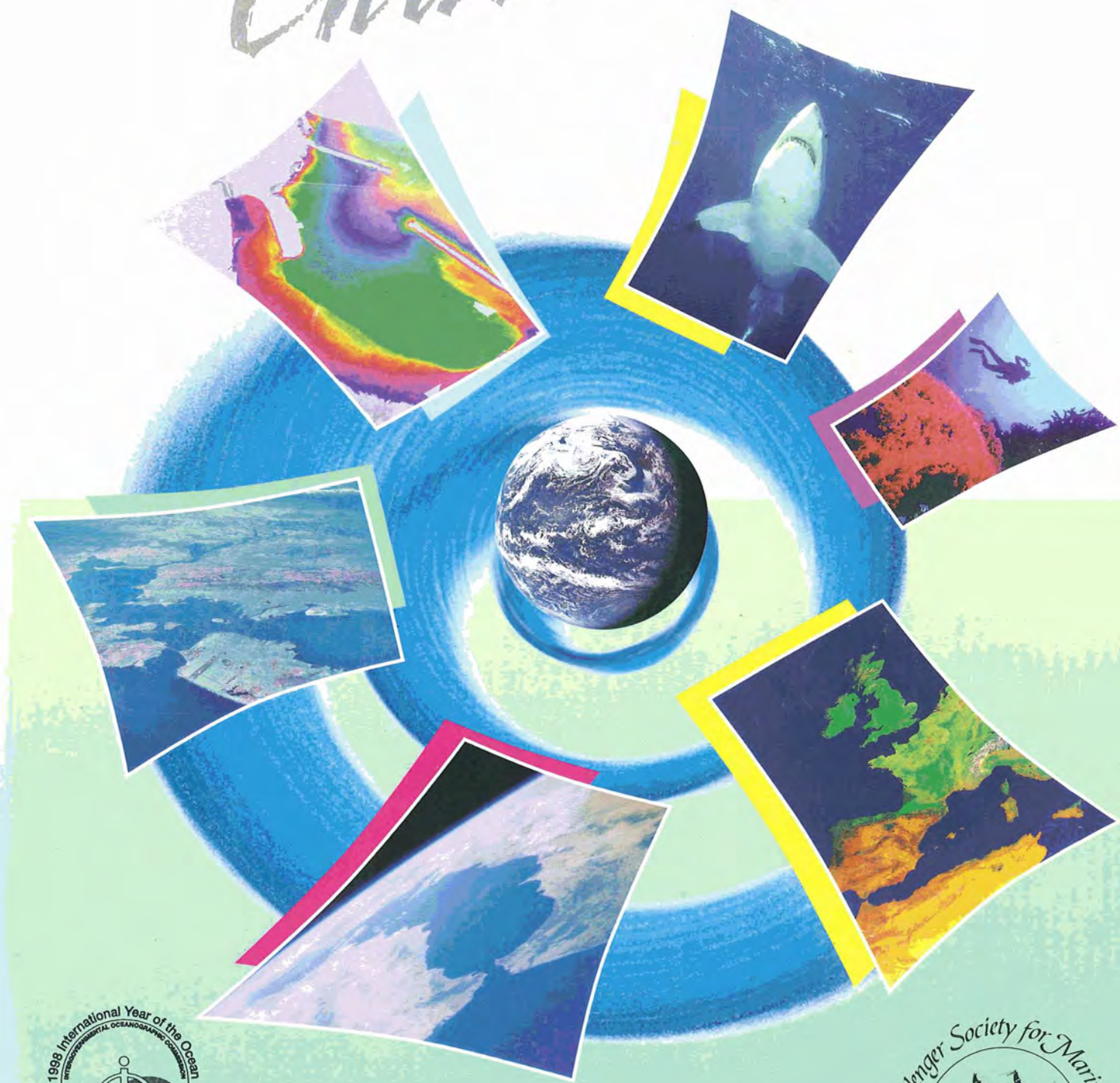
OCEAN Challenge



1998 International Year of the Ocean
INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
UNESCO

The Challenger Society for Marine Science

Volume 8, No. 1, 1998

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and the rest of Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

***Ocean Challenge* is sent automatically to members of the Challenger Society.**
For more information about the Society, or for queries concerning individual subscriptions to *Ocean Challenge*, please contact the Executive Secretary of the Society at the address given on the inside back cover.

INDUSTRIAL CORPORATE MEMBERSHIP

For information about this, please contact the Executive Secretary of the Society at the address given on the inside back cover.

ADVERTISING

For information about advertising in *Ocean Challenge*, and about availability of back issues, please contact the Executive Secretary of the Society at the address given on the inside back cover.

INSTITUTIONAL SUBSCRIPTIONS

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The cover image top left is reproduced by kind permission of Sonar Research and Development Ltd, Beverley. It shows a sea-bed visualization of Peterhead Harbour, which combines computer graphic techniques with accurate sonar imaging.

The cover was designed by Ann Aldred Associates.

It's the International Year of the Ocean!

What are the Aims of IYO?

Through the UNESCO Intergovernmental Oceanographic Commission, the United Nations has designated 1998 the International Year of the Ocean. This gesture is in recognition of the importance of the oceans, the marine environment, and the sustainable development of their resources for life on Earth. The aim of IYO is therefore to create awareness and obtain commitments from governments to take action, provide adequate resources, and give oceans and coastal areas the priority which they deserve.

There will be initiatives to introduce ocean ecology and management into the curricula of schools in many countries and, in collaboration with GESAMP (Group of Experts in the Scientific Aspects of Marine Pollution), to undertake a global evaluation of the state of the marine environment

The task of coordinating the UK response to this initiative has been given to IACMST, the Inter-Agency Committee for Marine Science and Technology. A database of activities contributing to the aims of IYO, being undertaken by a wide spectrum of organizations, including professional and industrial groups, scientific societies and non-governmental organizations (e.g. WWF), has been compiled and is being widely circulated nationally and internationally. Many of these events are listed in our Forthcoming Events pages, or are mentioned elsewhere in this issue, but for a complete listing contact Martin Angel at the Southampton Oceanography Centre, by letter or Email (mva@soc.soton.ac.uk). You should also contact Martin if your organization would like to designate an event as a Year of the Ocean activity, so that it can be entered on the database.

Below: Bottle-nosed dolphins, reproduced on the new 10p Isle of Man stamp, issued in recognition of the Year of the Ocean.
See opposite for more information.

Ocean Charter

Amongst the initiatives being sponsored by the IOC is the signing of an Ocean Charter, which is a statement of principle, intent and commitment to the future of the oceans and the marine and coastal environment. The Charter has been promulgated internationally by the Canadian Government with the objective of ensuring that in the international arena greater attention is paid to the importance of managing the oceans sustainably.

There are two versions of the charter – one a personal statement of commitment to the concept of managing the oceans sustainably, the other is a similar document for organizations and governments. Copies of both are reproduced at the very end of this issue. Once signed, copies should be sent to Martin Angel (see previous item) so that they can be registered. The register of signatories will be used internationally in debates and discussions in the United Nations and other international arenas, such as OSPARCOM, the Oslo–Paris Commission.

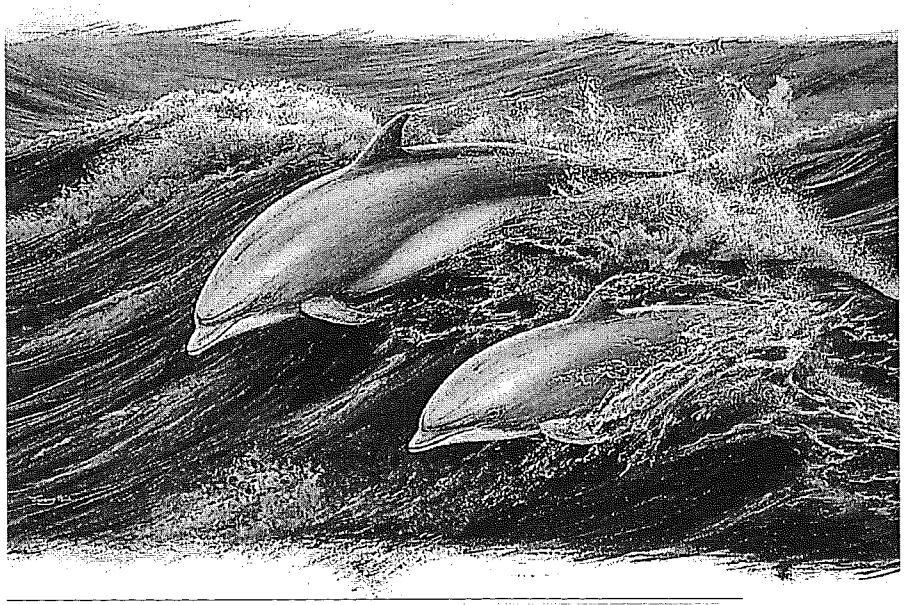
IYO Regional Open Forums

Another initiative is the promotion of a series of regional Open Forums, being held at various venues throughout the UK. The aim of these events will be to provide an opportunity for a broad spectrum of interested organizations to contribute to the debate about marine resources, and the challenges that have to be overcome if they are to be rationally and sustainably exploited; also, to discuss regional issues and opportunities.

These Open Forums will report to the annual Open Forum of IACMST which is to be held in the IMO building in London in September. The product of each regional forum will be a summary of:

- An assessment of the region's marine resources, placing the regional potential in a broader North Atlantic and global context.
- A summary of the existing and potential problems of sustainable exploitation of these resources.
- An outline of the science and technology needed to overcome these problems.
- Recommendations as to how to introduce more about the oceans into education, and improve public awareness at all levels.

It seems likely that the Forums will reveal broad areas of both consensus and disagreement. The regional summaries will be provided as documentation to IACMST's central open forum to be held in London in



September 1998, and so broaden the scope of the discussions.

Open Forums set up so far include ones at Plymouth, Cardiff, Belfast (Irish Sea Forum), Aberdeen (at the Fisheries Research Services Aberdeen), Oban, Glasgow, Newcastle, Dove Marine Laboratory), Lowestoft, Portsmouth and Southampton.*

The format of each meeting and the main themes to be discussed are being left to the local organizers. However, the events are being billed as 'debates on sustainable use of the oceans for the 21st century' and convenors are being encouraged to consider one or more of the 'challenges' identified by the Marine Foresight Panel, namely:

- *Offshore Energies* The challenge is to achieve the capability for total sea-bed processing of hydrocarbons, and improve yields from existing hydrocarbon reservoirs by reducing proportions of residual hydrocarbons by at least half.
- *Maritime Transport and Construction* Here the challenge is to develop efficient inter-modal marine transport systems and to re-establish the UK as a major force in design, construction and operation of specialist ships, including high-speed craft.
- *Marine Fisheries and Aquaculture* To improve aquacultural productivity world-wide through the application of UK science and technological expertise.
- *Exploitation of Non-living Marine Resources* To develop comprehensive operational oceanography to underpin marine environmental forecasting services.
- *Coastal Water and Marine Leisure* To increase exploitation of the coastal zone in proportion to population growth in a sustainable manner.

Cutting across this list must be concerns about environmental quality and the need for improvement in education on marine matters throughout all levels of society.

* More information about these events may be obtained from Dr David Pugh, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH; Tel. 01703 596611; Fax: 01703-596395; Email: dtp@soc.soton.ac.uk

Isle of Man Celebrates the Year of the Ocean through Stamps

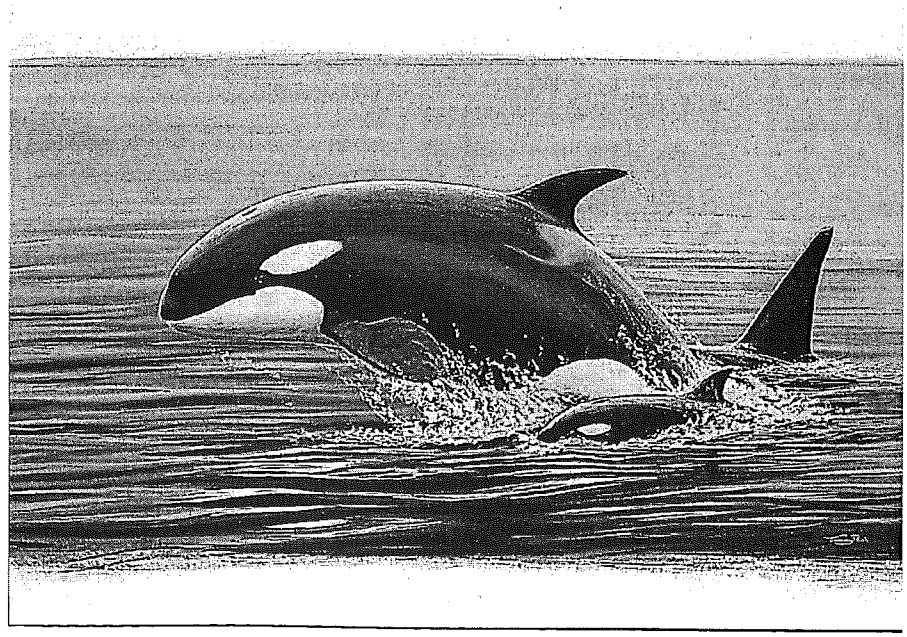
Anyone who is interested in International Year of the Ocean memorabilia or is a keen stamp collector might like to know that on 16 March the Isle of Man issued a set of five stamps celebrating IYO. The stamps feature dolphins, whales and sharks, and the same charismatic species have been used on postcards and limited edition prints.

The Philatelic Bureau on the Island (Email stamps@po.gov.im) is offering first-day covers, and a gift pack is also available. This contains a specially minted crown featuring a basking shark,a first-day cover, a set of postcards and some extra information about the island.

Orders can be placed by phone +44-(0)1624-686130 or fax +44-(0)1624-686132 or by letter to IOMPO P.P Box 10M, Douglas, IM99 1PB.

Other countries and regions that have produced or are producing special IYO stamp issues include: Guernsey, Greenland, Peru, Finland, Germany, India, Kuwait, Sweden, Turkey, Mexico, Faeroes, Iceland, Monaco, Jersey, San Marino, Portugal, Azores, Madeira, Malta, Bahamas, Costa Rica, Lebanon, Mauritius, Seychelles, South Africa, Sri Lanka, Thailand, Tonga, Germany and Cuba.

Below:* Orca, *the killer whale, reproduced on the new 63p Isle of Man stamp.



Forthcoming Events

Events in 1998
The Year of the Ocean

NB For information about special Year of the Ocean events relating to local conservation and WWF, see p.4.

Seminar on Underwater Defence Technology (Organized by Nexus Technology). 23 June, Institute of Electrical Engineers, Savoy Place. *Contact* Dr A.J. Bentley, Learned Societies Services, Savoy Place, London WC2R 0BL; Tel. +44(0)171-344-5463; Fax: +44(0)171-497-3633; Email: jbentley@iee.org.uk

Benthic Processes in the Arabian Sea: Biogeochemistry, Biodiversity and Ecology (Royal Society of Edinburgh, SAMS and the Challenger Society). 1–3 July, Edinburgh. Keynote lectures will address multidisciplinary studies on the oxygen minimum zone and the complex forcing dynamics of the monsoon cycle in relation to biogeochemistry, biodiversity and ecology of the benthic system, present and past. *Contact:* John Gage, SAMS; Email: J.Gage@dml.ac.uk or Deep Arabian Sea, The Royal Society of Edinburgh, 22–24 George Street, Edinburgh EH2 2PQ; Tel. +44-(0)131-225-6057; Fax +44-(0)131-225-6277; Email: RSE@rse.org.uk (For regular information see: http://www.nerc-oban.ac.uk/dml/meetings/)

Conference on UNCLOS: Issues of Implementation 9 July, London organized by the Foreign and Commonwealth Office. *Contact* Dr David Pugh, Secretary of IACMST, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH; Tel. +44-(0)1703-596611; Fax: +44-(0)1703-596395; Email: dtp@soc.soton.ac.uk

Open Day Sea Fish Industry Authority, Hull 21 July. Open Day for the UK fish industry at SFIA Technical Division. *Contact* Mr Philip MacMullen, Seafish House, St Andrew's Dock, Hull HU3 4QE; Tel. +44-(0)1482 327837.

Conference on Changing Health and Safety Offshore – the next 10 years 22–24 July, Aberdeen. *Contact* Robert Simpson, Merton House, Stanley Rd, Bootle, Merseyside L20 3DL; Tel: +44-(0)151-951-3073; Fax: +44-(0)151-951-3098.

Tenth International Meiofauna Conference (XIMCO) (Jointly organized by PML and University of Plymouth). 27–31 July. *Contact* XIMCO (J.M. Gee), Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH; Tel. +44-(0)1752-633100; Fax: +44-(0)1752-633101; Email: ximco@plymouth.ac.uk

Oil Spill '98 29–31 July, Southampton. Aim: to close the gap between theoretical developments and practical applications. *Contact* Ms Liz Kerr, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA; Tel. +44-(0)1703-293223; Fax: +44-(0)1703-292853; Email: liz@wessex.ac.uk

Sixth International Congress on the History of Oceanography (ICHO VI).15–20 August, Qingdao, China. *Further details are available from:* Mr Gong-Ke Tan, First Institute of Oceanography, SOA, 3A Hongdao Branch Rd, Qingdao 266003, P. R. China. Fax: +86-532-2879562. Email: fiokjc@ns.qd.sd.cn

International Conference on Satellites, Oceanography and Society (at Expo 98). 17–21 August, Lisbon, Portugal. *Contact* David Halpern, Email: halpern@pacific.jpl.nasa.gov

RRS *Discovery* at Expo'98 12–19 August, Lisbon, being organized by Research Vessel Services. Prestigious exhibits, receptions and events on board; high-level visitors to the ship. *Contact* Dr Ifeanyi Uwechue, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH; Tel. +44-(0)1703-596170; Fax: +44-(0)1703-596101; Email icu@soc.soton.ac.uk

Second International Festival of the Sea 28–31 August, Portsmouth Dockyard, held in partnership with the Royal Navy and with major sponsorship from GEC Marine. *Contact* Mr James Stewart, Exhibition Director, HM Naval Base, PP 16, Portsmouth PO1 3NH; Tel. +44-(0)1705-725000; Fax: +44-(0)1705 727560; Email: SeaFest@Portsmouth98.co.uk

UK Oceanography '98 7–11 Sept, Southampton. *Contact* Neil Wells, Southampton Oceanography Centre. Email: oceans98@soc.soton.ac.uk (See full-page advert opposite.)

33rd European Marine Biology Symposium, 1–7 September, Wilhelmshaven, Germany. *Contact* Tel. +49-4421-944-0; Fax +49 4421-944-199; Email: embs@terramare.fhwilhelmshaven.de http://www.fh-wilhelmshaven.de/terramare/embs33.htm

Energy and the Oceans: British Association Annual Festival of Science 7–11 September, Cardiff, Small Chemistry Laboratory, Main Building, University of Wales, Cardiff. 20,000 Joules under the the Sea: Energy for Life – with talks on: Ocean Circulation – the Earth's heating and air conditioning system; Ice cold heat: gas hydrates, the fuel of the future? Energy and the single seal; Life without sunshine. Organized by the Natural Environment Research Council. *Contact* Dr Sheila Anderson, NERC Policy and Communications Division, Polaris House, North Star Avenue,Swindon SN2 1EU; Tel. +44(0)-1793 411646; Email: sand@wpo.nerc.ac.uk

LOIS RACS Final meeting (Joint with the British Hydrological Society). 25 September, Institute of Civil Engineers, London. *Contact* LOIS Office, PML; Tel. +44-(0)1752-633161; Fax:+44-(0)1752-633101: Email: lois@pml.ac.uk

Solent Science Conference 21–22 September, Southampton Oceanography Centre. Will include one of a series of forums initiated by the IACMST debates on Sustainable Use of the Oceans for the Twenty-first Century. *Contact* Kate Sisman, Solent Project Officer, c/o Hampshire County Council Planning Dept, The Castle, Winchester, Hants SO23 8UE; Tel. +44-(0)1962-846027; Fax: +44-(0)1962 846776; Email: planks@mail1.hants.gov.uk

Coastal Environment 98 8–10 September, Cancun, Mexico. Will address the subject of the computer modelling of seas and coastal areas under normal and extreme conditions, with particular attention to the practical applicatons currently carried out around the world. Organised by Wessex Institute of Technology. *Contact* Ms Liz Kerr, Conférence Secretriat, Ashurst Lodge, Ashurst, Southampton, SO40 7AA; Tel. +44-(0)1703 293223; Fax: +44-(0)1703 292853; Email: liz@wessex.ac.uk

Challenger Society for Marine Science

UK OCEANOGRAPHY '98

Southampton, 7 - 11 September 1998

Oceanographers throughout the UK and Europe are invited to offer contributions to this, the 8th biennial conference in the UK Oceanography series. Participants from other parts of the world are also warmly welcomed. It is our aim to produce a balanced programme of presentations from established scientists and young researchers. Papers on all aspects of Oceanography including Applied Oceanography and related topics are welcomed and papers emphasising the interdisciplinary nature of the subject are particularly encouraged.

KEYNOTE SPEAKERS

Tony Rice	**Abysmal Biology**
Nick Owens	**Nitrogen Cycling**
Peter Killworth	**Ocean Modelling**
Keith Hiscock	**Sea bed Habitats**
Colin Grant	**Operational Oceanography**
Gwyn Griffiths	**New Technologies**
John Gould	**Acoustic Oceanography**
Julian Priddle	**Polar Oceanography**
Jean-François Minster	**Ocean Forecasting**
Patricia Birnie	**The Law of the Sea**

The Annual Buckland Lecture will take place during the meeting:
Martin Angel "The Deep Ocean - a sustainable option for waste disposal"

All correspondence should be addressed to:

UK Oceanography '98
Southampton Oceanography Centre
European Way
Southampton
Hants
SO14 3ZH. **email: ukoc98@soc.soton.ac.uk**

GEOS

DERA

Southampton Oceanography Centre

FURTHER INFORMATION AVAILABLE ON THE WORLD WIDE WEB:
http://www.soc.soton.ac.uk/OTHERS/CSMS/oceans98.html

Forthcoming Events

Ports 98 23–25 September, Liguria, Italy. Will discuss the design, building and operaton of maritime works and ports which are now experiencing rapid changes. *Contact* Ms Sally Radford, Conference Secretariat, Ashurst Lodge, Southampton, SO40 7AA; Tel. +44-(0)1703 293223; Fax: +44-(0)1703 292853; Email: sradford@wessex.ac.uk

Atlantic Frontier Environmental Conference 6–7 October, Aberdeen. Aim: to expand discussions on environmental protection and monitoring of oil production from fields on the Atlantic Margin. *Contact* Ms Lynda Kingham, Aberdeen University Research & Industrial Services Ltd, 23 St Machar Drive, Aberdeen AB24 3RY; Tel. +44-(0)1224 272884; Fax: +44-(0)1224 273405.

East Anglian Estuaries (ECSA Local Meeting), 11 September, University of Essex. *Contact* Prof. David Nedwell, Dept of Biological Sciences, University of Essex, Colchester CO4 3SQ; Email: nedwd@essex.ac.uk; Tel. +44-(0)1206-872211.

International Conference on Wetlands Development, 8–14 November, Senegal. *Contact* Maria Pierce, Wetlands International, Marijkeweg 11, PO Box 7002, 6700 CA Wageningen, The Netherlands; Email: post@wetlands.agro.nl

Technology for deep sea geological investigations: developments, applications and results (Geological Society of London/SUT) 11–12 November. *Contact* Dr Peter Styles, Microseismic Research Group, Department of Earth Sciences, University of Liverpool, L69 3BX; Tel: +44-(0)151-794 5174; Email: sr15@liverpool.ac.uk

First Meeting of European Federation of Ocean Sciences 12 December, Paris. *Contact* Prof Mike Whitfield, The Laboratory, Citadel Hill, PLymouth PL1 2 PB; Tel. +44-(0)1752-633331; Fax +44-(0)1752-669762; Email: miw@mba.ac.uk

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Remember If you are organizing a conference or meeting on any aspect of oceanography, you can publicize it through *Ocean Challenge*. Details should be sent to the Editor at The Dept of Earth Sciences, The Open University, Milton Keynes, Bucks MK7 6AA, UK. Email: A.M.Colling@open.ac.uk

Events in 1998

Limnology and Oceanography: Navigating Into the Next Century the 1999 ASLO Aquatic Sciences Meeting, 1–5 Feb, Santa Fe, New Mexico. Sessions relating to the theme are especially encouraged. Session concepts should facilitate a mixture of both marine and freshwater contributions when possible. *Contact* ASLO Planning Commitee, University of California, Santa Cruz, Marine Sciences Program, Santa Cruz, CA 95064; Fax: +1-408-459-4882; Tel. +1-408-459-3171

Intertidal Mudflats: Properties and Processes 12–16 April, University of Plymouth. Sessions will includes: Mudflat classification; Hydodynamics and sediment transport; Atmospheric processes; Sediment properties; Biological processes; Implications for mudflat management. *Contact* Professor K.R. Dyer, Institute of Marine Studies, University of Plymouth, Plymouth PL4 8AA

IYO Wildlife Events

The World Wide Fund for Nature and other conservation organizations are running a wide range of events to celebrate the Year of the Ocean. These range from 'Shark Swims' to raise funds for shark conservation, throughout June, 'Beach Day Events' at a range of venues throughout July and August, and 'Coastal walks for the WWF' throughout October, at various localities. On 1 October there is an Internet conference on a marine theme, and in December there is a conference reviewing the year's events, both organized by WWF UK.

For more information on all these events, contact Ms Sylvette Peplowski, WWF UK, Panda House, Weyside Park, Catteshall Lane,Godalming GU7 1XR,Tel. +44-(0)1483-426444; Fax: +44-(0)1483-426409.

Marine Science in Multi-Media

Roger Fenby of the **BBC World Service** is producing seven 30-minute features to run throughout IYO. He is using the Southampton Oceanography Centre as a focus and will identify key/interesting projects in each of the oceans/seas. For more information, contact Dr Ifeanyi Uwechue, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH;Tel: +44-(0)1703-596170; Fax: +44-(0)1703-596101; Email: icu@soc.soton.ac.uk

Marine Science for schools on the Web Throughout the year, NERC is runing a schools' web initiative. For more information, contact Dr Sheila Anderson, Policy and Communications Division, Polaris House, North Star Avenue, Swindon SN2 1EU, Tel: +44-(0)1793 411646; sand@wpo.nerc.ac.uk

Proudman Oceanographic Laboratory have devised two tutorials, one on 'Tides' and another on 'The Weather'. These may be accessed on the Web, and are available on floppy disk. A Windows version of the Tides tutorial is under development. For more information, contact the coordinator, Dr Graham Alcock, Tel:+44-(0)151-653-8633.

Proudman Oceanographic Laboratory have also produced **POLTIPS** for Windows, with tidal predictions for over 700 UK ports, and **POLPRED** for Windows which provides predictions of tidal currents and levels offshore, for the European continental shelf, the north-east Atlantic, the Mediterranean, Arabian/Persian Gulf and the Patagonian Shelf (contact details as above).

The Met Office is advertising its involvement in ocean model development and products on Home Pages on the Web. For more information, contact Professor Paul Mason, Chief Scientist and Director of R&D London Road, Bracknell RG12 2SZ; Tel. +44-(0)1344 854604; Fax: +44-(0)1344 856909; Email: pjmason@meto.go.uk

NERC is launching an internet-based project on the **LOIS** research programme. For more information, contact Dr Sheila Anderson, Policy and Communications Division, Polaris House, North Star Ave., Swindon, SN2 1EU; Tel: +44-(0)1793 411646; Email: sand@wpo.nerc.ac.uk

News and Views

Enduring the Cold

During January and February, staff from the British Antarctic Survey led a multinational team of twelve scientists on a physical oceanography cruise in the southern Weddell Sea.

Physical oceanography cruises in this region are generally awkward because of the difficult sea-ice conditions that prevail even during the summer, but such cruises are not unusual. What was different this time was the use of a Royal Navy vessel as the research platform. During her 1997 summer refit, the Royal Navy's ice-patrol vessel HMS *Endurance* was modified to enable her to be fitted with containerised laboratories, a suite of meteorological sensors, a winch for deploying and retrieving moorings, and a combined CTD winch and gantry. As part of the Hydrographic Squadron, the ship already had the capability for high precision bathymetric surveying. The equipment was installed on the ship in the Falkland Islands before she sailed for the Weddell Sea. The scientific team represented seven institutes and three nationalities, and the work included CTD observations, mooring deployments and retrieval, surface meteorology, sea-ice observation and coring, and the deployment of bottom pressure recorders.

A remarkable aspect of the 1997/1998 austral summer was the extraordinary scarcity of sea-ice in the southern Weddell Sea. From the point of view of summer navigability, last season will probably turn out to be the best on record for this area. Most of the broad continental shelf north of the Ronne Ice Front was free from sea-ice, allowing unhindered access to large areas hitherto unvisited. Not so good for the sea-ice observers who, glum-faced, took at one point to giving affectionate names to their favourite ice floes. Much of the interest of the cruise was in connection with shelf-edge processes, and the ship was still able to demonstrate her capability in heavy sea-ice. Captain Tim Barton took his ship as far as the 2500 m depth contour on the western continental slope before vast multi-year floes made further progress impossible.

HMS *Endurance* has frequently been used as a logistical support platform by the British Antarctic Survey. Indeed, her helicopters were used during this cruise to help RRS *Bransfield* deploy large fuel depots on the Ronne Ice Shelf. This season, however, the officers and crew have demonstrated that their ship can also be a very capable and comfortable platform for polar oceanographic research.

Keith Nicholls
British Antarctic Survey

The Eagle has Landed

The Oceanography Department of the University of Southampton has recently received funding of £111 000 from the Joint Research Equipment Initiative to develop *AQUILA* (*AQU*eous *I*ntegrated *LA*nder), a marine environment monitoring system.

The lander will be capable of making simultaneous measurements of current velocity, sea-bed and sea-surface height variations (induced by the effect of tides and waves), suspended sediment concentration, conductivity, temperature, and self-generated noise. It is hoped that these data will shed light on the processes controlling sediment resuspension and transport. The small size of the lander means that it will be capable of deployment from medium-sized vessels operating in continental shelf waters. *AQUILA* data will be used to plan and manage coastal and offshore areas, and will be used to improve the predictive capability of numerical and physical models of coastal processes.

AUV Competition

The US Office of Naval Research has announced a competition for an Automated Underwater Vehicle to cover a prescribed course. The competition will be held in Florida during 1–3 August, and will be open internationally. The full competition rules and description may be found on the Web at http://www.auvsi.org/auvsicc/auvcomp.htm

Our thanks to Patrick Friend (SOC) and Alan Weinstein (ONR) for contributions to News and Views.

Opening of New National Marine Aquarium

The new National Marine Aquarium in Plymouth opened on 6 May, and received 16000 visitors in its first week. It has a water cycle theme, following water from a Dartmoor stream, through river and estuary, into the coastal environment, out to the reef off Plymouth and then on to the tropical Atlantic and the Gulf Stream.

The Aquarium is an incorporated charity with its primary emphasis on education and conservation. Joint programmes are being developed with the Marine Biological Association, Centre for Coastal and Marine Sciences and the University of Plymouth – but this is a truly *national* facility and wider contacts are welcomed.

The fax number of the Aquarium is 01752-275205. Alternatively, contact can be made via Prof. Mike Whitfield, The Laboratory, Citadel Hill, Plymouth PL1 2PB; Fax: 01752-669762; Email: miw@mba.ac.uk

New ship for US Fleet

The US Office of Naval Research has announced that the University of Hawaii, School of Ocean and Earth Science and Technology, will be the operator of the newest US oceanographic research vessel. This ship will be operated under the auspices of the University–National Oceanographic Laboratory System (UNOLS). Officially designated as *AGOR 26*, this ship will be configured as a Small Waterplane Area Twin Hull (SWATH) vessel for increased operational capabilities.

The University of Hawaii will carry out ocean research of interest to the Navy and other government agencies under a charter agreement with the US Navy. Through UNOLS, the ship will be also be available to other researchers, including international users by means of barter agreements for exchange of ship-time. She should be ready for use in 2002.

For further information contact Ms Sujata Millick, ONR32, 800 N. Quincy Street, Arlington, VA 22217; Tel. 001-703-696-4530, Fax: 001-703-696-2007; Email: millics@onr.navy.mil

Challenger in Europe

The Challenger Society has been playing a leading role, together with the Deutsche Gesellschaft für Meeresforschung (DGM) and the Union des Océanographes de France (UOF), in the formation of a European Federation of Marine Science and Technology Societies (EFMS). A framework for the establishment of the Federation was developed through productive discussions at the Institut Océanographique in Paris in December 1997. The resulting draft Articles of the EFMS were considered in detail at the first scientific meeting held under the auspices of the three societies at Boulogne-sur-Mer in April 1998.

At this meeting, the Swedish Society for Marine Sciences and the Finnish Marine Science and Technology Society joined the three founding societies in stating formally their intention to establish the EFMS.

The objectives of the EFMS will be:

- to contribute to the advancement of research and education in Marine Science and Technology; and
- to disseminate information to promote the advancement of Marine Science and Technology in Europe.

Its Registered Office will be at the Institut Océanographique in Paris, and all Marine Science Societies and Marine Technology Societies within the European Union and its associated countries will be eligible to become full members. Each constituent country will be able to nominate one member of the governing Council of the Federation.

The new draft of the Articles is being presented to delegates at the Third European Marine Science and Technology (MAST) Conference in Lisbon in May, with an invitation to other countries to join the group of five societies establishing the Federation. There will then follow a period when each individual society will seek the approval of its members to join the Federation. The formal signing of the Federation document will then take place in Paris in December 1998.

This is an excellent opportunity for the development of closer working links and better communication between marine scientists throughout Europe and for the promotion of more effective lobbying on their behalf. The Challenger Society will address these matters at a special debate during its AGM on Tuesday, 8 September at Oceanography '98 in Southampton.

Mike Whitfield
Challenger Society President

UK Oceanography'98

This year, UK Oceanography is being hosted by Southampton Oceanography Centre. It is being sponsored by GEOS and DERA (the Defence Evaluation and Research Agency). The conference will provide a forum for the exchange of ideas on all aspects of oceanography.

Special sessions devoted to the Challenger Society's special interest groups – Ocean Colour and Ocean Modelling – will take place on the Thursday and Friday, as will a meeting of the Marine Studies Group of the Geological Society of London.

The keynote talks should prove fascinating. The title of Tony Rice's talk – 'Abysmal' Biology – is already giving rise to speculation. Also, for the first time there will be a talk on the Law of the Sea, by Patricia Birnie.

The venue and travel

The conference will be held at the University of Southampton – its facilities and location make it a popular venue for national and international meetings. Overnight accommodation is available in the modern Wessex Lane Halls of Residence, with both *en suite* and standard rooms available.

The University has excellent communications by road, rail, sea and air. It is about an hour to London by train (three trains an hour for much of the day) and there is an hourly coach service to Heathrow. The M3 and M27 provide road links to the rest of the country. Southampton Airport is only a few minutes from the University and offers regular and fast links with Europe.

Special events

The Buckland Lecture, 'The Deep Ocean – a sustainable option for waste disposal', will be given by Martin Angel on Monday evening, and will be followed by a reception in the poster area.

Posters will be on display all week, but there will be a special Poster Evening on Tuesday, accompanied by a reception. On Wednesday, the Southampton Oceanography Centre will host a 'Science and the Media' evening, with a programme of presentations and informal discussion.

The Conference Dinner on Thursday evening will be held in the Southampton Guildhall.

For relaxation

Excursions have been arranged for the afternoon of Wednesday, 9 September. These include trips to: Osborne House, Isle of Wight; Portsmouth Historic Ships; New Forest and Bucklers Hard; the Oil Spill Response Centre. There is also a sporting event – *informal* volleyball – for the more energetic.

Prizes and competitions

Two Challenger Society Prizes will be awarded at UK Oceanography '98: the Norman Heaps Prize, for the best verbal presentation by a young (under 35) non-established researcher, and the Cath Allen Prize for the best poster.

The Presidents' Photographic Competition will also be judged at the Conference. As at the last UK Oceanography Conference, a prize of £50 will be awarded for the best report of the meeting, which will be published in *Ocean Challenge*. For more information about both of these competitions, see p.15.

For more information about UK Oceanography '98, see advert on p.5.

Challenger Society AGM

The Challenger Society AGM will be held during the UK Oceanography conference and will begin at 16.40 on Tuesday, 8 September. If you wish to raise a matter at the AGM, please let the Honorary Secretary, Carol Robinson, know by Monday 27 July so that it may be included on the Agenda. Carol's address is Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, and her Email address is carol.robinson@pml.ac.uk

The Honorary Secretary and Honorary Treasurer continue their terms of office through 1999. Prof. Ernest Naylor will succeed Prof. Michael Whitfield as President. In addition to these officers, the Council consists of nine members elected by ballot. Elections are due for two members of Council as Alison Weeks and Trevor Guymer come to the end of their terms of office in 1998. Nominations are therefore invited for two Challenger Society members to serve on Council from September 1998 for three years. Nominations should be sent to the Honorary Secretary at Plymouth Marine Laboratory (address above), accompanied by the names of the members who proposed and seconded the nomination, the written agreement of the candidate, and a brief *curriculum vitae* (not more than 100 words). The closing date for receipt of nominations is Monday, 27 July 1998. Voting will take place at the AGM.

Challenger Society Awards

Members of the Challenger Society are invited to provide nominations for the award of the Challenger Medal for 1998. This honour is reserved for a distinguished marine scientist who has made a major contribution to the development of marine science, or whose innovation has opened up new perspectives.

Nominations are also requested for Honorary Members of the Society. This award recognizes substantial contributions to the work of the Society and to the national and international development of marine science. Honorary membership is restricted to a total of 2% of the membership of the Society. There are currently six Honorary Members. There are no restrictions on the nationality of the nominees, and they do *not* have to be members of the Society.

In preparing your nomination for either award you should be supported by a second member of the Society, and include a brief one-page statement of the reasons for your nomination.

The Awards Committee of the Society (Prof. Michael Whitfield, Prof. Ernest Naylor, Prof. John Simpson and Dr Brian McCartney) will consider nominations and make an announcement of the awards at the AGM.

Nominations should be submitted to the President (Prof. Michael Whitfield, Marine Biological Association of the UK, The Laboratory, Citadel Hill, Plymouth, PL1 2PB; Email miw@mba.ac.uk or mikewmba@dial.pipex.com; secure Fax 01752 669762) *to arrive not later than 31 July 1998.*

Volcanoes, Earthquakes and El Niño

Apocalyptic tales of the havoc being wrought by the 1997–98 El Niño suggest it is similar in scale to the 1982–83 event – some reports say 'the worst for 50 years'. Meanwhile, a major eruption at the Axial Seamount (46°N on the Juan de Fuca Ridge) has triggered a recollection that in the past some Earth Scientists linked ENSO events with submarine lava eruptions and associated hydrothermal activity.

In the early 1990s there was strong seismic activity along part of the East Pacific Rise south of the Equator, apparently associated with the eruption of extensive lava flows in the same region, and this coincided with a low in the Southern Oscillation Index. This correlation, and similar ones during the 1980s, led some geoscientists to speculate that thermal effects resulting from massive submarine volcanic and hydrothermal activity (signalled by the enhanced seismicity) could be the cause of El Niño events.

Calculations suggest that something like 100 km^3 of lava would be needed to provide the rise in water temperature that normally accompanies El Niño events, and this volume would all have to be erupted every few years, in the eastern equatorial Pacific. That alone would be enough to render the hypothesis implausible, for 100 km^3 is roughly an order of magnitude greater than the total volume of oceanic crust formed annually along the entire global oceanic ridge system. Moreover, the thermal anomalies associated with El Niño extend no deeper than a few hundred metres, and there is no evidence that the undoubtedly large temperature perturbations generated by major submarine eruptions, and especially by hydrothermal megaplumes, can penetrate the main thermocline to affect these surface layers.

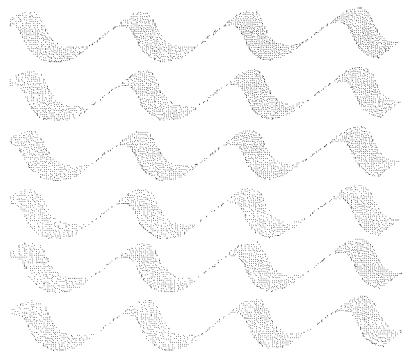
But perhaps there are more subtle and less direct relationships. Could enhanced geothermal heating in the deep oceans eventually feed through to surface waters and affect the climate some years or even decades hence? For instance, while there is fairly compelling evidence that climatic fluctuations in the North Atlantic region are related to the North Atlantic Oscillation, this may not be the only explanation of such fluctuations. Is it possible that variations in submarine volcanic activity along the Reykjanes Ridge, south of Iceland, could be a factor, albeit indirect? An idea along those lines was in fact recently put forward by one Dr W.T. Roach, a geophysicist – it remains to be seen whether there is evidence to support it.

An alternative proposal is that climate change itself can affect volcanism on islands and near coasts, through the effects of sea-level variations on (among other things) water tables and confining pressures in magma chambers. Evidence for this suggestion comes from observed increases in volcanic activity in the eastern and central Mediterranean during the last 100 000 years,* a time of rapid sea-level fluctuations; and it is suggested that similar relationships might be observed in other Quaternary volcanic provinces.

There remains the intriguing possibility that somewhere a very large submarine eruption may generate a 'gigaplume' ('petaplume'?) capable of reaching the surface and perhaps heating the ocean enough to set off 'a hypercane' (*BRIDGE Newsletter*, No.10, 1996, p.65). But that would be a completely different – and more exciting – story.

At all events, relating volcanic activity to climate change and ENSO events does seem more plausible than blaming a hapless citizen of California whose name just happens to be Al Niño. He was the unfortunate recipient of well over a hundred phone calls suggesting – jocularly for the most part, but some very abusively – that he is the cause of the recent climatic travails experienced by the Sunshine State. He apparently responded to his ruder callers by telling them he'd make it go on raining!

*See *Nature* **389**, 2 October, 1997, pp.473–6.



El Niño and El Gordo

The previous item described just one comparatively small fragment of the growing body of evidence that climatic fluctuations can influence ecological processes. It was related specifically to the El Niño–Southern Oscillation phenomenon, but there is plenty of other such evidence. For example, recent studies have demonstrated the effect of the North Atlantic Oscillation (NAO) on pelagic primary production, on zooplankton abundance in the North Sea, and on the progressively earlier spring breeding of European amphibians and birds in recent decades (e.g. *Nature*, **391**, pp.29–30, 1998). The growing body of research in this field has now come to the notice of social scientists, who have begun to investigate the extent to which climatic fluctuations could also affect what they term 'human ecological processes'.

Spain is the home of what is probably Europe's most famous lottery – El Gordo (the Fat One). Spanish social scientists recently made use of the increased computer power available to the national meteorological observatory and weather forecasting centre, to test an idea that occurred to one of their number, Juan Luis Espadrille, a social anthropologist. He had noticed that media reports about the global effects of the most recent El Niño seemed to coincide with larger than average winnings on Spain's national lottery.

With the help of climate scientists from the national weather centre, Espadrille and a couple of colleagues correlated the size of the monthly jackpot against monthly means of the Southern Oscillation index – a measure of the difference in atmospheric pressure between the South-East Pacific and Indonesia, and found a statistically significant inverse relationship: when the index is low, the winnings are higher than average.

How to account for this seemingly bizarre tie-up? We have all heard of teleconnections, but this seemed so implausible that the team were laughed at by their colleagues, and told to go away and learn some proper statistics. But the correlation refused to disappear, and Juan Luis and his colleagues have come up with a possible explanation. They reasoned that the size of the

lottery jackpot depends on nothing more than the number of tickets bought, that is, on the number of people playing. So what might make more people play when the Southern Oscillation index is low? The answers lies in that elusive concept – the 'feel-good factor'. It is well known that the majority of people feel better when atmospheric pressure is low than when it is high (the murder rate goes up when anticyclonic conditions prevail, especially if inversions make the air hot and humid).

And sure enough, they found a teleconnection. When they looked back at the national meteorological records it turned out that times of low ENSO index did indeed correlate well with periods of lower than average atmospheric pressure over Iberia. The underlying climatic mechanism is not yet clear to the researchers, but they believe it may be related to interaction of the Southern Oscillation with the NAO, which in turn affects the strength and position of the Azores High and its effect on the climate of continental Europe. If there is anything in these interesting results for those running Britain's national lottery, our more northerly location suggests that correlations should be sought with the NAO index rather that with the ENSO index.

More information on the El Gordo research can be obtained from the Institute of Social Anthropology at the University of Madrid: Email: brincada1.4@madrid.ac.es

El Niño and Corals

Scientists from the Miami University School of Marine and Atmospheric Sciences and from NOAA have found evidence of extensive coral bleaching along the Panamá coast. Bleaching results from departure and death of the symbiotic algae (zooxanthellae) that live within reef-building corals and provide them with nourishment as well as giving them their bright colours. These algae leave the corals when ambient water temperatures are maintained above 29 °C – and so the corals turn pale and die. Because of the strong El Niño, temperatures in the area have been in the 29–30 °C range since mid-1997, well above normal, and as much as 90% of the corals along parts of the Panamá coast have been bleached and killed off. In the adjacent Caribbean too, it appears that corals experienced severe bleaching during the 1982/83 and 1986/87 events, and it is confidently predicted that the same will happen again during 1998.

Irrespective of the cause of El Niño events (see p.10), there appears to be a vogue for implicating them in whatever phenomenon is being investigated. In fact, elevated temperatures are not the only reason that has been advanced to explain coral bleaching (see *Ocean Challenge,* Vol. 7, No. 2, p.16), and such bleaching events have been attributed to the pervasive effects of global warming, rather than specifically to El Niño. Other possible causes include reduced temperatures (*sic*), salinity changes, and pollution, both from toxic substances and from sediments.

However, if the recent correlations between bleaching and ENSO-related temperature rises in the East Pacific *are* valid, then continued global warming can only be bad news for coral ecosystems all over the world, especially as so many of them are being carelessly exploited, be it for tourism, for fishing, or for limestone, rather than conserved – even though 1997 was the 'Year of the Reef'.

Turtles, Migrations and Continental Drift

These days, turtles receive publicity chiefly on account of their relative rarity and vulnerability to habitat destruction, not least because they most inconveniently (for them) choose warm sandy beaches to nest on, especially in the Mediterranean. Much of the attraction of turtles lies in their antediluvian appearance – their line extends back at least to the Jurassic, and fossil turtles recognizably similar to modern species are found in Cretaceous sediments around 100 million years old.

Turtles undergo annual migrations of thousands of kilometres between nesting and feeding grounds. This activity is of course not peculiar to turtles: they share the migrating habit with several other marine animal groups as well as with birds. There is evidence from satellite tracking that the animals follow essentially straight paths to their goals, and there seems to be a growing consensus that they do so by detecting small variations in the intensity and inclination of the Earth's magnetic field.

Just one among the many striking examples is the annual trek of the green turtles (*Chelonia mydas*) that nest on Ascension Island and regularly migrate between their nesting beach and their feeding grounds in Brazil, some 2000 km away. Ascension Island is in the South Atlantic, which began to open during the Cretaceous, around 100 million years ago, and fossil turtles are plentiful in the sedimentary basins that developed round the continental margins of West Africa and north-eastern Brazil at that time.

The question is, when did turtles get the migrating habit? We marvel at their ability to find their way across thousands of kilometres of 'trackless ocean', but is it possible that the navigational ability of the Ascension turtle population evolved along with the widening of the South Atlantic? There cannot be a simple 'yes' or 'no' answer to that question, if only because Ascension lies near the Mid-Atlantic Ridge and can be no older than about 5 million years – turtles couldn't have nested on it before that time, because it wasn't there; and 5 million years ago the South Atlantic was only a couple of hundred kilometres short of its present width. Could migrating turtles have used other islands, that have since subsided and are now seamounts?

Speculations along similar lines could be applied to populations of other turtle species that migrate back and forth across the North Atlantic too, as that has been widening since the Jurassic. But what of the loggerhead turtles (*Caretta caretta*) that nest in Japan and cross the Pacific Ocean to California? Or the leatherback turtles (*Dermochelys coriacea*, said to be the world's largest) that nest on the west coast of Costa Rica and then travel south-westwards for thousands of kilometres along an oceanic 'corridor' estimated to be no more than 500 km across? The Pacific Ocean was at its widest in the Mesozoic, and has been contracting since. So how did the migrating habits of Pacific turtles evolve?

All the same, the idea that the evolution of marine animal migrations may be related to the movement of lithospheric plates has some appeal. No doubt it is not new. We would not presume to claim that 'You Read it Here First'!

Sea Mammals and Sound Bites

The US Navy have apparently conceived the notion that blasting very loud, very low-frequency signals into the oceans, and analysing the echoes that return, may reveal the presence of submarines, hostile or otherwise.

It is a bit puzzling at first sight. If the submarines are not hostile, surely they will tell you where they are, without recourse to sonic booms? If the submarines are hostile, whose would they be? The Cold war has ended, and it seems that the Russians are trying to sell off their submarines – or at least some of them (*Ocean Challenge*, Vol. 7, No. 3, pp.5–6) – and they surely haven't got the financial or industrial resources to produce sophisticated new models. Perhaps that is the point though: if a rogue group or nation were to buy even one of the Russian submarines, complete with weaponry, it could do a good deal of damage. Perhaps we'd prefer its whereabouts to be known, after all.

At all events, the US Navy's project is simply another version of an experiment that gained some publicity a few years ago, though that did have an intellectually more respectable objective: to monitor ocean-wide global warming by recording travel-times of low-frequency sound pulses over many thousands of kilometres. As we reported at the time (*Ocean Challenge*, Vol. 6, No.2, p.10), there were objections from environmentalists that the fequency and intensity of the signals would be likely to disturb, if not seriously damage, marine life, especially the mammals which use sound to communicate. Little has changed since then. Sound levels of up to 200 decibels or more are being discussed – and some scientists claim that 195 decibels is a lethal 'dose' of sound – which is not surprising, since that's a great deal louder than a 747 at close range. The experiments continue nonetheless, despite the protests, and it seems that there is still no consensus about the damage they might (or might not) cause.

An interesting new dimension is that the hearing of marine mammals can be permanently damaged by persistent loud sounds, such as those from offshore drill-rigs or the engines of large vessels in well-frequented shipping lanes – let alone large underwater bangs. Indeed, otherwise unexplained strandings and mass-mortalities of whales have been attributed to the disorienting effects of loud low-frequency submarine detection systems (e.g. *Nature* **392**, 1997, p.29). On the other hand, there are plenty of counter-claims that whales are insensitive to low-frequency transmissions, that they can continue to communicate without apparent difficulty during the experiments.

Meanwhile, a much more mammal-friendly application of underwater sound is being developed, to prevent other mass-mortalities, this time in the infamous 'wall-of-death' drift nets, which are still being deployed over large areas of ocean, despite legislation to restrict their use. The nets are fitted with an array of powerful transmitters that sit there silently until triggered by the range-finding 'clicks' of dolphins or porpoises attracted by the fish in the nets. They then emit a barrage of sound all along the line, sufficient to drive the animals away. It would be nice to think that, as they depart, the dophins and porpoises will alert other animals such as turtles and birds to the proximity of the nets – but it's doubtful if that could happen.

In the final analysis, though, this is yet another example of a techno-fix solution to an environmental problem. As always, it would make more sense to eliminate the source of the problem (drift nets, in this case), instead of inventing ways of mitigating its adverse side-effects.

But let's end on the bright side. In light of the objections, the oceans may after all not be subjected to great numbers of loud bangs, whether to detect submarines or in an ocean-side sonar experiment to monitor global warming. Unless, of course, you know something we don't ...

Duke's Appeal on Overfishing

Starting off the Year of the Oceans in his usual forthright style, Prince Phillip told the world's fishing nations to get together and stop overfishing. He pointed out, as countless others have done before him, that it not only depletes fish stocks, it also decimates populations of other marine animals (turtles, seals, dolphins, birds, sharks, even whales, to name but a few), through by-catches.

There are of course international agreements to prevent overfishing and its attendant devastations, but most of the top 20 fishing nations are reluctant to sign (let alone implement) them, for fear of the job losses that would result from reduction of fishing effort. Britain is one of those nations. In order to keep their fishing fleets employed, these richer fishing nations are even now paying hundreds of millions of dollars to buy up the fishing rights of poorer developing countries. It has been alleged that the EU is one of the biggest players in this field, chiefly (it is further alleged) so that the Spanish and Portuguese fleets can stay in business. The ironic outcome of these activities is that because their own fish are no longer available, the developing nations must import food, using the funds raised from sale of their fishing rights!

It is a fairly safe bet that, on this issue, even the Duke of Edinburgh's is merely another small voice crying in the wilderness, and that by the end of the Year of the Oceans, overfishing will not have declined significantly anywhere. Yet some fisheries analysts have forecast that within a couple of decades there will be no fish left, unless action is taken. The Common Fisheries Policy is not helping, since 15 European countries can now fish where only one fished before. Quotas continue to be widely ignored, and 'black' (over-quota) fish are conservatively estimated to account for some 30 per cent of the total tonnage landed each year in Britain alone.

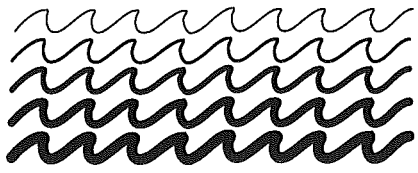
Still, since throwing dead fish back into the sea does nothing to conserve stocks either, it is better to sell these 'illegal' fish for consumption than to let them rot. Rumour has it that the authorities turn a blind eye to the practice, partly because they benefit indirectly from harbour dues paid by all vessels that enter port, perhaps partly because they don't like waste either.

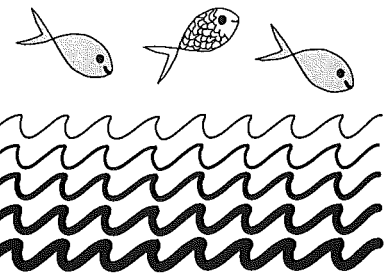
Other people evidently share these views. Our subversive remarks on this subject in *Ocean Challenge*, Vol. 7, No.2, p.13) were echoed soon after publication by an episode of the radio comedy 'North-east of Eden' (by Peter Carey), which was about (illegally) selling fish surplus to quota. It was heartening to hear one of the characters remark that it is more environmentally friendly to sell such fish than to dump them back into the sea, dead, to rot.

But are we not ignoring good old natural variability in all this? After all, it has been known for many years that fish stocks can fluctuate naturally by an order of magnitude between years. So nobody should be surprised that fisheries scientists who were forecasting collapse of North Sea cod stocks over the past couple of years were recently being criticised as doom-mongers. Apparently there's now a surplus of cod in the North Sea, somewhat offset by a reported shortage of herring and mackerel there. It was announced that EU quotas for these latter two would be reduced by nearly a third in the next round, those for cod increased by a like amount. But that's the trouble with natural variability. In a year or two, there could be a glut of herring and/or mackerel, while cod stocks could once more be critical.

Anyway, it isn't true that there will be *no* fish left, even if overfishing does continue at present levels. But since the fish we eat are mostly from the higher trophic levels, removing them must surely leave only those at lower trophic levels. Would these be sufficiently abundant to make up? Who can say? It has even been suggested that we should 'cut out the middleman' and go straight for the phytoplankton – shades of 'Soylent Green'. Then there really would be no fish left in the sea!

Luckily the fish themselves don't know anything about all of this ... or do they? How many readers caught the news item about the drifter that was nearly capsized off Norway when the herring shoal in its nets decided to head for the bottom *en masse* as they were being hauled aboard?





Cod – A Reminiscence

The recent appearance of this pocket-sized volume, *Cod: A Biography of the Fish that Changed the World* by Mark Kurlansky, reviewed elsewhere in this issue (p.42), put me in mind of another book I read many years ago, about the Portuguese cod fleet that for hundreds of years had been making annual voyages to fish for cod on the Newfoundland Banks. That book, *The Quest of the Schooner Argus*, published in 1951 (by Hodder & Stoughton) and long out of print, was written by Alan Villiers, who sailed aboard one of the ships of that fleet.

I managed to find a copy the other day, and it is as rivetting now as it was when I first read it over 40 years ago. Even as late as the 1950s, the privations and rigours of long-line fishing for cod in one-man dories out of sight of the mother ship, adrift in the cold and foggy waters of the Banks, were formidable. Small wonder that these annual 'pilgrimages' on sailing vessels began with the whole fleet being blessed by the Bishop of Lisbon. The expeditions faded away in the 1960s as mechanised fishing became the norm – still a hard life, to be sure, but a touch less risky for most of the fishermen involved.

Villiers' book is a great read, and I was sorry to find that it doesn't appear in Kurlansky's bibliography. I guess it's been out of print so long that hardly anybody knows about it any more. Alas for those of us with pretensions to creative writing, there is no direct link between authorship and immortality!

John Wright

Get Your Cameras Clicking!

UK Oceanography will again include the judging for the 'Presidents' Photography Prize', sponsored by past and present Presidents of the Challenger Society. There is still time to take some new photographs or to reappraise some old ones.

This year, photographs may be entered under three different categories. These are:

- Oceanographers in Action
- But is it Art? A chance to reconsider the significance of some of your more creative marine shots, (please supply an appropriate title).
- The Sea Around Us – photographs for this category should take as their subject the marine environment and its inhabitants.

Photos should not be larger than A3, and should be submitted by noon on Monday, 7 September. Please do not send pictures in advance by post.

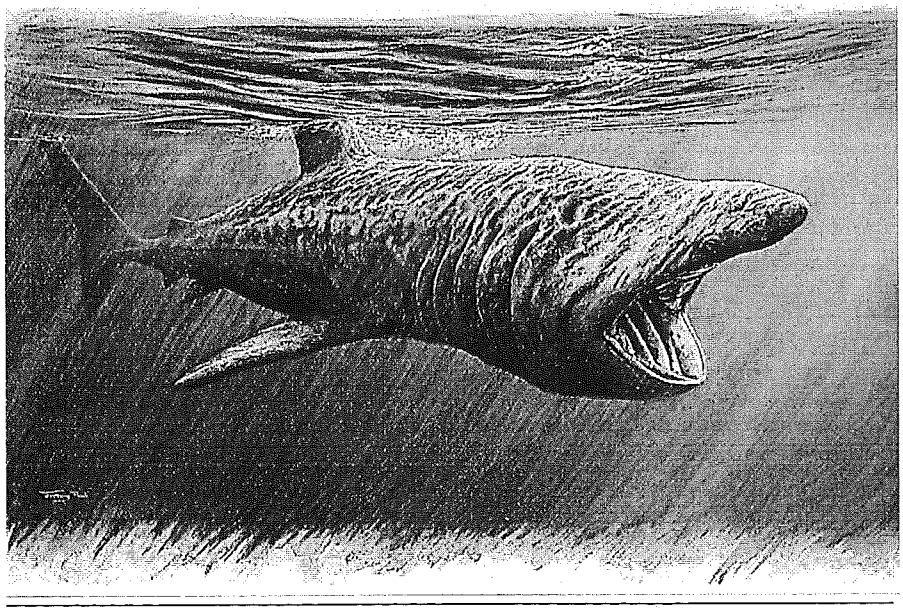
Develop Your Communication Skills

As at the last UK Oceanography Conference, a prize will be awarded for the best report of the meeting, which will be published in *Ocean Challenge*. The report should be a personal impression, highlights and lowlights, rather than a 'blow by blow' report of the meeting. The emphasis should be on lively writing and good communication.

The basking shark, as depicted on the Isle of Man special IYO stamp issue. For more information, see p.3.

The Grape Vine

- Professor Ernest Naylor, who will be the next President of the Challenger Society, was awarded an OBE in the 1998 New Year Honours List; the award was in recognition of his services to marine science research.
- Professor Bill Jenkins has been appointed as the Chair in Oceanography at Southampton; he starts in July.
- The School of Ocean and Earth Sciences at Southampton will be formally inaugurated on 1 August.
- John Gould has just been appointed as the new Director of the International CLIVAR Project Office which will be located at the Southampton Oceanography Centre. CLIVAR will study Climate Variability and Predictability (see also p.26).
- Bob Munns, retired captain of RV *Atlantis II*, died at home on 14 February. Bob had worked at Woods Hole Oceanographic Institution since 1957 and had many friends in the NIO, IOS and now Southampton Oceanography Centre.
- The annual public lecture that is held in Plymouth to increase awareness of marine science was given on November last (1997) by Prof. John Huthnance, Acting Head of the Proudman Oceanographic Laboratory. His subject was the Physical Oceanography of the North European Shelf Edge from Iberia to northern Scotland.



Director of POL Retires

This spring saw the retirement of Brian McCartney after eleven years as Director of the Proudman Oceanographic Laboratory, Bidston. Brian began his work on marine acoustics as a research student at Birmingham University. He moved on to the Ministry of Defence, and from 1964 was at Wormley (then the National Institute of Oceanography) – where he was also a keen cricketer! In 1973, with the formation of the Institute of Oceanographic Sciences, Brian succeeded Tom Tucker as Head of Applied Physics at Wormley. Through these years, he worked on scanning sonars including the 36/38 kHz side-scan sonar, the Cambridge seismic streamer, acoustics in relation to fish (notably fish bladders), ambient acoustic noise and near-surface measurements. A parting 'shot' was initiation of the *Autosub* (autonomous submersible) project. Brian came to Bidston as Director when the laboratory became independent within the Marine Sciences Directorate of NERC in 1987.

His time at POL was marked by whole-hearted embracing of the 'host laboratory' role in the pioneering North Sea Community Research Project. He encouraged the further development of interdisciplinary collaborations in succeeding NERC and European programmes (Marine Science and Technology, Enviroment and Climate); he fostered the laboratory's role as a strategic high-quality 'bridge' between university research and user applications; and he favoured a balance of work at sea, technological developments, interpretation and modelling.

Brian was President of the Challenger Society for Marine Science in 1992–94, when serious discussions began with comparable societies on the continent, with the aim of improving exchange of news and information, and joint meetings.

'Retirement' will not see Brian withdrawing completely from marine developments, but perhaps allow him time to pursue some consultancies as well as his golf.

Our thanks to John Huthnance for this item.

Tony Rice – Sea-Green Anti-Environmentalist?

Tony Rice – whose writings both serious and entertaining – are often seen in the pages of *Ocean Challenge* – has retired after spending his working life as a marine biologist. He did his degrees at the University of Liverpool and then spent two years as a Harkness Fellow at the University of Miami. He returned to the UK, first to work for Unilever trying to rear prawns in Aberdeen for two years, and then as 'Curator of Crustacea' at the Natural History Museum. In 1972 he moved to the Institute of Oceanographic Sciences, then at Wormley near Godalming but now part of SOC, to lead the deep sea-floor biology team – which he has ever since. His research interests include deep-sea benthic ecology, impact assessment, and taxonomy and ecology of decapod crustaceans. He also has a continuing interest in the history of oceanography. This is just one of the subjects that we hope will continue to inspire Tony to put pen to paper for *Ocean Challenge*.

According to Tony, his only claim to fame (or infamy) is his involvement in the *Brent Spar* affair, when he suggested that deep-sea disposal would not be the environmental disaster that Greenpeace claimed it would be. He was (wrongly) labelled as an anti-environmentalist and a lackey of the oil industry.

Brent Spar watchers will be interested to know that a book about the controversial rig by Tony Rice and Paula Owen (Head of the Environment Section of the British Library) will be published early next year. Provisionally entitled *Decommissioning of the Brent Spar*, it is being published by E. & F. N. Spon, New Fetter Lane, London.

The book explains what exactly the *Brent Spar* was (and now is), how Shell got the disposal licence, the story of the Greenpeace occupation and Shell's climbdown. It covers the ensuing arguments, including the scientific debate and the findings of the Scientific Group on Decommissioning Offshore Structures, the 'Way Forward' and the search for the final solution. It also looks at the impact of the *Brent Spar* saga on Shell, and on the oil and gas industry generally, and the effect the controversy has had, both on politicians and on environmental groups, particularly Greenpeace.

OTEC Meets Iron-Ex?

Dear Editor

There seems to be general agreement that an excess of carbon dioxide in the Earth's atmosphere is one of the main causes of global warming. A great deal of CO_2 already enters the oceanic food chain via the phytoplankton. I suggest that it may be possible to increase this amount significantly.

In many warm oceanic areas there is a permanent thermocline. Most of the plankton is above the thermocline, but dead plankton tends to sink through the discontinuity, releasing its nutrients below as it decomposes. The upper layers are thus starved of nutrients, and plankton production is low. It would be unrealistic to try to break down the thermocline over any sizeable area, but a modest injection of less impoverished water into the surface layers is quite feasible and could have a marked effect on the plankton production of the area. Pumping water upwards through the thermocline, or heating it so that it will rise through the thermocline, would achieve this. There is no need to go deeper than 100 m in any area, and many thermoclines, including those in tropical areas, are much shallower.

Pumps could be powered by the wind or solar energy. Allowing the subsurface water to warm up before releasing, or hastening this process with solar panels, would ensure that it remained above the thermocline. Solar energy could be used to heat water below the thermocline sufficiently for it to breach the discontinuity. Pilot plants could be set up in any warm oceanic waters, but the eventual aim would be to enrich the plankton of all tropical waters.

Artifical upwelling would increase the oceanic biomass from the surface to the abyss, but there must be limits to this increase, and the oceans would not provide a permanent solution to the problem. Some limited solutions are, however, already being implemented: e.g. the Norwegians pump some of their excess CO_2 into spent fuel wells. If carried out on a sufficient scale, artificial upwelling could make a significant impact for very many years, and it would give us more time to work out permanent solutions. In the meantime, fishermen could take advantage of the increased productivity of tropical oceans.

A few pilot plants would provide an extremely interesting and not prohibitively expensive research poject and, if the results are encouraging, a worldwide tax on fossil fuels would pay for thousands of pumps.

Phytoplankton and forests together might save the planet!

Don Williamson
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Editorial comment

At first sight, at least, this idea would appear to have some practical problems. Back-of-envelope sums (based on textbook values for mean primary productivity in upwelling zones) suggest that for any noticeable effect on atmopheric CO_2 the number of pumps that would be needed would be very large – perhaps many tens of thousands. This large number is mainly because the percentage of carbon incorporated into sea-bed sediments (and thus 'permanently' removed from the atmosphere–ocean system) is generally less than 1%.

However, we may have overlooked something in our calculations, and this type of proposal should at the very least be debated. Should there be further investigations along these lines? Or is this an example of a 'techno-fix' rather than a true solution?

Comments on this suggestion, and further ideas from other readers – experts in the field, or otherwise – would be welcomed.

Of Dams and Diatoms

The Douro in Portugal was once a mighty river, with gorges and rapids that were regularly negotiated by men in small boats – *barcos rebelos* – equipped only with sail and steering oar. They carried barrels of young port wine from the vineyards of the upper Douro to be matured in huge casks in the lodges and warehouses of the Oporto merchants (mostly British firms, incidentally, founded in the 18th century).

Portugal's need for hydroelectricity was such that by 1985 a series of five dams had effectively tamed the Douro, making it navigable for small passenger craft up to and beyond the Spanish border, as each dam has a lock system (one of them with the highest rise – and fall – in Europe). Use of *barcos rebelos* was abandoned some time ago, and the port is now all carried by road.

The dams are useful for water supply, and along one particular stretch dredgers take sand and gravel from the river bed for the construction industry, while helping also to keep the channel navigable. With the reduction in flow velocities resulting from dam construction, these aggregates must be a dwindling resource, though no doubt sand continues to be supplied by tributaries and by run-off.

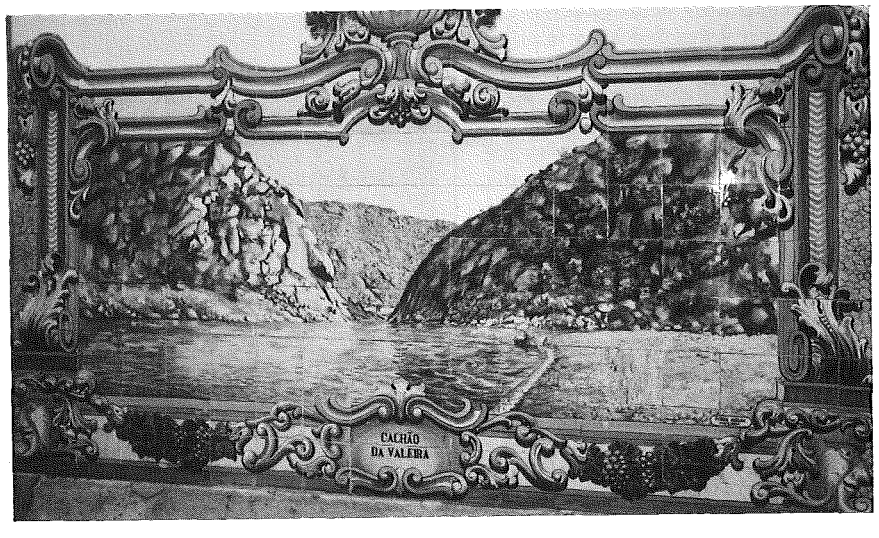
Construction of the dams must also mean that the lower reaches of the Douro are less well flushed than they used to be. The river is now tidal only up to a few tens of kilometres from Oporto, and the narrow steep-sided estuary upon which the citiy is built has every appearance of being seriously polluted, though the pollution must be mostly organic, as there are plenty of fish to be seen.

The often stormy waters off northern Portugal's Atlantic coast are not likely to suffer as a result of being supplied with less silt and sand from the river than heretofore, and damming the river has probably not affected nutrient supplies to coastal and offshore ecosystems significantly. Judging from the abundance of fishes that can be observed at many places up-river from Oporto, there is no shortage of nutrients anywhere along the Douro, perhaps because supplies have been enhanced by agricultural fertilizers and sewage effluent. But the Douro is just one among the many thousands of rivers that have been dammed all over the world, for hydroelectricity or water supply.

It has of course been known for some time that the extra anthropogenic nutrients in river water can lead to coastal eutrophication (as off the Rhine and Mississippi). Damming a river can offset this to some extent, because the nutrients are utilized by algae in the reservoirs behind the dams and removed into the sediments. Dissolved nitrate and phosphate tend to be replaced by fertilizers in the irrigated areas downstream of the dam. Not so for dissolved silica, however, which can be significantly depleted in the waters that reach the sea. Most of it is sequestered by blooms of freshwater diatoms behind the dams, and it is not replenished by additions further downstream.

Resulting changes in the relative proportions of nutrients reaching the sea (i.e. greatly increased N : Si and P : Si ratios) can hardly fail to affect marine phytoplankton populations: where diatoms once bloomed in the sea, other algal species will come to dominate. Enclosed seas must be especially vulnerable to such shifts in relative species abundance, as has been documented (*Nature*, 27 March 1997, p.385) for the north-western Black Sea, following dam-construction across the Danube's Iron Gates Gorge in the early 1970s. Silica concentrations in river water downstream of the dam are less than half what they were before 1970, whereas concentrations of nitrate and phosphate have increased three- to fourfold. Diatoms have been largely replaced by coccolithophores and flagellates. Recent restoration of wetlands in Romania's part of the delta following the disastrous conversion to intensive agriculture by the Ceaucescau regime has done little to mitigate these trends. Comparable changes have occurred in the Gulf of Mexico off the mouth of the Mississippi, where there is also concern about hypoxia resulting from excessive influx of anthropogenic N and P (and reduction in Si). Similar nutrient imbalances will presumably be found elsewhere, such as the south-eastern Mediterranean, for example, since the Aswan High Dam must surely have decreased dissolved silica supplies to the Nile Delta, while farming on the delta itself will have increased inputs of N and P.

None of this is likely to affect the $20 billion-a-year dam-building business, widely justified on the grounds that it brings irrigation electricity and 'progress'. In many cases this claim can be upheld, particularly where the dams are relatively small, as in countries like Switzerland and Portugal. But the mega-dams in developing countries are another matter, for they may involve community destitution, social upheaval, and sometimes even the deaths of large numbers of people.



Tile mural showing the upper reaches of the Douro gorge before the river was dammed. This is Cachão da Valeira, now the site of the fourth dam.

China's giant Three Gorges dam across the Yangtze is going ahead, and Namibia's Epupa Falls dam across the Cunene is likely to do so too, both with the help of international finance and in the face of all sorts of objections. These are simply two of the latest in a long line of such projects, initiated amid much fanfare and promise of wealth for all, that are now seen to have been fatally flawed in one way or another: Aswan, Chixoy, Iron Gates, Itaipu, Kariba, Pergau – the list goes on. Small wonder the dam-building business is recognized by more perceptive observers to be run 'By a Few for the Few'.

About 20% of the world's electricity needs are presently provided by hydropower, and there are plenty of large rivers still un-dammed, especially in developing countries. There is still a widespread perception that hydroelectric power is 'clean' without harmful emissions: no carbon dioxide, no smog, no acid rain. The less obvious environmental and socially disruptive side-effects are commonly not noticed – in part at least because mega-dams tend to be built in remote places of which we know rather little.

The hydropower potential in the UK is limited yet a large company in northern England announced recently that its electricity would henceforth come chiefly from hydropower – the company will stop using electricity from fossil fuels. Laudable though the initiative may seem to the company's shareholders and customers, this example cannot be emulated on any scale, because the UK simply hasn't enough hydropower to go round.

Perhaps it is a case of being damned whatever you do?

John Wright

Dams and Climate Change

Dams are in the news in other ways too these days. Not so long ago Rhodes Fairbridge (the eminent American geomorphologist) suggested that the damming of major rivers on every continent has so reduced their flow into the oceans that the rate of sea-level rise (due to global warming) is less than it might otherwise be. Other people have done similar sums on rates of extraction of water from underground aquifers (which nowadays significantly exceed rates of replenishment) and its return to the hydrological cycle. The net result is to increase rainfall and run-off into the oceans, and so counteract any effect that dams might have on reducing the rate of sea-level rise. Some people even suggest that it might over-compensate, because of all the water released into the atmosphere by combusion of hydrocarbon fuels, e.g.

$$CH_4 + 2O_2 = CO_2 + 2H_2O.$$

Coal actually contains some water within it, which is also liberated. Then there is all the formation water that comes up from reservoirs with oil and gas, and goes more or less straight into the sea.

But that's not the only way in which dams could affect climate. Dams across major rivers round the Mediterranean are not only altering the nutrient balance (see previous item), they are also making Mediterranean Water saltier, because of the reduced run-off. The latest story is that after this water mass enters the Atlantic at Gibraltar and moves north it rises and mixes with water in the North Atlantic Drift, increasing its salinity. This causes the water to sink more readily when cooled in the Norwegian Sea, which in turn increases the rate of production of North Atlantic Deep Water, releasing more heat to the atmosphere and warming north-western Europe even more.

Is that really possible? Mediterranean Water is indeed a couple of psu more saline than Gulf Stream water, but how much of that is still there when it reaches 55°N? Even the core of Mediterranean Water at about 1000 m has a salinity of no more than 35.4 off western Britain. Is that really enough to raise the salinity of Gulf Stream water by upward mixing sufficiently to have the proposed climatic effect?

If this *is* happening, may we not suppose that the extra warming would accelerate melting of Arctic ice sheets and glaciers, bringing closer the time when the North Atlantic conveyor is shut off by a lid of low-density meltwater?

Marine Science in Schools

This item is prompted by an article in *Geoscientist* for February 1998, entitled Teaching Geoscience in Schools, which has this sentence near the beginning: 'We need more teachers with a geoscience background.' The emphasis is strongly geological, as you would expect, but the article does suggest how marine science might be brought to a wider audience.

Earth Science features in the National Curriculum for England and Wales, and is taught to pupils from 5 to 16. It is mainly solid Earth Science, but the article states that in many schools it is taught by people without a formal Earth Science background. Most oceanography graduates have some acquaintance with solid Earch Science, having covered subjects such as plate tectonics and sedimentation in their degree courses.

If the responses to Martin Preston's questionnaire distributed at UK Oceanography in Bangor in 1996 are anything to go by, only a small minority of oceanography students are presently interested in teaching (see *Ocean Challenge* Vol. 7, No.2, p.13). Should the Challenger Society become more proactive in trying to persuade young marine scientists to consider a career in teaching? Attempts to modify the syllabus to include more oceanography would surely achieve better results if there were support from teachers familiar with the subject. Even without such changes, imaginative and inventive teachers should be able to use many examples from the marine realm to illustrate any number of basic scientific concepts and principles.

One major snag with this bright idea is that it would take several years to achieve any measurable increase in public awareness about the oceans. Another is that to be a teacher you need to get a Post-Graduate Certifcate in Education, which takes another year or so. But isn't it worth a try anyway?

CPR goes high-tech

The ups and downs of plankton sampling

Bill Prior-Jones

Plankton provides the basic food supply for most of the life in the ocean. The distribution of plankton species in space and time, and the growth and decay of plankton populations, have been studied for decades in relation to fisheries. But yet more information can be inferred from characteristics of plankton themselves, including features of oceanic circulation, climate variation and pollution levels. For these reasons, plankton-sampling of the North Atlantic and North Sea has been carried out regularly since 1931 using the Continuous Plankton Recorder (CPR), perhaps one of the most successful pieces of oceanographic equipment of all time.

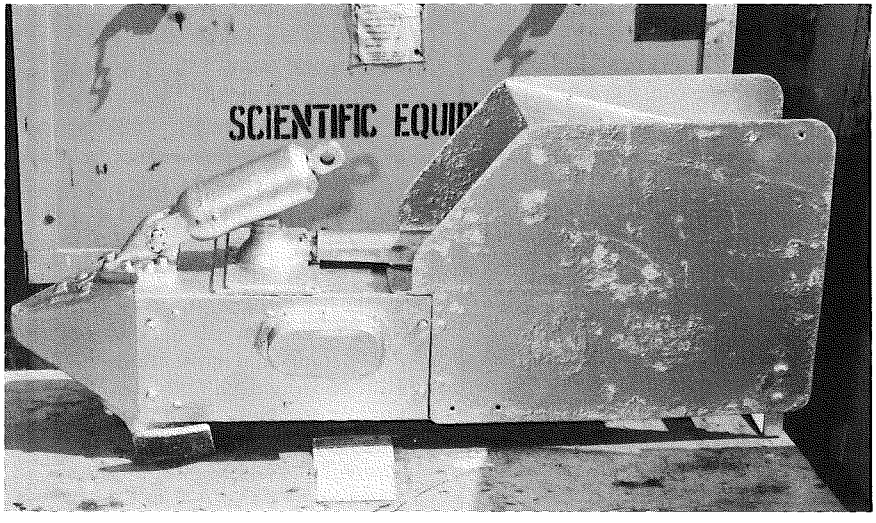
The CPR was invented by Sir Alister Hardy in 1922 and was first put to use to sample euphausids in the Antarctic on the *Discovery* cruises of 1925–27. It was later modified for regular use in the North Sea and North Atlantic, and has remained essentially unchanged ever since. The CPR Survey continues, funded by an international consortium, through the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) based in Plymouth, UK.

The CPR was designed to be towed from merchant ships during their normal sailings – 'ships of opportunity'. It works by filtering plankton from the water over long distances (up to 450 miles) on to a constantly moving strip of silk in a self-contained cartridge loaded at the laboratory before deployment. The towed body itself is about a metre long and made of gunmetal, phosphor-bronze and stainless steel, with a lead nose cone. Its angular, 'heavy metal', appearance looks crude alongside today's towed instruments, and it seems little more streamlined than a brick, but CPRs are regularly deployed in rough seas and can be towed at 10 m depth on a 10 mm wire rope at speeds of up to 22 knots.

Their record is impressive – more than 3 900 000 miles of sampling since 1946, resulting in over 170 000 samples. CPRs are now towed every month along ten routes in the North Atlantic, eight in the North Sea, one in the Irish Sea, one in the Mediterranean Sea and three in the Gulf of Guinea (*see map opposite*).

The methods of sampling and analysis have remained almost constant since the beginning, so the CPR database is the longest and largest consistent set of plankton data on a basin-wide scale. The sampler's internal mechanism continuously winds the silk strip with the filtered plankton together with a second strip, sandwiching the sample in between, on to a take-up reel in a tank of formalin. Winding power is provided by an impeller mechanism driven as the sampler is towed through the water.

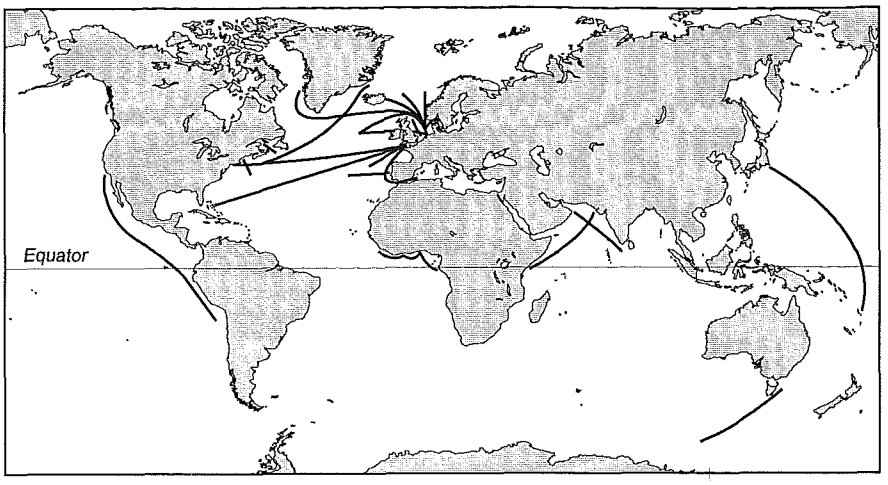
The hard-working heavy metal CPR, which has now sampled for nearly 4 million miles



On long tows, the ships are supplied with several internal mechanisms which they load into the CPR to increase the sampling range. On return to the laboratory, the silk is removed from the mechanism and divided into samples representing 10 nautical miles of towing. The plankton on these samples are then analysed according to standard procedures. After analysis, the counts are checked and added to the CPR database.

The down-side of building up long time-series of consistent data is that it becomes difficult to introduce any changes into the sampling scheme. The CPR performs remarkably well but it does have limitations – it cannot measure other variables while it samples the plankton, and it samples continuously and at a fixed depth. One of the strategic aims of SAHFOS has been to develop a new towed body to carry a range of new sampling and sensor systems for both plankton and environmental variables, and in particular capable of undulating as well as fixed-depth deployment. Working in collaboration with SAHFOS and MAFF, Valeport Ltd began developing a Continuous Plankton and Environmental Recorder (CPER) in 1994. This led to the versatile 'U-Tow' vehicle, now produced commercially by WS Ocean Systems Ltd.

U-Tow can be towed at speeds in the range 4–20 knots and is specified to undulate between 5 m depth and 25 m at 20 knots or 40 m at 15 knots. Undulation can be self-contained, with 'flight' characteristics pre-set before deployment, or under real-time control with real-time data output via an electro-mechanical cable. U-Tow can accommodate sensors to measure environmental variables including flow, fluorescence, turbidity, pH, and dissolved oxygen, together with a CTD (for salinity, temperature, depth) and an improved mechanism, manufactured by Valeport Ltd, which allows incremental and event-triggered plankton sampling.



CPR towing routes, including some projected routes

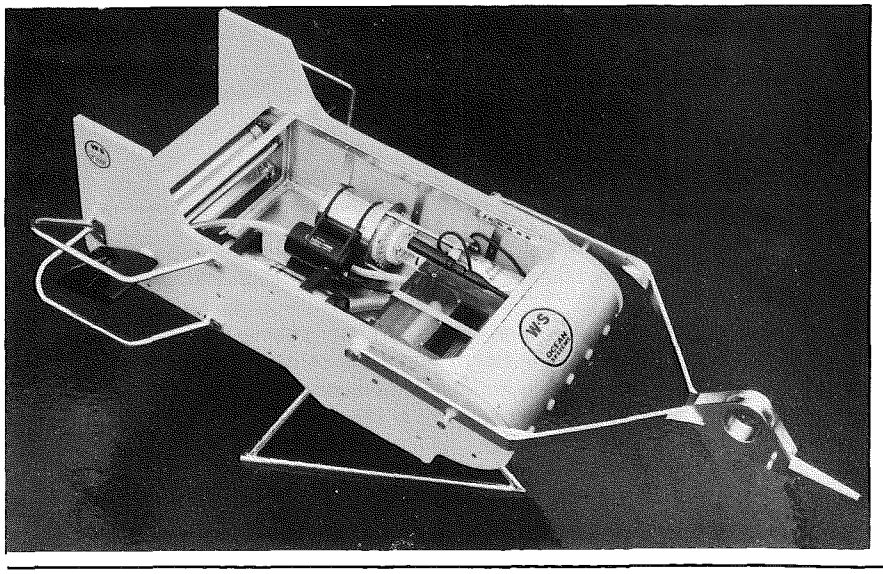
Neither the original CPR nor the new Valeport plankton sampling mechanism can sample the microplankton smaller than 250 µm, the mesh size of the silk filter, so SAHFOS began a three-year venture to design and develop a towable automatic water sampler in collaboration with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and the Department of Agriculture for Northern Ireland (DANI), with funding from the Department of Environment, Transport and the Regions. This project has recently come to fruition in the form of WS Ocean Systems' Aqua Monitor. It can take up to 50 discrete water samples using a syringe-based mechanism operating with a multi-port valve assembly. Sampling can be triggered by the signals from instruments such as a fluorometer or turbidity sensor and the samples are stored in flexible transfusion bags to make the most of the space available in the U-Tow. Aqua Monitor provides for samples to be taken and held or rejected so that, for example, when linked with a programmable data-acquisition system, samples can be taken at a peak or above a threshold in fluorescence.

All this seems very satisfying. It's good to see some ideas from the UK research effort being developed commercially and leading to marketable products which can in turn improve the instrumentation and equipment available for scientific research. Technology transfer is really happening.

Bill Prior-Jones is a consultant in applied ocean science.

Photographs are by courtesy of SAHFOS.

The U-Tow, produced commercially by WS Ocean Systems



Marine Foresight

Marine Foresight is part of the UK Foresight Programme (previously Technology Foresight) – a systematic process for identifying market opportunities and related scientific and technological priorities for 10–20 years ahead. It is also a mechanism for bringing academics and industry together to explore a range of possible futures and their implications for science and technology development and market growth.

Marine Foresight is a late-comer to the field, because although the Steering Group set up to initiate the programme in 1993–94 established no less than 15 so-called Sector Panels, a marine panel was not among them, on the grounds that 'technology foresights for the marine industries would be accommodated within the other panels' – a wry comment on the UK scientific establishment's awareness that 70% of Earth's surface is oceans. The Marine Panel (the 16th) was finally set up early in 1996, and it has the following objectives (somewhat tendentiously – but when you look at the list perhaps realistically in some cases – termed 'challenges'. These are listed in full on p.3.

The Marine Panel should be of some interest to academics, because, as pointed out by former Director of IOSDL, Colin Summerhayes (who is on the Panel) in an article he wrote elsewhere on the subject: 'You can influence its direction by becoming involved ... [because] ... you may eventually benefit from the funding of research proposals directed at problems identified by the Foresight exercise.' It may even be possible to change the thrust of some of the objectives ('challenges'), if enough people feel strongly about doing so.

A 55-page booklet on the Marine Panel (published May 1997, No. 16 in the Series) can be obtained from the Office of Science and Technology, Albany House, 94–8 Petty France, London SW1H 9ST. Fax: 0171-271-2015. Its reference number is: DTI/Pub.2653/5k/5/97/NP.URN97/639. You may also be able to find out more from the Web at: http://www.dti.gov.uk/

Oceanology '98 – bigger, brighter and more upbeat?

The Brighton Oceanology event is the world's largest and most prestigious exhibition and conference in Marine Science and Technology, alternating in even-numbered years with 'OI Pacific Rim' (odd-numbered years). Not only was OI'98, held in March, bigger than ever, but the mood of optimism was generally felt to be greater than it has been for some time.

Even a cursory and superficial wander among the stands, and perusal of the enormous number of handouts, brochures and press releases, produced a strong impression that the frontiers of marine technology are being pushed both deeper and further poleward, in the search for oil and gas and other resources. Supporting and guiding these activities is an ever-growing array of ROVs and AUVs, several of which were on display at company stands. Remote sensing of the marine environment is of course also growing apace, both from orbiting satellites (producing images with better resolution than ever before), and with increasingly sophisticated acoustic instruments – all of these developments being made possible by the virtually exponential improvements in computing power and software versatility.

Although the main focus must be on the exhibits, the conference proceedings should not be forgotten. There were sessions on contemporary issues and recent developments, including acoustics, coastal zone management, environmental monitoring, littoral oceanography, marine biodiversity, wave and current measurement, and so on, each opened with a keynote address by a distinguished speaker.

The OI'98 Award for Lifetime Contribution to Marine Science was presented to Professor Emeritus Noriyuki Nasu of Tokyo, Japan, during the opening plenary session, which was addressed by Michael Meacher, Minister for the Environment. He announced that the UK Government will be hosting a second Oceans Workshop in London at the end of 1998 (a follow-up to an event hosted with Brazil in 1995) to discuss what still needs to be done to improve the ways in which the global ocean environment is managed. He also spoke of the enormous value of the marine sector to the nation's economy on the one hand, and the crucial need to conserve the marine environment on the other.

Although Mr Meacher didn't say it, as Environment Minister he must be as aware as anyone that over the coming decades, the trick will be to keep the money rolling in without significantly degrading the natural support systems upon which the whole of life on Earth depends. Given the increases in numbers and aspirations of the human population, that is likely to prove a rather greater challenge than devising ever more ingenious techniques and gizmos for finding and extracting profitable products from previously inaccessible parts of the oceans.

The OI'98 Conference proceedings are available in three volumes. Vol.1 covers the sessions on Coastal zone management, Modelling and information systems, Key enabling technologies, and Life sciences; Vol. 2 is devoted to the sessions on Rapid environmental assessment technology and Acoustics; and Vol. 3 is on AUVs/UUVs, Littoral Oceanography, Remote sensing, Wave measurement and modelling, and Integrating models and observations. Costs are £50 per volume or £125 for the set of three, plus mailing: £10 (UK); £15 (elsewhere in Europe) and £20 (outside Europe. For further information on this and all aspects of OI'98 and OI'2000, contact Spearhead Exhibitions Ltd;
Fax: +44-(0)181-949-8186
Email: oi98@spearhead.co.uk

The History of Marine Meteorology

Andrew Cormack

This fascinating topic was addressed by members of the Royal Meteorological Society and the Challenger Society on14 March at the Architecture Centre, Narrow Quay, Bristol. The meeting was opened by Malcolm Walker (University of Wales, Cardiff) who observed that, from the first days of sailing ships, seafarers have always had a very practical interest in meteorology. An early application of this knowledge to navigation (as opposed to propulsion) seems to have been made by the Pacific Islanders who, 1500 years ago, were using cumulus clouds as distant markers for low-lying islands. Both they and the Arabs had experience of the Indian Ocean where the monsoon caused seasonal variation in both winds and currents. These changes had been recorded by 800AD, and by around 1450 there were books of sailing directions for the ocean, suggesting different routes for different seasons.

Prevailing winds were also understood by navigators elsewhere, allowing Columbus to use them in both directions for his trans-Atlantic voyages. An early example of forecasting is found in a work by Dampier published in 1697, where he describes how he had read the disruption of prevailing wind as a storm warning, prompting him to sail from Hong Kong to gain sea room. By the 1860s, practical seafarers were proud of their understanding of marine weather and contemptuous of the 'closet scientists' who developed meteorological theories from the safety of dry land.

One seafarer who carried his practical experience into a land-based job was Robert FitzRoy, who had been captain of HMS *Beagle* in the early 1830s, and whose later life was described by Jim Burton (Ilkley, West Yorkshire). After the 1853 international meteorological conference in Brussels, a Meteorological Office was founded within the British Board of Trade and FitzRoy was given charge of it. Shipwrecks were of great concern – even during the Napoleonic Wars more than twice as many ships were struck by natural disaster as suffered enemy action – and by the 1850s nearly a thousand ships a year were being lost. The sinking of the *Royal Charter* in 1859 finally prompted action. FitzRoy was already obtaining weather reports by telegraph from ports, and using a simple model for the movement of weather systems he was able to send gale warnings in return. The first warning was issued in February 1861 and the system soon gained the trust of sailors. FitzRoy himself designed the storm signals which were hoisted. These used cone and drum shapes to indicate the expected strength and direction of the wind and were so successful that they continued in use until 1984.

The story was continued by Tim Hunt (University of Wales, Cardiff). FitzRoy's system had its detractors among those who had suffered from incorrect forecasts; ship repairers also complained of loss of business! After his death, the Royal Society took responsibility for the scientific work of the office but refused to publish forecasts because it considered such activity 'unscientific'. The service was allowed to lapse but resumed for weather reporting (rather than forecasting) until 1874 when storm warnings restarted with slightly modified signals. The development of lithography made possible daily weather maps but their cost meant that they were not available to most sailors. FitzRoy had offered sets of charts in exchange for reliable observations, and in 1857 the first barometer was presented for long service. The trans-Atlantic telegraph allowed ships to send records from their voyages back to the UK from America but shore radio was not used until 1907. Two years later, ships of eleven companies were making daily reports, but the limited range of marine radios meant these often had to be relayed from ship to ship, resulting in long delays. By 1911, 47% of observations arrived within 24 hours but some were still taking five days to reach land. The *Marine Observer* was first published in 1924 and explained how ships could use their own, and others', observations to construct synoptic charts.

The start of trans-Atlantic flights after the Second World War required information about the upper atmosphere which could only be obtained by regular observations with weather balloons. Voluntary observing ships could not provide these, so in 1946 the International Meteorological Organization (IMO) recommended that dedicated ships be located at fixed positions in the North Atlantic to make the necessary measurements. The history of these Ocean Weather Ships was told by Martin Stubbs (Crowthorne, Berkshire). The ships also acted as navigation beacons and an emergency search-and-rescue service so were funded by the International Civil Aviation Organization (ICAO). The original plan involved thirteen stations but was reduced to ten in 1949. Britain was responsible for three of these and from 1947 to 1958 they were occupied by converted Flower class corvettes.

Those who have spent time in the North Atlantic can well imagine conditions on board these 725-ton vessels: others may have read *The Cruel Sea*, concerning a fictional ship in the same class. From 1958 they were replaced by Castle class frigates. ICAO funding ceased in the mid-1970s as the radio beacons were now redundant; around the same time the Americans left their stations in the western Atlantic, leaving five stations in the east to be funded by the IMO. In 1982 the British frigates were withdrawn and the remaining British and Dutch stations combined into one, to be occupied alternately by ships from the two countries. In 1985 the Dutch ship *Cumulus* was purchased by Britain. The IMO agreement expired in 1989 but the great 1987 storm had persuaded the British authorities that satellite observations were not yet sufficient and *Cumulus* remained on station for 25 days in every 33 until her final transmission at 1500 hours GMT on 29 May, 1996.

Arnold Court (California State University at Northridge) considered mariners' and meteorologists' shared preoccupation with the wind. The first instruments measured the effect of the wind on a flat plate, either lifting it against gravity or pressing it against a spring. However, these techniques measured wind pressure rather than speed and the relationship between them is far from simple. Early tables of wind speeds were published by Derham and Defoe, the latter in 1703, but the first table giving conversions from measured pressure to speed was given in 1759

by Smeaton, who attributed it to Rouse. This table uses the twelve steps (so familiar to meteorologists) with maximum speeds greater than 60 knots. The scale was re-used by many authors and became accepted as fact even though no calibration at over about 30 knots was possible for another century! Only by using steam trains was it possible in the 1870s to expose an instrument to winds of known high speed.

A related problem was how to summarise the wind measurements for mariners. A simple wind rose was first used in print (but not on a chart) by Osler in 1840. At this time, Maury was still using numerical tables on his charts; by 1849 he had adopted graphical methods but only to show the strength and direction of individual observations. At about the same time, FitzRoy used a polygonal 'windstar' to summarise the frequency of winds in different directions but the combination of direction, frequency and strength in a single segmented wind rose does not appear until used by Brault in 1874. Interpreting these early examples is complicated, as there is no standard either for wind direction or compass orientation.

Bob Shearman (Meteorological Office) discussed the development of meteorological observation at sea. Ships' motion was an early difficulty for instruments designed for use on land but once such problems had been solved alternative platforms were soon adopted. Both drifting buoys and weather balloons were in use early this century while the first moored buoys appeared around the Second World War. Comparing results from different instruments or platforms has always been a problem. The first 'Beaufort' scale in 1806 described the effect of the wind on a ship's sails and could be applied reasonably consistently. However, when the scale was re-stated in terms of sea state, to allow its use on steam ships, observations from different sea areas were no longer comparable. The same wind speed has very different effects on the deep North Atlantic and the narrow, shallow North Sea. The first intergovernmental meteorological conference in Vienna in 1873 tried to establish standards for calibration, times of observation and record-keeping. Despite the huge technological changes in the past century, the Commission for Marine Meteorology is still concerned with much the same issues today.

One of the stranger episodes in the joint history of oceanography and meteorology relates to the Scottish Meteorological Society's research into herring fisheries in the 19th century, described by Margaret Deacon (University of Southampton). The Society had begun measuring sea temperatures in the late 1850s to see if these had any influence on climate. An early finding was the unexpectedly high sea temperature off the west coast of Scotland, which was correctly attributed to warm water from the Gulf Stream. The Society's President at the time was the Marquis of Tweedsdale who had already discovered the influence of soil temperature on crop germination and suggested that there might be a similar link between sea temperature and fish. The Royal Commission into Sea Fisheries in 1863 had observed that the peak herring fishery moved south along the east coast during the year. Comparing the catch records for 1867 to 1872 with coastal sea temperatures seemed to show a clear link. Between 1873 and 1875 twenty thermometers were given to 'intelligent fishermen' and temperatures were taken at the fishing grounds themselves. These results showed that the relationship, if any, was much more complicated, but by the late 1870s there was insufficient money for further investigation. In fact, even after another hundred years, the influence of sea temperature on fish is still unresolved. However, *some* things have changed in that time: in 1877 a Royal Commission reported that 'nothing man has done, or is likely to do, can damage the stock of herring in the sea'!

The effect of wind on the ocean must have been obvious from the earliest times, but scientific studies were not possible until the 1920s when instruments were developed by the Meteorological Office. Neil Wells (University of Southampton) told the history of this study and, in particular, described the work of the late Henry Charnock to whom his talk was dedicated. The key relationship is the stress exerted on the water surface by the wind, and during the late 1940s George Deacon and Henry Charnock attempted to quantify this using various different techniques. Once the relationship was understood, the effect of the ocean could be included in numerical models of the atmosphere used for weather forecasting.

The Global Atmospheric Research Programme was initiated to validate the models against reality, and in 1966 the Royal Meteorological Society proposed the JASIN Project to provide the necessary high-resolution measurements. JASIN took place over two months in 1978 and involved fourteen ships and three aircraft in an intensive survey of a 300-km box near Rockall. As well as providing data for detailed modelling, the experiment was also able to provide ground-truth measurements for the *SeaSat* satellite.

The study of ocean and atmosphere was brought up to date by Chris Thorncroft (University of Reading) who explained his work on tropical cyclones. There is an understandable shortage of observations from surface vessels but satellites can watch the formation and movement of these storms. This information has led to a qualitative description of the conditions necessary for a storm to develop. When an existing atmospheric vortex moves over the ocean with a surface water temperature greater than 26 °C, water evaporates, increasing the already high relative humidity. At latitudes more than 5° from the Equator the winds around the vortex spiral inwards, increasing in speed as they approach the centre. The faster winds absorb more moisture making the air more buoyant. It rises and, if the vertical structure of the atmosphere is relatively calm, can reach a height where the water condenses. This raises the temperature and decreases the pressure at the centre of the vortex, thereby sucking in faster and faster winds. If this convection continues to build up, the vortex may become a tropical storm or even a hurricane. Numerical models are now being developed to allow better forecasting and understanding of hurricanes and, in particular, the likely effect of climate change. The variation in the number and strength of storms in different years makes it hard to observe any such effect but if it exists, the future may bring more or stronger hurricanes, or even produce them in new locations. The photographs and satellite images of hurricanes gave a suitably dramatic close to a very enjoyable day.

Andrew Cormack, formerly of Research Vessel Services, is now at Cardiff University.

The UK Contribution to WOCE

Graham Quartly and Adrian New

In January, a meeting was held at Imperial College, London, to review the achievements of the UK World Ocean Circulation Experiment (WOCE) programme. The meeting was organized jointly by the Royal Meteorological Society and the Challenger Society for Marine Sciences, under the title 'Ocean Circulation'. The programme was assembled by Trevor Guymer (Southampton Oceanography Centre, SOC), and brought together speakers from diverse fields to highlight the broad contribution to WOCE by the UK community. The meeting was chaired by David Carson (President of the Royal Meteorological Society) who gave the opening address. He particularly commented how much Henry Charnock would be missed, as with his wide range of interests, he had been a keen advocate of the UK's participation in WOCE.

The primary aims of WOCE have been to develop ocean models useful for predicting climate change, to collect the observational datasets necessary to test these models, and to investigate how the ocean varies on longer time-scales. The origins of WOCE can be traced back to 1978, when, following the success of the *Seasat* satellite – and in the expectation of further satellite launches and ever-increasing computer power – a committee of the World Climate Research Programme (WCRP) met and discussed how best to address the question of the rôle played by the oceans in the physical climate system. Since then, there has been a concerted international effort towards these goals. The observational phase of WOCE took place during 1990–97, and has seen a trebling of the total number of ocean hydrographic observations ever made, along with the development of new instrumentation, enhanced analysis techniques, the launch of several Earth-observation satellites, and great leaps in computer power and ocean modelling.

Observations

As part of WOCE, the UK has undertaken several successful ocean surveys across the Atlantic between 45° S and 63° N (see Figure 1). Harry Bryden (SOC) examined the oceanic transport of heat and freshwater across these (and other) sections, and showed that the ocean is a significant component in the coupled global atmosphere–ocean system, transporting polewards, in both hemispheres, an amount of heat comparable to that carried by the atmosphere itself. In the Atlantic, the heat transport is accomplished primarily by the vertical overturning ('thermohaline') circulation rather than by the horizontal gyral circulation. At high northern latitudes, wintertime cooling leads to the sinking of dense water masses which then flow southwards as North Atlantic Deep Water (NADW). The sinking regions therefore act as pumps for the thermohaline circulation since they result in a compensating northward flow of lighter waters in the upper ocean. The South Atlantic is different from the other southern ocean basins in that it transports heat equatorwards, in response to the strong sinking in the North Atlantic. The decadal variability of the North Atlantic has also been investigated by making repeat sections at 24° N. These showed there has been a large-scale and marked change in the water masses at intermediate depths, which have risen steadily in temperature by about 0.3 °C over the last 30 years, a possible signature of global warming.

The formation of cold, dense water masses at high latitudes was a theme developed further by Bob Dickson (Centre for Environment, Fisheries and Aquaculture Sciences, Lowestoft). Bob showed that, in the Arctic and North Atlantic, the production and characteristics of the deep southward 'return' flows may be related to the NAO, the North Atlantic Oscillation, an oscillation in the pressure difference between Iceland and Lisbon. It was proposed that the extreme positive state of the NAO in the early 1990s was connected with the warming of the current near Spitsbergen (north of Norway, warmest in 1994), and that this temperature anomaly propagated around the Nordic Seas, reaching the Denmark Strait (between Greenland and Iceland) three years later (warmest in 1997). The recent drop in the NAO index leads to *predictions* that colder water may now be following this route. In the Southern Hemisphere, the ADOX survey revealed the flow rates and pathways by which Antarctic Bottom Water (AABW, produced in the Weddell Sea at a rate of 1 Sv, i.e. 10^6 m^3s^{-1}) flows northwards through the trough between the Crozet Plateau and Kerguelen Plateau, into the Indian Ocean (where the flow rate has increased by mixing to 12.8 Sv). AABW is also an important component in the world's thermohaline circulation, and the Crozet–Kerguelen gap is one of the few places where this water mass can flow northwards through the Antarctic Circumpolar Ridge.

On the other hand, the deep southward flow of NADW out of the Atlantic is partially compensated for by the influx of warm salty Indian water around South Africa. Examining data from a recent WOCE cruise (A11), Elaine McDonagh (University of East Anglia) showed that this occurs not just via the northward-flowing Benguela Current, but also because of the spawning of Agulhas 'rings' (large eddies) from the retroflection of the Agulhas Current south of South Africa. Previously, hydrographers had used the 10°C isotherm as the limit for defining advected Indian water masses; Elaine McDonagh showed that this choice significantly underestimates the total heat and salt contents, and volumes transported by the eddies. The total volume flux of the Agulhas rings was estimated to be about 10 Sv (with just over half of that being of water below 10 °C), compared with 25 Sv in the Benguela Current, showing the importance of these eddies (which are too small to be resolved by present-day coupled climate-prediction models).

In addition to the data collected on dedicated research cruises, there are a host of surface observations from merchant vessels, albeit predominantly from the major trade routes, and with errors peculiar to each ship. Simon Josey (SOC) showed how he and his colleagues combined the COADS dataset (COADS = Comprehensive Ocean–Atmosphere Data Set), containing

data covering 1980–93, with 'metadata' describing the siting of, and methodologies used for, the various instruments, in order to establish corrections and derive an improved climatology of air–sea heat fluxes. The derivation of improved fluxes such as these, which can be used to force ocean models, is an important component of WOCE. The global mean of the total heat flux into the ocean is 28 W m^{-2} for this dataset; this value corresponds to a much more rapid increase in ocean temperature than is observed, and thus must be understood as an error. However, a global change to the bulk formulae used in the calculation of the fluxes (as espoused by some researchers for other heat-flux datasets) would mar the good agreements with direct estimates seen in many regions. Instead, a severe lack of data in the Southern Ocean was proposed as the primary reason for this large net flux. Other disparities were noted in western boundary currents, and the region west of the Sahara, where insufficient account has been taken of the increased aerosol loading due to Saharan dust.

Models

During the WOCE period the UK has developed considerable expertise in high-resolution ocean models of basin-scale to global scale. These are now being assessed against the WOCE observations, both to provide insights into the way in which the ocean works, and to identify those areas in the models that can still be improved. David Webb (SOC) discussed the major recent developments in UK modelling. These are: improved horizontal resolution (with global coverage at a horizontal resolution sufficient to resolve the eddies); the emergence of models incorporating a free surface; and the 'spin-up' of a capability in isopycnic modelling (models using density surfaces rather than constant depth levels). David discussed how models could aid in the interpretation of (necessarily sparse) survey data, and how they could guide future surveys, and give new insights into the processes involved. For example, models suggest that the outflow (at depths between 800–1200 m) of salty Mediterranean Water into the Atlantic, drawing in fresher water at the surface, is partially responsible for the existence of the eastward-flowing Azores Current, a major

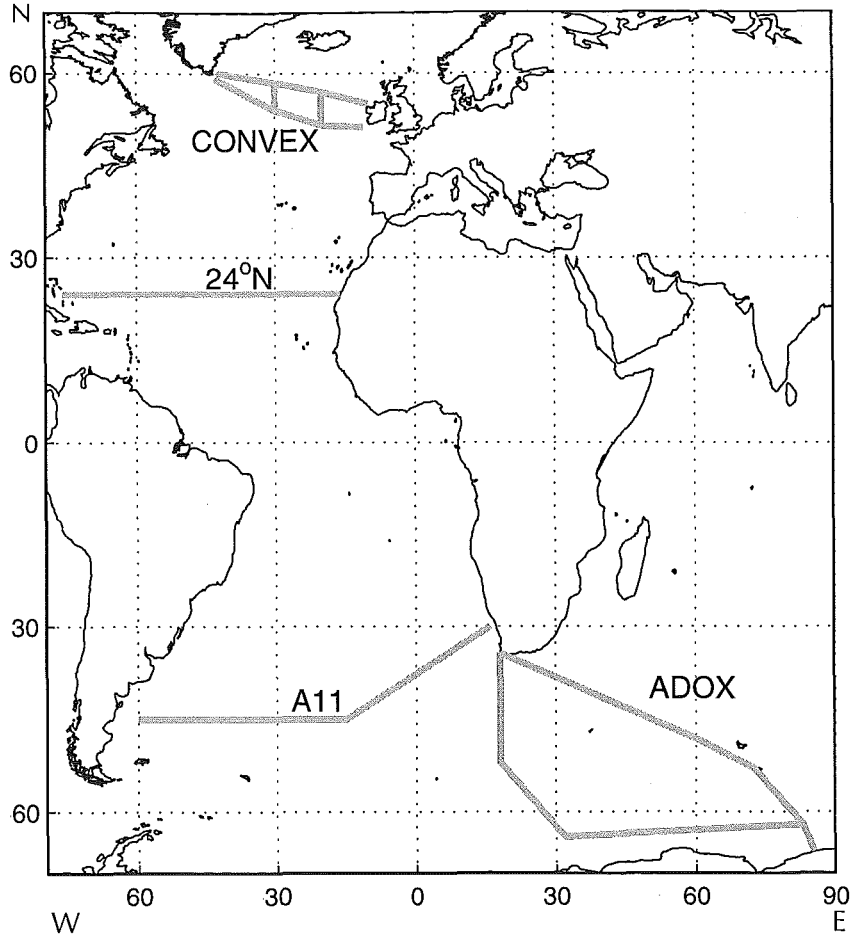


Figure 1 *A selection of the WOCE-related cruises with UK participation. CONVEX (Control Volume Experiment) examined flows in the NE Atlantic; the 24° N section was a repeat section used to look at decadal change; A11 was one of the WOCE Hydrographic Program sections; and ADOX (Antarctic Deep Outflow Experiment) laid moorings to monitor the deep water fluxes.*

circulation feature in the North Atlantic. Models are also showing that the Azores Current itself is responsible for setting the pathways by which water masses, drawn down from the ocean surface, are then able to circulate around the North Atlantic. And, furthermore, there is currently an open question in the observations as to whether or not water from the Mediterranean overflow pursues a path polewards as far as the Nordic Seas. Model studies, however, are indicating that saline water masses this far north have instead followed a near-surface pathway, and are not of Mediterranean origin. Future experimental campaigns can now be planned to validate these ideas. Overall, the emergence of ocean models with different specifications, and comparisons of these models with each other and with data, is producing rapid improvements in our ability to model the way in which the ocean works.

The modelling theme was continued by Chris Hughes (Proudman Oceanographic Laboratory) who looked at the forcing of the Antarctic Circumpolar Current (ACC). This is the world's strongest ocean current system, and is also important because it connects all the world's oceans together. Using FRAM (the Fine-Resolution Antarctic Model, developed in the UK), Chris showed that the streamfunction of the seasonal variations in flow lies not along the mean path of the ACC, but along a contour of f/H (Coriolis parameter over depth) which, in most places, is some way south of the ACC itself. FRAM reveals the seasonal variations in ACC transport to be well correlated with the wind field along this line. Furthermore, the zonal gradient of the surface height field of the model showed coherent structures, spanning 10° in latitude, representing the advection of Rossby waves by the ACC, whilst the meridional gradient highlighted a wealth of zonally coherent strands within the ACC – features which have also been borne out by analysis of satellite altimeter data.

A good example of model–data comparisons was then presented by Helene Banks (Meteorological Office). Observations made on the WOCE cruise A11 (near 45° S) were compared with results from the latest Hadley Centre coupled ocean–atmosphere climate model (which has global coverage, but not at a sufficiently small scale to resolve the ocean eddies). It was shown that while the model gave a reasonable representation of the different fluxes of surface and intermediate waters across this section, its northward flux of Antarctic Bottom Water (AABW) was less than a tenth of that revealed by the A11 survey (0.5 Sv as compared with 6.6 Sv). However, the presence and northward transport of AABW in this area were much improved by artificially deepening critical sills in the topography (the Vema and Hunter Channels) which could not otherwise be correctly represented at this model resolution.

Conclusions

The final presentation of the meeting was by John Gould (Director of the WOCE International Project Office), who began by summarising some of the main developments and achievements of our international partners in WOCE: the monitoring of the Kuroshio through combined altimetry and hydrography; the use of chemical tracers (CFCs) to time the circulation of deep water masses around the world's oceans; the comparison of sea-surface variability deduced from satellites and models; the deployment of hundreds of autonomous floats (some of which are capable of profiling – a new tool developed within WOCE), which are now giving basin-scale pictures of the ocean circulation; improved estimates of the heat and freshwater fluxes carried by the oceans; and basin-scale and global scale ocean circulation models at high resolution. Databases are being set up to enable wide access to the WOCE hydrographic data: in all, 85% of the planned world ocean survey has been successfully completed, and the resulting data will be freely available to all interested parties.

John then focussed on further aims These include bringing modellers and observationalists together to work closely with one another to interpret the datasets and improve the models, and the assimilation c both satellite and *in situ* data into an ocean circulation model to giv a dynamically consistent 'state-of the-ocean' for the 1990s, which could act as a baseline for past ar future changes. This dataset coul then be used to determine the key ocean observations that need to b monitored as part of the step towards the creation of a Global Ocean Observing System. Anothe important task ahead is the identi cation of the most effective ocean model formulation, and the use of such models for climate and biogeochemical investigations. In view of the considerable skills which have now been developed within the UK under the WOCE framework, it was seen as unfortunate that further direct funding has so far not been forthcoming to support these future plans, and to capitalise on the investments made so far.

Discussion

The meeting then concluded with a discussion. This centred on the best ways to exploit the UK skill-base built up within WOCE. It was evident that the US, and most other European countries, were directly funding a continuation of WOCE-like work, and that the UK was therefore in danger of losing its position as a leading player. No ready solution could be identified at this stage, save the need to press for new WCRP projects, such as CLIVAR, to be supported in the UK (see right). However, it was agreed that the meeting had given a good overview of the UK science which has been developed within WOCE (with several talks by young researchers who had been trained during the WOCE period), and of the advances that have been made since the early 1990s. Overall, the UK has pulled together effectively to tackle problems of global significance, and it is hoped that individual researchers will still be able to work together to capitalise on the undoubted skills which have now been developed.

Graham Quartly and **Adrian New** are at the James Rennell Division for Ocean Circulation, part of the Southampton Oceanography Centre.

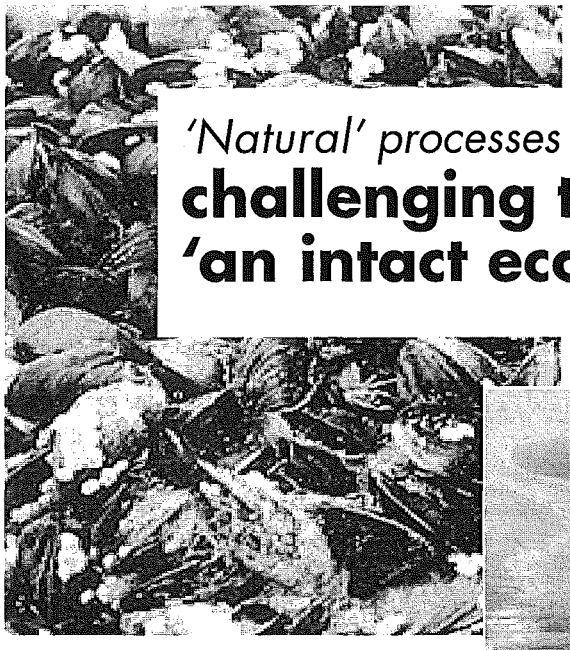
New CLIVAR Project Office to be located at SOC

John Gould has just been appointed as the new Director of the International CLIVAR Project Office which will be located at the Southampton Oceanography Centre. CLIVAR will study Climate Variability and Predictability and will be the central component of the World Climate Research Programme (WCRP). Its formal launch will be at an international conference in Paris in December 1998.

For several years John has been Director of the International Project Office for the World Ocean Circulation Experiment (WOCE), another WCRP project, which is in its final phase and finishes in 2002 (see previous item). This office is also hosted by SOC, and John will continue this role alongside his new position.

CLIVAR will study phenomena which take place on a wide range of scales starting with the striking seasonal effects of monsoons and the El Niño phenomenon, of which a dramatic example is currently unfolding in the Pacific Ocean and affecting weather patterns world-wide. At longer time-scales CLIVAR will address the role played by the global oceans in influencing changes in climate over tens of years through the interactions between atmosphere, ocean and ice, and finally to the detection and attribution of anthropogenic influences in the inherently variable climate.

Information by courtesy of Trevor Guymer, Head of the James Rennell Division at SOC.



'Natural' processes in the Wadden Sea – **challenging the concept of 'an intact ecosystem'**

Stefan Nehring

In 1991, the 6th Intergovernmental Conference of the three Wadden Sea countries – Germany, Holland and Belgium – met at Esbjerg, and adopted the guiding principle for a policy for trilateral management of the Wadden Sea: as far as possible, the objective should be a natural and self-sustaining ecosystem, in which natural processes can operate without interference. After the 7th Intergovernmental Conference at Leeuwarden in 1994, estuaries were included in the trilateral cooperation area, so river mouths are also covered by the Wadden Sea protected status. This future-oriented approach gives priority to the natural development in the Wadden Sea and its estuaries. Local activities (fishery, hunting, building dikes, mining for sand), and importation of remotely generated noxious or fertilizing substances, should be restricted, as has already been done in some smaller areas. However, a review of the latest results of German coastal research makes it clear that 'natural' processes in the Wadden Sea ecosystem include surprising aspects, inconsistent with the theoretical image of an ecologically sound Wadden Sea.

Decline of blue mussel beds

Since the mid-1980s there has been a continual decline in wild beds of the blue mussel *Mytilus edulis* over wide areas of the Dutch and East Friesian Wadden Sea, and it is feared that they may become extinct in the eulittoral (intertidal) zone of the area. The factors responsible for this decline are still the subject of discussion, but the cause seems to be a combination of natural factors (*inter alia* storms, freezing winters, feeding pressure of birds) and developments of anthropogenic origin (eutrophication, mussel-harvesting, input of contaminants and so on). What is striking, however, is the fact that blue mussels in the North Friesian and Danish Wadden Sea are not yet similarly threatened.

Other organisms threatened in at least parts of the Wadden Sea include the amphipod *Corophium volutator* and the shore crab *Carcinus maenas*, both of which repeatedly suffer mass kills. The mortalities have probably been due to an excessive infestation of these animals by parasitic trematodes. The increase in the populations of many sea-birds may also play a role here: infested birds are final hosts to these worms and massive excretion of infective stages may lead to high infestation rates of other animals (the so-called primary hosts). Depending on the degree of infestation, the animals may die off in a very short time. Whether these developments have only natural causes (parasite cycles are in evolutionary terms nearly as old as the hosts themselves), or whether there are also anthropogenic influences, remains a topic for further studies.

However, the disappearance of species is not the only puzzle. It is also unclear why some macrozoobenthic species (> 1 mm in size) – for example, the polychaetes *Spio filicornis*

and *Nepthys cirrosa* – have extended their area of dispersal considerably. Recently, three genuine brackish-water species were rediscovered in the Weser Estuary, having previously disappeared for many decades. These are the snail *Hydrobia ventrosa* and the bryozoan *Electra crustulenta*, along with the amphipod *Leptocheirus pilosus*, thought to be extinct along the entire German North Sea coast.

Invasion of alien species

Over the last 100 years, the Wadden Sea and its estuaries have been invaded by numerous alien macrozoobenthic species, of which some, such as the bivalve *Ensis americanus* and the polychaete *Marenzelleria viridis*, have even became dominant (Table 1). Invading species arrive in ballast water or as encrustations on ship hulls, with oyster spat imported for cultivation, or indeed simply by being intentionally released off the North Sea coast. Other species which can live in freshwater and brackish water have spread through rivers and canals (from the Caspian Sea, for instance) into the estuaries of German rivers. Over the past 100 years the banks of European oyster (Figure 1, opposite) have disappeared completely, and *Sabellaria* reefs, sertularian moss and eelgrass, with their associated faunas, have almost become extinct. Surprisingly, however, an inventory of the present state of the macrozoobenthos shows an increase in species diversity, an increase in population densities, and in some areas also an increase in biomass.

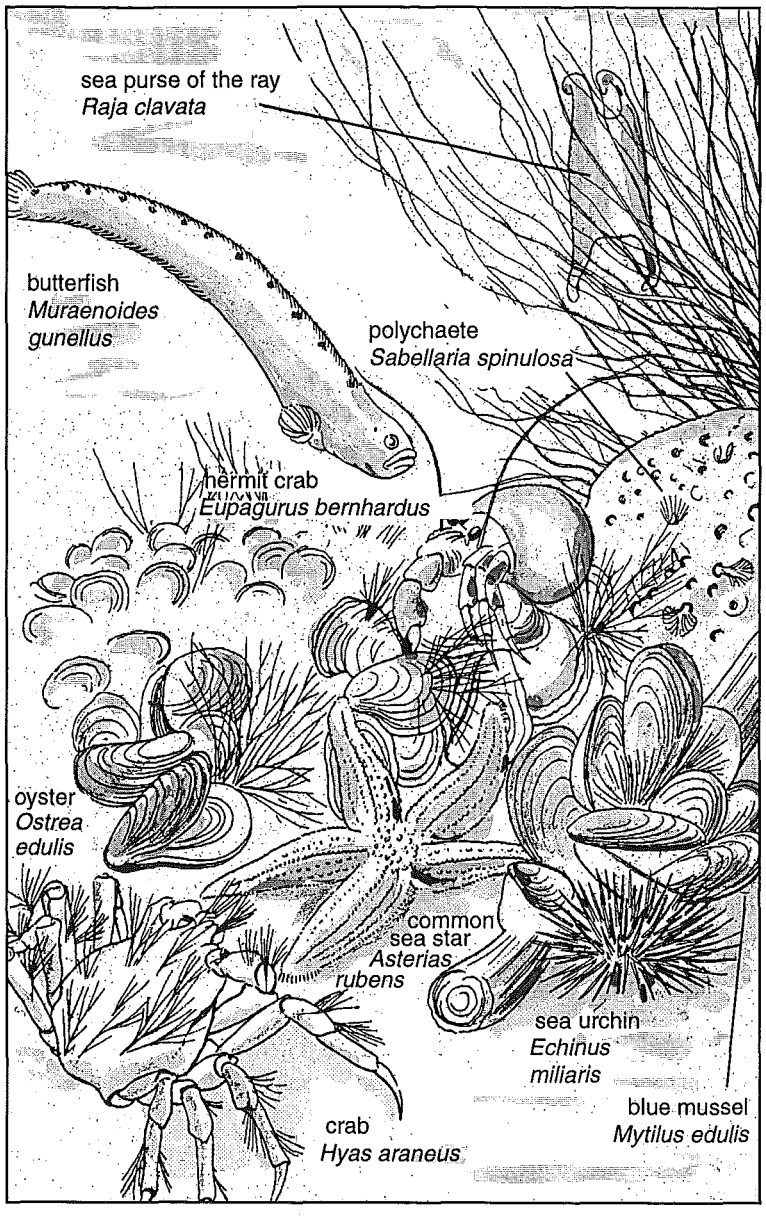
An interesting example of population 'enrichment' is the Pacific oyster, *Crassostrea gigas*, introduced in 1971 for cultivation. In the past few years some specimens that had gone wild have been found living in eulittoral mussel banks as 'squatters'. This alien species appears to be more 'ecologically potent', i.e. more adaptive, than its local predecessor, the European oyster (*Ostrea edulis*), although it requires warmer water of at least 20°C for spawning. However, it is difficult to assess the likelihood of natural oyster banks becoming established in the Wadden Sea, along with their associated community of organisms (Figure 1).

In addition to the Pacific oyster, there is one other introduced alien species that can be classified as an accessory species of oyster banks – the tunicate *Aplidium nordmanni*. The barnacle *Verruca stroemia* and the polychaete *Pomatoceros triqueter*, which used to live mainly on oyster banks, are again being found more frequently. It will probably take several years without disturbance before the typical Wadden Sea

Table 1 *A selection of macrobenthic species which have established populations in the German Wadden Sea and its estuaries in the past 100 years.*

Species	Year of first appearance	Possible origin	Likely transport mechanism
Crustacea			
Corophium curvispinum	~1920	Caspian Sea	Migration/drift/encrustations
Elminius modestus	1952	Australia	Ballast water/encrustations
Eriocheir sinensis	~1910	China	Ballast water
Gammarus tigrinus	1965	North America	Released
Gastropoda			
Crepidula fornicata	1935	North America	In aquaculture products
Potamopyrgus antipodarum	~1900	New Zealand	Ballast water/encrustations
Bivalvia			
Corbicula fluminalis	1968	North America	Ballast water/encrustations
Crassostrea gigas	1971	Japan	Imported as aquaculture product
Ensis americanus	1978	North America	Ballast water/encrustations
Petricola pholadiformis	1904	North America	Ballast water/encrustations
Polychaeta			
Nereis virens	~1920	?	?
Marenzelleria viridis	1983	North America	Ballast water
Marenzelleria wiremi	1932	North America?	Ballast water
Tharyx killariensis	~1970	?	?
Tunicata			
Aplidium nordmanni	1985	Netherlands	In aquaculture products

Figure 1 *The community associated with the European oyster bank* (Ostrea edulis) *in the northern Friesian Wadden Sea at the beginning of the 20th century.*



This illustration is a modification of a drawing in Das Tier als Glied des Naturganzen *by F. Doflein, published in 1914 by Teubner, Leipzig.*

'oyster bank' biotope can become established in the same way that the predecessor species were. Oyster larvae need a solid substrate for colonization, preferentially accumulations of shells. The sites of the former oyster banks in the sublittoral (i.e. below the low water line) are nowadays occupied by blue mussel cultures. However, the decline of eulittoral mussel beds, mentioned above, will perhaps allow a successful dispersal of the Pacific oyster.

Another important group, namely phytoplankton, shows a distinct increase in species diversity. In contrast to invasions by macrozoobenthos, the great majority of phytoplankton invasions have come via natural current pathways. Here, it is notable that during the past ten years or so it has been mostly thermophilic plankton species (including the potentially poisonous dinoflagellate *Gymnodinium catenatum*) that have been able to establish persistent populations in the surface waters of the Wadden Sea. It is thought that climate change, with repeated milder winters, has contributed to this phenomenon, although the measurable slight trend of increasing surface-water temperature (approximately 1°C) over the past 100 years is still within the range of natural variability.

Climate change – the factor of the future

The Wadden Sea is subject to diverse influences. For some years now, intensive efforts have been made to find solutions for the adverse effects of many anthropogenic impacts on the ecosystem (such as eutrophication, fishing and agricultural practices). There is also the uncertainty of future climate scenarios, which many experts have discussed in the general context of 'global change' but have so far examined only theoretically, concluding that coastal ecosystems will experience massive changes. These changes include (to mention only two): decrease of intertidal areas, as sea-level rises faster than tidal flats build up, and establishment of communities that are richer in species but have fewer individuals (similar to those found today on the French coast of the Atlantic, or in historical terms, during the last interglacial episode (the Eemian) that ended about 70 000 years ago). For the Wadden Sea, therefore, impacts of climatic change are becoming an influence to be borne in mind for the immediate future, not just for 50–100 years from now.

Already, one can observe along German coastlines changes in flora and fauna that are probably temperature-induced (either because of natural cycles or because of the enhanced greenhouse effect). As far as the Wadden Sea is concerned, it is possible that climate-impact research (a discipline established in Germany in 1991) will suggest that potential impacts of future climate change can be inferred from experimental combinations of expected processes and, especially, by comparative analyses of previous and present changes. It might then be possible for meaningful political and administrative strategies for coastal management to be developed.

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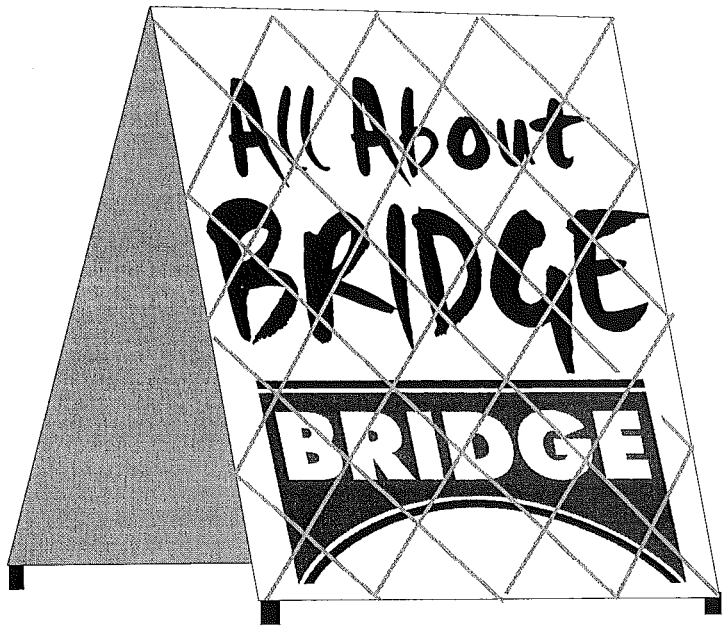


The British Mid-Ocean Ridge Initiative

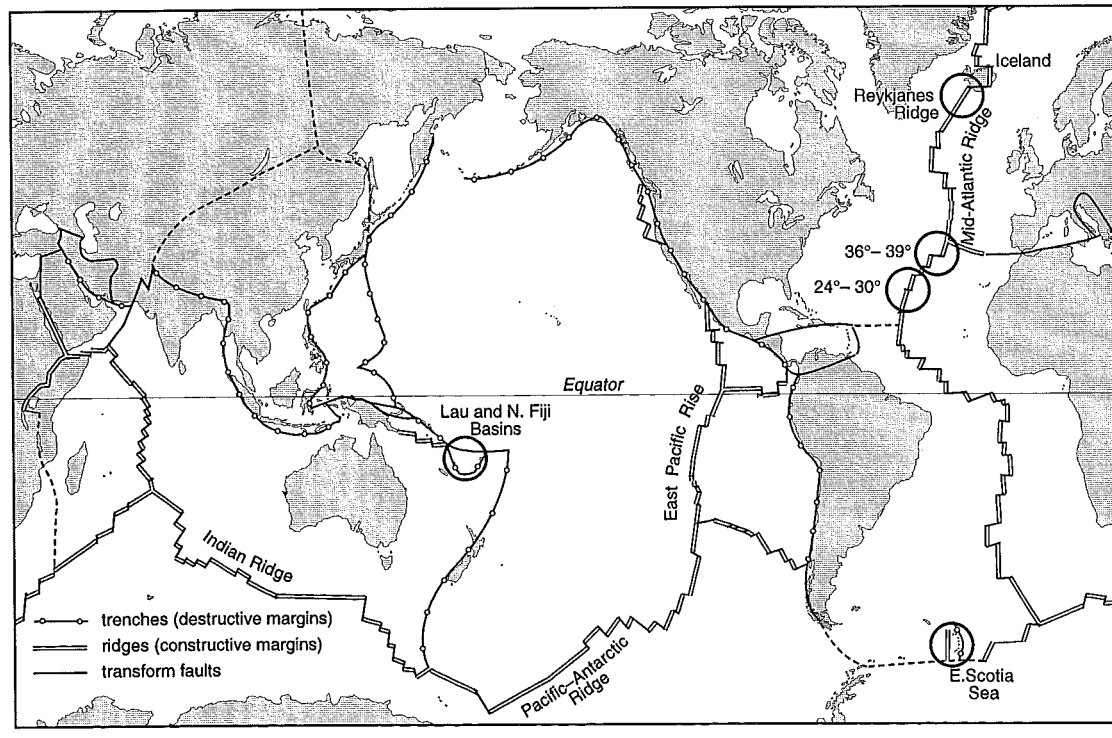
Keith Harrison

Funded in 1993, and running until 1999, BRIDGE is a multidisciplinary investigation of the mid-ocean ridge system, a continuous deep-sea volcanic mountain range rising 3 000 m above the surrounding sea-floor – as high as the Pyrenees – and running for 60 000 km through every ocean of the world. This ridge is the site of creation of two-thirds of the surface of the Earth (Box 1).

BRIDGE focusses its work at five designated geographical research sites: the Mid-Atlantic Ridge (MAR) at 24–30° N and 36–39° N; the Reykjanes Ridge south-west of Iceland, and the Icelandic mainland; the East Scotia Sea back-arc basin in the South Atlantic; and the Lau Basin/North Fiji Basin complex in the western Pacific.

The BRIDGE Programme sprang from the attendance of Professors Joe Cann and Roger Searle at the meeting that launched the American 'RIDGE' programme in Oregon in April 1987. The first meeting of British researchers interested in ridge studies – an informal grouping which came to be known as 'the BRIDGE consortium' – was held in the summer of that year. At that meeting it was agreed that UK researchers should seek to

Areas of BRIDGE research



bring about a new UK initiative to maximise the scientific returns from the interest that already existed.

After three further meetings it became clear that the Natural Environment Research Council (NERC) would be receptive to a formal approach from the marine science community for funding. At a meeting in the Lake District in January 1989, 30 scientists representing the whole UK deep-ocean community drafted a BRIDGE Science Plan and a formal proposal for a new NERC programme. The proposal was submitted to NERC in September 1989 and by the spring of the following year had received a positive grading. The programme having thus been officially adopted, a formal Steering Committee for BRIDGE was installed, but the BRIDGE proposal now had to enter into open competition for government funding with other proposals from NERC and proposals from other research councils. It took several attempts by NERC to steer BRIDGE to success, but the BRIDGE consortium had not been waiting, they were already building an unstoppable machine.

The volcanic Mid-Atlantic Ridge creates new ocean floor as the New World and Old World drift apart *(By courtesy of NOAA)*

Building BRIDGE

The name 'BRIDGE' was used in the research community long before funding to support the programme was agreed. British 'ridge' studies were being described as part of the 'BRIDGE' initiative. British ridge cruises were being labelled as 'BRIDGE' cruises. In an unusually successful use of the media, consortium spin-doctors managed to ensure the use of the name BRIDGE in national newspaper reports in February 1989 – more than four years before science funding commenced – and again in March 1990.

Box 1 Plate tectonics and continental drift

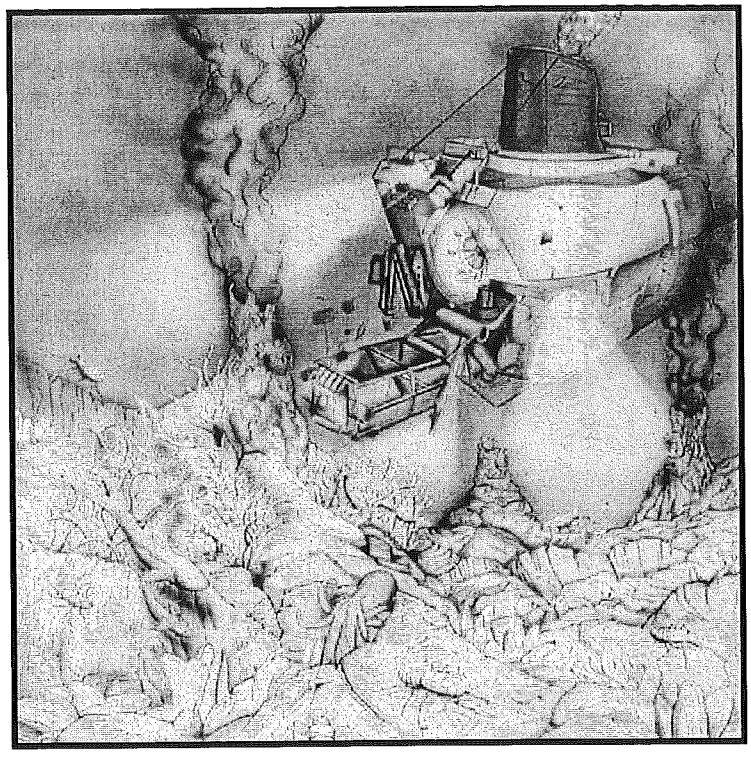
The mid-ocean ridge is a junction between the plates that form the Earth's crust ('tectonic plates'). These plates move on the underlying mantle like ice-floes in an Arctic ice pack. The less dense continents ride on these plates and it is the movement of the plates relative to one another that produces 'continental drift' through geological time. North America and Europe are currently drifting away from each other at about the speed fingernails grow (a few centimetres a year).

These two continental masses are separating along the line of the Mid-Atlantic Ridge, the branch of the ridge system that runs down the centre of the Atlantic from the north, where it breaks the sea's surface to form Iceland, to the sub-Antarctic (see the map opposite, and illustration above). At this mid-ocean ridge 'spreading centre', often beneath several thousand metres of water, there is volcanic activity as lava fills the widening crack between the separating plates. This creates new ocean floor to replace that being lost elsewhere on the Earth's surface at 'subduction zones'.

'Subduction' occurs where plate margins converge and one plate sinks under the other. This occurs off the coast of Japan, which suffers periodic earthquakes from the colossal scraping that occurs as the floor of the Pacific Ocean slides under the edge of the plate carrying the Japanese islands. Plates converging in this way form the deepest ocean trenches in the world.

Continental masses carried on converging plates are not dense enough to be subducted. When continents collide, the sediments on the sea-bed between them are squeezed, heated, folded and uplifted to form mountain chains like the Alps and the Himalayas.

Elsewhere plate margins slide past one another, as in California. The San Andreas Fault is one such junction between two plates. Here too, friction of one plate against the other leads to irregular Earth tremors at the plate edges. Occasionally, the movement of the plates is not sufficient to release all the stresses in the crust. These build up, to be released suddenly as the plates finally break free, as in the earthquake of 1906 that almost destroyed San Francisco.



Artist's impression of the Woods Hole submersible* Alvin *at a vent site. *BRIDGE access to* Alvin *and to the Russian* Mir *submersible has been crucial at vent fields. Small subs are essential for positioning sensitive instruments precisely, viewing organisms* in situ, *and sampling microhabitats.*

(© D.R. Dixon, Southampton Oceanography Centre)

The first *BRIDGE Newsletter* (eight A4 sheets and a staple) was produced in August 1991 and carried the optimistic editorial: 'As you can see, things have started on a modest footing, and we will await later issues for the pop-up models and scratch card competitions. ... It is anticipated that the next issue will ... contain the emergency self-help kit for coping with the trauma of the government's announcement that they *are* putting money into BRIDGE.'

Sure enough, the decision to fund BRIDGE arrived in time to be reported in the second newsletter in March 1992. A small funding advance was made in that year to support BRIDGE co-ordination and develop the BRIDGE community, and by September of that year BRIDGE was able to issue its first invitation to submit proposals for funding. The 1993/94 financial year saw the beginning of BRIDGE as a fully fledged programme. As BRIDGE began in earnest, a brochure was produced and distributed to politicians, companies and libraries, as well as members of the scientific community.

The programme now got into its stride. Further funding invitations were made in 1993, 1994 and 1995, and eventually resulted in the support of over 40 proposals (Box 2). In all, over a hundred scientists and support staff in the UK work on BRIDGE-funded research at 26 research laboratories in universities and research institutes. With the conclusion of the final funding round, BRIDGE has completed its financial investment. However, projects will continue to run until the end of the century.

BRIDGE Results

The 'final results' from funded projects began to arrive in mid-1995, starting with results from projects supported in the 1993 funding round. Preliminary results from these and other BRIDGE awards are published in the *BRIDGE Newsletter* and elsewhere and have already demonstrated considerable successes by the programme across a range of disciplines.

BRIDGE research, using BRIDGE-developed technology, has shown that there is far more hydrothermal activity in the deep ocean than was expected. The UK is now seen to lead the world in hydrothermal exploration, and BRIDGE researchers in this field are applying their technology and expertise as integral partners in international research projects within Europe, with the USA and with Japan.

BRIDGE has made a significant contribution to the understanding of faulting at mid-ocean ridges. Mid-ocean ridges can teach us a great deal about continental geology because, in contrast to land-based systems, the faults are neither eroded nor covered in thick layers of sediment or rock, and a time-sequence of fault development exists over a relatively short distance: young faults next to the ridge crest, older faults away from the crest. BRIDGE has proved extremely effective at imaging deep-ocean geological features at high resolution, and in 1996 identified and imaged previously unseen corrugated slip surfaces at the site of the Atlantis Fracture Zone transform fault (where the whole ridge is broken and displaced sideways).

BRIDGE has contributed significantly to the imaging of the mid-ocean ridge under Iceland and offshore where the ridge approaches the ocean surface. Activity at the ridge in this region has an impact on human activity via seismic threats and, on the positive side, by making land-based geothermal exploitation possible. Knowledge of the ridge anatomy is therefore of direct relevance to the local economy and human well-being.

As an understanding of the physical nature of the mid-ocean ridge system is developed and improved, BRIDGE-funded biologists are using this background, coupled with modern molecular techniques, to unravel the problems of species distribution and dispersal in these areas of the deep ocean.

As well as the increasing volume of research results being assembled by the programme, two further elements are set to dominate future BRIDGE affairs: public relations and data-management.

BRIDGE PR

Good public relations are of critical importance for fulfilling NERC's commitment to public understanding of the environment, and – closer to some researchers' hearts – ensuring that UK deep-ocean science continues once the BRIDGE Programme has made its final contribution.

Box 2 BRIDGE projects 1993–99

Multidisciplinary projects

A multidisciplinary submersible study of hydrothermal activity on the Mid-Atlantic Ridge at 29°N and 26°N.

Integrated energy, chemical and biological flux measurements at the 29°N segment of the Mid-Atlantic Ridge: a baseline study.

FLAME: The FLuxes at AMAR* Experiment (*Azores–Mid-Atlantic Ridge).

Geology

Multibeam bathymetric and potential field studies of the influence of subduction on ridge-crest processes; the East Scotia Sea back-arc basin.

Petrogenesis of oblique spreading ridges (PETROS).

Measuring tectonic strain at slow spreading ridges.

Controlled source electromagnetic and seismic studies of the Valu Fa Ridge, Lau Basin (SW Pacific).

Imaging the Iceland Ridge-centred hotspot (IRICH).

Submarine rifting: laboratory studies of extensional fracture and fluid permeability in mid-ocean ridge rocks.

The behaviour of volatiles during mid-ocean ridge processes and their bearing on upper mantle volatile compositions.

Spatial and temporal variations in stress fields that accompany spreading episodes and large earthquakes, resulting tectonic and morphological evolution, and inter-segment relationships.

Crustal deformation and serpentine intrusion in the NOBSKA* spreading segment, Mid-Atlantic Ridge (*North of Broken Spur, Kane–Atlantis Fracture Zones)

Back-arc basin mineralisation: helium isotope constraints on fluid interaction history.

Melt generation and transport processes at mid-ocean ridge and back-arc settings.

Crustal structure of the north-east Atlantic.

The magnetic properties of mid-ocean ridge basalt (MORB) and the interpretation of deep towed magnetic anomalies.

Detailed investigation of accretionary processes occurring at the slow-spreading Reykjanes Ridge at 57°45′N.

Water-column hydrothermal projects

Hydrothermal Exploration at the Azores Triple Junction (HEAT).

Fluid dynamics of hydrothermal plumes.

Benthic hydrothermal projects

Manned submersible studies of the recently discovered hydrothermal vent site at 29°N on the Mid Atlantic Ridge; the Broken Spur vent field.

Monitoring the physics and chemistry of mid-ocean ridge hydrothermal systems.

The influence of microbes on the rates of aqueous reactions in mid-ocean ridge hydrothermal systems.

Post-ODP(Ocean Drilling Program) TAG* submersible programme (*a hydrothermal vent field in the mid-Atlantic at 26°N).

Laboratory and theoretical models of hydrothermal circulation systems.

The biogeochemistry of hydrothermal sediments from the *Mir* site at 26°N on the Mid-Atlantic Ridge

Silica in sea-floor hydrothermal systems: precipitation and transformation.

A precise chronology for mid-ocean ridge hydrothermal sulphides.

Experimental studies of chemical processes in hydrothermal systems at slow-spreading centres.

Biology

Microbiology and enzymology of deep sea hydrothermal vent habitats.

Molecular genetics of the bivalve *Bathymodiolus* from the Lucky Strike and Menez Gwen hydrothermal vent sites.

The influence of spreading rate on gene flow in the polychaete *Branchipolynoe* spp., a commensal of deep-sea hydrothermal vent mussels.

Pelagic distribution of larvae from hydrothermal vents.

Feeding and behaviour of hydrothermal vent shrimps.

Lipid profiles of hydrothermal vent animals.

Technology projects

Construction of a towed instrument package for BRIDGE to detect, map and sample hydrothermal plumes (the BRIDGE Towed instrument – *BRIDGET*).

Technical development and enhancement of *TOBI* (the Towed Ocean Bottom Instrument).

TOBI upgrades – Swath Bathymetry and Heading Sensor.

The application of synthetic aperture processing to the *TOBI* side-scan sonar.

A sea-floor drill for oriented rock cores.

SHRIMP – a Sea-bed High-resolution Real-time IMaging Platform.

An autonomous plankton sampler for conducting molecular studies of larval dispersal in hydrothermal vent environments (*PLASMA*).

Monitoring the physics and chemistry of mid-ocean ridge hydrothermal systems: new technological development ('MEDUSA').

Scientific researchers generally attribute little or no importance to publicising their work. As long as their research is funded they are happy to report it only in scientific journals and at meetings. But how long *will* their research be funded?

A future for any endeavour requires the support of those taking political and economic decisions. If your favoured subject is allowed to drop below their personal horizons it will cease to exist – metaphorically to the decision-makers and in reality as a consequence.

Coverage of science in the newspapers, on the radio and on television, can inform the public and the decision-makers. A high media profile reinforces the impression of importance and relevance – of key importance to today's funding bodies.

BRIDGE has had considerable success in recent years in maintaining a high media profile. In 1995, Channel 4 broadcast its documentary 'Deep Diving with the Russians' which followed BRIDGE and Russian scientists aboard one of the largest research vessels in the world, the Russian RV *Akademik Mstislav Keldysh* on a joint BRIDGE/Russian cruise to send two *Mir* submersibles – each with a crew of three – to depths of 3 500 m on the Mid-Atlantic Ridge. In 1996, the British Association devoted a full day to BRIDGE science at its annual public festival of science. BRIDGE research was reported on the BBC's 'Tomorrow's World' world-wide web site, and BRIDGE researchers appeared on breakfast television and BBC radio. In 1997, BRIDGE scientists appeared in Channel 4's deep ocean documentary series 'The Deep', and in 1998 BRIDGE researchers feature in the BBC's new eight-part series on the Earth, 'Earth Story'.

However, modern science is primarily a complex technical enterprise and before scientists can explain their findings to the public – in words everyone can understand – they must assemble and analyse vast arrays of detailed measurements and intricate observations. It is critical that these hard-won datasets are not lost to future generations of scientists, or their information content underused by today's.

BRIDGE data

Starting at regional scales and progressing to detailed work on individual hydrothermal systems, BRIDGE has collected and compiled: multibeam bathymetry, sonar imagery, seismic data, electromagnetic data, gravimetry, petrology (including rock sections, cores, sediments and analytical data), chemical and physical oceanography (samples and analytical data), macro- and microbiology (specimens, film and analytical data); numerical models and audio-visual records.

In a multidisciplinary programme such as BRIDGE, which aims to relate and understand *all* aspects of a complex environment, archiving such data on a discrete project-by-project, cruise-by-cruise basis, with no attempt to integrate the various datasets, would be an ineffective and disjointed way to present and use scientific results. The BRIDGE Programme's objective has always been to draw together findings from disparate disciplines investigating the same locations.

Modern information technology permits data collected from diverse sources to be united in a dataset which can be interrogated by the user to provide the information required. The surface contours for an area of ocean floor can be overlain with data for the same area to show surface details: rocks, sediments etc. Fly-through imagery can be produced. Distribution maps for animals or rock types can be overlain on this structural image. Various scales can be correlated to permit the interrogator to 'zoom into' an area of interest and obtain information regarding the sediment composition or biology of the region.

BRIDGE is actively pursuing the production of an interactive CD-ROM set carrying BRIDGE results. This will integrate data at diverse scales to provide information covering everything from overall sea-bed shape to geochemistry and microbiology. Such an interactive package will have market opportunities for educational use as well as research.

NERC, with an expressed aim of 'collecting, curating, interpreting and supplying environmental data' recognizes such datasets are a resource in their own right. Data from programmes such as BRIDGE contribute to NERC's overall 'Data Resource' which will be exploited not only for research, but also commercially and educationally, long after individual programmes have ended.

It is BRIDGE's intention to leave a high-quality record of its achievements as a useful and valuable legacy for future researchers. Given the success of the programme, the results will undoubtedly be used to address future environmental questions and will provide a valuable resource for related scientific, commercial and political programmes addressing resource and hazard management in the deep oceans.

Copies of the BRIDGE Newsletter *can be obtained by registering an interest with the BRIDGE Office, Earth Sciences, University of Leeds, Leeds LS2 9JT, UK; Email: BRIDGE@earth.leeds.ac.uk. Further information is available via the NERC web site at http://www.nerc.ac.uk/es/bridge.htm*

Keith Harrison is the BRIDGE Programme Manager and is based at the BRIDGE Office in the School of Earth Sciences at the University of Leeds, UK. He began life as a shallow-water and coral-reef biologist, only later migrating into the deep oceans.

The Influence of Benthic Fauna upon Preservation of Organic Matter at The Oman Margin

Barbara Smallwood

The control of organic matter preservation within ocean sediments is a highly controversial issue. There is considerable argument within the literature about the driving force(s) behind carbon preservation. At first, lack of oxygen in bottom waters was thought to be the most influential factor, but more recent studies have shown that this may not be the case. The productivity of the water column can directly influence the amount of organic matter preserved, but it has been observed that in highly productive areas, redox states of bottom waters, microbial activity within the sediments, and strong bottom currents which winnow away the surficial sediments, may all limit preservation (Figure 1). Could the benthic fauna living within and upon the sediments also influence the burial of carbon, by constantly reworking and recycling the organic matter? I hope to go some way towards answering this question with my research.

Why the Oman Margin?

The North-East and South-West Monsoons induce variability within the water column by seasonally reversing both the wind and surface currents. The South-West Monsoon leads to strong seasonal upwelling and intense primary productivity; while the chief effect of the North-East Monsoon (which has weaker winds) is to cause the complete semi-annual reversal of surface water currents, which gives rise to the greatest seasonal variation in surface waters anywhere in the world's oceans. The South-West Monsoon also carries aeolian dust from the African continent, and this acts as ballast for the aggregates of organic matter in the water column, contributing to the high sedimentation rate (thought to be approximately 40 cm per thousand years on the continental slope). The waters overlying the Oman Margin are characterized by an intense permanent oxygen minimum zone (OMZ), so the sea-bed there should, in theory, be a perfect place for enhanced carbon preservation, compared with abyssal areas where sedimentation rates are much lower and oxygen concentrations are greater.

We can begin by addressing two specific questions:

- What are the controls of organic-matter preservation within the OMZ at the Oman Margin?
- How do benthic fauna influence the burial and recycling of organic matter there?

What causes organic carbon to be preserved in sea-bed sediments?

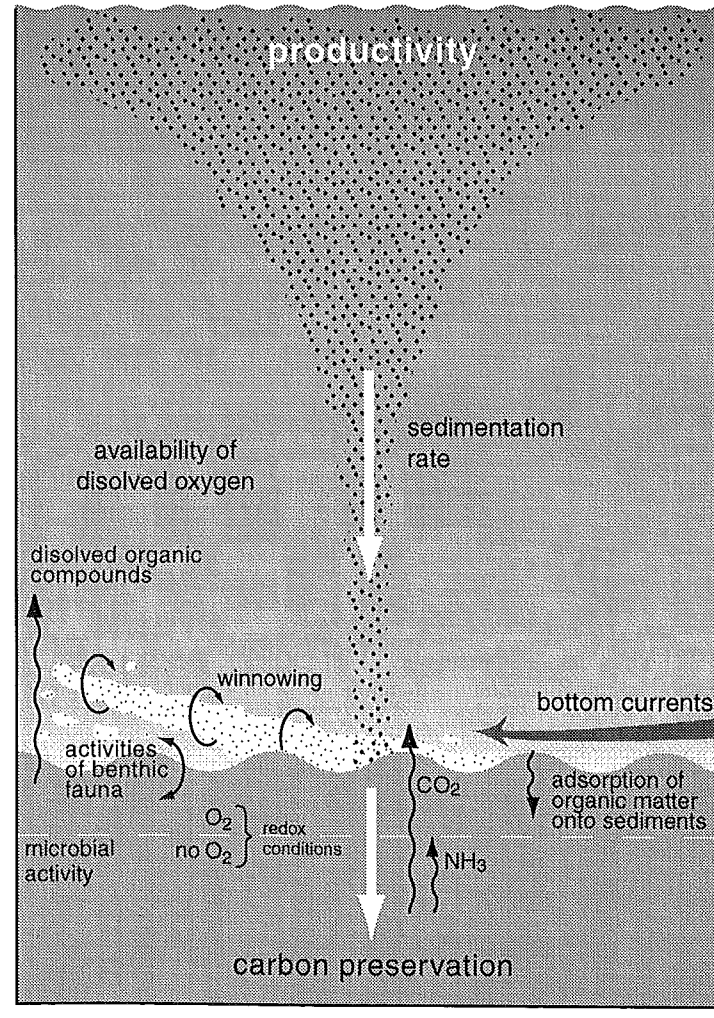
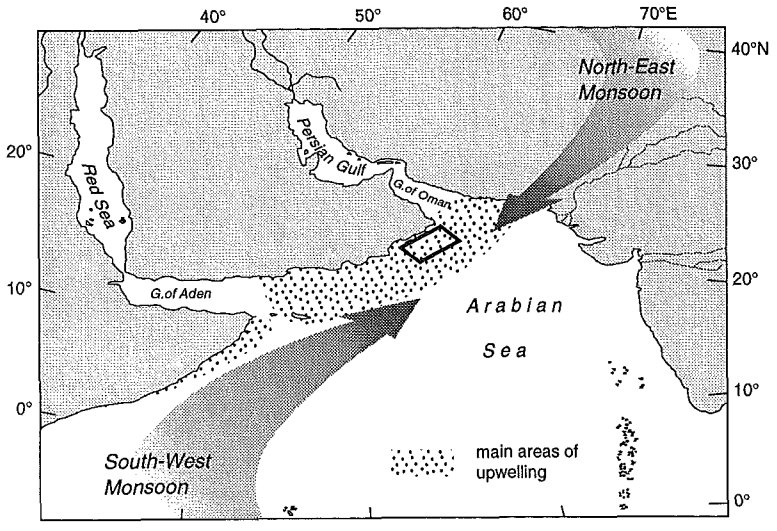


Figure 1 *Factors affecting (and associated with) preservation of organic carbon in sea-bed sediments.*



The South-West Monsoon has a powerful influence on conditions at the Oman Margin

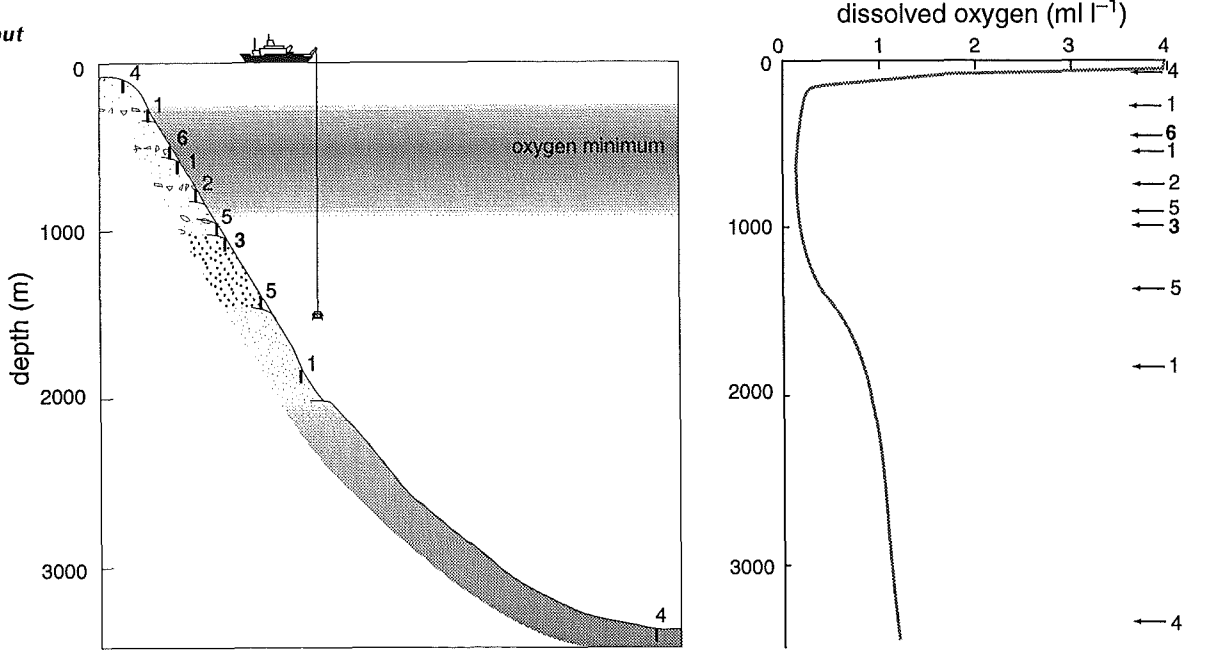
Figure 2 *The position of the study area in the Arabian Sea. The prevailing wind directions during the two monsoon seasons are shown, along with the main areas of upwelling affecting the Oman Margin during the South-West Monsoon.*

Approach

Samples were collected from the study area (Figure 2) during a cruise on RRS *Discovery* in October/November '94. The continental slope is extremely steep and undulating, but we were fortunate to obtain 32 undisturbed sediment cores from a transect down the continental slope and onto the abyssal plain. A multiple corer was used and replicate cores were taken at several locations down the slope (Figure 3). Replication is important in such studies, because there is great variability within sites and the more cores we can obtain the better our understanding is likely to be.

Figure 3 *Schematic diagram to show* ***(left)*** *the number of replicate cores taken at different depths on the Oman continental margin (topography simplified, vertical scale greatly exaggerated); and* ***(right)*** *generalised profile of dissolved oxygen concentration in the overlying waters. Different shadings represent different sediment textures.*

The oxygen minimum impinges on the Oman margin at about 400 m depth



The OMZ is most intense at 400 m where oxygen levels are as low as 0.16 ml l^{-1} compared with 4 ml l^{-1} in surface waters. By a depth of 1200 m, oxygen concentration has increased to approximately 0.4 ml l^{-1}. I will concentrate here on the sites at about 400 m and 1000 m.

The cores were sectioned and freeze-dried prior to decarbonation and analysis for bulk components such as total organic carbon (ΣC_{org}) and total nitrogen (ΣN), as well as solvent extraction and chromatographic characterization of biomarkers within different fractions of organic matter, notably lipids such as *n*-alkanes and sterols (Figure 4, *opposite*).

The carbon to nitrogen (C/N) ratio tells us the source of the organic matter – high values (>15) indicate material of terrestrial origin, low values (<12) indicate marine material, and anything in between could be a mixture. The more labile nitrogen is released or recycled more quickly than the carbon and a downcore increase in the C/N ratio is indicative of diagenesis (degradation).

Groups of lipids (fat-like substances) that are ubiquitous in marine sediments include:

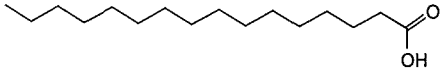
- Saturated straight-chain alkanoic acids. These are predominantly marine in origin (from a wide variety of marine organisms, including phytoplankton) (Figure 4(a)).
- Saturated branched alkanoic acids. These are characteristic of (marine) bacteria (Figure 4b)).
- Unsaturated alkenoic acids, which are predominantly marine in origin (algae and a wide range of other organisms, vertebrates and invertebrates) (Figure 4(c)).

• Sterols, which come from various sources, including a wide variety of organisms (including plankton, marine invertebrates and terrestrial plants) (Figure 4(d)).

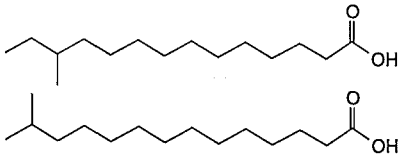
• *n*-alcohols, whose origin may be marine (short-chain: algae and bacteria, copepods and crustaceans) or terrestrial (long-chain: sea-grasses, higher plants) (Figure 4(e)).

• *n*-alkanes, again both marine (short-chain: algae and bacteria) and terrestrial (long-chain: higher plants) (Figure 4(f)).

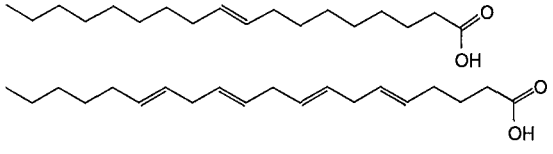
Figure 4 *Examples of solvent-extractable lipid biomarkers found in Arabian Sea sediments.*



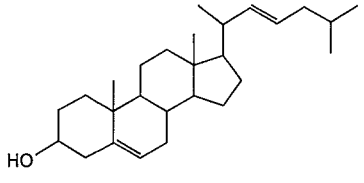
(a) *Hexadecanoic acid (saturated straight-chain alkanoic acid)*



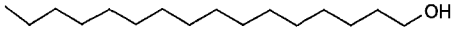
(b) *Two different isomers of methyltetradecanoic acid (a branched alkanoic acid)*



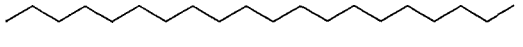
(c) ***Upper:*** *octadec-9-enoic acid;* ***lower:*** *5,8,11,14-eicosatatraenoic acid (unsaturated alkenoic acids)*



(d) *Cholesta-5,22-dien-3-ol (a sterol)*



(e) *Hexadecan-1-ol (a straight-chain alcohol)*



(f) *Eicosane (a straight-chain alkane)*

Results from cores at ~ 400 m depth

The first observation that can be made is the large degree of variability within this site (Figure 5). Total organic carbon (ΣC_{org}) is high in the surficial sediments, being between 5% and 6% of the total, and these values are comparable to those found in previous studies. However, although Figure 5 shows that the *average* ΣC_{org} decreases only slightly downcore, the considerable variability below the surface emphasizes the importance of replication.

Two specific cores from near 400 m depth will now be discussed to show differences between carbon preservation at the same site. The first core was from a depth of 409 m and the second from a depth of 422 m.

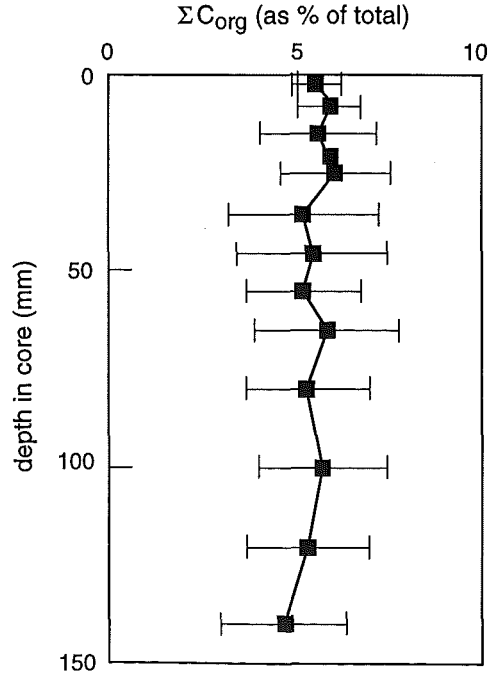
The 409 m core

Bulk components

ΣC_{org} is high in the surficial sediment, at nearly 6%, decreasing downcore to about 2%; while the C/N ratio increases downcore from approximately 8–10 at the surface (Figure 6(a) *overleaf*). This is typical of a core in which the organic matter is being gradually re-mineralized and is in the process of steady-state diagenesis.

The lipids from this core are predominantly of marine origin, with the saturated branched alkanoic acids being the major group in all profiles downcore. However, a patchy terriginous signal in the form of long-chain *n*-alkanes and *n*-alcohols (cf. Figure 4(e), (f)) indicates variable inputs to the sediment from land. This may be due to aeolian dust transported via the South-West Monsoon, but the sampling resolution is not great enough to detect a seasonal signal.

Figure 5 *Variation with depth of average ΣC_{org} (as % of total sediment) for six samples from about 400 m depth.*



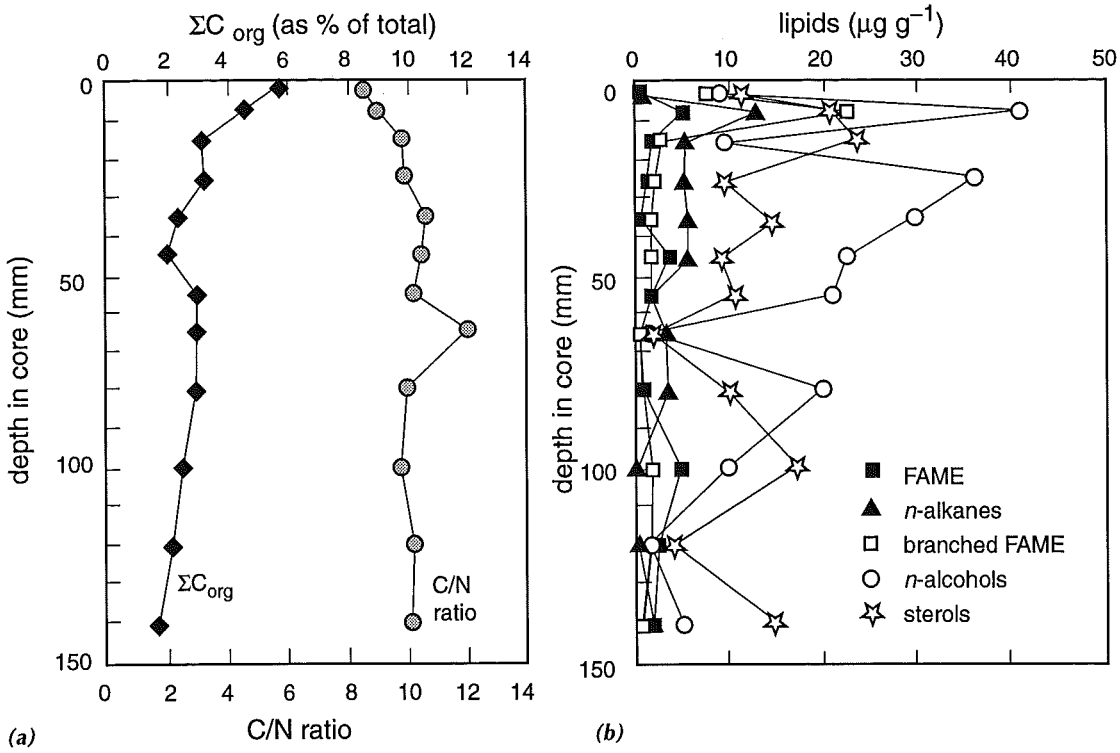


Figure 6 *Variation with depth in the 409 m core of* ***(a)*** ΣC_{org} *and C/N ratio, and* ***(b)*** *lipids. (FAME = fatty acid methyl ester, a derivitive of alkanoic/alkenoic acids used in analysis.)*

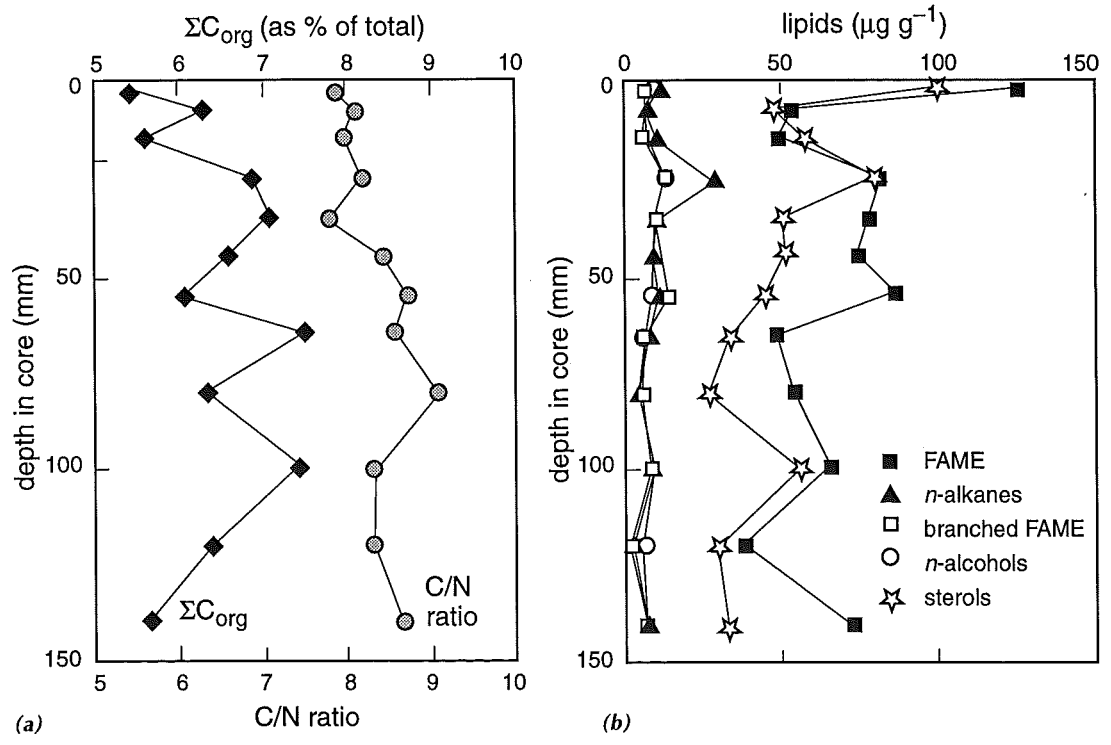
Relative downcore distributions of lipids show considerable variability, which reflects complex water column processes and a variety of inputs to the sediments. Profiles of individual lipids show subsurface maxima of the alkanoic/alkenoic acids (represented by FAME) with a general downcore decrease, and a similar profile is observed for the *n*-alkanes and *n*-alcohols (Figure 6(b)). These subsurface maxima indicate that the sediment has been disturbed in some way, the most likely cause being small-scale mixing by benthic fauna (bioturbation), where fresh material has been dragged down into the sediment.

The ~422 m core

Bulk components

A contrasting result is observed in the second core taken from further downslope at ~422 m.

Figure 7 *Variation with depth in the 422 m core of* ***(a)*** ΣC_{org} *and C/N ratio, and* ***(b)*** *lipids. (For 'FAME' see caption to Figure 6.)*



ΣC_{org} is similar in the surficial sediment (at 5–6%), but there is no obvious downcore trend. The C/N ratio of ~8 is still indicative of a marine input, but only a slight downcore increase is observed, suggesting that diagenetic changes are not pronounced (Figure 7(a)).

Molecular signature

The distribution of biomarkers is very different from that in the 409 m core. Alkanoic/alkenoic acids (represented by FAME) are still important but sterols are relatively more abundant and are more evenly distributed with depth. The terriginous signal (long-chain *n*-alkanes and *n*-alcohols) is not as pronounced as before, but this is more likely to be because it has been swamped by the marine components than because of a reduced supply of terrigenous material.

In comparison to the core at 409 m, there is little downcore variability, no obvious downcore trend or pronounced subsurface maxima of any of the lipids (Figure 7(b)). The top half (down to 50 mm) of the core therefore appears to have been mixed, but by what processes? Sterol distributions are consistent with a strong (marine) invertebrate signature which could suggest that bioturbation has been responsible for sediment mixing, but there is little other evidence to back this up. At this depth there are no large invertebrates that could mix the sediment to such an extent. A more likely mechanism would be large-scale resuspension and redeposition, or slumping.

So, at 400 m there are two mechanisms of organic matter preservation: steady-state diagenesis and large-scale slumping.

Results from cores at ~1000 m depth

At 1000 m, the oxygen concentration of the bottom waters is approximately 0.2 ml l^{-1}. It is at this depth that the spider crab *Encephaloides armstrongi* is found in great abundance (more than 120 individuals per square metre – see Figure 9, *below*).

Molecular signature

Three cores were analyzed for % ΣC_{org}, ΣN and C/N ratio. The ΣC_{org} is much lower in the

Figure 8 *Average downcore ΣC_{org} for three samples from about 1000 m depth.*

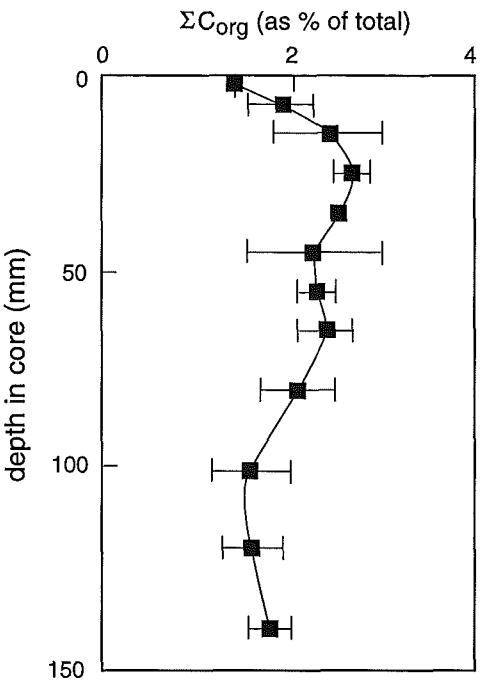
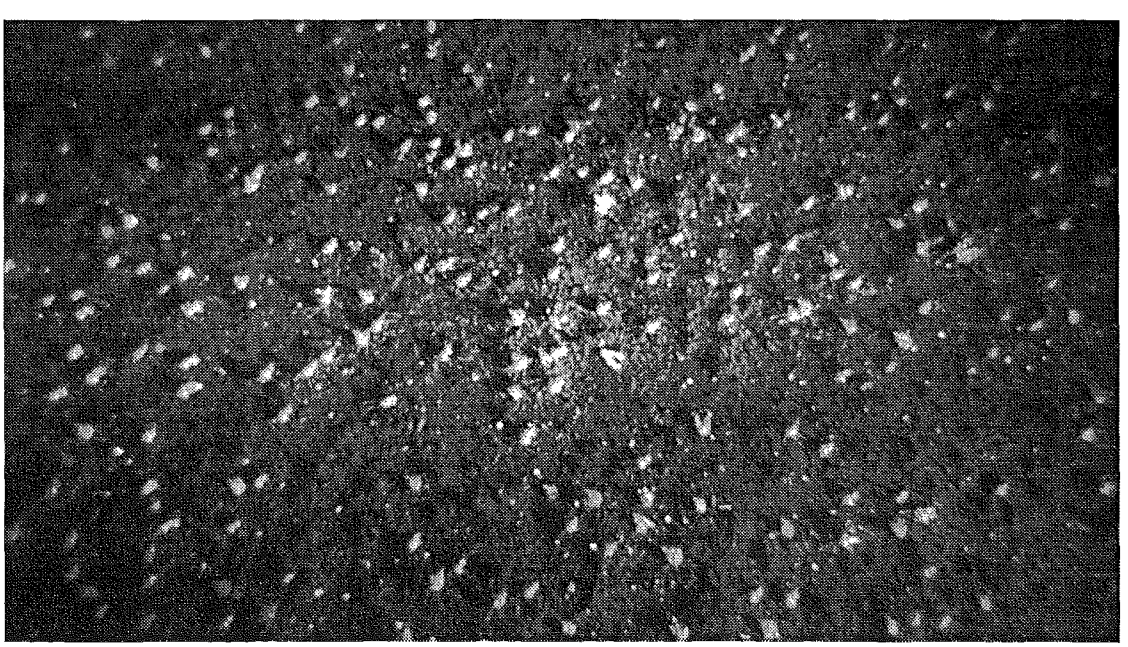


Figure 9 *Spider crabs at ~1000 m depth, photographed from the IOS epibenthic sledge system; the camera is about 80 cm above the sediment surface and inclined downwards by 30°. The crabs seem to be tolerant of very low oxygen concentrations and occur throughout the the OMZ, with maximum densities recorded at its base, at ~1000 m (cf. Figure 3). Their feeding habits are unknown, but the photographs show the majority of crabs to have a common orientation, and such behaviour may be consistent with a scavenging life-style, though the crabs are likely to have fairly catholic tastes.*



A multitude of spider crabs at 1000 m, near the base of the OMZ

surficial sediments at ~1.5%, but all three cores show pronounced subsurface maxima which suggests that carbon has somehow been carried down into the sediment (Figure 8). The C/N ratio is indicative of organic matter of marine origin, but there is no obvious downcore increase. The ratio in the surficial sediment (~10) is greater than that at 400 m (Figure 10(a)), which suggests that there has been more reworking (i.e. remineralizing) of organic matter either within the water column, or at the sediment–water interface. We also found the sediments at this depth to contain significantly more coarse material than sediments above or below this site.

For the purposes of this article I will concentrate on just one of these deeper cores, from a depth of 1002 m.

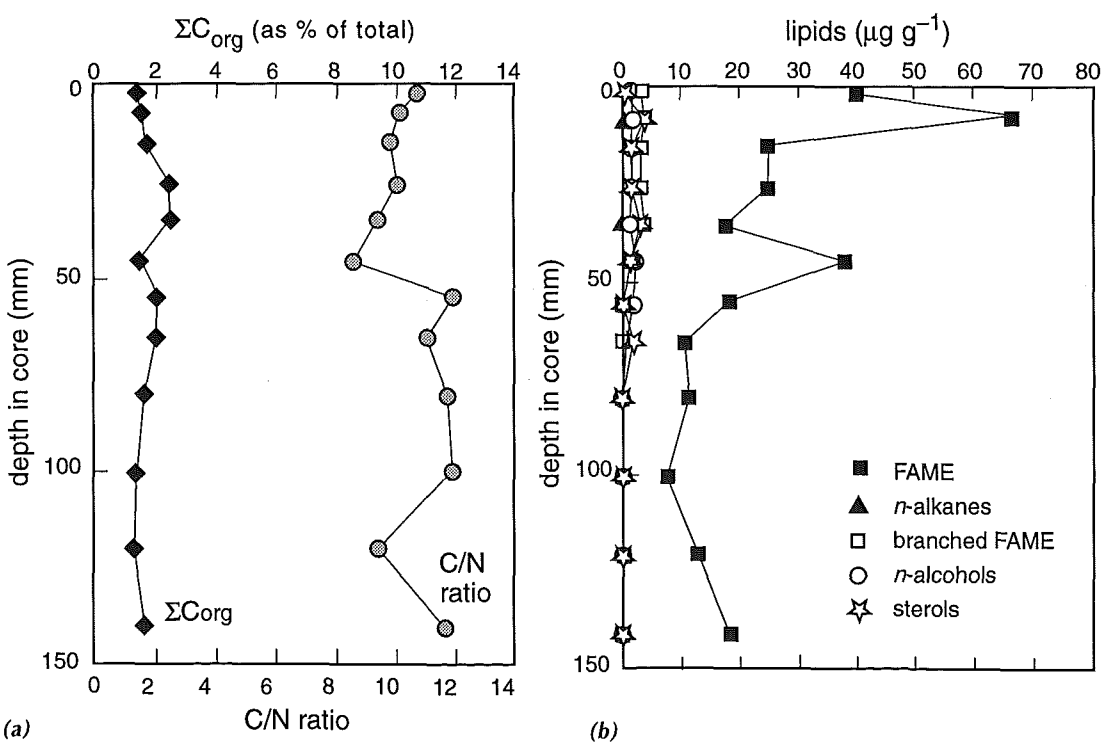
The 1002 m core

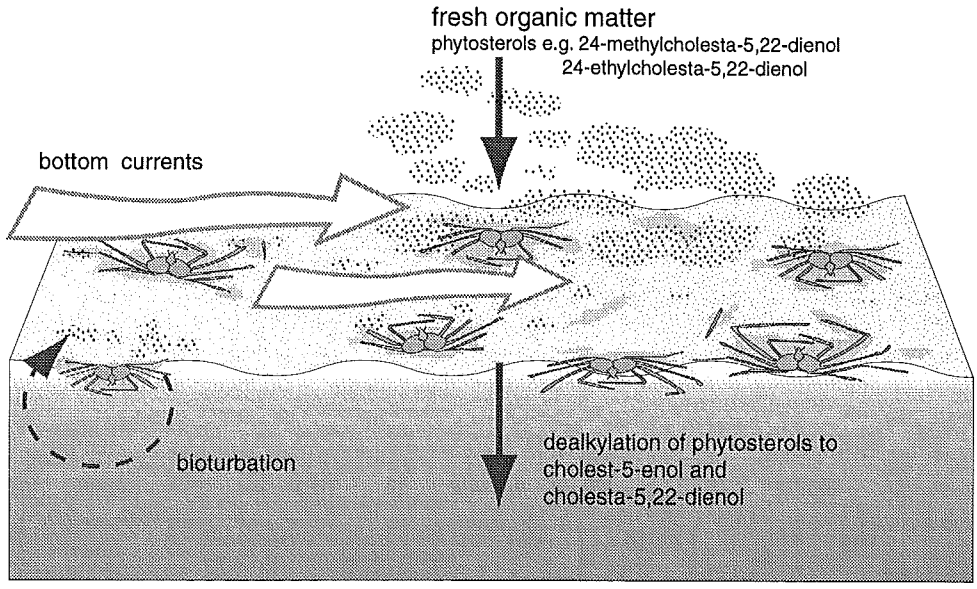
The sediment shows a severe depletion of lipids (Figure 10(b)). The alkanoic/alkenoic acids (represented by FAME) are still predominant but at lower absolute concentrations. However, if the lipids are normalized to ΣC_{org} then the concentrations of alkanoic/alkenoic acids, *n*-alcohols and *n*-alkanes are comparable with those observed at 400 m. This is not the case for the sterols. Even when normalized to ΣC_{org} the concentration is an order of magnitude lower, which indicates that the sterols are being affected in some other way. The distribution of sterols is also significant as they indicate the presence of invertebrates. There is very little downcore variability which suggests once again that mixing is a predominant factor. To understand the processes involved within this core we must look at the sterol distribution in more detail.

At 1000 m, cholesterol is abundant with relatively low quantities of the phytosterols; for example, dinosterol is undetectable and further downcore the effect is even more pronounced. By comparison to the sterols at the 400 m sites, these have a relatively wide distribution with no domination of any individual sterol. How can the coarser sediments, the low ΣC_{org} and the different sterol distribution at the 1000 m site be explained? Are the spider crabs having an impact on the sediments – and if so, what are they doing?

Fresh organic matter reaches the sea-floor and is ingested by the spider crabs. It is known that crustaceans are incapable of synthesizing their own sterols *de novo* and therefore have to modify their food to satisfy their own dietary requirement. Phytosterols ingested by the crabs in this way would be de-alkylated to form cholesterol and cholesta-5,22-dienol (Figure 4(d)), and we (Brian Bett, George Wolff and I) suggest this is why there is a high relative abundance of these sterols within the surficial sediments (Figure 11). Meanwhile, the constant movement of crabs results in turning over of the sediment, causing the fine organic-rich particles to be winnowed away by the strong bottom water currents, leaving the coarser sediments behind.

Figure 10 *Variation with depth in core of* ***(a)*** ΣC_{org} *and C/N ratio at 1009 m and* ***(b)*** *lipids at 1002 m. (For 'FAME' see caption to Figure 6.)*





Crabs modify organic matter in the sediment by their physical activity and their feeding habits

Figure 11 *Schematic diagram showing how the sediment might be winnowed and chemically modified by the spider crabs.*

The crabs thus appear to have an impact on organic matter recycling and preservation at this site by both their physical activity and their feeding habits.

Conclusions

This detailed molecular investigation of the sediments of the Oman Margin has helped to increase our understanding of carbon preservation here. The results of our research so far may be summarised as follows:

- There is elevated organic carbon within sediments of the OMZ of the Oman Margin which generally decreases downslope from ~ 5.5% at 400 m to ~1.4% at 1000 m.
- There is high variability of organic matter distribution both within and between sites.
- The C/N ratios and lipid distributions indicate a primarily marine origin for the organic matter in the sediments.
- Both steady-state diagenesis and slumping are important mechanisms at 400 m.
- Winnowing of fine particles by the spider crabs as they burrow and shake up the sediment could account for the lower absolute concentrations of lipids at ~1000 m, and the crabs may be responsible for sterol removal and modification. Hence, the activities of benthic fauna can strongly influence the preservation of organic matter at the Oman Margin.

Acknowledgements

I would like to gratefully acknowledge the following in appreciation for their help with this work: Dr George Wolff, Dr Brian Bett, Jane Barnard, Dr Anu Thompson, Doris Angus, Research Vessel Services, Master and crew of the RRS *Discovery*.

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Editor's Postscript

Right on cue, a recent article in *Nature* (Hartnett *et al.* (1998) **391,** 572–4, also C.E. Reimers in the same issue, pp.536–7) discussed the preservation of organic matter in oceanic sediments. The proportion of organic matter reaching the sediments that gets preserved is influenced by the length of time that it is exposed to dissolved oxygen in the pore waters. Other factors are also important, however, and as Barbara Smallwood's article demonstrates, bioturbation can signficantly accelerate organic matter modification and decomposition.

The balance between consumption and preservation of organic matter in marine sediments is of more than local importance. High burial rates of organic carbon will over time increase levels of atmospheric oxygen. This eventually feeds back into the ocean and thence into sediment pore waters resulting in increased consumption of both organic matter and dissolved oxygen – which in turn will eventually reduce atmospheric oxygen levels once more.

Book Reviews

Cod Piece

Cod: A Biography of the Fish that Changed the World by Mark Kurlansky (1998) Jonathan Cape, 294pp. £12.99 (hard cover, ISBN 0-224-05104-0).

Some books are enjoyable to read and some are enjoyable to write. This little book is fortunate in being both these things. Attractively designed and pocket-sized for reading on the hoof, the impression from the outset is of a labour of love, exposing the author's passion for anything to do with this remarkable fish. Like the recent film recreating the *Titanic* disaster, we know that the story of *Cod* ends with only a few survivors and that this 'Biography' is rapidly becoming an 'Obituary', but this doesn't mean that there are no surprises.

In fact, the reader is served a constant flow of information ranging from Acts of Trade through to zooplankton. Some early tales from the Grand Banks fisheries of lobsters 'six foot in length' and cod 'as large as a man' might stretch credulity, but how many Trivial Pursuit players know that there actually was a Clarence Birdseye who began large-scale freezing of fish, or that the first Cod War took place in 1532? I was also as surprised as John Cabot must have been when 'discovering' a New Found Land in 1497, that there were 1000 Basque vessels fishing there already.

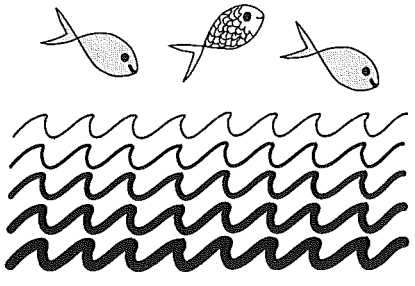
Like all biographies, there is inevitably some history, but it is the connections that are so intriguing. Through their inexperience of farming or fishing, the Pilgrim Fathers almost starved during their first New England winter, and only survived by stealing hidden caches of food from the native Americans. Within a generation, though, they had learnt to expolit the superabundant fisheries offshore and were exporting 300 000 salted cod annually. Perhaps more importantly, instead of trading with England, they became vigorous free traders and unwittingly set in train a series of events that led to the War of Independence and beyond. These codfish aristocrats prospered by a triangular trade, shuttling to Africa with cod, then to the Caribbean with slaves and finally back home with salt (for the next cod shipment) and molasses to make rum. Even today, salt cod is part of the cuisine of both the West Coast of Africa and the Caribbean, despite both areas being a considerable distance from the nearest commercial cod fisheries.

Along with some amusing extracts about cod from poems and books, the text is punctuated by a collection of recipes for cooking cod, and this virtue is perhaps over-indulged at the end, with 40 pages devoted to it. After all, most biographies don't end with a section on how to cook the subject, but this is carping criticism (excuse the pun), especially as the whole purpose of catching cod is to eat it. The author's background as a professional chef as well as a writer is perhaps the justification for including these recipes, and I particularly recommend the chowder on p.254!

The preceding sections on the development of the law on marine resources are both concise and informative, as is the discussion on the decline of fish stocks. A lawyer would prefer more detail about marine law while a marine biologist would look for more data on stocks, but this entertaining book is essentially for the non-specialist and is none the worse for that. If threatened commercial species such as cod are to have any future, then ultimately the debate must take place outside of University campuses and the specialist media and include both producers and consumers. Mark Kurlansky's book makes a significant contribution to this debate as well as providing a good old-fashioned read.

Gerry Bearman
The Open University

Editor's Note: See also p.13.



Evolution of Hydrothermal Ecosystems on Earth (and Mars?) edited by Gregory R. Bock and Jamie A. Goode (1996). John Wiley & Sons, 334pp. £55 (hard cover, ISBN 0471-9609-X)

This rather odd book is the proceedings of the Ciba Foundation's symposium on 'Evolution of Hydrothermal ecosystems on Earth (and Mars?)', held at the Ciba Foundation in London in January 1996. It is odd in a number of ways – the theme, contributors and presentation are all a bit eclectic. Given all the recent excitement about putative evidence for bacterial life on Mars being discovered in meteorites, exobiology and the origins of life on Earth are certainly highly topical subjects. And they are likely to remain so, as both NASA and the European Space Agency (ESA) have recently announced ambitious plans to explore the Red Planet for signs of ancient life. Thus, a book which examines the complex chemical and biological processes taking place in the exotic high-temperature environments of deep-sea hydothermal vents, and which explores the fossil record of life that flourished in such environments on the early Earth, is bound to be both fascinating and useful.

There are certainly some extremely valuable contributions, written by the big names in their respective fields – who could be better than Mike Carr on evidence for the existence of water on early Mars? Or Andrew Knoll and Malcom Walter on the nature of the early fossil record ('Finding the gold amongst the dross')? For readers looking for reviews of some current big issues in Earth Sciences, the book could be very useful. Progress on the understanding of the curious bacterial life-forms that thrive in hot springs and submarine hydrothermal vents has been rapid in recent years, leading to some unexpected discoveries, with profound implications. One of these is just how remarkably 'hardy' some bacteria can be, positively flourishing at extremely high temperatures – between 80 and 110°C – and in aggressive chemical environments. Another is the discovery that these 'hyperthermophiles' are probably the most

primitive of all organisms. We are probably all descended from a chemolitho-autotrophic hyper-thermophilic common ancestor. An important inference from this conclusion, of course, is that if life evolved on Earth in this harsh environment, it could also have done so on Mars, or in the sub-glacial oceans of Europa, or anywhere where hot water and minerals provided the appropriate cocktail of energy and chemicals.

Having said all that, some of the other contributions seem a bit out of place. One could just about make a case for the logic of including a paper on the role of remote sensing in finding hydrothermal mineral deposits on Earth, since presumably similar remote-sensing techniques could be used to spot potential sites on Mars which might have been congenial for life. But the paper by Huntingdon sticks fairly narrowly to the well known themes of the spectral properties of alteration minerals and the satellite sensors used to map them on Earth, and ignores entirely all the telescope and satellite remote-sensing work that has been done over the years on Mars. Similarly, the paper by Horn on exploration strategies for discovery of hydro-thermal deposits is merely a review of current practice of economic geologists prospecting for gold, copper and other minerals found in hydrothermal deposits.

Intended as the enduring product of the Ciba symposium, the book emphasises the discussions that took place, both after individual papers and in general discussion sessions, and presents apparently verbatim transcripts of the sessions. For the book, this resulted in both strengths and weaknesses, which no doubt reflect the nature of the discussions themselves. One gets a good sense of the lively and informative debates that took place, with some penetrating questions being posed and answers extracted. This was clearly not a conference at which speakers over-ran their allotted time so that questions were squeezed out of the time-table. Nor was the audience so supine – or so soporific after lunch – that the session chair was obliged to think up some token question. On the contrary, the discussions were extensive, and the transcripts from them form a substantial part of the book. But while they make for some stimulating reading – much easier going than the technical meat of the papers, they are inevitably rather rambling, reflecting the stream of consciousness of the members of the audience, and whoever happened to catch the chair's eye.

Overall, the book is much more successful than the average conference proceedings, and addresses a compulsively interesting subject. Anyone with a serious involvement with hydrothermal ecosystems – wherever they are located – would find it both useful and stimulating.

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Who says Milankovich Rules?

The Glacial World According to Wally by Wally (W.S.) Broecker (1995). Eldigio Press, 318pp. plus appendices.

For price and further details, see end of review.

This is a splendidly individualistic, not to say indiosyncratic, contribution to the climate debate. It is truly multidisciplinary in its scope and I found it a compelling read – though I must admit that you need to concentrate quite hard in places. The contents are set out in four main sections with short sub-sections, so it is quite easy to find your way about. That is just as well, for there is no index.

The book is a prodigious review of much relevant literature, informed by Wally Broecker's own penetrating insights into the problems and issues of climate change – though he admits the bibliography reflects his own reading rather than the total corpus of knowledge. Much of the author's rationale for writing the book lies in his belief, explained in the Prologue, that, so far, '... no Earth system model has been able to adequately account for the growth and maintenance of large ice sheets ... which occupied most of Canada and Scandinavia during peak glacial time nor for the atmosphere's low CO_2 content and high dust content during those times.'

One of the great attractions of this book is the way in which so many different kinds of palaeoclimatic record are brought together, discussed and compared: ancient snowlines and mountain-top temperatures; concentrations and isotopic signatures of gases in ancient groundwaters; desert rock varnishes (did you know that the Fe:Mn ratio in rock varnish is significantly lower during wet than during dry periods?); boron isotopes as indicators of palaeo-oceanic pH; the physics of snow consolidation (here called 'lithification'); all of these and more, in addition to the more familiar standbys like oxygen and carbon isotopes, Cd : Ca and trace-element ratios, coiling directions in foraminiferans, dust in ice-cores, orbitally forced changes in solar radiation, ancient shorelines, and so on. From time to time I encountered pictures I've seen in the Broecker and Peng treatise on *Tracers in the Sea,* but this book has a much wider scope.

The notes I made as I browsed through the book are somewhat eclectic. This is no doubt a reflection of my own butterfly mentality, flitting from topic to topic. But one of the things that struck me was that Broecker has the notion '... that Earth climate has a tendency to drift towards ever colder conditions ...' James Lovelock has made similar assertions, and I have to differ from both of them. The last major Ice Age before the Pleistocene was about 300 million years ago, the ones before that about 450 and 650 million years ago. The geological record does not suggest that in between these events large ice-caps and glaciers characterised polar and mountainous regions.

Perhaps most arresting is Broecker's personal conclusion that the main forcing factor in climate change, specifically in the context of glacial–interglacial oscillations, is atmospheric water vapour, since this is the principal greenhouse gas. Changes in orbital parameters, concentrations of other greenhouse gases etc., are merely modulating factors. In this connection, a powerful modulating factor is what he calls 'seasonality'. That's quite different from what biological oceanographers understand by the term. Broecker uses it to mean seasonal contrast, orbitally driven by a combination of the precession and eccentricity cycles if I've understood him correctly. At present, the seasonal contrast in the Northern Hemisphere is less than in the southern because the Northern Hemisphere winter solstice occurs

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at perihelion (winters relatively warm), its summer solstice at aphelion (summers relatively cool); whereas in the Southern Hemisphere it's the other way round, so winters are relatively cold, summers relatively hot. The seasonal contrast is thus presently greater in the Southern Hemisphere. For reasons which I have to say I cannot fully comprehend, it seems that the global warming which terminated each of the Pleistocene glacials occurred during peaks of *Northern* Hemisphere seasonality – that would have been the situation about 12 000 years ago.

The author's enthusiasm for his subject permeates the book, which is why it's such an interesting, even exciting, read. It makes the minor eccentricities of style and spelling endearing rather than irritating: the phrase 'in this regard' is used umpteen times, and there are some odd spellings: distill for distal, incites for insights; and I still don't know the difference between '^{14}C years', 'Libby years' and plain ordinary 'years'. Another thing that makes me a fan of Broecker's is that his appendix on alkalinity treats the subject in a way which I understand, namely as the balance between total cations and anions held (mainly) by HCO_3^-/CO_3^{2-}. I know this treatment is anathema to the purists, but simpletons like me can follow it.

There is another appendix containing what the author has called 'Superproblems', dealing with exploration of a fictitious planet called Wallyworld, which fortunately is sufficiently Earth-like to display (among other things) patterns of carbon and oxygen isotope fractionation similar to those we know and love, and to have an atmospheric composition like our own. The problems are entertainingly presented and look very interesting, but they are not easy. And in the absence of at least outline answers from the author, I am loth to spend time trying to solve his problems. In my experience it is only when you try to answer your own questions yourself that you discover what bits you left out, what guidance you failed to give.

I also enjoyed a short section that discussed the effectiveness of the biological pump in drawing down CO_2. Broecker reckons that the pump may be working at only about half its capacity at present, because during winter at high latitudes the available nutrients don't get used, as there isn't enough light. He suggests that the pump may have been more efficient during glacial times, drawing down more CO_2, though I don't quite see how that could be. He introduces the rather chilling concept of the Strangelove Ocean, one in which there is no life and hence no biological pump, and he calculates that were this to happen, the atmospheric CO_2 concentration would increase to nearly 450 p.p.m. There seems to be no danger of that happening, at least for a few decades, despite continued overfishing and marine pollution.

This review may appear to be a bit late, for which I apologise. However, we only found out about the book last year, and the author sent it for review upon request. Details about how to obtain a copy follow below.

The book is printed from camera-ready copy, and is available for $80 (spiral-bound) or $100 (hardback); the price includes postage. Prepayment should be made out to 'Trustees of Columbia University' and sent to Parry Catanzaro, Eldigio Press, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964 US; Tel. +1-914-365-8515; Fax: +1-914-365-8155; Email: pcat@ldeo.columbia.edu

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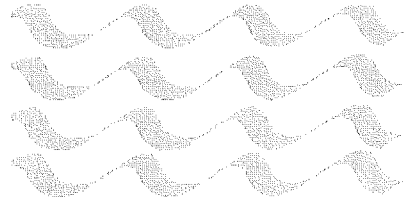

The Atmosphere and Ocean by Neil Wells (1997). John Wiley & Sons Ltd, 365pp. £22.50 (flexicover, ISBN 0471-96216-3).

As climate scientists delight in telling people, the ocean and atmosphere are coupled, and should be considered as a package. Even so, many of the books written to date are biassed towards either the atmosphere or the ocean, so that the other system is often reduced to the status of a boundary condition. This book therefore fills a gap in the market.

The book can be divided into four parts. The first part is a scene-setting description of the Earth's place in the Solar System. The second discusses the physical properties of the ocean and atmosphere, ranging from explanations of the blueness of the sea to the causes of double diffusion. Winds and ocean currents are covered in the third, and most challenging, section. Even here, the maths is easy. There are clear discussions of geostrophic flow, the difficult concept of vorticity, and Rossby waves. The last section then describes the consequences of the sea–air transfers of heat and moisture, and the air–sea fluxes of momentum, that link the two systems. Included here are discussions of El Niño, climate change and predictability.

In the first and second (mainly descriptive) sections a great deal of detailed information (e.g. on precession, or on the radiative impact of clouds) is delivered. Occasionally, there is too much to absorb, and throughout the book more in-text references to other literature would have been useful, especially for students wanting a signpost to other texts. However, there are chapter-specific references at the back and the lack of copious in-text references does make for easier reading.

One of the strengths of the book is that facts are not presented cold. For example, we are told that sea water is 'almost' incompressible, which is an easy comment for the reader to ignore. However, it is then stated that if seawater *were* perfectly incompressible, sea-level would be 30 m higher. This encourages the reader to stop and think, is more interesting, and is more likely to be remembered at exam time. This is typical of the style of the book, with facts being related to consequences in the real world. The back-of-the-envelope calculations used for these examples also set a good example for students of climate, since in this subject such calculations are often the only ones possible without resorting to a numerical model.

The book covers well most aspects of the role of heat and water vapour in the climate, large-scale currents in the open sea, winds, and aspects of air–sea coupling. There is little reference to coastal oceanography, computer or idealised climate

models or the history of oceanography or meteorology.

Recommended on the back cover to second- and third-year climate students, the book would also be a useful complement to the *Seawater* and *Ocean Circulation* books of the Open University's Oceanography course. Although the paucity of in-text references may reduce its usefulness as a detailed guide to the scientific literature, the book could be recommended to new climate research students as interesting background reading which discusses the big picture. This should help to counter the tendency towards specialization which is often inevitable in research.

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Climate Change: Developing Southern Hemisphere Perspectives by Thomas W. Giambelluca and Ann Henderson-Sellers (1996). John Wiley & Sons Ltd, 488pp. £75 / $125 (hard cover, ISBN 0471-96214-7)

In this book, the editors, Thomas Giambelluca and Ann Henderson-Sellers, have assembled a wide-ranging collection that embraces both scientific and policy aspects of greenhouse warming. The 17 articles represent the combined expertise of 24 contributing authors. The term 'Southern Hemisphere' in the book's title reflects the political and economic divide between North and South rather than the obvious geographic divide at the Equator. To distinguish between the developed countries of Europe and North America and the developing countries of the South, here the Southern Hemisphere encompasses everything south of the Tropic of Cancer.

Of course, no brick wall separates the climate of the Northern Hemisphere from that of the Southern Hemisphere. In the course of providing a Southern Hemisphere perspective, many of the chapter authors end up examining global processes. Thus, chapters in the book may be of value to readers interested in processes occurring in the Northern Hemisphere and in the vicinity of the Equator, as well as those in the Southern Hemisphere.

The book is divided into four sections. The first section lays the groundwork by outlining some of the differences between the Northern and Southern Hemispheres in terms of geography, natural resources, and access to climate data. Section II focusses on climate modelling, outlining the scientific material needed to understand climate change. Individual chapters address coupled climate models, the predictions of these models for the Southern Hemisphere, equatorial processes, and palaeoclimate. Authors emphasize results of climate models rather than the equations that describe climate theory. This emphasis will make the presentations of current science accessible even to a non-specialist readership.

The third section addresses the 'ecological and human dimensions' of climate change. The impact of tropical deforestation on the Earth's albedo, and on climate in general, is considered. One chapter predicts possible health impacts of a warmer climate by considering how warmer winters and hotter summers might change the ways in which diseases spread. The final chapter in this section addresses the impact on vulnerable Pacific island nations of global warming and possible increases in the frequency of tropical storms.

The final section is a thorough summary of climate policy. Two chapters discuss the political process that established the Intergovernmental Panel on Climate Change (IPCC) and then worked with it. Other chapters address the economic considerations in assigning responsibility for greenhouse warming and the cost-benefit analysis required to decide how to respond to climate forecasts.

For readers seeking information on the Southern Ocean or the influence of the Antarctic continent on climate, the book will prove disappointing. The focus is more on the inhabited tropics than on the sub-Antarctic. The collected chapters do not devote extended discussions to specific questions such as how the Circumpolar Current interacts with the atmosphere, how air–sea gas exchange works in the Southern Ocean, or how ice over Antarctica controls atmospheric circulation. As much as anything, the gaps in this volume reflect the fact that high-latitude processes are poorly understood compared with equatorial/low latitude phenomena like El Niño.

For readers interested in broadening their understanding of climate change beyond their own disciplinary interests, this book will be helpful. It grew out of a graduate summer school on coupled climate system modelling held in Australia in February 1993. Chapter authors updated their material to reflect scientific knowledge and policy decisions that occurred nearer the time when the book went to press. Despite this, given the rapid developments in climate modelling and in international climate policy, parts of this book run the risk of becoming outdated in another five or ten years. For the present, however, *Climate Change* is a useful resource for researchers interested in science and policy aspects of greenhouse warming.

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Systematics and Evolution of *Littorina* by David G. Reid (1996). The Ray Society, 463pp. £89 (hard cover, ISBN 0-903874-26-1); obtainable from the Ray Society, c/o Intercept Ltd, PO Box 716, Andover, Hants SP10 1YG; add £6 p&p. for UK and Europe, £10 for rest of world.

Unless you are devoted to periwinkles, why should you want to shell out nigh on a hundred pounds (with the postage) for a large book about these – to quote the Preface – 'small, drab, familiar' snails that are 'common on all the chill northern seashores'? The answer, in short, is that it is a shining vindication of the specialist's ability to get to grips with questions of the broadest interest, in this case concerning evolution. For teacher, researcher and student alike, the book is a goldmine for lucidly explained examples of all sorts of evolutionary phenomena. Winkles as food for thought!

During his famously long delay in publishing his evolutionary theory, Charles Darwin spent eight years studying barnacles. Far from being

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a curious diversion while he ruminated on one of the great revolutionary ideas in science, this work on barnacles was to provide him with crucial first-hand experience of comparative anatomy and classification. And since evolution reflects the compounded fate of individual variability, there is no better way to understand its workings than to immerse oneself in the details of examples. Two volumes of Darwin's barnacle work were published by the Ray Society, in 1851 and 1854. I'm sure he would have rejoiced in the shared spirit of enlarged curiosity in David Reid's monograph on another group of commonplace shore-dwellers, published by the same body nearly a century and a half later. Space precludes a detailed run-down of the contents, so, after a broad overview, I'll dwell on some of the nuggets whose glint caught my eye.

Following a brief introduction to the huge literature on *Littorina*, the next two chapters cover 'Material and methods' (nomenclature, specimens and features investigated) and 'Morphology' (soft and hard parts, and influences on their variation). Next comes the meaty Chapter 4 on 'Systematic descriptions', taking up three-quarters of the text. Nineteen extant and four fossil species, assigned among four subgenera, together with six fossil species of uncertain status, are described. Nomenclatural aspects, diagnoses and accounts of anatomy, shell form and distribution are covered, with superb illustrations, together with discussions of other (especially molecular genetic) data. Non-specialists may not want to plough through this, but at least they will be able to cross-check the basic data where necessary for the last two chapters, on 'Phylogeny' and 'Macroevolutionary history', which they certainly will want to peruse. Though a full-time researcher, David Reid is clearly also a born teacher. He is always careful to explain his analyses of the data in an accessible way, despite using some complex cladistic and phenetic methods (the former being based on shared derived characters, the latter on observable similarities).

Now for the nuggets. Several contrasting shell forms associated with particular microhabitats, previously regarded as distinct species, are now recognized as 'ecotypes' within single species – convergent forms produced under similar local regimes of natural selection. Despite some genetic differentiation, there is evidently greater gene flow between different ecotypes on the same shore than between the same ecotypes on different shores. Ecotypy is much more pronounced in species of the subgenus *Neritrema*, whose attached benthic egg masses release crawling larvae, than in those of the other three subgenera, which produce pelagic spawn yielding plankton-feeding larvae. Hence the key to ecotypic differentiation is a limitation of gene flow due to the mode of reproduction, allowing highly localized adaptation. Add assortative mating (noted in one case), and sympatric speciation (i.e. splitting of species in the same area) becomes a distinct possibility in the longer term. This discussion of speciation should be required reading for those laboratory-bound biologists who mistakenly suppose that natural history is dead as a source of biological enlightenment.

Distributions today *vis-à-vis* past events, the fossil record and genetic distances between species can together constrain the timing of phylogenetic branching points. Thus the age and pattern of at least some speciations can be inferred. For example, the northern Atlantic species of *Littorina* can be shown to have been derived from two northern Pacific lineages. The trans-Arctic migration must have followed the opening of the Bering Strait in Pliocene times, and climatic cooling in the late Pliocene would then have broken the connection. All but one of the Atlantic species cluster within *Neritrema*, and molecular estimates for the age of separation from their Pacific cousins in that subgenus fit nicely in the Pliocene window. Hence a clear case of climatically induced vicariant speciation. The origin of the remaining northern Atlantic form (*Littorina littorea*) is more equivocal, but Pliocene fossils from the southern North Sea show some resemblance to its Pacific sister species, again hinting at vicariant speciation. Only the first lineage showed multiple speciation thereafter, in contrast to the pelagic-spawning *L. littorea*, which remained as a singleton. As noted above, the radiation of the former may well have involved sympatric speciation. What a complex interplay of geography, climate, natural history and genetics speciation is! In *Littorina* at least, vicariant allopatric and sympatric models of speciation seem to fit the facts better in most instances than the much-vaunted peripatric model (based on the isolation of small peripheral populations) beloved of text-books. Bad news, too, then, for the idea of punctuated equilibrium, which assumes the latter as its starting point.

A final nugget concerns what these periwinkles feel – literally – about each other. Their eyesight being what it is, snails have no easy task spotting a potential mate. So their strategy, more or less, is: if it looks about right, give it a go (in a previous study on a close Pacific relative, *Littoraria*, David Reid recorded that of 1198 pairs observed in copulation position, 43 (3.6%) involved individuals of different species). On the other hand, in terms of genetic fitness it only pays to go all the way with the other sex of the same species. So natural selection can be expected to have favoured ways to keep one on track. This, it seems, is where the impressively elaborate penis of the male comes in – as part of a 'specific mate recognition system'. You can imagine the rest; but what serves as a badge for the snails is obviously a boon to the taxonomist, too. Pity the poor palaeontologist trying to classify fossil shells of these beasts, without those vital clues by means of which they classify each other!

I could go on with many more such nuggets, but these must suffice. A real gem of a book, then – a work of fine scholarship, full of well explained case histories that will be of interest to anyone concerned with evolutionary studies, and, incidentally, also a real pleasure to behold and handle.

Peter Skelton
Department of Earth Sciences
The Open University

THE OCEANS CHARTER

The undersigned agree:

* *The oceans and their resources are a necessary element of life on this planet.*

* *The health of the oceans and the sustainability of the renewable resources, together with the wise and safe uses of its other bounties must be an axiom for all governments to accept and honour for the long-term benefit and existence of their respective and collective peoples.*

* *The acquisition of the knowledge necessary for the understanding and stewardship of the oceans and their adjacent seas and for the adoption of policies, standards and regulations to protect the ocean environment and to husband its resources, are goals to be pursued both nationally and internationally.*

* *There must be mutual assistance and the will to work together to achieve common goals for the oceans - adjacent and regional coastal states should cooperate in the adoption of local policies and actions - countries with knowledge and resources should assist less fortunate neighbours - data and information for global and regional problems should be readily available - States should make use of international and intergovernmental organizations to generate global programmes and agreements.*

Acting on behalf of our governments, we recognize the wisdom of acting in unison to protect the oceans and to use its resources in a sustainable manner and accept this Oceans Charter as a basis for future action.

Signed in the Year of the Ocean, 1998

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MY OCEANS CHARTER

I agree:

* *The oceans and the creatures therein are a necessary part of life on this planet.*

* *Maintaining the health of the oceans and the abundance of its fisheries, together with the wise and safe uses of all its resources, must be accepted and honoured by governments so that future generations can enjoy the continuing benefit for all peoples.*

* *Understanding the marine environment and its living community, is necessary for the stewardship of the oceans and the seas and for the making of decisions to protect and husband its resources.*

* *We must work together to succeed - within countries people can influence ocean policies if they act together - internationally, countries should help their neighbours and accept regional policies and actions - countries having the knowledge and resources should assist less fortunate nations - data and information on the ocean should be readily available - international and intergovernmental organizations should be used to generate global programmes and agreements.*

I promise to remember my Oceans Charter, in my treatment of the oceans and the waters that flow into the ocean, in my work and in my play and in the decisions that I make.

Signed in the Year of the Ocean, 1998

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

To advance the study of Marine Science through research and education.

To disseminate knowledge of Marine Science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management.

To contribute to public debate on the development of Marine Science.

The Society aims to achieve these objectives through a range of activities:

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

Publication of a range of documents dealing with aspects of Marine Science and the programme of meetings of the Society.

Membership provides the following benefits:

An opportunity to attend, at reduced rates, the biennial four-day UK Oceanography Conference and a range of other scientific meetings supported by the Society.

Regular bulletins providing details of Society activities, news of conferences, meetings and seminars (in addition to those in *Ocean Challenge* itself).

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The subscription for 1998 will cost £25.00 (£12.00 for students in the UK only). If you would like to join the Society or obtain further information, contact The Executive Secretary, Challenger Society for Marine Science, Room 251/20, Ocean Technology Division, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references. If at all possible, they should be well illustrated (please supply clear artwork roughs or good-contrast black and white glossy prints). Manuscripts should be double-spaced and in a clear typeface.

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