OCEAN

Challenge

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and 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.

The views expressed in *Ocean Challenge* are those of the authors and do not necessarily reflect those of the Challenger Society or the Editor.

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Ocean Challenge is sent automatically to members of the Challenger Society for Marine Science. For more information about the Society, see inside back cover.

DATA PROTECTION ACT, 1984 (UK)

Under the terms of this Act, you are informed that this magazine is sent to you through the use of a computer-based mailing list.

CONTENTS

The cover image show the global phytoplankton distribution. Phytoplankton concentrations are low in the central gyres (purple, deep blue), and tend to be high along coasts (yellow, orange and red). The images, which were made by processing thousands of individual scenes from the Coastal Zone Color Scanner, have been used by courtesy of Gene Feldman. NASA/Goddard Flight Center, Space Data and Computing Division, Greenbelt, Maryland 20771, USA.

The cover was designed by Ann Aldred Associates.

CHALLENGER SOCIETY FOR MARINE SCIENCE

UK OCEANOGRAPHY '94

Stirling
29 August – 2 September 1994

University of Stirling and the
Scottish Association for Marine Science

All oceanographers in the UK are invited to offer contributions to this conference. The aim is to review progress and to present recent work in Marine Science. Papers on all aspects of Oceanography and related topics are welcomed, and contributions on Applied Oceanography as well as purely scientific research are encouraged. Papers emphasising the interdisciplinary nature of the subject will be particularly welcome and it is hoped to offer all participants a broad perspective of the present state of Oceanography in the UK.

One of the objectives of the conference is to provide opportunities for young scientists, including research students, to present their work: The Norman Heaps and Cath Allen Prizes will be awarded for the best verbal and best poster presentations by young scientists. Oceanographers from abroad are also warmly invited to participate in the meeting.

PROPOSED TOPICS and KEYNOTE SPEAKERS

Intertidal Oceanography J. Pethick
Ocean Measurement Techniques W.J. Gould
Continental Margin Sedimentation D. Masson
Seasonality in the Ocean A. Clarke
Ocean Data Dissemination R.J. Gurney
Mid-Ocean Ridge Studies H. Elderfield
Palaeoceanography G. Shimmield
Shelf-Sea Predictability D. Prandle
The Southern Ocean R.T. Pollard

PAPERS and POSTERS

Contributed talks will last 15 minutes (plus 5 minutes discussion). Session themes will be organised on the basis of abstracts. Contributors may offer a poster as an alternative, or in addition to a verbal presentation. A formal poster session will be scheduled during the week to encourage discussion of these contributions. Accepted abstracts will be available to registrants as pre-prints. No other conference proceedings will be published, but authors are encouraged to consider writing papers for inclusion in the Society's journal, *Ocean Challenge.*

Abstracts should be submitted to the conference organisers AS SOON AS POSSIBLE, and NO LATER THAN 29 APRIL 1994.

CONFERENCE FEES and PROGRAMME

The conference fee (including VAT) will be £82.25 (£70.50 for Challenger Society members), or £52.88 for full-time students (£47.00 for student members) until 15 JULY. After this, there will be a late-booking supplement of £23.50 on all rates. The conference fee covers the paper and poster sessions, refreshments and the cost of the Conference Dinner on Thursday 1 September. There will be an opening reception on the Monday evening. An excursion will be available for the Wednesday afternoon.

Special meetings of Challenger Society Affiliated Scientific Groups may be held during the conference. The organisers of these groups will circulate their members with the relevant details in due course.

Participants are asked to submit the registration/booking form as soon as possible. If the allocated university accomodation is filled, late registrants may have to make their own arrangements. A small number of bursaries are available for those with no alternative means of funding attendance.

All correspondence and enquiries should be addressed to:

UK Oceanography '94,
SAMS,
Dunstaffnage Marine Laboratory,
PO Box 3,
OBAN, Argyll, PA34 4AD

Organising Committee

D.J. Ellett (DML, Chairman) V. Lawford (L.M. Services) A.R.D. Heathershaw (DRA) D.S. McLusky (Stirling) R.B. Heywood (BAS) M.R. Preston (Liverpool) A.E. Hill (UCNW) P. Statham (Southampton) D. Huntley (Plymouth) R. Whitmarsh (IOSDL)

FORTHCOMING EVENTS

EVENTS IN 1994

24th Symposium on Analytical Chemistry 16–19 May, Ottawa, Canada. Contact Dr M. Malaiyandi, CAEC, Chemistry Department, Carleton University, 1255 Colonel By Drive, Ottawa, Canada K1S 5B6.

Nutrification / The 1993 Copenhagen Interministerial Conference (Meeting of the Marine Forum). 20 May (11 a.m.–4 p.m.), Natural History Museum, London. *Contact* The Marine Forum for Environmental Issues, c/o Department of Zoology, The Natural History Museum, Cromwell Rd, London SW7 5BD; Tel. 071-938-9114; Fax 071-938-9158.

Characteristics of Estuarine, Coastal and Lake Ecosystems (Joint Meeting of the Association for Great Lakes Research abd the Estuarine Research Federation: ERF 94). 5–9 June, Winsor, Ontario, Canada. Will cover many processes characterising estuarine, coastal and lake ecosystems and their watersheds. *Contact* G. Douglas Haffner, Great Lakes Institute, University of Winsor, Ontario, Canada N9B 3P4; Fax +519-973-7050.

Aquaculture and Water Resource Management 21–25 June, Stirling. Meeting to address the impacts of aquaculture and its conflict with human activities in inland and coastal waters. *Contact* The Organizing Committee, Institute of Aquaculture,University of Stirling, Stirling FK9 4LA, Scotland.

International Symposium on the Marine Mammals of the Black Sea (Organized by the Faculty of Fisheries of the University of Istanbul). 27–29 June, Istanbul, Turkey. The aim of the Symposium is to provide an international forum for exchange of information and expertise among all those involved with, or interested in, marine mammals. *Contact* Dr B. Ozturk, Istanbul Universiti Su Urunleri Fakultesi Beykoz 81650, Istanbul, Turkey.

Electronic Engineering in Oceanography: Sixth International Conference in Electronic Engineering in Oceanography (Joint Meeting of the Challenger Society and the Institution of Electrical Engineers). 19–21 July, Churchill College Cambridge, UK. *Contact* Louise Bousfield. EEO 94 Secretariat, Conference Services, Savoy Place, London WC2R OB; Tel. 071-240-1871, extn 222; Fax 071-497-3633; Telex 261776 1EE LDN G.

INTERCHO 94 (4th Nearshore and Estuarine Sediment Transport Conference). 11–15 July, Wallingford, UK. *Contact* Jacqueline Watts, HR Wallingford, Howbery Park, Wallingford, Oxon, OX10 8BA, UK.

6th International Conference on Electronic Engineering in Oceanography (Joint Meeting of the Challenger Society and the Institution of Electrical Engineers). 19–21 July, Churchill College, Cambridge. Convenor: Dr B.S. McCartney, Proudman Oceanography Laboratory. *Contact* Louise Bousfield, Institution of Electrical Engineers.

Pacific Basin Meeting (Meeting of the Oceanography Society). 19–22 July, Honolulu, Hawaii. The purposeof the meeting is to provide an international science and policy forum for major international global change programs occurring in the Pacific, especially JGOFS, WOCE, TOGA/TOGA COARE and RIDGE/ODP. *Contact* The Oceanography Society, 1124 Wivenhoe Way, Virginia Beach, Virginia 23454, USA, or the registration contractor, E.H. Pechan & Associates, 5537 Hempstead Way, Springfield, VA 22151; Tel. (703)642-1120, extn 158.

Water Quality International 94 (17th Biennial Conference of the International Association on Water Quality). 24–30 July, Budapest, Hungary.

The South Atlantic: Present and Past Circulation (Symposium sponsored by WOCE and SCOR). 15–19 August, Bremen, Germany. *Contact* South Atlantic Symposium, Dr Barbara Donner, Fachbereich 5 der Universität, Geowissenschaften, Postfach 33-04-40, W-2800 Bremen 33, Germany.

UK Oceanography '94 28 August–3 Sept, University of Stirling, Scotland. *For further details, contact* Mrs Helen Anderson, PO Box 3, Oban, Argyll, PA34 4AD, Scotland.

29th European Marine Biology Symposium 29 August–2 September, Vienna. The main topics addressed will be the influences of organisms on their environment and the role of episodic events. *Contact* Mrs Elvira M. Olscher, Dept of Marine Biology / EMBS, Institute of Zoology, Althanstr. 14, A-1090 Vienna, Austria; Fax +43-1-31336-700.

Marine Biodiversity: Causes and Consequences (Joint Meeting of the Marine Biological Association of the UK and the Scottish Association for Marine Science). 30 August–2 September, University of York. *Contact* Rupert Ormond, Institute of Applied Biology, University of York, York YO1 5DD; Tel. 0904-432930; Fax 0904-432917.

Arctic Ocean Grand Challenge: Scientific Rationale–Strategy–Science Plan (European Science Foundation Conference, with ECOPS, AOSB and IASC). 2–7 September, Helsinki, Finland. Topics to be addressed are: Large-scale ice–ocean circulation and climate; biology and the carbon cycle; mesoscale physical processes; palaeoenvironment and climate. *Contact* Dr Josip Hendekovic, European Science Foundation, 1 quai Lezay-Marnesia, 67080 Strasbourg Cedex, France. Tel. (33) 88 76 71 35; Fax (33) 88-36-69-87.

1994 ECSA Annual Scientific Symposium (ECSA24) September 4–10, University of Aveiro, Portugal. Major theme to be the comparison of northern and southern estuaries, lagoons and coastal areas. *For further details contact* the ECSA Meetings Secretary, V.N. de Jonge, Rijkswaterstaat, Tidal Waters Division, PO Box 207, 9750 AE Haren, The Netherlands.

VIIIth International Colloquium on Amphipoda 12–15 September, Lodz, Poland. *Contact* Prof. dr. K. Jazdzewski, Dept of Invertebrate Zoology and Hydrobiology, University of Lodz, Banacha str. 12/16, 90-237 Lodz, Poland; Fax +78-39-24.

Ecotoxicology: Ecological Dimensions (5th Annual Meeting of SETAC-Europe, UK Branch). 13–14 September, University of Sheffield, UK. Six international speakers will address the meeting on various topics in the fields of ecology and ecotoxicology. *Contact* Dr Lorraine Maltby, Department of Animal an Plant Sciences, PO Box 1, University of Sheffield, Sheffield, S10 2UQ; Tel. 0742-768555; Fax 0742-760159.

Coastal Zone Canada '94: Cooperation in the Coastal Zone 20–23 Sept, Halifax, Nova Scotia Topics to include scientific research, engineering development, community initiatives, conservation and protection, socio-economic issues, law and politics. *Contact* Coastal Zone Canada '94 Conference Office, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, Canada, B2Y 4A2.

Biology and Ecology of the Deep Sea (7th Deep Sea Biology Symposium). 29 September–4 October, Crete. *Contact* The Secretariat, 7th DSBS, Institute of Marine Biology of Crete, Box 2214, Iraklion 71003, Crete, Greece.

MSc/Diploma in Ecosystems Analysis and Governance (starting in October 1994) Biological Sciences, Ecosystems Analysis and Management Group, University of Warwick. A new multidisciplinary postgraduate course, intended to promote knowledge of terrestrial and oceanic environments. It will integrate new conceptual tools from ecological, legal, economic and anthropological research. It aims to advance our understanding of ecosystem dynamics and the processes of policy development and decision-making for the natural and human environments. *For technical information about the course, contact* Dr Charles Sheppard, Dept of Biological Sciences, University of Warwick, Coventry CV4 7AL; Tel. +44 (90)203-522476 or 524620; Fax: +44 (0)203 524619. *For prospectus and application form contact* Dr Nick Mann, Dept of Biological Sciences, University of Warwick, Coventry CV4 7AL; Tel. +44 (0)203-523526 or 522587; Fax: +44 (0)203 52368.

Quality Status Report / Scientists and their Role in Decision-Making Procesess (Meeting of the Marine Forum). 19 Oct. (11 a.m.–4 p.m.), Natural History Museum, London. *Contact* The Marine Forum for Environmental Issues, c/o Dept of Zoology, The Natural History Museum, Cromwell Rd, London SW7 5BD; Tel. 071-938-9114; Fax 071-938-9158.

Chemical and Optical Sensors (Challenger Society Meeting) Nov., Plymouth. *Contact* Dr Alan Morris, Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DB. Tel +44 (0)31-752-222772; Fax +44 (0)31-752-670637.

Pollution of the Mediterranean Sea 3–4 November, Nicosia, Cyprus. *Contact* M. Nicolaou, WTSAC, PO Box 1735, Limassol, Cyprus.

Glacial–Interglacial Sea-level Changes in Four Dimensions: Continental Shelf Evidence of Sea-levels Over the Last 20 ka (European Science Foundation Conference). 5–10 Nov., St Martin, near Mannheim, Germany. Sessions will focus on northern and western European shelves and the north-east American shelf; time will also be devoted to detailed sub-sea data and dates from micropalaeo-logical evidence of depth, salinity and temperature of the depositional environment, and to the integration of the submarine data with onshore data and modelling. *Contact* Dr Josip Hendekovic, address as for ESF conference on 2–7 Sept, 1994. Deadline for participants: 6 May 1994; Deadline for applications is 8 July.

Marine Disposal Systems (Conference of the International Association on Water Quality). 23–25 Nov., Istanbul, Turkey.

Selection Mechanisms Controlling Biomass Distribution Between Cyanobacteria, Phytoplankton and Macrophyte Species (IAWQ–SL Specialized Conference) 11–15 December, Noordwijkerhout, The Netherlands. Topics will include nutrient interactions, physiological aspects and the role of toxins, hydrophysical processes and community mechanisms. *Contact* Secretariat for IAWQ–SL Conference, Laboratory for Microbiology, Niewe Achtergracht 127, 1018 WS Amsterdam, The Netherlands; Fax +31-20 5255698.

The Habitats Directive and its Implementation (Meeting of the Marine Forum). 30 Nov. (11 a.m.– 4 p.m.), Natural History Museum, London. *Contact* The Marine Forum for Environmental Issues, c/o Dept of Zoology, The Natural History Museum, Cromwell Rd, London SW7 5BD; Tel. 071-938-9114; Fax: 071-938-9158.

EVENTS IN 1995

Strategies and Methods in Coastal and Estuarine Management (ECSA 25). Date t.b.a.;Trinity College, Dublin Ireland. *Contact* Local organizers: Mark Costello and Jim Wilson.

Appropriate Waste Management Technologies for Developing Countries (IAWQ Conference). Feb., Nagpur, India.

Shipping / Pollution, Reception Facilities and Transport of Hazardous Goods (Meeting of the Marine Forum). 1 Feb. (11 a.m.–4 p.m.), Natural History Museum, London. *Contact* The Marine Forum for Environmental Issues, c/o Dept of Zoology, The Natural History Museum, Cromwell Rd, London SW7 5BD; Tel. 071-938-9114; Fax 071-938-9158.

International Maritime Defence Exhibition and Conference (IMDEX 95). 28–31 March, National Maritime Museum, Greenwich, London. *Contact* Spearhead Exhibitions Ltd, Rowe House, 55/59 Fife Rd, Kingston upon Thames, Surrey KT1 1TA; Tel. 081-549-5831; Fax 081-541-5657/541 5016/547 2807.

Estuaries of Central Scotland (Estuarine and Coastal Sciences Association meeting). 6–8 April, Heriot Watt University, Edinurgh. *Contact* D.S. McLusky, Dept of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 0786-467755; Fax 0786-464994.

Genetic Applications in Marine Systems (GAMES) (Meeting of the Marine Biological Association of the UK) 17–19 April. *Contact* Brian Bayne, Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DB. Tel +44 (0)31-752-222772; Fax +44 (0)31-752-670637.

Hazard Assessment and Control of Environmental Contaminants in Water (IAWQ Conference). 29–30 June, Copenhagen, Denmark.

Long-term Changes in Aquatic Biological Systems (Meeting of the Marine Biological Association of the UK) 6–8 Sept.. *Contact* Mike Whitfield, Marine Biological Association,The Laboratory, Citadel Hill, Plymouth, PL1 2PB; Tel. 0752-222772; Fax 0752-226865.

30th European Marine Biology Symposium 11–15 September, Southampton. The main topics will be about mechanisms whereby a specific process or processes respond to environmental parameters at the organism, population and community level. *Contact* 30th EMBS, Dept of Oceanography, University of Southampton, Highfield, Southampton, UK.

Estuarine Symposium Sept. Hamburg, Germany. *Further details* will be available from D.S. McLusky, Department of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 0786-467755; Fax 0786-464994.

EVENTS IN 1996

The Humber Estuary (Estuarine and Coastal Sciences Association Meeting). April, University of Hull. *Further details* will be available from D.S. McLusky, Department of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 0786-467755; Fax 0786-464994.

Crustacean Biology (Special Meeting of the MBA, the SEB and ECSA, in honour of Professor Ernest Naylor). 1–3 April, University of Plymouth. *Contact* Malcolm Jones, University of Plymouth. Tel. 0752-232900.

Behaviour and Ecophysiology of Marine Oganisms. (Estuarine and Coastal Sciences Association meeting). April, University of Plymouth. *Further details* will be available from D.S. McLusky, Department of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 0786-467755; Fax 0786 464994.

Joint Symposium of ECSA and the Estuarine Research Federation Sept. *Further details* will be available from D.S. McLusky, Department of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 0786 467755; Fax 0786-464994.

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, Walton Hall, Milton Keynes, Bucks MK7 6AA.

NEWS AND VIEWS

FOUNDER DIRECTOR FOR THE SOUTHAMPTON OCEANOGRAPHY CENTRE

It has been announced that the first director of the Southamton Oceanography centre is to be Dr John Shepherd. Dr Shepherd is currently the Deputy Director of Fisheries Research and Head of the Fis h Stock Management Division of the MAFF Directorate of Fisheries Research at Lowestoft. He has ben acting as senior advisor to MAFF ministers on the scientific aspects of fisheries management, and was closely involved in the work of the International Council for the Exploration of the Sea, standing as the UK representative on its Advisory Committeee for Fisheries Management from 1986 to 1989.

RVS BARRY GOOD VALUE FOR MONEY IT'S OFFICIAL

As a result of a market testing exercise on the management, crewing, maintenance and operation of its vessels *Challenger*, *Discovery* and *Charles Darwin*, NERC has decided to award the work to its in-house team, Research Vessel Services at Barry, South Glamorgan. Four other bids were received from UK-based firms in the shipping industry, but the in-house team was judged to represent the best value for money in terms of quality of service, techical capability and cost.

POLLUTER TO PAY — SOMETIMES

The House of Commons has passed without a vote the 'The Marine Salvage and Pollution Bill', proposed as a private member's bill by David Harris, MP for St Ives. Once the Bill has become law, payment for salvage firms will be guaranteed; the compensation to be paid by owners of polluting vessels will be increased; only small vessels like fishing vessels will be exempt. Furthermore, it will not have to be proved that masters have been negligent, only that their vessel was the source of the pollution. It is hoped that this change will cause ship owners to be responsible for maintaining high standards. However, a problem will remain in the case of ships flying flags of convenience, or in the case of pollution incidents for which the culprit is unknown

FISHY ISSUES

Pollution caused by dumping of wastes at sea can damage fish populations by causing deformity and/or stunted growth, skin lesions, liver damage, and so on. But you won't be reading scare stories about Mad Cod Disease because (it is believed) the temperatures at which fish live are such that pathogenic conditions in them cannot be passed to humans. More-over, although toxic substances taken up by fish in polluted waters can be transmitted to us as top carnivore, such incidents in UK are relatively few ... so that's all right then. However, while these appear not to be directly harmful to human consumers, they have adverse consequences for reproduction and growth of fish stocks – which must in turn have knock-on effects in other parts of the marine ecosystem.

Such introduction can occur:

- Deliberately, for commercial purposes,
- Accidentally, (a) through transport on ships' hulls (nowadays less common because of anti-fouling paints, faster passage and turn-round in port, which reduces colonization times); and (b) in ship's ballast, which is commonly rich in nutrients and allows organisms to cross natural biogeographic barriers (especially changes in temperature and/or salinity, and large stretches of open ocean);
- Naturally, through rafting or transport by birds; this has of course been going on for at least some tens of millions of years, but at rates that are negligible compared with those of anthropogenic mechanisms. For example, the soft-shelled clam *Mya arenaria*, originally native to Britain, was eliminated during the last Ice Age and might well not have returned for (at least) another millenium or two, had it not been re-introduced to British waters in the 16th or 17th centuries from North America, as food or bait or in bilge water.

Not only can alien species pass on diseases to native organisms, but they can disrupt local ecosystems. This may occur through some combination of predation on native species, competition for food and space and eventual displacement of native species, and alteration of habitat.

Plants appear to be more successful than animals at crossing natural barriers, and while climate change is not in itself a mechanism for bridging the main biogeographic barriers of the open ocean, it can aid the success of introduced organisms. Mobile species are not necessarily any more successful (neo-)colonizers than sessile ones. For example, the barnacle *Eliminium modestus* has found its way round the UK coastline since its introduction from Australia and New Zealand in World War II (probably on ships' hulls), both by marginal spread and by dispersal via coastal shipping.

The growth of mariculture and fish farming is more likely to exacerbate these problems than to ameliorate them. In 1990 the International Council for the Exploitation of the Sea (ICES) adopted a Revised (1990) Code of Practice to Reduce the Risks of Adverse Effects Arising from Introductions and Transfers of Marine Species. The matters referred to above have been aired at meetings of the Marine Forum for Environmental Issues during the past year. Interested readers may obtain a copy of the Revised Code of Practice, as well as more details of the meetings summarized above, and future similar meetings, from The Marine Forum for Environmental Issues, c/o Dept of Zoology, Natural History Museum, London SW7 5HD.

BEACHES ARE SPRING CLEANED

Riding on the success of Beachwatch '93, a beach-cleaning project run by the Marine Conservation Society and Reader's Digest last September, MCS organized another such event this April. Frazer McGilvray, Beachwatch Officer for MCS explained that many of the volunteers who took part last year were keen to repeat the event. MCS hope that as well as being a worthwhile project, the campaign will draw attention to the general problem of marine debris.

BOOKS ON OCEANOGRAPHY

My second catalogue of out-of-print books on the marine and other earth sciences is due to appear shortly. All previous customers will receive a copy, as will potential future customers who communicate their address to me

John Phillips
160 Waterside, Peartree Bridge
Milton Keynes MK6 3DQ

Tel. 0908-663579

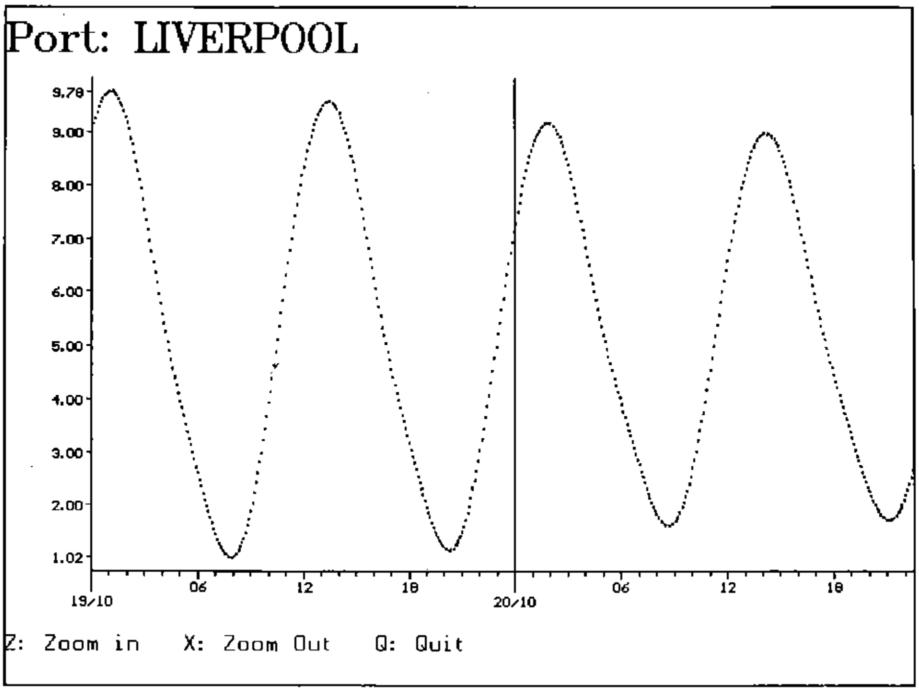
SOME USEFUL TIPS FROM POL

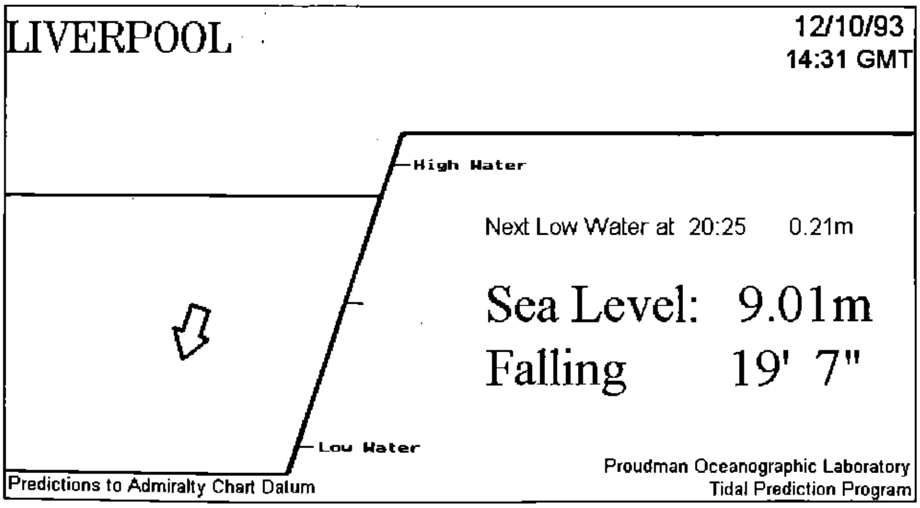
POLTIPS, the Proudman Oceanographic Laboratory Tidal Information and Prediction Systems, is a program for IBM PC and compatible computers which makes tidal level predictions for over 700 locations around the coast of the British Isles.

Bidston Observatory has provided a national and international tidal prediction service since 1924, based on increasingly refined analytical methods and modern computer hardware. As the laboratory responsible for the installation, maintenance and running of the UK's Class A tide-gauge network, Bidston has access to the most accurate and up-to-date data which it uses to produce analyses for the production of tidal predictions.

POLTIPS uses a subset of the constituents that are used for predictions which are sold to oil companies, publishers, almanacs, universities, port authorities, harbour boards, newspapers and television (teletext), the storm-tide warning service and the Met Office. From their database, they have analysed and extracted the 20 most significant constituents for each main port. This provides an average accuracy of better than 5% on heights and 10 minutes for high and low water times, but enables the predictions to be produced extremely quickly.

Example of the type of display produced by POLTIPS





Features of POLTIPS include:

- Predictions for all main ports using harmonic constants, with predictions for over 650 smaller locations available using secondary port time and height differences.
- Prediction of hourly heights for main ports as well as high and low waters for periods from one day to five years.
- Output which can be sent direct to a printer or into a file for importing into other programs (such as a spreadsheet).
- Software written and optimised to produce predictions in a minimum of time. The program will use a maths co-processor if one is available.
- Production of graphical plots for up to a month, with a zoom facility enabling specific parts to be examined in more detail.
- Real-time graphical display directly linked to the computer's clock. It shows the time and height of next high or low water, and updates every minute. This is suitable for continuous public display.

The software is available in two versions. Both are identical in features, but one is limited to three consecutive years' predictions, whereas the other permits up to five years (the actual time period can be specified when the software is bought). To obtain more information, contact either Joyce Scoffield, Helen Jones or Colin Bell at the Proudman Oceanographic Laboratory;
Tel. 051-653-8633; Fax: 051-652-3950.

EC FELLOWSHIPS AT POL

Several EC fellowships in 'Global and regional sea-level change' will become available at POL from about January 1995. The fellowships, which will be for one or two years, are EC 'Human capability and mobility ' awards and so will be available to Europeans who are *not* UK nationals and have not carried out research in the UK in the previous two years. The objectives of the project are to measure and understand global and regional sea-level changes on time-scales ranging from a few hours (e.g. tides), through seasonal and decadal time-scales, to secular variations. Further information may be obtained from Graham Alcock, POL (address and telephone number as above); Omnet: POL.BIDSTON Internet: plw@pol.ac.uk

Application forms must be returned by 30 June 1994.

CHALLENGER SOCIETY NEWS

THE PERSONALITIES BEHIND THE NAMES

SCIENTISTS REMEMBERED AT UK OCEANOGRAPHY

Two of the feature articles in this issue had their origins un events at the last UK Oceanography Conference in 1992. 'Pulling the Plug' by Tony Laughton, is based on his Raymont Lecture (see photo below); and 'Something for Nothing' by Rebecca Woodgate is on data assimilation, the subject of the talk that won her the Norman Heaps Prize for the best presentation by a young scientist. For financial reasons there will not be a Raymont Lecture at UK Oceanography 94, but this nevertheless seems an appropriate point to say a little about the two people who are commemorated by the Raymont lecture and the Norman Heaps Prize, especially as younger readers may know little or nothing about these exceptional people.

The Raymont Lecture commemorates the life and work of **John Edwin George Raymont** (1915–1979). John Raymont was appointed to the Chair of Zoology at what was then the University College of Southampton at the age of 31. He brought to Southampton research interests in biological oceanography, particularly in zooplankton, which he had developed as a visiting worker at Woods Hole and in academic posts at Exeter and Edinburgh. Among other investigations, he had undertaken early studies on the effects of fertilization on the productivity of sea lochs.

Marine biology became an important focus of research activity in the Department of Zoology at Southampton; various links were forged, notably with the Central Electricity Generating Board, which was subsequently to establish a research laboratory on Southampton Water, and further afield, with the marine station of Annamalai University on the Vellar Estuary in southern India.

In 1965 John Raymont moved from the Department of Zoology to become the first Professor of Biological Oceanography in the newly formed Department of Oceanography, which began as a postgraduate department. This new development was very much driven by his personal vision of interdisciplinary department with wide national and international links. He continued to lead the Department until his death in 1979.

The new Southampton Oceanography Centre, rising on the waterfront fifteen years later, has an important component of its origins in John Raymont's vision and achievements. He was much involved in the activities of nautical and international organisations, particularly IOC and UNESCO, and he held senior administrative positions in the University of Southampton. His role in the work of regional health authorities was recognised by the award of the OBE. His contributions to the scientific literature were numerous. Shortly after his death, the second edition of his major treatise, *Plankton and Productivity in the Oceans*, appeared to two volumes, embodying much of the scholarship which characterised a lifetime of dedication to oceanography.

Norman Heaps spent the first part of his career in the field of aerodynamics, first at RAE Farnborough, then at EEC's Aircraft Division at Warton, Lancashire. In 1962, after a period as Senior Lecturer in Mathematics at the Royal College of Advanced Technology, Salford (now the University of Salford) he began a long and fruitful association with Bidston Observatory. His work at Bidston covered a wide range of topics, including circulation in lakes and shelf seas, tidal resonance and tidal power, and storm surges. In the wake of the disastrous 1953 floods, the prediction of storm surges became a national priority. Initially, with the limited computational facilities then available, Norman could only attack the problem using elaborate analytical techniques. However, by 1969 he was able to demonstrate a two-dimensional numerical model of the North Sea, and it was this that was eventually developed into the fully operational storm-surge prediction model, run by the Met. Office.

Norman Heaps died in 1986 after a highly productive career that had been exceptional in terms of the diversity and originality of his ideas. It is appropriate that the prize named after him rewards good presentation: his scientific papers were concise yet highly readable, and his lectures, which have been described as "breathtaking", were eagerly anticipated.

To be eligible for the Norman Heaps Prize, a speaker must be 35 or under at the date of the presentation.

continued ...

Tony Laughton with Challenger Society President, Brian McCartney, after the Raymont lecture at UK Oceanography '92 *(Photo by courtesy of the University of Liverpool)*

The other prize awarded at UK Oceanography is, of course, the **Cath Allen** Poster Prize. Cath was a dedicated teacher and respected researcher. When she died in 1991, the high quality of her wide-ranging interdisciplinary research work was beginning to be recognized internationally. A memorial conference, 'Mixing and Transport in the Environment', held in Lancaster in June 1992, was attended by scientists from around the world.

Our thanks to Dennis Burton and Valerie Doodson (Information Officer, POL) for help in compiling the above.

*The proceedings of the conference have now been published: *Mixing and Transport in the Environment: a memorial volume for Catherine M. Allen (1954–1991)*, edited by Keith Beven, Philip Chatwin and John Millbank; Wiley, £75 (all royalties are going to Cancer Care).

JOHN HUTHNANCE WINS THE 1994 AMS EDITOR'S AWARD

John Huthnance, Honourary Secretary of the Challenger Society from 1988 until 1993, has been praised by the American Meteorological Society for his "knowledgeable, penetrating, thorough reviews for the *Journal of Physical Oceanography*". The Editor's Award, which is given in recognition of a referee's report of outstanding merit on a manuscript submitted for publication in one of AMS's journals, was presented at a banquet held during the 74th meeting of the AMS, in Nashville Tennessee. The AMS is a non-profit-making society which actively promotes the development and dissemination of information on atmospheric/oceanic/ hydrologic sciences and publishes nine journals in these fields.

John has worked at the Proudman Oceanographic Laboratory since 1977. As marine physics group leader, he has been the scientific coordinator of several laboratory and community projects, including the UK North Sea Project and the EC-sponsored 'Processes in regions of freshwater influence', as well as the physics component of the 'Ocean margin exchange', also sponsored by the EC. His research interests lie in dynamics, especially with respect to the seas over the continental shelf and slope, waves over topography and their implications for residual circulation, sediment movement, ocean–shelf coupling and exchange; he is particularly interested in the development of coupled models, involving physics, sediments and biology.

OCEAN NEWS

Last Autumn, Elsevier/Pergamon launched its twice-yearly newsletter, *Ocean News*. As might be expected, some of the content is related to Elsevier/Pergamon publications, but *Ocean News* is an interesting read nevertheless (perhaps because oceanography is close to the heart of the editor, Anne Vindenes Allen). The first issue included: an item about US WOCE; a foretaste of special issues appearing in Elsevier/Pergamon journals (*Continental Shelf Research, Marine Pollution Bulletin, Progress in Oceanography, Deep-Sea Research* and *Ocean and Coastal Management*); an article about the School of Ocean Sciences, Bangor (the first in a series about marine science institutes and seats of learning); an article about the need for an *in situ* environmental research laboratory in polar waters, and reviews of forthcoming Elsevier/Pergamon books.. If you would like to recieve *Ocean News*, contact Sue Cloke, Marketing, Pergamon Press Ltd, Headington Hill Hall, Oxford, OX3 0BW, UK.

INTERESTED IN ESTUARIES?

If the answer to this question is 'Yes', you could do worse than join ECSA, the Estuarine and Coastal Sciences Association. ECSA is a direct continuation of EBSA, the Estuarine and Brackish-Water Sciences Association, which was founded in 1971. The Society is the major European focus for the communication of research and scholarship in estuarine science. Membership is open to all who are interested in estuarine and coastal marine science, whether in Europe or further afield. The association holds local meetings, where work relevant to one specific estuary is presented, and annual symposia, which concentrate on particular chosen themes of estuarine and coastal science. Proceedings of many of the symposia have been published. The association has caused to be published Handbooks of Methodology for Estuarine Studies, and Synopses of the British and European fauna, which are available to members at reduced rates. The association has an associated journal *Estuarine and Coastal Shelf Science* which is available to members at greatly reduced rates. The *ECSA Bulletin* is distributed to all members, free of charge, three times a year. The Association has a small grants scheme and Nordic Fellowships, for younger scientists.

Further details and application forms for membership can be obtained from ECSA Membership Secretary, Dr P.C. Head, North West Water Ltd, Dawson House, Great Sankey, Warrington, WA5 3LW, UK.

INTERESTED IN MARINE LIFE?

The British Marine Life Study Society is a group of enthusiasts for the natural history of the marine environment. The Society produces a quarterly journal *Glaucus*, which covers a wide range of topics at an accessible level. Articles in the most recent issue include a description of a mass stranding in Torbay, information about the Anglesey Marine Zoo and an article about whales, dolphons and porpoises in British seas, written especially for younger readers.

The annual subscription for the BMLSS is £18. If you would like to find out more about the Society, or recieve an inspection copy of *Glaucus*, write to Andy Horton, Secretary, BMLSS, 14 Corbyn Cresent, Shoreham-by-Sea, Sussex, UK, BN43 6PQ.

BEQUESTS WELCOMED

The Challenger Society would be very grateful for any contribution that you are able to make through a legacy. A gift to the Society is completely free of inheritance tax.

There are two main options: (1) a residuary bequest (whatever is left from your estate when all other bequests have been made); (2) a cash sum.

Suitable working for a residuary bequest would be: *I bequeath to the Challenger Society of Marine Science, of IOS Deacon Laboratory, Wormley, Godalming, Surrey, (a one-third share of / all of / etc.) the residue of my estate ..., and the signature for the time being of the Treasurer of the Challenger Society of Marine Science shall be a good and sufficient discharge of my Executors in respect of this legacy.*

Suitable wording for a cash sum would be: *I bequeath to the Challenger Society of Marine Science, of IOS Deacon Laboratory, Wormley, Godalming, Surrey, the sum of £x inflation-linked to the Retail Price Index from the date of this Will, and the signature for the time being of the Treasurer of the Challenger Society for Marine Science shall be a good and sufficient discharge of my Executors in respect of this legacy.*

Anyone wishing to make a bequest is advised to consult a solicitor.

CHALLENGER SOCIETY MEMBERSHIP LIST

If you are a Society member and would like a copy of the membership list, please write to the Hon. Secretary, Dr Howard Roe, IOS Deacon Laboratory, Wormley, Godalming, Surrey, GU8 5UB.

MARINE SCIENCE FOR ALL?

The next 14 pages are about various ways in which people can find out about the oceans, including the science of the oceans – about marine science education in its broadest sense. The recent science and techology week ('set⁷' to give it its official acronym) was intended to raise the profile of science and technology in general, through seven days of displays and 'hands on' events. If the crowds visiting the Open University are anything to go by, the public in general, and children in particular, *can* be 'turned on' to science, including marine science. Children and adults alike were amazed to see marine plankton under the microscope; and the game in which visitors were invited to find out how salty the sea is was so successful that extra salt had to begged from the kitchens! No doubt there were other, equally successful ocean-related 'set⁷' events. Let's hope that there will be another such week next year, with even more effort put into marine science. *The Editor*

CALLING ALL SCHOOL SCIENCE TEACHERS

The **National Maritime Museum at Greenwich** (London SE10 9NF) produces packs including 'Ships and Seafarers' (for 7- to 11-year-olds) which is available from the Museum Shop at £5.95. It contains material that ties in with Key Stages 1, 2 and 3 in National Curriculum history, science and technology. A free teacher's information pack may be obtained by phoning 081-312-6608.

The **Greenpeace Environmental Trust** produces full-colour fact-sheets on environmental aspects of the sea. 'Seas', for children up to age 12, examines the threats facing the seas and suggests some solutions. Those for older children – up to age 16 – include 'Waste and Pollution' and 'Whales and Dolphins'. Teachers may order multiple copies at £2 per fact-sheet, but enquirers may be lucky enough to obtain single copies free of charge.

Greenpeace also produces reports which, although written for a target audience of journalists, scientists, politicians and industrialists, are also of interest to others concerned with environmental problems in the oceans. Reports of relevance include Death in Small Doses (the effect of organochlorines on aquatic ecosystems); Disappearing Dolphins; The Whale Killers; Slaughter in Paradise (the exploitation of sea turtles in Indonesia); Net losses, Gross Destruction (fisheries in the European Community); It Can't Go On For Ever (the implications of the global grab for declining fish stocks); Dangerous Waters (threats to Britain's dolphins and marine wildlife); So Remorseless a Havoc (the case for a permanent commercial whaling ban); and Clayquot Sound (the impact of logging on the west coast of Canada).

For more information write to the Greenpeace Information Office Canonbury Villas, London N1 2PN.

Much of the enormous variety of educational material produced by the **World Wide Fund for Nature** includes topics which relate to the ocean, but most is mainly concerned with terrestrial environments. However, *Ocean Challenge* (no relation!) is a teacher's book and full-colour wall chart designed to help teachers explore the oceans with 7–13-year olds (Key Stage 2 in the National Curriculum). The pack is full of ideas for activities and projects across a wide range of subjects, including science (navigation, knowledge of globes, maps, stars and compasses; life in the sea; the elements; and the resources of the oceans). Its ISBN is 0-947613-21-8 and it costs £8.95.

WWF also market tapes and scores for a musical 'Ocean World', which follows the hazardous journey of a humpback whale and her calf. For more information contact WWF UK, Publishing Unit, Panda House, Weyside Park, Godalming, Surrey GU7 1XR; Tel. 0483-426444. To purchase WWF material, contact WWF UK, Education Distribution, PO Box 963, Slough, SL2 3RS; Tel. 0753-643104.

MARITIME MATTERS ON MERSEYSIDE

If you feel like a day out with a maritime flavour, then Liverpool is the place to go. The Merseyside Maritime Museum is one of the largest of its type in Europe. It covers seven acres adjacent to Albert Dock, and includes full-size vessels, quay sides and two docks. The displays reflect the international significance of Liverpol as a port, and its development since the 13th century. The museum, which was opened in 1980, is still expanding, and two new galleries – one called '*Titanic* and *Lusitania:* Floating Palaces of the Edwardian Age' and the other on the Battle of the Atlantic – opened in 1993. A gallery about the Atlantic slave trade is due to open in October of this year.

Phase I of 'Anything to declare?', a National Museum of Customs and Excise has recently opened at the Albert Dock site. This first phase illustrates the work of the Customs and Excise today; Phase II, which will look at its history, opens for Easter 1995. For more information, phone Tel. 051-207-0001.

What's more, until January 1995, the Time and Space Gallery of Liverpool Museum (on William Brown Street) will be the site of a touring exhibition entitled 'Monsters of the Deep'. The exhibition features life-sized replicas of whales, sharks and giant squid. Alongside are specimens of extinct sea reptiles and giant crabs. Aquarium tanks contain live sharks (small ones), spider crabs and octopi, so that visitors can see how these small relations of the giants move. The whole exhibition is intended to give the visitor the feeling of being submerged. It is hoped there will be occasional demonstrations illustrating marine life under close-up video cameras, as well as a series of activities related to the display. There are also 'touch' tanks containing specimens that can be handled. For more information, ring Liverpool Museum education staff on 051-207-0001, extn 211 or 296.

EDUCATIONAL DAY AT OI94

This year's Oceanology International Exhibition and Conference, whose theme was 'The Global Ocean', included a free educational day for children. David Bellamy spoke on *Homo aquaticus* (why we all like to be beside the sea-side); Dr Sylvia Earle, past Chief Scientist of NOAA, who has led more than 50 expeditions underwater in connection with her research, talked about working with the Russians on their *Mir* submersible; Kathy Sullivan, astronaut and current Chief Scientist at NOAA, described her views on the 'the blue planet' – the Earth as seen from space; Tom Ruxton, Head of Marine Technology at the University of Plymouth, spoke about Marine Technology and its impact on the environment; and Peter Mumby, Science Coordinator of Coral Cay Conservation described the project's work surveying the barrier reef off the coast of Belize. Don Lennard, Chief Executive of the Marine Technology Directorate (who put the programme together) acted as Master of Ceremonies. There are plans for a similar educational day at OI96.

OCEANS OF WEALTH – THE VIDEO SERIES

'This series started out with two objectives – to be suitable for schools and colleges, and at the same time to appeal to industry. We wanted to excite their respective interests in the vast, unexplored two-thirds of our planet that lies beneath the waves. We realized early on that we would be making dramatic and exciting programmes that deserved as wide an audience as possible, and we were able to arrange for them to be shown on Channel 4 TV.

This video series explores the political, scientific and economic importance of the world's oceans and seabed. The programmes are not mere travelogues, they are serious presentations of how we can locate and exploit the potential mineral, food and energy resources that lie there.

There are six half-hour programmes, supported by an illustrated book and by a set of notes to guide teachers and tutors who wish to use the videos educationally.'

The above is taken from the publicity blurb that accompanied the *Oceans of Wealth* package when it was launched at a rather grand ceremony in the hallowed halls of the Royal Society. It was sponsored by British Gas and forms a part of their Film and Video Library. *This means that it is available for free loan to educational institutions.*

The package may also be purchased through Richard Bacon at Videotel International, Ramillies House, 1/2 Ramillies Street, London W1V 1DF; Tel. 071-439-6301; Fax: 071-437-0731. It is not cheap: the set of six videos on one cassette for £1690, or individual videos for £340 (both plus p&p).

The package deserves further publicity, and the object of this review is to remind Challenger Society members of its existence and potential usefulness; though some effort may be needed to gain the maximum benefit. The series should not be seen as providing instant off-the-shelf education about the oceans.

So far as schools are concerned, the National Curriculum is so full that it could be difficult to find a slot for the package, which covers not only marine science and technology but also the economics and politics of exploitation and management of the oceans. However, the Teachers' Notes provide clear guidance on the relationship of each of the six programmes to one or more Attainment Targets.

But teacher time is important, too. The package cannot simply be presented to the class – there has to be some preparation if optimum results are to be achieved. The videos should be used interactively, which means (at least) stopping the tape at intervals for discussion and/or exercises. This is where the 'Book of the Series' will be useful.

So far as universities are concerned, the series can be helpful in providing an [illegible] component in General Science modules. Potential users in institutions where marine science is taught to degree level, however, need to be aware that the emphasis is on applied oceanography, and specifically on the technology and economics (and politics) of exploiting 'oceans of wealth'.

In fact, all potential users should be warned that there is very little marine science *per se*, little or no mention of ocean circulation or ocean chemistry, of marine geology or ecology. Nor do environmental issues get much of an airing – the emphasis is more on exploiting the oceans than protecting them. However, these seeming deficiencies can be turned to advantage. Scientific and environmental issues can be raised in discussion of the programmes. And in any case, it is nowadays increasingly important for science students to learn how economics and politics both influence, and are influenced by, the acquisition of new knowledge through oceanographic research.

I have seen all the programmes (some more than once) and I found them very interesting; all had something to teach me and I gained new insights into the way individuals and societies perceive the oceans and their resources.

Here is a summary of the contents of each video:

1. The Ocean Commons A semi-dramatized documentary account of the evolution of maritime law, especially from the 17th century onwards, with a good account of the tortuous and protracted Law of the Sea negotiations and conferences in the decades after World War Two. The rate of change of world events in recent years is really brought home when the presenter (Michael Culver) talks about 'countries of the eastern bloc'.

2. The Last Frontier on Earth The first part gives an account of the development of *GLORIA* by IOS and of how the system was used to map the United States continental shelf – a project not unconnected with negotiations over the definition of 'legal continental shelf' at the various Law of the Sea conferences. The second part is a straightforward account of the Ocean Drilling Programme: the drilling technology itself, some glimpses of what oceanographers do with the cores, and insights into the international nature of the project, including a brief history of Britain's contribution.

3. Fruits de Mer Another two-part programme, the first part devoted to fish farming and the use of cryotechnology to improve breeding efficiencies and of brewing technology to enhance the production of algae for feeding farmed fish stocks. This was all interesting new material for me. A shorter and somewhat inconclusive second part looks briefly at Japanese squid fishing in the Southern Ocean and Britain's so far unsuccessful attempts to get a share of this market from the seas round the Falkland Islands.

4. Making Waves and Pipe Dreams This is about energy from the oceans, and begins with a review of research into wave power. It features Stephen Salter, who describes the development of his idea and makes some interesting comments about the political context – it appears that the closer he got to an efficient and cost-effective system, the more obstacles were put in his way by (it would seem) the nuclear lobby. So what's new? The experimental American Ocean Thermal Energy Conversion (OTEC) plant on Hawaii forms the subject of the second part of this programme. The point about OTEC is that although its conversion efficiency is very low (less than 5 per cent), there are all sorts of spin-offs: the condensers produce desalinated water that can be used for drinking and for irrigation; while cold (clean) nutrient-rich water from below the thermocline is ideal for mariculture, especially of shellfish.

5. Salts of the Earth Another funny title, which, in this case, means minerals from the oceans. First, we are shown Japanese research into mapping the distribution of manganese nodules and into the technology of retrieving them on a large scale. This is a fascinating insight into forward thinking, typical of the Japanese: there is so far no international consensus on the vexed question of international rights to deep-sea mining and the role of the International Sea-Bed Authority. This may be partly because markets for the principal metals for which nodules are considered valuable (especially nickel and cobalt) are still relatively plentiful in land-based ore deposits. But the Japanese, having very few metal resources of their own, are preparing for the time when nodule-mining will become a viable proposition. The second part of this programme was a real eye-opener for me. I had no idea that so much progress (if that is the right word) had been made in techniques for exploiting metal-rich muds in the Red Sea deeps. A German–Saudi consortium got a long way with this, having brought in the Warren Spring Laboratory (of blessed memory) to help them with developing sulphide flotation cells for ore separation that would work successfully on a ship, even in rough seas. This project has not gone beyond the pilot stage either, chiefly because of the state of the metal market.

However, I was disappointed that the programme made no effort to address the considerable likelihood of severe environmental disturbance caused by hoovering nodules off the deep sea bed on the one hand, and of discharging huge amounts of waste muds plus flotation chemicals into the surface waters of the Red Sea, on the other.

6. Resources from the Sea This is the least successful programme, and I found it a bit tedious, as it is mostly talking heads (Donald Braben, BP; Dale Krause, UNESCO; George Porter, Imperial College). The discussion was somewhat unfocussed, though it purported to deal with issues raised in the five preceding programmes. Lip service was paid to the idea that the oceans should be sustainably managed, but the thrust of the programme was in essence capitalist and consumer-oriented. Notable quotes include: 'People will always pay for the cheapest form of energy'; 'Oil will last only as long as people are willing to pay for it'; 'Market forces cannot be the only factor – governments must play a role too'; and my favourite: 'Fish is a luxury food'.

The accompanying book of the series (written by Frank and Wendy Barnaby) contains a great deal of additional detail that is not in the videos, including several illustrations. Unfortunately, there is little indication which parts of the book also feature in the programmes. I would also have liked to see suggestions for possible exercises, or at least some questions and answers about concepts and issues related to the programmes.

On the whole, though, this lot is worth getting your hands on if you can do so without laying out too much folding money. The Editors of *Ocean Challenge* have a complete set, which we are prepared to offer on loan to anyone interested in using the series for educational purposes. Just let us know.

John Wright

Oceanography Textbooks

from the
Open University,
Milton Keynes, UK

Each volume in this series is well laid out and copiously illustrated with full colour photographs, graphs and graphics. Questions to help develop arguments and/or understanding can be found in the text and at the end of each chapter, with worked answers provided at the back of each volume. Chapters conclude with a summary to help consolidate understanding before the next chapter is begun.

For students of oceanography, geophysics, marine biology, geochemistry and sedimentology.

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Describes the processes that shape ocean basins, determine the structure and composition of the ocean crust, and control the major features of the continental margins. Further subjects examined are the 'hot springs' of the deep oceans, the main pattern of sediment distribution in ocean basins including the recording of past climatic and sea-level changes, and the role of oceans as an integral part of global chemical cycles.
120pp 100 illus approx 1988
0-08-036365-2 (P*) **(£15.75/US$25.00)**

Seawater Vol. 2
Its Composition, Properties and Behaviour
A concise account of the special properties of water and the role of the oceans in the hydrological cycle. Explains the distribution of temperature and salinity in the oceans, and their combined influence on water density and movements. Behaviour of light and sound are also considered together with the applications of acoustics to oceanography. Further subjects examined include the composition and behaviour of dissolved constituents (minor and major ions, gases and nutrients) together with such topics as residence times and redox relationships.
169pp 1989
0-08-036367-9 (P*) **(£15.75/US$25.00)**
0-08-036368-7 (H) **(£34.00/US$54.00)**

Ocean Circulation Vol. 3
The essential role played by atmospheric processes in the control of both surface and deep currents in the oceans is stressed throughout the volume. All the basic topics and concepts essential to a proper understanding of ocean circulation are covered, including Coriolis force, vorticity, geostrophic currents, continuity, and the exchange of heat and water across the air-sea interface.
240pp 161 illus 1989
0-08-036369-5 (P*) **(£16.75/US$27.00)**

Waves, Tides & Shallow-Water Processes Vol. 4
Describes waves, their measurement and characteristics, their behaviour in shallow water and unusual waves. Considers mainly theoretical aspects of sediment movement and deposition of currents, wave estuaries, and the interaction of waves, tides and river flow in deltas. Concludes with a look at shelf-sea processes and their mineral resources.
187pp 1989
0-08-036371-7 (P*) **(£16.75/US$27.00)**

Ocean Chemistry and Deep Sea Sediments Vol. 5
Shows that chemical elements enter the oceans from a variety of sources and are cycled many times within the body of the oceans by both biological and inorganic processes before ending up in the sediments.
128pp 76 illus 1989
0-08-036373-3 (P*) **(£15.75/US$25.00)**
0-08-036374-1 (H) **(£34.00/US$54.00)**

Case Studies in Oceanography and Marine Affairs Vol. 6
Firstly provides an historical review of the Law of the Sea culminating in the present day situation. The second part is devoted to two case studies, covering the scientific aspects of a particular oceanographic environment, the social, political and legal consequences and implications of human interactions with that environment.
252pp 111 illus 1991
0-08-036375-X (P*) **(£15.75/US$25.00)**
0-08-036376-8 (H) **(£43.00/US$69.00)**

A Companion Volume

Biological Oceanography
An Introduction
C. M. LALLI, and **T.R. PARSONS**, *University of British Columbia, Vancouver, B.C., Canada V6T 1Z4*
Describes the major marine environments and the marine organisms living in pelagic and benthic habitats. Emphasis is placed on biological production and food chains and their geographical variation according to different physical and chemical regimes. The exploitation and conservation of marine resources are considered.
349pp 125 illus September 1993
0-08-041014-6 (P*) **(£22.00/US$34.50)**
0-08-041013-8 (H) **(£59.00/US$95.00)**

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SPREADING THE WORD

School and Popular Marine Science Education in the United Kingdom

Two hundred years ago, Brighton, Scarborough, Weymouth and a number of other places on the coast of Britain were developed as fashionable resorts for the upper social classes to relax and breathe sea air. With the coming of the railways, the accessibility of coastal towns improved greatly for everyone. Visiting the seaside became popular for all, whatever their social class. Breathing sea air and bathing in the sea was considered beneficial for health. Today, the love-affair of the British with the seaside continues; and not only the British flock to the coast at weekends and holiday times. Throughout the developed world, relaxation at the seaside is a popular pastime. For many British people, as for many other Europeans, the trend of the last three decades has been for the family holiday to take the form of a 'package' to the sun and beaches of the Mediterranean.

As long ago as the late 1960s, holidaymakers returned from abroad with stories of polluted beaches, some so polluted that bathing was discouraged or even prohibited. Holidaymakers were not, however, deterred. In ever-growing numbers, they flocked to the Mediterranean for sunshine and instead of bathing in the sea bathed in the hotel pool (which may not, in fact, have been any better for their health than bathing in the sea!). Back home in the the UK, concern mounted over litter, oil and even, in some places, human faeces on beaches.

Education of the General Public

By means of articles in newspapers and magazines, through reports in radio and television news and current-affairs programmes, and by documentaries on television, the media have informed the public and continue to do so, thereby contributing to public concern over the state of coastal waters. Tanker disasters have received much attention, and emotions have been aroused by pictures of polluted beaches and oiled seabirds. The media have not only contributed to the concern over coastal waters but have also responded, by taking to task the appropriate officials of local authorities, government departments, industry and so on.

Not everyone is reached by such radio and television programmes and such newspaper and magazine articles. Though television programmes about the environment are quite popular, many people prefer to watch chat shows, quiz programmes, soap operas and other forms of entertainment. The articles tend to be published in quality newspapers and magazines, and many British people never read such publications, preferring the tabloids. Education of the general public is not easy. Some people may choose to attend evening classes or sign up for other types of courses, but most adults are unwilling to be educated in an obvious fashion. Their education has to be surreptitious. In the UK, television companies generally produce excellent wildlife documentaries and some are superb. Many focus upon marine life and do indeed educate surreptitiously. Most of the documentaries are intended for prime-time viewing and consist for the most part of spectacular, often close-up, pictures of wildlife or natural phenomena. Explanations tend to be kept to a minimum.

When explanations *are* attempted, problems can arise. Programmes all too often contain misconceptions, oversimplifications and other shortcomings. A documentary about global warming shown on television in the UK a few years ago provides a case in point. It included a feature on islands of the western South Pacific Ocean where the sea had risen 40 or 50 cm in a matter of weeks. Waves had washed across the islands and destroyed crops. This was portrayed as a consequence of global warming – a rise of sea level of 40–50 cm in a matter of weeks! Thanks largely to the media and alarmist environmentalists, many members of the general public in the United Kingdom are quite confused over global warming and its effects on sea level; and this programme did not help. The islanders in question had experienced such a sudden rise of sea level before. La Niña had happened in the past. Why had the media not bothered to make sure their story was correct? Who advised them? What were the credentials of the advisers? It was not obvious from the credits at the end of the programme.

To explain the principles and concepts of science to the general public is certainly a challenge. Though it may seem condescending to say so, many people are incapable of grasping even the simplest of scientific concepts, and some who are capable do not trust scientists. They may be quite sceptical, taking the attitude that the human species has survived thus far, so why should we be concerned now? Indeed, they point out, with some justification, that the doomsters who predicted two decades ago that the Mediterranean and other seas would soon be dead have not been proved correct. They accept that problems may arise on a local scale – such as the methyl mercury disaster at Minamata (Japan) – but, overall, they are not convinced there is much to worry about.

Nevertheless, there is, in the UK, considerable unease over the state of the marine environment. Pressure groups often overstate their cases and engage in questionable, sometimes stupid, tactics, but the public are left with the uneasy feeling that something is amiss. Moreover, surveys of beaches by conservation groups sometimes contradict the British government's position on the implementation of European Community Bathing Water Quality Directives and Objectives. Their surveys suggest that many beaches may not be as clean as the government claims.

Marine Science in the National Curriculum of England and Wales

As a group, the youth of Britain are greatly concerned over the state of the marine environment. It is, for example, common to see on the T-shirts of young people slogans such as 'Save the Whales' or 'Save the Planet'. Sadly, however, marine science is much neglected in British schools, and though youngsters are concerned over the state of the marine environment, they generally do not receive adequate scientific explanations of why they should be concerned. For many youngsters, the concern does not progress beyond the superficial emotional level. They do not gain even a basic understanding of the underlying scientific principles.

In 1989, a National Curriculum was launched in England and Wales (but not Scotland or Northern Ireland). Surprisingly, for an island nation so dependent on the sea, the science curriculum contains no marine science, though it does contain meteorology and geology. By law, children must study these subjects in both the science curriculum and the geography curriculum, right through from age 5 to age 16.* The reason for there being meteorology and geology but no marine science in the National Curriculum is partly that the Challenger Society was not consulted when the National Curriculum was designed in the mid-1980s, whereas the Royal Meteorological Society and the Geological Society were.

A review of the National Curriculum took place in 1993, but at the time of writing the outcome is not known. The Challenger Society has made a plea for marine science to be included and hopes for a positive response from the Curriculum Council. However, the signs are not promising. Many teachers would like the size of the National Curriculum reduced, and Earth science is one of the components that is threatened (see, for example, Holman 1993). Governments are often blamed for problems in education, and certainly some of the problems with the British educational system do stem from government policy, but reduction of the Earth science component of the National Curriculum is, in fact, being urged by physics, chemistry and biology teachers, who want to share the science curriculum on the basis of one-third each.

Oceanography does appear in the geography curriculum, but the amount is small. At the age of 7 or 8, for example, children have to learn the names of the major oceans and know where on the globe these oceans are. Later, the effects of oceans on climate must be studied, and so, too, must the climatic importance of carbon dioxide and other greenhouse gases, with particular reference to global warming and changes of sea level. The seas as sumps for river-borne pollution must also be considered, along with the need to manage the seas. All in all, however, there is not a lot of science in the geography curriculum.

What scope is there for introducing children to fundamentals of marine science through the present science curriculum? In the part of the curriculum called 'Life and living processes', various aspects of biology can be taught in the context of marine life. Photosynthesis, for example, can be considered with reference to life in the sea, leading pupils to the important realization that the harvest of the sea is finite and not nearly as large as claimed by those who would have us believe that we have only to turn to the seas to feed the starving of the world. In addition, pupils might consider how fish and mammals can ascend and descend rapidly in the sea and withstand the huge pressures that occur deep down, whereas humans cannot. In the section of the curriculum called 'Materials and their properties', the salts in the sea can be studied in relation to dissociation, corrosion and electrical conductivity. Moreover, icebergs can be considered in the context of Archimedes Principle; and the load-line regulations for ships can be related to the density of seawater. In the part of the curriculum called 'Physical processes', ways and means of extracting energy from the sea can be investigated, as, too, can the physical and chemical processes that create bioluminescence. Furthermore, the study of optics can be made more interesting by a study of the colour of the sea. Why blue, or maybe turquoise, or maybe some other colour?

* Implementation of the National Curriculum is mandatory only in schools which enjoy government or local education authority support. For schools that are independent of the state and local authority sector, there is no obligation to follow the National Curriculum, though most of these schools do, in fact, follow it.

The aim must always be to consolidate principles that are in the science curriculum and therefore have to be taught. At the same time, children must be made to think. The development of an enquiring mind is an important objective in education.

The potential for teaching facets of marine science in secondary schools (age range 11 to 16) is considerable. In biology, chemistry, Earth science, physics, mathematics, geography and history, marine topics can be included. They can be taught in the classroom, laboratory or field, and much can be achieved without sophisticated or expensive equipment. Consistent with the objectives of the National Curriculum, there is in British schools a growing emphasis on combined science. Accordingly, there is scope to exploit the interdisciplinary nature of marine science. It follows, however, that teachers must be interested in the sea, imaginative enough to teach in the context of the sea and able to cross discipline boundaries. Herein lies a problem, for very few teachers meet all of these requirements.

The Rôle of the Challenger Society in Marine Science Education

What are the Challenger Society and other organizations doing to promote marine science in schools? In the UK, responsibility for the formal education and training of professional marine scientists rests with employers and universities. Accordingly, the educational activities of the Challenger Society are concerned largely with the promotion of school and popular marine science education. Nevertheless, the Society accepts that ways and means of increasing marine inputs to college and university courses that are not specifically oceanographic or marine-oriented should also be sought. The Society's need to increase its involvement in education was recognised by its Council in late 1991 with approval of the proposal that an Education Committee be formed. Though it had collaborated with a number of other bodies to produce a careers pack, *Oceans of Opportunity*, which first appeared in 1990, the Society had not previously involved itself in school and popular marine science education to any great extent. It had, however, encouraged the participation of undergraduate and research students in conferences and other scientific meetings (providing financial support or reduced registration fees whenever possible).

Opening the first meeting of the Education Committee, held in March 1992, the chairman (the present author) stated that the terms of reference of the committee were, broadly, to further the aims of the Challenger Society through education. He mentioned the growing concern over the inadequacy of science education world-wide, pointing out that oceanography has a rôle in helping to improve science education as a whole. The committee agreed that its endeavours should be complementary to those of bodies such as the British Association for the Advancement of Science and the Royal Society of London which are both committed to raising levels of science education in schools and increasing public understanding of science. These bodies were both represented at the meeting. The chairman also stressed the need to cooperate and collaborate with organizations with related interests, to avoid unnecessary duplication of effort and to maximize effectiveness. In the the UK, the foremost organizations in this respect were the Deacon Laboratory of the Institute of Oceanographic Sciences and the Society for Underwater Technology, both of which already promoted marine science (and technology) in schools. These two organizations were also represented at the meeting. At its second meeting, held in June 1992, the Education Committee was strengthened by the appointment of a representative of the

Geographical Association, the person concerned being the chairman of the Association's Geography / Science in Schools Working Party. In early 1993, the committee was further strengthened by the appointment of a representative of the Association for Science Education.

Marine Science Education in Primary Schools

Among the various bodies involved in environmental education, there is a considerable emphasis on the education of children aged 7 to 11 years. When in this age group, children are passing through their most formative years. Moreover, they are not yet involved in preparations for General Certificate of Secondary Education and other public examinations sat by children aged 15–16, with all the demands, limitations and traumas that these entail. The opportunity to mould sensible attitudes to the natural environment should not be missed. Children's studies of the sea can (and should) be incorporated, to a considerable extent, in broad programmes of environmental education.

It is widely accepted that the emphasis when teaching young children should be upon exciting curiosity about the sea, developing an enquiring mind and generating a sense of wonder at the behaviour of the sea and life in the sea. Children are naturally inquisitive. This should be exploited. Children should be encouraged to ask questions. They also like to be active and to make things; they can easily make simple equipment in the classroom and use it out-of-doors. For young children, scientific rigour is not especially important. Arousing interest certainly is. In any case, a competent teacher will, as a matter of course, point out shortcomings of simple equipment.

Herein lies a problem: school teachers at the primary level (teaching ages 5–11) tend to know rather little about the sea. Thus, there is a need for book lists, information sheets, posters, booklets and explanatory leaflets, particularly for project work (a popular means of teaching/learning in primary schools). The language used in such material must be simple and free from jargon. Furthermore, the material must be prepared by persons who are scientifically qualified to do so, with the assistance of teachers who are familiar with children's capabilities. At all levels in education it is important that educational materials not only meet the needs of intended users but also do not contain misconceptions or outmoded ideas.

Young children should be encouraged to explore the seashore and rock pools, but they must be made aware of the dangers of the sea. They should count, collect, observe, investigate and, to a limited extent, classify. For many purposes, they should work in groups. They should think about what they are doing and, when back at school, prepare displays (posters, collections of shells, etc.). To aid their literary development, they should write about their field excursions.

It is, of course, a limitation of marine science field work that, in the normal course of events, it can be carried out only by children who live close enough to the sea. Wherever the classroom, however, certain basic scientific concepts can be studied. Water density, buoyancy, floating and sinking, for example, can be considered in an interesting way with reference to corks, ships and submarines. Furthermore, simple ideas on water waves and the motions of water particles in waves can easily be illustrated in the classroom of a primary school.

In collaboration with staff of the South Glamorgan Seawatch Centre and with the assistance of staff and students of the Department of Maritime Studies in the University of Wales College of Cardiff, a colleague of the author, Dr Chris Wooldridge, has taken hundreds of children and adult members of the general public on educational cruises on the Bristol Channel (off South Wales). These cruises, which have formed part of the Welsh Heritage Cruise Programme, have focussed on life in the sea, marine phenomena and coastal geomorphology. Dr Wooldridge is also involved in the establishment of sea-life centres, a means of marine education which has only recently come to the fore in the UK.

The Deacon Laboratory of the Institute of Oceanographic Sciences has for several years offered an educational outreach programme through which a considerable number of children from primary and secondary schools have been introduced to oceanography (see, for example, the article by Penny Hollow cited under Further Reading). Unfortunately, however, the programme has lately had to be curtailed somewhat, for financial reasons. This is a pity. It is surely necessary for marine science institutions to engage in educational outreach and possibly shortsighted of them not to do so.

Conclusion

Why does marine science education matter? Much of the answer should be obvious from what has already been said, but the point about the inadequacy of science (and mathematics) education world-wide should be restated and stressed. Oceanography has a rôle in helping to improve science education as a whole. Through it, children may be attracted to science as a career, the aim being that oceanography should attract the best science graduates. Of course, it is not possible for all who become interested in marine science to become professional oceanographers, but that is not particularly important. What is important is that the general public and decision-makers of tomorrow are better informed about the sea than those of today. The primary-school children of today are the scientists and decision-makers of tomorrow. They need to know why the seas are important and how they behave.

To advance marine science education, resources are required. Herein lies another problem: money, time and goodwill are limiting factors for learned societies and, to some extent, professional bodies. For example, the Challenger Society possesses resources in the form of people with enthusiasm and expertise. It is not a commercial body and it cannot underwrite expensive projects. Therefore, links with commercial and other organizations must be forged. Those who hold the purse strings have to be convinced that marine science education is important. Arguments must be cogent. There is today a great deal of competition for financial support. The co-operation of oceanographic institutions is also needed. Among their employees, there are many with the enthusiasm and expertise needed to promote school and popular marine science education effectively, and it is surely in the interests of these institutions that resources be allocated for such education.

To promote school and popular marine science education effectively, a good deal of missionary zeal is required, with the onus on the Challenger Society and other organizations to show teachers and educationists what they are missing by neglecting the sea. Furtherance of marine science education is certainly a challenge! If, at the very least, the holidaymakers of the future can enjoy their visits to the seaside and bathe safely in the sea, the effort will have proved worthwhile.

Further Reading

Penny Hollow, 'Young scientists for the future: education links at the Institute of Oceanographic Sciences', *Ocean Challenge*, **2**, Winter 1991, 22–4.

John Holman, 'Give us a break, Sir Ron', *New Scientist*, 25 September 1993, **139** (1892):53–4.

Malcolm Walker
University of Wales, College of Cardiff

Malcolm Walker has chaired the Challenger Society Education Committee since 1991. At present, the members of the committee are: Stephan Hall, James Rennell Centre; Richard Hatton, The Downs School, Wraxall, Bristol (representing the Association for Science Education); Ed Hill, University of Wales, Bangor; Penny Hollow, IOS Deacon Laboratory; John Phillips, The Open University; Geoff Potts, The Marine Biological Association; Barbara Smail, The British Association Youth Section (BAYS); Roger Trend, University of Exeter (representing the Geographical Association); Simon Wakefield, University of Wales, Cardiff; David Wardle, Society for Underwater Technology; Chris Wooldridge, University of Wales, Cardiff; and Martin Preston, University of Liverpool, who will become chairman of the Education Committee in May 1994.

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If you would like to know more about tutoring oceanography for the OU, write to The S330 Course Team, Department of Earth Sciences, The Open University, Milton Keynes, Bucks, MK7 6AA.

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I just hope vorticity doesn't come up ....

(or how to tutor Oceanography for the Open University and stay sane)

"That was quick – you must be desperate!" Leeds 1977. It was with those words that a colleague greeted me two minutes after Harry Elderfield had passed on the news that the Yorkshire Region of the OU was looking for someone to tutor its new Oceanography course. As a post grad, any way of making more cash was worth investigating (times haven't changed) and this one looked promising. For a start, I quite enjoyed the demonstrating I was doing (even the reflected light microscopy!) and secondly, and more importantly, I might learn some oceanography in the process. As an Earth Scientist entering the marine field in research, some oceanographic knowledge was going to be necessary and this looked like an ideal way of self study. 17 years later I'm very pleased that I signed on.

You may think that the main providers of oceanographic education in the UK are, say, the departments in Southampton and UCNW Bangor, plus possibly Liverpool, UEA and other places such as Edinburgh and Cardiff where there are strong marine research interests and hence undergraduate modules. You would be wrong. The main single provider of oceanographic education in the UK is the Open University which, through a third-level course in Oceanography and with the help of 20–30 tutors reaches ~ 500 students a year.

Ah, I hear you say, that doesn't count, it's different. And you'd be right, it is different – it's harder, not easier; more multidisciplinary, less focussed; more theory, no practical, and students who are ... well, different. Older, wiser, keener and more naive – all these things and more. The challenge – to harness this enthusiasm and convince them that vorticity is important but not *that* important, so not to fret if it's passed you by.

You will no doubt have all seen the excellent books that form the basis of the course. These are designed to be a teach-yourself system with in-text questions and excellent diagrams. Indeed, increasingly at meetings slides from them are being shown by professional marine scientists. This is no Mickey Mouse course, this is for real. Nothing in too much detail but most concepts covered somewhere. The problem for the tutor (and for the student) is the breadth of material. I'm glad I've never had to answer a 40-minute exam question on the 238 pages that make up *Ocean Circulation*!

So what questions *do* I have to answer? Well the first thing to realise is that some of the students are very bright indeed and hence do come up with some perceptive queries. Others are just interested, and for most of them mathematics is a concept way beyond their comprehension (hence the problems with vorticity). Some think oceanography is what Jacques Cousteau does and some think it's all about oil spills and seals.

Some are practising scientists or seafarers in their own right whose background knowledge and experience provides a firm base upon which to build with more specialists bricks. Some find chemical equations baffling, while others I'm sure just ignore them and hope they'll go away. (They don't of course – just like the problem of discussing alkalinity!)

Most of the takers are not just doing 'mental press-ups' but are keen to pass the examination as well as possible. Hence a common question is often "What do we *need* to know?" And the learning process can undoubtedly be lightened by anecdotes of the trials and tribulations associated with oceanographic research. A series of face-to-face tutorials (South Wales has 14 hours per year) are the main means of contact and help. The telephone call is secondary. The computer at the OU does half the marking while we tutors do the rest. Four assignments a year to be commented upon and graded according to a set of guidelines and a mark scheme devised by the course team. Increasingly the questions are set around recent oceanographic articles from *Nature* – up-to-date and relevant. Though quite how easy it is to concentrate on hydrothermal venting when the kids want their tea and you can't remember whether magnesium is Mg or Mn I'm none too sure.

Certainly most people seem to enjoy the course. We professionals sometimes forget just how exciting the oceans can be to people encountering them for the first time. Why is the sea salty? What does drive the tides? You mean the ocean floor isn't flat? But how do you get oxygen at the bottom of the sea? These nodule things look strange! So there's life in the deep sea as well? But someone must control the Aegean. And anyway whose responsibility is it if a Liberian registered ship with a Greek captain carrying Iranian oil bought by BP to be sold to Shell in Rotterdam goes aground on the Spanish coast? And what *is* vorticity...?

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The *Jason* Experience

The Jason Project is an American educational initiative set up to change attitudes about science and motiviate students to enter careers in science and technology. The venture is highly relevant to Britain, where there continues to be concern about science education. The project is the brainchild of Dr Robert (Bob) Ballard, first seen on these shores way back in 1978, when he told TV audiences about *Alvin* and the FAMOUS project, but much better known for discovering the wrecks of RMS *Titanic* and the battleship *Bismark*.

At the core of the Jason project are Telepresence Workshops which, by means of a specially designed satellite system, enable studio audiences and individual scientists in numerous colleges and universities on both sides of the Atlantic to participate directly in oceanographic research that is actually in progress at remote field locations.

The key element in the project is that students are able to interact with the new technolgy and to participate in real science. The centrepiece of the technology is *Jason*, the versatile robot submarine with underwater eyes and ears and a control system which almost rivals that of a fish in precision and manoeuvrability.

In the first year of the programme, hydrothermal vents were found and ancient shipwrecks examined in the Mediterranean. In the second year, the locale was Lake Ontario, where sunken warships from the War of 1812 were surveyed. In the third year, the scientists went to the Galápagos, looking at sites on land as well as underwater. The project is continually developing new technology that can be applied by participating scientists and students, thus helping to advance both scientific research and distance learning. Thus, in the first year it was possible only to question the scientists about what they saw, using a two-way audio link; while in year four (1993) there were trans-continental and trans-Atlantic satellite links, enabling scientists as well as students to manipulate – and even actually 'fly'– *Jason* from thousands of miles away, to collect data for their researches.

The 1993 Jason Project centred on the Sea of Cortez, about halfway along the Gulf of California, where two scientific programmes were in progress: a physiological and behavioural study of grey whales, and a survey and sampling programe at a hydrothermal vent field in the Guaymas Basin, using both remotely controlled and manned submersibles. The Guaymas Basin is unique among vent systems so far studied, in being in a rift valley setting, where sedimentation rates (c. 1 mm yr^{-1}) are an order of magnitude greater than at mid-ocean ridges. In consequence, the sediments are both thick and organic-rich, and the lavas form sills instead of reaching the surface as flows, because the density contrast between soft sediment and lava is little more than that between water and lava. The organic matter in the sediments is heated by these sill intrusions and rapidly matures to hydrocarbons, on time-scales of years to decades rather than of millenia, as is the case in most conventional petroleum fields.

The 1994 Jason Expedition visited Belize in Central America, in late February and early March. The theme was 'Planet Earth' and the objectives were to study the health of the Earth and the effect of people on the environment. Only one of the live-broadcast sites was marine: this was South Water Caye, where participants investigated the ecosystem around mangrove roots, and studied a coral reef using a remotely operated underwater vehicle. One of the aims of the reef study was to identify areas of bleaching that indicate that the coral is being damaged.

The wonder of the Jason Project is that scientists can participate in the research from their own laboratories in real time. We were lucky enough to attend one of the sessions at the Liverpool Maritime Museum in 1993 (when Liverpool was the only UK centre participating) and during that session, for example, *Jason* was conducting a CTD survey in a precisely controlled grid pattern above a hydrothermal plume, to find out about mechanisms of entrainment and mixing of ambient seawater with rising vent solutions. The data were being transmitted direct to a laboratory in Rhode Island University for processing, as the survey was actually in progress; and the scientists in the laboratory could see and talk to those on the mother ship (the *Laney Chouest*) via the satellite link-up. Scientists in other laboratories were asking for samples of fauna and bacteria to be collected from locations which *they* could specify precisely as they watched on their own cinema-sized screens the progress of *Jason*'s sampling gear moving over the sea-bed.

It may be hard to understand if you haven't actually experienced it, but seeing some new and amazing phenomenon 'as it happens' is completely different from seeing the same thing in a scientific documentary. You feel *as if you are there* – the inelegant term 'telepresence' really is the right one! The thing that really bowled *us* over was a vent chimney that had grown flanges so that it resembled a pagoda; the 'roof' of the pagoda was trapping rising hydrothermal vent fluids which formed upside-down reflecting pools of water at about 300 °C. At the time, not a lot of people knew about these upside-down pools, and fewer still had actually seen them!

The satellite technology and electronic wizardry involved in getting these 'telepresence' shows to work was breathtaking, while the administrative logistics of ensuring that all the people concerned appeared live 'on cue' at locations thousands of miles apart was truly mind-boggling. And Bob Ballard and his team, who pursue their own research interests in between the 'shows' (which must be exhausting), generate enormous enthusiasm.

The educational potential is clearly immense, which is why the studio link-ups are so important. Students of all ages, as well as the researchers present, could put questions directly to the people on the mother ship, who were able to manoeuvre *Jason* to display some particular feature of the vent system or its fauna, to help explain their answers. In addition, graphics and diagrams, still photographs and film clips, could be called up at any time to illustrate vent structure and processes. Although it did not come to pass that a Liverpool school pupil actually got a chance to 'fly' *Jason*, we did watch a ten-year old girl doing just that by remote control from the headquarters of the Project.

As well as teaching young people about the science itself, the project also invites them to explore carreer opportunities in marine-related fields, which need not be confined to science and technology. For example, legal, financial, commercial, personnel, communications, and many other activities must be combined when setting up a project such as this.

Several members of the crew aboard the *Laney Chouest* were directly interviewed from thousands of miles away, about how they got involved in this work and what qualifications they would advise young people to aim for, should they wish to embark on a smilar career.

It could be argued that Jason is of limited importance because it can reach only a relatively small audience. But this year there were 30 downlink sites in the US, Canada and the UK, the UK sites being at Liverpool, Nottingham, Southampton and Brackley, Northamptonshire; there were 60 shows (five a day, Monday to Saturday, for two weeks) during which thousands of participants on both sides of the Atlantic interacted and exchanged data and ideas in real time, with each other and with scientists at the expedition sites in Belize. For the children and adults who attend such live 'shows' the experience is unforgettable.

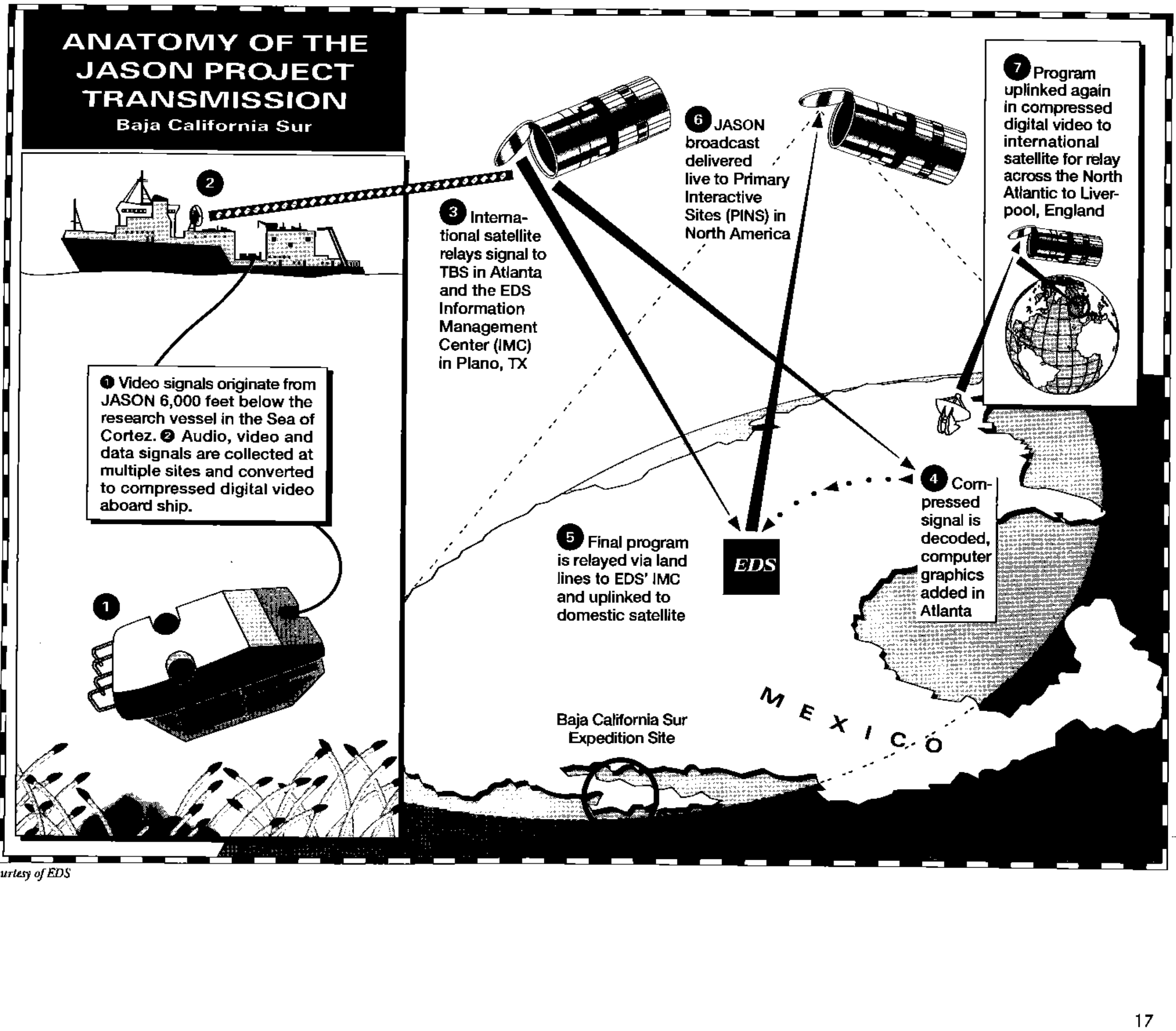
Another great feature of the Jason Project is the Student Argonaut scheme, which selects each year a number of school-age students for their all-round abilities and special interest in science, to work alongside Dr Ballard and his research team. They are chosen through a competition run by the JASON Foundation for Education in the United States. The two UK children who have been working alongside scientists in Belize this year are both girls, one from Liverpool and one from Glasgow.

Over the next three years the Jason Project in the UK will be benefiting from £600 000 donated by Barclay's Life. The funds will be used to support Jason's UK project managers, and to help schools taking part in Jason voyages and distance-learning programmes. There are rumours that the next telepresence location will be somewhere in space, but let's hope that Bob Ballard and his team will return to the ocean before too long.

Teaching Pack: Each Jason Project is accompanied by a Jason Curriculum Pack, compiled by the California Natural Science Teachers Association. This is a weighty compendium of exercises, activities and projects for science students to try out, and the good news is that it is annotated for use with the UK National Curriculum.

The pack can be obtained for the modest sum of £10 from the Jason Project Coordinator, National Museums and Galleries on Merseyside, 127 Dale Street, Liverpool, L69 3LA; Tel. 051-207-0001, extn 622.

How a Jason 'Telepresence' session works – the example shown is the link with the Guaymas Basin during the 1993 Jason Project



Courtesy of EDS

SEA BOFFIN IN MEDIA SCAM

Many of us will have received that call from the Departmental Secretary saying "I've got someone on the phone from the radio/TV/newspaper ...". How do you react? Are you a 'hide-under-the-desk' type or an enthusiast for the media? Perhaps like me you have a whole range of responses involving enthusiasm in principle and little short of terror in practice. Recently, I have been through a kind of therapy for this mental confusion. It's called a British Association Media Fellowship, and I would like to tell you a little about what I learnt and some ideas it has given me for the development of the Challenger Society.

The British Association (for the Advancement of Science) scheme aims to introduce working scientists to the media and in the process make the scientists better communicators. This is done by putting scientists to work as science journalists for four to eight weeks. I had not really thought about science journalism in detail before the Fellowship, though my gut feelings were probably the usual clichés about shallow treatment and sensationalism. At the end of my eight weeks working in the BBC World Service Science Unit, I am a total convert, enthusing like a born-again zealot. I developed a deep respect for the breadth of knowledge and professionalism of all the science journalists I met. I've talked to other media fellows, past and present, and all are equally impressed by the science journalists they encountered in domestic radio and TV, and the broadsheet papers. (The tabloid press in general doesn't have science specialists which is unfortunate since they have the biggest readership.)

The journalists do a remarkably good job of reporting science and producing interesting programmes or articles. Making *interesting* programmes or articles is one of the key issues here. We scientists are trained to give worthy talks that perhaps are also dull, full of grinding detail to impress and convince our peers. This style does not make for exciting communication with the general public. Making our own work interesting to a general audience need not involve simplification, but it does require distilling things down to their essence in a jargon-free way, as well as explaining the broader context.

A commonly heard view is that scientists are unwilling or unable to communicate to general audiences. During my time at the BBC every scientist I contacted was very helpful and positive about talking to me. Scientists may not always be very effective communicators, but I found nobody who was not willing to try. A frequent charge against science journalism is that it focusses on extreme opinions – 'breakthroughs' and quirky stories – while not coping well with the real uncertainties of science. This charge has some validity but it is a consequence of the need to interest and entertain. I soon learnt that it is vital for a piece to have a strong and simple story if it is to hold the attention of the reader or listener. The science journalists themselves understand the nature of scientific progress – indeed many were working scientists at one time – and they can help any scientist to convey their story if he or she can come to trust them.

As oceanographers, we have a built-in advantage in explaining our work – the oceans are an interesting and exciting place, both to us and to more general audiences. However, it does seem to me that perhaps oceanographers do not get their fair share of coverage, although of course that could just be my blind prejudice. Certainly medical matters get a much higher profile, and when I stopped trying to sell the Editor stories on ozone holes or hydrogen bonds and moved to gene therapy cures for haemophilic dogs, my stories were greeted with more enthusiasm. Clearly there is a greater public interest in medicine because we all have visions of our own mortality. But there must be more to it than that, because some areas such as molecular genetics and astronomy do get a surprisingly high media profile. I have been musing on why this is.

In this context, it's instructive to consider where the science journalists get their stories. Some come from personal contacts, some from press releases by universities, research councils or industry, some from specialist journals and some from science meetings. The meetings that attract journalists are not necessarily those that attract scientists. The British Association annual meeting is a media circus with most of the country's science journalists in attendance all week. The science is not all new in the sense that it is fresh from the laboratory, but the journalists are attracted by eminent figures (often invited specifically for their communication skills), very diverse science and first-class facilities to work in. There may be lessons to be learnt here, since there is positive feedback in the cycle: once a meeting gets a good reputation with journalists, coverage increases and more journalists attend.

However, the dominant source of material for science journalists is a small group of wide-ranging and very high profile journals: *New England Journal of Medicine, The Lancet, British Medical Journal, Nature, Science* and *New Scientist*. In the oceanographic context only the last three matter. Any bias in science coverage may reflect selectivity in these journals. But here again there are feedbacks. Many of us know from personal experience that *Nature* often rejects papers as 'not of general interest' and do not even send them out to review. The definition of general interest is, of course, related to what is reported in the media.

Once a journalist finds a story that they are interested in they must persuade their Editor that it is worth following up. If the story survives this hurdle the next step is to get an interview to provide variety and authority for the piece. All of this may have to be done in the space of a day, or less, with the added complication of time-differences for overseas contacts. The completed item then goes back to the Editor where it may still get scrapped or drastically edited to fit with the pressures from other stories at that time. In a newspaper, headlines are added at a late stage by sub-editors; the journalist has no control over this. Journalism is no place for fragile egos, as I quickly discovered.

None of the above is intended as a criticism of the media, for whom I developed an enormous respect and liking, nor indeed of editorial policy in the key journals. These observations are simply my assessment of the way the system operates. Oceanography does not do badly; we get some coverage, probably in reasonable proportion to our numbers in the scientific community. Our public image is quite good, particularly in comparison to the ambivalent public attitude to fields like genetic engineering. Many oceanographers are already very effectively spreading news of our science through the media. It is unfortunate that their reward for this effort is sometimes a feeling that it undermines their scientific credibility.

There are many complex factors determining the public and media interest in different aspects of science, but the attitude to the media of scientists in a particular discipline is certainly a factor. I believe British/European oceanographers can choose to raise their public profile, and the increasing public interest in environmental issues should help this process.

There seem to be a number of reasons why we might want to seek a higher profile. There is obviously some personal satisfaction in dealing with the media – the 'hello mum' syndrome. At a much more important level we are funded from the public purse and have a duty to explain what we do, and why, to a public who, surveys suggest, are genuinely interested in science. In addition, by dealing positively with the media we can try to ensure that they get the story right. If they are covering a story they will find somebody to give them a quote, so if you are the expert then it's better it comes from you than 'rent a quote'.

Finally, recruitment of students to science in general and oceanography in particular depends on firing the imagination of the next generation. This interest is surely influenced by what the young hear, see and read; we need to be communicating our science to students appropriately. It's no use hoping that A-level students will read *Deep-Sea Research*: we are better off re-writing a simplified version for the popular media.

There are obviously things we can do as individuals if we are approached by the media; perhaps we can even approach the media ourselves. There may also be things we can do as the Challenger Society. *Ocean Challenge* is a great start and the promotion of this vehicle to as wide an audience as possible is vital. Perhaps we should also consider other steps. A Press Officer, even part-time, is expensive, but could act to feed oceanography stories from the more specialist journals to the media, and could promote our conferences. University and research council press officers already do this to some extent, but a Society-based initiative might pay dividends. The media have space and time to fill, and the upper levels of the BBC say they want to produce more science programmes. The journalists need stories from as many sources as possible, so are keen to listen. A press officer and our own increased commitment would obviously cost all of us time and money. The payback may be indirect perhaps, via more students wanting to do oceanography. It should also mean more money. While at the BBC, I sat in at a press conference given by William Waldegrave and listened to him talk of the government increasing the number of university science students (albeit at below the poverty level) and increasing support for science. Initially, I was unconvinced. Graduate unemployment is high, and I spend my professional life scraping together money to keep research students and post-docs going in poorly-paid and very insecure jobs. But then I thought that it's not entirely Mr Waldegrave's fault. As the Minister for Science he has to sit in Cabinet and argue for more funds for science, in competition with hospitals, roads and nuclear submarines. Unless there is a public consensus in favour of science he cannot win the argument. Regardless of political persuasion, we ignore public and political support for our science at our peril, and our main vehicle to communicate with the public is the media. We cannot leave this task to somebody else. We all need to take responsibility.

There are a number of books which discuss the relationship between science and the media. *Selling Science* by Dorothy Nelkin (Freeman, £11.95) is a philosophical and sociological investigation which can be a thought-provoking read. *Hitting the Headlines* by Stephen White, Peter Evans, Chris Mihill and Maryon Tysoe (BPS Books / British Psychological Society, £6.99) is a much more practical guide. It is written by practising science journalists and is both entertaining and instructive, with separate chapters on newspapers, magazines, radio and TV, press releases and interviews (the contents are essentially the same as the briefings given to the Media Fellows). I would strongly recommend this book to any scientist who wants to get involved in communicating their subject through the media. The BPS are to be congratulated on getting the book published and for keeping the price to such a reasonable level.

I cannot leave the subject without a few votes of thanks to UEA for releasing me so that I could take up the Media Fellowship, to Phil Williamson and Tim O'Riordan for help with this article, to my research group for tolerating my absence on this adventure, to the BA for awarding me the Fellowship and to the other Media Fellows for their good company. John Wilson and the rest of the BBC World Service Science Unit welcomed me and tolerated my ignorance and ineptitude; I will always be grateful for their kindness and friendship.

If anybody is interested in further information on the Media Fellowship scheme they should contact Sue Lowell at the British Association, Fortress House, 23 Savile Row, London W1X 1AB.

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SHOULD WE TEACH *ABOUT* SCIENCE?

Wherever two or three are gathered together in the name of Science Education, there seems to be a consensus that there are not enough entrants to science and technology/engineering courses at universities. In the correspondence columns of the 19 November 1993 issue of *Nature* (p.199) Sir Hermann Bondi pointed out that there cannot be a real shortage of scientists and engineers, for if there were, then industry would pay scarcity salaries.

Bondi went on to say that the real shortage is of people in responsible positions who know something about science – people like administrators, bankers, managers, and (especially) politicians; and that this is chiefly because most science teaching is geared to producing professional scientists (and engineers) using 'overloaded and overspecialized syllabuses'. He favours teaching science and technology 'attractively and educationally', paying more attention to communication skills and teamwork, and thus increasing the proportion of scientifically literate people in the population as a whole.

I found Bondi's views echoed independently in an article by Nicholas Booth in an *Education Guardian* earlier this year (9 January) – though his remedy may seem a touch prescriptive for already overloaded lecturers. He would like to see the less numerate, those unlikely to follow a career in science or engineering, to be nonetheless given some insight into the history of science, paradigm shifts, nature of hypotheses and so on – in short, some basic scientific understanding. As he says: 'Not everyone can be expected to work out Newton's Laws of Motion from first principles, but everyone should be aware of why they are important. Science teaching ... should reflect that, but it seldom does.'

What do readers of *OC* think?

John Wright

NVQs and SVQs:

what are vocational qualifications all about?

A new system of national vocational qualifications – NVQs or, in Scotland, SVQs – is now firmly established in the United Kingdom, and is getting better known also among our fellow member states in the European Community. These new qualifications are aimed at people in work and enable more people to gain qualifications that are relevant to the work they are currently doing and that meet nationally specified occupational standards. But what are these qualifications? Why did they come into existence? And are they relevant to people engaged in oceanographic and other scientific work?

In the past, there has been a confusing array of work-related qualifications which did not easily provide for individual progression between occupational, academic and professional programmes. A coherent national framework of qualifications, ranging from the basic competences required in some job situations, to those requiring professional competences, now cuts through this confusion and lack of comparability. NVQs and SVQs are now available in occupational areas as diverse as offshore production, conservation management, forensic science, gamekeeping, and occupational health and safety.

NVQs and SVQs are also making a useful contribution to the debate on the recognition of qualifications in the European Community, and the exchange of ideas on education and training. The EuroQualifications Programme involves twelve partners from eleven Member States (Germany has observer status only at present, and Belgium has two representatives). The aim is to move towards greater mobility through training programmes, exchanges and, eventually, the recognition of qualifications.

The distinguishing feature of the UK's qualifications, which is, so far, unique, is that they are defined in terms of a specific form of outcome: the demonstration of vocational competence against specified standards. Qualifications are usually achieved in the work setting by an individual being recognized as competent in carrying out specific tasks Competence is judged to nationally agreed standards which are set by one of the 120+ Industry Lead Bodies. These Bodies are made up of representatives of employers, employees, trainers, and awarding bodies for each occupational area. The qualifications are accredited by the National Council for Vocational Qualifications (NCVQ) in England, Wales and Northern Ireland, and by the Scottish Vocational Education Council (SCOTVEC) in Scotland, which also acts as the awarding body for all Scottish vocational qualifications.

It is now realized that Britain's working population is far behind its competitors in training and occupational qualifications. In 1986, a Government White Paper identified training as a key element in improving Britain's competitiveness *vis-à-vis* her industrial competitors, particularly Japan, Germany and the USA. The Government recognized that if the UK were to be part of this highly competitive market, opportunities were needed to develop the highest levels of education and skills and make life-long education and training a top priority. The Government's determination to give priority to its policy of reform was reinforced in May 1992 at the conference 'World Class Britain' through the launch of the mission statement: 'To provide the world's most effective national framework of vocational qualifications'.

The Government has set a number of National Education and Training Targets and has urged employers as well as providers of education and training to do their part in achieving them. Key among these targets are:

- by 1996, 50 % of the work force is to be aiming for NVQs or SVQs, or units towards them; and
- by 2000, 50 % of the work force is to be qualified to at least NVQ level 3 (or equivalent).

N/SVQs are based on nationally recognized standards. They are qualifications about work, based on measurable standards of performance determined through extensive consultation. For the first time, these set out what is expected of people in work at different levels of competence. The outcomes of education and training are expressed in terms of what individuals can do and to what standard.

The standards describe what people need to be able to do in the work environment to be considered 'competent'. They reflect not only the routine and technical aspects, but also the way in which work is managed, the interpersonal relationships, and the values the organization wishes to be expressed in action (equal opportunities, for example). The underpinning knowledge and understanding required for successful performance are also made explicit. The standards are expressed in terms of outcomes people are expected to achieve, rather than the specific tasks they carry out or the skills they need to do those tasks. For example, a scientist working towards a high-level NVQ in Environmental Conservation would need to demonstrate their ability to manage projects successfully as well as develop and carry out field surveys and data analysis; similarly, a young technician keen to develop their computing skills could use their work experiences to gain an NVQ relating to computing or software production.

For the individual, assessment involves demonstrating that he or she can meet specified standards, preferably in the workplace. Units – that is, parts of a N/SVQ – can be assessed when the candidate is ready, and at any reasonable time and place that suit the candidate and assessor. Quality and consistency are assured through a system of verifiers appointed by the awarding body for a particular qualification. In addition, assessors must themselves demonstrate competence in assessment and in the relevant occupational area at the appropriate level, and assessment centres have to meet certain criteria before they can be approved by awarding bodies.

The introduction and assessment of these standards have potentially far-reaching implications for employers (industrial and commercial), and education and training (including both further and higher education) providers alike. Although the qualifications have the workplace as the focus, training may include course work at a local college, and at higher levels, the knowledge and understanding needed may be acquired through a diploma course, management qualification, HND or degree. However, the development of standards alone does not guarantee success in raising skill levels and competitiveness. Systems must be set in place for assessment of standards, for awarding qualifications, and for training. This demands a real commitment and investment on the part of the institution and employer if the standards and qualifications are not simply to lie on the shelf. For those who embark on such investment there can be real gains, including improved staff motivation, improved quality of products or services, improved planning within the workplace, and an institution or company better able to attract and retain skilled staff.

For individuals, the system can offer flexible training based around the workplace, where they can gain accreditation and learn at their own pace, where they can gain credit for prior work experiences, and where they can use their qualification for continued professional development. A major advantage of this system is that it offers a variety of progression routes between vocational and academic frameworks. Thus an individual with a first degree in oceanography may be involved with computing in their first professional post, and develop extensive IT skills; under this system, these skills can be accredited at an appropriate level. Some years later, that same individual may have moved into a management role, and here, they could gain an N/SVQ (or SVQ) in management thus gaining access to continued professional development and recognition of current skills.

Students already enter higher education and training programmes through a number of different routes. In the future, there will be three main routes – via A-levels, via N/SVQs or via the new 'vocational' A-level, GNVQ (gSVQ in Scotland). GNVQs (General National Vocational Qualifications), and their Scottish equivalents, are different from N/SVQs in that they are assessed within an educational setting, that is, school, FE college or HE institution, and are specified in terms not of one particular occupation, but of a broad occupational area and the skills, knowledge and understanding which underpin it. Currently GNVQs (and gSVQs) exist to advanced level (equivalent to A-level) in the following areas: Art and Design; Business; Health and Social Care; Manufacturing; and Leisure and Tourism. In 1993, pilots began in three more areas: Built Environment; Hospitality and Catering; and Science. This year, the six remaining areas will be introduced: Land-based Industries; Distribution; Engineering; Information Technology; Management; and Media and Communications. Also this year, a widespread consultation is planned to canvas views on high-level GNVQs from HE, professional bodies and industry.

Any one employment sector is likely to be able to offer a number of vocational qualifications at different levels which allow individuals to operate in a range of settings. Provision is grouped at five levels of vocational competence. These range from level 1 ('competence in the performance of a range of varied work activities, most of which may be routine and predictable') to level 5 ('competence which involves the application of a significant range of fundamental principles and complex techniques across a wide and often unpredictable range of contexts ... very substantial personal autonomy ... responsibility for the work of others ... allocation of substantial resources ... personal accountabilities, etc.'). At the present time, over 100 N/SVQs exist in a variety of occupational areas at levels 1, 2 and 3. Around 50 N/SVQs exist at level 4 and one N/SVQ has been accredited in management at level 5.

Priority development has now been given to developing professional awards at N/SVQ level 5. *Scientists and engineers need to play a major role in helping to develop these professional awards.* Recent work carried out by the Council of Science and Technology Industries (CSTI) has provided illuminating data on the numbers of people using science, technology and mathematics within their jobs. CSTI, working with industry, professional bodies and academic institutions, is now working towards defining occupational standards and qualifications for scientists, technologists and mathematicians. The Challenger Society could play a major role providing detailed guidance on such things as identifying the knowledge base of professionals and elements of good practice within different work-related jobs. This is not an easy or simple task. Professional scientists may also be managers, be involved in specific technical expertise and training programmes, work with information systems, be involved in health and safety regulations and training or have their own consultancy business. Science is often only a part of their work.

Currently, there is no NVQ or SVQ entitled 'Oceanography' but there exists a whole battery of units that relate to, or are part of, the work of scientists and technicians. As a professional manager, there is a responsibility to ensure staff have maximum opportunities to develop and enhance their skills – and gain a qualification for them. For professionals, there is the responsibility to ensure that standards are maintained and improved, that new professional awards are defined to the highest standards, and that the opportunity for life-long learning for all is provided. For the future, vocational qualifications are planned to cover all professional/vocational areas. It is now time to find out how you and your organization can get involved.

For general information about vocational qualifications contact NCVQ at 222 Euston Road, London NW1 2BZ (Tel. 071-387-9898) or SCOTVEC at Hanover House, 24 Douglas Street, Glasgow, G2 7NQ (Tel. 041-248-7900).

Further information about the CSTI project from Alastair Robertson, Q-West, Ty'r Wennol, Croes Faen, Penalt, Gwent, NP5 4SF.

Linda Hodgkinson
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MET SOC HELP TEACHERS

Meteorology has become part of the science curriculum for 11–16 year olds, with the requirement that it should be cross-curricular and included in the science attainment target headed 'Earth Sciences'. Many science teachers have no more than general knowledge of the subject and the Met Office education service has already run two one-day courses for teachers on how to read weather maps, what the symbols and numbers mean, how to draw isobars, and so on.

Other topics relate specifically to curriculum attainment targets, such as the relationship between pressure and winds and how atmospheric pressure changes are related to weather patterns. Growing demand could lead to the course going nationwide with a travelling teachers' roadshow touring Met Office weather centres. However, the Met Office appears to be as much in the dark as the teaching profession about exactly what will need to be taught from 1995 onwards, Predicting the weather may be an inexact science, but it seems to be easier than predicting the curriculum.

OCEANOGRAPHY AT MOSCOW UNIVERSITY

by Professor Oleg Mamayev

'Oceanography' encompasses the full spectrum of disciplines in the marine sciences. At Moscow University – one of the biggest universities in the world, and ranking among the first ten – the subject is taught in a number of courses, including: Physics of Marine and Terrestrial Waters (in the Physics Faculty); Hydrobiology, Ichthiology, Zoology of Vertebrates and General Ecology (in the Biology Faculty); and Lithology and Marine Geology and Geophysics (in the Geology Faculty). The course in my own Department of Oceanology (in the Geography Faculty) is concerned mainly with physical oceanography and is the only one where the Diploma in Oceanology is granted upon graduation. This is the aspect of oceanography teaching that I shall focus upon, for the simple reason that I graduated from the Department of Oceanology, spent most of my scientific career in it, and am now in charge of it. In Russia, comparable teaching of physical oceanography is provided only at the Hydrometeorological Institute and University in St Petersburg, and at the Far-Eastern University in Vladivostok.

The Department of Oceanology of Moscow University was founded in 1953, exactly forty years ago, by the famous Russian Oceanographer, Professor Nicholai N. Zubov, known in the West primarily because of his outstanding monograph (among many others) entitled *Arctic Ice*, and also for his *Oceanographical Tables* ('the famous Zubov's Tables', as Sir George Deacon described them during his short visit to the Department, many years ago). Since it came into existence, the department has been visited by many distinguished western oceanographers.

Each year approximately ten students (some years more, some years less) enter the Department. This means that about four hundred scientists have graduated from our Department, and the majority of them stayed in oceanography. Many became Doctors of Science and even Professors, many more are PhD's and are well known in oceanography in this country and abroad. Students and post-graduates from foreign countries have acquired their education at the Department, among them young people from East Germany, Poland, China, Bulgaria, Egypt, Senegal and Vietnam.

Education

The formal university education traditionally takes five years, though changes are now foreseen which will introduce a four-year system ending with a Batchelor's Degree, a fifth year being available only for the most talented. The first two years are devoted to fundamental physical sciences (mathematics, physics, fluid dynamics, chemistry) and selected Earth Sciences (meteorology and climatology, terrestrial hydrology, geomorphology, cartography). The second year also introduces some oceanographic disciplines – practical oceanology and principles of navigation. Marine sciences are taught from the third year onwards, with special emphasis on the principal discipline of the Department – Oceanology – which consists of several courses, taught by the staff of the Department (e.g. seawater and its properties; mixing and turbulence; waves, tides and sea-level; ocean currents; water masses; sea ice; ocean–atmosphere interaction; oceans and climate, etc.). The syllabus is not rigidly prescribed, and can vary according to developments in the science and the taste of the lecturers.

The main subject is accompanied by related disciplines in marine sciences, such as: marine chemistry; marine geology; river discharge and estuaries; hydrobiology and fisheries oceanography; marine forecasting; regional oceanography; satellite oceanography, etc.; these disciplines are taught partly by invited scientists from scientific institutions and partly by academics from other departments in the University and Faculty. The first semester of the fifth year is devoted to 'special courses' or 'case studies' and these vary every two or three years. They cover topics such as synoptic eddies, fine thermohaline structure, laboratory modelling of ocean processes, energy from the ocean etc.

After the second year, students write a literature review on a selected topic. After the third and fourth year they present their own results in oceanology. The final 'diploma thesis', is defended by the graduate before the independent Examinations Commission. This thesis, together with an examination on the whole range of courses studied, concludes the formal education. Outstanding results of course and diploma work are quite often published in oceanographic and geographic periodicals.

There is also a system of postgraduate education at the Department, with two or three young people admitted each year. Briefly, this education (*aspirantura* in Russian) lasts for three years and terminates with the presentation and defence of the PhD thesis.

Training

At the end of the second year, two summer months are devoted to 'educational practice' which includes about six weeks spent at sea by the whole group, with one or two staff members. Since the inception of the Department, the Black Sea has been the traditional area of marine expeditions with student groups. They range from Odessa to the shores of the Caucausus and include special areas and topics of study, such as the central part of the Black Sea, the edge of the north-western shelf region, and contamination in the resort areas of the Crimea and Sochi.

After the third and fourth years the students go on to do 'real' independent research work at sea, spending up to three or four months on board research vessels of different oceanographic institutions. For many years the Department tried to follow the motto of its founder, Professor Zubov: "After the third year, *fish*; after the fourth year, *ice*": the initial research practice was on board fisheries research vessels, the next on ice-patrol ships. Times change, of course, and for the last ten years or so, many students have gone aboard weather ships in the North Atlantic. We continue to maintain students' research work on vessels run by the Hydrometeorological Service and the Academy of Science, which sail as far as the Arctic Ocean and the seas of the Russian Far East.

MEETING REPORTS

SURFACE EXCHANGE OF RADIATIVELY ACTIVE GASES AND AEROSOLS

This topic was discussed at a joint meeting of the Challenger Society and the Royal Meteorological Society, on 9th November 1993. The first speaker of the day was Professor Peter Liss of the University of East Anglia (UEA) who tackled the broad theme of oceans, dimethyl sulphide (DMS) and climate. There has been a great deal of interest in DMS, especially since Charlson and others postulated a climate feedback mechanism between the production of DMS by plankton and sea-surface temperature. Global temperature is affected by cloud albedo which in turn may depend on the cloud condensation nuclei resulting from the gas-to-particle conversion of DMS. The production and evasion (transfer to the atmosphere) of DMS is agreed, and there is a correlation of condensation nuclei concentrations with methane sulphonate (MSA), a daughter product of DMS. On the other hand, the response of plankton populations and DMS production to temperature changes is poorly understood. A major difficulty for the estimation of DMS fluxes is the spatial and seasonal patchiness of phytoplankton in the ocean and coastal seas.

Two talks focussed on the air–sea transfer velocity of gases, a coefficient of turbulent transport between atmosphere and ocean. Dr Robert Upstill-Goddard of Newcastle described the dual tracer method for measuring air–sea gas transfer velocities, by a novel technique developed at the Plymouth Marine Laboratory. Two volatile tracers, helium-3 and sulphur hexafluoride are released and transfer velocities can be deduced from the variation of their ratio with time. Several experiments in the southern North Sea have provided long-awaited information on the dependence of transfer velocity of gases on wind speeds, notably in storm conditions, and the coefficients introduced by Liss and Merlivat have been substantially verified. The transfer velocity of carbon dioxide, according to carbon-14 modelling is, however, higher than can be explained by the dual tracer technique.

Professor Wiebe Oost from KNMI, the Dutch meteorological organization, has recently led ASGASEX, a truly international effort to quantify the processes controlling the flux of CO_2 from the southern North Sea. He described the fixed platform, 5 miles from the Dutch coast, from which experiments have been made. He bravely showed some preliminary results collected by Stuart Smith of the Bedford Institute, Nova Scotia, which raised some eyebrows: the direction of fluxes appeared to correspond to the gradient of partial pressure, but the technique showed surprisingly high piston velocities at low wind speeds. These observations stimulated lively coffee-time conversations.

Continuing the theme of North Sea oceanography, Dr Jim Jickells of UEA described the efforts that he and his collaborators have been making to assess the deposition of nutrients and pollutants by rainfall and fallout of dry particles, into the southern half of the the North Sea. Extensive measurements made from RRS *Challenger* and coastal stations show increased levels of of trace metals and nitrogen species nearer to the continent. The trajectory of the wind is therefore clearly important, as may be the presence of anticyclonic pressure systems and their associated capping inversions. The dry and wet deposition of zinc, lead and some other environmentally damaging substances is significant, though still much less than the fluxes from direct discharge into the sea. The annual atmospheric supply of nutrients is considerable, with a few episodic events, when meteorological conditions are favourable, being responsible for a major proportion of the deposition. It is too early to say if plankton blooms can be initiated by deposition of nutrients in this way.

After lunch, the session resumed, continuing with oceanographic studies. Dr David Woolf of Southampton University introduced us to the role in air–sea exchange processes of bubbles entrained by breaking waves He showed that, given a knowledge of these bubbles, it is possible to predict the associated air–sea gas transfer. So far, it has been demonstrated that supersaturation of some gases can be forced by bubbles, and that there will be a general enhancement of gas exchange by bubbles. Marine aerosols, produced either by bubbles bursting at the sea surface, or bodily ripped from waves, have been studied for many years. In spite of these efforts, neither the size-spectra of aerosols nor the size-spectra of surface bubbles are agreed (or mutually consistent). It seems instead that much more oceanic data are needed.

Dr Mike Smith from UMIST raised important questions about the direct contribution of large droplets to the sensible and latent heat fluxes over the ocean. We do not yet understand how important these processes are to the heat budget but Dr Smith suggested that it may modify the latent heat flux by up to 100 W m^{-2}. He then turned his attention to smaller particles, and in particular the significant contribution of sea salt to concentrations of cloud condensation nucleii in remote regions, experimentally determined by investigating the volatility of small particles. This was related to the debate on the significance of DMS for cloud albedo, confused by the existence of numerous sea salt particles. In field work conducted on the Hebridean island of South Uist, Dr Smith has measured aerosol size-distributions and fluxes. He found the droplet fluxes to be systematically smaller than those obtained by other workers, and he attributes this difference to the height of the measurements: because fluxes decrease with height in the first few metres above the sea, care has to be exercised in comparisons between different sites. Some discussion ensued on the possible influence of a surf zone adjacent to the experimental site.

Dr David Fowler from the Institute of Terrestrial Technology, Edinburgh, gave his talk on the atmospheric methane budget. After noting the fall in the rate of increase of global methane during the last year, he drew attention to our lack of knowledge of what controls its flux, and showed how the biggest sources were wetlands and rice fields. His team have conducted an experiment in a large wetlands region in Caithness, in Scotland. Eddy correlation techniques were used to measure the flux, which was found to vary on time-scales of a couple of hours. The total budget of the wetland region was also evaluated by use of the Meteorological Research Flight. In another study, pieces of bog were placed in isolated controlled environments. The presence of sulphate was demonstrated to reduce methane flux, whereas overlying water could increase it, as could an increase in temperature. Methane is an important greenhouse gas and models of global warming must parameterise its quantity in the atmosphere. A warmer, wetter climate could lead to increased levels of methane, with wetlands becoming a more important contributor.

Another very important greenhouse gas is di-nitrous oxide, N_2O. Dr Keith Smith of the Scottish Agricultural College gave his presentation on the effects of soil on the sources of this gas. Under anaerobic conditions, de-nitrification of nitrates can cause N_2O to be released into the atmosphere. It has been shown by others that a high carbon soil, such as can be found when organic manure is extensively used, can accelerate de-nitrification. Low-technology solutions to irrigation, as found in many developing countries, can lead to waterlogged soils and more anaerobic conditions. It also seems that N_2O is more rapidly produced in areas that are extensively grazed. It is possible that a very significant development of the last few decades has been the switch from ammonium sulphate to ammonium nitrate in fertilisers. The latter increases greatly de-nitrification and may have an impact on global warming.

The inclusion of Soil–Vegetation Atmosphere Transfer (SVAT) schemes within General Circulation Models was described by Dr Richard Harding of the NERC Institute of Hydrology. These schemes consist of one-dimensional models for the transfer of water from soil to vegetation to atmosphere, applied to each cell of a global model. The difficulties encountered because of the necessity to define ensemble average values for a single cell, which could contain many different soil and vegetation properties, were considered (the UK, for example, would typically be represented by only four cells in such a model). Presently, there are instances where basic fluxes are poorly predicted by the global models.

Professor Paul Jarvis of Edinburgh presented an overview of the global carbon budget. He started with one of the budgets familiar to most oceanographers, which included details of the flux to each oceanic region, but much less detail on terrestrial fluxes. He reminded us that Tans and others have identified a 'missing sink' concentrated in middle northern latitudes. The efforts of Professor Jarvis and his colleagues to pin down the magnitude of both terrestrial sources (particularly deforestation) and sinks (uptake by temperate and tropical forests) were described.

Professor Peter Liss summed up an interesting and multi-disciplinary day of discussions. A rare meeting of terrestrial and marine natural scientists proved stimulating for all present.

Marcel Cure, David Woolf, Neil Wells
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Southampton

60TH ANNIVERSARY MEETING OF THE PERMANENT SERVICE FOR MEAN SEA LEVEL

This two-day meeting was held at the Linnaean Society's room in Piccadilly, London, 9–11 December 1993. It was organized by Phillip Woodworth, Trevor Baker and David Pugh. In the course of his opening address, Phillip Woodworth said:

"Research into present day sea-level changes is no longer just about installing a tide gauge. A researcher needs to have some familiarity with techniques such as satellite radar altimetry, the Global Positioning System (GPS) and absolute gravity, as well as being conversant with developments in understanding sea-level changes on geological time-scales, modelling possible changes in the future with the use of climate models, and modelling the geoid or gravity field via surface gravity, satellite altimetry and satellite perturbation data. ...

"...1993 could be said to be the sixtieth anniversary of the Permanent Service for Mean Sea Level (PSMSL), which is based at POL at Bidston Observatory on Merseyside (and which is responsible for one of the main sea-level research datasets), but that is not entirely the case. The PSMSL, so named, was in fact established as a 'Permanent Service' of the International Council of Scientific Unions (ICSU) in 1958, around the time of the International Geophysical Year. However, in practice it was a continuation of the Mean Sea Level Committee which had been set up at the Lisbon International Union of Geodesy and Geophysics (IUGG) conference in 1933 at the initiative of Professor Witting from Finland. Most of the work of data compilation for the Committee fell to its Secretary, Professor Joseph Proudman, of what was then the Liverpool University Tidal Institute at Bidston, and that work was continued by Drs Corkan, Doodson and Rossiter also from Bidston. So it is not stretching the facts too much to claim that in practice the PSMSL started at that earlier date – and it is anyway nicer to have a meeting celebrating a sixtieth anniversary than a thirty-fifth one!"

Many papers and several posters were presented, and some (alas, not all) of the abstracts have been compiled by Phillip Woodworth into a 37-page booklet (which includes appendices and a list of delegates). It can be obtained from PSMSL, Bidston Observatory, Birkenhead, Merseyside L43 7RA.

NERC LAUNCH STRATEGY FOR 1994–2000

At a recent meeting of the Foundation for Science and Technology, NERC launched its *Strategy for Marine Science and Technology 1994–2000*. Taking up the challenge of the 1993 Science and Technology White Paper, the *Strategy* places a strong emphasis on closer collaboration with industry, and outlines plans for an ambitious programme of pre-operational R&D, notably in developing new instruments for ocean observations, and improving existing diagnostic and modelling capabilities. The programme will be funded through the Science Budget, topped up by income from commissioned research and, hopefully, money from industry and commerce.

Speaking at the launch, Dr John Woods, Director of NERC's newly named Marine Science and Technology Directorate, predicted that 'The turn of the century will mark a revolution in oceanography as operational monitoring and forecasting become feasible for more and more aspects of the sea.' The ultimate aim is to develop a 'global observing system' – GOOS – an oceanic equivalent of the World Weather Watch for weather forecasting. The cost of running such a system is unlikely to be less than the $2 billion a year spent on weather forecasting. However there are many potential customers: managers of local and regional monitoring and prediction services, used by both government and commercial bodies involved in ship-routeing, defence, climate prediction, coastal protection, insurance, oil and gas production, pollution management, fisheries, waste-disposal, and perhaps, eventually, mining in the deep ocean.

The task of making routine observations of the ocean to meet the demand of present computer models is already beyond the capability of the world's fleet of research vessels. The future lies with satellites, autonomous underwater vehicles, intelligent long-term moored platforms, drifting observatories and acoustic remote sensing. An increasing trend towards interdisciplinary research wil require new innovative instruments, such as sensors based on fibre optic technology, for use in the deep ocean. A start has been made in developing a cost-effective method of monitoring the global circulation during WOCE, the World Ocean Circulation Experiment, which will provide a major scientific input to GOOS.

BOOK REVIEWS

An Essential Introduction to Marine Science

Essentials of Oceanography (4th edn) by Harold V. Thurmann (1993). Macmillan Publishing Co., 393 pp. £18.95 (flexicover, ISBN 0-02-420802-7)

Introductory Oceanography (6th edn) by Harold V. Thurmann (1993). Macmillan Publishing Co., 526 pp. £22.95 (hard cover, ISBN 0-675-21317-7)

Here are two comprehensively multidisciplinary introductions to the full spectrum of marine science, lavishly and handsomely illustrated. In both books, the author is concerned to discuss and explain the effects of human activities on the marine environment, as well as teaching the basic science. To help the student, the books feature summaries, questions and exercises at the end of each chapter, as well as references and suggested further reading. Both volumes are also well furnished with appendices and glossaries, in addition to their indexes.

After such a good start, it may seem churlish of me to carp. But even quite cursory examination of both books together could tempt the more curmudgeonly among us to mutter, Scrooge-like: 'One book for the price of two, sir? That is humbug, sir!' What could cause such an outburst? Well, the author's rationale for there being two books appears to be that the longer one, providing the more comprehensive coverage, is aimed at the first-year college/university market, while the shorter of the two (the 'Essentials') is a condensed version on the same basic pattern: it is 'designed for courses in oceanography taught to students with no formal background in mathematics or science'. When you compare them, you find that chapter order and headings, most of the illustrations, and large tracts of text are duplicated; and virtually all the end-of-chapter questions in the shorter volume occur also in the longer.

Perhaps it is inevitable, given such duplication, that the conceptual level and density of the science in the two books seems (to me, at least) not to be significantly different – the longer one has more material, to be sure, but it is still at the same level. I found very few mathematical formulae, and students of comparable background would be able to understand both books equally well: the longer one would take a little more time, that's all.

In the preface to each book, the author states that for these new editions he has made major text revisions and added several illustrations, especially coloured ones. In the longer ('Introductory') book, this has led to some idiosyncracies of layout. Some of the new material has been provided as 'inserts' (on, for instance, ophiolites, meteorite impacts in the oceans, El Niño, hurricanes, to name but a few), and these can interrupt the flow of your reading, sometimes very abruptly: you turn the page in the middle of a sentence, and without warning, you are into a quite different subject. I found that very distracting.

However, the author is to be congratulated on a major publishing coup: both his books have the Heezen–Tharp ocean floor map as a full-colour two-page spread. Not many authors can claim to have achieved that. In fact, I think it is the pictures that will sell these books, for the text explanations of more difficult concepts are not noticeably more lucid than in most other standard texts at this level. That is not the author's fault. There are only so many ways to explain tides or thermohaline circulation or biogeochemical cycling – but the clearer and more attractive the pictures, the better the understanding.

All the same, the author of these books is in competition with at least one other of comparable quality, the one by Tom Garrison, reviewed in this issue by Sue Greig. It is really quite hard to choose between them, and we at the Open University shall recommend all three as both introductory and supplementary reading for our own oceanography students. They are designed to arouse the interest of their readers, and they certainly achieve that.

John Wright
The Open University

Update In his review of *An Introduction to Marine Biogeochemistry* by Susan Libes (*Ocean Challenge*, 2 (No.2/3)), Tim Jickells lamented the fact that this book was available only in hardcover. We are pleased to report that a paperback edition is now available, priced at a more affordable £16.95.

Oceanography: An Invitation to Marine Science by Tom Garrison (1993) Wadsworth Publishing Company, Belmont, California, 540 pp. £29.95 (ISBN 0-534-15600-2)

Instructor's Manual (including set of transparencies based on text figures) £16.50 (ISBN 0-534-15603-7)

Writing an introductory text on Oceanography is certainly a tall order. What do you put in? What do you leave out? How much Maths do you put in? *An Invitation to Marine Science* has taken on this challenge. Comprising 20 stand-alone chapters, it is written in an enthusiastic style reminiscent of *Scientific American* and is aimed at the student with no scientific background – hence no mathematics and some simple introductory chemistry and physics. However, there is the caveat in the Appendix, 'Working in Marine Science', that to take the subject any further you must study maths, physics and chemistry – wise advice.

Much information is packed into the book, with few pages without illustrations. Colour is used, although many of the diagrams are blue and grey. Each chapter starts with some kind of 'vignette' – an observation, experience or tale of the sea designed to whet the appetite and stimulate interest. Chapter headings are what you would expect – Continental Margins and Ocean Basins, Sediments, Seawater Chemistry, Ocean Physics, Ocean Circulation, Primary Producers and so on; the Poles and Tropics are take as a 'study in contrasts'.

Within the main body of the text, the ubiquitous 'box' gives information of particular interest on controversial or unique topics, e.g. F.P. Shepard's eyewitness account of a tsunami, 'Rogues at sea' (giant waves), and 'If it moves don't eat it' (the perils of consuming sushi and sashimi). Each chapter ends with a question-and-answer section (questions the author has been asked over the years) followed by a set of straightforward study questions (no answers) and a comprehensive list of references for further study (mostly American and including some up-to-date ones) for further study, plus a reminder of terms and concepts to remember. A fairly extensive glossary along with some additional appendices on navigation, maps and charts etc., complete the work.

In a high-tech age (and bearing in mind the importance of current research projects) it would have been good to see a chapter on topics such as FRAM, WOCE, BOFS and some of the newer technology used in exploring the ocean. That aside, as an introductory text this book succeeds very well. No doubt there would be disagreement on the emphasis on particular topics – some dealt with in more detail than others – but the book is thorough in its broad coverage of all aspects of marine science. I would recommend it to any Sixth Form library to promote interest in the subject, and to anyone wishing to know what oceanography is all about at a first-year undergraduate level. Its lively engaging approach should do much to encourage students to enter this exciting field and provides much solid background material on which to build. My copy was an international student edition, rather thin paper but solidly bound in hardback. At £29.95, the cost is, however, on the high side.

Available with the text and designed to be used with it are an *Instructor's Manual* and a lovely set of overhead projector transparencies based on various text figures – far superior to my efforts. The transparencies would prove useful at a variety of levels to introduce topics for further study. The *Instructor's Manual* has the same chapter headings as the textbook and gives suggestions for presenting the material (based on what worked for the author) together with test questions – both essay titles and a series of multiple choice/true/false exercises. The questions are based on the text and are very straightforward (that is, introductory with no maths or data-handling). As the author suggests, you will need to add questions specific to your lectures, and to develop lab sessions and additional assignments.

By his enthusiastic approach, Professor Garrison aims to stimulate an already eager student population (in the USA, and now hopefully worldwide) to 'draw together the diverse threads of Marine Science into some coherent whole'. He succeeds very well.

Susan Greig
Forest Row

The Challenger Expedition, 1872–1876: A Visual Index (1994) by Eileen V. Brunton Natural History Museum, London, 189 pp. £15 including p&p (ISBN 0-565-0-1139-1)

The Challenger Expedition was one of the first UK government-sponsored undertakings to be provided with the services of an official photographer, at least three different men holding the post during the ship's three-and-a-half year absence. Now, almost 120 years after the event, and thanks to the efforts of Eileen Brunton, we finally have an easily accessible and highly informative catalogue of the photographs they took, along with those taken by other members of the ship's complement and by professional photographers at various of the ports visited during the voyage.

Over more than ten years, Mrs Brunton painstakingly tracked down more than 800 separate images in nine different collections in England, Scotland, Germany and the US. Somewhat surprisingly, at least to me, the John Murray collection of 366 images in the Natural History Museum, for which Mrs Brunton has had personal responsibility for many years, was by no means the most extensive. Thus, the National Maritime Museum at Greenwich holds 429 images, the Hydrographic Office in Taunton 433, the Moseley collection at Oxford 471, while the J.Y. Buchanan collection at Christ's College, Cambridge, contains no less than 494, of which 113 have not been found elsewhere.

A total of 829 photographs are listed, including a relatively small number which were included in contemporary listings but of which, for one reason or another, no surviving image has been located. Of the remainder, the vast majority are reproduced in this volume, six to a page and each about 90 × 70 millimetres. To accompany the photographs and the catalogue listing, Mrs Brunton provides valuable information on the photographers and the chequered history of the fruits of their endeavours, including the tragic flood damage suffered by the Natural History Museum collection in the 1960s.

Unfortunately, neither the efforts of the compiler, nor the photographs themselves are done justice by the quality of the reproduction. For the parsimony of the Museum authorities resulted in the use of a photocopying technique and a rather cheap and nasty plastic ring binder to hold together a volume that will undoubtedly fall apart quickly if it gets the extensive use that it deserves. On the other hand, the resulting modest price should be well within the range of all interested users and libraries.

However, despite the cheap reproduction, it is obvious that the original photographs are generally of superb quality considering the relative infancy of the 1870s photographic technology and the photographers' appalling logistic difficulties in lugging heavy equipment to inaccessible vantage points and developing glass plates at sea. But the obvious tenacity of the *Challenger* photographers simply could not overcome one major technological problem, the extreme slowness of the available emulsions by modern standards. Consequently, they were quite unable to capture movement, or to take photographs from any but the most stable of positions. So there are no images obtained while the ship was at sea, and all the photographs of people, including those of the natives at the different land-falls, are clearly in rather stiff, holdable poses.

Nevertheless, while the photographs are therefore of limited direct oceanographic interest, they are extremely emotive and must be of great potential value to anthropologists, geographers and naval and architectural historians. This volume will bring to the notice of these various interest groups the hundreds of *Challenger* photographs that have never appeared in print before. Mrs Brunton has provided us all with an important service.

Tony (A.L.) Rice
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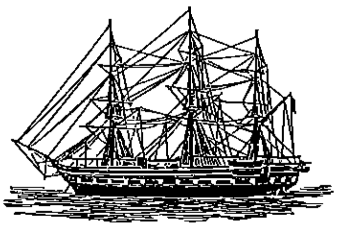

El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation
edited by Henry F. Diaz and Vera Markgraf (1992). Cambridge University Press, 476 pp. £40.00 (hard cover, ISBN 0-521-43042-9)

El Niño and the Southern Oscillation are respectively oceanic and atmospheric aspects of the large interannual climatic variation known as ENSO. Although these aspects are concentrated in the tropical Pacific, ENSO has world-wide impacts through associated changes in global circulation. The occurrence and magnitude of recent ENSO events (i.e. during the last 100 years when reasonably reliable instrumental records are available) are quite accurately known, but earlier behaviour of ENSO is much less clear. A better picture of how ENSO might have changed could lead to better understanding of longer term, less well observed past climate changes. This historical behaviour is also of particular interest because a change in ENSO activity could occur, due to global warming for example, and this could have a larger year-to-year impact than the global warming itself.

With the incentive of deducing past ENSO behaviour, a workshop on palaeo-ENSO was held in USA in 1990, and this book basically derives from that meeting (the aims and methods of which are clearly described in the first part of Chapter 17). Between an introduction and a closing synthesis the book has five sections containing 20 articles by various authors, mostly from USA institutes. The articles are carefully written, and range from general overviews to detailed specifics. At the end of this exploration of ENSO history the reader is left with few firm conclusions, but the journey is rewarding and often fascinating as tree rings, corals, ice sheets etc. are examined for clues.

Section A on 'the modern record' opens with a good overview of ENSO climatic features and teleconnection effects (i.e. global temperature and rainfall variations associated with ENSO): regions of relatively high impact are likely to be good places to look for ENSO clues. Hints on how ENSO may have behaved differently in the past are provided in a chapter on computer simulations of present and doubled CO_2 climates: there is a warning that in a warmer world ENSO teleconnections could be different – as if the palaeoENSOlogist's life wasn't difficult enough already!

Actual past behaviour is examined in Section B on 'the historical record': starting again with a useful general overview and examples of various direct and indirect records. There are several historical notes: the first direct documented evidence (1525) stems from the Spanish conquest of Peru. Described elsewhere as 'the world's largest, best quantified climate proxy', Nile river records (which reflect rainfall over a large catchment area that is influenced by the Southern Oscillation) go back to 622 AD, the start of the Moslem era. The Nile chapter contains useful tables of the long Nile record and classifications of related ENSO and regional features, and evidence that 'seven years of plenty and seven years of famine' were not unusual. Also good is the chapter describing ENSO effects and possible impacts in Australia, including examples of native species which are adapted to highly variable conditions. It is suggested that evidence of when such strategies were first adopted could hint at when ENSO began. Section B also contains some technical statistics, with a reminder that EN and SO are not synonymous: oceanic El Niño events sometimes occur before, after, and separately from atmospheric Southern Oscillation events.

The next section, 'tree rings', is largely detailed and technical: most readers will find the general overview sufficient to find out how statistics can be used to relate variations in tree growth to aspects of ENSO, and hence to attempt to reconstruct past behaviour over several centuries. The remaining chapters give examples, nearly all from North America. The reconstructions have drawbacks, and there is evidently a need to combine data from different regions – a recurring theme in this book.

Section D on 'ice cores and corals' is less technical in style and, while still containing some detailed information, easier to read for the non-expert. A 1 500-year record from an ice-cap in Peru is presented, which provides data on accumulation of dust, isotopes etc.: while ENSO should lead to less accumulation there, other processes also seem influential, and again information from other regions is apparently needed before definite conclusions can be made. A link to nearby archaeological evidence of cultural dependence on climatic conditions is also described. I particularly liked Chapter 17 on the implications of different records, with tree rings, ice caps, documentary and instrumental records compared. The comparison allowed useful identification of 'missing years' in some records, and gave a clear warning against relying on any one historical record to validate/calibrate others. Intercomparison and combination is apparently the future strategy for palaeo-ENSO. The following chapter on corals is also instructive: the investigation of recent data demonstrates how coral skeleton chemistry can (depending on location) variously reveal information on sea-surface temperature/rain/wind/upwelling, and hence capture subtle differences among ENSO events – and these records are potentially thousands of years long!

The last section, on 'low-resolution indicators' contains contributions about decadal to millenial time-scales. There is a good but verbose article on climate change (not just ENSO) and fish populations, with many examples. Sediments provide millenial records, and samples have been analysed to seek evidence to relate ENSO and long-term climate change. Palaeo-records of, for example, pollen, indicate changes in temperature and precipitation through variations in vegetation: there is some evidence that ENSO was not an important climatic factor before 7 000 BP, but that by 3 000 BP conditions were like the present.

In all, this is a timely and high-quality book that reflects a recent surge of interest in palaeo-ENSO now that the wide impact of ENSO is apparent. There is a certain amount of jargon, but this is generally explained in the overviews: technical expertise is not needed to get something from most of the contributions. Cross-referencing is good, and each chapter has ample diagrams and an extensive reference list. On the negative side: the repeated descriptions of basic ENSO features are superfluous, and some contributions are more suited to specialized journals.

The editors state that their 'aim was to give the reader a sense of the richness of the available paleoclimatic indicators of ENSO activity, as well as some measure of the limitations of each of the proxy records'. In this they have succeeded. If you are particularly interested in ENSO or climate history, then this book is definitely worth considering, both for the summaries and for the various detailed examples. It is too long and detailed to recommend purchase just for general interest, but if you have access to a copy, take a look at the overviews.

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SOMETHING FOR *almost* NOTHING

the quest of data assimilation

by Rebecca Woodgate

To a civilization based almost entirely on land, the sea has long held a position of fascination and awe. To the oceanographer, the ocean is a system of intrigue, to be cajoled into simplification, trapped by science and finally trimmed into understanding. Theoreticians construct theories, modellers model, but at the end of the day, theory and models must stand or fall on their ability to explain, agree with and even predict real experimental measurements.

Such are the axioms of science, but how does one go about verifying or improving an ocean model or theory, when the oceans cover over two-thirds of the globe and processes within them vary on all scales up to hundreds of kilometres? The oceans are simply too vast to measure completely. Our attempts can at best merely scrape the surface of the problem. How can we overcome this lack of data, and what can we hope to achieve with the data we do collect? This is where data assimilation comes in.

Data Assimilation in Brief

Data assimilation is about combining data and dynamics, about using a model of the system under consideration to interpret the data in the light of the underlying physics. The techniques are valid in many different complex physical situations, but here we consider the oceans. Let's assume we have some information about our system (say a series of vertical temperature profiles at a set of points), and we wish to know something more about the system (e.g. the full temperature and velocity fields). Can this be deduced from the data we have? The answer is no, not without drawing on some knowledge of the physics. If the system were simple, the fields might then be reconstructed from the data by solving the relevant equations, but the ocean is too complicated a system to treat analytically in this manner. Only in special cases can the equations that govern the ocean be solved without resorting to a computer. However, if a computer model of the system, which contained all the physics you cared to consider, could be made to reproduce the data that have been obtained, then we might hazard that the model also could reconstruct the *un*measured fields. The model would have combined the data with its 'knowledge' of physics to produce a dynamically consistent scenario, and would thus have extracted from the data more information than was actually measured in the first place – in a way, it has given us something for nothing!

The techniques used to achieve this are the methods of data assimilation. The goals are three-fold: to explain the ocean system; to estimate the current ocean state (in order to obtain initial conditions for a forecast run); and to improve ocean models (by considering things that continually disagree with observations). The gains of a successful assimilation scheme are many – a better understanding of the oceans is invaluable for climate studies, for exploitation of offshore resources such as oil and gas, for fisheries, marine pollution studies, prediction of weather and much, much more.

Data Assimilation in Pictures

But how does one go about assimilating data? In order to avoid maths, we will look at data assimilation in a more pictorial sense.

Let us introduce the concept of 'phase space'. Think of a frictionless pendulum swinging to and fro (Figure 1, upper). At any one time two pieces of information about the system – where the pendulum is and which way it is going – are sufficient to tell you everything about it. We say the pendulum has two 'degrees of freedom'. Now imagine plotting a graph of these two pieces of information, i.e. a graph of the pendulum's position versus its velocity (Figure 1, lower). At any point in time, the state of the pendulum is represented by a point on the graph. As the pendulum moves in time, so this point moves on the graph, and traces out a trajectory (here it happens to be a closed loop because the motion of the pendulum repeats). This graph is an example of a 'phase space representation' of the pendulum's motion. It doesn't trace the movement in real space, but tells you enough for you to be able to reconstruct it.

Now to come back to the ocean system. The ocean (or part of the ocean) requires many more variables to describe it, so we say it has many more degrees of freedom (to be general, let's say N of them). Thus it has an N-dimensional phase space and we would need an N-dimensional graph to represent it. Like the pendulum, the ocean can be thought of as a point moving through this phase space (Figure 2). In Figure 2, N is taken to be three so we can draw it; in models N will be thousands, in reality it is infinite.

So the changing ocean can be represented by a trajectory in an N-dimensional phase space. Similarly, as a model is run forward in time (i.e. is used to simulate the time evolution of the system), it too marks out a trajectory in a phase space (although as the model will be a simplified representation of the real ocean, the model phase space will have fewer dimensions). To get the model to reproduce the data, we must make the model trajectory follow the real ocean trajectory for those dimensions the model has.

Though we do not know the trajectory of the real ocean, we do have data from the real ocean. At any one time, the data would ideally give us a point on the ocean trajectory in this phase space. (In reality, these will be 'volumes' through which the ocean trajectory must pass, since it is unlikely that all the data from any one time will tell us exactly where the ocean is in phase space.) Our task is to try and get the model trajectory to match the real trajectory, by making it go through all the points corresponding to data. So our problem becomes a rather esoteric form of join-the-dots!

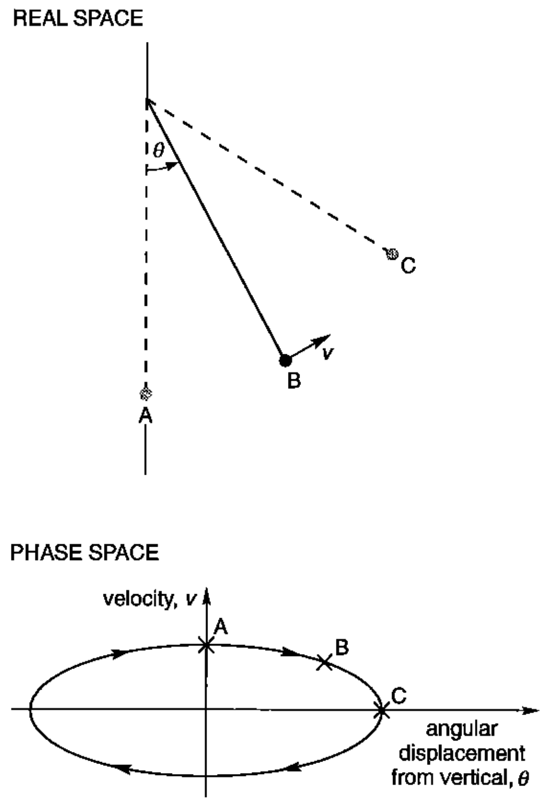
Data Assimilation in Words

Using this N-dimensional picture we can now go on to explain all the commonly used data-assimilation techniques. They come in two main types: variational methods and statistical methods.

Variational Methods

Variational methods can be thought of as taking a bit of wire (the model) and bending it to fit all the points in the phase space, much in the manner of a least squares fit of a graph to data. The purpose is to adjust the model parameters (such as viscosities), and the initial conditions, to get the best fit to the data when the model is integrated forward in time over the period for which there are data.* This is achieved by running several integrations, both forward in time and backward in time over the period in question, the latter using something called the 'adjoint', a code produced from the original model code. Thus in our phase space, we start at some guessed initial conditions and

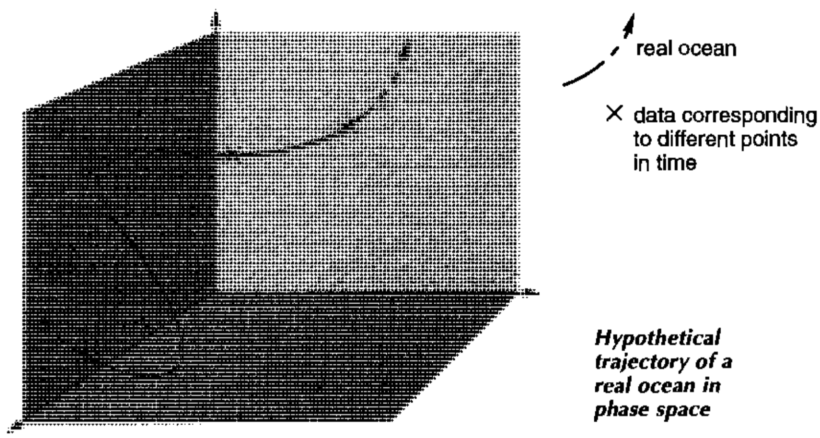
*This tacitly assumes that if you start the model in the right place (i.e. with the correct initial conditions) it will remain on the correct trajectory. In other words, this relies on the model doing a reasonable job of simulating the ocean.



Phase space for a pendulum and ...

... for a complicated system like the ocean

Figure 1 *Representation of a pendulum in real space and phase space. At point A, the pendulum passes the vertical, θ = 0, and the velocity of the pendulum bob, v, is at a maximum. As it passes through point B it slows, until at point C, the pendulum is momentarily stationary, θ is at a maximum and v = 0. The oval loop (ABC etc.) represents the trajectory of the pendulum in phase space.*



Hypothetical trajectory of a real ocean in phase space

Figure 2 *A hypothetical trajectory of a real ocean in an N-dimensional phase space. Any set of measurements gives a point on the line of the ocean trajectory. (In reality, the data would not constrain all N dimensions, but instead would delimit a 'volume' through which the ocean trajectory must pass.)*

run the model forward to see how well we reproduce the data. The backward integration of the adjoint then tells us how the parameters and initial conditions should be adjusted to improve the fit. Other constraints can also be built into the method, since it depends on the minimization of some 'cost function'. This cost function is in the first instance the difference between the model and the data, but could also include things like the smoothness of the final solution.

The variational method is a very powerful technique and can give good results. It is however computationally expensive, requiring several integrations of the model over the time period in question. Deriving the adjoint code itself is a non-trivial exercise and, in the nonlinear case (where all the variables of the model must be stored at all time steps to be used by the adjoint code), variational methods also require very large storage.

Statistical Methods
The statistical methods cover a large number of techniques, all with the same basic idea, which is to correct the model as/before it gets it wrong. In our phase-space trajectory sense, this is like making one pass through the phase space, pushing the model towards the data points as you go. There are of course many subtleties to this; for example, how hard you push the model towards the data depends on how much you believe the data as opposed to the model.

Many different methods are used. The model can be forced using the difference between the model and the data ('nudging'); the data can merely be placed in the model, replacing the model's predictions ('direct insertion'); or some weighted averages of the data and the model predictions may be used ('optimal interpolation'). The weights in this latter case are determined by some estimate of the errors involved. The theoretically optimum limit of this is the Kalman Filter, with the weights being altered throughout the integration. Data are likely also to be infrequent in both space and time. Though the model could be left to 'fill in the gaps' ('dynamical interpolation'), often statistical schemes use spatial or temporal interpolations based on correlation lengths of fields (e.g. as in successive correction techniques).

Data Assimilation in Action

That's the theory of data assimilation, but in the real world, how do these schemes work in practice? Though data assimilation is new to the oceanographic community, meteorologists have long been assimilating data to aid forecasting. All the schemes discussed above have been developed and used with varying degrees of success in the atmospheric context. Data assimilation is now used daily in weather forecasting centres throughout the world, incorporating both local and global data, with a great deal of success. (Indeed sometimes the data assimilation process, which has to take into account the expected errors in the data, can uncover large errors in the data collection.)

If, then, data assimilation is so routine in the atmospheric case, why isn't the oceanographic issue a solved problem?

There are significant differences between the oceanic and the atmospheric systems. Firstly, time- and space-scales – the atmosphere changes more quickly, on scales of days to weeks, while ocean time-scales are weeks and months to years. This should act in favour of oceanic data-assimilation. However, the ocean varies on smaller space scales – a typical atmospheric eddy is of order 1 000 kilometres across, an oceanic one is more like 10–100 kilometres across, making density of data points important.

Secondly, there is the difference of data coverage in space and time – if I say merely that meteorologists get about 2 million measurements a year compared to approximately 8 thousand for oceanographers, I think I can rest my case! Oceanic data are at best sparse. Until recently, coverage in both space and time was sporadic, data coming mainly from ships or moorings, which can only be in one place at a time. For many years the only global dataset available was the Levitus dataset which for 1 degree resolution is time-averaged over 70 years to obtain adequate spatial data coverage. Now with the advent of satellites, all that is slowly changing. For the first time oceanographers have access to a moderately global and simultaneous (synoptic) dataset. However, every silver lining has its cloud – though a satellite can sound the entire depth of the atmosphere, the information it acquires about the sea (e.g. the surface winds, the wave heights, the sea-surface height and the sea-surface temperature) is only from the top few microns of the ocean.

Thirdly, the models. Sadly, ocean models are not yet as advanced as those of the atmosphere, the ocean modelling effort being smaller and less advanced. The problems are also slightly different, due to the different space- and time-scales, other important processes (e.g. the effect of salinity), and the different physical situations (e.g. continents divide the oceanic system into basins). Computer models are also often limited on resolution by computer power. For example, FRAM (the Fine Resolution Antarctic Model), which simulates the Antarctic Circumpolar Current at a horizontal resolution of ~30 km, takes ~7 days of Cray computer time to run for one year.

Data Assimilation in the Oceans

So, we are trying to infer the behaviour of a complicated dynamical system, the ocean, given only sparse, irregular data (either at depth in local areas, or only from the surface in a global sense), and using models which are frequently complicated and often crude either in resolution or in physics – nothing like a challenge!

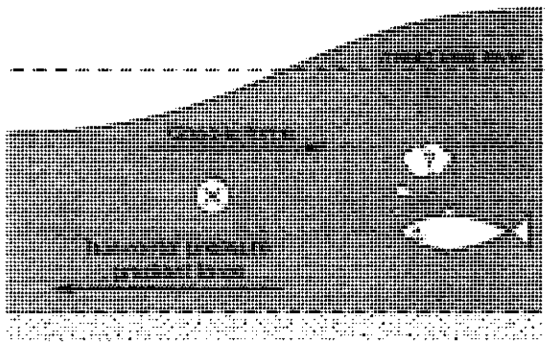
What are we doing about it? The answer is quite a lot. There are many groups in the oceanographic community researching various methods, both variational and statistical. Different systems are being studied, ranging from limited-area fine-resolution to ocean-wide coarse-resolution. Different geographical areas are being considered, including the tropics, the Gulf Stream and the North Atlantic – and, more simply, a hypothetical square box. All manner of models are being used, from those containing all the physics we believe we understand (primitive equation models), to models running with simplified physics (e.g. quasi-geostrophic models). The variations are seemingly endless, but all have the same goal – to extract more information from the data.

It is, however, the issue of data coverage that makes the oceanic data-assimilation problem unique. Since conventional ocean measurements are scarce, our major data source for assimilation is satellite data, which is surface data only. But how can surface information give any clue as to what is occurring underneath? Think about a stream or a river. Instinctively we feel that the shape of the surface is in some way determined by the roughness of the bottom, and by how the water flows over it, and indeed it is. The same is true for the oceans, though in a rather more subtle sense.

From the point of view of oceanic dynamics, there are two things that affect sea-surface height. The first is currents, through the action of the Coriolis force* (see Figure 3). Figure 3 shows that the gradient of the sea surface is dependent on the sum of the currents below. The second is horizontal density variations, the 'steric effect'. In simple terms, this reflects the fact that although a column of water expands as it gets hotter, the pressure at its base will stay the same: see Figure 4. The problem is complicated, because these features interact – horizontal density variations drive currents, which will change the horizontal density gradients, etc. The important thing to note is that it is the depth sum of the currents or density structure that is reflected in the sea-surface height. Can data assimilation be used to unravel this sum and get the subsurface information out of the surface data?

Therein lies the question! Perhaps the most obvious approach is to use a model that explicitly predicts the sea-surface height. The observed data can then easily be assimilated. More often, a 'rigid lid' assumption is made.

The shape of the sea surface reflects the effect of the Coriolis force on moving water



(X) Current flowing into page

Figure 3 *The effect of the Coriolis force on the sea surface, here illustrated for a constant-density ocean. A current (shown flowing into the page) is deviated to the right by the Coriolis force in the Northern Hemisphere. At steady state, this deviating force is balanced by an opposite horizontal pressure gradient which results from the difference in surface height.*

Sea-surface height is also affected by variations in density

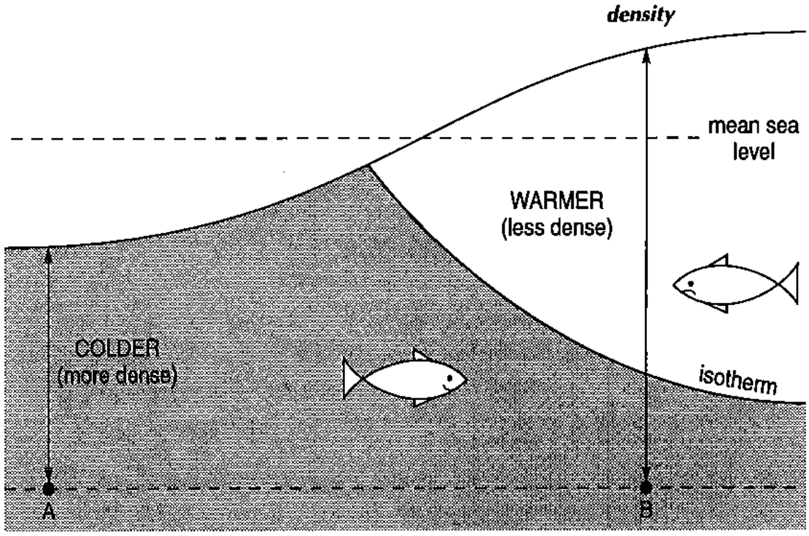


Figure 4 *The steric effect. Though the sea-surface height is greater at B than at A, due to different overlying densities, the pressure at A and B could be the same, and there would be no flow at this depth. Thus the sea-surface height reflects the underlying density structure.*

This still allows the pressure to vary under the lid and thus a sea-surface height can be deduced, but the procedure is not straightforward. Though simpler models (based on physical approximations such as quasi-geostrophy) show some degree of success in the assimilation of surface data only, for the more complex, hopefully more realistic, primitive equation models, it seems extra information is required. This could be other data (ship data, mooring data, acoustic tomography data) or previous knowledge, be it statistical (e.g. vertical correlations), or dynamic (e.g. theoretical relations, vertical normal modes, a physical basis for vertical correlations). It is methods of projecting surface information to depth that form the subject of current research in oceanic data assimilation.

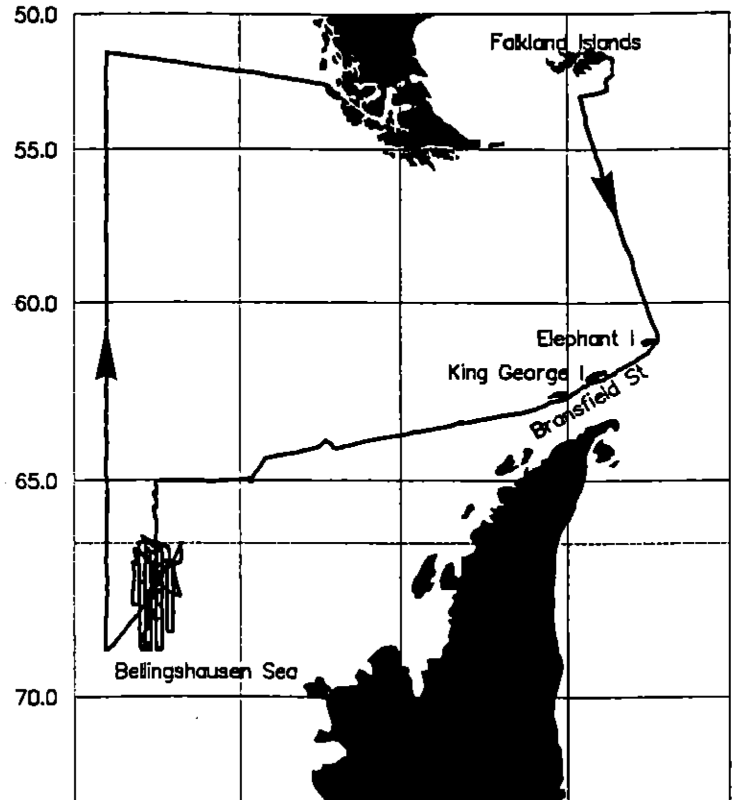
* A force due to the spinning of the Earth, which acts on everything that moves, tending to cause deviation to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Data Assimilation in the Future

If successful, the benefits of the assimilation of oceanic data will be enormous. The greatest advances will come from being able to analyse and incorporate data from satellites, which will give far greater coverage than ship data. There is still the issue of validating the satellite data, the accuracies we can expect and require, and indeed for sea-surface data, the question of what exactly the satellite measures. For example, the quantity important for dynamics is the sea-surface height relative to the geoid (the hypothetical surface formed by a stationary ocean on the rotating globe), and the geoid itself is not well known. Also, as mentioned earlier, the sea temperature as measured by the satellite is that of the top few microns only. However, the data available from satellites will be global and synoptic, a luxury never afforded oceanographers in the past. The problems are still many, but if data assimilation can use satellite data (along with data from ships etc.) to unlock the properties of the deeps, then we have the key to global ocean observation and an improved understanding of the oceans.

Rebecca Woodgate, after completing a first degree in Physics at Cambridge, is now finishing a D.Phil. (in assimilation of satellite data into a free-surface primitive equation ocean model), in the NERC Oceanography Unit, based in Oxford University. Rebecca won the Norman Heaps prize for the best presentation by a young scientist at UK Oceanography 92: this article is based on the issues that led to the work discussed in that talk.

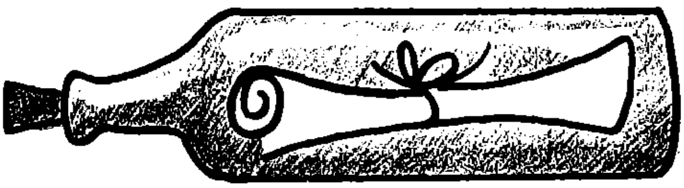
Discovery's track during the 'Sterna' cruise



During 1991, the Royal Research Ship *Discovery* was completely gutted, lengthened and rebuilt. This was done to increase her endurance and to provide a better platform for the international, multi-disciplinary research programmes of the '90s and beyond. Brief trials were held in the North Atlantic before her first season of research cruises, to be undertaken in the Southern Ocean. The first cruise (number 198) was planned by the Plymouth Marine Laboratory and the British Antarctic Survey, under the auspices of BOFS (the Biogeochemical Ocean Flux Study) and was called 'Sterna'. It was to be interdisciplinary and multi-project, with two ships surveying the ice edge in the Bellinghausen Sea. The primary objectives were to investigate the importance of the region as a sink or source of climatically significant gases and to evaluate the magnitude and variability of biogeochemical fluxes associated with the phytoplankton spring bloom period. The cruise also included two sections for WOCE (the World Ocean Circulation Experiment) and hydrographic surveys for the Institute of Oceanographic Sciences Deacon Laboratory research project: 'Physical processes determining the structure of the upper ocean'. The plan was for the *Discovery* to survey the open water north of the ice edge, following the ice as it retreated, while the BAS ship, RRS *James Clark Ross* investigated the water beneath the solid pack ice. The *Discovery* sailed from the Falkland Islands on 11 November 1992 for her six-week cruise. Jane Read's account (opposite) conveys what it was like to be on *Discovery* during that cruise.

Letter from Discovery

by Jane Read

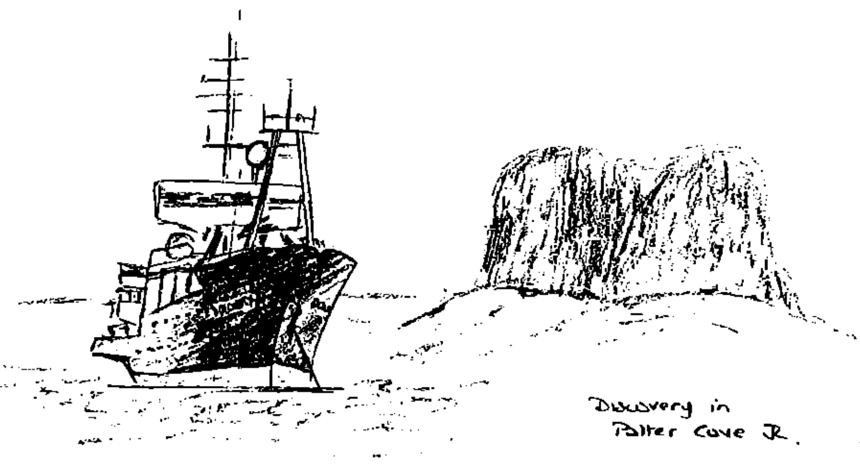


Some things never change – the Discovery used to roll, and she still does, even in the slightest of swells. It's a long slow roll that never seems to end – not even when you, and your chair, are flung across the lab. I lost my first mug as soon as we sailed out of Berkeley Sound (leaving the Falkland Islands). Fortunately we had good weather as we headed south across Drake Passage. It was foggy at times, restricting our work, but this, one of the roughest areas of the world's oceans let us off quite lightly. We had a superb passage between Clarence Island and Elephant Island – glorious sunshine, crystal clear skies, spectacular scenery, all shapes and sizes of icebergs. Penguins, petrels, albatrosses and even a tern. Surely an Arctic Tern, Sterna paradisaea, must be a good omen for this, the 'Sterna' cruise?

Our next excitement came in Potter Cove at King Edward Island. Anchored for twenty-four hours while we calibrated an acoustic 'fish' device, we were given permission to go ashore to visit the Argentinean base. Sadly, rough and worsening conditions meant that only a few people made it, the chief engineer deciding that it was too rough to try to land anyone else. The rest of us had to make do with boat trips around the ship. But even that was fun: exhilarating, spectacular and wet.

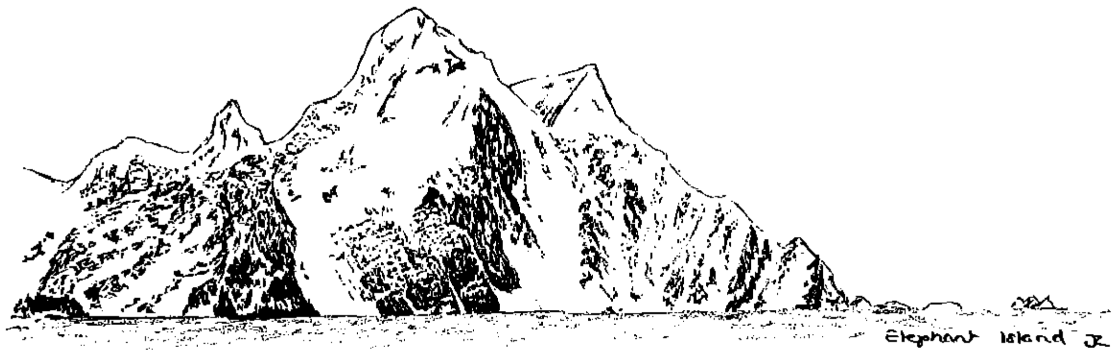
From Bransfield Strait we headed due west into the Bellingshausen Sea, stopping occasionally for a station on the way – just to keep our hand in. But before we reached the survey area we learnt that we were to have an early rendezvous with the RRS James Clark Ross. Our chef was very ill and the Master wanted to consult the doctor on the British Antarctic Survey ship.

I would recommend a diet before joining ship. Not only was the food good, it was imaginative and very appetising. Some of us carnivores even explored the culinary delights prepared for the vegetarians on board. A far cry from the legendary days of hard tack and bully beef. The new 'cafeteria' system worked well, the 'two-sitting' system almost vanished as the cruise progressed and people came and went as they pleased. Meals became a lot more sociable than they used to be. So it was with great concern that we learned that our chef was sick.



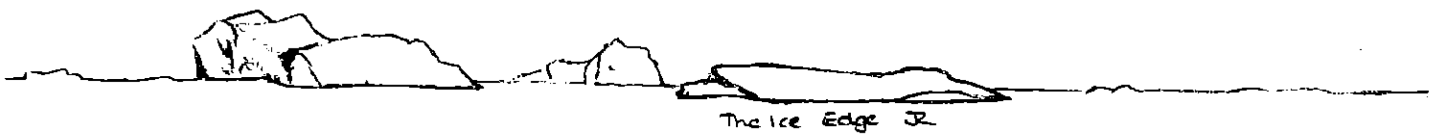
Discovery in Potter Cove JR.

It was an anxious afternoon, rumours and counter-rumours abounded as we waited for the doctor's diagnosis, and the Master's decision, and then a decision from the Research

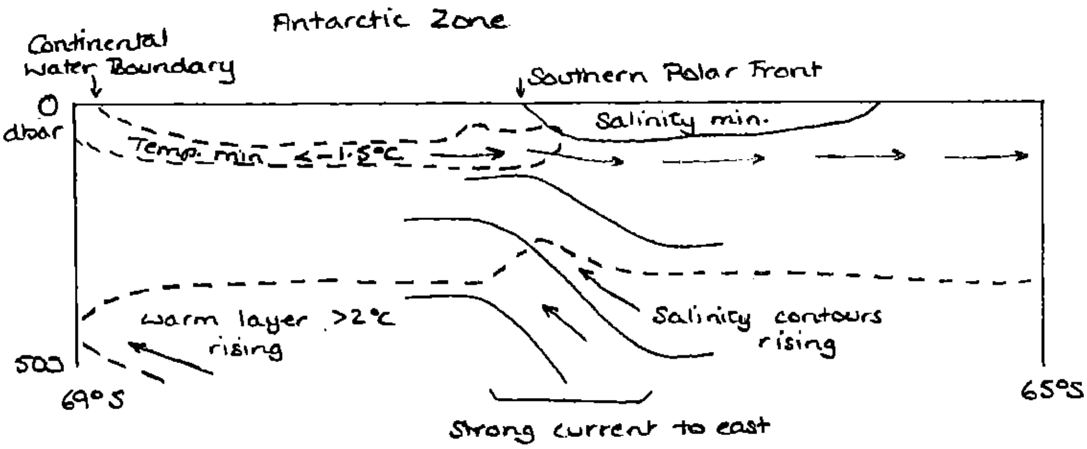


Vessel Service base and another from the British Antarctic Survey. We worked on our intercalibration exercise, drawing off water samples and exchanging them with our opposite numbers on the James Clark Ross, but we still found time to linger – had anyone heard anything? Eventually our waiting was over. Despite the bad conditions our invalid was to be transferred to the James Clark Ross and they would evacuate him to the hospital on the Falkland Islands. We tried to keep out of the way but were reluctant to leave the rails as one of the small boats was hoisted on board and the sick man – so pale he was barely recognisable – climbed into the boat with the doctor, to be let down as gently as possible into the stormy sea. We waved good-bye as they sped back to the James Clark Ross, and she made off, full speed into the deteriorating weather. We waited to hear our own fate: an overnight break, then on with the survey! (During the remainder of the cruise we were kept up to date with bulletins of the chef's condition and were pleased and relieved to hear that he made a good recovery. Meanwhile, the remaining catering staff took on the extra work of the chef and did an excellent job of keeping us fed.)

After delays from the bad weather we were eventually able to start our ice-edge survey, and made our way down to the starting point. From the bridge, we could see a long line of white marking the horizon. Bright sunshine caused it to sparkle, and as we drew closer we could distinguish the massive icebergs and thin brash ice in between. Time for us to turn back, as we were not 'ice-strengthened', but there were plenty of other icebergs around to see. We had to detour several times to go round them. For the next few days we surveyed backwards and forwards, approaching the ice during the day, heading away from it in the 'dusk' that passed for night. We saw little of the ice edge itself – most days it was shrouded in fog.



Our task was to map the temperature, salinity, chlorophyll and currents of the upper ocean, together with a wide variety of surface measurements including CO_2, light, various inorganic nutrients, biogases and phytoplankton production. Sampling the water was a chilly business – the highest temperatures reached only 2 °C, while the lowest were well below zero. The surface layers were the worst, having been cooled to less than -1.5 °C by the winter weather, although now it was spring, the surface was warming up, leaving a subsurface temperature minimum – a characteristic feature of the Antarctic Zone. We found that we were surveying a front, which we called the Southern Polar Front, where a tongue of fresh surface water lay almost due east–west and beneath which there was a strong salinity gradient. The gradient wasn't so noticeable in temperature, which showed steeper gradients further to the south, at the Continental Water Boundary. But the currents were most pronounced at the Southern Polar Front and showed a jet of water flowing to the east at speeds of up to 1.5 knots.



South to north section at 85° W, showing some of the hydrographic features of the top 500 m of the Antarctic Zone

Running alternately due north and south brought us almost beam-on to the swell and the Discovery's roll became more and more exaggerated. The galley lost a great variety of plates, bowls, dishes and glasses, and I lost my second mug. Just when we thought there would surely be nothing left to eat from, the Master called a halt to the scientific programme. Only to discover that we couldn't retrieve our gear. During the rough weather some bolts in the overhead gantry on the stern had sheared off and the massive roller arm was held in place only by a hydraulic ram. It was too rough to repair, but too risky to work underneath to recover our equipment. With 500 m of wire hanging over the stern we couldn't heave to, because of the risk of fouling the stern propeller. All we could do was steam slowly into the wind and sea and hope that at some stage the wind would drop enough for recovery. Some of us had visions of sailing on for ever and ever, unable to get out of our predicament. In fact, once again we were lucky. Next morning the weather had moderated and soon there were men swarming all over the gantry frame. It didn't take them long to repair things and they soon recovered our gear.

This was not the only problem we had. There were plenty of teething problems to be sorted out: the air conditioning couldn't be fixed until refit and despite sub-zero temperatures outside, the labs and cabins were hot and stuffy. On our passage west we took a heavy wave over the side which smashed the side door into the deck lab. We had to spend most of the day hove-to as the engineers welded a protective barricade in place. It looked like Fort Knox by the time they had finished, but it seemed that Discovery was vulnerable to waves. On the extremely stormy passage preceding our cruise one of the portholes had been stove-in, and this could have caused serious injury if anyone had been near. So we had to have all the deadlights bolted down over the portholes in case it happened again and I thought the worst thing was the claustrophobic feeling this engendered. And it meant we missed out on all that happened outside when we were working in the labs. One scientist called the bridge at 4.30 a.m. to ask for deck lights to be turned on so that he could work outside. The mate wanted to know why he wanted lights because it was broad daylight! Well, we were not accustomed to nearly 24 hours of daylight.

After a break from our first survey it was time to start the second, a repeat of the first but further south to follow the retreating ice edge. But after only two days it ended even more ignominiously than the previous one. Our equipment dropped off the end of the cable. It took some time for the news to sink in as we wandered round with dazed looks on our faces. This was definitely not planned! Later the same day we had another rendezvous with the James Clark Ross to borrow some of their equipment, and a technician to run it. It wasn't the same, but at least we are able to measure something. Still, it was with some relief that we gave equipment and technician back to the James Clark Ross a couple of days later and started on the last leg back to South America. For some this was the signal to visit the bar, to celebrate? drown their sorrows?

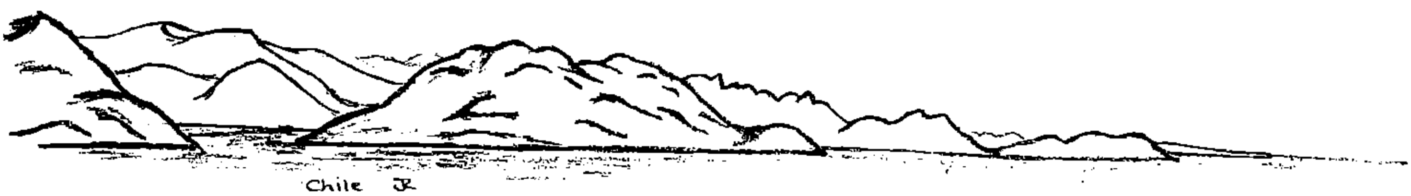
The bar was popular in all weather and at all times. Compared to the old bar, the room was so vast that the spare barrels of beer had to be kept in the library because it was closer than the other end of the bar. Both rooms, bar and library, were useful for meetings, large and small groups respectively. The saloon was also used but suffered the severe drawback of being directly above the stabiliser control valve. This debatably useless piece of equipment clanged and echoed like an old train in a tunnel. Normal conversation was made very difficult.

At last we came to the end of our final section: All the equipment was stripped down and packed into its boxes, and customs forms were prepared for docking. For some it was a chance to relax, spend some more time in the bar or wander round the deck looking for the first sign of land. For others there was the more serious task of archiving all the data, so laboriously collected, that was to be analysed back at home.

Land! Most people spent the best part of the day out on deck watching the scenery go by as we made our way through the Magellan Straits. We were no longer surrounded by sea but by bleak hills, with snow-capped mountains beyond, and once, in some remote valley, the glimpse of a glacier. The pilot boat brought the pilot to us, to direct the ship on the very last part of its voyage, and eventually we docked at about 1 o'clock in the morning in Punta Arenas, Chile. All of us, of course, stayed around on deck to watch the momentous occasion. Later in the morning we began the interminable waiting that signifies the end of a cruise: waiting to sign off, waiting for dockside equipment, waiting for customs clearance, waiting for 'subs' (foreign money that is essential to our survival in a foreign country), waiting for transport, waiting to go! Eventually we made it.

Ashore at last, and so begins the re-adaptation to 'normal' life. Waiting for the bed to stop swaying when you lie down. Listening to the ringing in the ears – you become so accustomed to the continuous throb of the ship's engines that penetrate all but the most remote parts of the ship that you still hear them long after reaching home.

And how do people react to being ashore? Hugging a tree – or business as usual in the bar. Walking to stretch legs cramped by six weeks on board. Setting off to explore as much as possible of this strange new place chance had landed us in. Or slipping away to be alone for a little while, maybe make a quick phone call home ... or post that letter which has been six weeks in the writing.



Jane Read is a scientist at IOS Deacon Laboratory. Her research interests include the large-scale oceanic circulation, and physical processes of the upper ocean. Associated fieldwork has taken her on cruises in many parts of the world.

We hope to have a report of the 'Sterna' cruise in the next issue of *Ocean Challenge*.

Pulling the Plug: the ocean floor revealed

Anthony S. Laughton

"The trouble with oceanography is the water," complained a distinguished marine geologist, "How nice it would be if we could pull the plug and let the water out – then we could really see what is there." I have spent my research career trying to 'see' what is really there – with underwater photography, with echo-sounding and ocean-mapping, with side-scan sonar and with sea-bed sampling. Indirectly, I have had to use the whole armoury of geophysical techniques. I want to share with you some of my experiences in discovering submarine morphology and to give you some insight in the achievements of the many people who have worked in this field.

Bathymetry – a Boon to Navigators

Because light has such a limited range under water, the earliest ideas about the sea floor were limited to the very shallow water along the shore, or to depths which divers could reach by holding their breath. But navigators needed to know of the shoals and rocks so as to make safe passage, and measured the depth by lowering weighted lines to the bottom. For centuries the lead and line were the standard method of sounding the depth of the sea. Not only were hazards discovered, but seamen found that depths, and particularly the change of depth along a course, could help them to navigate. In 1584, the first printed volume of compass charts and sailing directions was published in Holland for the use of mariners working around Europe. It was called *The Mariner's Mirror* and the charts included spot depths which could be used as aids to navigation (Figure 1, overleaf).

The need for knowledge about the shape of the sea floor for navigation continues to this very day. Supertankers operating on the continental shelf sometimes sail with as little as two metres clearance under their keel. In the deeper ocean, submarine warfare would today be conducted as a cat-and-mouse operation, with submarines taking advantage of sea-floor features to hide from sonar detection – as anyone who has read *The Hunt for Red October* will know.

Economic Incentives

The exploitation of the oceans and their resources has been a stimulus to finding out the shape of the sea-bed. Fishermen have always been wary of snagging their nets on the sea bed, especially when trying to catch the fish that live just above it. Many of the most prolific fish stocks live around sea-floor features where they can hide from predators, or can take advantage of the high biological productivity resulting from upwelling induced by topography.

In the 19th century, the development of cable telegraphy led to the need to lay cables across the Atlantic to speed communication between the old and the new worlds. Surveying for the routes of these cables, and the engineering aspects of laying them, required a new understanding of the shape of the sea floor. A mountain range was found to lie in the centre of the Atlantic, and was named 'Telegraphic Plateau' by Matthew Fontaine Maury, of the US Navy. Depths were determined by wire

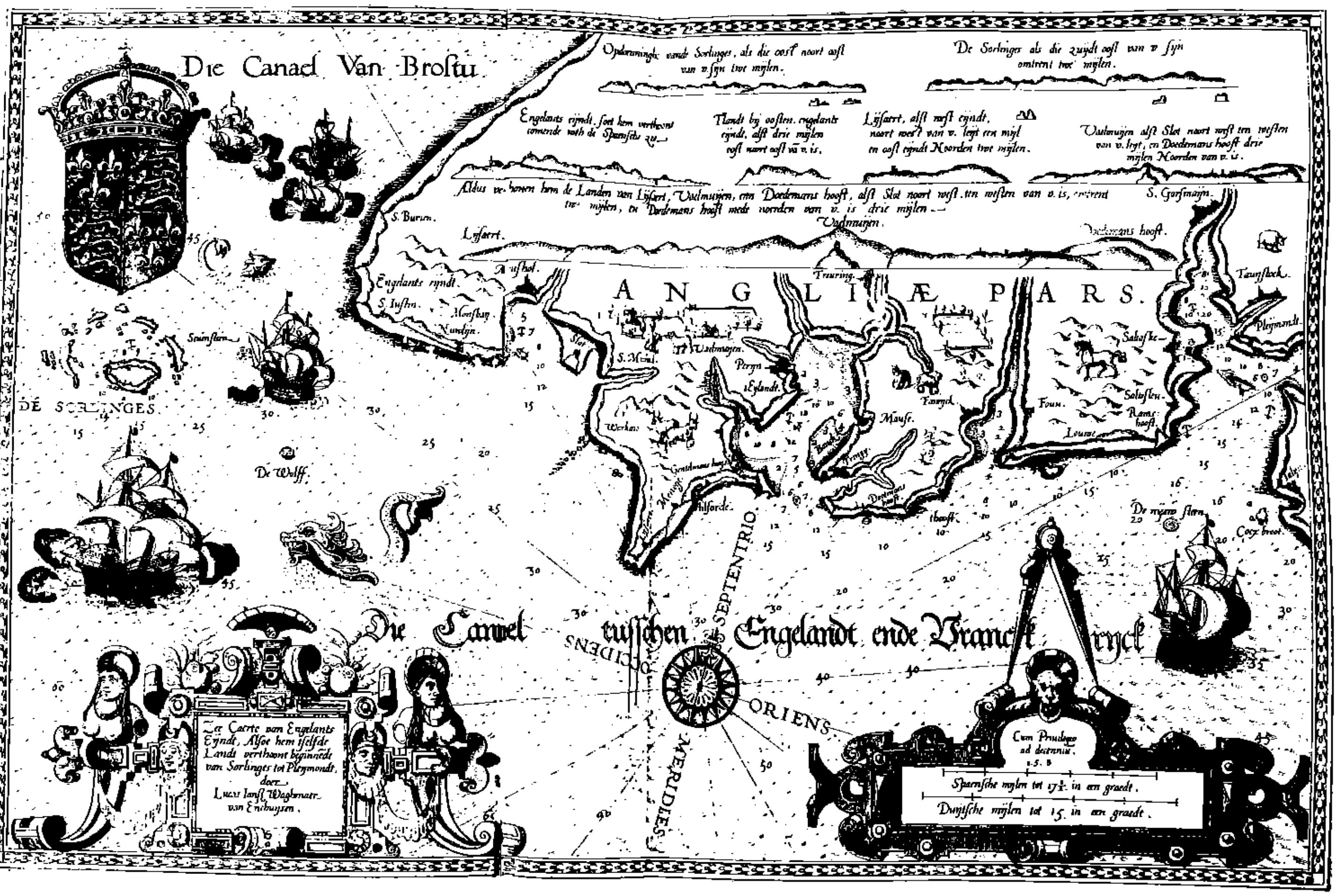


Figure 1 Sea-chart of the coast of south-west England by Waghenaer, from The Mariner's Mirror, *published in 1584.*

sounding machines which could also bring back samples from the bottom, either embedded in tallow placed in the bottom of the lead or, later, as cores taken with the sounding apparatus (Figure 2, right). These sea-bed samplers opened the way to submarine geology.

The potential for exploiting minerals from the sea-bed has also been a stimulus to ocean-floor mapping. Although hydrocarbon extraction is still limited largely to the continental shelf, there are believed to be substantial reservoirs in the sedimentary aprons of the continental rises and in continental fragments, such as the Rockall Plateau, that lie offshore in deeper ocean

The discovery of huge fields of manganese nodules on the floor of the Pacific Ocean and elsewhere led some to believe that there was a financial bonanza to be had from ocean-floor minerals. This was a trigger for the United Nations Conference on the Law of the Sea (UNCLOS) which culminated, after ten years, in the 1982 Convention. This regulates not only the ownership and extraction of mineral resources from the sea, but almost every other aspect of legislation regarding the rights and duties in the oceans of individual states and the world community of nations. The concepts of the Territorial Sea, the Exclusive

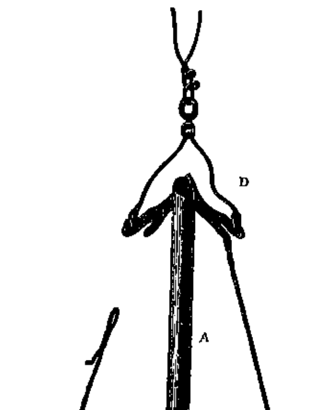


Figure 2 A deep-sea sounding apparatus and corer, designed by John Mercer Brooke of the US Navy in about 1854. As the apparatus hit the sea-bed, the weight (a 64 lb shot) drove a hollow tube into the sediment. The impact with the sea-bed (shown here) activated a release mechanism, so that when the sediment core was retrieved the weight remained behind on the sea-bed.

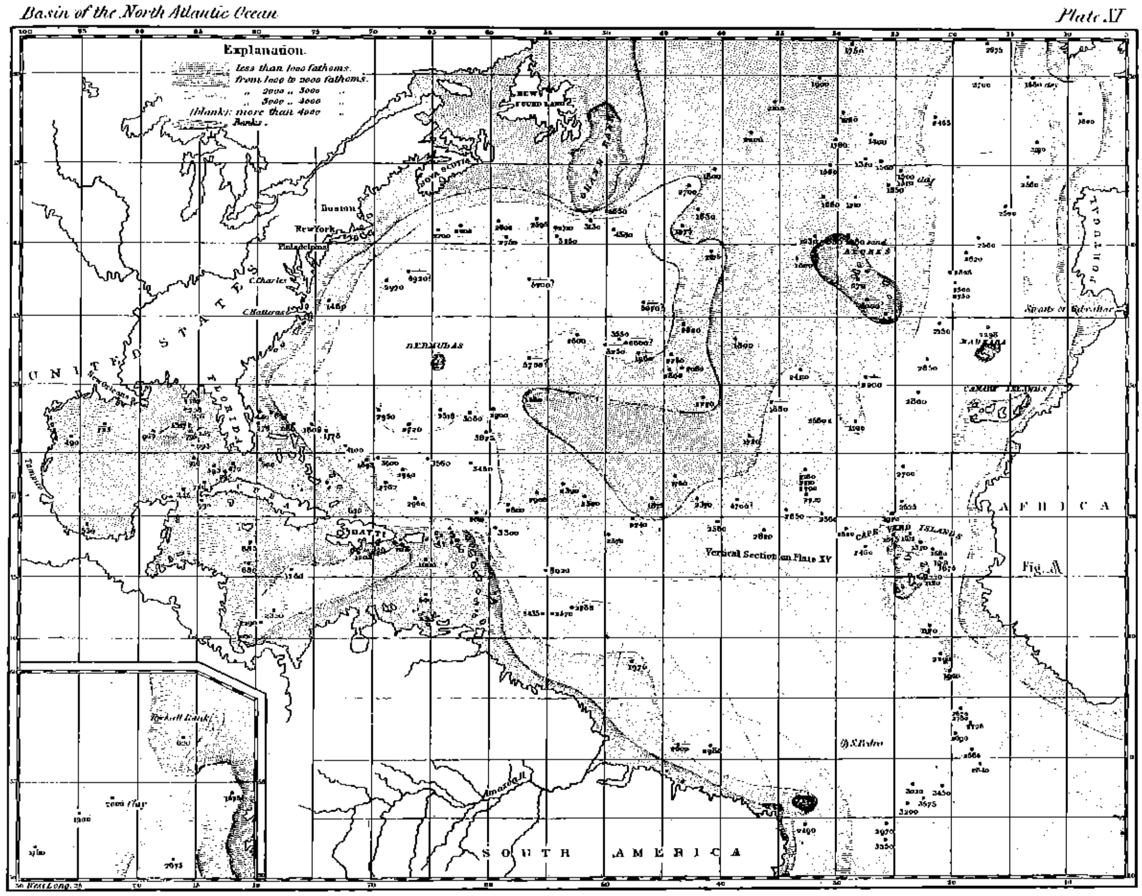


Figure 3 Maury's chart of the basin of the North Atlantic, one of the earliest contour maps of a whole ocean basin. This is the 1861 edition, repoduced in The Physical Geography of the Sea.

Economic Zone (EEZ) and the Continental Shelf have been defined. In the case of the Continental Shelf, the legal definition was quite different from that used by oceanographers and required precise location of such bathymetric features as the 'foot of the continental slope' and the 'maximum rate of change of the slope'. A complex formulation, known as the Irish Formula, was developed to define the term in order to make the text of the 1982 Convention text compatible with the 1958 Law of the Sea Convention on the Continental Shelf. In November 1994, having been ratified by the required sixty states, UNCLOS becomes international law.

But the greatest stimulus to exploring the floor of the oceans was curiosity, leading to scientific investigation. Ancient Greek philosophers speculated that the depth of the oceans was probably the same as the height of mountains, and in that they were not far wrong. The first attempts to measure the depth of the deeper ocean by lead and line were made in 1773, when Captain Phipps sounded a depth of 683 fathoms (= 1 250 m) in the Norwegian Sea. But the really great ocean depths were not measured until 1840 when Sir James Clark Ross (now commemorated in the name of the new UK research vessel) measured the fall rate of a weight on the end of four miles of sounding line and noted the slowing down when the weight hit the bottom. He measured a depth of 2 425 fathoms in the South Atlantic.

The Development of Contour Charts

More and more line soundings were made, so that by 1855 Maury was able to publish a contour chart of the Atlantic Ocean (Figure 3). The oceanographic significance of sea-floor bathymetry was recognized by Charles Wyville Thomson and Thomas Henry Tizzard in 1876 when they deduced the continuity of the Mid-Atlantic Ridge in the South Atlantic from the difference in the temperature of the bottom waters on either side.

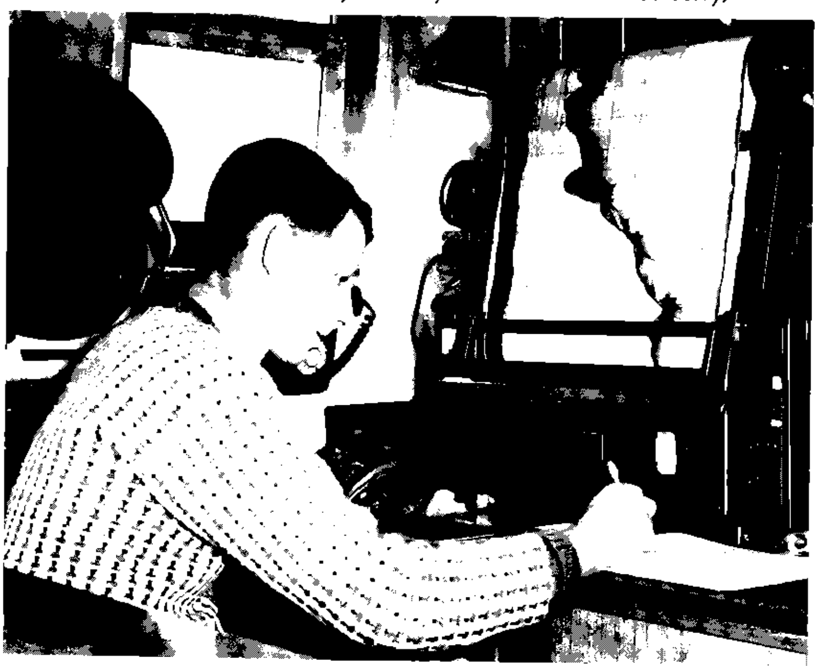
The explosion of soundings that took place when sonic methods were developed, and especially after the 1939–45 war when oceanographic expeditions multiplied (Figure 4, overleaf), meant that new methods of collecting and distributing the data had to be developed. Both in the UK and in the USA, sheets of collected soundings were compiled at a scale of 1 : 1 000 000 to provide a database for preparing contour charts. Eventually the responsibility for different areas in the world were allocated to particular countries.

The first contoured charts to cover the whole world were initiated by a group of scientists at the 14th Geographical Congress in Paris in 1899 who recognized that there were enough data to prepare a set of maps in a uniform style. Prince Albert the First of Monaco, a distinguished amateur oceanographer, undertook to have these compiled and contoured in Monaco, and in 1904 the 24 sheets of the General Bathymetric Chart of the Oceans (GEBCO) were published at a scale of 1 : 10 000 000.

It was inevitable that the first edition of the GEBCO charts rapidly became out-of-date, and new editions had to be published periodically. The responsibility for producing these new editions passed to the International Hydrographic Bureau in Monaco and later to the Institut Geographie National in Paris. But in the 1960s funds ran short; the quality of the product deteriorated, the charts failed to reflect the new knowledge of sea-floor processes that were being discovered, and sales fell to only a few charts a year.

To improve matters and to introduce a scientific element, in 1972 the Intergovernmental Oceanographic Commission joined with the International Hydrographic Office in guiding the GEBCO project. As a result, for the production of the 5th Edition, new discoveries in marine geology were used in the interpretation of the sounding data, and new standards were developed. All the tracks used in contouring are shown on the face of the chart so that interpolations can immediately be recognized (as, for example, on Figure 8, on p. 44). The contours and tracks of the 5th Edition have now been digitized and form the basis of the GEBCO Digital Atlas (GDA) which will provide a tape or CD-ROM output of contours of the world oceans. The GDA will be regularly updated with new contoured data as these become available. The GDA can be converted into a gridded database, incorporating the marine geologists' interpretation of the data, from which any number of products (e.g. oblique views, showing 'shadows') can be made, to assist the visualization of the ocean floor.

Figure 4 *Precision Echo-Sounders were developed in the late 1950s and enabled details of the abyssal plains to be resolved. The photograph shows the NIO Precision Echo-Sounder and the author during the international Indian Ocean Expedition in 1964. (Photo by courtesy of IOS Deacon Laboratory)*



In the USA, NOAA and the National Geophysical Data Center have produced ETOPO 5, a gridded database of Earth topography – land heights and ocean depths – on a 5-minute grid. From this, global and regional charts can easily be generated by computer. However, for maps produced from ETOPO 5, it is not possible to judge the accuracy of the contours or to 'know' where they are supported by observational data. In some parts, data from classified surveys have been used whereas in others the interpolation is across large distances.

Seeing the Sea Floor in 3D

In the years after the Second World War, knowledge of the bathymetry of the oceans was of great military value for sonar performance, and for its relationship with the gravity field, and hence much of the best data were classified by the navies of the world. Unfortunately the restrictions imposed by classification slowed up the advance of marine science, so means had to be found to overcome them. Bruce Heezen and Marie Tharp developed the technique of drawing profiles of bathymetry along the cruise tracks at a vertical exaggeration of 20 to 1 and then sketching in their interpretation of what lay between. Thus were born the physiographic diagrams that are now found on every laboratory and classroom wall where the sea is studied. The ambiguity of position was sufficient to satisfy the worries of the navy! Arising from this work was the classic volume of 1959, *The Floor of the Oceans: 1. The North Atlantic,* in which the provinces of the ocean floor were defined, named and described in detail (Figure 5, opposite). Unfortunately, no further volumes were published.

In the 1960s, as part of their defence activity, the US Navy developed a multi-beam echo-sounder that was the first of the swath echo-sounders. The modern commercial counterparts are *SeaBeam, Hydrosweep* and others. The quality of data and the geographic coverage immediately improved by another quantum jump. Saturation coverage with overlapping adjacent lines meant that interpolation and interpretation were no longer necessary and that contouring could be done reliably by computer. Huge areas of swath bathymetry in the US EEZ, for a long time classified by the US, have now been released with great benefit to science. But there is still a vast amount from the open ocean that has not been released and which has immense scientific value. With the ending of the Cold War it is hard to see the justification for keeping it under wraps.

In those areas where there is saturation coverage by swath bathymetry, the data can be translated straight into a gridded data base and hence be used for all kinds of presentation. Profiles can be constructed, oblique

Figure 5 *Part of 'The Physiographic Diagram of the North Atlantic', by Bruce C. Heezen and Marie Tharp, from Heezen, Tharp and Ewing (1959)* The Floors of the Oceans 1. The North Atlantic, *Geological Society of America Special Paper 65. Copyright by Marie Tharp 1957.*
Reproduced by permission of Marie Tharp,1 Washington Avenue, South Nyak, NY 10960.
The map was first published in 1958, and a revised version was published in 1968. Further revisions were incorporated into the well-known 'World Ocean Floor Map', first published in 1977.

views of a pseudo-three-dimensional model can be generated and hill shading can be added. The information can be combined with other data as overlays or manipulated statistically. In other words they can be handled with considerable flexibility.

Side-scan sonar can also give saturation coverage of the morphology of the sea floor. The *GLORIA* system (Figures 6 and 7) has surveyed about 5 per cent of the ocean floor giving data on the texture, the shape and the trends of sea-floor features such as faults, seamounts, canyons and channels, sediment waves and slumps. It can also record the reflectivity of the sea-bed from different azimuths and at different inclinations, giving an insight into the composition of the sediments or rocks. These data are much more difficult to integrate into the conventional bathymetric databases since side-scan sonar does not give depth measurements except immediately beneath the ship's track. A new version of *GLORIA* combines swath bathymetry with side-scan sonar, but it is not possible to match the swath width since at the far sonar ranges the sound rays are nearly horizontal and depth calculations cannot be made.

Even less direct, but nevertheless important, data on the major features of the ocean floor come from the measurements by satellite of the deviations in the level of the sea from mean sea-level, as recorded by radar altimetry. These are caused by variations of irregularities of the equipotential surface arising from the varying distribution of depth of water and horizontal variations in the density of the sediments and rocks of the oceanic crust and upper mantle. Thus the signal includes a substantial influence of bottom topography. Since satellites have given a very complete world coverage of altimeter observation, there are data from this source from parts of the oceans which have never been visited by ships. Analysis of the altimeter from *SEASAT* gave a global view of morphology not unlike the global physiographic diagrams. More recently the data from the much closer spaced orbits of *GEOSAT* have refined this dataset so that in certain areas there is much new data with a resolution of 2 to 3 kilometres.

However, these data have to be treated with considerable caution. The measurements are of the perturbations of the gravity field. Thus large features (e.g. parts of the Mid-Atlantic Ridge) or microcontinental fragments, which are gravitationally compensated at depth in the crust or mantle, do not show up and smaller scale features are emphasized. Nevertheless, some very significant new data on the existence and trends of hitherto unknown fracture zones and seamounts have been found, especially in the more remote parts of

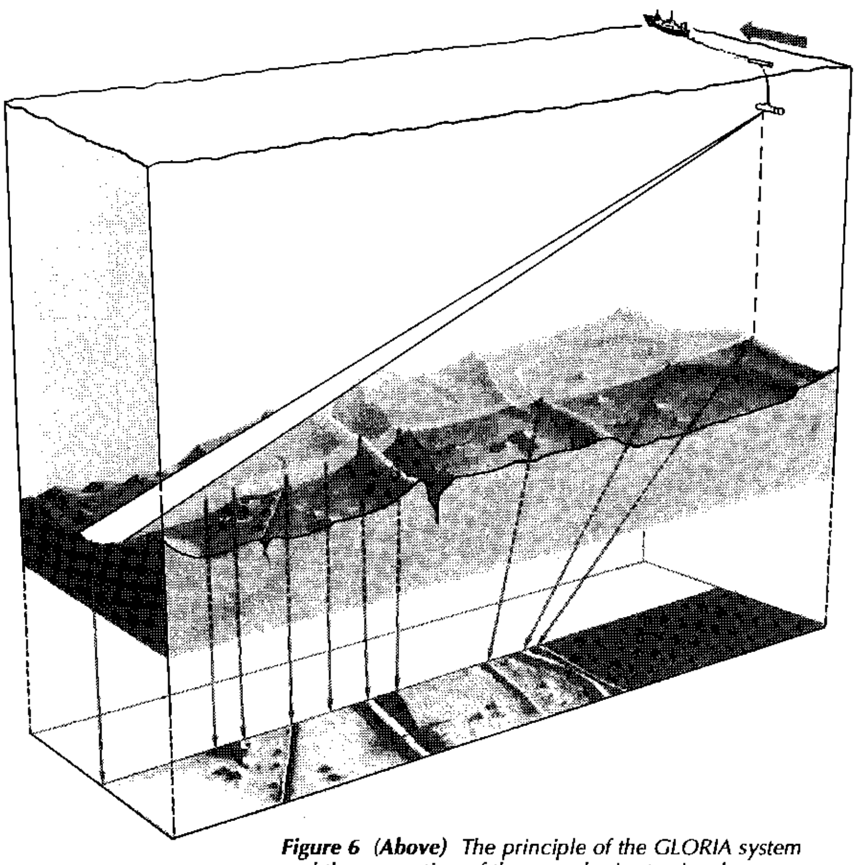
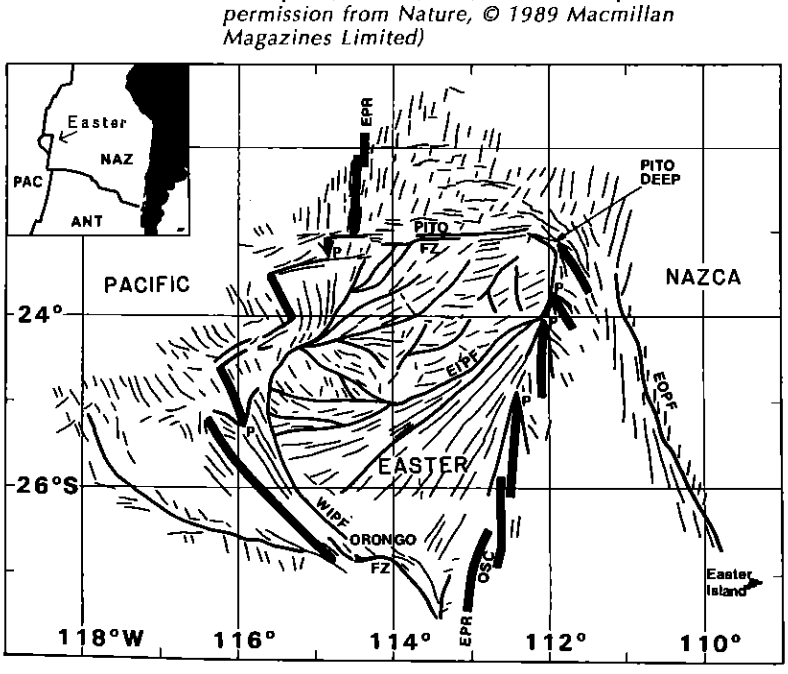


Figure 6 ***(Above)*** *The principle of the GLORIA system and the generation of the record prior to signal-processing to correct for slant range errors. Data is now acquired from both sides of the ship's track out to a range of about 30 km.*

Figure 7(a) (Below) *Tectonic interpretation of the GLORIA Easter Microplate survey (Figure 7(b), opposite) showing the plate boundaries and the fabric of the sea floor newly created by sea-floor spreading. (P indicates the tip of a propagating rift; WIPF, EIPF and EOPF are known as the West Rift Inner Pseudofault, the East Rift Inner Pseudofault and the East Rift Outer Pseudofault, respectively; FZ indicates a fracture zone and OSC indicates an overlapping spreading centre) (Searle* et al. *(1989) Comprehensive sonar imaging of the Easter microplate,* Nature, ***341****, 701–705. Reprinted with permission from Nature, © 1989 Macmillan Magazines Limited)*



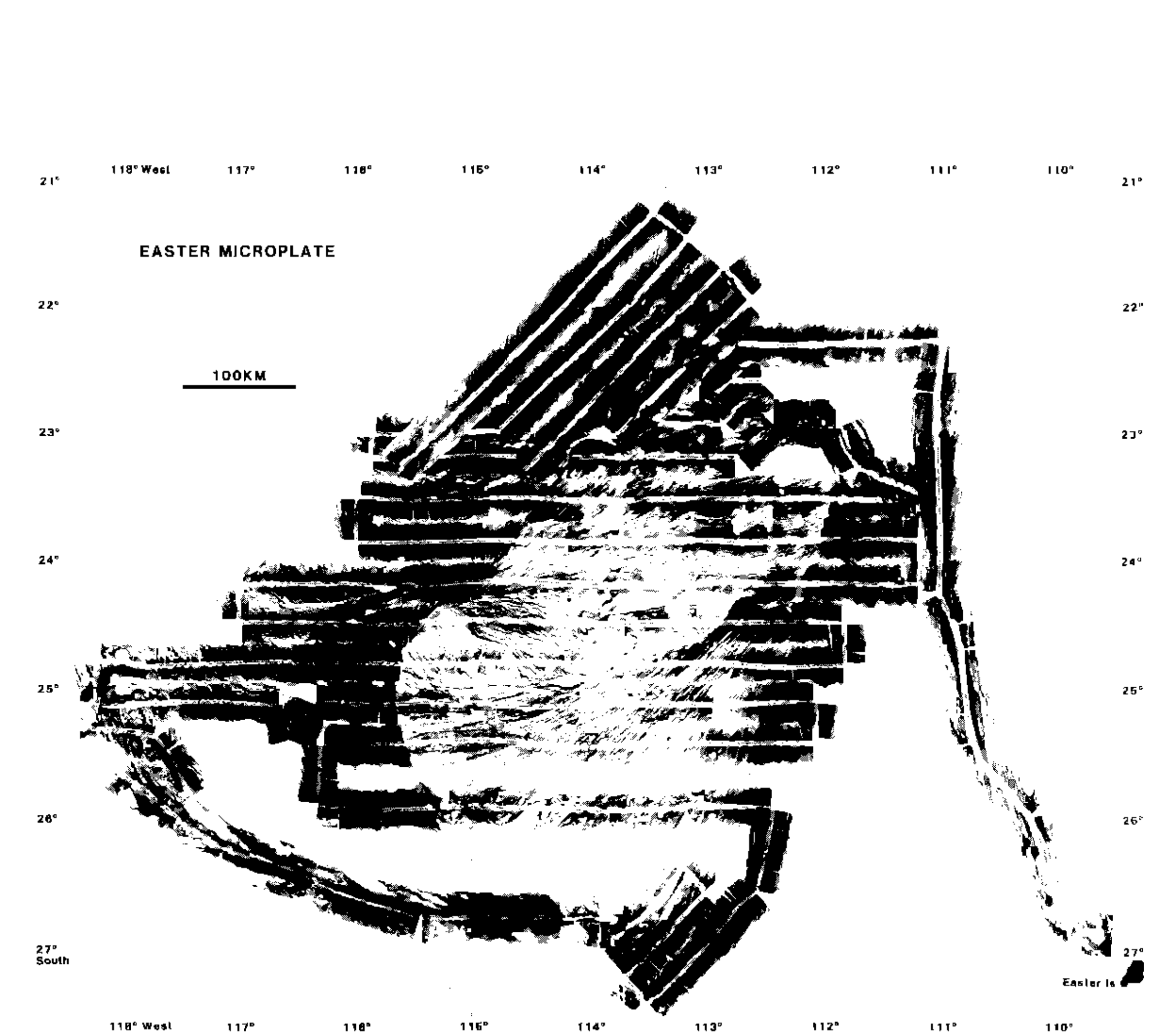


Figure 7(b) A mosaic of a long range side-scan survey by GLORIA of the Easter Microplate in the south-east Pacific. (Searle et al. *1989)*

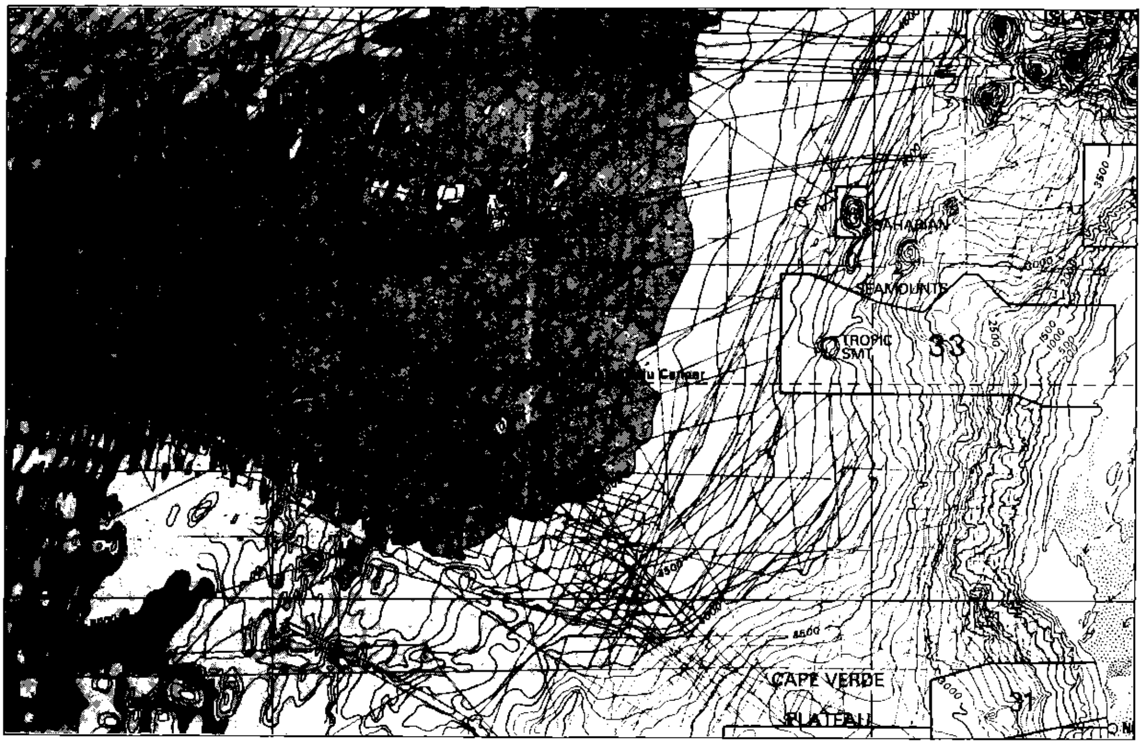
the south-west Pacific. It is clearly difficult to include these data in a bathymetric compilation since there are no direct measurements of depth, but it is essential that they are used in guiding the hand of the interpolater or interpreter when contouring.

The Bathymetric Database and Computer Contouring

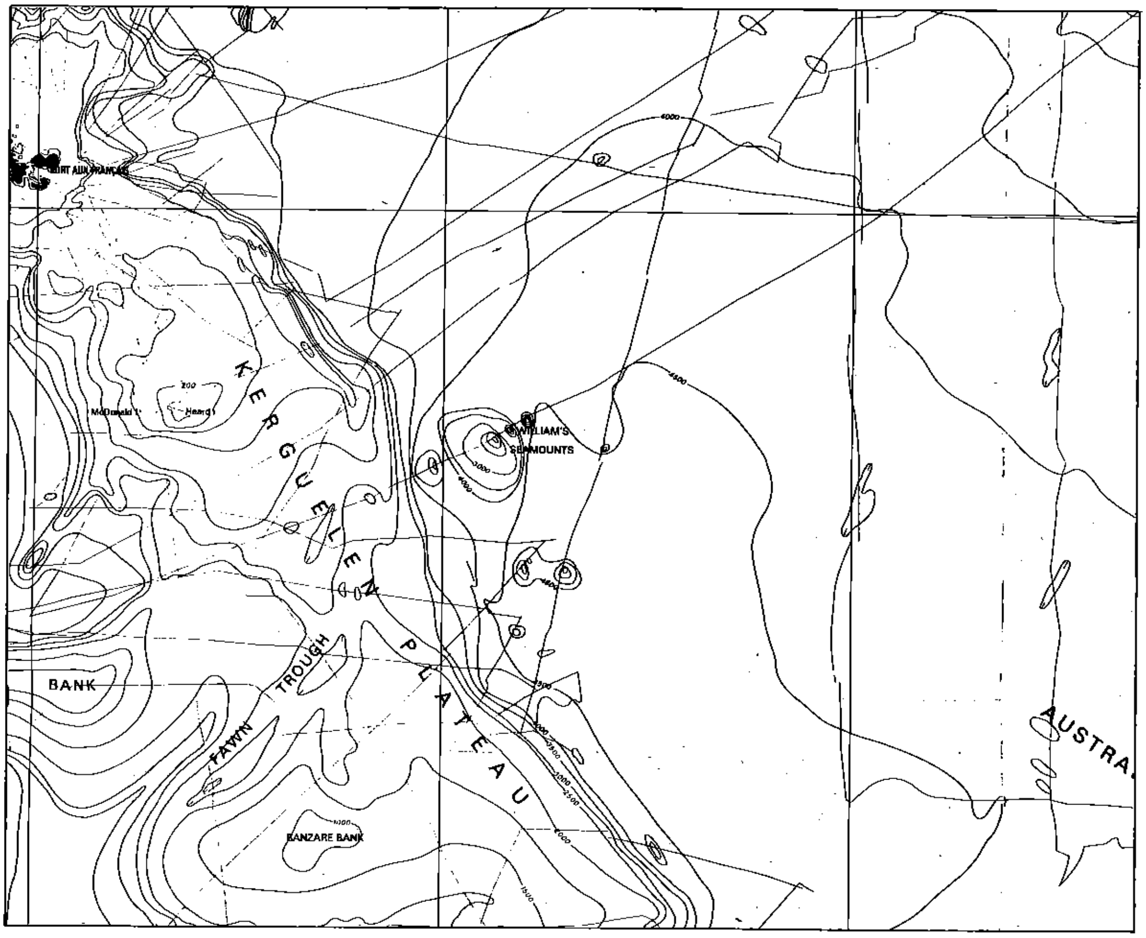
Our knowledge of the bathymetry is still limited by insufficient data. Although soundings along a track are very closely spaced, the separation of tracks outside those few areas of saturation coverage by swath echo-sounding is still very large. Even in the densely criss-crossed North Atlantic there are frequent holes where tracks are spaced by 100 kilometres (Figure 8(a), overleaf). In the remote parts of the southern Indian Ocean the holes are 500 kilometres wide, large enough to contain a large seamount chain or ridge (Figure 8(b)).

To contour such regions of low density sounding, the geologist has to draw on his or her other general knowledge, and on the contemporary understanding of sea-floor evolution and sea-floor processes, such as the continuity and trends of spreading centres and fracture zones, the tectonic fabric of comparable areas elsewhere where the data is denser, the sedimentation processes of turbidity current flow in generating abyssal plains and submarine canyons, and the relationship of sediment drift features to bottom currents. He or she will also be guided by sonar and satellite data.

Can this contouring be done by computers using expert systems 'trained' to include the knowledge of the marine geologist? There are widely differing views on this, often held with some vehemence. There are several groups around the world trying to tackle the problem. Amongst these are groups at the Alfred Wegener Institute in Bremerhaven, the University of New Brunswick in Canada, the NERC Unit of Thematic Information Services in Reading, as well as the mapping agencies in the USA. The problem breaks down into three stages: first to produce a digital database of *x*, *y*, and *z* (coordinates for position and depth), and quality control of the primary data; secondly to interpolate this to produce a regular gridded database at a suitable grid interval; and thirdly to contour the gridded database. The second stage is clearly where the difficulties lie, where assumptions have to be made about the nature of the surface between tracks, and procedures developed for interpolation, which incorporate the knowledge about the processes shaping the sea floor. I believe that there is still a long way to



(a)



(b)

Figure 8 (a) *Part of GEBCO sheet 5.08 in the North Atlantic, showing one of the more densely sounded regions of the world, but still with substantial gaps in coverage (the straight lines are the ship tracks along which sounding data have been. collected).*
(b) *Part of GEBCO sheet 5.13 of the southern Indian Ocean, showing the sparsity of sounding data. For both maps the width of the area shown is about 1 850 km or just under 1 000 nautical miles.*

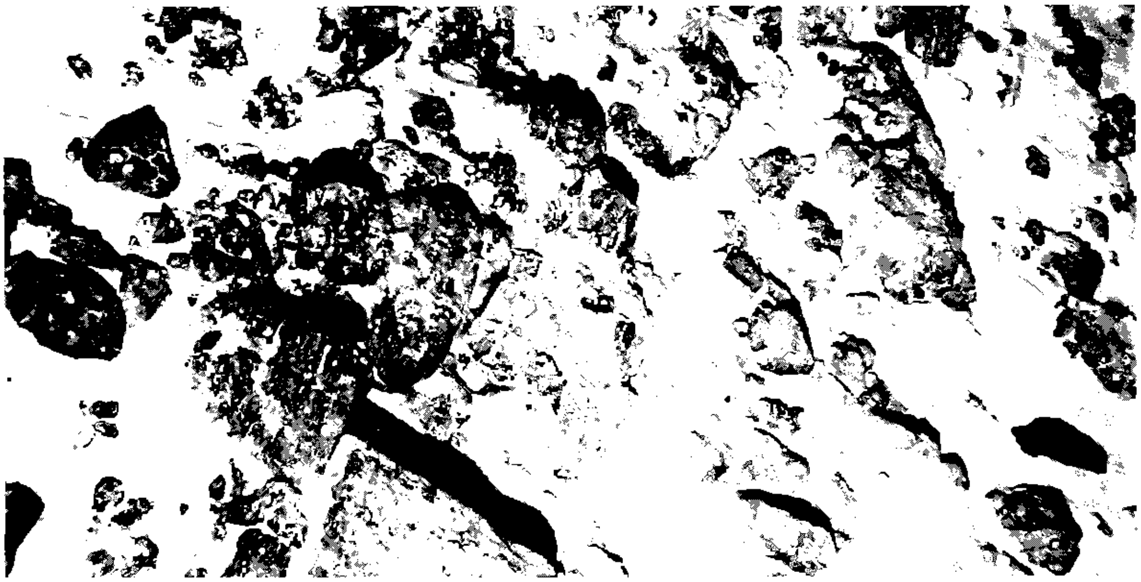


Figure 9 *Rock outcrops and boulders on the flank of Palmer Ridge, a faulted and exposed section of the oceanic crust in the north-east Atlantic. The slope is draped in white calcareous ooze. The photograph, which is of an area about 3 m x 4 m, is from a depth of 3 391 m.*

go before a machine-generated contour chart will be better than one incorporating the knowledge – and the prejudices – of the expert marine geologist.

Ultimately, the quality of any chart or product describing the morphology of the ocean floor depends on the data input. Apart from the rather small areas that have so far been mapped in great detail as part of a surveying programme, by far the greater part of the data come from research and naval ships on passage between ports and operations areas. It is still essential that every opportunity is taken to collect sounding data on passage and to ensure that it is of high quality and is submitted through the appropriate channels to the world databases. These are organized by the International Hydrographic Office whose members have specific areas of responsibility, and include the IHO Data Center for Digital bathymetry at Boulder, Colorado, USA. The appropriate channel is usually through the national hydrographic office.

Conclusion

In conclusion I would like to make three points:

• We are far from knowing the depth of the sea in the detail that is necessary. I would encourage, and indeed persuade, all those of you who go to sea to collect sounding data wherever you go and to submit them to the appropriate data centre.

• I would urge the navies of the world to examine their holdings of classified soundings and to consider whether it is essential still to classify them. Their release to science would be of enormous benefit and could avoid considerable expense in unnecessary re-acquisition of data.

• Digital methods are already enabling the shape of the sea-floor to be represented in a number of different ways and at different scales. We need now to be able somehow to incorporate the additional sonar and satellite data that can fill the gaps and improve the quality of the charts and atlases.

I started by talking about the marine geologist who complained about the water in the sea. When I see the waves on the sea surface, in my mind's eye I see the sea floor in all its complexity beneath (cf. Figure 9). I would like others, who have not had the good fortune to spend a lifetime studying the sea-floor morphology, to be able to interrogate a database and call up on a screen at their desks the images of the sea floor as they need them.

Further Reading

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This article is based on the John Raymont Memorial Lecture, which he presented in September 1992, at UK Oceanography (see p.7).

KRILL
the ecology of aggregation

Julian Priddle John Watkins Eugene Murphy

Since their exploration became possible, the seas around Antarctica have been the focus of considerable human attention and – as the devastated state of the stocks of great whales in the Southern Ocean testifies – not all of this attention has been benign. However, exploration and scientific investigation have proceeded steadily alongside the commercial exploitation of marine living resources.

Initial biological investigations indicated that the large numbers of whales and seals were the apex of a short food web in which dense blooms of large diatoms were grazed by a dominant zooplankter – the Antarctic krill. However, perceptions of this system have changed radically over the last decade. Of most significance has been the realisation that the early picture of abundant and productive phytoplankton was based on atypical coastal environments, and that in fact overall primary production is low. Smaller members of the microplankton have been shown to play an important part in nutrient cycling and primary production, and herbivorous zooplankton other than krill are important within the food web.

Although the importance of other members of the zooplankton is now recognized, it remains clear that krill are a very significant component of the Southern Ocean ecosystem, and that understanding the biology of this key species is essential. Several statistics indicate its importance. Krill are the subject of the largest pelagic crustacean fishery in the world, with annual catches reaching 500 000 tonnes in the 1980s. They are also the staple diet of a very wide range of predators – fish, squid, birds, seals and baleen whales; their combined uptake is more difficult to estimate, but has been put at between 10 and 500 million tonnes.

Krill Swarming

A crucial aspect of the biology of krill is the formation of dense aggregations, usually referred to as 'swarms'. Swarms range in size from metres to several kilometres in extent and may contain animals at densities of a few thousand individuals per cubic metre of seawater (i.e. at least one per litre) (Figure 2, opposite). Here, we explore the implications of swarming for krill and for other components of the food web.

Most of the information on krill swarms is derived from three sampling techniques – capture in nets, direct observation, and acoustic sensing (Figure 3, opposite). Classically, nets have been used to capture krill along with other zooplankton. Research trawls sample such large volumes of water that they do not resolve individual swarms, but these may be sampled by multiple or serial nets (Figure 4, overleaf) such as the MOCNESS system or the Longhurst–Hardy Plankton Recorder (LHPR). Initially, direct observation of krill swarms was only possible for those aggregations close to the sea surface, but modern cameras allow

***Euphausia superba* Dana**

Figure 1 *Antarctic krill are euphausiid crustaceans. They are quite large, reaching an adult length of 60 mm, and long-lived, with a potential lifespan of 5–7 years. They are predominantly herbivorous, feeding by sieving particles of between 5 and 50 μm from the water. They are planktonic, and spend most of their lives in the upper 200 m of the water column. They are active animals which need to swim continuously to maintain their position in the water column.*

Within a krill swarm there is a high 'packing density' of individuals

scientists to study swarms *in situ* at all depths. Recently, acoustic techniques originally designed for fisheries have been modified to provide the means to detect and quantify krill biomass over very large areas of the Southern Ocean.

Despite the large amount of data on Antarctic krill, including the results of the multinational BIOMASS programme and recent data from commercial fishing operations, several important questions about swarming remain unanswered. How do swarms form? How long do swarms last? What proportion of the population is contained in swarms? Why do krill swarm?

Unfortunately, we lack the technology to make the direct measurements necessary to answer many of these questions. Collation of existing information often fails to provide sufficient consistency to allow us to test hypotheses – krill have obviously taken to heart the adage that rules are made to be broken! However, existing techniques have enabled us to gain important insights into the characteristics of individual swarms, and thus start to build up an understanding of the role of these aggregations.

Figure 2 *Photograph taken within a dense krill swarm, illustrating the high 'packing density' of individuals. Underwater photography, both with cameras lowered from ships and those used by divers, has provided a valuable research tool. Diver observations have shown that sometimes krill in swarms may be aligned, as is frequently observed in fish schools. However, random orientation as seen in this picture is also common. Stereo photography enables precise positioning of animals to be measured, and these data together with information on orientation are needed for refining models of acoustic backscatter.*

Our group of biologists as BAS has been involved in a programme of research on krill swarms for several years. We identified one key problem that could be tackled with existing technology – the composition of

The position and shape of krill swarms may be determined using echo-sounders

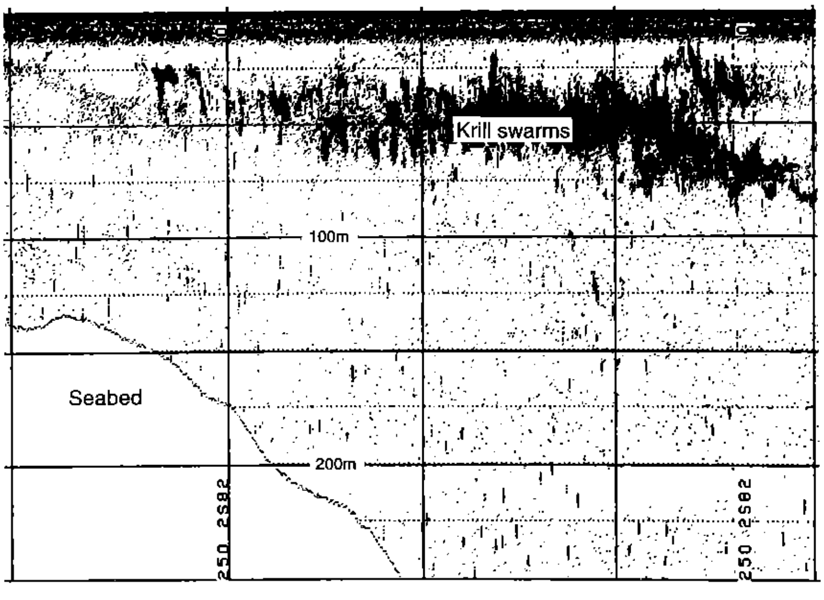


Figure 3 *Acoustic image showing krill swarms associated with the shelf-slope break at the sub-Antarctic island of South Georgia. This image was obtained using a 120 kHz hull-mounted transducer – the horizontal scale is approximately 4 km, and the depth range is 250 m beneath the hull. High scatter close to the surface is due to bubbles. The scientific echo-sounders used in krill research are usually of slightly higher frequency than those used for fish – frequencies up to 200 kHz are employed.*

Deployment of the BAS serial sampler

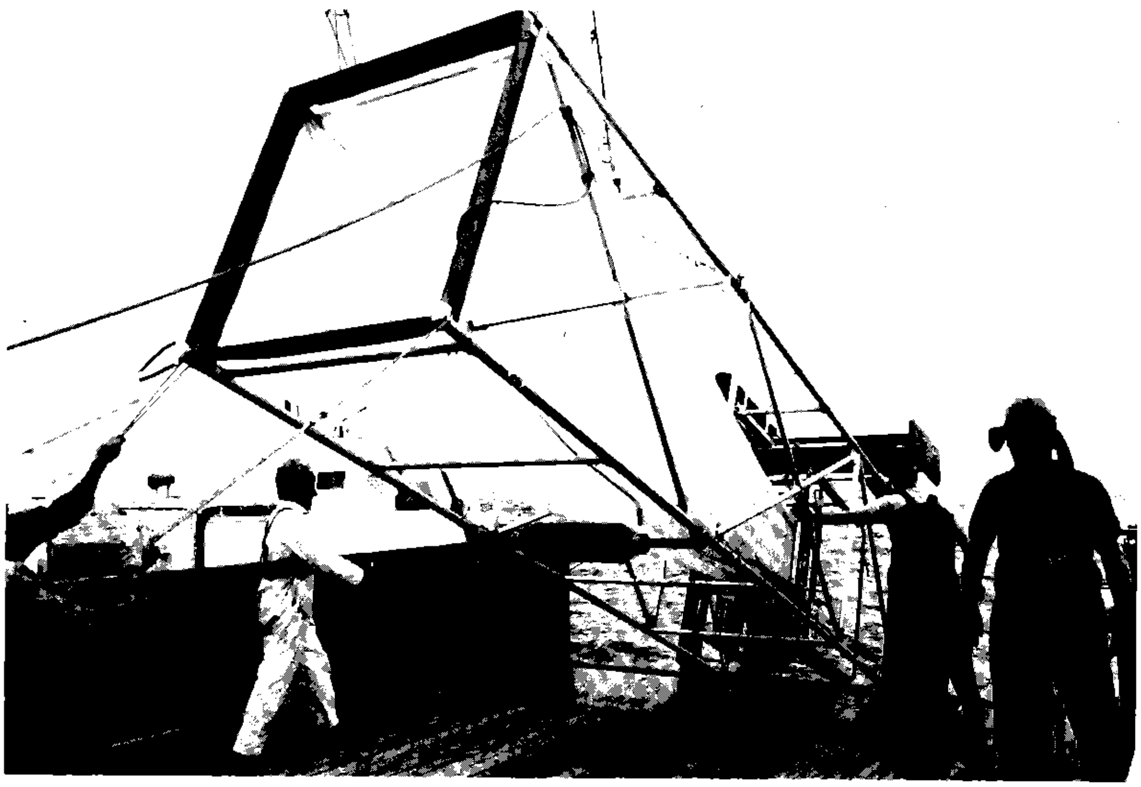


Figure 4 *Large serial sampler for krill, developed at BAS and deployed from RRS* James Clark Ross. *The sampler consists of a large mouth joined to a mesh cone which concentrates animals at the back of the net. A series of individual cod-ends can be opened and closed by command from the surface, and capture individual catches of krill and other zooplankton.*

individual swarms. Working in waters off the tip of the Antarctic Peninsula, we sampled swarms with a very large version of the LHPR. Using the presence of discrete catches of krill in the LHPR in conjunction with acoustic techniques, we could identify individual swarms – up to five in a single tow. Animals from distinct swarms were classified according to size, sex and maturity stage, moult class and fluorescence of chlorophyll in the gut. Analysis of these data show that the animals in different swarms do not simply represent a random subsample of the local population. A few swarms showed dramatic peculiarities – such as a 1 :4 sex ratio (instead of the more usual 1 :1), or over 90 per cent moulting animals – which could not have arisen by chance. Such was the heterogeneity of the swarms, that adjacent swarms in single hauls of the LHPR were likely to differ as much as swarms from different hauls. We estimated that it would be necessary to sample over twenty swarms to gain a statistically reliable characterization of the local population. The differing compositions of swarms seem to indicate some process of segregation, although the nature of this is unclear. Certainly, we cannot link the properties of the swarms to any simple environmental factors such as depth or time of sampling, or to characteristics of the swarm such as size or shape (estimated acoustically).

Whereas sex or length are properties of the animals themselves, with little or no short-term variability, gut fullness (measured by fluorescence of chlorophyll in the gut) is affected by food availability over short time-scales. Great variability between and within swarms was observed. No link to the type of animal could be established, nor could the variability between swarms be linked to the abiotic environment or properties of the swarms. Clearly, the main determinant of gut fullness in swarming krill is the *distribution* of the phytoplankton food supply. Gut throughput time for krill is of the order of 30 minutes to one hour, and krill can feed sufficiently fast to ensure that plentiful food is exploited rapidly. Thus krill swarms have short 'memories' of feeding. The distance scales of swarms are similar to the range of significant patchiness in phytoplankton abundance, and feeding by swarms could be a major determinant of phytoplankton patchiness at these scales.

We have further developed this scale-based approach to krill, with the aim of determining how krill interact with the environment both as individuals and in aggregations. We have started with the premise that interactions within an ecosystem are mediated by processes which have similar time- and space-scales. Thus vertical mixing over the euphotic zone on time-scales of hours determines the photosynthetic physiological adaptation of phytoplankton, whilst environmental variation on larger scales determines biomass accumulation and, ultimately, species composition. Underpinning this framework is the simple relationship between time- and space-scales for different turbulent processes in the open ocean (Figure 5). According to our hypothesis, this same relationship can be used to construct similar diagrams for phyto-plankton, krill and large predators. The processes involved in particular interactions can be identified, as can the importance of different degrees of aggregation of krill.

Krill are exploited by a wide range of predators, ranging in size from other zooplankters to whales. The smallest krill predators exploit krill as individuals. Here swarming may carry some of the benefits that schooling imparts to fish – the ability to avoid predation by forming dense groups. However, we also see that the largest predators are interacting with swarms as the functional unit – they feed on swarms rather than on individual krill. It is only possible for baleen whales to feed on krill *because* they swarm, and it would seem that, in this case, swarming is counterproductive so far as the krill are concerned.

On ice ... or under it?

So far, we have discussed krill as an inhabitant of the open ocean. However, during the winter a significant proportion of the Southern Ocean is ice-covered, and much recent research has been directed at the question of how krill survive during winter. It was supposed that phytoplankton biomass was too low to support krill during the Antarctic winter, and various 'strategies' were suggested.

Statistics compiled from pelagic whale catches suggested that the southward-migrating whales were feeding at the receding ice edge. We now know that these whales were exploiting krill overwintering beneath the ice. During the last five years, other research groups have deployed remotely-operated vehicles at the ice edge and discovered high densities of krill feeding on algae growing on the underside of the ice.

The scale-related connotations of this habitat switch are interesting. From being a pelagic animal, krill are seasonally adopting an epibenthic way of life (albeit upside-down). The two habitats are very different as far as variability is concerned. We noted that krill swarms as feeding units were moving in an environment where the food supply was patchy on scales similar to the size of the swarms. We can hypothesize that below this scale, turbulent mixing of the phytoplankton is sufficiently rapid that no environmental variations can be distinguished by individual

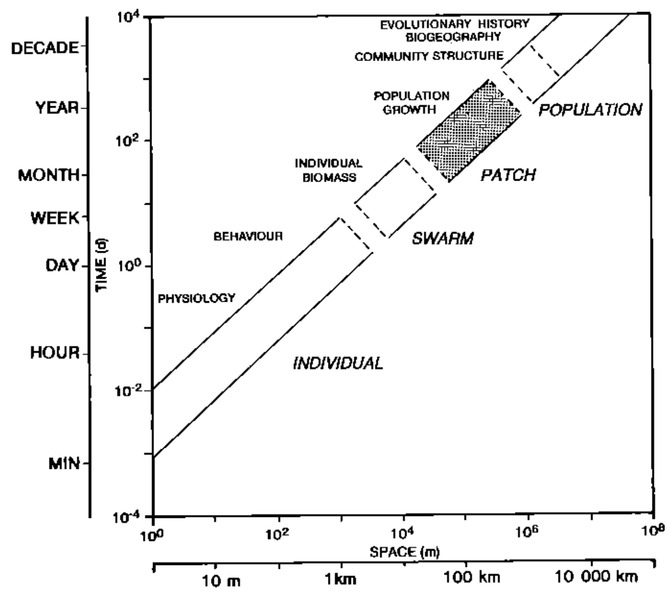
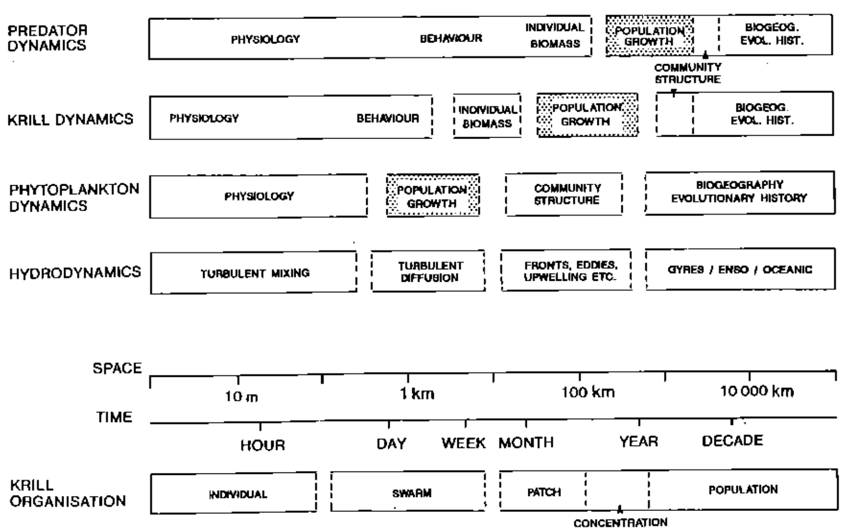


Figure 5 The interactions of krill and krill swarms with other parts of the Southern Ocean ecosystem are complex, and different phenomena occur at different scales.

In the ***upper panel****, we have superimposed aspects of krill biology and aggregation on a conventional relationship between space- and time-scales for turbulence in the ocean. What is represented is variability and the organisms' responses, not an indication of the physical dimensions.*

The ***lower panel*** *illustrates ecosystem interactions over a range of scales – the space–time relationship has been collapsed to a single axis. Note that this relationship for the under-ice ecosystem and other habitats will differ markedly from that for the pelagic ecosystem.*



For krill, their food and their predators, variations in different aspects of their behaviour and ecology – including population growth – may be related to variations in environmental factors occurring on similar time- and space-scales

krill. On the underside of ice, which is by contrast a structured, nearly-static environment, the feeding biology alters radically, and the individual krill can browse on a lawn of diatoms.

As well as feeding grounds, the ice also provides refugia from predators. We do not believe that all krill participate in this cycle, emerging from under the ice each spring to spend summer in the plankton, but it seems likely the behaviour represents a significant mechanism for over-winter survival in the Weddell Sea and some other regions.

The Place of Krill in a Changing Ecosystem

In addition to their importance to a wide range of predators, krill are the subject of a major fishery. The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) has the goal of limiting impact on any species to acceptable and reversible levels, in addition to recommending management criteria for exploited species. Scientists from many countries are seeking to extend management models for single species to a model for a complete ecosystem. The need for such a management strategy is emphasized by past events. At the beginning of the century, baleen whales were probably the single main consumer of krill in the Southern Ocean, perhaps accounting for half of the total predator uptake. Following the massive reduction in stocks of the baleen whales by shore-based and then pelagic whaling, a significant adjustment in the Southern Ocean ecosystem must have taken place.

The temporary change in uptake by predators is considered by some to have produced a surplus of krill, which in turn would have become available to other consumers. Is there evidence for this attractive hypothesis, to test the effects of one of the largest – albeit unintentional – experiments in the manipulation of an ecosystem? Our scale-based approach to krill–predator interactions predicts that it will be larger predators, exploiting krill at the swarm level as did the baleen whales, that might benefit from the putative surplus. Demographic data on the minke whale (a baleen whale that was not exploited during the main era of Antarctic whaling) and the crab-eater seal (another large mammal dependent on krill) seem to indicate that animals are breeding earlier and populations are expanding.

However, this information reflects complex interaction amongst species, and between species and their environments, and is difficult to interpret. First, some other predators whose populations are expanding at present are themselves recovering from exploitation. The Antarctic fur seal is a prime example, spreading from a group of a few animals on islands near South Georgia to reach such levels all around the maritime Antarctic that it has a major ecological impact at some coastal terrestrial sites. Secondly, we are only just beginning to appreciate the importance of long-term variability in the Southern Ocean ecosystem. A recent study of the population biology of sibling species of penguins suggests that climate-mediated habitat availability, rather than a surplus of krill in the 1940s and 1950s, may be responsible for population changes of some krill predators. Long-term data for a number of Antarctic seal populations indicate interannual variability which correlates well with El Nino–Southern Oscillation (ENSO) events. Documented year-to-year variation in the reproductive success of land-breeding predators at South Georgia can be related to local krill availability, and periodic crashes where krill are absent appear to be caused by hydrographic phenomena and also show possible correlation with ENSO events. Similar variability is apparent in whale-catch data from South Georgia in the 1920s. Thus at the upper end of the ecosystem variability framework (cf. Figure 5), the relationships between krill, swarming, predators and environmental variability and change, are highly complex.

Even after reassessment of the Southern Ocean ecosystem, the Antarctic krill emerges as an important species. Aggregation is a crucial aspect of its biology, which determines how it interacts with other parts of the food web. The species also provides a useful case-study for ecological modelling, as an organism which participates in a range of differently-scaled interactions at different levels of aggregation.

Julian Priddle, John Watkins and Eugene Murphy are all biologists at the British Antarctic Survey, Cambridge.

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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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