where and when they are made and with what purpose. Based on this an assessment would be made of the overall coverage of the cumulative Marine Observations programme with a view to identifying any gaps and the wider potential use of the collected data. To initiate the activity a simple questionnaire was distributed to all the organisations known by members of the Action Group to undertake Marine Observations (33 in all). This was followed up with discussions with representatives of key organisations, mainly Government Departments and Agencies, aimed at clarifying present and future policy needs for Marine Observations.

Marine Observations fall into three main categories. The first group comprises those undertaken for academic and research purposes; these are usually either one-off field observations or are very intermittent in nature. The second group are undertaken in response to some sort of special event e.g. an oil-spill and are directed specifically at establishing effects and recovery. They are usually also of limited temporal duration. The third group are undertaken more consistently, albeit with varying frequency, over longer periods of time. There is often some sort of intention of identifying temporal trends and, in some cases, the intention to forecast future events or trends. Whilst it was recognised that the first two groups of observations are of value to the purpose for which they are designed it was agreed they have only limited value in relation to an overall Marine Observation programme. It was therefore decided this Review should concentrate on regular environmental quality or monitoring type observations. To this end monitoring was defined as:

"*The taking, on a reasonably regular basis, of any form of observations relative to the (long-term) status of the marine environment, regardless of the frequency of, or purpose for which, the observations are made.*"

It was recognised at the outset that, in relation to the quality of the marine environment in terms of contaminants and their effects, the Marine Pollution Monitoring Management Group (MPMMG) had conducted a Baseline Survey of the estuarine and coastal waters region around the UK in the mid 1990s. This had led to the development of a National Marine Monitoring Programme (NMMP), which was designed to meet both UK national and international needs, and is designed to follow trends in contaminant levels and effects. This Programme received approval by the Department of the Environment, Transport and the Regions early in 2000 and was considered for the purposes of this Review to meet UK needs in relation to observing contaminant levels and effects. Accordingly this Review considers only observations undertaken for other purposes e.g. for long-term natural environmental change purposes, the forecasting of weather, water movements, wave heights and storm surges etc.

For many of the contacted organisations much was already known about their observational programmes, through an inventory of data already held for the IACMST at the British Oceanographic Data Centre (BODC). Accordingly respondents were invited to review the coverage of their programmes as held on a CD-ROM of the Inventory of UK Marine Observing Programmes that was supplied with the questionnaire. If this covered their programme adequately they were invited simply to confirm that fact, to indicate why the observations are made and what other observations they would find useful.



Observational data collected, quality, frequency and availability

As was expected not all the organisations contacted provided detailed responses to the questionnaire. Likewise only a limited number positively confirmed the BODC Inventory of UK Marine Observing Programmes was complete. Nevertheless, replies were received from a total of 15 organisations i.e. almost half the total contacted. A list of the responding organisations and a summary of the type of data they collect etc., based on their responses, are provided respectively in Appendices 1 and 2 to this Review. Most of the known major organisations involved in monitoring did respond and for the few that did not, details of their activities are held by the BODC Inventory. Furthermore note was taken of the results of:

- The Review of NERC funded Long-term monitoring Observations which had been prepared by Dr E Buttle;
- A collection of information on long-term marine monitoring programmes gathered by Dr P C Reid on behalf of the MPMMG and,
- A collection of information on marine, terrestrial and atmosphere monitoring programmes gathered by the Environment Agency as part of its Collaborative Forum on Environmental Monitoring activity.

This Review therefore takes account of the observing programmes undertaken by all major UK organisations and most, if not all, of the smaller ones. The only major exception is the Review does not cover remote sensing observations e.g. of sea surface temperature or altimetry from satellites for which no returns were made. Where the replies did produce information not currently held on the BODC maintained Inventory; steps will be taken to expand the Inventory's coverage accordingly. It should however, be noted that although this will result in the Inventory being more complete, it does remain an Inventory, i.e. for the most part the actual data are not held by BODC but are retained by the organisation making the observations. In some cases this means they are not readily available to other interested parties: this issue is addressed further in later sections.

Figures 1 to 4 (pages 14 and 18) show the location and distribution of the sites most regularly subjected to observation by The Met. Office (in co-operation with the oil industry), by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), by Fisheries Research Services (FRS) and other laboratories in Scotland, and by the Centre for Environment, Fisheries and Agriculture Science (CEFAS) and other laboratories in England, Wales, Northern Ireland and the Isle of Man. Figure 5 (page20) shows the location of the NMMP sites. This last Figure is included purely to give the entire picture and for reference in case co-ordination of existing other sites might be considered in the future as part of an overall marine observations programme.

As will be apparent from Appendix 2 (page 27), the various organisations involved operate a variety of programmes, each of which is designed to produce the key observations required to meet their own particular purposes. The data collected currently cover weather conditions such as atmospheric pressure, wind strength and direction, air temperature etc. as well as purely marine observations. The marine observations include physical data e.g. temperature, salinity, water depth, wave height, current speed and direction, as well as measurements of a limited range of chemical constituents such as nitrate, phosphate and silicate. There are also some observations of biological parameters such as benthic species and numbers, phyto- and zooplankton abundance and, to some extent, species. Although normally used in the context of fish catch regulation the long-time series of fish stock and abundance data held by the Fisheries Agencies also have a value in the interpretation of other data. For example good year-classes of haddock are seen to be associated with strong stratification, whereas poor cod recruitment is associated with warm winters.

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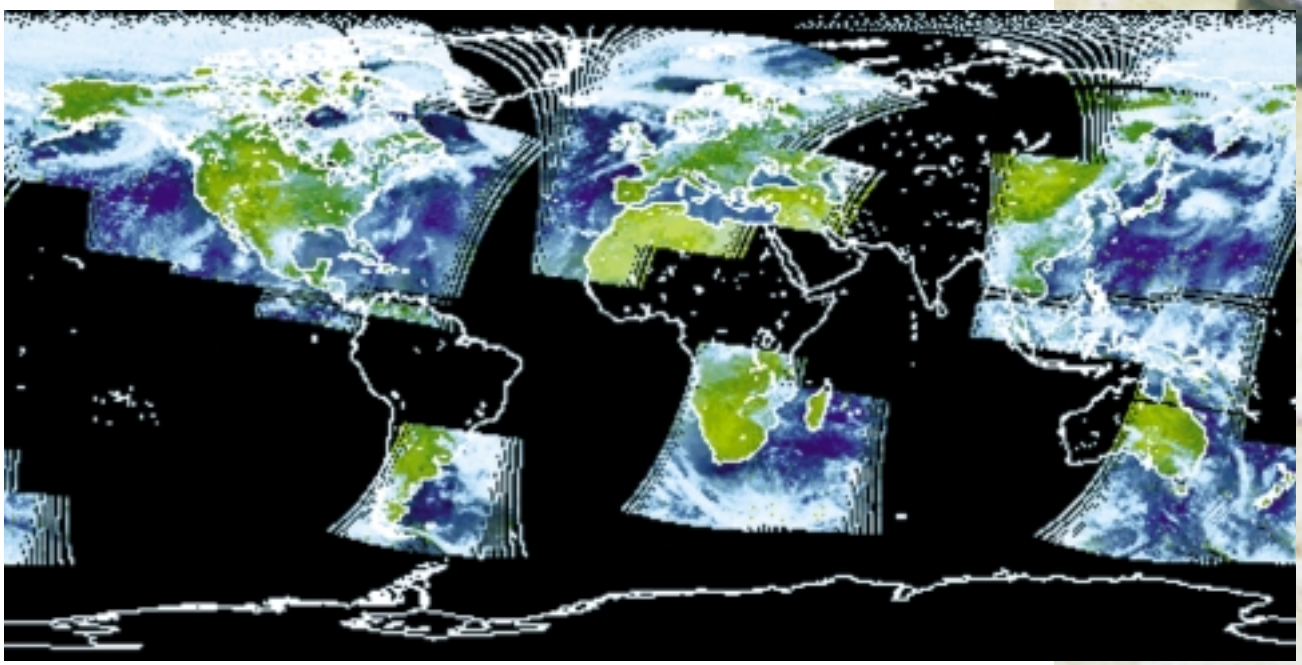
Data quality

Before the MPMMG undertook its baseline studies of contaminant presence and biological effects, it was clear that data quality assurance would have to be established before the programme started and maintained in parallel with it. This was because experience had shown different laboratories did not necessarily produce the same results when analysing the same samples for the same determinand. The questionnaire issued to initiate this Review did not seek information on quality assurance procedures and none was provided, although some was obtained subsequently in the course of discussions. Accordingly if data from different organisations are to be pooled it will be advisable to conduct basic comparability checks. In most cases this is unlikely to reveal a problem in relation to measurements of physical parameters. This is because procedures and the equipment used for data collection are fairly standard and certainly well tried and tested. In many cases there are also routine checks of data quality.

The quality of nutrient data ought to be acceptable. However, if doubt exists, the QUASIMEME scheme utilised in the NMMP, should provide an adequate means of checking data quality and comparability. The QUASIMEME scheme was developed with EU support and is now run, on a full cost recovery basis, for European-wide use. Similarly under the NMMP there is a nationally run Biological Quality Control Scheme for benthos identification that could be used to confirm data comparability in the wider area observational context. Also under the NMMP there are moves to introduce a range of biological effects and a comparability test programme will be organised to cover these.

In the last few years the Fisheries Departments have instituted a toxic algal blooms monitoring programme in shellfish fishing and harvesting areas in accordance with the requirements of the EU Shellfish Hygiene Directive. A pattern of toxic algal species occurrence is beginning to emerge from this programme, which is slowly expanding. However, almost all of the long-term plankton data available to date have been collected through the Continuous Plankton Recorder (CPR) survey system. This is now operated by SAHFOS and although in recent years CTD and fluorescence measurements have been added on some routes, the procedures used for both sample collection and analysis have changed little since the programme started in 1932. Long-term data comparability is therefore assured.



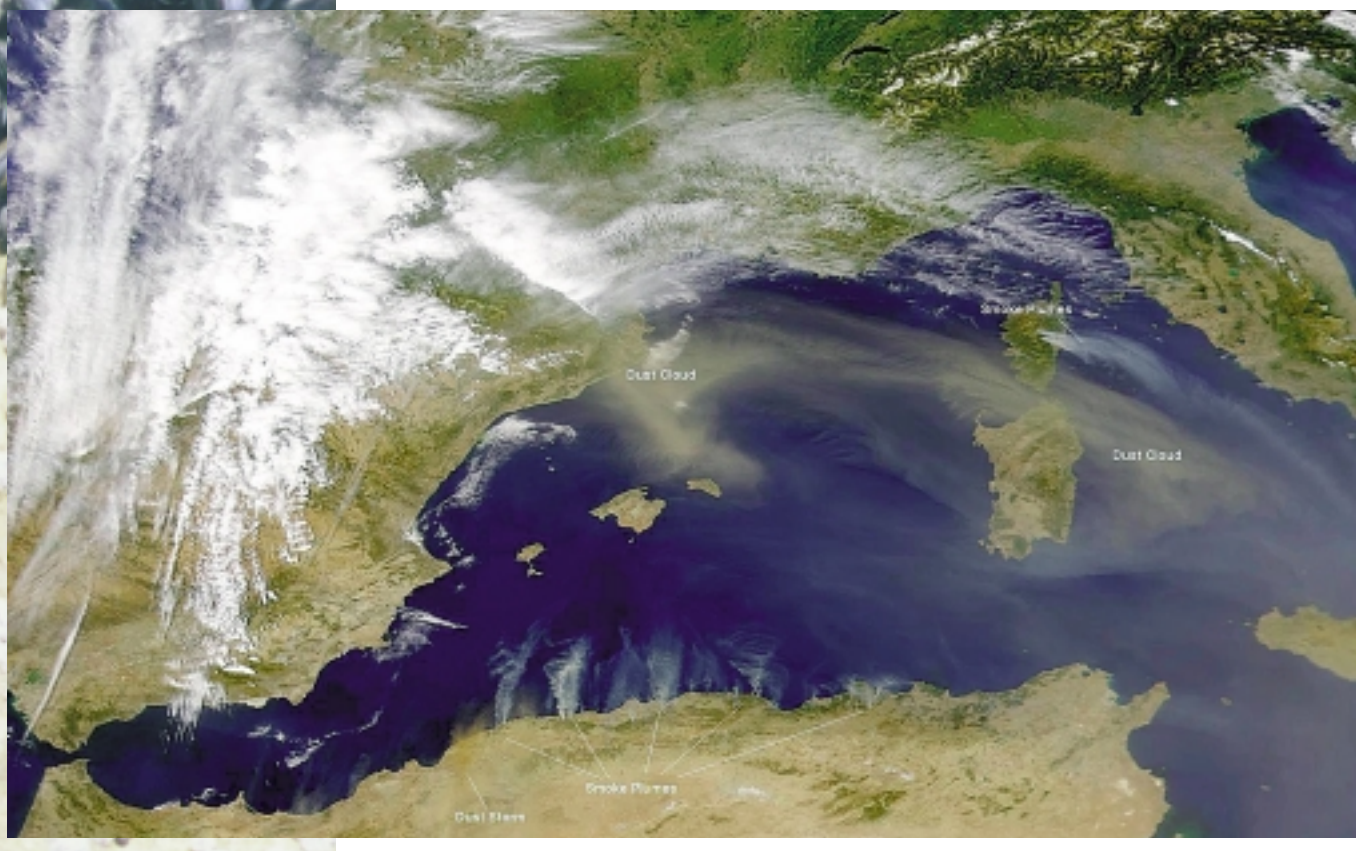
Global composite showing Field of View of SeaWiFS
High Resolution Picture Transmission Stations (dark areas outside field of view)
NASA/GSFC and ORBIMAGE

Data frequency

The frequency with which data are collected varies: from hourly, as in the case of The Met. Office automatic weather stations and the sea level data network maintained by CCMS Bidston, through daily for certain coastal temperature observing stations such as those operated by CEFAS around England and Wales, the Port Erin Laboratory in the Isle of Man and the Millport station in the Clyde Estuary, to seasonal for nutrient observations and monthly for most of the CPR routes, or annual for most of the fisheries data and some current measurements. Based partly on information obtained in the course of this Review and partly on the outcome of enquiries into the data needs of modellers, it is clear that generally the observing organisations consider their own observing frequency adequately meets the purpose for which it is intended. Nevertheless several of those making infrequent observations would like to have a broader range of data to meet their wider needs.

Only The Met. Office considered that its present set of observations adequately meet its present needs in terms of areal coverage and range of parameters observed. However, The Met. Office budget is not fully secure and the cost of maintaining its present buoy network means the long-term security of all the stations and observations cannot be assured if the sole purpose is to meet The Met. Office's requirements. On the other hand in order to meet some of its future needs The Met. Office would like data on a number of additional parameters. Most other organisations would like to have greater frequency data from more stations and for a wider range of parameters. This would increase their ability to cover a wider range of activities but more importantly would increase their confidence in the information they utilise. (See Appendix 3, page 31, for a summary of responses in relation to the data requirements of modellers.)

SeaWiFS image acquired at Rome 25.8.2000
NASA/GSFC and ORBIMAGE



Data availability

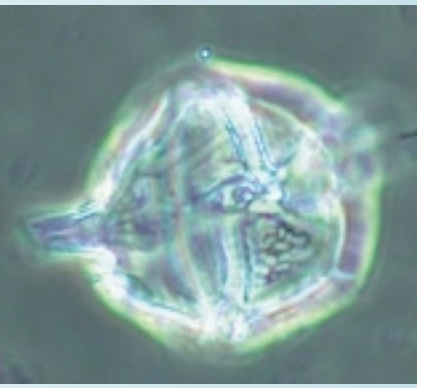
Although it is clear that, in order to meet their own particular needs, a considerable number of observations are made by a wide variety of organisations, there is little co-ordination and not as much awareness of each others programmes as there could be. There appears for example to be under utilisation of the Inventory of Marine Environmental Data run for IACMST at BODC as a means of establishing what data are available and from which organisations. Even where awareness is not a problem most organisations impose some form of restriction on access to the data they collect. At present the Environment Agency and SAHFOS appear to be the only organisations to operate an open access policy to their centrally held records of verified and processed data. However, the JNCC has indicated it intends to make its data from monitoring marine SACs openly available via the World Wide Web. Most research organisations apply the principle of open exchange of data with other research establishments, subject to a time limit to allow their own work-up of data and publication of data products. The Fisheries Agencies (CEFAS, FRS and DANI) will supply their data to other users but if the user organisation concerned operates commercially the Fisheries Agencies are expected to apply commercial principles and recover some of the observation collection costs. The Met. Office and Hydrographic Office operate a commercial charging and licensing policy. However, commercial rates may be waived or modified depending on circumstances, for example The Met. Office observation data are available freely via the GTS and research organisations are charged only the cost of retrieving and outputting the data in the form required by the user. Such charges may however be quite large if the requirement involves substantial reworking of the data records.

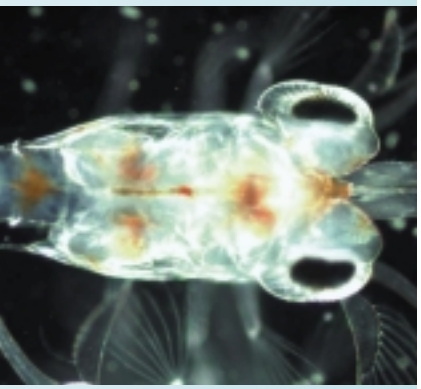
Thus for a variety of reasons the end result is that there is, at present, little general sharing of marine observation data outside bilateral or multilateral agreements between organisations. The consequence is under utilisation of data, much of which is collected at taxpayers' expense, despite the obvious desire for its wider use by both parties. Most organisations involved in making marine observations have limited budgets to support their programmes and staff and their ability to pay for anything, other than the basic costs charged by another organisation for data extraction and transmission, is severely limited. As a consequence they may either do without or use alternative less reliable but cheaper sources of data. Indeed in the worst cases, the rather ridiculous situation can arise where a research organisation or Agency uses its programme funds and staff to collect data itself, rather than use its funds to obtain data from another supplier e.g. weather data collected in relation to current prediction or measurement. Whilst this is understandable, it is also wasteful, as it means staff and equipment are used on a more limited range of activities. Where the organisation concerned is using public funds, such action is highly undesirable, but equally so would be the alternative of effectively using taxpayers' money to process the same data twice. Much of this could be avoided if more thought were given to the needs of all data users before data are actually stored, as it is often the way in which data are stored that leads to high costs of extraction for other users. It is also worth noting that, in principle at least, most of the organisations involved in marine observations, including those operating data access restrictions, have agreed in principle to make their data available, through GOOS, to the wider Oceanographic Community. If this is taken forward in practice it would be logical to adopt a similar stance in relation to the availability of data and data products within the UK.

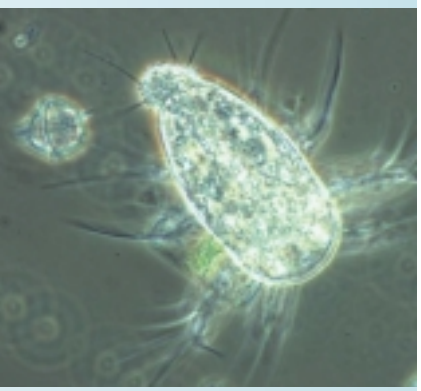
Phytoplankton images © *Karl Embleton Sir Alister Hardy Foundation for Ocean Science*

Fig.1
The UK Network of Marine Automatic Weather Stations

SeaWiFS image of estimate of chlorophyll concentration







Zooplanton images © *Karl Embleton Sir Alister Hardy Foundation for Ocean Science*

Use of data now and in the future

From the responses received and discussions with some of the main observing organisations, it is clear there is a range of applications for the data collected. On the biological side the long-term nature of the CPR records means not only can they be used to follow changes in plankton abundance and species over time, but that these can be linked to changes in fisheries and fish species abundance, for which good long-term records also exist. Given access to long-term records of temperature and salinity they can also be linked with water mass changes and perhaps weather and climate changes. There was for example a step-wise change in North Sea benthos in the late 1980s which coincides with a similar step change in plankton species which in turn was probably linked to water movement changes due to weather or climate change. Data on nutrients are also of relevance in interpreting primary productivity differences over time. With the exception of the data on fisheries and some data on benthos at a few sites around the coast, other long-term monitoring data on biological features do not exist. It is also an unfortunate fact that, although organisations like CCMS, MBA and SAMS have in the past collected data that are useful in a monitoring context and could in principle do so in the future, they are not encouraged to do so under the terms of their present remit and funding situation.

The observational data collected by The Met. Office are used routinely in forecasting of weather, wave height and storm surges. The resulting model output information on marine currents, which is generated in association with their storm-surge forecasts, can be used to show past and future water movements for non-weather purposes. However, at present the use of the model output information in such a mode is limited due to lack of demand (in turn influenced by lack of funds to pay for extraction of the data/products). In turn The Met. Office is keen to improve its forecasting abilities, but in order to do this it requires data on seabed characteristics and bottom water temperature, salinity, turbidity and currents. Ideally it requires these data from frequent measurements but data such as those collected by the Fisheries Agencies on a seasonal, annual or even occasional basis, would be of value. At present such transfers do not occur.

FRS maintains two sections between Faroe and Shetland on which data collection started in 1893. These are surveyed 2 or 3 times a year by FRS and a Faroese laboratory now conducts observations on the same line up to 5 times a year. A similar position applies to the North Sea JONSIS section. Although this was first sampled only in1970, it is now surveyed 2 or 3 times a year by FRS, with the Norwegians conducting additional surveys giving up to 5 surveys a year. The data from these surveys are used, alongside a number of other data sets of salinity and temperature to which FRS have access, to produce an Annual Ocean Climate Status Report. This report illustrates graphically what can be detected in terms of changes in temperature and water mass characteristics, given a set of records going back over a reasonable length of time. There can be little doubt that even more could be done if more data were utilised in such investigations.

Clearly where there is an on-going demand for the generation and use of monitoring data there is greater security of funding for its acquisition. The majority of the data collected by The Met. Office fall into this category. The annual Ocean Climate Status Report generated by FRS for the waters around Scotland and the similar but more ambitious report produced annually by the Norwegian Institute for Marine Research, have created demand for further reports by their respective audiences. This in turn helps to secure the future for collection of the data involved. The importance of the CPR time series data was recognised by the establishment of SAHFOS as an internationally funded charitable foundation. This became necessary when NERC decided that long-term monitoring was no longer an area it wished to support. (This decision has recently been reversed and NERC once again features in the list of organisations funding SAHFOS.) The data SAHFOS holds and continues to generate are freely available nationally and are regarded as a contribution to GOOS. This will only apply so long as the funding it receives is adequate to allow it to continue operating. Greater financial security would allow it either to expand CPR coverage to other areas or to resume some of the transects it was found necessary to discontinue, when its earlier research funding source was withdrawn.

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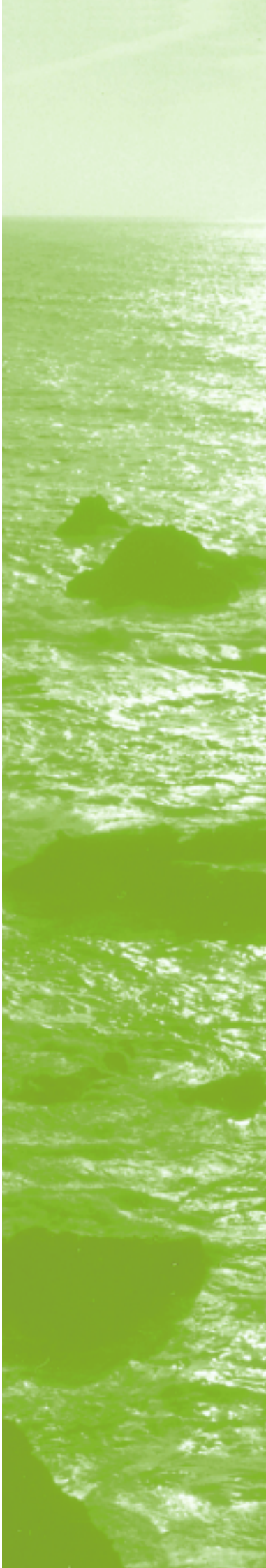
A number of other marine observation sets exist which have been either discontinued or are under threat. In the former category are the Ellett Line and Tiree Passage Section hydrographic observations and the nutrient data set for the western English Channel. The Ellett line (also known as the Rockall or Anton Dohrn Seamount section) extends from 56°40′N 6°8′W to 57°35′N 13°38′W. It is important for two reasons, firstly it crosses part of the oceanic section across which the transport of water holds the key to much of the North Atlantic density driven circulation. Secondly, although the observational data actually miss the majority of the flow into the Nordic Seas and the entire outflow, the data are of considerable relevance to the measurement of deep-water convection west of the UK. The line continues to be operated on an informal and partial basis, jointly by SAMS, CCMS, SOC and FRS but the observations are under continual threat and the present operation omits most of the original inshore stations. The Tiree Passage Section currently runs to 10 years of data on temperature, salinity and currents at a number of depths but continuation is in serious question due to the loss of one of the buoy-based instrument packages used on the section.

There have been occasional surveys by PML since the regular English Channel nutrient observations ceased in 1987, unfortunately just about the time when water movements began to show change. They could very usefully be restarted if funding was available. Much the same applies to the benthos stations previously visited by SAMS at Rockall, Porcupine Bank and the FRS Faroe to Shetland sections. Observation systems under threat are the benthos, nutrient and plankton station operated by the Dove Marine Laboratory and the temperature data currently collected on behalf of CEFAS at a network of coastal stations. It is just these sorts of data that could be utilised in conjunction with physical data for an expanded Ocean Climate Status Report based on that produced by FRS for Scottish waters. Indeed the CEFAS coastal temperature records provide a very good picture of the impact of the North Atlantic Oscillation (NAO) in coastal waters. It is a matter of some concern that the future of this observation system is currently far from secure.

It is worth noting that, in addition to their application to GOOS and a broader range of national programmes than at present, many of the data collected by UK organisations are of considerable interest to our Irish neighbours and to our partners on the European mainland. Collaboration with Ireland could be of mutual benefit. Ireland is now deploying several buoys west and south of Ireland, which could provide shelf break data of value to The Met. Office. The desire of our European colleagues to have active UK participation as full partners in SeaNet and the SNDI programme is based on their knowledge of the existence of monitoring data that would be of considerable use to them for modelling, forecasting and trend assessment purposes.

One new international project to which the UK is contributing is the deployment of a global array of profiling floats known as Argo, which in turn is seen as part of GOOS. As currently envisaged it is anticipated that Argo will yield information of considerable value in relation to the developing Forecasting Ocean Atmosphere Model (FOAM).

In turn this is expected to yield more accurate boundary conditions for models predicting conditions in shallow waters. The lead in the UK is being taken by The Met. Office in co-operation with SOC, BODC and the Hydrographic Office, supported by funding from DETR, NERC and MoD. The project is currently expected to deploy up to 3000 floats throughout the World's oceans by 2003; thereafter it is anticipated the project will prove sufficiently valuable that it will achieve operational status. In very simple terms each Argo float has an anticipated life of 4 years or more and is designed to sink and drift for about 10 days at about 2000 metres depth before rising to the surface, recording a temperature and salinity profile as it does so. The float then transmits its position with the T and S profile, via a satellite to a base station. It then sinks back to drift passively with the current at 2000m for another 10 days.



At present the assessment of sea surface temperature data for the purpose of identifying changes over time is carried out at the Hadley Centre for Climate Prediction and Research at The Met. Office under DETR and MOD funding and by the University of East Anglia. The FRS Ocean Climate Status Summary is largely the result of the efforts of one person collecting together a few data sets gathered initially largely for other purposes. A point made in the course of several discussions and by a number of respondents was that, given the acknowledged role of the oceans in determining the World's weather it is somewhat surprising there is no marine equivalent to the terrestrial and freshwater Environmental Change Network. The data currently collected could provide such a system if a number of stations were designated as marine ECN stations. It is worth noting that just such a system would in fact be required, if discussions currently in progress elsewhere within the GOOS Action Group remit, concerning the production of a National Ocean Status Report at regular intervals, come to satisfactory fruition. It is also worth noting that there are other signs of increasing interest in long-term environmental data. For example the Ryder GCOS report and more recently the Inter Agency Committee for Global Environmental Change (IACGEC) has suggested, in a draft report to the Government's Chief Scientific Adviser, that long-term monitoring should be regarded as a scientific activity in its own right and be funded accordingly. The recently launched Greenwich Project seeks to encourage a network of real-time, in-situ observing stations as does the Fugro-GEOS 'Atlantic Challenge' Project. There is however, a danger that these initiatives could operate independently of each other and existing programmes unless positive efforts are made to co-ordinate all their activities.

Given the various new initiatives and the interest in identifying change and particularly change induced by alterations to climate it is possible that funding for some longer-term studies might be secured. There is also the possibility of securing funds from external sources e.g. from the EU. Such an approach would however, have to be explored selectively, as under current Departmental interpretation of 'additionality' no money would actually reach the Agency securing the funds.

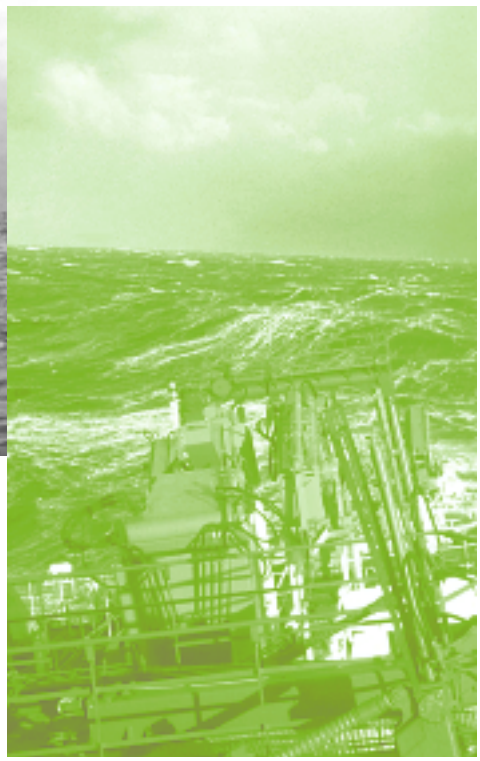


Fig.3 Stations operated by Scottish Laboratories

- ● *Rockall CTD section*
- ● *Marine Lab Aberdeen*
- ○ *Tiree Passage mooring*
- ● *coastal temperature (co-ordinated by Bill Turrell)*
- ● *DML benthic sites*

Rame Head Sunphotometer, part of the AERONET global network of sunphotometers measuring direct solar irradiance.

Continuous plankton recorder

Fig.2 Continuous Plankton Recorder Routes operated by SAHFOS

Fig.4 Stations operated by Laboratories in England, Wales and Northern Ireland

- ● *CEFAS coastal temperature*
- ● *national tide gauge network*
- ● *DARDNI moorings*
- ○ *University of Wales benthic site*
- ● *Port Erin temperature and salinity*
- ● *Dove Marine laboratory*

Securing future observations and maximising use of the data

What observations appear to be needed?

For contaminant observations there is an on-going need to establish the presence or absence of hitherto unidentified contaminants or adverse biological effects, in addition to the trends in concentrations of recognised contaminants and their effects. In short therefore such studies are somewhat open ended and liable to expand. In contrast, the range of observation types covered by this Review is unlikely to increase significantly in the foreseeable future. The main needs therefore are four-fold:

1. To increase the number of parameters measured at sites where observations already take place on a frequent/regular basis.
2. To secure the continuation of observations which already have a long history.
3. To increase our basic understanding of the marine environment by making more observations of the standard parameters at more sites more frequently.
4. To develop a network of Marine Environmental Change stations at which standard physical, chemical and biological characteristics are measured.

Achieving the identified aims

Although there are signs of a greater appreciation of the importance of long-term environmental observations, both as a means of forecasting and of establishing if changes are occurring, it is unlikely that substantial additional funds will be made available to allow all the above objectives to be met in full. However, there might be some scope for additional observations if greater use were made of existing measurements and advantage were taken of existing fixed monitoring locations and developments in technology. In this context, there is a case for more work in the North Atlantic aimed at a better understanding of the North Atlantic Oscillation. Instrumented buoys can now be deployed to undertake regular sampling and/or measurements, for periods of months or years, at a fraction of the cost of operating a ship. Ships are therefore probably best used for deploying instrumented buoys, making validation measurements alongside the buoys and for one-off studies in particular areas. Although lower than the cost of operating ships, the cost of maintaining an operational buoy network is still significant. For example, The Met. Office network of twelve open ocean buoys is considered an essential part of the UK contribution to GOOS, but its future will be at risk while it is funded by a single Agency solely on the basis of its own requirements. Means must be found to ensure that the buoys are used and supported by the wider oceanographic community as measurement platforms meeting a variety of needs rather than those of one alone.

Greater access to data from existing data sets e.g. those on winds and outputs on currents, collected by The Met. Office and those collected by the oil industry, would obviate the need for the Fisheries Agencies and research establishments to collect some of the observations they currently feel compelled to make for themselves. This might free up some of the effort they currently expend and encourage other non-duplicatory work such as undertaking additional observations at existing sites or by establishing new sites where a clear need can be identified. The present problems are not necessarily going to be reduced by new initiatives such as the previously mentioned 'Atlantic Challenge' and Greenwich Project unless plans for them and the use of their results are integrated with existing projects. In short there is a need to co-ordinate and share both observing activities and the resulting data.

The following ideas are intended as the basis for discussion aimed at achieving the aims identified above without incurring excessive additional cost.

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Fig. 5 Location of Natinal Marine (***pollution***) Monitoring Programme Stations

● ***Estuarine, Intermediate and Offshore stations***

In relation to **Aim 1**, provided the present network of monitoring stations, operated by The Met. Office in conjunction with the oil industry, can be maintained, it is probably sufficient for present forecasting needs. However, observations at more depths and particularly at the seabed are necessary to secure the development of the improved modelling capability The Met. Office aims to achieve. At a meeting in April 1999 on modelling, which was organised on behalf of IACMST by the GOOS Action Group, it became very clear that this is also something to which many other modellers would welcome access. Such data could be obtained by the additional deployment, at selected existing sites, of new Smart instrumentation and occasional field observations at sites identified jointly by the modelling community consulting together. (Smart instruments are capable of taking samples or observations at variable frequency according to environmental conditions they detect routinely.) Such instrumentation already exists, as does the facility for data transmission at the stations in question. It is therefore mainly a question of funding its deployment and maximising the utilisation of existing resources.

One need for new data, highlighted in the course of this Review, is that required to meet the growing range of applications for acoustic monitoring data. Users include the oil, dredging and fisheries industries but there is a lack at present of base-line data against which sensible legal and policy decisions can be made as to control of the generation and effects of anthropogenic noise.

In relation to **Aim 2**, the main requirement is to give longer-term security to on-going programmes such as The Met. Office buoy system, the CPR Surveys, the Ellett Line and Tiree Passage Section, the CEFAS coastal temperature stations and the Dove Marine Laboratory stations. This could be achieved if their funding organisations were to place them on long term contracts with a declared intention of renewal. In today's world indefinite contracts are an unrealistic expectation but

3-5 years ought to be possible and would be particularly useful if they were granted on a rolling renewal basis, with the expectation of continuation subject to satisfactory performance up to one year short of the contract duration. In the case of the western English Channel station network previously operated by the MBA it will only be possible to revive this if an appropriate new source of funding can be found. The re-establishment of these stations and their data would be of great assistance in understanding some of the changes that are occurring in that area at the present time.

In relation to **Aim 3**, it must be recognised that we do not live in an ideal world and major expansion is unrealistic. Nevertheless, modern instrumentation does offer an opportunity to expand the monitoring network where a clear need exists, provided use is made of existing facilities. For example, there are several marine institutes around our coasts but few maintain even the simplest records such as salinity and temperature at their own site or one close by. Notable exceptions are the Port Erin (Isle of Man) and Millport (Clyde) Laboratories. This despite the fact that cheap, accurate and reliable recording devices exist for temperature and could easily be installed and maintained by these establishments. Additional equipment could be installed at selected mariculture sites around the entire UK or on the end of harbour walls and piers. In most cases the manpower costs involved, once the equipment has been installed, would be minimal as the necessary personnel are already employed on site and could take on the minimal extra duties without disruption to their normal work pattern.

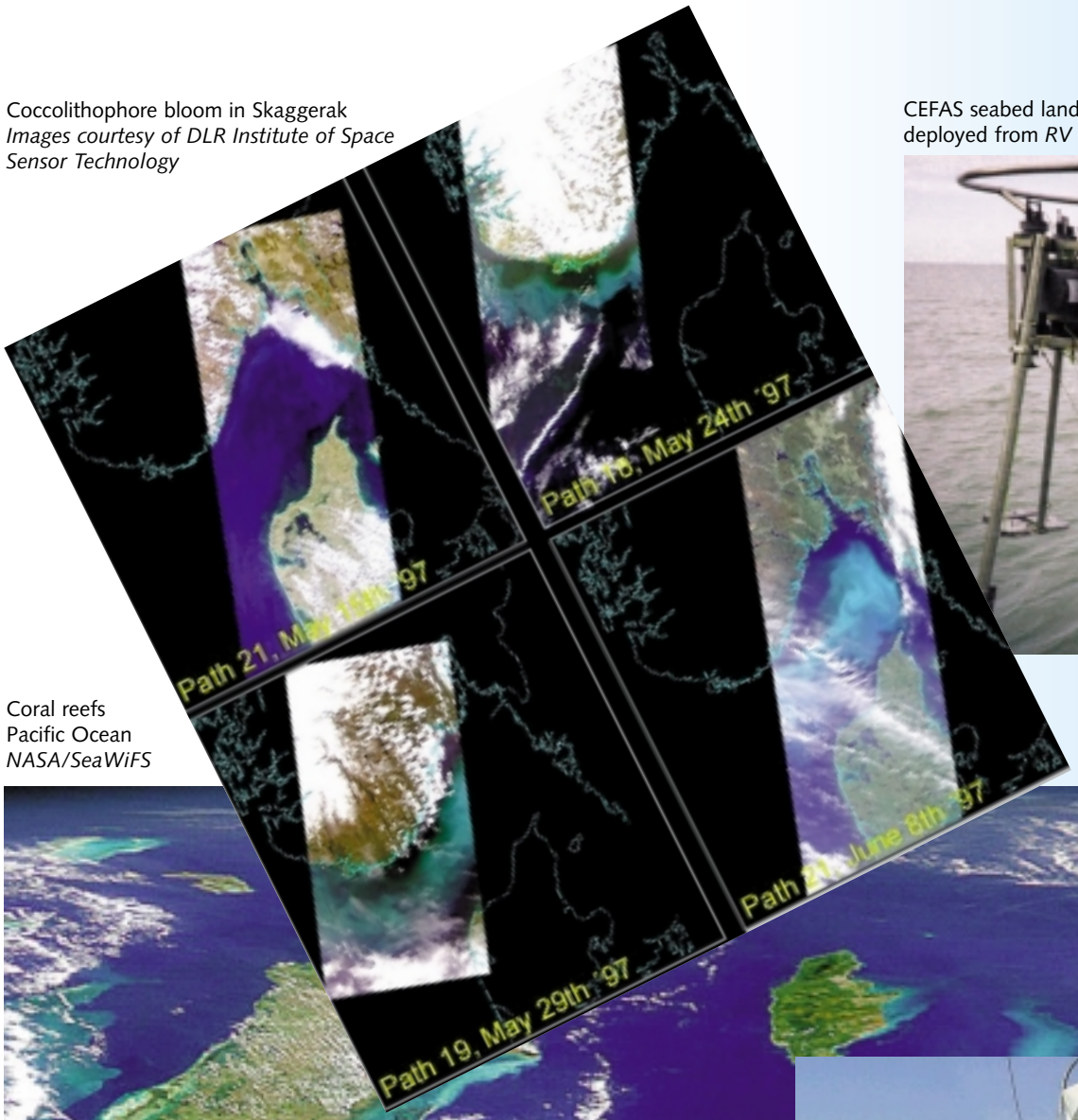
In addition, if current plans for continuous salinity (conductivity), nutrient sampling and analysis etc. come to fruition, there is the potential to add these observations at sites either coincident with the temperature data or on buoys at a few carefully selected additional sites. If on buoys at additional sites it would clearly be necessary to include a temperature-measuring device as well. The parallel move to utilise equipment designed to achieve automated sampling and stabilisation of water samples at intervals over long periods of time offers similar possibilities. On the biological side it would be useful to have more data on the variation over time in species and their abundance, particularly in relation to benthic species. This could be achieved by taking advantage of some of the past data collected by laboratories such as SAMS, FRS, MBA, Port Erin and Menai Bridge. It should be noted also that new data may become available via the Countryside Agencies through their monitoring of marine SACs, most of which are expected to feature benthos studies.

In relation to **Aim 4**, it is unlikely to be necessary to add any further observations to those undertaken in order to meet Aims 1-3. The aim would be to select a relatively small number of stations, each with multiple observations, in order to establish formally an on-going programme. The basic requirement would be reasonable security of funding for the set of observations and station facilities together with either knowledge or a reasonable expectation that the stations selected are representative of conditions in the general area.

Better utilisation of the data

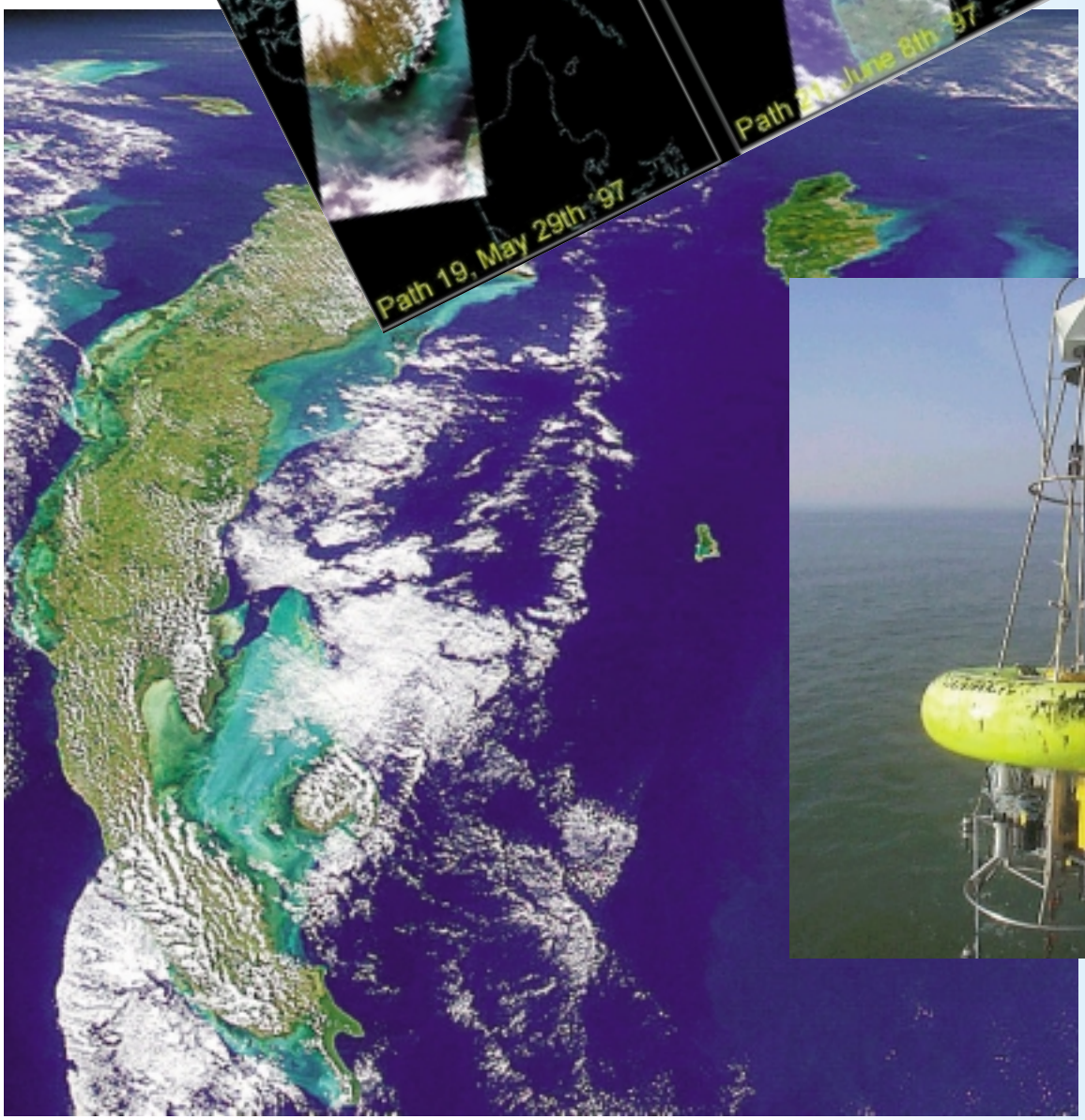
From the foregoing suggestions as to how a programme with greater coverage and value than at present could be created it will be apparent that it will only be possible through co-operation among the small group of major contributors. Provided this can be achieved, no party should need to sacrifice data they currently rely on and all should gain access to more sets of observations and at more sites, than at present. In some cases this might involve the MED Action Group in organising data exchange mechanisms, in others simple multilateral arrangements might suffice. Whichever system is used, the basic assumption is that co-operation will bring with it accessibility to processed data and agreed data products for all involved in the programme. The precedent of the NMMP, developed by MPMMG, demonstrates that this is possible and clearly illustrates the enhanced value of an overall programme relative to its constituent parts.

Coccolithophore bloom in Skaggerak
Images courtesy of DLR Institute of Space Sensor Technology

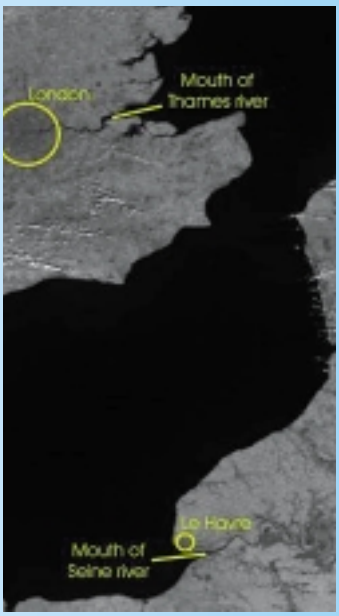


CEFAS seabed lander (Minipod) being deployed from *RV Corystes*

Coral reefs
Pacific Ocean
NASA/SeaWiFS



CEFAS Smartbuoy



MOS-IRS Path16 16.09.96
The English Channel
Images courtesy of DLR Institute of Space Sensor Technology

Overall Conclusions and Recommendations

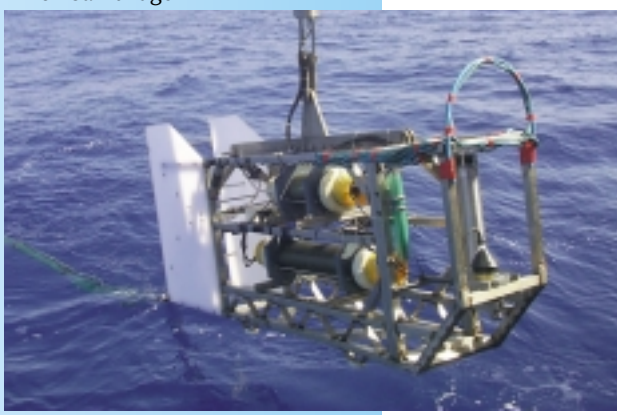
There already exists a sound basis for an overall UK marine environmental observations programme that will meet both future forecasting needs and the desire to be able to identify changes in this important compartment of the environment. There are however, some important provisos, namely, existing programmes need to be maintained, their results need to be made more widely available and utilised and a means must be found to allow planned activities to be fulfilled. Reductions in effort will increase even the present level of uncertainty about how representative the currently available observations actually are. This would lead to poorer ability to forecast future events. This in turn could result in the need to invoke greater precautionary measures. These measures would almost certainly be less if the necessary scientific understanding and predictive capabilities had been developed.

With the exception of acoustic observations, for non-biological data there are relatively few major gaps in coverage in relation to present programme objectives. Application of modern instrumentation, through the use of automatic sampling and measuring devices and modern data transmission systems, could help to fill some of the gaps, probably at little or no additional overall cost. Collaboration and multi-organisation use of buoy facilities, monitoring data and data products (such as model outputs), would clearly help to increase the value of existing programmes and give them greater security. So far as the need for acoustic observations is concerned this is a relatively new requirement and one where a co-ordinated approach to scoping the need would be beneficial.

Whilst it is a fact that a great deal of additional work could be undertaken by way of biological observations, the most significant gap is a lack of data on benthic species and their populations over time. There are some notable exceptions and new data should soon start to become available from the monitoring of marine SACs. Traditional benthos studies are time consuming both in the field and laboratory identification and this tends to deter on-going studies. However, acoustic mapping systems such as ROXANNE may provide a cheaper and therefore more viable alternative. Either way the addition of a few more sites around the UK coast taking advantage of previously sampled but now discontinued sites, would mean the generation of longer time series data sets than any new marine SAC monitoring will provide.

In order to develop an overall marine observing system capable of meeting most organisations' needs effectively and the UK's overall needs efficiently, only one major change is required. That change is for all the key organisations to be brought together and to agree on what data and data products they collectively require and then to work as partners providing a collective service to the nation as a whole. To achieve this requires some changes in current working arrangements but, given the necessary steer and authorisation for this to occur, there is clear evidence that the organisations concerned would work together. Furthermore, given that lead, the contaminants and effects programme operated via the MPMMG provides the experience and perhaps a model through which the co-ordinated programmes proposed might be implemented. This and other options should be explored.

DASI, a deep-towed electro-magnetic transmitter system for sea floor studies developed by the University of Cambridge



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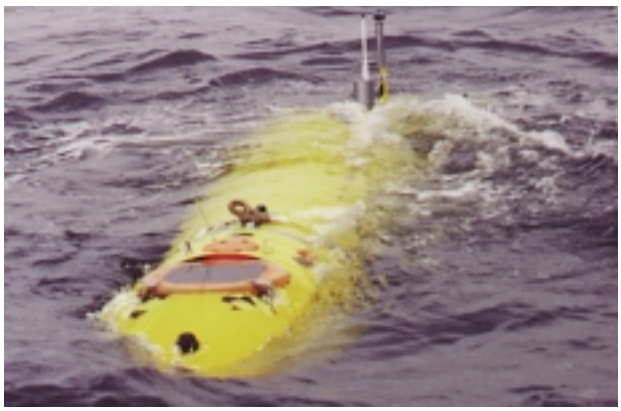

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Appendix I

List of Responding Organisations

Countryside Council for Wales

Centre for Environment Fisheries and Aquaculture Science (CEFAS)

DANI (Aquatic Sciences Group)

Dove Marine Laboratory

Environment Agency

Fisheries Research Services (FRS)

Fugro GEOS Ltd

InstallOcean Ltd

METOC plc

The Met. Office

MOD(N)

Port Erin Laboratory

Sir Alister Hardy Foundation for Ocean Science (SAHFOS)

Shell UK Ltd

UK Offshore Operators Association

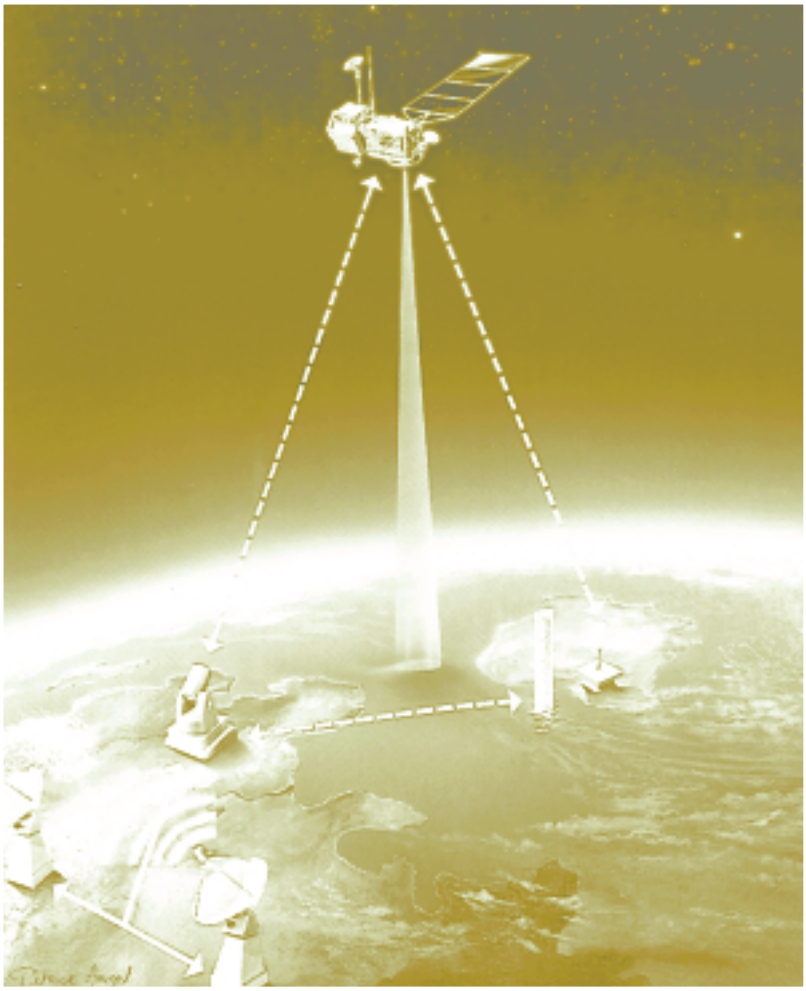
Organisations whose observations have been taken into account based on information previously supplied to the IACMST database at BODC

Marine Biological Association (MBA)

NERC Centre for Coastal and Marine Science (CCMS)

SAMS/SMBA

Southampton Oceanography Centre (SOC)



Appendix 2

Summary of Information on Physical, Biological and Chemical observations made

PHYSICAL MEASUREMENTS

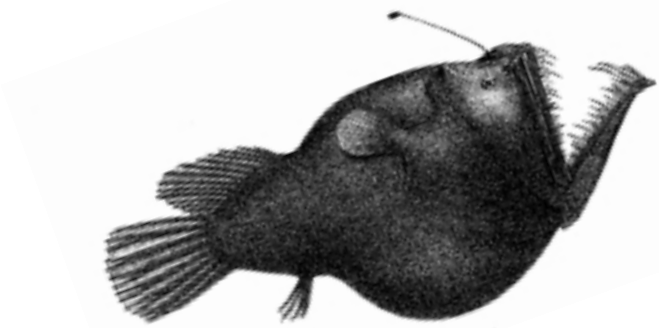
Observing Organisation	Type of Observation	Where	No of Stations	Frequency	Substrate Samples	Several Depths	Observations Commenced	Reasons for Programme
SAHFOS	CTD & Fluorescence	O & B Celtic Sea	40-50	Monthly	W	No	1997	Lt & Sc
	CTD & Fluorescence	O North Sea	40-50	Monthly	W	No	Mid-1980's	Lt & Sc
	CTD & Fluorescence	O & B NW Atlantic	40-50	Monthly	W	No	1994	Lt & Sc
	CTD & Fluorescence	O Irish Sea	40-50	Monthly	W	No	1996	Lt & Sc
Shell UK	Wave Ht & Period	O North Sea		8 Hourly	W		1995	Lt & F
	Wave Ht, Period & Dir	O North Sea		3 Hourly	W		1988	Lt & F
	Wind Speed & Dir & Temp	O North Sea		22 Hourly	Air		1995	Lt & F
	Sea Temp	O North Sea		2 Hourly	W		1988	Lt & F
Port Erin Lab	T	C Irish Sea	1	Daily	W	No	1904	Lt
	T & S	C Irish Sea	1	Fortnightly	W	No	1954	Lt
	T & S	C & O Irish Sea	9	2/Yr	W	Yes	1958,1965 1988 & since 1992	Lt
	S	C & O Irish Sea	1	Daily	W	No	1965	Lt
DARD	T &S Sub-surface irradiance	C & O Irish Sea	2	Monthly	W	Yes	1992	Lt & Sc
	T (Instrument mooring)	O Irish Sea	1	3 Hourly	W	Yes	1996	Lt & Sc
Dove Mar Lab	T & S	C North Sea	1	Monthly	W	Yes	1994	Lt & Sc
CCW	Turbidity	C Irish Sea (Menai)			W			Lt & Sc
	Turbidity	C Irish Sea (Skomer)			W			Lt & Sc
	Wave Ht & T	C Irish Sea (Skomer)			W			Lt & Sc
	Wind Speed, Dir & Temp	C Irish Sea (Skomer)			A			Lt & Sc
FRS	T & S	O North of Scotland	14	2-3/Yr	W	Yes	1893	Lt, Sc & F
	T & S	O North Sea		2-3/Yr	W	Yes	1970	Lt, Sc & F
CEFAS	T	C England & Wales	16	Daily	W	No	Most 1960's Redcar 1926	Lt, Sc & F
Millport Lab	T	C Malin Sea	1	Daily	W	No	1953	Lt & Sc
CCMS POL	Sea Level	C UK	44	15 mins	W	No	Various	Lt, F
The Met. Office and Oil Industry	Wave Ht, Period & Dir , T	O Around Brit Isles	30		W	No		Lt & F
	Air T, P & Humidity ,Wind Speed & Dir	O Around Brit Isles	25		A	No		Lt & F
	Air T, P & Humidity, Wind Speed & Dir	C Around Brit Isles	25		A	No		Lt & F
	Currents & T	O NW Scotland	1		W	Yes		Lt & F
CCMS DML	C T D	C & O Rockall Section	30	2-5/Yr	W	Yes	1975	Lt Sc
	T & S	O Rockall Channel	7	Monthly	W	No	1948	Lt Sc
	T & Current Speed & Dir	C Tiree Passage	1	Hourly	W	Yes 2	1981	Lt Sc

T Temperature
S Salinity
C Coastal (up to 6 miles)
O Offshore (beyond 6 miles)
W Water

A Air
S Sediments
Lt Long term record purposes
Sc Scientific purposes
F Forecasting purposes

Appendix 2
BIOLOGICAL OBSERVATIONS

Observing Organisation	Type of Observation	Where	No of Stations	Frequency	Substrate Samples	Several Depths	Observations Commenced	Reasons for Programme
SAHFOS	Phytoplankton Zooplankton CTD & Fluorescence	O & B North Sea & North Atlantic O & B North Sea & North Atlantic	3-400 3-400	Monthly Monthly	W W	Surface Surface	1946 1940	Lt & Sc Lt & Sc
Port Erin Lab	Chlorophyll a Chlorophyll a	C Irish Sea C & O Irish Sea O North Sea O North Sea	1 9	Fortnightly 2/Yr 22 Hourly 2 Hourly	W W	Surface Surface	1954 1958, 1965 1988, since 1992	Lt Lt
DARD	Chlorophyll a & Copepod nos Demersal Species Herring & Sprat Nephrops Scallops Juvenile Gadoids Larval Herring	C & O Irish Sea C & O Irish Sea C & O Irish Sea C & O Irish Sea C & O Irish Sea C & O Irish Sea C & O Irish Sea	2 45 450 20 30 40 40	Monthly 2/Yrs S & A 1/Yr A 2/Yrs S & A 2/Yrs S & A 2/Yrs S & A 2/Yrs S & A	W Bottom Bottom Bottom Bottom	Surface	1992 1991 1991 1990 1985 1994 1993	Lt Lt, F & Sc Lt, F & Sc Lt, F & Sc Lt, F & Sc Lt, F & Sc Lt, F & Sc
Dove Mar Lab	Zooplankton Chlorophyll a Macrobenthos Macrobenthos	C North Sea O North Sea C North Sea O North Sea	1 1 1 1	Monthly Monthly 1/Yr 2/Yr	W W Seabed Seabed	Surface Surface	1968 1994 1972 1973	Lt & Sc Lt & Sc Lt & Sc Lt & Sc
FRS	Fish Stocks Young Fish	O Scotland O Scotland	 60-70	1-4/Yr 1/Yr	W & Seabed		~1900's 1970	Sc F F
CEFAS	Fish Stocks Benthos Young Fish	O Eng & Wales O Eng & Wales O & C Eng & W		1-4/Yr Seabed Annual Annual	W & Seabed		~1910's 1980's	Sc F Lt Sc Lt & Sc
CCW	Phytoplankton Benthos	C N Wales Coast C S Wales (Skomer)	11 1		W Seabed			Lt & Sc Lt & Sc
SAMS	Benthic Species	C Scotland		Annual	Seabed			Lt Sc
UCNW	Benthic Fauna	C Wales (and Wharf Bay)	1	Annual	Seabed			Lt Sc

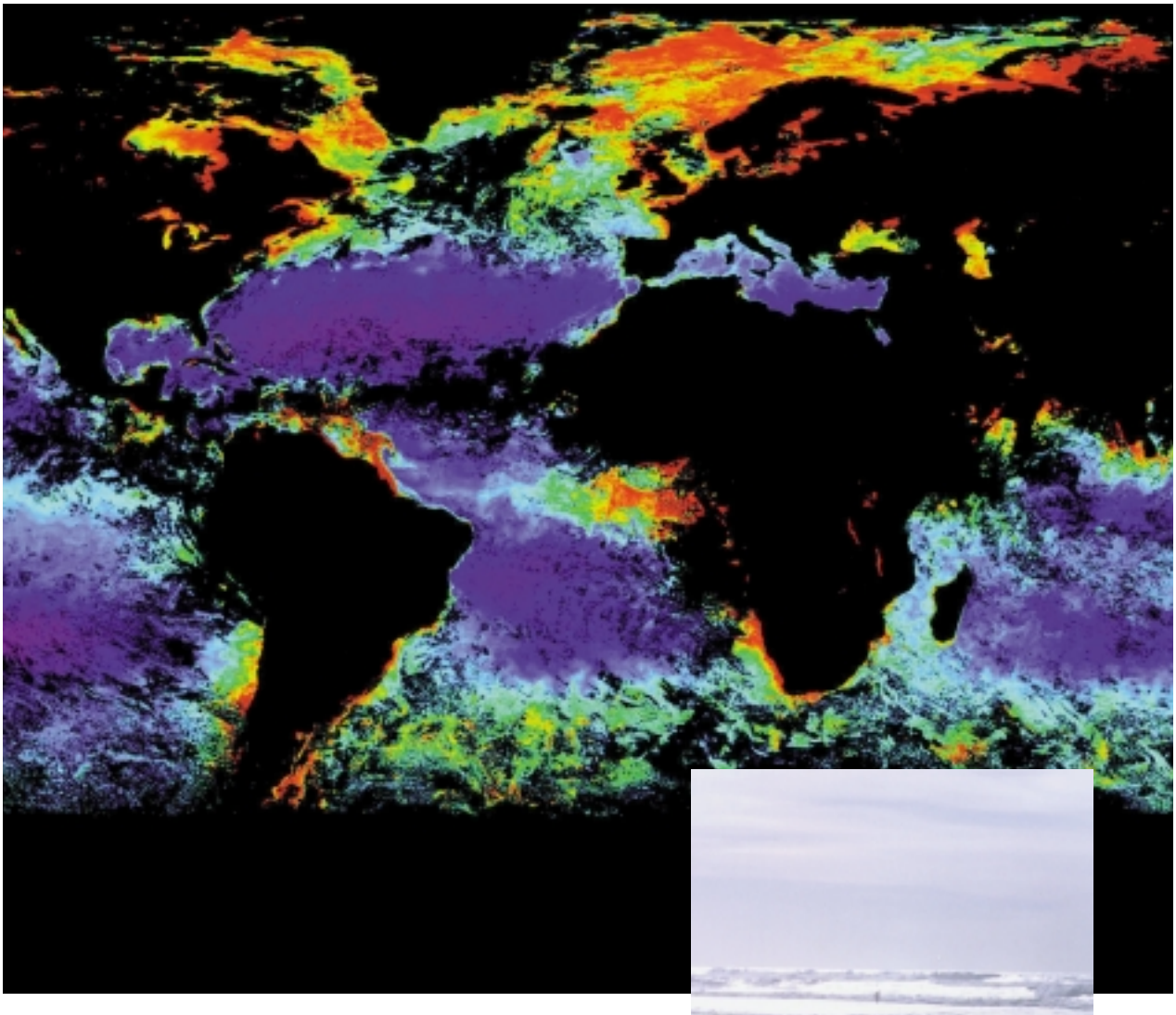


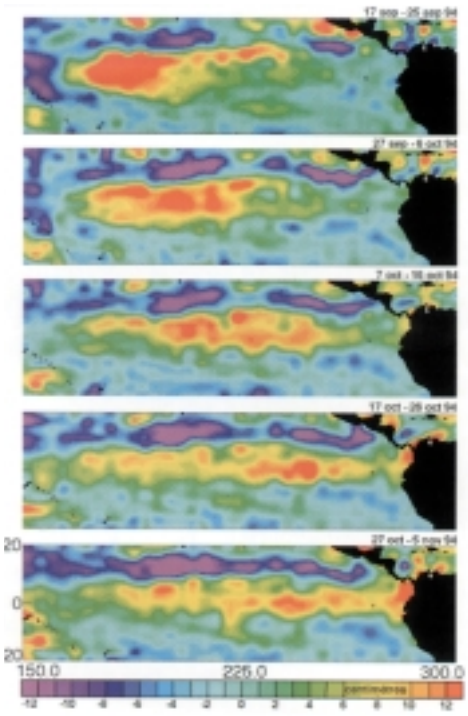
Appendix 2
CHEMICAL OBSERVATIONS

Observing Organisation	Type of Observation	Where	No of Stations	Frequency	Substrate Samples	Several Depths	Observations Commenced	Reasons for Programme
Port Erin Lab	Dissolved Oxygen (DO)	C Irish Sea	1	Fortnightly	W		1966	Lt
	o-Phosphate (PO_4)	C Irish Sea	1	Fortnightly	W		1954	Lt
	Silicate (SiO_3)	C Irish Sea	1	Fortnightly	W		1958	Lt
	Nitrite, Nitrate (NO_2, NO_3)	C Irish Sea	1	Fortnightly	W		1960	Lt
	$\sum$ Diss N & $\sum$ Diss P	C Irish Sea	1	Fortnightly	W		1996	Lt
	DO, o-PO_4, SiO_3 NO_2 NO_3	C & O Irish Sea	9	2/Yr	W	Yes	1958,1965, 1988 & since 1992	Lt
	$\sum$ Diss N & $\sum$ Diss P	C & O Irish Sea	9	2/Yr	W	Yes	1996	Lt
Dove Mar	NO_2 NO_3 SiO_3 PO_4	C North Sea	1	Monthly	W	Yes	1994	Lt & Sc
FRS	DO NO_3 NH_4 PO_4 SiO_3	O North of Scotland	14+16	2-3/Yr Max	W W	Yes	1903	Lt Sc
	DO NO_3 PO_4 SiO_3 Partic	O Scotland	12	2/Yr	W	Yes	1972	
	C&N	North Sea					1972	Lt Sc
CEFAS	DO NO_3 NO_2 NH_4 PO_4 SiO_3	C & O Eng & W		Annual	W	Yes		Lt Sc
DARD	NO_2 NO_3 NH_4 PO_4 SiO_3	C & O Irish Sea	2	Monthly	W	Yes	1992	Lt & Sc
	Particulate carbon	O Irish Sea	1	Monthly	W	Yes	1993	Lt & Sc
	Sol. Org. N	O Irish Sea	1	Monthly	W	Yes	1993	Lt & Sc
(Inst. Mooring)	NO_2 NO_3 NH_4 PO_4 SiO_3	O Irish Sea	1	48 Hourly	W	Yes	1996	Lt & Sc

June 2000

A global picture of chlorophyll concentrations averaged over 8 days in July 2000. *Image from SeaWiFS*





TOPEX-POSEIDON data showing the level of the ocean surface

Appendix 3

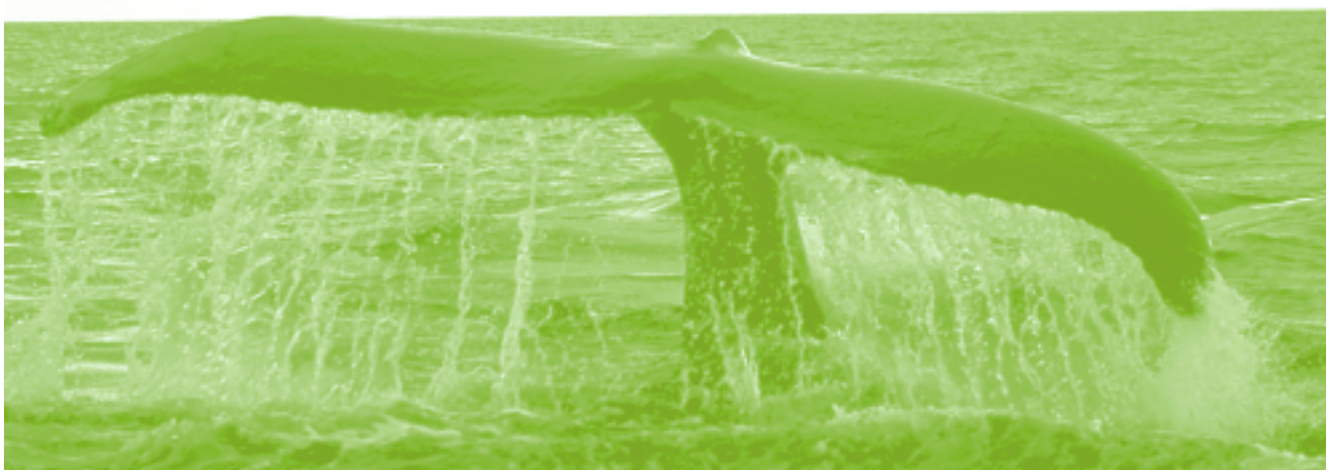
Summary of requirements of modellers and model users following an IACMST sponsored meeting on modelling in April 1999

Summary of responses received (9 in all)

Number of Requests for Observations	All
Parameter (SST/T Profile/S profile/currents/elevation/other) SPM Wave Ht & Period 2 1 2 1 2 1 1	4
Location 1 x world-wide, 4 x UK EEZ/NW Shelf, 1 x around Ireland, 1 x Shelf Edge	
Use in real-time 3	
Use hourly values/weekly mean/monthly mean/seasonal mean/all 4/daily 3 3 1 1 1 1	
Other comments: 1 x Coherent data for several points synoptically 1 x Would welcome any data that would help develop better models eg SPM, nutrients	
Model output required	
Gridded datasets (eg to drive nested models) 5	
Location (approximate) ie coastal waters/regional seas/shelf break/deep ocean) All 4 5 3 1	
Could you extract your sub-area from a dataset covering a larger area *Note typical source model grid resolution is (1999): deep ocean1/3 degree, shelf seas 1/9 degree (12 km) and coastal ca. 2km*	Yes/No 4 Possibly 2
Model parameters, please indicate which you require	
NWP surface fluxes 1	
Surface winds and pressure (hourly) heat or precipitation/evaporation (6-hourly average or 3-hourly average 1 1 1 Both the latter 4	
Wave energy spectrum (3 hourly intervals) profile of temperature /salinity/current 1 1 2	3
Total water elevation 4	
Frequency of output required (hourly/3-hourly/6-hourly/daily) Both 2 2 2	
Forecast period required (analysis only/48 hour/5 day forecast) Both 1 2 3 *Note that typically a shelf-wide model will be run once or twice daily, forecasting up to 48 hours ahead starting from 00z, 12z*	
Other comments: 1 volunteer to provide Most other respondents users	

High level products required	
Maps of modelled data (state which parameters) which level (surface, bottom, mid-depth, etc)	
Modelled transports (monthly mean or seasonal mean) 3 1	
Which locations Malin Sea, St Georges Channel, Irish Sea and Bristol Channel, Major Channels and Estuaries, 1 x NW Shelf, 2 x UK EEZ	
Differences in climatology	
Means from modelled data (which parameters?) 3-D residual currents T & S + SPM Weekly SPM transport plus T & DT surface to bottom	
Plotted product or gridded datasets 2 1 Currents and Waves	
Means of observed quantities	
Other comments: 1 Provider Rest of respondents users	
Data needed to set up models	
Bathymetry	6
River inflow 1 respondent stated major only	5
Do you have applications for other observed or modelled parameters such as sediment transport, SPM, biology etc? If yes, state what: 3 x SPM 1 x Geoacoustic data, gridded and world-wide 1 x Transport of fish/eggs/larvae, phyto & zooplankton 1 x Determination of water residence times 1 x Ecosystem models need nutrient data 1 x Sediment erosion/deposition models need data on sediment type	Yes/No 6 1

April 2000



Prepared by

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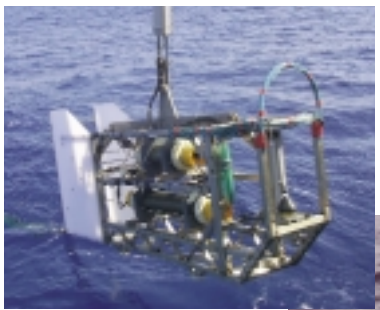
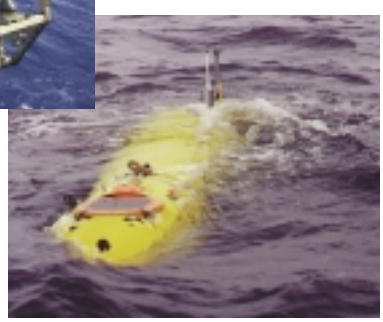
IACMST Information Document No.7
December 2000





Designed and produced by Ann Aldred Associates 07721 583463