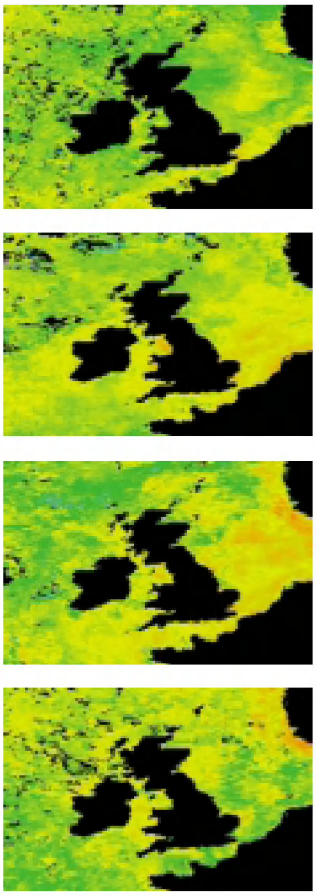
Climate of UK Waters at the Millennium
Status and Trends

Edited by Graham Alcock
and Lesley Rickards
(IACMST)



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Edited by Graham Alcock and Lesley Rickards
for the Inter-Agency Committee
on Marine Science and Technology
(IACMST)

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PREFACE

As part of its commitment to consult on and promote marine science and technology, the UK Government's Inter-Agency Committee on Marine Science and Technology (IACMST) publishes a series of Information Documents that review topical issues. This document draws on the expertise and contributions of two IACMST Action Groups, dealing with Marine Environmental Data (MED) and the Global Ocean Observing System (GOOS). Both Groups include representatives from Government Departments and Agencies, industry and other marine user groups. The MED Action Group works to improve the accessibility and availability of UK data relating to the marine environment, the GOOS Action Group co-ordinates the UK involvement in, and input to, that international programme.

The effective and sustainable management of the UK's marine environment needs the comprehensive collection and use of marine data in order to assess its present state, identify changes and meet future forecasting needs. This document, reporting on the current status and trends of some marine parameters in UK territorial waters, is a first step towards this. It should play a significant role in informing and stimulating debate on the usefulness of marine data sets, on the further and better use of existing data and on the commencement, continuation or resumption of marine measurements.

It is intended that this document will be the first of a series of ocean climate status and trends reports for UK waters, and that it will lead to the development of a more comprehensive web-based time-series atlas for the waters around
the UK. It is an example of IACMST's Action Groups working together on a collaborative venture between Government Departments and Agencies, university departments and commercial companies. We endorse its findings.

Dr Howard Cattle
Chair of GOOS Action Group

Prof. Mike Cowling
Chair of MED Action Group

July 2001

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EXECUTIVE SUMMARY

This report presents the current status and trends of some marine parameters in UK territorial waters.

Sea temperatures at most sites show a warming trend during the 20th Century, but with lower values in 1999 and 2000 compared to 1998.

Salinity records show considerable inter-annual variation, but do not indicate any overall long-term trend in recent decades. Generally, salinities in 1999 and 2000 were lower than in 1998.

Mean sea level rose by about 1.5mm per year in the 20th Century, but is now rising on average less fast than over a base period of 1921-1990. Trends in extreme sea levels match those of mean sea level closely, but there are no significant long-term trends in surge levels.

There is a large spatial and temporal variability in wave height, with some evidence of an increase between the 1960s and 1990s.

The abundance of the zooplankton *Calanus finmarchicus* has declined in the North Sea and the NW Approaches since the 1960s. Elsewhere, numbers are relatively low and show considerable inter-annual variability, making it difficult to infer any trends.

The abundance of phytoplankton shows an upward trend since the 1960s, except possibly in the Irish Sea.

Any trends in nutrients, metals or biological parameters are difficult to infer from existing measurements, because of short sampling duration or inter-annual variability in the longer records.

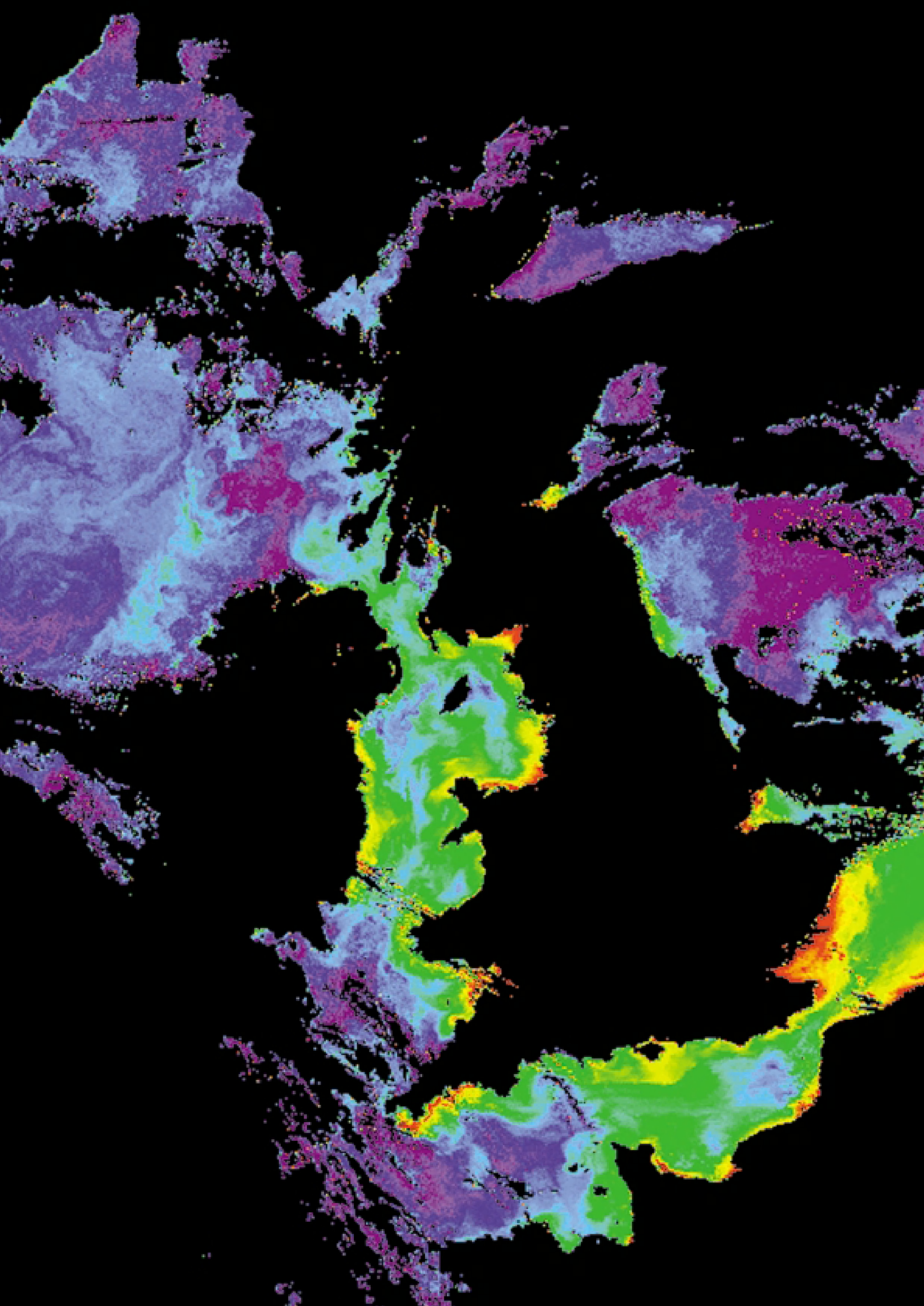
There is potential to monitor the status and trends of chlorophyll from the operational SeaWiFS instrument.

Changes in the North Atlantic Oscillation, and hence the strength of the westerly airflow, are a significant factor in the variation of marine parameters in UK waters.

Contemporary data for some parameters are not available, because measurements have never been made or have been discontinued.

Much better use can be made of existing data, especially if processing methods are standardised and data dissemination improved, including the timely provision of data to national, regional and international data banks.

The existing observation programmes provide a sound basis for a comprehensive observation and processing programme. This is needed to assess the present state and trends of the UK's marine environment, as a necessary part of its effective management.



SeaWiFS image of estimate of chlorophyll concentration

ACKNOWLEDGMENTS

We gratefully acknowledge the efforts of the following organisations, in contributing data, text, discussions and/or reviews:

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British Nuclear Fuels Ltd.

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University of Liverpool Port Erin Marine Laboratory, Isle of Man (Theresa Shammon)

University of Reading Department of Meteorology (David Stephenson)

We also thank John Portmann and Andy Tabor for their contributions, and Ben Moate of BODC for considerable help with the figures and the web site.

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1. INTRODUCTION

This report describes the present (1999/2000) status and trends of weather, climate, sea temperature, salinity, sea level, waves and plankton in UK territorial waters. Some data from adjacent areas are included to provide a regional and global context. We also include some representative data sets of chlorophyll and nutrients as examples of other parameters that could be used in future reports.

Data and/or accompanying text have been provided by a number of individuals and organisations. However, some data are unavailable because measurements have never been made or have been discontinued, or because the lack of resources (time or money) has precluded organisations from supplying existing data within our time scale.

A general aim of this report is to demonstrate the value of long-term marine measurements in aiding the effective management of the UK's marine environment; thus encouraging their commencement, their continuation or their restoration.

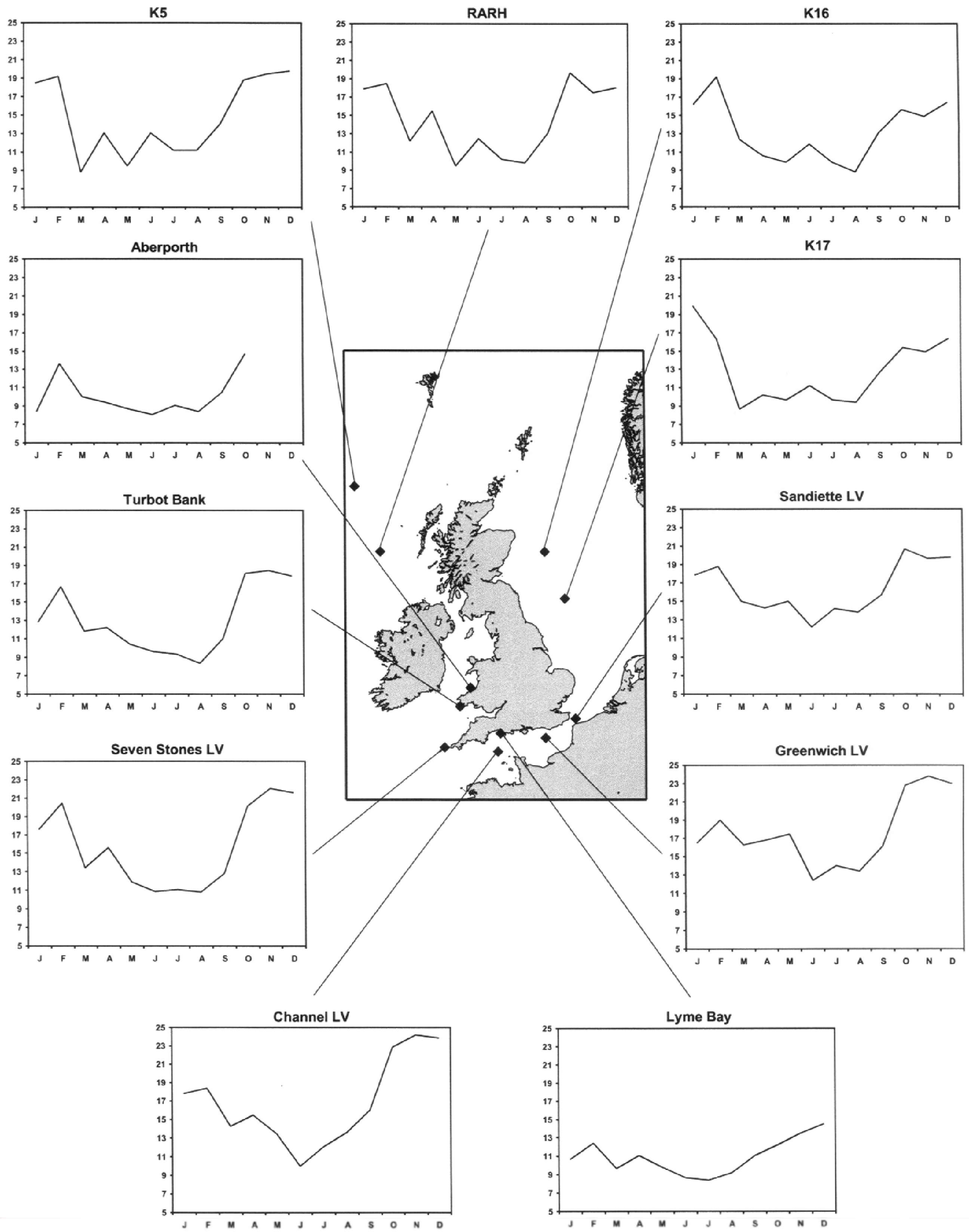
More specific aims are:

- to stimulate further scientific study of the parameters and their interactions,
- to increase public awareness of the present status and trends in UK waters,
- to enhance marine data inventories, e.g. the existing UK Inventory of Marine Monitoring Measurements and the planned EuroGOOS European Directory of the Initial Observing System,
- to provide reference to measurements for the validation of, and assimilation into, operational marine forecasting models (EuroGOOS, 1996),
- to enhance the use of marine indicators of climate change (Hulme and Jenkins, 1998; DETR 1999), whether due to natural variability or as a result of human activity, and
- to provide input to a wider study on Environmental Indicators and the State of the Seas by the UK's Marine Pollution Monitoring Management Group (MPMMG).

This report should be read in the context of other reports on the UK's marine environment, concerning:

- the status of the ocean climate and fisheries in Scottish waters (Turrell, 2000),
- the quality of UK coastal waters (MPMMG, 1998; EA, 1999),
- assessments of ocean climate and plankton in the NW and NE Atlantic by the International Council for the Exploration of the Sea (ICES 2001 and 2000b),
- the quality status of the NE Atlantic by the Oslo-Paris Commission (OSPAR, 2000), and
- assessments by the Intergovernmental Panel on Climate Change on the science of climate change (IPCC, 2001a), its consequent impacts, adaptation and vulnerability (IPCC, 2001b), and its mitigation (IPCC, 2001c).

A web version is available at www.oceannet.org/UKclimate-status, together with links to other sites containing marine data and information.


K5
RARH
K16
Aberporth
K17
Turbot Bank
Sandiette LV
Seven Stones LV
Greenwich LV
Channel LV
Lyme Bay

Wind speed (knots) for 2000, from the Marine Automatic Weather Station Network

Courtesy of the Met. Office

Global surface temperature has increased by about 0.6°C since the late 19th Century, with ten of the warmest years since records began in 1860 occurring since 1983 and eight since 1990 (IPCC, 2001a). The Central England Temperature (CET) record, representative of most of the UK, shows a warming of about 0.5°C during the 20th century. Since records began in 1659, five of the six warmest years have occurred in the 1990s, with 1999 (and 1990) the warmest and 2000 one of the 15 warmest. There is a high correlation between the CET record and the North Atlantic Oscillation (NAO); for example, the cold winter of 1995/96 was associated with the lowest value on record of the NAO Index (see below).

1999 and 2000 were much wetter in the UK than the long-term average, with 2000 the wettest year in England and Wales for over a century, and the third wettest since records began in 1766. 1999 was one of the sunniest years in the 20th century and 2000 was the seventh successive year with sunshine totals above the average.

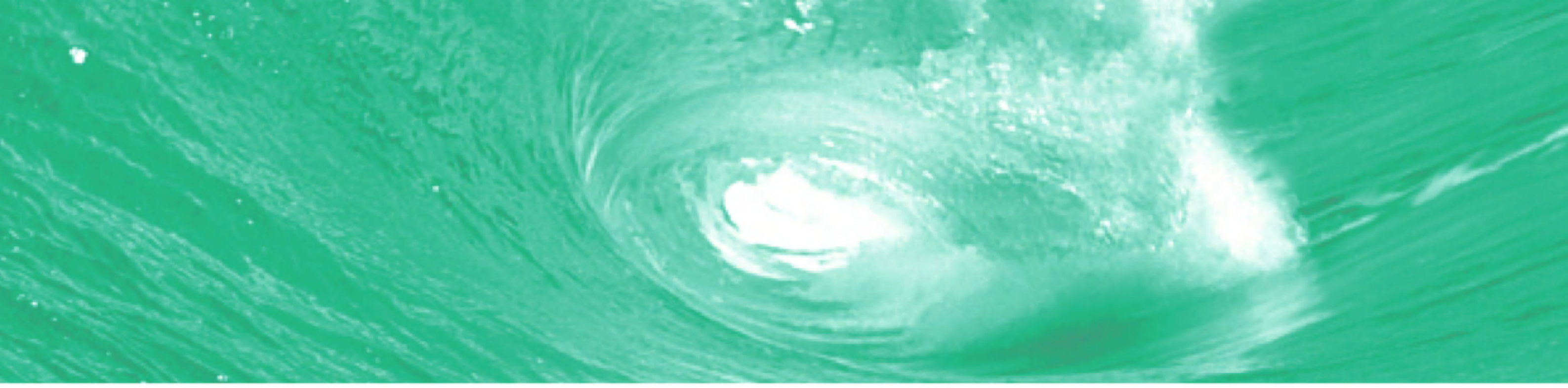
The storm climate or "storminess" in the NE Atlantic and UK waters depends on the storm tracks, intensity and frequency of occurrence. There has been no significant trend in the storm climate during the past century, but there has been major inter-decadal variation. The intensity in recent decades is comparable to that at the start of the twentieth century, with a lower intensity in the intervening period (WASA Group, 1998).

The weather and climate of the UK and its waters are influenced by changes in the strength of the westerly wind flow, driven by the NAO, a "see-saw" in atmospheric pressure between the subtropical high and the polar low (CRU, 2001; Stephenson, 2001).

The NAO's intensity is measured by a monthly, seasonal or annual Index based on the difference of normalised sea level pressure between stations characteristic of the subtropical high (Gibraltar or Lisbon or Ponta Delgada, Azores) and the polar low (Stykkisholmur, Iceland). A positive, or high, Index indicates a stronger subtropical high-pressure centre and a deeper Icelandic low than normal. The increased pressure difference results in strong mid-latitude westerly winds, with numerous cyclones bringing mild and wet winters and unsettled chilly summers to the UK. A negative, or low, Index indicates a weaker subtropical high and a weaker Icelandic low than normal, with a reduced pressure gradient resulting in weaker westerly winds. Anticyclones dominate, with colder winters and warmer summers than normal.

The most extreme decadal change in the NAO Winter Index has occurred recently, with an upward trend from generally low values in the 1960s to generally high values in the 1980s and 1990s. However there is significant inter-annual and inter-decadal variability, with both the highest (1994/95) and the lowest (1995/96) values on record occurring in the 1990s. The 'flip' from 1994/95 to 1995/96 was associated with radical changes in the weather, with more than 150% of the average winter precipitation over northern Europe in 1994/95 winter and less than 60% of the average in 1995/96 winter (ICES, 1999). There was a change in the wind regime over the UK and its waters, from a predominantly westerly flow in 1994/95 to a predominantly easterly flow in 1995/96. Changes in the maritime climate from 1994/95 to 1995/96 included a rapid cooling in the North Sea (ICES, 1999).

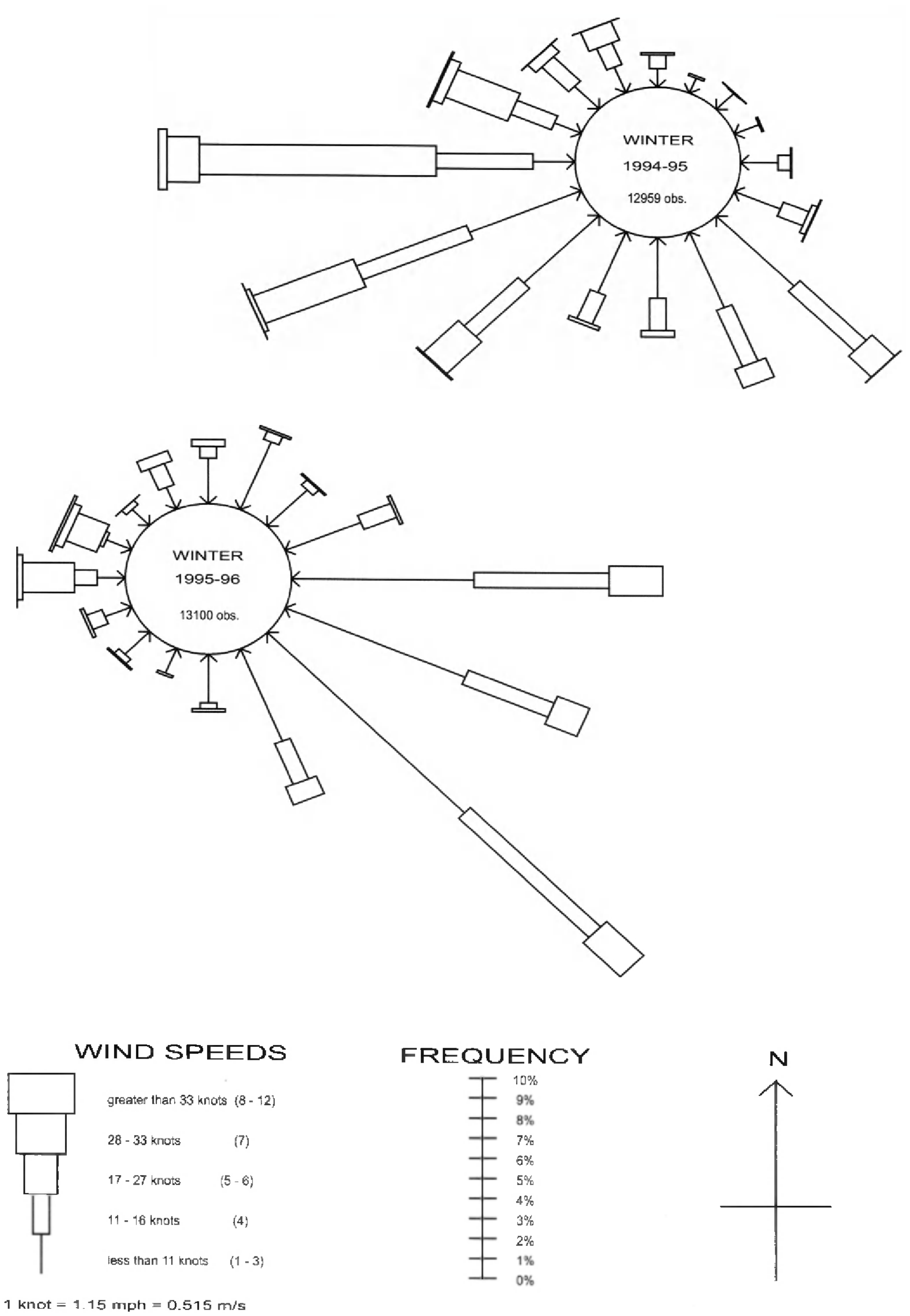
Although there was a high NAO Winter Index value for 1999/2000, there was a reverse to a low value in 2000/01. It is uncertain if the upward trend of the past few decades is part of a natural cycle or reflects a human influence on climate (IPCC, 2001a), or even if it has ceased or reversed.



Frequency, force and direction of winds at Bidston Observatory, Birkenhead

for winter (December to February) of 1994-95 (extreme positive NAO Index) and 1995-96 (extreme negative Index)

Courtesy of Proudman Oceanographic Laboratory



Frequency, force and direction of winds at Bidston Observatory, Birkenhead

for winter of 1999-2000 (positive NAO Index), 2000-01 (negative Index) and winters from 1992 to 2001

Courtesy of Proudman Oceanographic Laboratory

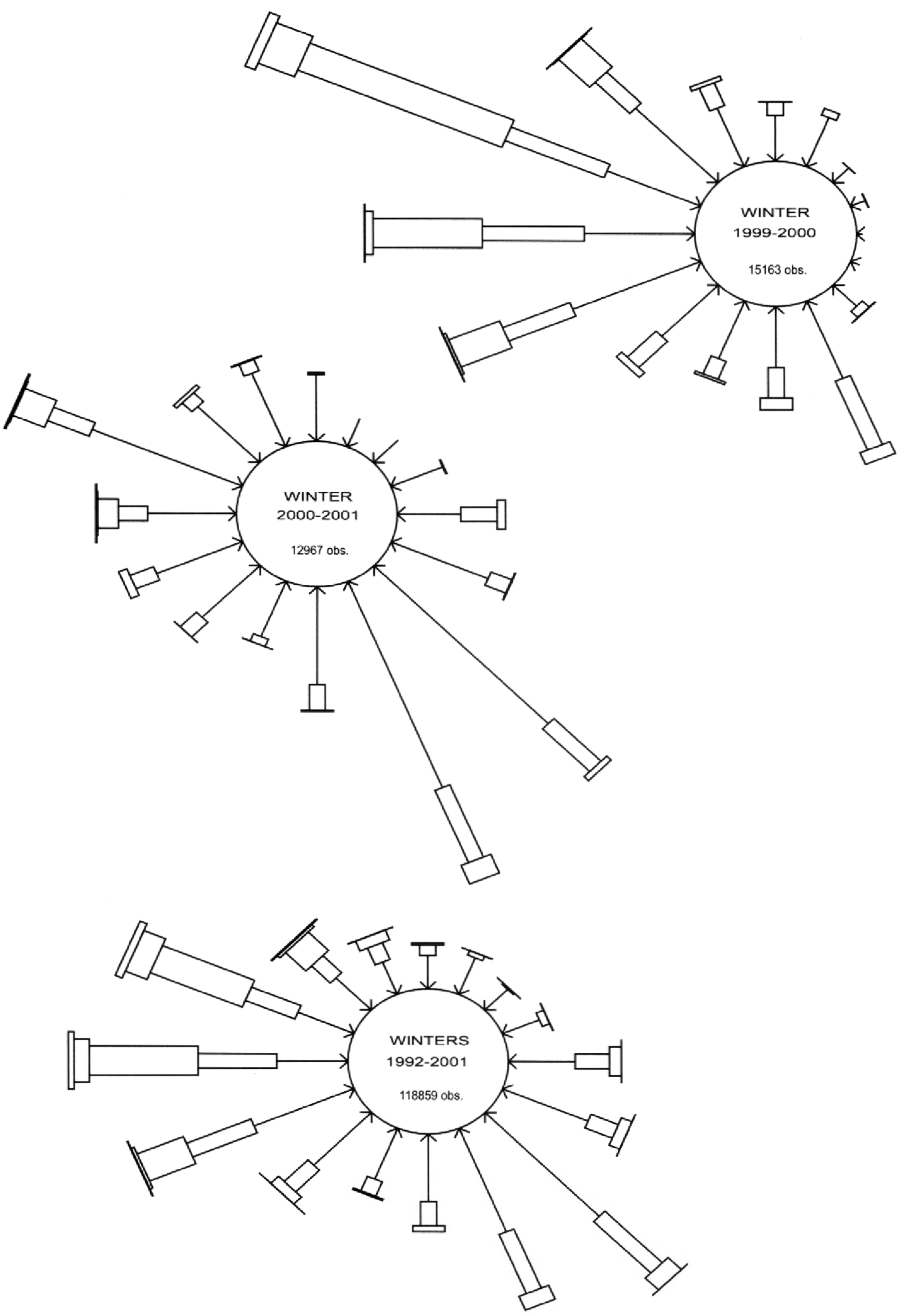


TABLE 2.1

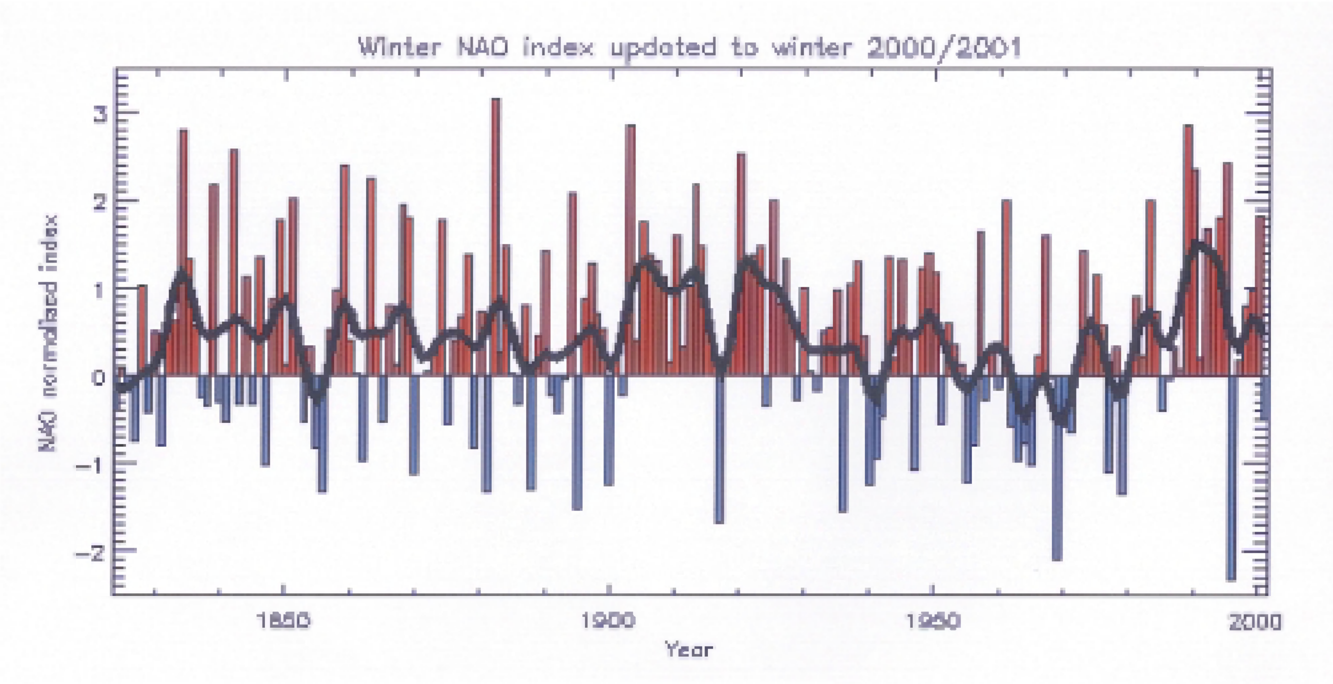
Weather anomalies for 1999. Temperature is the CET record, Rainfall is from the England and Wales Precipitation records, and Sunshine is an UK average from Mike Hulme's monthly Guardian column

	Mean temp (°C) relative to 1961-90	Rainfall (%) relative to 1961-90	Sunshine (%) relative to 1961-90	Brief description
January	+1.7	+40	+15	Mild and very wet
February	+1.5	-24	+42	Very sunny, rather mild
March	+1.7	-6	+14	Mild and rather sunny
April	+1.6	+25	+1	Mild and wet
May	+1.8	-15	-5	Mild, wet in Scotland
June	-0.2	+37	-4	Rather wet, cool in north
July	+1.6	-58	+14	Warm, dry and sunny
August	+0.4	+50	+6	Wet, and sunny in Scotland
September	+2.0	+55	+9	Wet and very warm
October	+0.1	-1	+18	Very sunny in England
November	+1.4	-27	+15	Mild, sunny and rather dry
December	+0.4	+50	+35	Wet, sunny, cold in Scotland
ANNUAL	**+1.16**	**+13**	**+8**	**Warm, wet and sunny**

Table 2.2

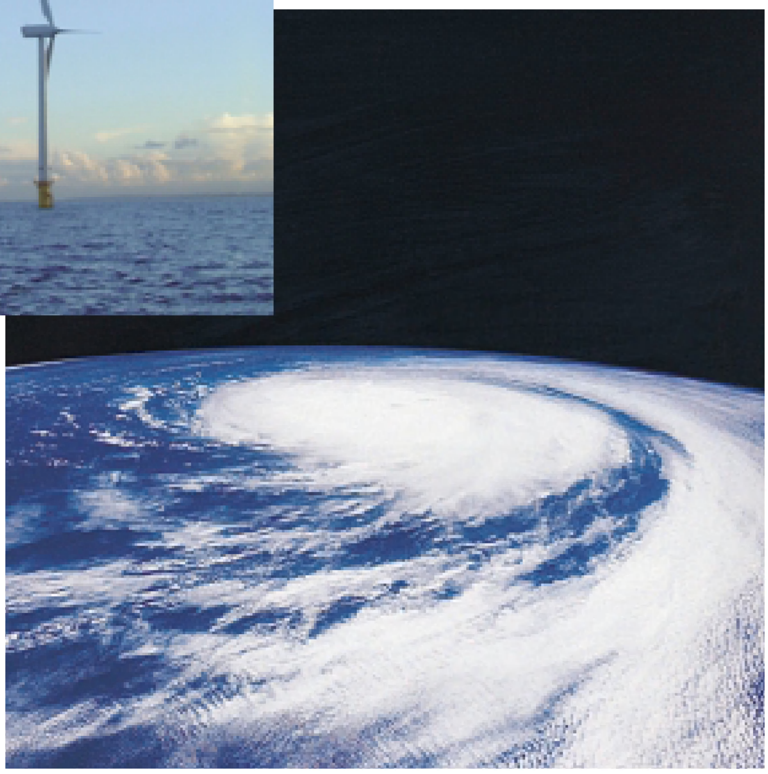
Weather anomalies for 2000

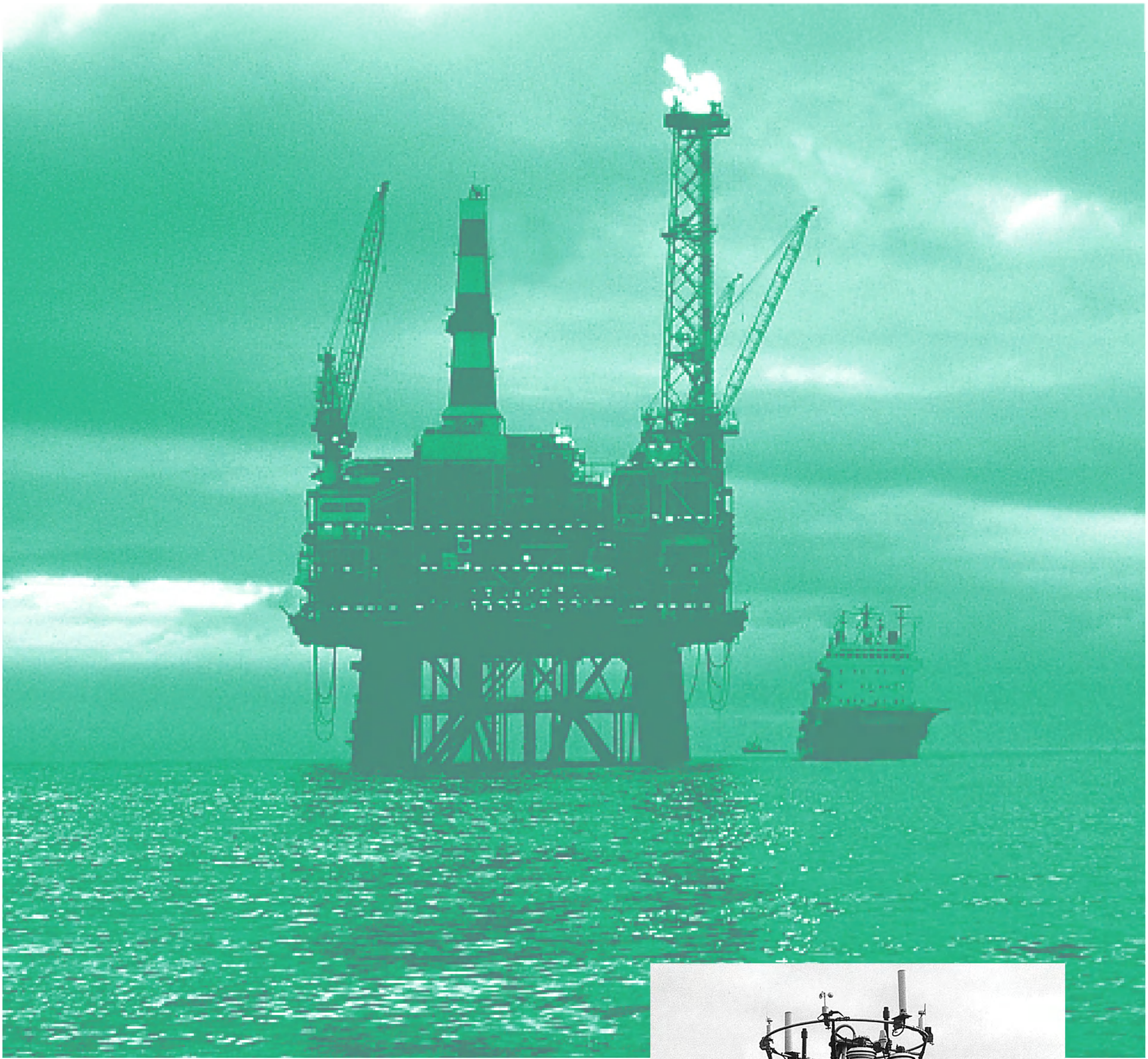
	Mean temp (°C) relative to 1961-90	Rainfall (%) relative to 1961-90	Sunshine (%) relative to 1961-90	Brief description
January	+1.1	-49	+29	Mild, sunny and dry
February	+2.5	+46	+24	Very mild, wet and sunny
March	+1.9	-56	+2	Mild and dry
April	-0.1	+134	-9	Dull and very wet
May	+0.9	+51	+17	Warm, sunny and wet
June	-1.0	-34	-12	Warm in S, cool in N
July	-0.6	+3	-9	Cool in E, dry in Scotland
August	+0.8	-14	+16	Warm, dry and sunny
September	+1.1	+70	-8	Wet, but mild
October	-0.3	+116	+9	Very wet, especially in South
November	-0.0	+98	+9	Very wet, especially in South
December	+0.8	+44	+9	Mild and very wet
ANNUAL	**+0.85**	**+35**	**+4**	**Warm and very wet**



Winter (December to March) NAO index, based on Gibraltar – Iceland data
Courtesy of the Climatic Research Unit, University of East Anglia

Courtesy of Amec Wind



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The Met. Office Marine Automatic Weather Stations (MAWS) Network

The Met. Office has developed a number of early warning systems to help reduce the effects of natural disasters such as flooding due to storms and abnormally high sea levels. One such system is the network of Marine Automatic Weather Stations (MAWS) which are deployed on the edge of the continental shelf in the North Atlantic. Meteorological and oceanographic parameters are collected at hourly intervals and the data transmitted to a meteorological database (MetDB), where they are available to the user community for use in weather forecasts and other Numerical Weather Prediction products. These observations from data-sparse oceanic regions have proved invaluable in routine forecasting, numerical modelling and helping to monitor the development of Atlantic storms.

Over the past couple of years the MAWS network has changed substantially, with the aim of reducing the operational costs of the network, while also improving the quality and range of data acquired. This is being achieved through system upgrades, collaboration, co-operation and, where feasible, the use of other data available from meteorological and oceanographic networks which cover the UK and surrounding waters.

Two new moored buoys

The geographical area covered by the MAWS network has been extended with the addition of two new moored buoys: K7 to the north and Gascogne to the south. K7 was deployed on 8 June 1999 and is being funded by The Met. Office for a year to determine the feasibility of putting and maintaining a buoy in this location on the Faeroes–Shetland channel, where the data are particularly useful to the oil industry. This open-ocean buoy has been modified to provide a platform for a self-contained Acoustic Doppler Current Profiler (ADCP), in a collaborative project with a commercial company — Fugro Geos. Fugro Geos supplied the sensor and are analysing the data collected, to assess the feasibility of collecting this type of current measurements as either real-time observations or logged data sets. External funding to help support K7 as part of the network is now being sought.
The Gascogne buoy was deployed during July 1998 in the southern Bay of Biscay in a two-year joint venture with Météo-France. It is anticipated that the project will continue, as it is providing vital information in an area that is difficult to model because of the steep bathymetry.

Future developments

To ensure the future feasibility of the MAWS systems, the project team is looking into a number of new developments in response to the UK Observational Network user requirement, including spectral and directional wave measurements from marine platforms. An experimental open-ocean buoy with two spectral and directional wave sensors was deployed for a one-year trial in St. Brides Bay in south-west Wales on 15 July 1999, in close proximity to a Datawell Waverider Buoy operated by the Countryside Council for Wales. Data from the wave sensor will be compared with the Waverider data and the current operational heave sensor data. The experimental buoy also incorporates various hardware and software modifications with the aim of increasing the functionality and improving the overall reliability of the open-ocean buoy platform, thus reducing operational costs. Future modifications to the operational open-ocean buoy system will depend on the results of this trial.

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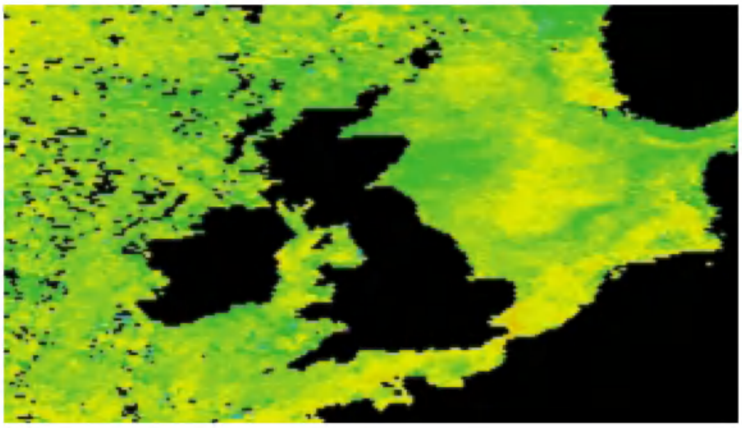
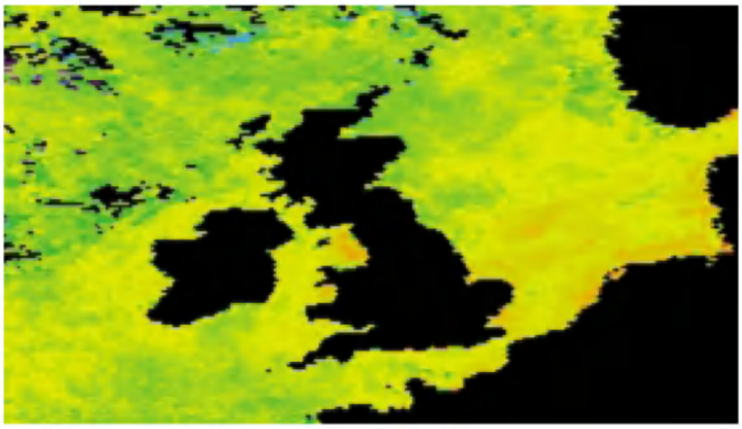
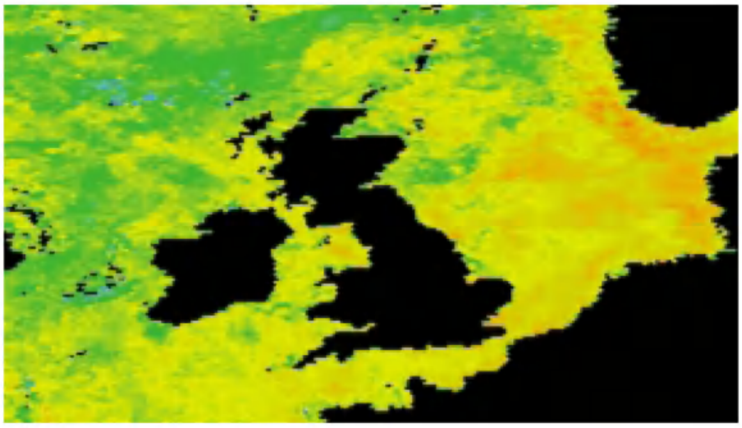


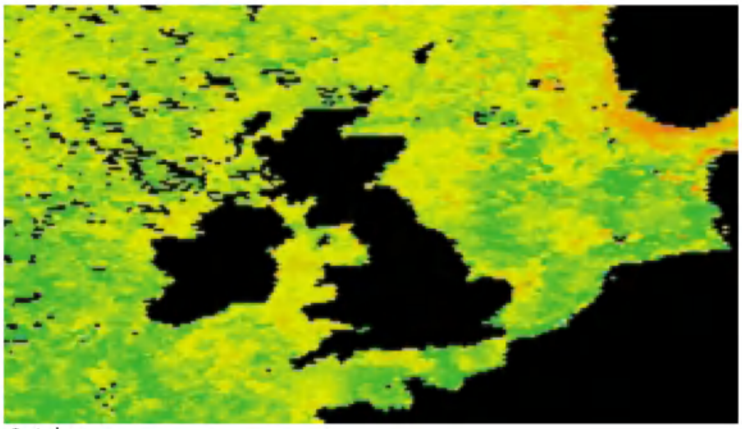
January



April



July



October

Sea Surface Temperature anomalies for January, April, July and October 1999 calculated by subtracting the 1987–1999 mean monthly SST from the individual monthly SST. The raw data were obtained on an equal angle projection; means were calculated from the night time data exclusively and compared with the night time monthly images.

Scale bar in ^{0}C

Courtesy of the Plymouth Marine Laboratory and NASA's Pathfinder project

3. SEA TEMPERATURE

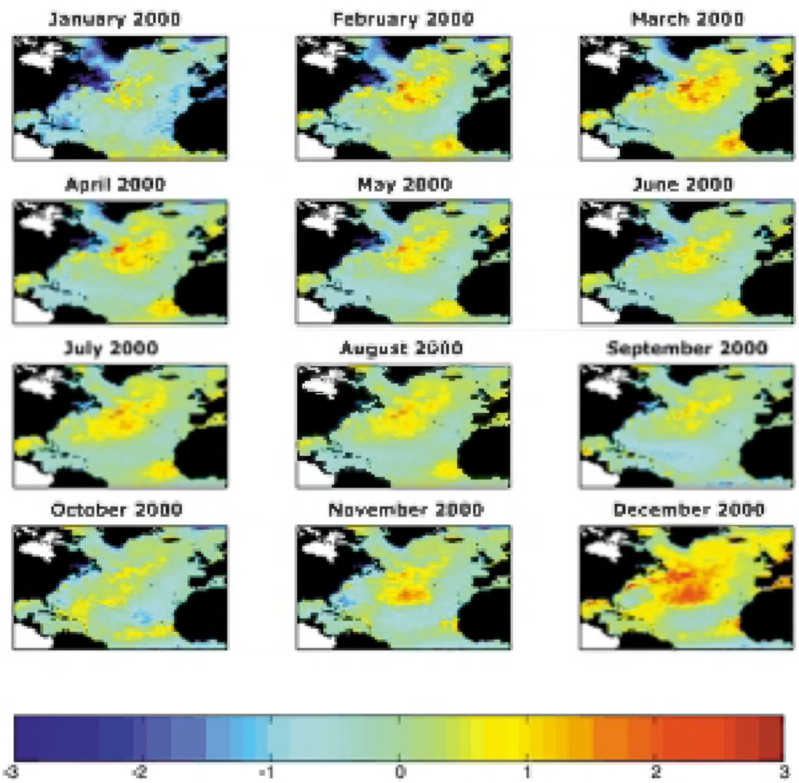
Sea temperatures in UK waters are affected by changes in the local surface heat exchange, local wind field and freshwater run-off, especially in the shallower regions of the Irish and North Sea. A significant influence is also the inflow of Atlantic Ocean water onto the continental shelf, related to westerly wind flow and hence the strength of the NAO.

Driven by atmospheric warming, the global ocean has warmed since the 1940s, with an increase of about 0.036°C per decade in the upper 300m (IPCC, 2001a). There was a notable warm period in the North Atlantic from 1925 until 1960, probably not related to the NAO (ICES, 2001). However high sea surface temperatures in the Atlantic were associated with the relatively high NAO index during the 1980s and 1990s. In 2000, warming episodes in the Atlantic were particularly marked from February to May and November to December.

The longest continuing records in UK waters (Dover, Eastbourne and Port Erin) show an increase in temperature of about 0.6°C over the last 70 to 100 years. The long records from the Newarp and Seven Stones Light Vessels, discontinued in 1986, also show a warming trend since the late 19th Century, but the latter has a cooling of about 1.5 °C from the early 1970s to 1986 (which invites further investigation). The Humber LV and E1 records both show a slight cooling from the late 19th Century to the late 1980s when measurements ceased.

Shorter records of both bottom and surface temperature generally show warming of up to 0.5°C per decade since the 1960s/1970s, but there is considerable inter-annual variability. The measurements at the St. Gowan Light Vessel show a cooling of about 0.1°C per decade from 1953 to 1987 when measurements ceased.

Temperatures for 1999 and 2000 were above the long-term averages at most stations, but lower than in previous years. Based on remote-sensing, the sea surface temperature in UK waters generally was warmer in 1999 than the 1987-1999 mean by up to 2°C. (Data for 2000 is not yet available.) The annual mean sea surface temperature in the North Sea in 2000 was the sixth warmest since 1971 (ICES, 2001).

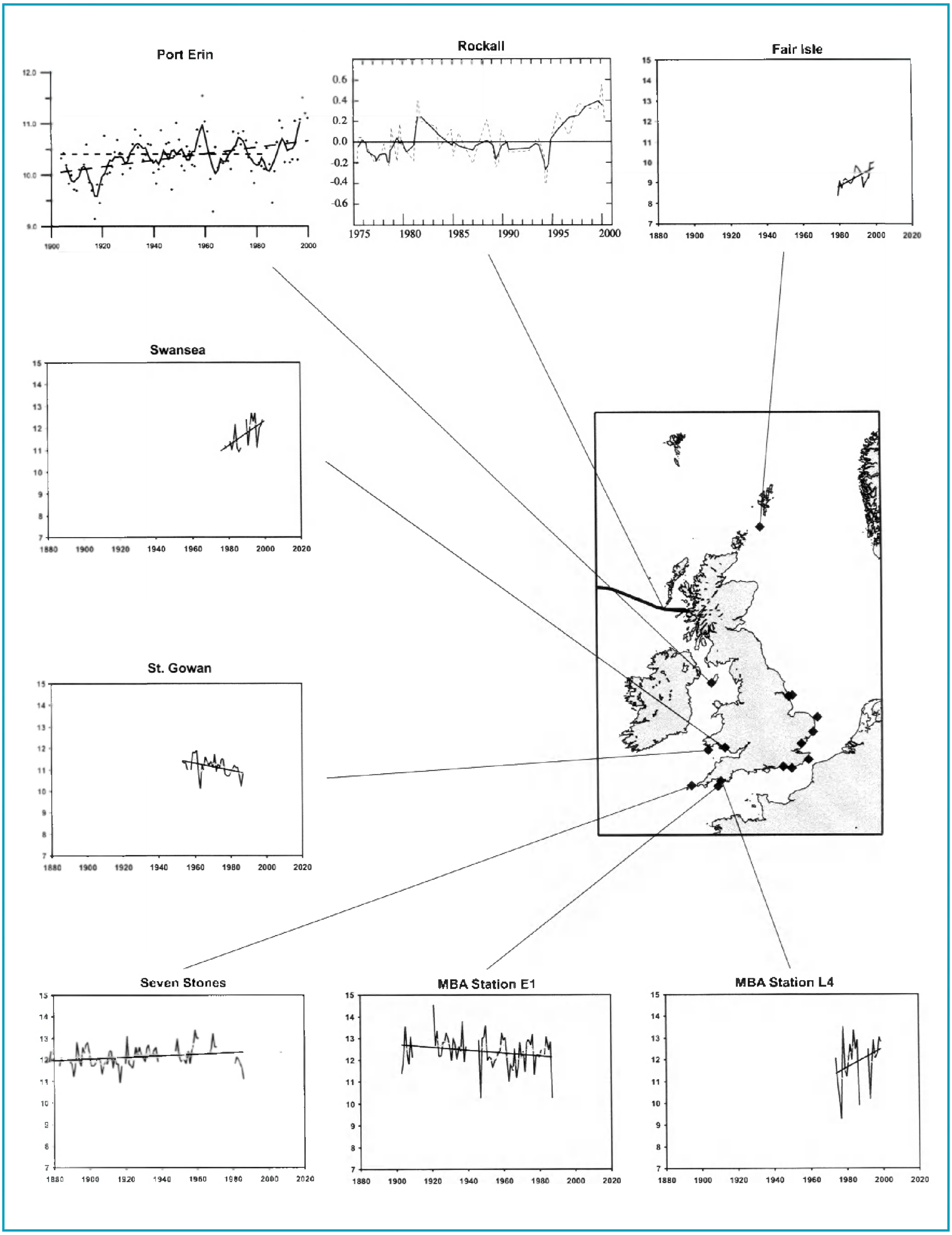


Monthly sea surface temperature anomalies, from the Multi-Channel Sea Surface Temperature (MCSST) data set derived from the 5-channel Advanced Very High Resolution Radiometers (AVHRR) on board the NOAA-7, -9, -11 and –14 polar orbiting satellites.

Warming episodes are particularly marked from February through May 2000 and November through Dec 2000.

Scale bar in °C

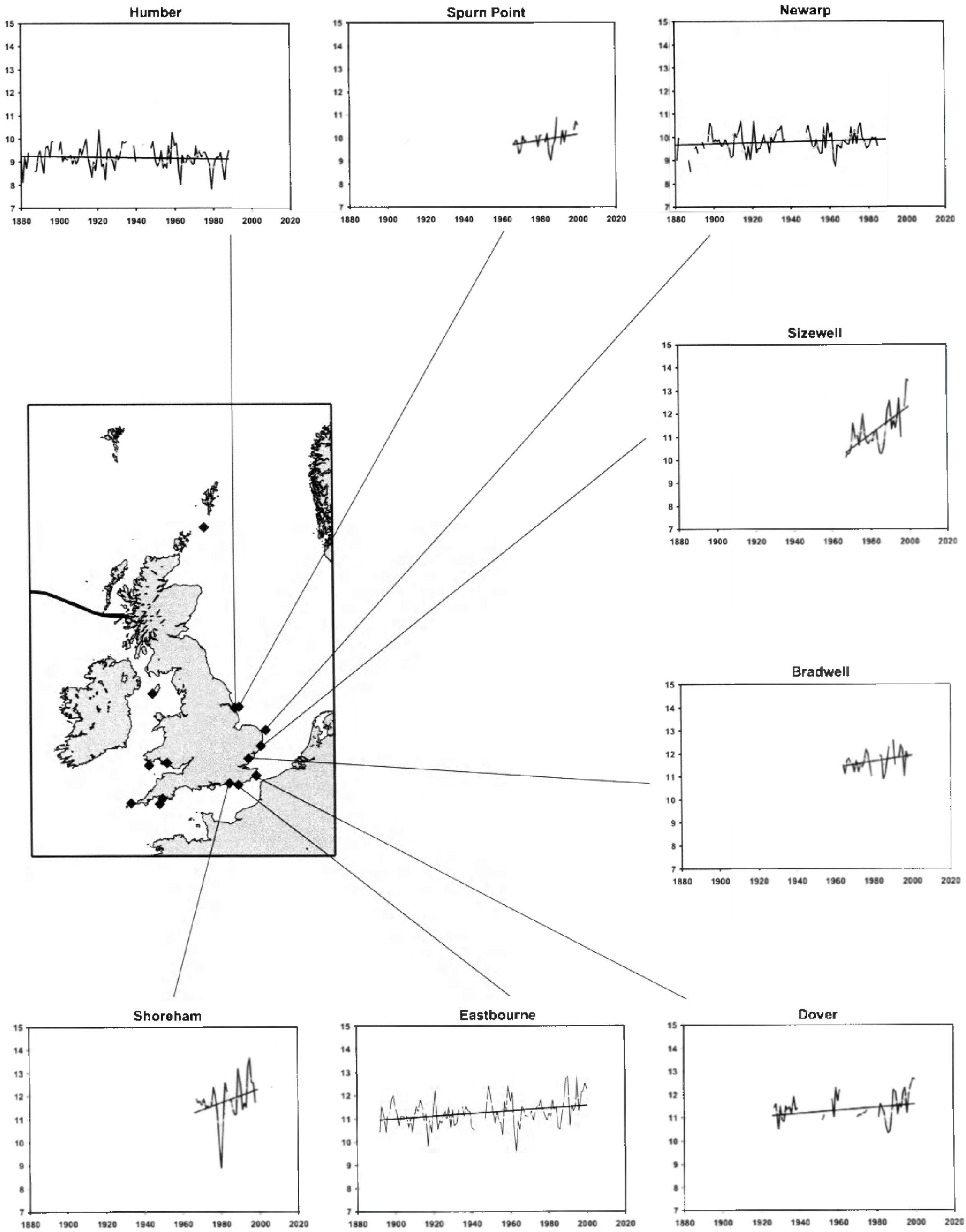
Courtesy of Southampton Oceanography Centre and NOAA



Annual SST °C (with best fit line) **in the Celtic Sea, Irish Sea and NW Approaches**

Rockall (de-seasoned averages over the upper 800m, with no best fit line)

Courtesy of CEFAS, Dunstaffnage Marine Laboratory, Fair Isle Marine Environment & Tourism Initiative, Plymouth Marine Laboratory, Port Erin Marine Laboratory and Southampton Oceanography Centre



Annual SST °C (with best fit line) in the North Sea and English Channel

Courtesy of BNFL, British Energy Generation, CEFAS, CEGB, Dover District Council and Eastbourne Borough Council

Faeroe-Shetland Channel – over 100 years of observations

Hydrographic Surveys along two standard lines crossing the deep-water channel lying between the European continental shelf and the Faeroese Plateau (the Faeroe-Shetland Channel) commenced in 1893. The first surveys were conducted by Dr. H. N. Dickson of the Fishery Board for Scotland, in support of international multi-disciplinary studies in the northern North Sea and north east Atlantic, which subsequently resulted in the formation of the International Council for the Exploration of the Sea (ICES). Since the initial surveys, the two lines have frequently been re-sampled by Scottish, Norwegian, Swedish, Danish and Russian oceanographers.

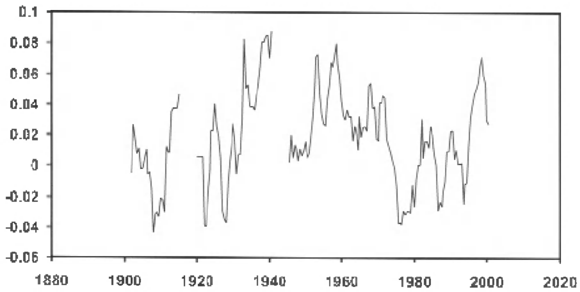
In the past these time series have been used in order to demonstrate oceanographic events such as the Great Salinity Anomaly, and to partly explain observed changes in marine ecosystems within the north west European continental shelf seas. Examples are changes in the migration of mackerel, changes in the distribution and abundance of northern North Sea sand eel populations. Data from the two lines have been used to examine the sources of the waters within the Channel, to estimate transports of mass and heat onto the Norwegian Sea and, more recently, to identify a previously unknown water type in the Channel.

The north-west European shelf edge, west and north of Scotland, is dominated by the pole-ward flowing slope current, carrying Atlantic water towards the Norwegian Sea. This water is the principle source for water crossing onto the shelf, and into the North Sea. The Atlantic water lying at the north-west European shelf edge has been warming since 1987 at a rate of 0.5 degC per decade. Particularly high temperatures were observed in the spring of 1998 but have remained fairly constant, although cooler, since then. The salinity of the Atlantic water reached a maximum in 1998, and has since been reducing.

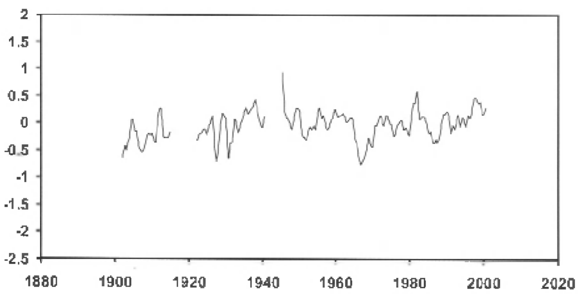
RV *Scotia*
Courtesy of T.G. McInnes, Fisheries Research Services

Faeroe Shetland Channel

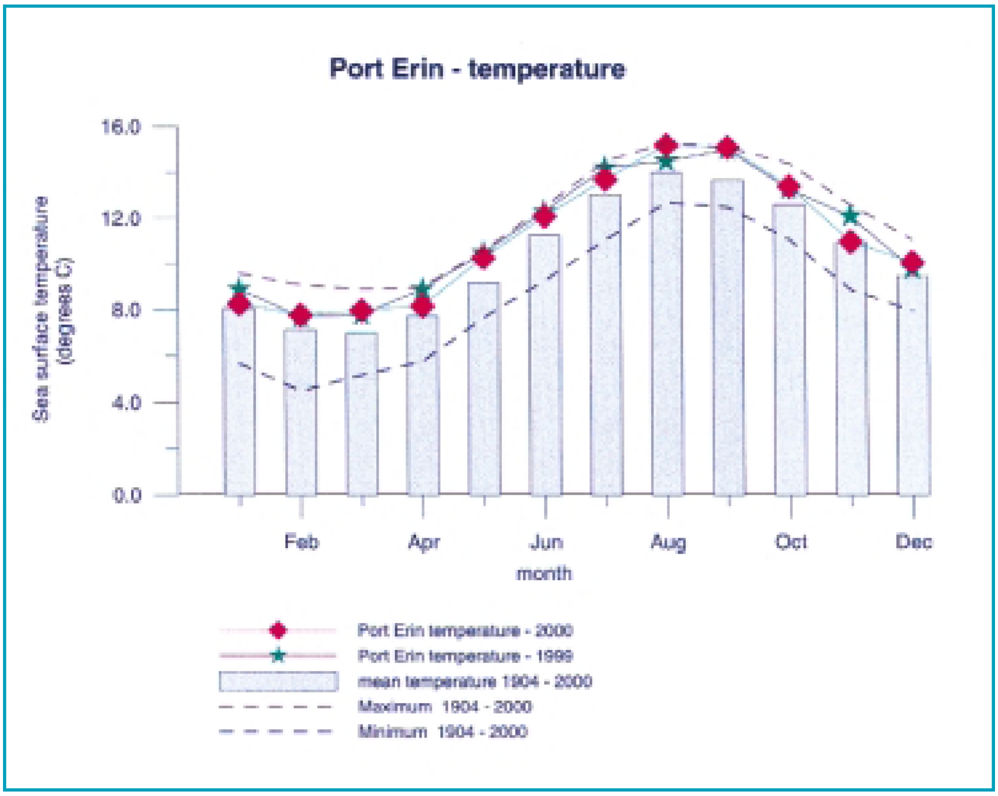
Filtered salinity anomaly



Filtered temperature anomaly



Courtesy of Fisheries Research Services



Surface seawater temperature at Port Erin. Monthly means for years 2000 and 1999, with long-term minima, maxima and monthly means 1904 to 2000.
Courtesy of Port Erin Marine Laboratory

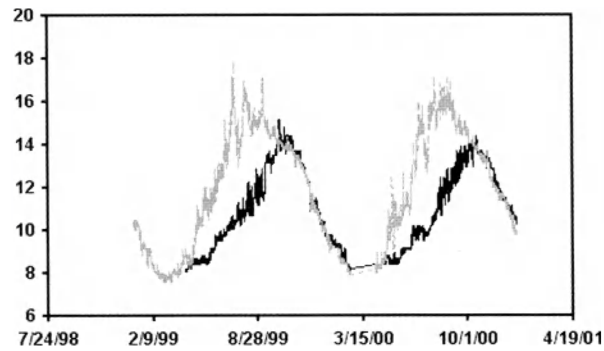
Irish Sea Monitoring by the Department for Agriculture and Rural Development

Monitoring is carried out at several stations in the Irish Sea by the Department for Agriculture and Rural Development, Northern Ireland (DARDNI). Temperature and salinity data from Station 38a (53°47'N, 5 38'W) are shown for 1999 and 2000. The temperature data are from *in situ* thermographs with several readings per day. The salinity data are from CTD casts at the same station. Earlier temperature data also exist extending back to around 1992; this is from CTD casts, not *in situ* monitors.

A second set of data is available from the records of temperature at the cooling water intake at Ballylumford Power Station (54° 50.8'N, 5° 47.3'W). Although the power station sits on Larne Lough, the intake is effectively drawing in North Channel water.

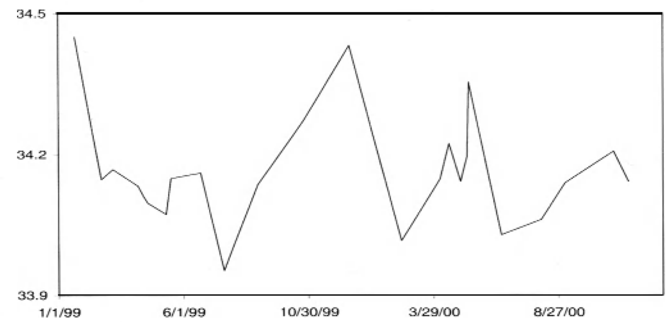
Station 38a

Bottom temperature °C (black line)
Surface temperature °C (grey line)
Courtesy of DARDNI



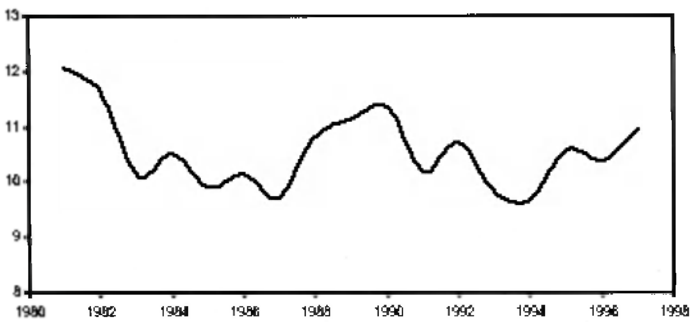
Station 38a

Surface salinity (PSU)



Ballylumford

Sea temperature °C



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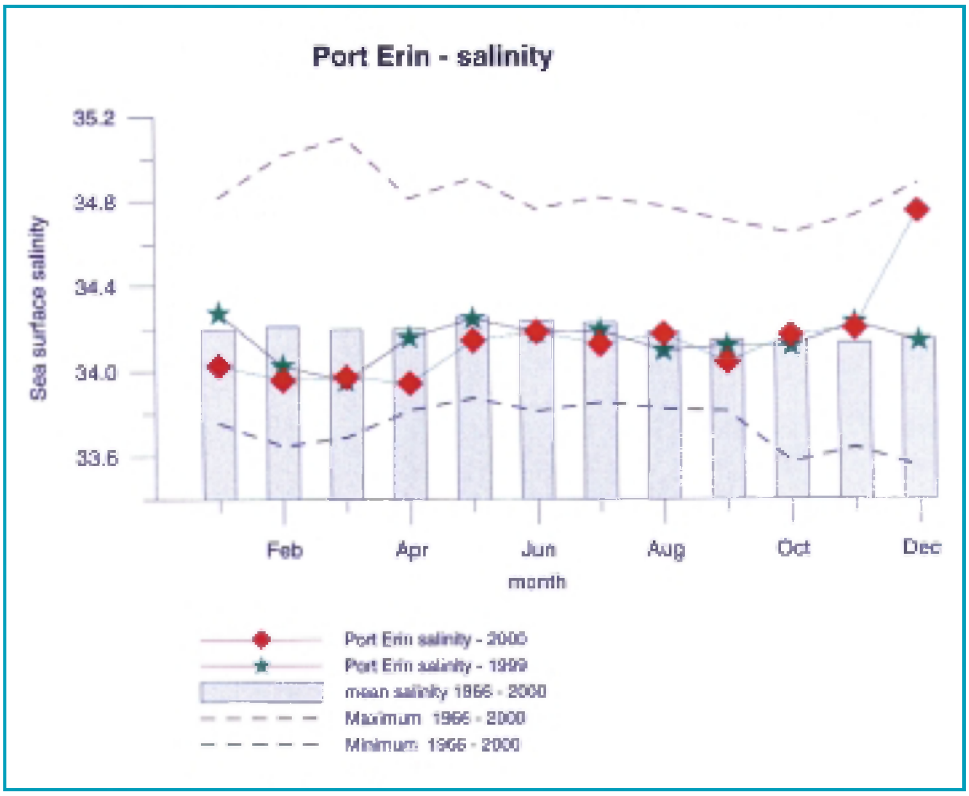
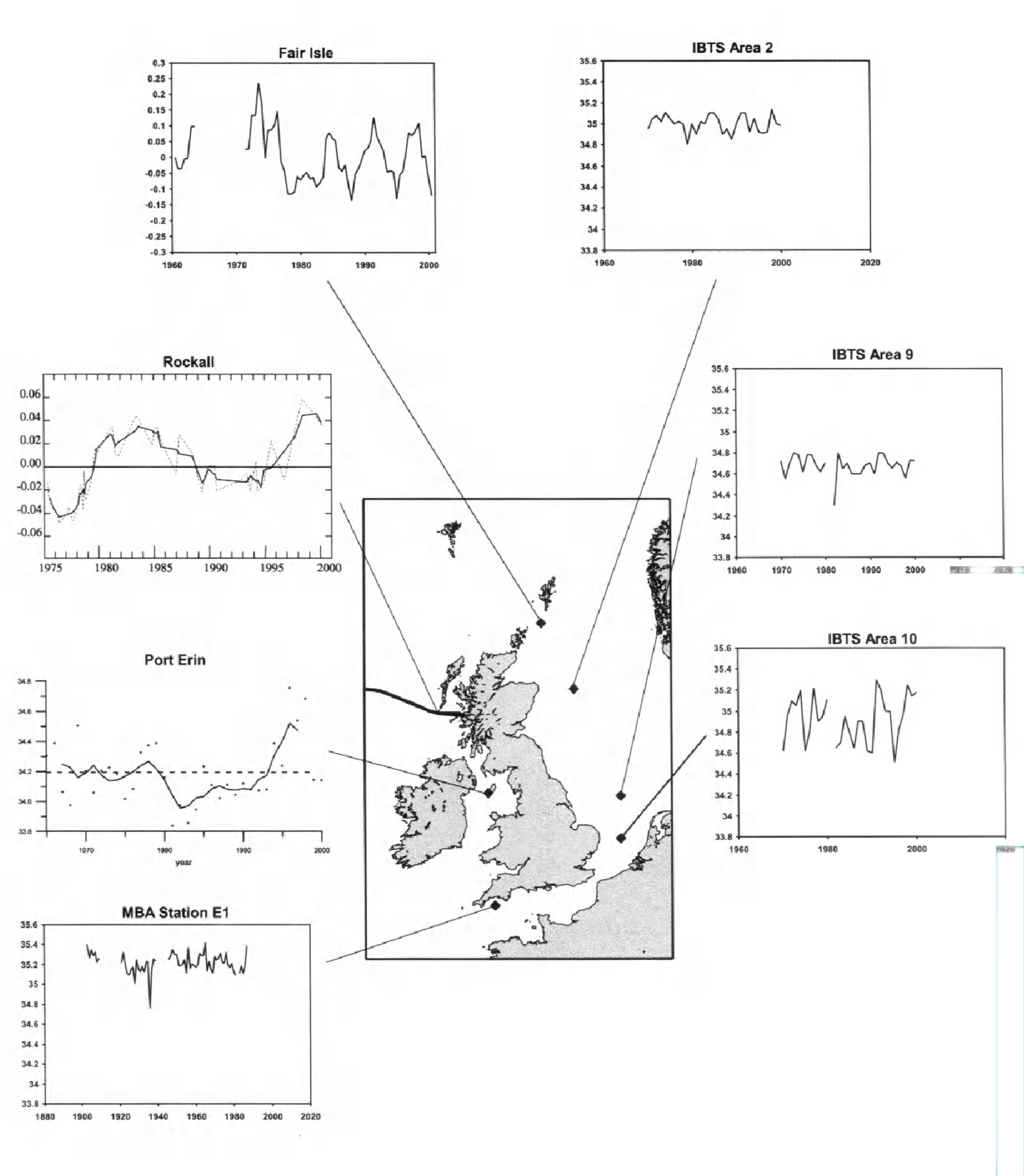
Only a few long-term time series exist for UK waters and these do not indicate any overall long-term trend. Records from the Atlantic waters around the UK (Rockall and the Faeroes-Shetland Channel (see Box)) and the areas on the shelf which are most influenced directly by in-flowing oceanic waters (Fair Isle, E1) reveal a general pattern of low salinity in the mid-late 1970s. This period is known to have been influenced by the passage of the "Great Salinity Anomaly" (Dickson *et al.*, 1988a) as it circulated around the Atlantic and Nordic Seas, and then followed by three decades of quite large inter-annual variability probably closely associated with changes in the NAO. In the shallower areas of the North Sea and Irish Sea, the salinity is much more dependent on local runoff from land and local evaporation / precipitation changes, and hence is much more variable. Salinities in the Rockall Trough rose from 1976 to 1998 but reduced in 1999 and 2000, though remaining considerably above average conditions. The annual means of surface salinities at Port Erin, Isle of Man, in 1999 and 2000 were just below the long-term average. Salinity at Fair Isle was lower in 1999 than in 1998, but data for 2000 was not available. Generally, conditions in the North Sea in 1999 and 2000 were very similar to recent years, with sustained levels of relatively high bottom salinity (ICES, 2001).



Surface seawater salinity at Port Erin. Monthly means for years 2000 and 1999, with long-term minima maxima and monthly means to 1966 2000.

Courtesy of Port Erin Marine Laboratory


Fair Isle
IBTS Area 2
Rockall
IBTS Area 9
Port Erin
year
IBTS Area 10
MBA Station E1

Salinity
Areas 2, 9 and 10 near-bed salinity. MBA station E1 and Port Erin surface salinity. Fair Isle surface salinity relative to zero, as seasonal cycle has been removed and the data has also been smoothed.

Rockall de-seasoned averages over the upper 800m

Courtesy of Dunstaffnage Marine Laboratory, Fisheries Research Services, ICES (International Bottom Trawl Survey), Plymouth Marine Laboratory, Port Erin Marine Laboratory and Southampton Oceanography Centre

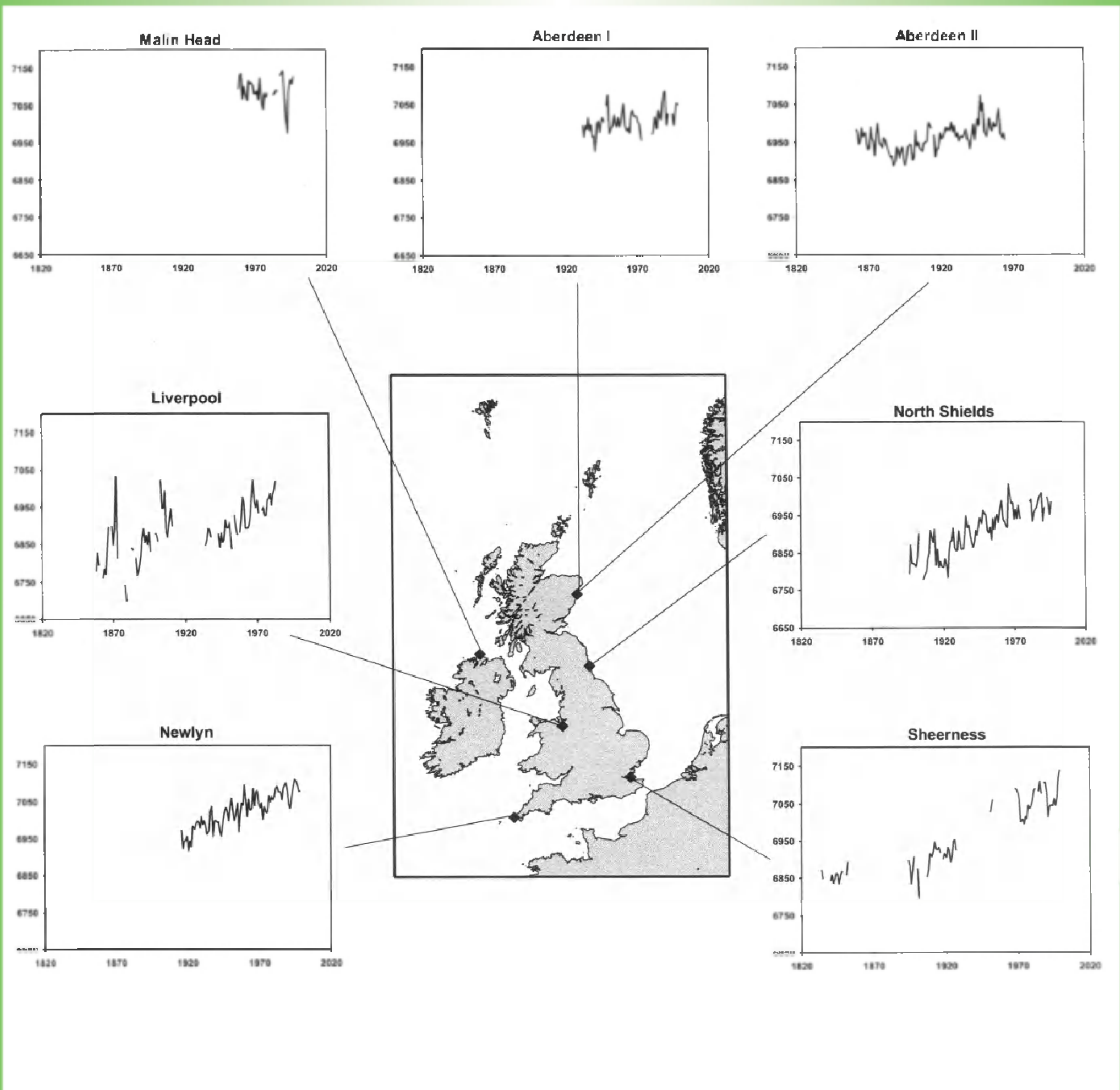
The Sound of Mull to Rockall Section (The 'Ellett' Line)

The success of the Marine Laboratory, Aberdeen, in maintaining a long-time series of physical observations in the Faeroe–Shetland Channel, led J.B Tait (Aberdeen) and A.J. Lee (Lowestoft Fisheries Laboratory, now CEFAS Lowestoft Laboratory) to propose in 1960 that research was needed upstream of the Channel in the then poorly known deep water to the west of Scotland. In response the UK Hydrographic Office arranged for the surveying ship HMS *Dalrympie* to be made available to representatives from both Aberdeen and Lowestoft. G.C. Baxter and J.H.A. Martin worked water-bottles sections across the Rockall Trough from Malin Head to Rockall on ten cruises between August 1963 and November 1965. The same section was subsequently repeated several times by R/V *Ernest Holt* — one of the Lowestoft Fishery Laboratory research vessels.

In the late 1960s, the Scottish Marine Biological Association (SMBA, now the Scottish Association for Marine Science (SAMS)) opened its new laboratory at Oban, on the west coast of Scotland, which had been the point of departure for several oceanographic cruises during the previous century. SMBA proposed a programme of work in the adjacent deep waters, and the new research ship RRS *Challenger* which was being built for the laboratory by the Natural Environment Research Council (NERC) was lengthened on the stocks so that she could be used to undertake these studies. Once *Challenger* was ready for service, a full programme of physical oceanography was initiated, and between May 1975 to January 1996 a section from the shelf-edge west of South Uist to Rockall, crossing the Anton Dohrn Seamount, has been regularly profiled with a CTD. This section traverses the narrowest part of the Rockall Trough, so its 20 stations can usually be completed within 40 hours - an important consideration in an area traversed by depressions on a roughly 5-day cycle throughout much of the year. Up until May 1993 the section has been attempted 43 times and completed on 29 occasions. Since January 1996 the section (excluding the shelf) has been surveyed approximately annually on cruises operated by the Southampton Oceanography Centre.

Although these observational programmes in the Rockall Trough have spanned only three decades, compared with the century of observations available from the Faeroe–Shetland Channel, they have already shown the occurrence of significant variations. The time coverage can be extended using the 45 years of observations of surface temperature water and salinity made mostly by UK Ocean Weather Ships on passage through the area. In addition, between the early 1960s and the 1990s the Weather Ships have made regular observations of the water column while on station to the south and west of the Rockall Plateau.

back



Malin Head
Aberdeen I
Aberdeen II
Liverpool
North Shields
Newlyn
Sheerness
7150
7050
6950
6850
6750
6650
1820
1870
1920
1970
2020

5. SEA LEVEL

Based on tide gauge data, global mean sea level (MSL) rose by about 1.5 mm per year during the 20th century (IPCC, 2001a). The increase in ocean volume, and hence sea level rise, was mainly due to a reduction in density due to ocean warming (i.e. a thermal expansion) and an increase in the ocean mass due to the melting of land-ice in glaciers, ice caps and ice sheets.

Based on the coherent variability in sea level changes around the British Isles (BI), Woodworth *et al*. (1999a) have derived a 'BI sea level index' as a guide to the 'average state' of MSL in UK waters. The index is computed from the five longest UK MSL records at Aberdeen, North Shields, Sheerness, Newlyn and Liverpool, detrended over the period 1921 to 1990 to remove low-frequency contributions. All five stations show a positive trend in MSL relative to the land, similar to most UK stations. Lerwick, Belfast and the Irish station at Malin Head have zero or negative trends, but the latter's large recent dip is probably instrumental (Woodworth *et al*., 1999a).

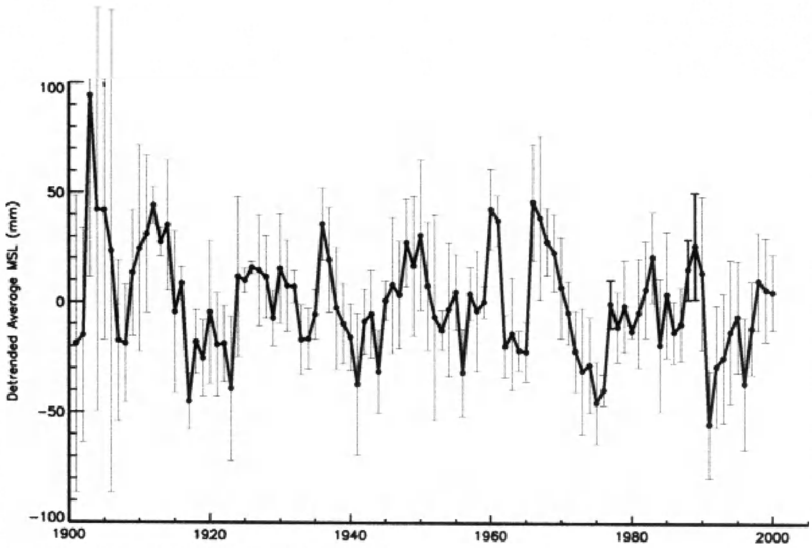
Mean sea level mm

Courtesy of the Permanent Service for Mean Sea Level

The inter-annual changes in the index are related to changes in local meteorological forcing (storm surges) and to oceanographic changes in shelf and nearby deep ocean circulation. The index shows a 'mid-1970s dip', which exists in all UK records, and also dips around 1920, 1940, 1962 and the early 1990s; with the latter as deep as the 'mid-1970s' dip. The generally negative values in the latter part of the index indicate that sea level is now rising on average less fast than over the base period of 1921-1990.

Surges are non-tidal variations in sea level caused by changes in atmospheric pressure and associated wind stress. Storm surges are generated by major meteorological disturbances, and can result in sea level changes of up to several meters lasting a few hours to days. Surge statistics from Liverpool show no long-term changes over the period 1768 to 1999 (Woodworth and Blackman, 2001). Also, surge data from Newlyn (1915 to 1985) and Southend (1929 to 1980) show no significant long-term trends (Vassie, personal communication) and therefore no evidence for a change in storminess in the North Atlantic or North Sea.

Trends in UK extreme sea levels, approximately 1mm per year, match MSL trends closely (Dixon and Tawn, 1992). Woodworth (1999b) found no significant increase in extreme high waters at Liverpool from 1968-93, other than what can be explained in terms of changes in local tidal amplitudes, MSL and vertical land movement.



British Isles sea level index

Courtesy of the Permanent Service for Mean Sea Level

Courtesy of Colin Bell,
Proudman Oceanographic Laboratory

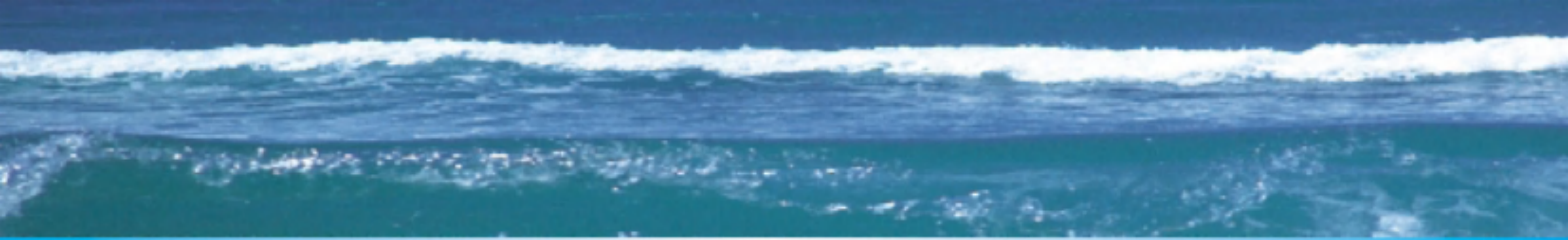
The UK National Tide Gauge Network

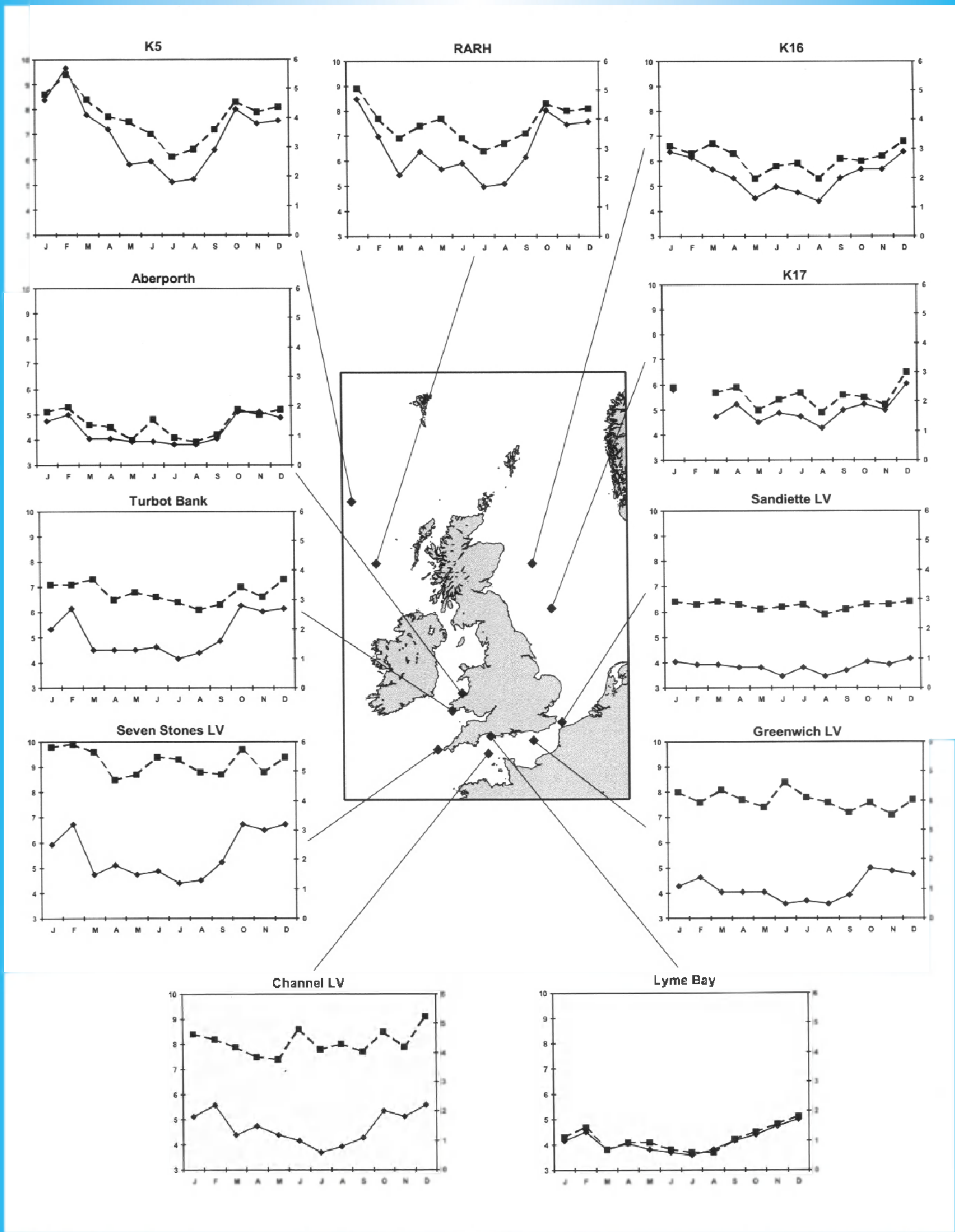
The UK national network of 'Class A' sea level gauges was established after violent storms in the North Sea in 1953 resulted in serious flooding in the Thames Estuary. The network comprises 44 gauges related through the national levelling network to Ordnance Datum Newlyn. The Proudman Oceanographic Laboratory (POL) is responsible for modernising and maintaining this network, with the objectives of obtaining high quality tidal information through telemetry and to provide warning of possible flooding of coastal locations around the British Isles. Data are collected, processed and banked centrally by POL to provide long time-series of reliable and accurate sea levels. These data are required for research and operational use and to facilitate specific scientific studies of coastal processes such as tidal response, storm surge behaviour and sea level rise; and for underpinning local and national operational systems such as the Storm Tide Forecasting Service at the Meteorological Office. They also have wide applications in climate change studies and contemporary modelling scenarios.

In addition to the data collected by the tide gauges, measurement of vertical land movements using continuous GPS and absolute gravity are undertaken at key UK tide gauges and in the area of the maximum post-glacial rebound in Scotland to enable the separation of the absolute and relative sea level trends and the determination of their spatial variations.

The Tide Gauge Inspectorate based at POL is responsible for the operation, maintenance and development of the tide gauge network. With the need to improve data acquisition and the ability to identify and respond to faults in the network, a centralised data collection and monitoring system was designed and developed. A number of sites also feed in wind speed and wind direction data. Further details can be found on the **POL web site (www.pol.ac.uk).**

The British Oceanographic Data Centre (BODC) has a special responsibility on behalf of POL for the remote monitoring and retrieval of quarter hourly sea level data from the National Tide Gauge Network. Daily checks are kept on the performance of the gauges. Any problems arising at the remote sites can therefore be quickly identified by the interrogating computer and appropriate action taken to minimise data loss. The data are downloaded weekly. These are then routinely processed and quality controlled prior to being made available for scientific use.




K5
RARH
K16
Aberporth
K17
Turbot Bank
Sandiette LV
Seven Stones LV
Greenwich LV
Channel LV
Lyme Bay
J F M A M J J A S O N D

Monthly mean wave data for 2000, from the Marine Automatic Weather Station Network

RH axis and solid line = Wave height (metres). LH axis and dotted line = Wave period (seconds)

Courtesy of the Met. Office

Reliable measurements of wave height in UK waters are available only since the 1960s. Analyses show a large spatial and temporal variability, but indicate an apparent worsening of the wave climate between the 1960s and 1990s. For example, wave height increased by about 2m from 1962 to 1985 off Land's End (Carter and Draper, 1988), correlated with air pressure gradients (Bacon and Carter, 1993).

Based on measurements over the last 30 years, in the northern North Sea there has been an upward trend in mean significant wave height for January–March. For the central North Sea, there is a suggestion that the trend for January–March is upwards until 1993/94, but the October–December means peak around 1982/83 and 1983/84, with a similar high value in 1999/2000. For the southern North Sea, there is no discernible trend in wave height for January–March and only a slight indication of a downward trend from 1980/81 for October–December.

Some of the inter-annual variability in wave height could be associated with the North Atlantic Oscillation, with high Index values associated with increased wave height compared to low Index values. Further, the increase in mean wave height between the 1960s and the 1990s could be related to the predominantly positive phase of the NAO during this period, with increased intensity and mean westerly wind speed.

The relationship between monthly wave heights and wind speeds, measured by satellite altimetry since 1985, has been used to examine the correlation between the NAO Index and wave statistics in UK waters (David Cotton and David Woolf, personal communications). The relationship at Holderness is insignificant, indicating that the North Sea coast of the UK is not well coupled to the NAO in terms of wave activity, but analysis of satellite and *in situ* data indicate a strong relationship in the northern North Sea (December–March). The wave climate in Lyme Bay, the Celtic Sea and the Irish Sea is also sensitive to the NAO, and a large area to the west of Ireland and Scotland is very highly correlated on a monthly basis with the NAO throughout the winter. Thus the winters 1992/93, 93/94, 94/95 were "rough" off NW Scotland, calmer in 1995/96 when the NAO Index was negative, and rough again in 1997/98.

In the North Sea, satellite data indicate a consistent trend in the day of maximum wave height, increasing northwards from late December at 52^{o}N to mid January at 62^{o}N (David Carter, personal communication).

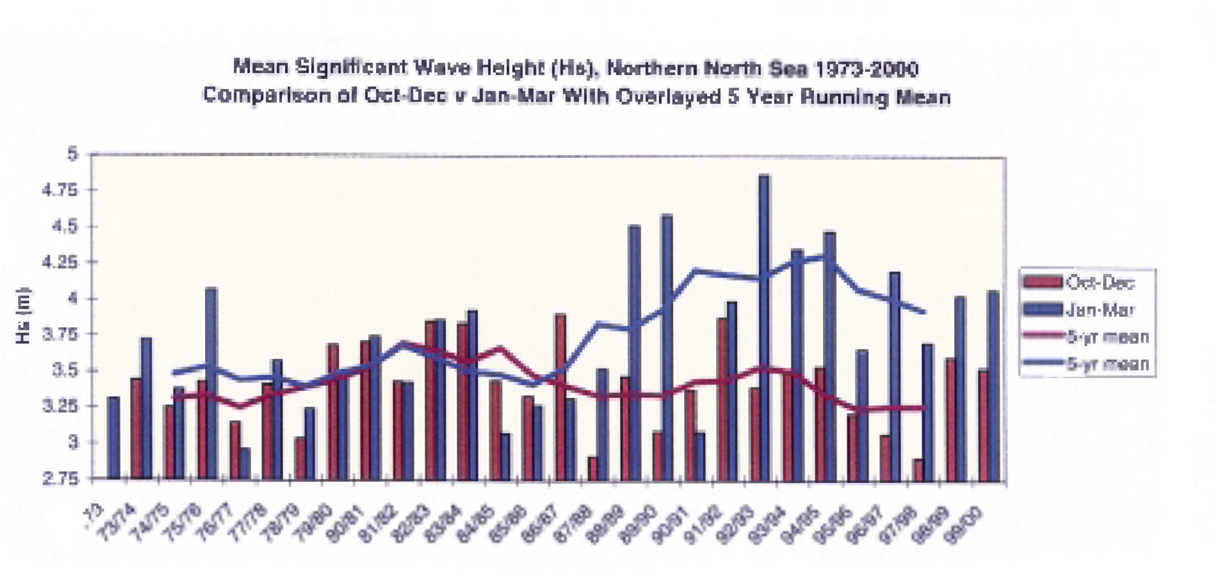
Shell U.K. Meteorological and wave monitoring network (METNET)

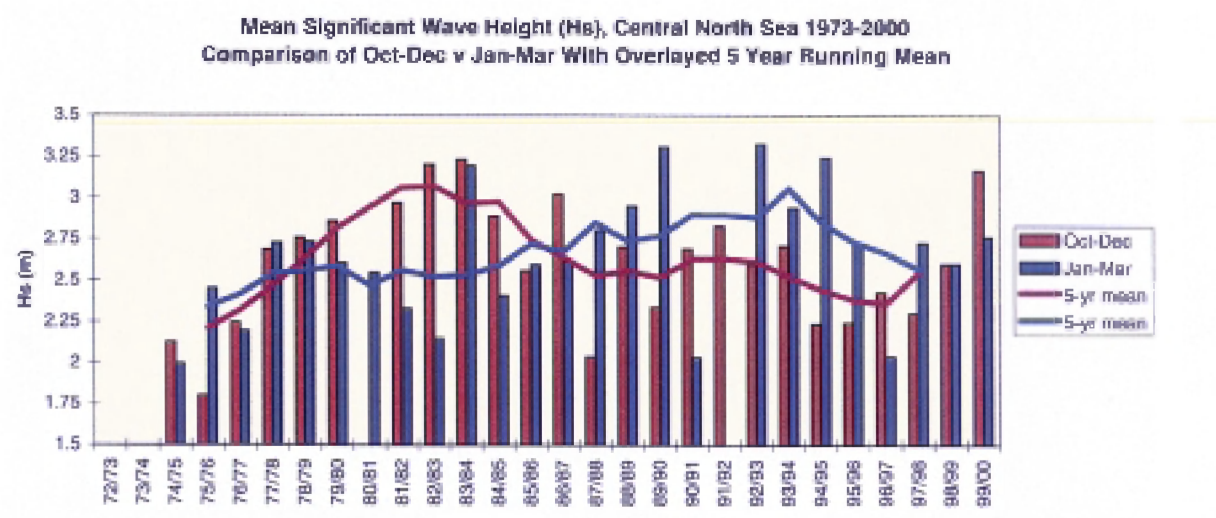
Shell U.K. Exploration and Production Ltd. operate METNET on 20 installations in the North Sea. The majority of the stations were installed in the late 1970s / early 1980s, and upgraded in the mid 1990s. Measurements include wind speed and direction, atmospheric pressure and temperature, humidity, precipitation, cloud height and visibility, with wave measurements taken from both radar and buoy-based systems.

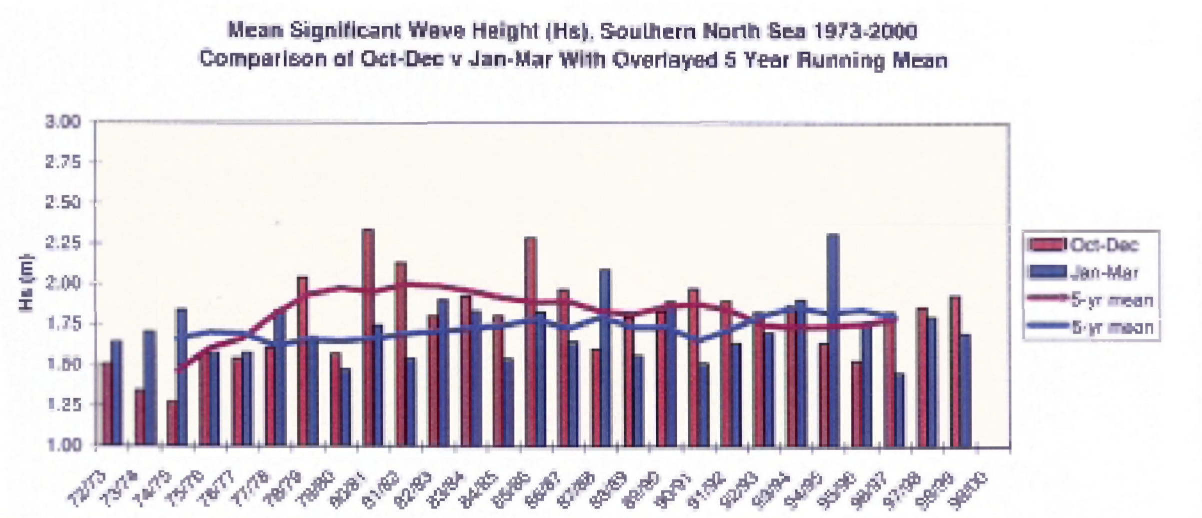
Real time data is used to aid platform, marine and aviation operations offshore, and is sent over a telecommunications network to Shell's UK headquarters in Aberdeen, for quality control and data management. Some data is sent from Aberdeen to other users, e.g. the Meteorological Office.

Mean Significant wave height in the North Sea

Courtesy of Shell UK Ltd

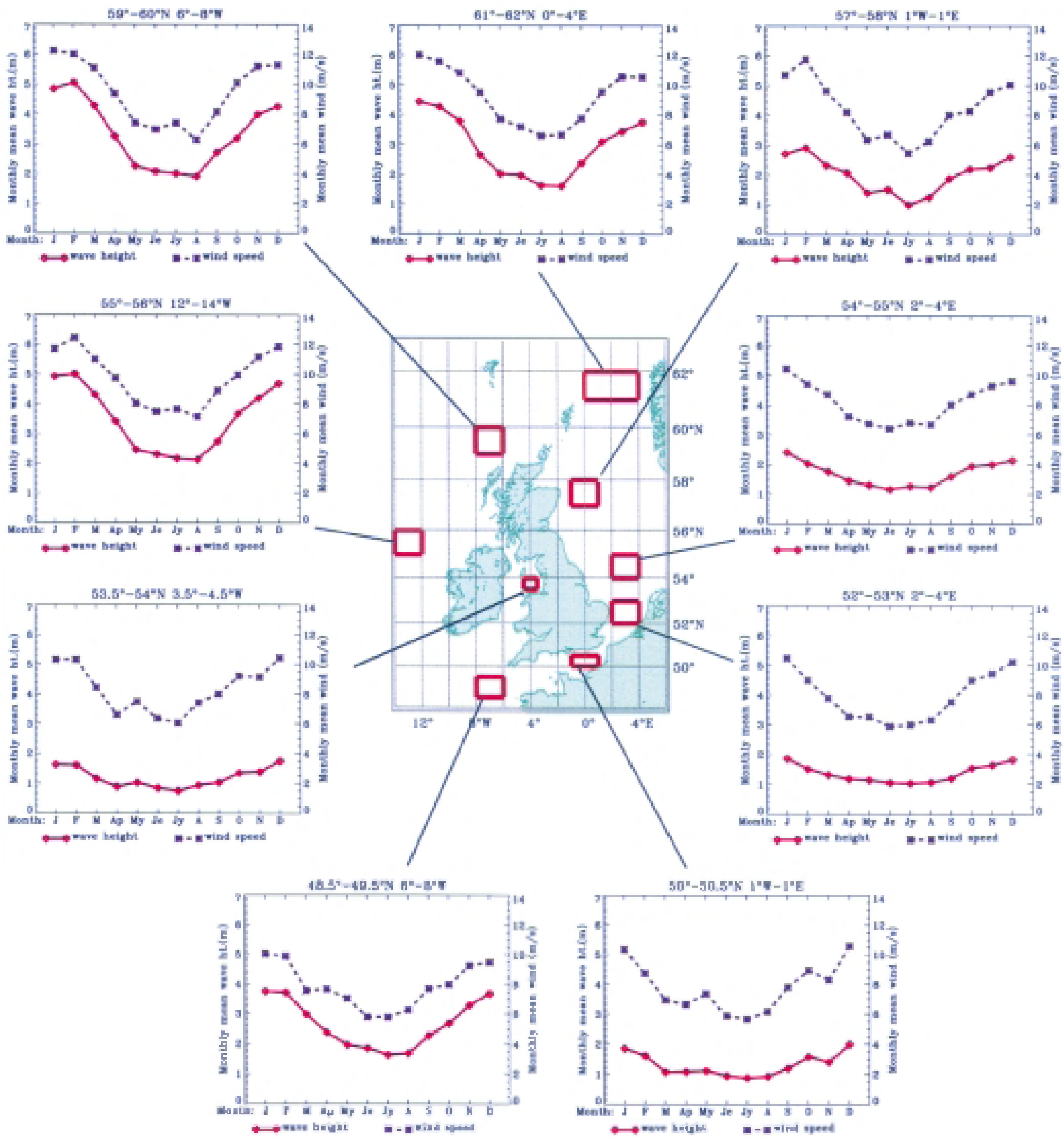






Monthly mean wave heights and wind speeds

from ERS-2 and TOPEX-Poseidon altimeter data, 1985 onwards.
The location box indicates the area of averaging.
Courtesy of Satellite Observing Systems Ltd



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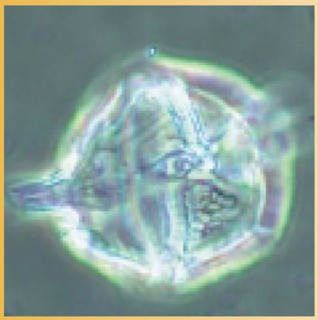
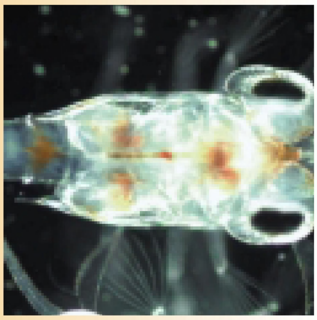
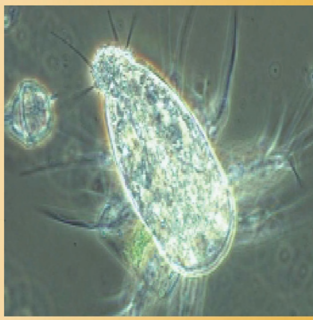
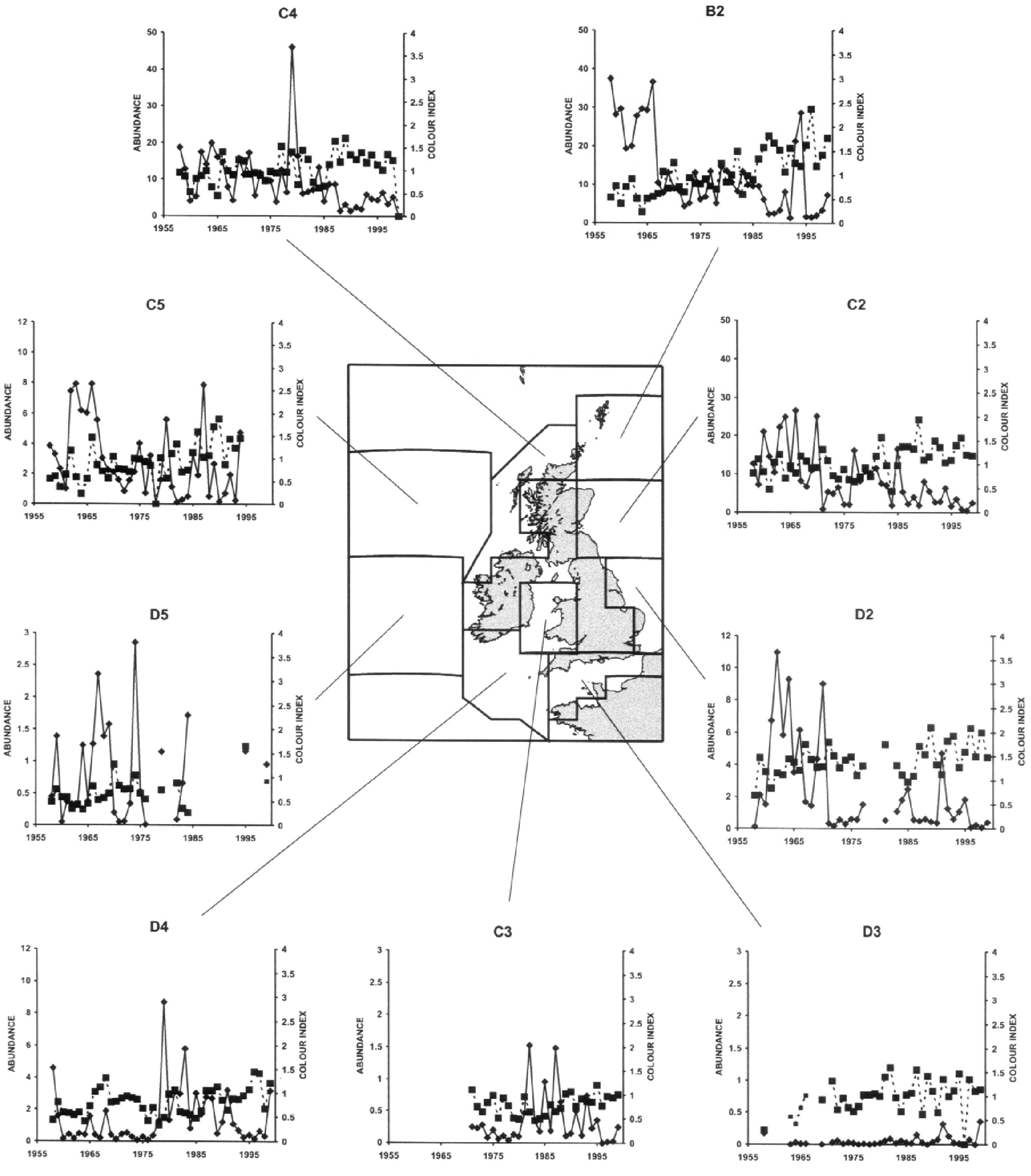





Plankton images
Courtesy of Karl Embleton SAHFOS



Annual abundance of zoo and phytoplankton
Left scale and solid line is abundance of *Calanus finmarchicus,* right scale and dotted line is Phytoplankton colour index. Note changes in abundance scale.

Courtesy of SAHFOS

The abundance of the zooplankton *Calanus finmarchicus* (a small shrimp-like crustacean) has shown a pronounced decline in the North Sea and the NW Approaches since the 1960s (SAHFOS, 2001). Elsewhere, numbers are relatively low and show considerable inter-annual variability, making it difficult to infer any trends.

During this period, the westerly wind flow, driven by the North Atlantic Oscillation, has increased in strength. This generates a strong mixing of the surface layer in winter and spring, delaying the spring phytoplankton bloom and reducing primary production (Dickson *et al*., 1988b). Furthermore, sea surface temperatures were warmer than normal, which is unfavourable to *C. finmarchicus*, a cold-temperate water species. The combination of these two negative circumstances, both driven by the NAO, probably induced the observed low abundances (Fromentin and Planque, 1996).

In terms of annual mean data, the abundance of phytoplankton (as measured by phytoplankton colour) has shown an upward trend in UK waters since the 1960s, except possibly in the Irish Sea. However, any possible delay in the spring bloom cannot be determined from this annual data.

The Continuous Plankton Recorder survey

NE Atlantic and European shelf waters adjacent to the British Isles

A synoptic plankton survey covering most sea areas around the British Isles and the adjacent ocean has been operated from the UK on a regular monthly basis since 1946 and since 1991 by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS). Called the Continuous Plankton Recorder (CPR) survey it originally started in the North Sea in 1931, but was discontinued during the Second World War. The CPR is a one meter long towed body that samples the plankton at a depth of ~7m using voluntary merchant ships of opportunity on their normal trading routes. A band of silk is moved across a sampling aperture at a rate that is proportional to the speed of the ship (4m of silk represents a tow of ~400 nautical miles (nm)). After a categorisation of the colour of the silks (a visual estimate of chlorophyll) the silks are cut into samples representing 10nm of tow, which is equivalent to ~3m^3 water filtered. Using a standard procedure phytoplankton and then zooplankton are identified and counted under a microscope. Where possible identification is to species level and grouped stages for some larger copepods; up to 400 taxonomic categories are identified. Some CPRs also carry additional instrumentation to measure temperature, salinity depth, fluorimetry and flow.

Data from the survey provides a baseline description of the natural seasonal and interannual cycles of plankton abundance against which changes that may be attributable to contamination, eutrophication, effects from the fisheries and climate change can be assessed. The results have also been of considerable value in providing a temporal and large spatial scale background to field oriented process studies. Annual reports outlining some of the research findings with a bibliography of publications are available on the SAHFOS web site **(www.npm.ac.uk/sahfos).**

An open data policy has been adopted by SAHFOS. The database, which already contains more than 2 million positive records of individual plankton taxa, is freely available for research to anyone. A copy of the Data Policy and Data Licence Agreement can be obtained from the SAHFOS Data Manager, to whom all requests for data should be made.

In 1999 the CPR survey was incorporated into the Initial Observing System of GOOS. As a first commitment to GOOS monthly mean values for the categories Phytoplankton Colour and *Calanus finmarchicus* have been made available on the SAHFOS web site processed for the traditional Standard Statistical Areas used by the survey in the North Atlantic. This information will be updated each year.

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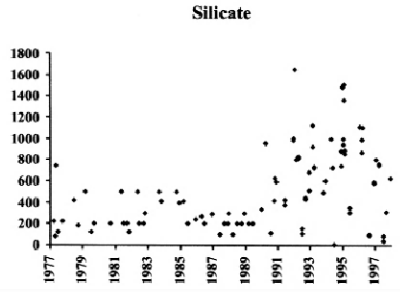
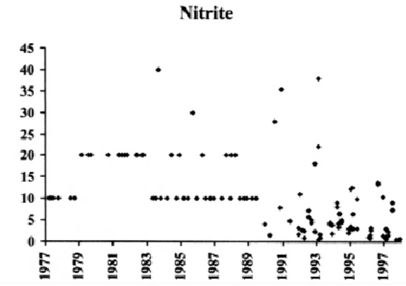
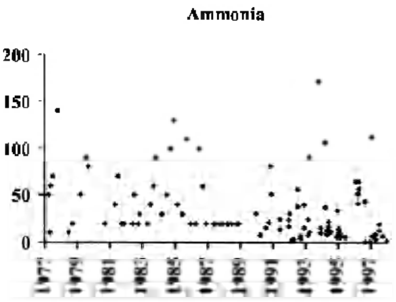
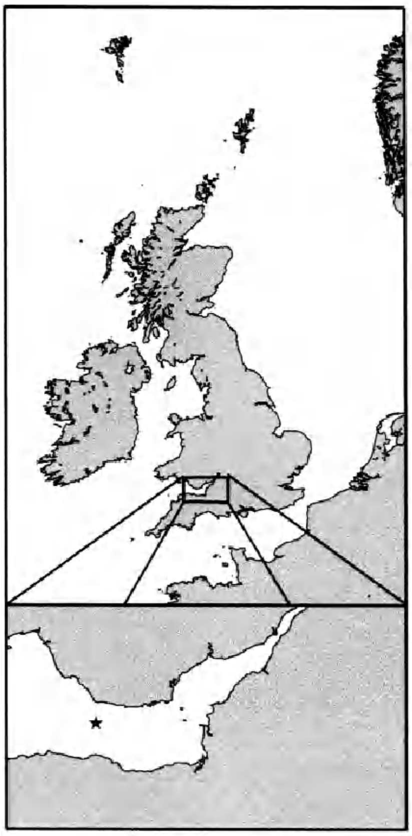
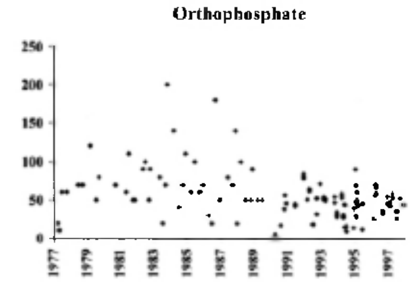
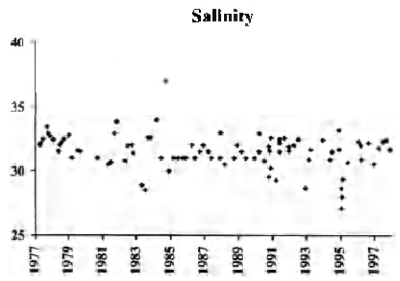

Silicate
0
200
400
600
800
1000
1200
1400
1600
1800
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997

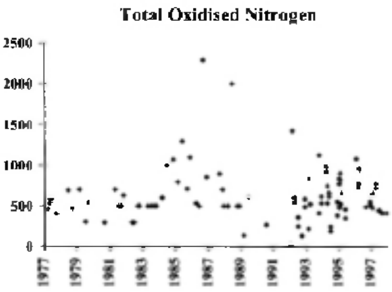

Nitrite
0
5
10
15
20
25
30
35
40
45
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997

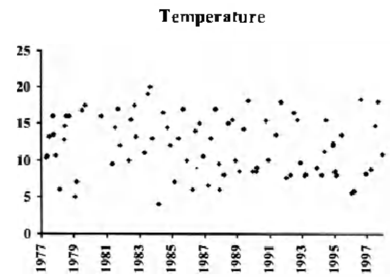

Ammonia
0
50
100
150
200

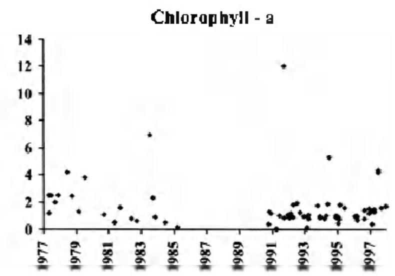



Orthophosphate
0
50
100
150
200
250
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997


Salinity
25
30
35
40
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997


Total Oxidised Nitrogen
0
500
1000
1500
2000
2500
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997


Temperature
0
5
10
15
20
25
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997


Chlorophyll - a
0
2
4
6
8
10
12
14
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997

Nutrient, chlorophyll and salinity data from Station 1a of the Severn Estuary Helicopter Survey
Temperature in ^{o}C, Salinity in PSU, all other data in $\mu g/l$

Courtesy of the Environment Agency

A National Monitoring Plan (now called the National Marine Monitoring Programme, NMMP) was initiated in the late 1980s to establish the spatial distribution and trends of contaminants in UK waters and to identify their biological impact. The NMMP's first phase established the pattern of marine quality, based on spatial surveys from 1993 to 1995 at 87 monitoring stations in estuarine, intermediate and offshore locations (Marine Pollution Monitoring Management Group, 1998). The NMMP's phase two is designed to look more closely at temporal trends, based on measurements at 115 stations. A report is planned for publication in late 2003.

A National Coastline Baseline Survey was carried out from 1992 to 1998 by the National Rivers Authority (NRA) and the Environment Agency (EA), to assess the broad-scale spatial and temporal variability in coastal water quality (EA, 1999). However, given the sampling frequency and duration, long-term trends are difficult to interpret.

Helicopter surveys at 43 sites along the Severn Estuary were undertaken by Water Authorities, the NRA and the EA from 1977 to 1997, to assess trends in water quality. The data at Station 1a (outer estuary) show no significant trends apart from around 1992, but this is probably due to a change in laboratory analysis techniques (Tim Sawyer, personal communication).

Since 1954, the Port Erin Marine Laboratory has measured concentrations of various nutrients in the surface waters at its Cypris station, off the Isle of Man. There has been an increase in nitrate concentration, but no trend in phosphate or silicate concentrations.

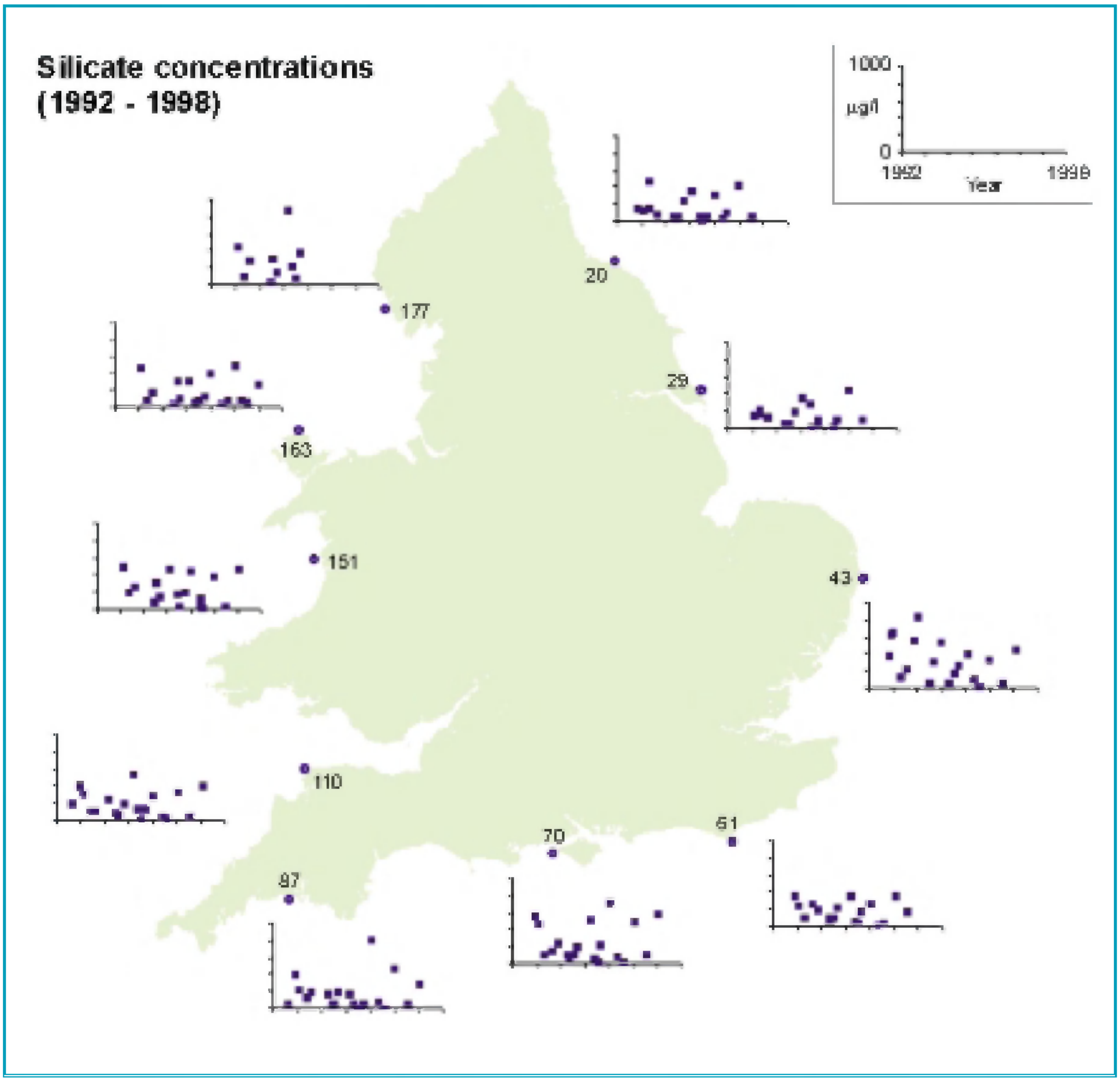
There is evidence of a trend in phosphate concentration at station E1 in the English Channel, but not in silicate concentration. These measurements ceased in the late 1980s.

There is potential to monitor chlorophyll in UK waters, using data from NASA's Sea-viewing Wide Field-of-View Sensor (SeaWiFS), an operational ocean colour instrument launched in August 1997. However, the interpretation of the images needs care, due to the complexity of the waters and the presence of suspended particulate matter (SPM) and organic matter.

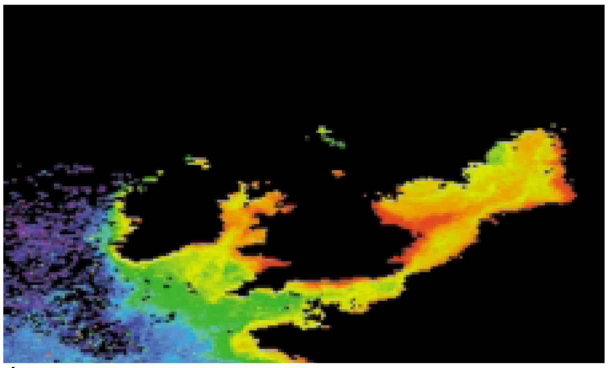
The January 1999 image shows low chlorophyll concentration in oceanic waters west of the UK. There are apparently higher estimates on the shelf; however, the chlorophyll retrieval algorithm can give erroneous values due to the presence of SPM, noticeably in the Irish Sea and North Sea.

In April 1999, the concentration had increased in oceanic waters to the south-west, but was still low north west of Scotland. Higher values in the Celtic Sea and northern North Sea were probably related to the rapid increase in phytoplankton concentration (the spring bloom), due to increases in light levels and water temperature. However, the very high concentrations in the southern North Sea in April and other months were principally due to SPM in the well-mixed waters. Also, the band of apparently high concentration around Norway is an artefact caused by highly coloured dissolved organic matter flowing into the North Sea from the Baltic.

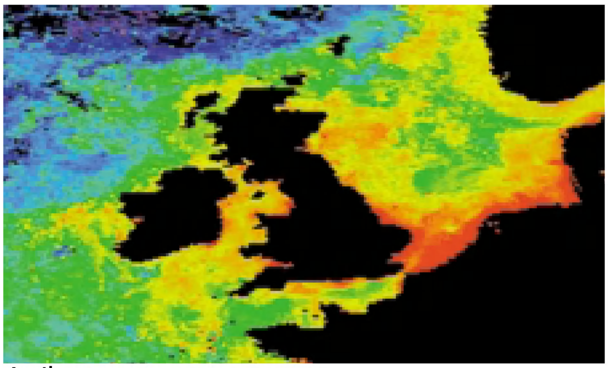
In July 1999, the chlorophyll concentration north west of the UK was high, but concentrations in the Celtic Sea and northern North Sea were lower than in April, due to the inhibition of photosynthesis caused by nutrient limitation in the surface waters. In October, the concentration was more uniform in both shelf and oceanic waters, and reduced later in the year through light limitation.



Concentration of silicate around the UK
Courtesy of the Environment Agency

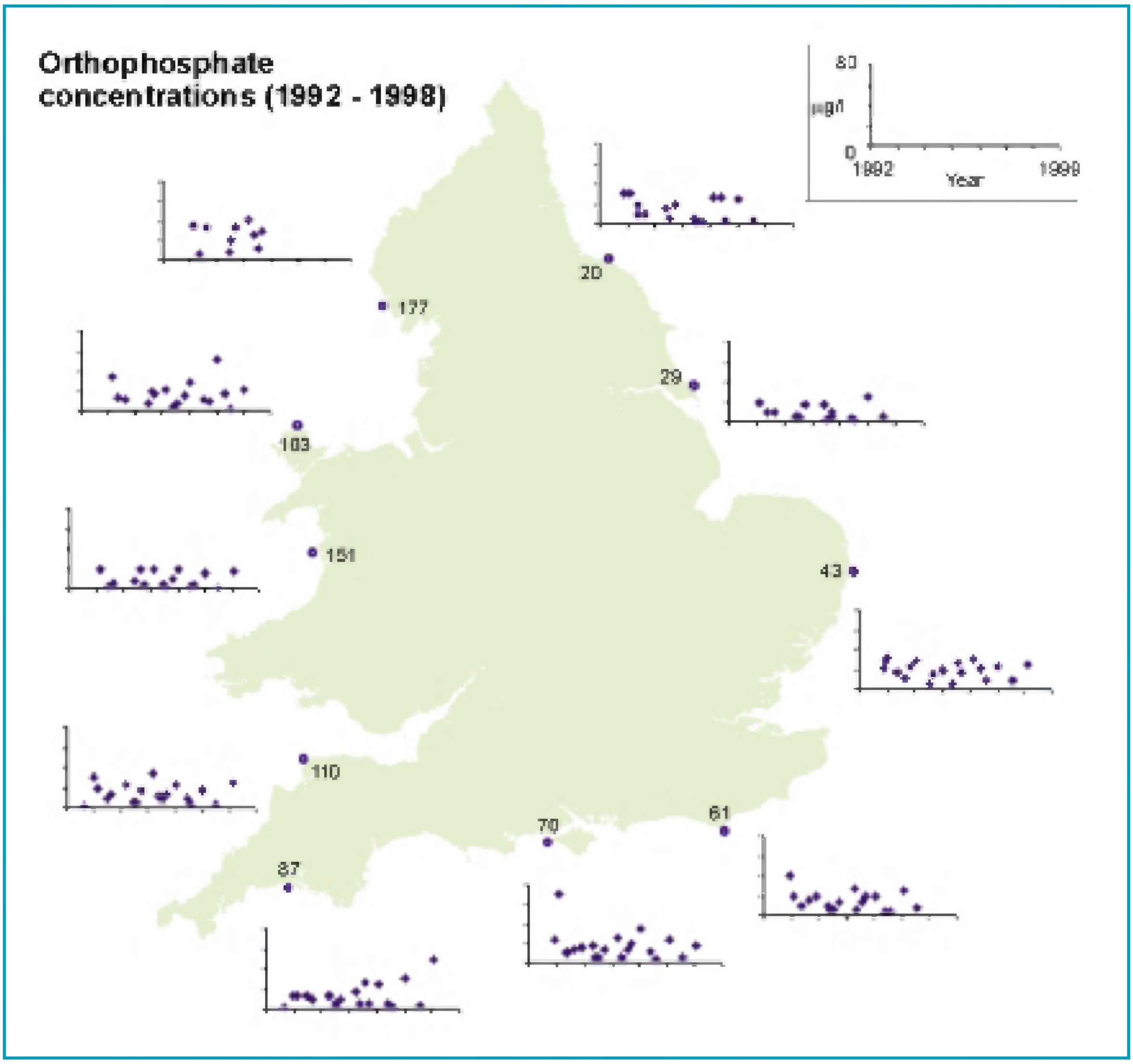


January

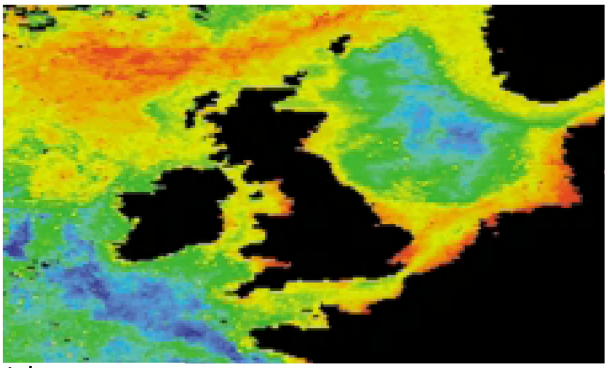


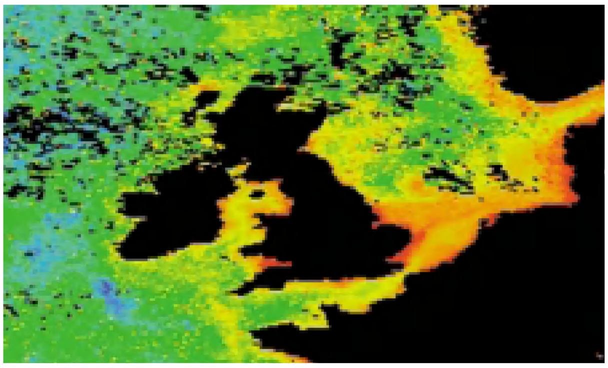
April

SeaWiFS chlorophyll images from January, April, July and October 1999, with a colour palette in mg/m3.
There are no data north of 56^{0}N for January since the low sun angle limits the accuracy of ocean colour measurements
Courtesy NASA SeaWiFS Project and Orbital Sciences Corporation



Concentration of orthophosphate around the UK
Courtesy of the Environment Agency


July


October

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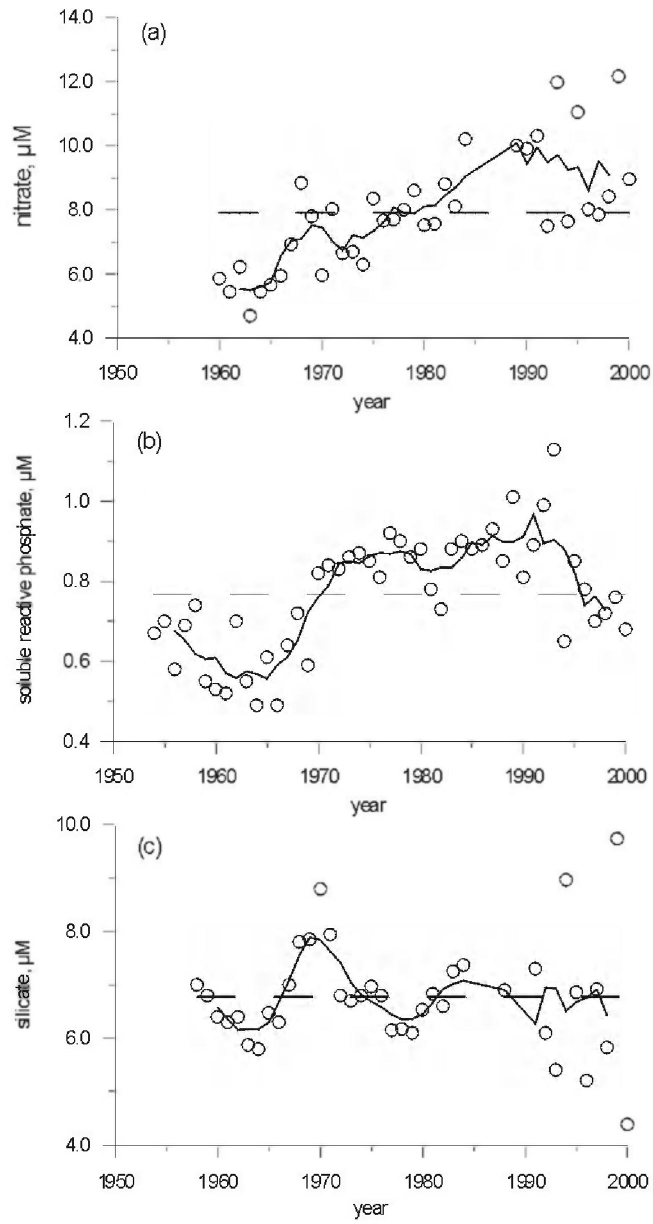
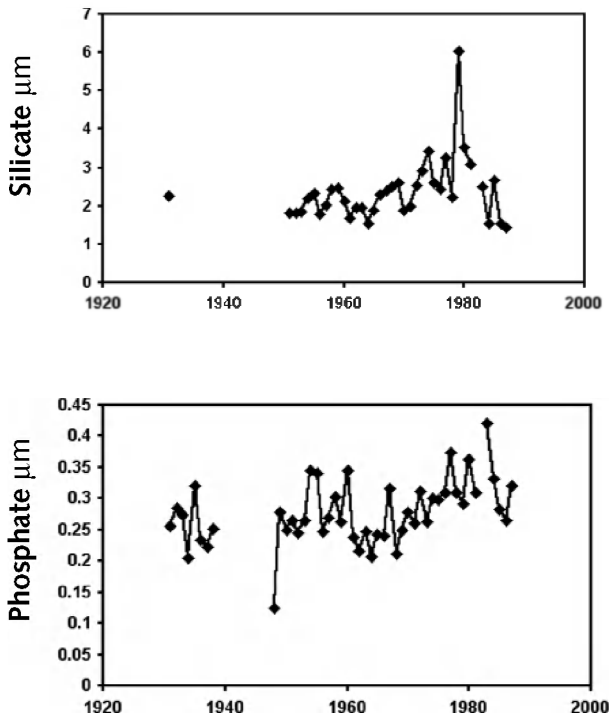


Annual winter (December to March inclusive) maximum concentrations of (a) nitrate, (b) soluble reactive phosphate and (c) silicate at time of winter maxima in the surface waters the Cypris Station 1954 to 2000 inclusive. (open circles – winter maximum concentration, solid line – 5 year running mean, dashed line – long term average)

Courtesy of the Port Erin Marine Laboratory



Silicate and Phosphate concentrations at Station E1, off Plymouth

Courtesy of the Plymouth Marine Laboratory

Environment Agency National Baseline Survey

The National Coastal Baseline Survey was in operation from 1993 to 1998, under both the National Rivers Authority (NRA) and the Environment Agency. Carried out 4 times per year, the survey aimed to assess broad scale spatial and temporal variability in coastal water quality, at 186 predefined sites (15 km apart) along the coast of England and Wales, between Berwick on Tweed and the Solway Firth. At each of these sites, water samples were taken for laboratory analysis of various determinands including nutrients, metals and various organic elements. These sites were put into a spatial perspective by continuous underway data, which in turn was made representative of the full width of the coastal zone by aerial remote sensing Compact Airborne Spectral Imager (CASI) and Thermal video scanning system.

In 1996 the baseline survey was reduced to two ship-based baseline surveys per year to monitor inter-seasonal nutrient variability between summer and winter. As an addition, a number of sites were studied intensively in a grid pattern to investigate spatial variability around the baseline sampling sites and its implication for the continuation of the baseline survey. This represents the most intensive survey of the coastal waters of England and Wales carried out to date, with the results providing an important input to the assessment of coastal water quality over these years.

The survey delivered the required spatial coverage to monitor changes in coastal water quality such as chlorophyll-a, but was found to give limited temporal coverage in this highly dynamic environment. A subsequent review of the survey suggested the use of continuous monitoring buoys to improve the temporal resolution, in addition to monitoring away from estuarine influences.

A revised coastal monitoring strategy has since been produced, that builds on the results of past surveys, whilst using new technologies to enable the collection of spatially and temporally more intense data from the coastal zone. This in turn will allow a clearer picture of the state of the coastal environment to be formulated.

Severn Estuary Helicopter Surveys

Helicopter surveys along the Severn Estuary were undertaken on a quarterly basis from 1977 to 1997, to assess spatial and temporal trends in water quality, at a total of 43 sites along the length of the estuary. The survey was initially undertaken by the water authorities and later by the NRA and the Environment Agency. Samples were taken from surface waters, around high water on both spring and neap tides. In-situ parameters were measured at all sites (temperature, salinity and dissolved oxygen) with water samples collected at 24 sites for subsequent laboratory analysis of nutrients, metals and biological determinands.

9. OVERALL CONCLUSIONS AND RECOMMENDATIONS

The main conclusions on the present status and trends of marine parameters in UK waters are given in the Executive Summary. However some data-holding organisations were not able to provide us with data known to exist, or with data processed in a consistent way. We believe that not all existing data are being used to their full potential. We recommend that organisations are encouraged and resourced to process and make available data in a timely and consistent manner to users and to national, regional and international data banks. Then much better use can be made of existing data, including improved future status reports.

Relevant data for some parameters just do not exist because measurements have never been made or have been discontinued. A recent IACMST report (Portmann, 2000) shows that there has been a decline in the UK's marine observational capacity as funding has steadily fallen in real terms. Several observations are under threat of cessation and some have already been discontinued or are now being made only intermittently. This limits the ability to define the present status and trends and we share Portmann's concern over the insecure future of some of the existing observation systems.

Recently, the Inter-Agency Committee for Global Environmental Change has suggested that long-term monitoring should be regarded as a scientific activity in its own right and funded accordingly. We note Portmann's conclusion that the UK's existing observation programmes provide a sound basis for an overall marine observing network at little extra cost, especially if the co-ordination and sharing of existing resources is improved. This would meet the UK's overall needs efficiently as well as the organisations' needs. We believe our report has endorsed his conclusion that the comprehensive collection and use of marine data is necessary to plan and carry out the effective management of the UK's marine environment, by assessing its present state, identifying changes and meeting future forecasting needs.

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10. REFERENCES

Bacon, S. and D.J.T. Carter, 1993. "A connection between mean wave height and atmospheric pressure gradient in the North Atlantic." International Journal of Climatology, 13, 423-436.

Carter, D.J.T. and L. Draper, 1988: "Has the Northeast Atlantic become rougher?" Nature, 332, 494.

CRU (Climatic Research Unit), University of East Anglia, 2001.
Web site at http://www.cru.uea.ac.uk/cru/data/nao.htm

DETR (Department of Environment, Transport and the Regions), 1999. "Indicators of climate change in the UK." Compiled and edited by M G R Cannell, J P Palutikof and T H Sparks. Produced by the Climatic Research Unit (University of East Anglia) and the Centre for Ecology and Hydrology.

Dickson, R.R., J. Meincke, S.-A. Malmberg, and A. Lee, 1988a.
"The 'Great Salinity Anomaly' in the northern North Atlantic 1968 - 1982." Progress in Oceanography, 20, 103-151.

Dickson, R.R., P.M. Kelly, J.M. Colebrook, W.S. Wooster and D. H. Cushing, 1988b. "North winds and production in the east North Atlantic."
Journal of Plankton Research, 10, 151-169.

Dixon, M.J. and J.A. Tawn, 1992. "Trends in UK extreme sea-levels: a spatial approach." Geophysical Journal International, 111, 607-616.

EA (Environment Agency), 1999. "The state of the environment: Coasts."
The Stationery Office, London. ISBN 011 310 1627.

EuroGOOS, 1996. "The strategy for EuroGOOS: 1996 – 2006." Contained on the EuroGOOS web site at http://www.eurogoos.org

Fromentin, J.M., and B. Planque, 1996. "*Calanus* and environment in the eastern North Atlantic. II. Influence of the North Atlantic Oscillation on *C. finmarchicus* and *C. helgolandicus*." Marine Ecology Progress Series, 134: 111-118.

HMIP (Her Majesty's Inspectorate of Pollution), 1994. "UK National Monitoring Plan". Marine Pollution Management Group, Monitoring Co-ordination Sub-group.

Hulme, M. and G.J. Jenkins, 1998. "Climate change scenarios for the UK: scientific report". UKCIP Technical Report No.1, Climatic Research Unit, Norwich, 80pp.

ICES (International Council for the Exploration of the Sea), 1999. "The Annual ICES Ocean Climate Status Summary 1998/1999." Working Group on Oceanic Hydrography, ICES, Copenhagen, Denmark. (Ed. Bill Turrell.)

ICES 2000a. "The Annual ICES Ocean Climate Status Summary 1999/2000." Working Group on Oceanic Hydrography, ICES, Copenhagen, Denmark.
(Ed. Bill Turrell.)

ICES 2000b. "Zooplankton monitoring results in the ICES area, Summary Status Report 1999/2000." Working Group on Zooplankton Ecology, ICES, Copenhagen, Denmark. (Ed. Luis Valdes.)

ICES 2001. "The Annual ICES Ocean Climate Status Summary 2000/2001." Working Group on Oceanic Hydrography, ICES, Copenhagen, Denmark.
(Eds. Bill Turrell and Penny Holliday.)

IPCC (Intergovernmental Panel on Climate Change), 2001a.
"Climate Change 2001: The Scientific Basis". Working Group I's contribution to the IPCC's Third Assessment Report. Cambridge University Press, in press.
The "Summary for Policymakers" is available via the IPCC web site, at http://www.ipc.ch/

IPCC, 2001b. "Climate Change 2001: Impacts, Adaptation, and Vulnerability". Working Group II's contribution to the IPCC's Third Assessment Report. Cambridge University Press, in press. The "Summary for Policymakers" is available via the IPCC web site, at http://www.ipc.ch/

IPCC, 2001c. "Climate Change 2001: Mitigation". Working Group III's contribution to the IPCC's Third Assessment Report. Cambridge University Press, in press. The "Summary for Policymakers" is available via the IPCC web site, at http://www.ipc.ch/

MPMMG (Marine Pollution Monitoring Management Group), 1998. "National Monitoring Programme - Survey of the Quality of UK Coastal Waters". MPMMG, Aberdeen, 80 + iv pp.

Norris, S.W., 2001. "Near surface sea temperatures in coastal waters of the North Sea, English Channel and Irish Sea, Volume II." CEFAS Scientific Series Data Report No. 40.

OSPAR (Oslo - Paris) Commission, 2000. "Quality Status Report 2000 for the North-East Atlantic." OSPAR Commission, London. 108 + vii pp.

Portmann, J.E., 2000. "Review of Current UK Marine Observations in Relation to Present and Future Needs." IACMST Information Document No. 7.

Sir Alister Hardy Foundation for Ocean Science (SAHFOS), 2001. Web site at http://www.npm.ac.uk/sahfos

Stephenson, D.B., 2001. "The North Atlantic Oscillation." Web site at http://www.met.rdg.ac.uk/cag/NAO

Turrell, W.R, 2000. "Scottish Ocean Climate Status Report 1999". Fisheries Research Services Report 06/00, Marine Laboratory, Aberdeen.

WASA (Waves and Storms in the North Atlantic) Group, 1998. "Changing waves and storms in the northeast Atlantic." Bulletin of the American Meteorological Society, 79, 741-760.

Woodworth, P.L. and D. L. Blackman, 2001. "Changes in Extreme High Waters at Liverpool since 1768." Submitted to the International Journal of Climatology.

Woodworth, P.L., M.N. Tsimplis, R.A. Flather and I. Shennan, 1999a. "A review of the trends observed in British Isles mean sea level data measured by tide gauges." Geophysical Journal International, 136, 651-670.

Woodworth, P.L., 1999b. "A study of changes in high levels and tides at Liverpool during the last two hundred and thirty years with some historical background." Proudman Oceanographic Laboratory Report, 56, 50pp.

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