OCEAN Challenge

The Challenger Society for Marine Science

Volume 7, No. 1, 1997

Volume 7, No.1, 1997

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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

PUBLICATION INFORMATION

The publication schedule has long been out of step with the calender year. We have decided to rationalise our publication dates, so there will be no Volume officially dated 1996. Volume 7, Nos. 1 to 3, appearing in 1997, is officially dated 1997. Please see pp.53–54 for a list of past issues and their content.

In the past, the difficulties of maintaining a high standard of production and content on limited resources has meant that publication delays have been unavoidable. We are happy to say that, with the increasing strength of the Society, this situation has now changed and support for the magazine is on a much firmer footing.

SCOPE AND AIMS

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

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

INDUSTRIAL CORPORATE MEMBERSHIP

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

INSTITUTIONAL SUBSCRIPTIONS

Ocean Challenge is published three times a year. The subscription (including postage by surface mail) is £70.00 ($133) per year for libraries and other institutions. New subscriptions, renewals and information about changes of address should be sent to Parjon Information Services, PO Box 144, Haywards Heath, West Sussex, RH16 2YX, UK.

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.

Printed in the UK by Halstan & Co. Ltd, Amersham, Bucks **ISSN 0959 0161**

CONTENTS

The cover was designed by Ann Aldred Associates.

Acknowledgements
Going anticlockwise around the spiral, from smallest picure to largest, the images are: (1) A false-colour visible wave-band image based on *SPOT* data showing the mouth of the Gironde Estuary in western France and illustrating the distribution of suspended particulates. Image produced by Ian Robinson from UNESCO educational material provided by P. Castaing and J. Froidefond. (2) *EOSAT* image showing turbidity in the northern Adriatic off the coastal lowlands of Albania. The processed and enhanced image is by courtesy of the British Geological Survey. Reproduced by permission of the Director, BGS, NERC. All rights reserved. (3) Modelled mean lagrangian velocities and long-term trajectories in the Channel, from the EU MAST project Fluxmanche. Reproduced by courtesy of J.C. Salomon, Ifremer, Brest. (4) Part of a global image of sea-surface temperature observed by the Along-Track Scanning Radiometer (ATSR). The data have been extracted from the ASST CD-ROM produced by the Rutherford Appleton Laboratory. Image produced by Ian Robinson. (5) Sea-surface temperature in the North Sea during early summer, showing a coastal fringe of warmer water, derived from data obtained by the NOAA AVHRR sensor. Image produced by Ian Robinson. (6) *ERS-1* ATSR image showing sea-surface temperature of the western Channel. © Rutherford Appleton Laboratory/NERC/ESA/BNSC. The central globe was produced by Tom Van Sant, Geosphere Project, and made available through the Science Photo Library.

Forthcoming Events

Events in 1997

The Impact of GPS on Future Navigation (Royal Society/Royal Geographical Society Technology Lecture). 20 May, London. By Prof. Vidal Ashkenazi. *Contact* The Scientific Meetings Secretary, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG. Tel. +44-(0)171-839-5561, extn 2576; Fax: +44-(0)171-839-2170.

Modern Ocean-Floor Processes and the Geological Record (Joint Meeting of the Marine Studies Group of the Geological Society, BRIDGE and the Challenger Society for Marine Science). 20–21 May (new date), The Geological Society, Burlington House, London. The latest research will be applied to ore-bearing and fossilised mid-ocean ridge systems on land. Leading experts will present their findings on both modern and ancient systems. Topics will be: Day 1: Crustal accretion at modern and ancient mid-ocean ridge systems; Alteration of oceanic crust and evaluation of hydrothermal fluxes. (Posters at the Royal Institution of Great Britain.) Day 2: Refining our understanding of ore formation; Site colonisation: evidence from modern systems and the geological record. *Contact* Dr Keith Harrison, BRIDGE Programme Manager, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT UK; Tel: +44-(0)113-233-5241; Fax: +44-(0)113-233-5259.

Connecting European and Mediterranean Coasts (6th EUCC International Conference, Coastlines '97). 2–6 June, Naples, Italy. The aim of Coastlines '97 is to improve the understanding, communication and collaboration between those who are concerned for the future of the European coastline. In particular an attempt will be made to confront the different aproaches and disciplines in order to achieve a more integrated understanding, to be able to act more efficiently at European level. *Contact*: Dr Giovanni Randazzo, Instituto di Scienze della Terra, University of Messina, Salita Sperone, 31-C.P.24, 98166 – S. Agata di Messina, Italy; Tel. +39-(90)- 6765095; Fax: +39-(90)-392333; Email: randazzo@labcart.unime.it

ECSA-27: Comparison of Enclosed and Semi-enclosed Systems (Joint Meeting of Baltic Marine Biologists (BMB) and ECSA). 9–14 June (during the 15th BMB Symposium), Marie Hamn; Island of Åland, Finland. The biology, hydrography, chemistry and management of enclosed and semi-enclosed marine and estuarine systems, allowing comparisons between these unique systems (e.g. the Baltic, Mediterranean) and with systems elsewhere. Themes include: functional responses of organisms to altered environmental conditions; differences in the major physical features /processes and related geochemistry; transport of sediments and its impact on chemical processes and biotic responses. *Contact* Dr Ea Maria Blomqvist, Husö Biological Station, Åbo Akademi, Fin-22220 Emkarby, Åland Island, Finland; Tel. +358-(9)2837221; Fax +358-(9)2837-244; Email: erik.bonsdorff@ra.abo.fi

Technology Transfer From Research to Industry (Seventh International Conference on Electronic Engineering in Oceanography). 23–25 June, Southampton Oceanography Centre. The aim of this conference is to review advances in all aspects of electronic engineering in marine applications, particularly in respect of technology transfer. *Contact* EEO '97 Secretariat, IEE Conference Services, Savoy Place, London, WC2R 0BL, UK; Tel. +44-(0)171-344-5473/5467; Fax: +44-(0)171-240-8830; Email: mswift@iee.org.uk; WWW home page: http://www.iee.org.uk

The Tagus Estuary and Adjoining Coastlines (ECSA Local Meeting). 25–27 June, Lisbon, Portugal. This is the first ECSA Local Meeting to be held in Portugal. The Tagus is one of Europe's major estuaries, and the shores are the site of the forthcoming Expo '98. *Contact* Prof. M.J. Costa, Dept de Zool. e Antrop., Faculdade de Ciências, Lisboa, Bloco C 2°Piso, Campo Grande, 1700 Lisboa, Portugal; Tel. +351-1-75-000-78; Fax +351-1-75-000-28; Email: zitasia@cc.fc.ul.pt

East Anglian Estuaries (ECSA Local Meeting). 1–2 July, Colchester, England. *Contact* David Nedwell, Department of Biological and Chemical Sciences, University of Essex, Colchester, Essex, CO4 3SQ, UK. Tel. +44-(0)1206-872211; Fax: +44-(0)1206-873598:Email: nedwd@essex.ac.uk

Earth–Ocean–Atmosphere: Forces for Change (Joint Assemblies of IAMAS and IAPSO). 1–9 July, World Congress Centre, Melbourne, Australia. Will include a meeting of the IUGG Tsunami Commission. *Contact* IAMAS/IAPSO Secretariat Convention Network, 224 Rouse St, Port Melbourne, Victoria 3207, Australia; Tel. +61-3-9646-4122; Fax: +61-3-9646-7737; Email: mscarlett@peg.apc.org

Ocean Colour: Perspectives to the End of the Century (Challenger Society Meeting). 3–4 July, Blackett Laboratory, Imperial College of Science and Technology, London, SW7 2BZ. A meeting about ocean colour and remote-sensing of the optically active constituents of the oceans. Speakers include Prof. A. Morel, France, Dr M. Rast ESA, Dr V. Barale, JRC, Ispra, Dr S. Hooker, NASA, GSFC, Dr J. Aiken and Mr G. Moore, PML. There will also be a session on the projects funded by the NERC Special Topic SeaWiFS Exploitation Initiative. *Contact* Dr Jim Aiken, Plymouth Marine Lab., Prospect Place, Plymouth Tel. 01752-633429 (direct line); 01752-633100 (switchboard); Fax: 01752-633101: Email: j.aiken@plm.ac.uk

The Challenger Society AGM will be held at 5.30 after the meeting, in the Blackett Laboratory.

The Evolution of Biological Diversity: From Population Diversity to Speciation (Royal Society Discussion Meeting). 9–10 July, London. Organized by Prof. R.M. May and Dr A.E. Magurran. *Contact* The Scientific Meetings Secretary (details as for 20 May).

Learning about the Earth as a System (GeoSciEd II; 2nd International Conference on Geoscience Education) 18 July–1 August, Hilo, Hawaii. The first of these conferences, held at Southampton in 1993, focussed on solid Earth Science. This time, Marine Science gets in on the act! *Contact* M. Frank Watt Ireton, Education and Research Directorate, AGU, 2000 Florida Ave. NW, Washington DC 20009; Email: fireton@agu.org

ECSA-28: Remote Sensing in Estuaries (Joint Meeting of ECSA and the Remote-Sensing Society). 1–5 September, University of St Andrews, Scotland. *Contact* Prof. John McManus, Geography Department, Purdie Building, The University, St Andrews, Scotland, KY16 9ST; Tel. +44-(0)1334-463948; Fax +44-(0)1334-463949; Email: jm@standrews.ac.uk

The Eighth Deep Sea Biology Symposium 22–27 September, Monterey Bay Aquarium, California, USA. Topics include: Diversity, adaptation, and evolution of deep-sea biota; Pattern and function of deep-sea populations and communities; Source and utilisation of carbon inputs in deep-sea systems; Metabolic or physiological studies of deep-sea biota; Microbial processes in deep-sea habitats; Deep-sea pelagic community studies; Sedimentation and Diagenesis in Deep Ocean Habitats; Reproduction in the Deep-Sea; Interdisciplinary Studies in Deep Ocean Settings (JGOFS etc.); Studies of Specialised Habitats (seeps, vents, oxygen minimum zone). For more information see Web site at: http://www.mbari.org/Info_Announce/DSBS/ *Contact* Annette Gough, 8th DSBS, MBARI, PO Box 628, Moss Landing,CA 95039, USA: Fax: +1 (408) 775-1645; Email: goan@mbari.org

Ocean Exploitation Tomorrow – will it be sustainable? (DGM General Assembly, '97). 10–11 October, Hamburg, Germany.

Coastal Environmental Management and Conservation (Bordomer 97) 27–29 October, Bordeaux. *Contact* M. De Loof, Ifremer, 155 rue J.-J.-Rousseau. 92138 Issy-les-Moulineaux Cedex, France

CO_2 and the Oceans (Challenger Society Meeting). 8 November, Meteorological Office, Bracknell. *Contact* Dr B. Callander.

The Role of Iron in the Marine Environment (Challenger Society Meeting). 5 December, London. *Contact* Prof. Andrew J. Watson, Tel. +44-(0)1603-593761 (direct) or +44-(0)1603-456161 (switchboard); Fax: +44-(0)1603-507719; Email: a.watson@uea.ac.uk *or* a.j.watson@uea.ac.uk; *or* http://www.uea.ac.uk/~ajw/ajw.htm

Marine Science and the Media: working together towards a better public understanding of the marine environment (Joint Meeting of the Marine Forum, Challenger Society, ECSA and SAMS). 16–17 December, University of York. *Contact* The Marine Forum, University College of Scarborough, YO11 3AZ; Tel. +44-(0)1723-362392; Fax: +44-(0)1723-370815; Email: marforum@ucscarb.ac.uk or Angela Colling (Editor, *Ocean Challenge*, address below).

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

News and Views

Brent Spar – Once Again!

Let us keep *Brent Spar* alive as long as it helps us to develop concepts which save the sea from becoming a cemetery for large constructions. *Ocean Challenge* played its part in Vol. 6, No.2, *New Scientist* did so on 30 November, and the distinguished German weekly newspaper *Die Zeit* dissected the case on 6 September 1996 in a comprehensive article marking the 25th anniversary of Greenpeace. Assuming that all relevant arguments raised so far are covered by these articles, I believe that I have spotted something crucial that no-one else has actually yet said.

To me it seems obvious that the colossus was planned, constructed, and used without any thought concerning its disposal once it became useless, unnecessary, or damaged. This was a classic case of omitting sustainability from the planning process. To correct this omission now, when we are more wise, has become difficult because the *Brent Spar* has suffered a particular accident which prevents tilting to a horizontal position to bring it ashore. This was not planned, of course, and here I might repeat my point concerning the sustainability of the general conception. Obviously, this point does not only hold true for the *Brent Spar,* but since the *Brent Spar* has become a symbol I'll stick to this example.

I know I am not being quite fair: the history of the *Brent Spar,* including the planning and construction, goes back to the time before the 1992 UN Conference for Environment and Development, at Rio de Janeiro, where Agenda 21 was passed – including Chapter 17 'Protection of the Oceans, all kinds of Seas, including enclosed and semi-enclosed seas and coastal areas as well as protection, rational exploitation and development of their life resources.' As a principle, it is stated that: 'New approaches for the cultivation and development of marine and coastal areas are necessary ... These approaches have to be integrative and their results have to be preventive and precautionary....'. This is necessary (as demonstrated by *Brent Spar),* but not so revolutionary that it could be completely outside consideration of the investors in a project such as *Brent Spar.*

Thomas Höpner

Dr Höpner is currently chairman of the Deutsche Gesellschaft für Meeresforschung (DGM). His commentary on *'Brent Spar* and Agenda 21' appeared in the October 1996 issue (No. 3/96) of the *DGM-Mitteilungen.*

Salinity Units

If you were to study a selection of the latest editions of oceanographic textbooks, you would find most (if not all) of them express salinity in terms of p.s.u., parts per thousand, p.p.t. or ‰. This is surprising when you consider that the current definition of Practical Salinity, which was introduced in 1978, clearly states that it is dimensionless with no units. The Practical Salinity Scale 1978 (PSS78) is a scale derived from a series of measurements which link the salinity of a seawater sample with its electrical conductivity under controlled conditions.

So why the confusion over units?

Prior to PSS78, salinity was calculated from a measure of the halide concentration, or chlorinity, of the seawater. As a result, salinity was expressed as a concentration (p.p.t., ‰). When the PSS78 was introduced, attempts were made to publicise the changes but the use of concentration units was ingrained, particularly as it had been happening for over 70 years. So difficult was it to break this habit, that some workers adopted the p.s.u. or Practical Salinity Unit. This unit, although completely spurious, is now widely reported. Some authors have found their research papers 'corrected' by misinformed journal editors, to include the p.s.u. as the unit of salinity.

To set the record straight once and for all (or at least until salinity is redefined again!):

Salinity should be reported with no units such as in the following examples:

'The sample had a salinity of 35' or
'The salinity was 35 on the Practical Salinity Scale 1978' or
'The salinity of the water was 35 (PSS78)'.

Paul Ridout
Director of the IAPSO Standard Seawater Service

Reports from the Front Line

Scientists participating in large national and/or international projects tend to present their results in 'company' newsletters, for the delectation of their peers (though of course they publish in the major journals too); other groups choose to issue press release. Some of this diverse output finds its way to the Editor's desk. WOCE – the World Ocean Circulation Experiment – seems to be particularly prolific, and has also just produced an overview report.

Understanding Ocean Circulation

The above is the title of the recently produced colour report summarising the achievements of WOCE during its first six years. In 35 short articles, the report summarises all results of UK research that are either already published or in press. Together, they provide a useful summary of the present state of our knowledge of ocean circulation and climate, as well as an indication of problems that still need to be addessed.

WOCE observational work began in 1990, and interpretation of results is scheduled to be completed in 2002. UK WOCE is a 'Community Research Project', which means that bodies other than NERC institutes are involved. The report highlights the collaborative nature of the research, with joint initiatives involving MAFF, the UK Meteorological Office, the Department of the Environment.

Understanding Ocean Circulation: UK WOCE – the first six years, edited by Raymond Pollard and Denise Smythe-Wright, is available by writing to: Mrs Louisa Allen, James Rennell Division for Ocean Circulation, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK.

Other News from WOCE

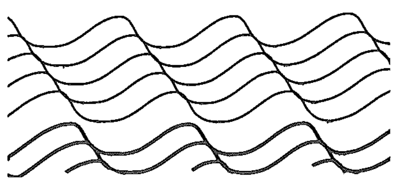
Sigma, the newsletter of UK WOCE is a mine of fascinating information, of which we here present some highlights.

WOCE Processing of *TOPEX/Poseidon* altimeter data has revealed intraseasonal fluctuations (20–100 day periods) in sea-surface elevation of up to a few centimetres in both North and South Pacific Oceans and along the Pacific Equator. Modelling results suggest these fluctuations may be associated with barotropic motions, i.e. they can be attributed to changes in surface wind fields. The researchers suggest that the global distribution of barotropic motions identified in this way can be used to deploy current meters strategically in the deep oceans, and to study the dynamical relationship between the wind and the deep oceans.

The WOCE radiocarbon programme is tracing the distribution of ^{14}C produced in the atmosphere by the nuclear bomb tests of the 1950s to early 60s. Initially driven into solution (as $^{14}CO_2$) primarily by air–sea gas exchange, the ^{14}C provides an excellent tracer for monitoring global circulation. Some interesting changes have been revealed since the first global radiocarbon study was made by GEOSECS scientists around 20 years ago.

Increased ^{14}C concentrations in equatorial Pacific surface waters show that water upwelling at the Equator is from a source that has been significantly ventilated since GEOSECS, and higher concentrations in subsurface waters of the South Pacific compared with those of the North Pacific show the thermocline to be ventilated significantly faster in the south – as might be expected. So far as the deep ocean is concerned, one of the most interesting results has been the finding of a ^{14}C minimum in the south-eastern Pacific (at 32° S) coupled with slightly elevated concentrations in the south-western Pacific at the same latitude. This confirms the basic model of circulation here, first proposed by Stommel in the 1950s, of a deep northward flow of relatively young Antarctic Bottom Water in the west and a return flow of much older water in the east. There is also a ^{14}C minimum in the deep North Pacific, further evidence (if it were needed) that some of the oldest deep waters in the oceans are in that region.

Considerable strides have been made in identifying routes and volume transports from the Pacific to the Indian Oceans via the restricted passages ('choke points') of the Indonesian Seas. Incidentally, the results were quite recently reported in *Nature* (1996, **379**, 146–9).



New hydrothermal vents created

During a recent expedition aboard the ODP drill-ship *JOIDES Resolution*, two new hot springs were created on the sea-floor about 150 miles west of Vancouver Island, Canada. An existing hydrothermal system which had become sealed within the sea-floor was punctured by the drill-hole, allowing hydrothermal fluids to gush out under pressure.

Hydrothermal systems occur where seawater circulates through hot volcanic rocks, generally where new oceanic crust is being generated. In this case, water as hot as 286 °C was being expelled from the sea-floor within a few miles of the drill site, but ODP researchers were at the time sampling the extensive mineral deposits formed by an ancient hydrothermal system, now inactive.

Scientists on board the *JOIDES Resolution* inspected the site of the new hydrothermal activity (hole 1035F) by lowering an underwater camera 2448 m to the sea-floor. One of the first to witness the new vents was co-chief scientist Dr Yves Fouquet, from IFREMER in Brest, France. According to Dr Fouquet, 'It was incredible. We couldn't even see the sea-bed because hot water was rushing out of the hole so fast that it was carrying mud and rock fragments out of the hole and forming a cloud more than 30 m above the sea-floor.'

The new hydrothermal vents provide an unprecedented opportunity for scientists to study the 'life cycle' of a vent and its associated biological community. Vents are known to have limited life spans, but how long any given vent lasts, how it evolves, and how the biological community it supports evolves is largely unknown. One of the biggest mysteries is how animals manage to migrate from one vent to another. Dr Melanie Summit, a microbiologist from the University of Washington says: 'We can now start from time zero and watch how these sites become colonized. This is our first opportunity to watch how a new hydrothermal vent and the animal communities that thrive in these environments grow and change with time.'

The international research team are sealing instruments into the drill holes to monitor temperature and pressure changes during the next few years. The data will be stored in computers on the sea-floor and will be recovered in the future by remotely operated vehicles (ROVs) or the submersible *Alvin*. Scientists will then examine the records to see how events like nearby earthquakes and volcanic eruptions affect the flow of hot water from the vents.

News from BRIDGE

While on the subject of the sea-bed, we understand that the BRIDGE Programme, which began in 1993, has now completed the allocation of its funding after four annual Announcements of Opportunity. Results are beginning to come in from the early projects but BRIDGE researchers will be active until the middle of 1999. In all, 43 science projects have been supported, in geophysics, physical and chemical oceanography, geochemistry, macrobiology, microbiology and deep ocean engineering – and even at this early stage of the scientific returns it is clear that considerable success has already been achieved. The media have been particularly interested in the programme, with coverage on national TV, radio and in numerous national newspapers. As scientific understanding of the mid-ocean ridge environment increases with the programme's maturity, BRIDGE will hopefully continue to capture the public imagination.

The *BRIDGE Newsletter* contains much fascinating material. Here are some highlights from a recent issue.

The supposed size of axial magma chambers at spreading ridges has in recent years decreased markedly, from large convecting bodies at least a couple of kilometres wide and deep and up to a few tens of kilometres long, to barely detectable 'crystal mush zones'. Now we learn that at some axes (both fast- and slow-spreading) there is seismic evidence of what are described as 'robust magma chambers', with lateral and vertical dimensions up to a few hundreds of metres and 10 km or more in length.

Could such magma chambers give rise to submarine eruptions large enough to affect the atmosphere? The idea is that super-hurricanes (quaintly named 'hypercanes') could be produced by huge thermal plumes forming pools of surface water at 60–70 °C. Such mega-superplumes, much larger than the giant 'bubbles' that intermittently pop out of hydrothermal systems, would have to penetrate the thermocline to reach the surface – perhaps modellers can tell us if this is feasible?

IronEx Revisited – You Read it Here First

Last year, Andy Watson informed our readers (*Ocean Challenge*, Vol. 5, No. 3) that whereas IronEx I in the eastern equatorial Pacific had rather limited success, IronEx II had a 'huge effect on CO_2'. There was substantial media coverage, and further details were to be found in no fewer than four papers in *Nature* last October. In brief, it appears IronEx II produced a nearly 30-fold increase in phytoplankton and that DMS production went up by a factor of about three.

The results support suggestions that low atmospheric CO_2 concentrations during glacial periods resulted at least partly from increased biological productivity in the oceans, stimulated by increased availability of iron. The iron was transported to the surface ocean as wind-blown dust, which was more abundant during glacial periods because these were times of relative aridity. Concomitant increases in DMS production would generate more cloud condensation nuclei, and greater cloud cover increases the Earth's albedo. Lower atmospheric CO_2 concentrations and increased albedo are widely believed to be associated with periods of global cooling.

We were taken to task by Andy Watson for suggesting that the results of such experiments might inspire seekers after technological fixes for contemporary environmental problems to propose an 'Iron Solution to Global Warming'. He pointed out that the idea was suggested as a joke anyway, and will probably remain so, though at least two newspapers reporting on these results seemed to be taking the joke seriously (indeed, one report even warned its readers to 'Beware the quick fixes of nutty professors').

Come to think of it, the notion of pumping excess CO_2 into the deep ocean, which we mentioned in the last issue (*Ocean Challenge*, Vol. 6, No. 3, pp.8–10) will probably also remain a joke, not least because the investment required to implement such a scheme would be prohibitive. At all events, the IronEx research has proved to be a very elegant piece of science that has done much to improve our understanding of climate change – good to think that it's not likely to be highjacked by planetary engineers.

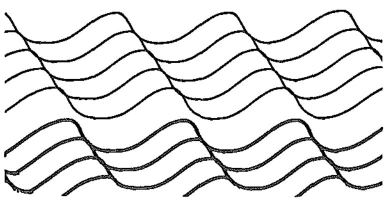
Another Techno-fix Joke?

There is growing interest in the so-called deep biosphere, arising from recent discoveries of micro-organisms thriving deep below the Earth's surface, notably (but not exclusively), beneath the sea-bed. The record reportedly stood at 4.2 km and 110 °C in mid-1996. The discoveries have given added impetus to the search for technological applications of bio-mediation. Examples include: oxidation of sulphide ores *in situ* (and pumping out the acidic metal-rich solutions); *in situ* production of fuels like hydrogen and methane from hydrocarbon source rocks; and decontamination of groundwaters, including decomposition of toxic chemicals such as organo-halogens. These ideas are not especially new, it is just that their implementation seems more feasible, now that we know the deep biosphere to be vastly more pervasive than was previously supposed.

However, an application that is allegedly attracting increasing global attention is yet another wheeze for subterranean disposal of combustion gases from fossil fuels. This is not some crackpot idea being mis-reported in the press, this is from the world-renowned journal *Science*.

Cracks and crevices in the lava caves of Hawaiian basalts are encrusted with Ca–Mg carbonates, formed by reactions between silicate minerals and acid soil solutions percolating down from the forest cover above. The reactions seem to be biologically (bacterially) mediated, and the idea is to dispose of excess CO_2 (and NO_2) from fossil fuels in a similar way, by converting them to carbonates. We are not told just how and where this would be achieved, but we are assured that: 'If such processes can be developed for these combustion products, many of the transient energy problems of the world could be eliminated, as with the future needed use of coal in nations such as China and India.' Comments anyone?

Well, it would at least save the oceans from being 'fertilized' with loads of extra iron, or used as a dumping ground for all that excess CO_2 (see previous item).



Bacterial Aid to Navigation

It has been known for some time that certain bacteria in soil contain magnetite, the magnetic oxide of iron, Fe_3O_4 – this is why archaeologists can use magnetic techniques to trace the layout of ancient structures through the influence of soil disturbance on drainage. Now researchers at the Department of Biomagnetism at the University of Gdansk, Poland, have isolated a new species of iron-bearing marine bacterium that may play a role in aiding migration of animals, in species ranging from whales to turtles.

It is known that many migratory species have sensors that enable them to detect small changes in the Earth's magnetic field. However, until now it was not realised that an additional agent is needed to reinforce the navigational sensors of larger marine animals, and this realisation has coincided with the timely discovery of the new bacterium.

Specimens had in fact been found previously in marine sediments and cores, but had probably been misidentified as inorganic precipitates. The bacterium has been named *Holobolus avrilensis*, after the first daughter of the scientist who first isolated it from sediment samples cored from the Caspian Sea at a depth of 160 m, on 1.4.97.

Research is now underway to determine whether industrial debris in long buried in the mud of estuaries and coastal waters could be responsible for confusing the navigational systems of dolphins and whales, often with tragic results.

Voice from the Past – in a Bottle

Several years ago we published a intriguing article entitled 'Drift Bottles from the Past' by Jim Adams, Eric Henderson and Bill Turrell (Vol. 2, Winter 1991). The authors described how drift bottles were used in turn-of-the-century lagrangian experiments to chart current systems in the North Sea. Recently (October 1996) a tantalizingly brief news item reported that a fisherman had found a drift bottle of 1914 vintage in his nets off Shetland.

Alas, the news item did not mention where the bottle had been released, so we have no information about how far it had moved. However, as the

continued >>

report states that 'most years, two or three cards from bottom drift bottles released before the First World War are returned to the offices of SOAFD in Aberdeen', this find is unlikely to be the last, or even especially noteworthy. But these old drift bottles are a link with the past and the story of their deployment remains a small but significant chapter in the history of British oceanography.

History Lesson

Question Why, 15 years ago, did the British Government send ships and aircraft and troops to fight and die in the Falkland Islands, ten thousand miles away? Was it:

1. To stop the islands from being renamed Las Malvinas and coming under Argentinian rule (not such a daft idea on the face of it, given the islands lie only a couple of hundred miles from mainland Argentina)?

No, it wasn't that, though it is certainly what we were told at the time.

2. To prevent rich fishing grounds round the islands from being lost to British interests?

No, it wasn't that (except perhaps incidentally). The big money from fish didn't really start to arrive until later, when licences to operate within the Fisheries Conservation Area round the islands were granted to foreign fleets.

3. To make sure that, if oil was found there, Britain would get the 'Lion's share' of the profits.

Right. The oil was also the main reason that the Argentinians invaded the Falklands in the first place.

Now, 15 years on, major multinational oil companies (including Amarada Hess and Shell) are about to begin (may even have begun) detailed seismic surveys as a prelude to drilling. By the end of next year (if not sooner) we should know if there really is as much oil round the Falklands as in the North Sea.

It is something of an irony that the Argentinian oil company seems to have been the only bidder to have been excluded in the first licensing round – even though it was bidding in partnership with British Gas. Apparently, the company was not commercially attractive enough, even though 'it has much to offer politically'. Presumably, the Argentinians can either buy into one of the consortia that *were* granted a licence, or they can wait a couple of years for the next round.

Whatever happened about ...

... Mururoa?

Mid-1995 saw a series of French nuclear tests at Mururoa atoll in the Pacific, amid lots of protest and not much support for France (except from Britain and China). The French dealt robustly with both local and international protests against their tests.

A centrepiece of environmental arguments against the tests was that nuclear explosions, albeit in a hole drilled deep into the volcanic infrastructure beneath the lagoon, would fracture the rock and let in the sea, resulting in widespread radioactive contamination. The atoll and its surrounding marine environment have presumably been monitored since the tests. Does the absence of information on this topic mean that, in the event, fears of serious leakage of radioactivity were groundless?

... *OSPREY*?

Launched amid a certain amount of publicity, heralding a new dawn of renewable energy, the *O*cean *S*well *P*owered *R*enewable *E*nerg*Y* generator was installed off Dounreay in 14 m of water less than two years ago (August 1995). Two weeks later, storm waves ruptured two of its ballast tanks, which meant it would have to be towed ashore for repairs. Tough luck on the backers, who'd sunk close on £2 million into the venture, the Government having pulled out of wave-power research. But what happened then? Was it worth it? With a power output of up to 2 MW ('enough electricity for 2000 homes') and weighing 800 tonnes, is *OSPREY* a bit like taking a sledgehammer to a nut?

... the *Derbyshire* affair?

A typhoon in 1980 in the South China Sea caused the loss of the bulk carrier *Derbyshire*. There were widespread allegations of faulty construction or a design fault, or both, leading to catastrophic structural failure. Few heeded the allegations until an identical vessel broke in two after running aground six years later. Only then was an inquiry set up, chaired by Lord Donaldson. At the end of 1995, the inquiry panel recommended further investigation: the wreck was to be photographed and fragments brought to the surface for examination. This was to happen 'in early spring' (1996). The families of those lost in the *Derbyshire* have been campaigning for answers for over 15 years. Let us hope they will learn something soon.

Time-Capsules? ... or Mass Graves?

Modern submarine and communications technology now enables many more sunken vessels to be discovered and allows scientists and archaeologists – not to mention treasure-seekers – to examine them in greater detail than ever before.

Some of these wrecks are true time-capsules, treasure troves for historians, the most famous being the *Mary Rose*. The *Swain* – the recently discovered man-o'war wrecked off Mull in 1653 – could be as important. And there's the Dutch East Indiaman, the *Amsterdam*, which went down in 1749 off Hastings, and is now apparently deteriorating rapidly because nobody seems able to decide who's responsible for dealing with it.

Other wrecks are treasure troves in the real sense, like the *Douro* which sank in the Bay of Biscay in 1882 with about £1.5 million in gold coins and 17 people; or the Japanese submarine which was torpedoed in mid-Atlantic in 1944 and sank with over £15 million in gold and other commodities, and more than 100 people. The *Titanic,* however, seems to have become a treasure trove for the tourist trade. If reports are to be believed, she is to become a feature of luxury cruises. Passengers can explore the floodlit wreck from the comfort of armchairs in the lounge, thanks to remotely-operated vehicles equipped with video cameras. Might the same be done with the *Lusitania*? She is more conveniently situated just off southern Ireland, where she was torpedoed in 1915, and sank with great loss of life.

Some people hold strong views about such activities, considering them to be ghoulish and claiming that such wrecks should be treated with respect as mass graves and left alone. But where do you draw the line?

How old does a wreck have to be to justify regarding it as a time-capsule? How valuable should its cargo be to justify retrieval? Indeed, it could be argued that merely gawping at the *Titanic* is likely to 'disturb the dead' much less than physically removing all or part of a sunken ship from its resting place. How would *you* feel if one of these vessels had gone down with people *you* had known?

Whatever Next?

Here are some snippets you may find interesting and/or amusing.

Deep-sea cores confirm human tool-making 176 000 years ago

Deposits containing artefacts and dated at 176 000 years old were recently discovered on the Kimberley Plateau in north-western Australia. If the dating is confirmed, this discovery will mean that humans were making tools much earlier than previously thought, which will mean a radical re-think about the course of hominid evolution – or so we are reliably informed.

Now, charcoal layers have been found in sediments of comparable age on the Lombok Ridge in the Timor Sea between Indonesia and Australia. The charcoal is inferred to have come from the home fires of the early tool-making hominids in north-western Australia, washed or blown out to sea to settle in the sediments. Natural forest fires are ruled out as a source of the charcoal, because the climate was (allegedly) too humid at this time. But could a few camp fires really produce enough charcoal to show up in marine sediments two hundred miles away?

In fact, that question may have become a bit academic. Earlier this year came news of 400 000 year-old wooden spears found in association with the bones of many different butchered animals and 'an unmistakable hearth'. In short, early hominids were using both tools and fire as long as 400 000 years ago – that's during the fourth interglacial back from the present one!

Biologists to teach sealions to film whales

Understandably perhaps, humans find it difficult to keep up with whales underwater, so the idea is to train sealions to do it instead. They will wear special harnesses fitted with video cameras. They will also tag the whales with radio transmitters. How will they do that? The normal method at present is to fire a dart with the transmitter at the whale. Will the sealions be trained to fire darts, or are they to affix them by hand (flipper)? The project is to begin with monitoring the migration of humpback whales. Presumably other methods will be used to track carnivorous whale species?

Burial at Sea from £500

Britain's last sea-going paddle steamer, the *Waverley* is reported to have begun providing sea-going burial services last summer. Simple scattering of ashes sets the family back about £1500, a full-blown funeral ceremony (including wake) will cost ten times that. It's a bit macabre, but you can see the attraction, especially on a calm, sunny day. For further details you should please contact Peace Burials of Lancashire, NOT *Ocean Challenge*.

Crabs to clear mines?

Forget ALACE, meet ALUV (Automated Legged Underwater Vehicle). Robot crabs, no less. The idea is to deploy hundreds (thousands?) of automated crab-like devices in shallow coastal waters to clear any mines laid there. The 'crabs' scuttle about to locate the mines, then blow themselves (and the mine) up when they find one. One 'crab' for one mine. This bright idea provides an intriguing insight into the prevailing mindset of the US military (yes, it is their 'baby'). In this era of hi-tech, we can evidently still contemplate conventional beach-landings and anticipate conventional defences.

The Arsenal Ship

This is a possibly even more bizarre (and a lot more expensive) brainchild of the Pentagon's: a gigantic missile launcher, capable of firing 500 missiles (conventional ones, thank goodness) in support of ... well, presumably the kind of military invasion for which all those ALUVs will clear the mines. It seems that six of these vessels are *already* in production and they are *huge*: 40 000 tonnes and over 800 feet long. The crew will number no more than 50; some reports claim no crew at all, that the vessels will be fully automated – help! Estimated cost per vessel is stated to be 550 million dollars – but with cost over-runs there is likely to be little change out of a billion bucks per ship. Is this a fantasy, have the editors of *Ocean Challenge* been victims of an April Fool joke? Well maybe, but you'll know soon enough. The first vessels will be stationed in the Mediterranean, in the Persian Gulf, and off Korea – unless of course, the location of political 'hot spots' has changed by the time the vessels are commissioned. The ships will be able to submerge to make themselves invisible to radar, they are designed to be unsinkable and the thinking is that this will be so formidable a weapon, that it will intimidate malefactors into keeping the peace. Remember what they said about the *Titanic*? ('unsinkable') ... about the torpedo ('so terrifying it will mean the end of war'). Well, maybe it is a spoof after all.

PS And now would you believe, British companies are getting in on the act with rival designs for a similar vessel. Whatever next, indeed!

Sea Launch

Four nations, including Russia and the US, are collaborating in a money-saving space programme to launch satellites into orbit from a converted oil rig in the Pacific. Sounds crazy? They've already started work on part of the project at a Glasgow shipyard.

Land-based satellite-launching requires enormous areas of ground to be cleared, whereas an ocean-based launch pad would only need an empty stretch of sea. Another advantage is that the shortest and most efficient route into geostationary orbit is from launch sites near the Equator; this crosses either ocean or countries of uncertain political allegiance, so at present space programmes have to launch from further north or south, which costs more money. This project avoids such problems. A 50 000 tonne ship, the *Sea Launch* now being built on the Clyde, will transport the rockets (plus satellites) to a converted oil rig (the *Sea Odyssey*) stationed off Christmas Island. The rockets will be transferred to the rig, which will then be evacuated and the rockets will be fired by remote control. The first launch is scheduled for 1998. Could somebody please tell us what we need all these new satellites *for*?

Whaleboat Pioneer

No, no, not a whaleboat for whaling, a boat shaped like a whale. You may have seen press pictures of *Moby* (looking like a sperm whale with a grin) on its way to being launched in the Irish Sea off Scotland, in spring of this year. *Moby* is 65 feet long, 25 feet high and diesel-powered. Its creator is Tom McLean, the first man to row the Atlantic single-handed, who later this year plans to take the contraption to New York via the Azores.

Bishopstone Tidemills: an historical perspective on the use of tidal power

Richard D. King

From the small port of Newhaven, a regular ferry service plies to and from the French port of Dieppe. About 250 km south-west of Dieppe is the River Rance. Across this river stretches a great tidal barrier used for the generation of electricity. Opened in 1966, this installation can generate up to 540×10^6 kWh of electricity per year. Rightly, this barrier is considered to be a prime example of the contemporary use of 'green' energy, producing environmentally clean electricity. Far less well known is the fact that, back at Newhaven, on a low-lying area to the east of the mouth of the River Ouse on the Sussex coast, are the remains of an 18th century tidal power installation. Constructed in 1761, and known as Bishopstone Tidemills, this mill successfully used the natural power of the tide to grind corn into flour.

Bishopstone Tidemills were not unique, there being at that time some half-a-dozen similar installations in West Sussex, and many others elsewhere in the country, for this technology had been in use in Britain since medieval times. In 1941, the Reverend R.A. Evans reported that the earliest known tidemill was at Woodbridge, on the Deben Estuary in Suffolk, built in 1170, and still believed to be working in the middle of the 20th century – with an active life of nearly 800 years, that's pretty good technology. In fact, there is a tidemill still working in Britain today – the Eling Mill at Totten, near Southampton. The present-day buildings were erected in 1785 on the site of a tidemill known to have existed since at least the 13th century. The mill ran commercially until 1946 – considerably longer than the Bishopstone mill. Subsequently, it was purchased by a trust and restored in the period 1975–80. It is now a tourist attraction – but it still grinds corn to make wholemeal flour.

Despite the difference in use between historical and modern applications of tidal power, despite the difference in size, despite the difference in output and in materials, the underlying principles are the same. During the rising tide a basin or channel is filled with seawater. Once the basin is full, a barrier is closed so that return flow is constrained to pass through sluices via a device which uses the energy of the flowing water to do work. In the case of La Rance, it drives turbines (which can also operate with the inflowing tide); in the case of the Bishopstone Tidemills, it turned undershot water wheels. The location of the 'Bishopstone Tidal Barrier' was over a creek, opening just inside the mouth of the Ouse, which was the remains of an earlier river outflow. The mouth of the Ouse has migrated over the centuries as a consequence of longshore drift and deposition of shingle. In Roman times, the mouth was where it is now (Figure 1), but by the medieval period this had become closed and the river emerged some 3 km to the east, at Seaford (beyond the right-hand edge of Figure 1). Seaford became a major port with links to the famous Cinque Ports.

However, shingle deposition continued to block this exit, and in 1539 an artificial mouth was made, at 'New Haven', where the original Roman mouth had been. By 1698 this, too, had migrated east, and in 1731 the channel was re-cut, with protective piers installed to keep it open. In 1791, a breakwater was constructed

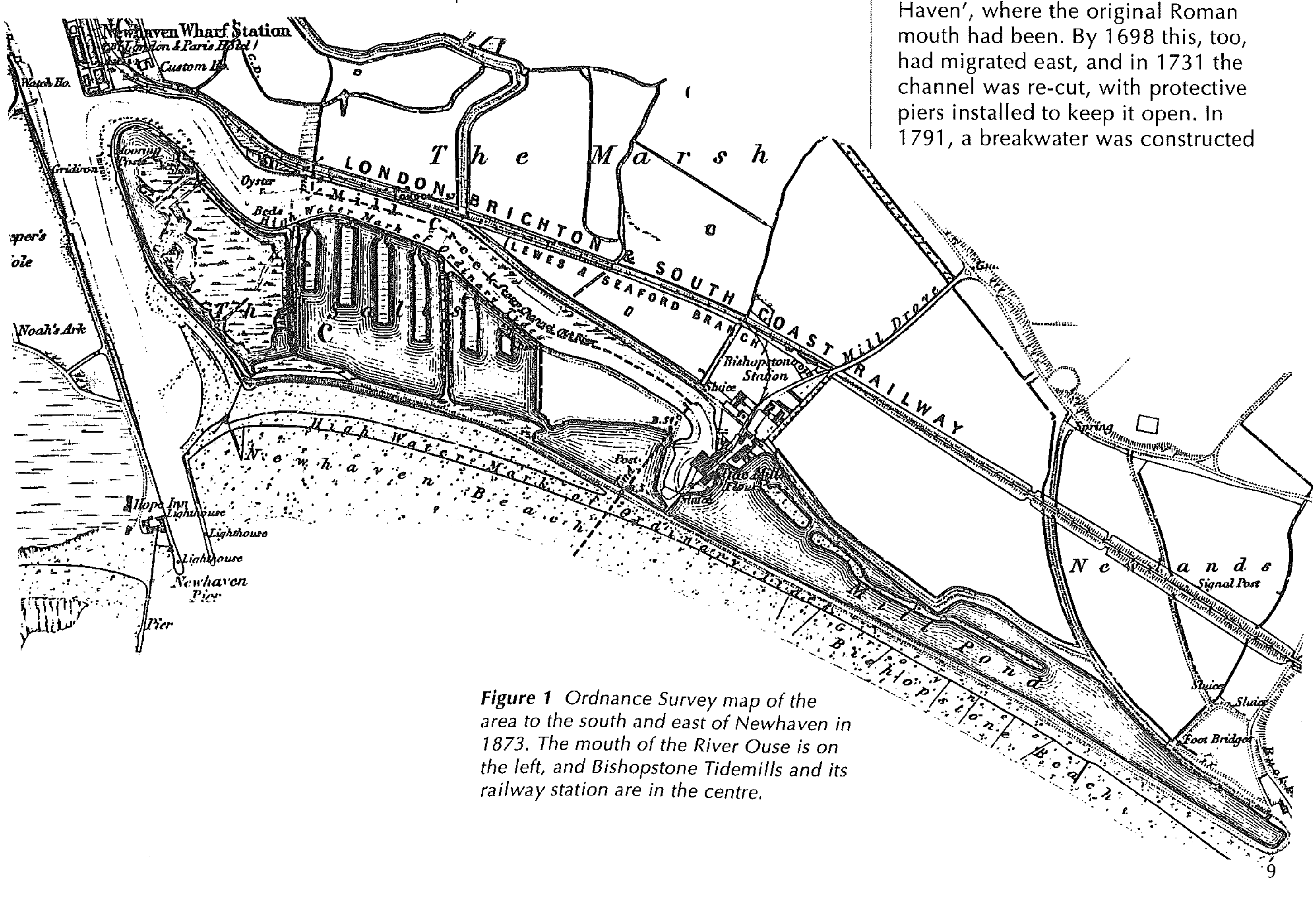


Figure 1 Ordnance Survey map of the area to the south and east of Newhaven in 1873. The mouth of the River Ouse is on the left, and Bishopstone Tidemills and its railway station are in the centre.

to divert the still-encroaching shingle, and was replaced successively with a 150 m groyne in 1847 and with the existing longer breakwater in 1890 – this final construction has had a major impact on erosion and deposition patterns eastward of Newhaven. The 1873 map (Figure 1) illustrates the shingle bar which by medieval times had separated the Roman outflow from the sea. The net result of the opening of New Haven in 1539, and of re-excavation of the channel in 1731, was that the medieval channel, down to Seaford, became the tidal creek on which the tidemills were eventually built.

When the channel at New Haven had been re-cut in 1731 the value of this creek was soon recognised, and in 1761 an Act of Parliament, sponsored by the Duke of Newcastle (who lived locally), was enacted. This bill empowered John Woods, William Woods and John Challenor to:

'... make and build a Weir Dam or Fender across the said Channel or Creek with proper Floodgates or Sluices therein to be opened with the Flux and shut with the Reflux of the Tide and thereby to collect and reserve a sufficient Head or Quantity of Water for working the said Mill during the time of such Reflux.'

It is interesting to note that the justification for the work was very much based on the public interest and value to the community:

'... such Mills will not only facilitate the Sale and Deposition of the Produce of the Lands there, but also render the Navigation of the said Channel more practical and effectual, and consequently be of great Benefit and Advantage to the said Country and of Public Utility.'

The operation was very simple. Figure 2 is a diagram showing how it is believed that the system worked. Water would flow down the creek, filling the pond A via a channel. Sluices in the channel would then close, and the water flow back via the mill's undershot water wheels. These in turn were connected to five mill wheels, situated directly above the outflow, and were operated for some 4 to 6 hours during each tide.

Around 1800, the most famous of the mill owners, William Catt, increased the number of mill wheels to sixteen, so making a significant improvement to production. He also constructed a second mill pond, shown in Figure 2 as pond B, connected to the first by a culvert. The incoming tide would fill both ponds. Pond B and the culvert were then closed off with sluices, and the first pond operated as before.

When the first pond was empty, the sluices on the culvert would be opened, providing a further head of water to drive the mill wheels, enabling more corn to be ground with each tide.

Output from the mill itself is reported to have been 1 500 sacks of flour per week in its heyday in the early 1800s, which translates approximately into 2 000 tons of milled flour per annum. By way of a brief but hopefully entertaining digression, the energy content of that flour amounted to some 3×10^{13} J yr^{-1}, nearly two orders of magnitude less than the 10^{15} J or so generated annually at La Rance. Admittedly we are not comparing like with like, but the difference is in any case hardly surprising, given the time gap of a couple of centuries and bearing in mind that the barrage at La Rance is hundreds of metres long, the barrier at Bishopstone barely 20 m in length.

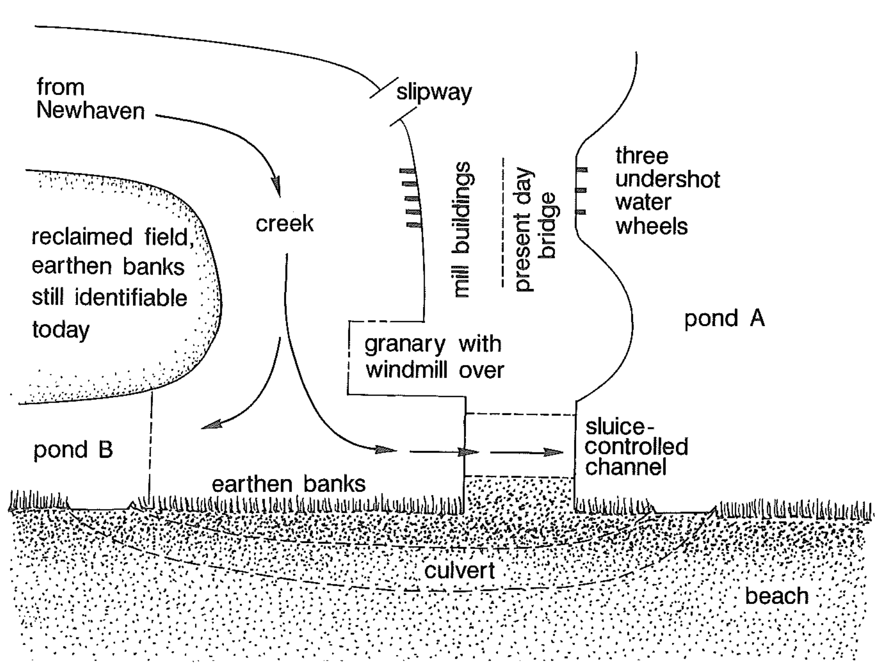
It must be remembered that this installation was in a bleak wind-swept area of land, quite some way from the nearest major town, which was Lewes, about five miles up the river. Because tidal power was being used, the mills had to be operated day and night. It is reported that this 'averaged some 16 hours out of every twenty four', and meant that the workers had to live on-site, so that Bishopstone Tidemills became a community of its own, of some 60 families. There were workers' cottages, perhaps a small school, and the house of the mill owner himself. William Catt adopted the role almost of a feudal lord, even imposing a curfew on his staff, locking the gates at the curiously precise time of 10 minutes past 10 o'clock every night, and 'gating' workers who disobeyed the curfew!

Catt was also a keen fruit-grower and trained pear trees up the walls of the mill buildings. Local residents claim that 'Sweet William Pears' were named after him (the 'sweet' alluding, it is said, more to the flavour of the fruit than to the character of Catt himself).

Figure 3 (*opposite*) is a sketch of what was left of the mill in the early years of this century. Most of the mill itself and the granary had already been demolished. All that remained were the five arches, within which sat the undershot wheels when the mill was working. There were wooden buffers between the arches to avoid damage to barges, and each archway had a metal grating to prevent seaweed and driftwood from clogging or damaging the wheels.

The decline was gradual but inevitable, caused by a combination of the Repeal of the Corn Laws (allowing cheap corn to be imported from abroad), increased use of steam engines for grinding, and the advent of the railway system. Ironically, although there was eventually a station at the Tidemills (Figure 1), and a single-track line ran down to the mill itself, the railway, with its faster communications, sounded the final death knell of Bishopstone Tidemills.

Figure 2 *Operation of the tidal mill system.*



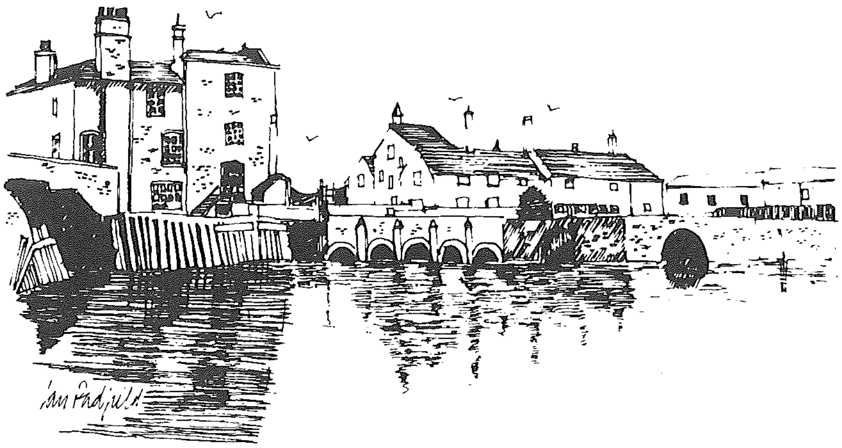


Figure 3 *View of the Bishopstone Tidemill from the north-west, after 1901. (From McCarthy, E. and M. (1975)* Sussex River; Seaford to Newhaven*)*

The mills were dependent on slow sailing barges plying the south coast for the delivery of relatively small quantities of grain, and the flour itself was also distributed mostly by sea but also locally by horsedrawn wagons. Flour from Bishopstone was shipped as far as Falmouth and Plymouth. However, these slow forms of transport were no match for the rapidly growing railway system, nor could the mills, built more than a century before, provide enough flour for the rapidly growing Victorian population.

In 1876 a major storm broke through the walls of the ponds, and shingle rapidly began to be deposited. Despite the efforts of the Catt family, by 1878 there was considerable gravel incursion, and the end of the Bishopstone Tidesmill was in sight. In 1879 the Newhaven Harbour Company purchased the site, as they wished to extend the railway to the Port of Newhaven. This meant closing off the creek to shipping. No ships meant no corn, and no corn meant no work. By 1884 ships could no longer reach the mill, and it closed.

Between 1884 and 1918 the buildings were used in various ways, but during the First World War many buildings were destroyed. Between the wars, the area was firstly used by a Racing Stables, and in the 1930s a 'Beach Hospital' for disabled children (now run by the Chailey Heritage Trust) was established. The Second World War saw the final destruction of any remaining buildings.

The area is once again bleak, the ever-encroaching shingle is everywhere. All that is left of a once-thriving community, whose livelihood was based entirely on the use of tidal power, is now no more than the remains of the mill (Figure 4), a few flint stone walls and some remnants of front door porches. Flowers which once graced local gardens now grow wild amongst the scattered stones and broken walls.

Figure 4 *Photograph taken in 1995, showing all that remained of the arches.*

One wonders what John Woods, William Woods or John Challenor would make of tidal barrier technology more than two centuries after they built the Bishopstone Mill, not to mention William Catt who presided over its period of greatest prosperity. It is reported that William made visits to King Louis Phillipe to advise on the building of tidal mills in France. It is perhaps somewhat of an irony that the world's largest tidal power station should be in that country, 100 years later!

One may also wonder whether the technicians, managers and controllers of the barrage at La Rance would appreciate the further irony that at Bishopstone, just across the Channel, tidal power was replaced first by steam power and then by electricity – which *they* now generate, using tidal power!

Acknowledgement

Grateful thanks are due to Mr Geoffrey Mead, of Sussex University, for his advice and assistance.

Further Reading

Ashby, R. (1924) 'Old Sussex Tidemills' in *West Sussex Gazette & South of England Advertiser* (Dec).

Evans, R.A. (1941) 'A Countryman's Diary' in *The Sussex County Magazine*, Vol. XV, No. 11 (Nov).

Farrant, S. (1975) 'Bishopstone Tidemills' in *Sussex Archaeological Collection*, Vol. 113, pp.199–202

Kidner, R.W. (1979) *The Newhaven and Seaford Branch*, Oakwood Press, Blandford.

McCarthy, E. and M. (1975) *Sussex River; Seaford to Newhaven*, Lindel Organisation, Seaford.

Willett, F. (1934) 'The Tide-Mill, Bishopstone' in *Sussex County Magazine*, Vol. 8.

Williams, R.R. and Robinson, D.A. (1983) 'Sussex Past and Present' in *Sussex Environment, Landscape and Society*, Geographical Editorial Committee, University of Sussex.

Richard D. King is a retired computer systems analyst and designer, with interests in oceanography, local history and industrial archaeology. He has a BA from the Open University and a Diploma in Landscape Studies from Sussex University.

The birth of Portuguese Oceanography

Last year, Monaco and Portugal issued simultaneously two identical stamps illustrating, respectively, Prince Albert I of Monaco and his yacht *Princesse Alice*, and Dom Carlos I of Portugal and his yacht *Amelia* (*see below*). This was an unusual event in philatelic terms, but for oceanographers it had a wider significance since the stamps commemorate the centenary of the oceanographic cruises of the two sovereigns in 1896, that of Dom Carlos being his first scientific voyage and so reckoned to mark the birth of Portuguese oceanography.

The friendship between Albert and Carlos, based particularly on their common interest in marine science, was the subject of a handsome analysis of their correspondence in 1992 by Jacqueline Carpine-Lancre and Luiz Saldanha (reviewed by Margaret Deacon in *Ocean Challenge*, Vol.4, Nos.1/2). By 1896, Albert had been a committed oceanographer for many years and had been conducting research cruises each summer since 1885. But in 1896 he discovered the Princess Alice Bank to the south of the Azores and it was his enthusiastic suggestion that this area might support new fisheries which prompted Carlos to begin his own series of research cruises, tragically ended by his assassination in 1908.

To mark the centenary further, Luiz Saldanha organised the striking of a commemorative medal (*above right*) and also a three-day symposium at Cascais, Portugal. The symposium was opened by the Monegasque heir apparent, Prince Albert, and attended by guest speakers from Austria, China, Egypt, France, Japan, Russia, the UK and the US, as well as from Portugal and Monaco. The papers presented ranged from accounts of the work of Portuguese marine scientists and developments in Portuguese oceanography, through the work of non-Portuguese oceanographers in Portuguese waters, to reviews of national or geographical developments in oceanography with

Bronze medal, 89 mm across, showing Dom Carlos and the* Amelia*; on the obverse is the inscription '1896/1996 Centenário da Oceanografia Portuguesa, Rei D. Carlos'

little or no connection with Portugal. There was even a presentation on the role of the concept of 'oceanic paradise' on early exploration and oceanography and another on fishes depicted on postage stamps. Luiz Saldanha is producing a special commemorative volume from this disparate selection of contributions, to be published later in the year.

Tony (A.L.) Rice
Southampton Oceanography Centre

First Day Cover carrying the two pairs of Portuguese and Monaco stamps against the background of Prince Albert's soundings on the Princess Alice Bank

... and its Legacy in the Azores

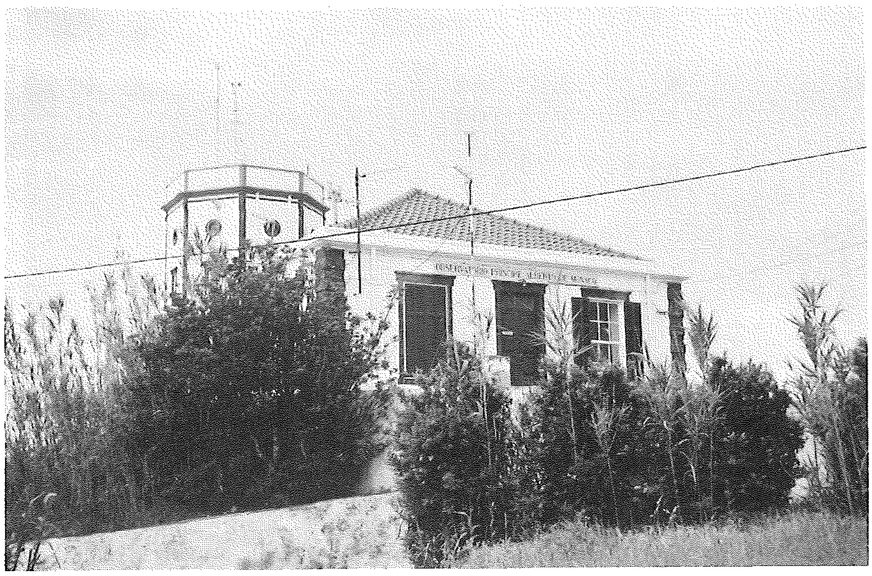


Figure 1 *Still in use today, a meteorological observatory built by Prince Albert on one of the steep hills above Horta on the Azorean island of Faial. The inscription over the door reads 'OBSERVATORIO DE PRINCIPE ALBERT DE MONACO'.*

Prince Albert of Monaco was certainly a key figure in the history of early oceanographic research in the Azores (cf. Figure 1), but he was by no means the only one, nor the first. To be sure, visits he made aboard his yachts *Hirondelle* and *Princesse Alice* contributed greatly to making the late 19th and early 20th centuries a particularly productive period for marine research in the region; but there were other scientific visitors too. HMS *Challenger* called at the Azores on one of the early legs of her four-year (1872–76) circumnavigation of the oceans, and the French ships *Travailleur* and *Talisman* visited during oceanographic cruises in the eastern Atlantic in 1880 and 1882. The German South-Polar Expedition visited the islands in 1903, the Norwegian steamer *Michael Sars* in 1910, and later (1928) during a round-the-world scientific cruise, there was a visit by the Royal Danish research ship *Dana*.

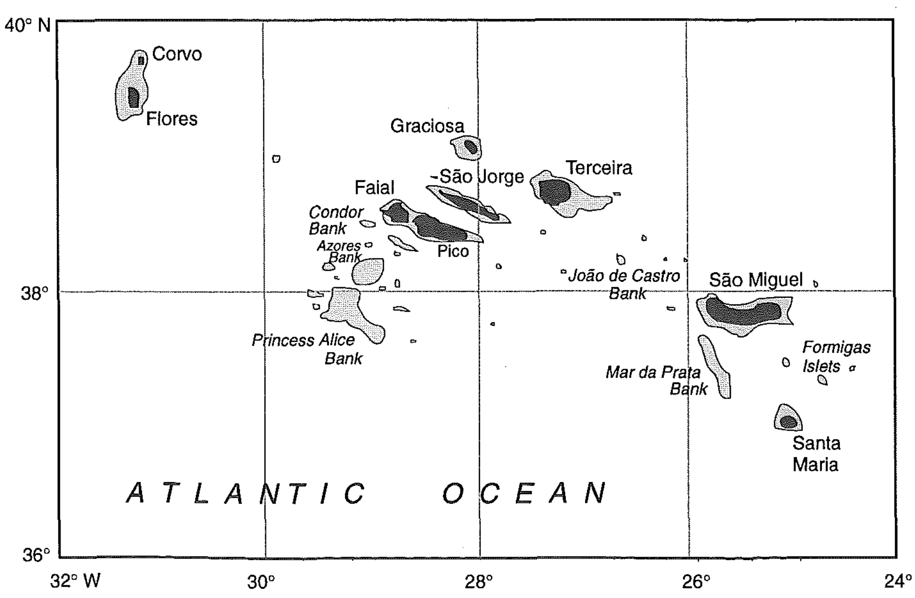
Several Azoreans made pioneering contributions to marine research in the archipelago, along with other Portuguese from the mainland, and scientists from elsewhere in Europe, notably France, Germany, Norway and Denmark.

But of course the history of the islands themselves began long ago, before there were even humans on the planet, let alone marine scientists. The archipelago of the Azores consists of nine volcanic islands and several small islets, forming three groups along a tectonic zone running west-north-west–east-south-east between 37° and 40° N, and 25° and 32° W, in the middle of the Atlantic (Figure 2). The oldest rocks, on Santa Maria, have been dated to the Miocene, ~10–8 million years ago. Since then, the islands have been in continuous formation as the result of volcanic activity in the vicinity of the Mid-Atlantic Ridge. Each island is thus a mosaic of rocks of different ages. The youngest rocks (forming the volcano of Capelinhos on the Island of Faial) are less than 40 years old, and most islands are between 3 and 1 million years old or less. There are also various seamounts, including islands that have subsided since formation. The precise relationship of the archipelago to the Mid-Atlantic Ridge and the Azores Triple Junction is still not fully understood, but it seems that the westernmost islands (Corvo and Flores, see Figure 2) may lie to the west of the spreading axis, which means that the distance between them and the rest of the group could be increasing by a couple of centimetres or so each year.

The Azores were uninhabited until colonized by the Portuguese in the 15th century (see Further Reading). Since then, many endemic species of land plants have suffered from human influence, particularly agriculture and the introduction of exotic plants. The marine environment of the Azorean archipelago and its surrounding Exclusive Economic Zone (EEZ), of more than 1 million km^2, is of considerable conservation and marine biological interest, in large part because of its isolated position in the middle of the north-eastern Atlantic and the short time that the archipelago has been in existence.

Humans have exploited littoral, nearshore and offshore living resources since the earliest colonization, and in recent years pressure on marine resources has grown, with the switch from essentially subsistence or artisanal exploitation to more commercial operations. Meanwhile, the

Figure 2 *Map of the Azores archipelago, including major seamounts as well as islands. The shaded areas are less than 200 m deep. The name 'Formigas' means 'Ants'.*



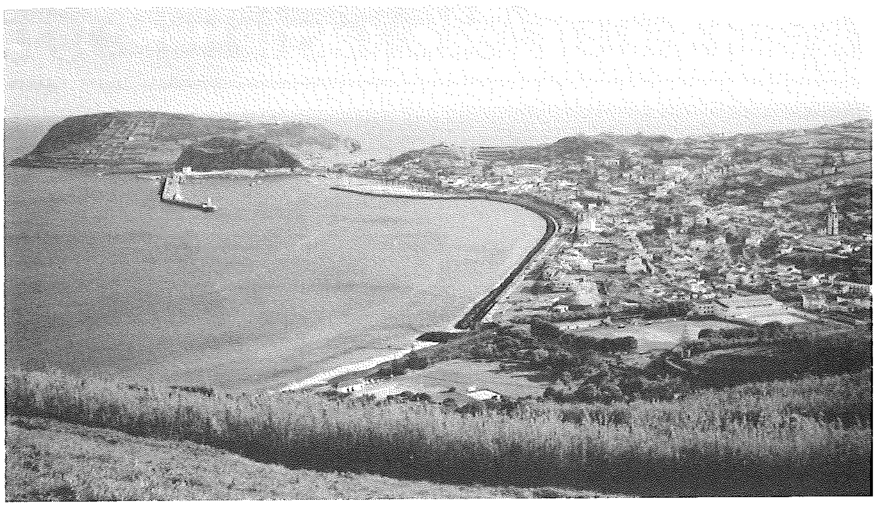


Figure 3 *The beautiful setting of the Dept of Oceanography and Fisheries of the University of the Azores, in Horta, on Faial. The buildings are situated close to the harbour, near the 'land-bridge' to the small volcanic islet on the left.*

cessation of commercial whaling and greater environmental awareness, at international, national and regional levels, have increased the pressure to protect marine wildlife.

In light of the importance of fisheries, it is not surprising that until relatively recently most research in the region focussed on biological resources – even now, most research programmes in the area have relevance to this field. In fact, relatively few papers were published in the first half of the 20th century; however, after the Second World War there was an increase in activity, involving both Portuguese and British scientists. With the creation of the University of the Azores in 1976, scientists based on the islands initiated research on different aspects of the natural history of the archipelago, and the 1980s saw an upsurge in scientific activity.

The mid-ocean setting of the islands, surrounded by deep water with varied submarine topography, makes them a unique area for research, quite different from coastal waters off mainland Europe. Partly for this reason, the University became a centre of attraction for scientific cooperation with other marine research institutions, both Portuguese and foreign. Interesting papers, including bathyscaphe studies in the Azores in the 1960s, are presented in a retrospective volume celebrating the centenary of the last oceanographic cruise by Prince Albert of Monaco (compiled by Luiz Saldanha and others and published in 1992; see Further Reading). Other recent works on the systematics and ecology of the Azores include studies of intertidal algae, and of algae collected during a recent expedition using the *Sea Diver* submersible; others involve decapods, amphipods and various little-known invertebrates, as well as octopods, inshore fish, and birds.

Staff and students of the Department of Oceanography and Fisheries of the University of Azores (based at Horta on Faial; Figure 3) have made important contributions to all of these studies, as well as to other fields of marine science. Principal research interests of scientists in the Department are Ecology and Marine Biology, Physical and Chemical Oceanography, and Fisheries, and there continues to be active regional and international collaboration with other institutions.

Currents in the NE Atlantic

The mean ocean circulation pattern of the North Atlantic is the large-scale asymmetric gyre that has the narrow Gulf Stream on its western side, and a broader southward flowing, multi-branched current system occupying much of the rest of the ocean. The Gulf Stream very efficiently transports warm water of equatorial and tropical origin into colder regions. The current patterns result in the high salinity, high temperature and low nutrient regime (dissolved silica is around 10 $\mu mol\ l^{-1}$) which typify the Azores; seawater pH is between 8.1 and 8.2. During winter, the mixed layer extends to about 150 m depth, and in summer a seasonal thermocline develops at around 40–100 m.

The Gulf Stream leaves the North American coast at about 40°–45° N, and flows towards the centre the North Atlantic where the Azores are located. Figure 4 illustrates some of the general ocean circulation patterns that have been deduced recently for the central/eastern North Atlantic, using hydrographic data available from the US National Oceanographic Data Center. The complexity of the current system that surrounds the

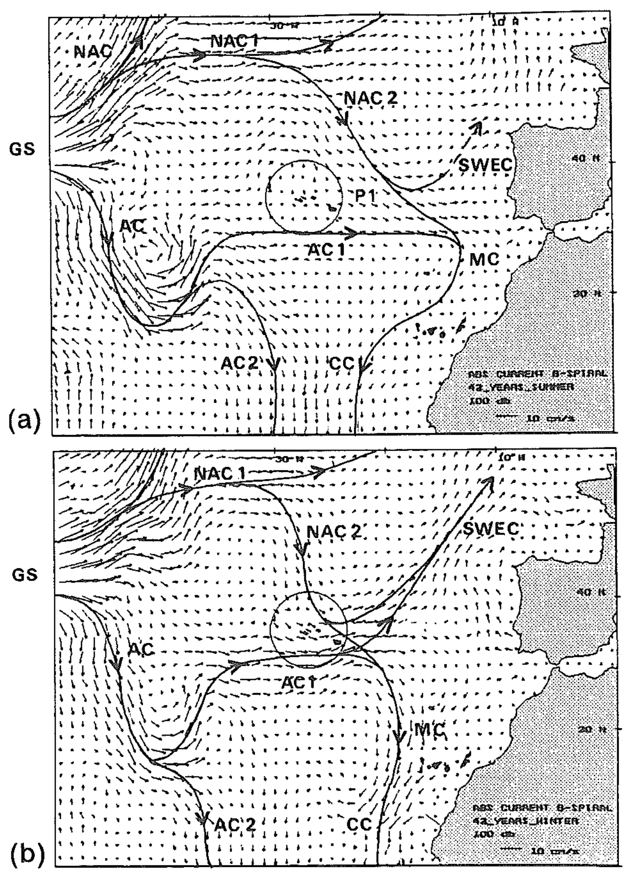


Figure 4 *Oceanic circulation within the area 20°–50° N and 0°–50° W at about 100 m depth, for:*
(a) *average summer conditions;*
(b) *average winter conditions.*
The averages have been derived for the 42 years between 1947 and 1988, and the computations were performed using the β-spiral method. The Azores are inside the circle. For point P1 see the caption for Figure 5.

islands is remarkable, and helps to explain what is observed locally in the Azores (circled on Figure 4). The Gulf Stream (GS) can easily be identified entering the region at about 40° N and then splitting into two main branches, the North Atlantic Current (NAC) and the Azores Current (AC). Each of these in turn divides into further branches (NAC1 and NAC2, and AC1 and AC2, on Figure 4(a)). It is also clear that the Canaries Current (CC) is a continuation of the Madeira Current (MC) and that both are fed mainly by the AC1 system.

As shown in Figure 4(a), during the summer months (July–September) the northern part of the Azores is influenced by the NAC2 system, and the southern part by the AC1 system. During winter (Figure 4(b)) average conditions are very different. The most notable difference is strengthening (indicated by size of arrows) of the South-West European Current (SWEC) and of the Madeira Current–Canaries Current (MC–CC) system, both originating downstream of the confluence zone between NAC2 and AC1, east of the Azores. The AC1 system also strengthens during winter. Furthermore, while in summer the maximum intensity level of the AC1–MC–CC system is deeper than 100 m, during winter it is relatively shallow.

However, these are long-term average patterns and there can be many changes during the average year. For example, flow in the Canaries Current (CC) can be reversed at some times of the year, flowing to the north-west – that is, *from* Africa towards the Azores. Similarly, south-east of the Azores, the general west to east flow pattern (AC1) is sometimes reversed, with the current flowing from Madeira towards the Azores.

Below is a representative year-long time series of current measurements at a point well inside the NAC2–AC1 confluence zone east of the Azores (point P1 on Figure 4(a)). The general regime is from west to east but there is a clear seasonal and half-seasonal oscillation of the mean direction, with periods where NAC2 dominates (current coming from the north-west) and periods where AC1 is present (current coming from the south-west).

Effects on biogeography and diversity

The complex current systems indicated by Figures 4 and 5 are the major influence on the hydrography and climate of the Azores. Because the large-scale current circulation is dominated by the Azores Current system with its dominant flow from west to east, the subtropical thermohaline front stays very near the islands, generating considerable mesoscale activity; indeed, the eddies that spin off from its meanders affect the whole regional ecosystem.

Even though the dominant ocean currents reach the Azores from the *west*, the littoral flora and fauna have affinities with the *eastern* coasts of the Atlantic. This is probably due to the great distance between the Azores and the American coast, making colonization from that side particularly difficult, expecially for animals. At an average speed of 30 cm s^{-1}, an advective current journey to the Azores from the point where the Gulf Streams leaves the American coast (i.e. via either the Azores Current or the North Atlantic Current) would take more than three months. Another reason is that littoral conditions on the North American coast are very different from those found at the Azores: water from the northern side of the Gulf Stream is mainly of Labrador Sea/sub-Arctic origin, whereas the Azores are predominantly subtropical. Any colonizers that did arrive, therefore, would be unlikely to survive.

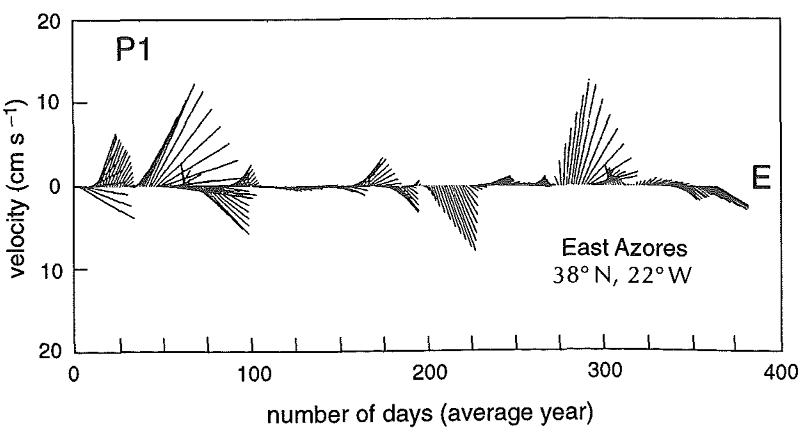


Figure 5 *Time-series of current measurements for an 'average' year at point P1 on Figure 4(a). The horizontal axis represents the time of year in Julian days and the vertical axis the N–S intensity of the current. Each 'stick' represents the current direction at the time corresponding to the origin (north is up, south down, west is towards the left, east is towards the right), and length is proportional to current speed.*

The episodic anomalies described above (e.g. Figure 5) thus assume particular importance when it comes to colonization. If measurements made in the period 1947–88 (cf. Figure 4) are any guide, there must have been many current anomalies in the past (especially during autumn and winter), when colonization by larvae or algal propagules was possible from east to west, via current systems from Europe or North Africa to the Azores. Present-day reversals of the mean currents are sufficient to maintain gene flow and reduce the likelihood of new species arising through isolation of populations.

However, current patterns must have been very different in the more distant past – especially during the Pleistocene – and colonization must then have occurred under very different circumstances. One of the outstanding features of the Azores ecosystem is the relatively small number of endemic species. This is attributed to the fall in sea temperature during the last glacial period in particular, leading to mass extinctions in the region. Most of the organisms now present are thought to have reached the Azores in the last 17 000 years – too short a time for species differentiation, which would account for the low endemism. Diversity is also relatively low (lower than in Madeira and the Canaries), but it is no lower than might be expected for an isolated mid-oceanic archipelago.

The picture that emerges is that the Azores are at a 'crossroads' where shallow marine fauna and flora of different origins meet. The geographic links of the different groups must be related to factors such as rafting and dispersal capacity, length of larval stages, ability to disperse as adults, environmental conditions in the regions of origin, and physiological requirements. For example, some sponges and crustaceans seem to be able to disperse from the Mediterranean in deep eddies, which penetrate into the region of the Azores at depths below 800–1000 m. This mode of transport seems unlikely for the littoral fishes, thus explaining the lower Mediterranean affinities among these vertebrates. Eddies circulating from western Africa, the Canaries and

Madeira on the one hand, and from the Atlantic coasts of Europe on the other, must be the main source of eggs and fish larvae, and even of young and adult fish. Small islets and shallow seamounts, which are a common topographic feature of the ocean between the Azores and the African continent, could have served as 'stepping stones' for the dispersal of organisms. It would be highly interesting to evaluate the role of seamounts in regard to dispersal of benthic fishes, as was done along a seamount chain in the southern Atlantic for prosobranch gastropods.

Fisheries and marine pollution

Azoreans have always heavily exploited their littoral and nearshore waters. Most of the species that are caught very near to the shore using artisanal methods, with or without boats, are specially regulated to control human exploitation, and their importance for the local economy can be significant. In recent years, considerable problems for both resource management and nature conservation have arisen, while pressures have generally increased with the greater availability of cheap snorkelling gear since the 1970s. Although collection using SCUBA (Self Contained Underwater Breathing Apparatus) gear is banned, except for scientific purposes by authorized personnel, abuse is common.

Until now, pollution has not represented a great threat to the marine environment in the Azores. The Azores are situated in one of the safest parts of the Atlantic Ocean as far as marine pollution is concerned: although recent spills in Madeira and Shetland emphasize the vulnerability of islands, the only oil spill known in the vicinity of the Azores region occurred in 1970.

Organic pollution due to leachates from visiting yachts occurs in the harbour of Faial but is extremely localized, the effects on whelks (*Thais haemostoma* Linnaeus), for example, being restricted to the harbour itself. The same probably applies to the other major harbours, on Terceira and São Miguel.

During the last few years, sewage pollution has been increasing through discharges to the sea. This problem mainly affects areas close to the main towns, but is more likely to cause a public health problem than a major ecological impact. Collection of shellfish on the shore, very close to sewage pipes discharging at mid-tide, has been observed at Vila Franca de Campo on the island of São Miguel, and may well occur elsewhere.

Other types of locally derived pollution have not had much impact, mainly because of the limited industrial development. Some localized impacts can, however, be detected. Most factories are located on the coast and their effluents are discharged into the sea. A recent case involved a problem relating to the tuna fish factory on the island of Faial, situated close to an important bay and to a Protected Landscape.

Despite the remote geographical location of the Azores, concentrations of heavy metals and other chemicals in the waters around the archipelago do not seem to differ significantly from levels observed in other areas of the North Atlantic. This is true for levels of heavy metals in seawater; for levels of mercury in large migratory fish, in cephalopods and in seabirds; and for levels of organochlorines and mercury in resident fish. Surprisingly, a recent coastal study has shown that mercury concentrations are five times higher in octopus from coastal locations near urban centres (such as harbours), than they are in remote sites. This may be due to sewage effluent and careless disposal of used batteries, lamps and antifouling paints. Nevertheless, the absolute values were considered low.

Recently there has been evidence of enhanced bioaccumulation of mercury in mesopelagic fishes (200–1000 m), and there is reason to believe that a general global rise in mercury concentrations is affecting marine ecosystems, especially in the mesopelagic environment.

The Azores offer a unique opportunity for the measurement of historical variations in heavy metal contamination within the North Atlantic marine environment. A study using seabirds as bio-indicators will add to the assessment of patterns of atmospheric deposition of metals in the Northern Hemisphere. Several authors have emphasized the importance of the Azores as a region for comparison with levels of contamination on the coasts of Europe. The number of indicator species that are available is limited – for example, mussels (*Mytilus*) are absent from the Azores. However, there are other possible bio-indicator species, including *Pachygrapsus* spp., *Octopus vulgaris, Chthamalus stellatus* (Poli) and *Patella aspera,* all of which have mainland conspecifics. *Enteromorpha* spp. and *Fucus spiralis* Linnaeus are two types of algae which may also be useful.

Looking to the future

The littoral zone is now under extremely heavy pressure from subsistence, semi-commercial and recreational collectors, and also rod and line fishermen. The increasing exploitation of offshore banks and seamounts by line fishermen will inevitably affect top predators. Snagged or lost fishing gear and anchoring equipment may also have impacts on benthic communities.

New fishing areas are being exploited, in addition to existing ones, and there is a tendency for small open boats to be replaced by larger covered-deck boats. Expansion of the fishing effort has also been encouraged by improved preservation facilities. A few demersal species are already threatened by over-exploitation, the most important being the red sea-bream (*Pagellus bogaraveo*). In contrast, predators of little commercial interest, such as the silver scabbard fish (*Lepidopus caudatus*) are increasing in numbers at the expense of other species. Other non-target species, like the hornback ray (*Raia clavata*) are under threat through being removed (and dying) as by-catch of commerical fisheries

Various regulations have been enacted to prevent the loss of some littoral shellfish in the Azores. This may have happened already in the Canaries with one type of limpet (*Patella candei candei*). Certainly *P. ferruginea* is facing extinction in the Mediterranean. Given the cultural importance attached to limpets ('lapas') in the Azores, similar losses must be prevented by enforced regulations and establishment of littoral reserves. The same considerations apply to various species of lobsters and the large barnacles (*M. tintinnabulum*).

Biochemical genetic studies of limpets suggest that the Azorean population of *P. candei* can be considered sufficiently genetically different to be elevatd to a specific status Although clearly conspecific, *P. aspera* shows considerable genetic differentiation between the Azores, Madeira, the Canaries and mainland Europe. If these and similar species were acutely overexploited, then changes caused by re-colonization would be limited – an exception is the lobster, *Scyllarides latus* which has a teleplanic larva.

It could also be argued that there is a case for designating at least one or two seamounts as reserves. The Formigas (Figure 2), which barely rise above the surface, partially fulfil this need, and it may be difficult to persuade the fishing community of the necessity to designate other suitable seamounts as reserves. However, such a measure could contribute to the conservation of exploited demersal species, and would be of major importance for the future of the demersal fisheries in the Azorean EEZ (see below).

Much basic marine ecological, systematic and biogeographic research is still required to place the Azores into their proper context in the north-east Atlantic. Some groups have been well studied (e.g. algae, fish, amphipods, decapods, tunicates) and biogeographical conclusions can be drawn, but for other groups there are huge information gaps. Comprehensive catalogues of the flora and fauna would be immensely useful for future studies on the conservation of biodiversity in this area of the north-east Atlantic. There is also a need for further basic survey work to describe major habitats and communities (biotopes) throughout the Archipelago. This work needs to be extended beyond the limits of diving, using remote vehicles and submarines.

Of particular interest are the various seamounts in the area. Communities surrounding volcanic springs and vents have recently been discovered at around 1100–1700 m depth at the Lucky Strike site, and at 860–970 m at the Menez Gwen site. The Azores also offer the best potential for studying shallow vents in the Mid-Atlantic Ridge area; such vents have been observed on the João de Castro seamount (Figure 6) and off São Miguel.

Another aspect deserving close attention is the potential impact of climate change. It is now well established that global climate is warming and that this will have impacts on marine fauna and flora, both at global and regional scales It is probable that in the north-east Atlantic there will be a rise in sea temperature; and an increase in temperature of coastal waters, even if only by a few degrees, will lead to the loss of many cold temperate forms which are at the southern limit of their distribution here. In continental seas, these losses may be followed by a concomitant increase of warm temperate and subtropical species. However, in the case of the most isolated Atlantic islands of the Azores, it is unlikely that losses of 'northern forms' will be followed by the concomitant substitution (or increase) of 'southern forms'. Most adult coastal fishes have a limited capacity for crossing the large stretches of deep ocean that separate these remote islands from the nearest coastal zones. Recolonization would depend on larval dispersion. Given the distances involved, and the differences of larval biology of the coastal and benthic species, it could be expected that the loss of northern forms would result in a reduction of biodiversity in these islands. This could only be mitigated by colonization by species with great capacity for dispersal. There is a need for detailed investigation, using historical databases as well as comparative and empirical research, to characterize the compositions of, and variations in, both coastal and pelagic assemblages. Monitoring programmes should be established.

There is a profusion of legislation for conservation in the Azores. However, it needs to be implemented and enforced. It also needs to be respected. The most important way of promoting marine conservation in the islands is by education – formally in schools as well as informally for local adults and visitors. Steps have been taken to increase awareness, such as a TV series produced about a joint Anglo-Portuguese Expedition in 1989 ('Ilhas Vivas'), exhibitions and lectures. Interest in promoting eco-tourism is growing. Whale-watching and a museum of whaling attract visitors in the former whaling town of Lajes do Pico. Realisation is growing that marine life needs to be seen in the wild – as well as on display, and in restaurants. The Department of Environment and Tourism and the Department of Fisheries of the Regional Government of the Azores must continue to protect wildlife and provide its appreciation by a wider audience, both locally and through tourism.

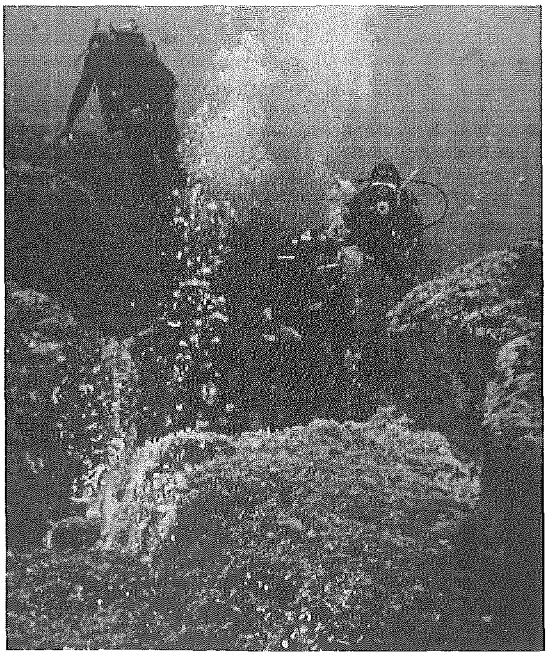


Figure 6 *Divers from the Dept of Oceanography and Fisheries studying hydrothermal vents at a depth of 35 m on the D. João de Castro Bank.*
(Courtesy of Dr Ricardo Serrão Santos)

Further Reading

Saldanha, L., Ré, P. and Martins, A.F. (eds) (1992) *Centenaire de la dernière campagne océanographique du Prince Albert de Monaco aux Açores à bord de L'Hirondelle. Açoreana*, Suppl.

Santos, R.S., Porteiro, F.M. and Barreiros, J.P. (1997) Marine fishes of the Azores: Annotated checklist and bibliography. *Arquipélago – Life and Marine Sciences, Supplement 1.*

Walker, M. (1992) The voyage that changed the world, *Ocean Challenge*, Vol. 3, Nos. 2/3.

Acknowledgments

Much of this article is drawn from: Santos, R. S., Hawkins, S., Monteiro, L. R., Alves, M.and Isidro, E. J. (1995) Marine research, resources and conservation in the Azores, *Aquatic Conservation: Marine and Freshwater Ecosystems*, **5**, 311–54.

Figures 4 and 5 are reproduces by kind permission of the publishers, John Wiley & Sons, Ltd.

We would also like to thank staff of the Department of Oceanography and Fisheries of the University of the Azores, particularly Dr Helen Martins and Dr Ricardo Serrão Santos.

Celebrating the Oceans at Expo 98

Colin Pelton

When I was first asked to write this article, my immediate thought was 'who initiates global events such as the 1998 International Year of the Oceans, and how do they get organised and fixed in the calendar?' In the case of this particular event, the answer lies with Portugal.

My reason for becoming involved in the Year of the Oceans (which I freely admit I knew nothing about beforehand), started with EXPO 98 – the World Exposition in Lisbon. The Portuguese have taken the opportunity to celebrate their magnificent maritime culture by making the theme of the Lisbon EXPO 'The Oceans – a Heritage for the Future'. The organisers have taken the bold step of tackling current oceanographic themes head-on with a specific set of topics which have to be addressed and interpreted for a public audience. For instance, a major part of the exhibition will be the Pavilion of the Future – designed to create public awareness of the importance of oceanographic research. The themes will be demonstrated by state-of-the art computer simulations, and fit comfortably within current topics of research including remote sensing, submersibles, automated underwater vehicles, the coastal zone, climate change, biological productivity, surface pollution, CO_2 and other greenhouse gases, turbidity currents, and of course mid-ocean ridges and hydrothermal vents.

During my days (years actually) at IOS Deacon Laboratory, I realised some of the benefits of getting involved in large international exhibitions such as Columbus '92 in Genoa and the Seville EXPO, also in 1992. The audience is untargeted, but international and potentially enormous. After the events we recovered the purpose-built display models which we now use in-house.

The Southampton Oceanography Centre (SOC) was not even open for business in September 1995 when António Nabais, Director of the EXPO Contents Department and his colleagues, took time off during a UK visit to call in at the Southampton International Boat Show. The British Consulate in Lisbon contacted us and suggested that the EXPO team look round the UK's newest oceanographic centre. We took the opportunity to bring them to SOC and made the team fully aware of the wealth of oceanographic expertise and technology available at SOC and throughout the UK.

This was followed up in early 1996 by a DTI-sponsored visit to Lisbon. UK organisations made a series of presentations to the EXPO team on a complementary range of skills available to them: design, display, project management, and of course marine science. My remit, as part of a small Industrial Liaison Team at SOC was to promote the Centre's work, not only to the EXPO organisers, but also to the major UK design companies and event organisers who would need guidance during design and verification stages.

I am sometimes guilty of taking our work for granted after so long in the business, but I was still gratified to see a lecture hall of hardened international event organisers (the Seville EXPO, Barcelona Olympics etc.) completely bowled over by a time-lapse video of a feeding worm, recorded by a deep-sea camera. The grazing habits of benthic animals were a major topic of discussion in the bar afterwards. Faced with interpreting a bewildering array of marine-related topics, the design and construction teams have now seen exciting ways to put across a marine science message to over 10 million visitors.

At home, the baton has been taken up by the Foreign and Commonwealth Office (FCO) who are organising the UK Pavilion. They have also toured the UK looking for ideas, and we were delighted that they seem to be using the new book by Colin Summerhayes and Steve Thorpe, *Oceanography: an illustrated guide* (reviewed in the last issue of *Ocean Challenge),* as their handbook for interpreting current marine science themes. Designs for the UK exhibits will be prepared this year and I hope that with enough impetus from the UK scientific community, and support from the FCO, we emerge with focussed, state-of-the-art marine science displays of the highest quality, showing UK expertise and aimed unreservedly at a general international audience. However, we will undoubtedly be up against some stiff competition in Lisbon: it was interesting to learn from a visiting public relations team from the Japanese Marine Science and Technology Centre (JAMSTEC), that they were being fully funded by the Japanese Government to headline their research vessel and deep ocean submersible technology at EXPO.

So what's on offer at Lisbon? The developers have recovered a large area of derelict land on the site of an old oil refinery on the banks of the Tagus and constructed a marina area where, during the six months of the exhibition, research vessels and other craft will make appearances in port. We hope that a UK research vessel, if time and money allow us, may make an appearance. They have also built the Lisbon Oceanarium complex, which will be Europe's largest aquarium, with environments ranging from the coral seas to the Antarctic Ocean. There will be separately themed pavilions; water parks and an Olympic-size swimming pool; the Tall Ships Race will call in to port; and there will also be spectacular water and light displays and other events. The Shell oil company are sponsoring a 500 m^2 display of sea shells, and on the more serious side, the MARIS Project will be presented. MARIS is a programme, funded by the EU and Canada, that has been researching the application of new information systems and communications technology for shipping and ocean management on a world-wide scale.

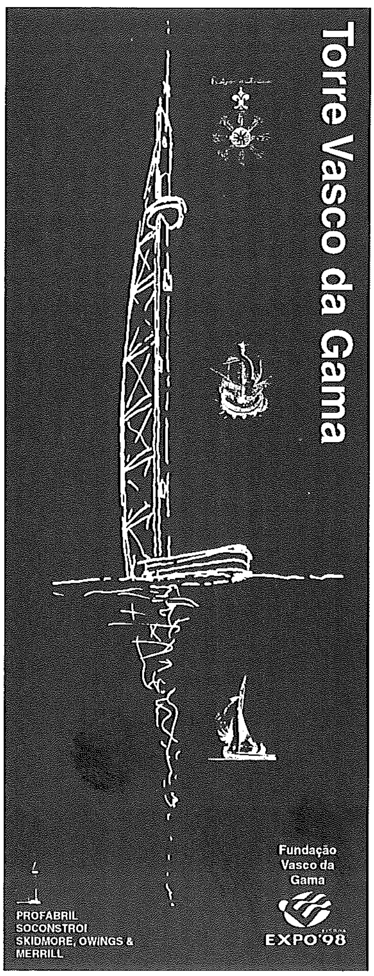
The EXPO exhibition is open to all and runs from May to September 1998. If you do go to Lisbon, look out for UK marine science and technology – our *GLORIA* survey system (now a European Union 'Large Scale Facility') will be featured along with, we hope, much more ... that worm might even make an appearance!

And as for the provenance of the International Year of the Oceans – it was first put forward by the Portuguese to the International Oceanographic Commission (IOC) some four years ago (Resolution 17 of the March 1993 Assembly, to be precise) presumably as a hook to hang their EXPO hat on. In November of the same year, UNESCO took up the proposal and it was then passed up through the UN Channels until it was approved and adopted by the 49th UN General Assembly in December 1994. Amara Essy, President of the UN General Assembly, pronounced in favour of the proposal (quite a victory for Portuguese diplomacy) and said that 'he hoped that the action needed all over the world regarding the oceans would be crowned with success.' We hope so too.

So what's happening in Britain in 1998? Very little as far as I can ascertain but as I've only just found out that we are already well into the 1997 'International Year of the Reef', I am willing to be disproved. SOC will undoubtedly be involved in 1998 as will, I trust, other NERC marine laboratories and the Challenger Society, but it will need impetus, real support and adequate funding to get any serious event off the ground.

Colin Pelton
Southampton Oceanography Centre

More information about Expo 98 can be found on the World-Wide Web: http://www2.expo98.pt/en/index.html



Just one of the stunning buildings being designed for Expo 98, the sail-like tele-communications tower celebrates Vasco da Gama's discovery of the maritime trade route from Europe to India. The elliptical pier-building at the base, which extends 60 m out over the River Tagus, will act as the EU Pavilion. (Reproduced by courtesy of the architects, Skidmore, Owings & Merrill, Inc.)

Reminiscences of the Indian Ocean

Anwar Abdel Aleem

In 1964, I was privileged to join the International Indian Ocean Expedition on board Cruise 9 of the RV *Anton Bruun* from Woods Hole, scheduled to explore, among other things, coral reef life in the western Indian Ocean. Taking off from Mombasa, Kenya, the ship worked out of the islands of Latham, Al Dabra, the Comores, Farquhar, Amirante and the Seychelles. Most of these islands had formerly been visited during the 8th and 9th centuries by medieval Arab navigators and seafarers. Those men wrote wonderful accounts of their explorations, enduring at the same time the hardships of life at sea. They encountered breathtaking adventures with cyclones, currents and sea monsters, as well as shipwreck.

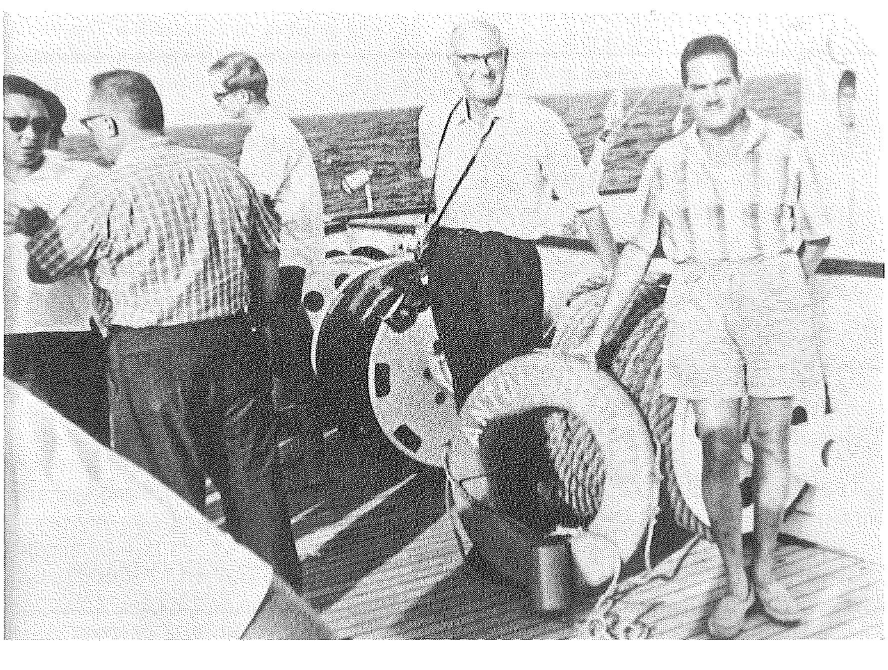
Nautical Arab literature features in travel books such as the *Voyage of Sulayman the Merchant* (1851AD) the *Voyage of Ibn Battuta* (1325–1354AD) and in books on the wonders of land and sea known as *mirabilia*, including one known as the *Wonders of the Sea of India*. This book was compiled in 953AD by a Persian pilot named Buzrug Ibn Shahryar . It was published in Leiden after an Arabic manuscript by Van der Lith in 1883–86, with a French translation entitled *Merveilles de l'Inde* by Marcel Devic. Such fascinating literature no doubt contributed to books like *One and Thousand Nights* and the *Voyages of Sindbad.*

With this wealth of information in the back of my mind, I ventured to sail in the Indian Ocean. The splendid ship was nothing to compare with medieval Arab dhows, yet life itself had not changed much in those remote parts of the Ocean for millennia.

Approaching an island like Al Dabra towards sunset brought to my mind the mystery of the enchanted island full of gems and poisonous snakes. The surrounding mangrove forest seemed to teem with dancing ghosts and spirits, while the air was filled with the aroma of jasmine, ginger, cinnamon and other tropical spices. Giant turtles recalled stories of legendary animals or extinct prehistoric flying reptiles reminiscent of the phoenix or gryphon of Ancient Egypt, Babylon or Greece.

When our ship landed on the quays at Mahé Island in the Seychelles we were greeted by multitudes of women of a genetic pool including English, French, Chinese, Indian, Arabic and African races. The sight of such a fantastic number of women reminded me of the 'Island of Women', so well described in the Arabian Nights. That the old Indian Ocean sailors were not exaggerating is supported by the tourist bulletin of the Seychelles which states that women outnumber men on the island by a ratio of 7 : 1.

On board the* Anton Bruun *during the International Indian Ocean Expedition: Dr Chen, the Chief Scientist, is on the far left, and the author is on the far right.



It should be said that not all *mirabilia* tell of legend or fiction; some are the results of sound and keen observations of phenomena such as bioluminescence or discolouration of seawater, or of habits of fish and cetacea. Among physical aspects, mention is made of the reversing currents in the Indian Ocean, and of the cause of the cyclonic winds referred to as Al Tannin (the dragon).

Here are some interesting tales.

Ibn Battuta and Maldive Ginni

During his stay on the Maldive Islands, Ibn Battuta was told of a *ginni* that appeared with the new moon on dark nights, in the form of a huge fire on the sea surface. This spread havoc among the inhabitants. In order to keep off his evil, the people had to sacrifice a virgin girl by tying her up with rope and leaving her on the shore overnight. In the morning they would find the girl dead and violated; each family had to present a girl in turn. Aware from his extensive travels at sea that the 'fire' must be the natural phenomenon we call bioluminescence, Ibn Battuta vowed to stop this inhuman custom. He offered to replace the girl on the following new moon and spend the night alone on the shore reciting Quran. When they found Ibn Battuta alive, the people of the islands acclaimed him, and it was not long before he had become the judge of the islands and married the sister of the Sultan.

Discoloration of seawater

In the *mirabilia* of Abu Hamid al Andalusi (1081–117AD) known as Tuhfat, the author speaks of this phenomenon as follows (transcript by Ferrand, 1925):

De même dans la mer d l'Inde, il y a un golfe ou l'eau est rouge comme le sang, un autre ou elle est jaune comme l'or, un autre ou elle est blanche comme le lait. Mais Allah sait mieux ce qu'il en est en ses endroits. Par elle même l'eau de cette region est blanc, pur comme toutes les autre mers.

Thus Abu Hamid noticed colour changes in seawater beween different gulfs in the Indian Ocean. Unaware of the organisms responsible for the phenomenon, he gives no explanation and with all honesty admits that only God knows what causes these changes.

The Wak-Wak island

These mysterious islands appear in several *mirabilia*. According to legend, the name is derived from the so-called 'tree of wonders' growing on these islands. This tree bears rounded fruit resembling the heads of women suspended by their long hair (so Arab sailors imagined). When these fruit are ripe they fall down to the ground making a sound like 'wak-wak'. Geographers are divided as to the location of these islands in the ocean. As for the identity of the plant, I am of the opinion that it could be a species of *Atrocarpus* known as the bread plant, a tree which bears rounded fruit suspended from long stalks and is widespread in the Indo-Pacific region.

The analogy between the St Brendan Navigatio *and the Adventures of Sinbad*

As a member of the Hakluyt Society in London, I received an invitation to attend the first International Symposium on Saint Brendan, held in Trinity College, Dublin, in September 1985. I presented a paper entitled 'Wonders of the Sea of India and the Saint Brendan Legend'.

The *Navigatio*, considered as the Odyssey of the old Irish church in medieval Europe, is concerned with the other world as a land of happiness and plenty. Some authors, however, try hard to relate the Saint's voyage to known islands and landmarks in the Atlantic, ignoring the fact that it is a spiritual voyage in time and space analogous to mystical (*sufi*) writings of the Moslems.

A scene from the Wak-Wak Islands traced from a 13th century painting by a Persian artist

In the *Navigatio*, Saint Brendan encounters such temptations and wonders as The Island of Joy, The Land of Women, the Isle of Sheep, birds of paradise, monsters and other strange creatures. Amazingly, there is considerable similarity between the *Navigatio* and medieval nautical Indian Ocean folklore as set down in the *mirabilia* referred to earlier. For instance, the Island of Joy, Isle of Sheep,* Birds of Paradise and the Land of Women are found in the Indian Ocean and in the Atlantic. Other stories are modified so as to suit the environment in the ocean concerned. For example, the moving island in the Atlantic is a whale, while in the Indian Ocean it is a giant turtle .

Saint Brendan's gryphon is identical to the one seen by Sinbad

The following is a translation of a passage from the *Wonders of the Sea of India* concerning this story:

There was panic on board, and the sailors unloaded the cargo onto an island on which they stayed until they mended the defect. Then they loaded back the cargo and lit a fire to cook. To their surprise, the island started to tremble and then sank down. They managed to throw themselves into the water and reach for the lifeboat, encountering great difficulties. The island proved to be a giant turtle which started to move when it felt the heat of the fire.

The Atlantic version is the same almost word for word, except for the large animal forming the 'island'. I am therefore of the opinion that the Saint Brendan legend and other similar tales have been written following the translation into Latin, in the monasteries of Cordova (Spain) and Sicily, of medieval nautical Indian Ocean literature After all, knowledge is the legacy of mankind.

* In the Indian Ocean, pilots used to release sheep to breed freely on certain islands so that they would be available on later visits.

Further Reading

Aleem, A.A. (1967) Concepts of currents, tides and winds among medieval Arab geographers in the Indian Ocean, *Deep Sea Research*, **14**, 459–63.

Aleem, A.A. (1980) On the history of Arab navigation. *Proc. of the Third International Congress on the History of Oceanography* (M. Sears and D. Merriman, Eds.) pp.582–93 Springer Verlag.

De Courcy Ireland, J. and Sheehy, D. (eds.) (1988). *Atlantic Vision,* Boole Press, Dublin.

Ferrand, G. (1925) *Le Tahfat al Albab* de Abu Hamid Al-Andalusi édité d'aprés les Mss 2167, 2168, 2170 de la Bibliothèque Nationale, *J. asiat.*, **207**, 1–148, pp.193–304.

Anwar Abdel Aleem D.Sc. is a Professor of Biological Oceanography and former Head of the Ocean-ography Department of the University of Alexandria, Egypt.

The hunt for TWA Flight 800

the challenge of ocean search and recovery

David W. Jourdan

The disastrous explosion and crash of TWA Flight 800 brought international attention to the technology and techniques involved in ocean search and recovery operations. Within hours of the event, news coverage was in high gear, and the public waited anxiously for word of survivors, and reasons for the tragedy. As the days turned into weeks and flight recorders still yielded no clues, victims remained missing, and no large pieces of aircraft were found, impatience began to grow. Almost every conversation about the disaster included the question ...

Why the delay?

Imagine that you lost a contact lens somewhere on the floor of a school gymnasium, the size of a basketball court. The lights are out, but you have a penlight that can illuminate a six-inch-wide area. You have to keep your eyes one inch off the floor to see well enough to recognize the lens, and you have to move slowly ... it takes 45 minutes to cover one six-inch strip from the basket to the free throw line. To be sure you don't miss anything, you overlap each strip by half its width. If you keep at it 24-hours a day, it will take you over a month to search that floor.

In sonar terms, you have covered over 160 square miles of search area, measuring about 18 miles by 9 miles. This is the scale of the area which had to be searched to find and collect debris from the TWA Flight 800 crash site. Nonetheless, you might think that finding and retrieving the wreckage and the victims would be relatively easy as the crash happened so soon after take-off: TWA Flight 800 went down only about 10 miles off Long Island (New York) in some 100 to 120 feet of water. However, just the mobilization of four ships, countless small craft, search and salvage equipment, dive recompression chambers, and over 100 specially-trained divers is a major undertaking. Add to this the coordination of efforts, problems in navigation, the impact of weather, assimilation of different types of information, and differing objectives of families, forensics experts and safety investigators, and maybe we can begin to understand the scope of the task set before the National Transportation and Safety Board (NTSB) team as they worked frantically to recover evidence, hoping to solve the mystery of TWA Flight 800.

Seeing in the dark

Television and films have popularized the notion that one can see quite clearly under water. From the picture window on the *Seaview* (in 'Voyage to the Bottom of the Sea') to the panoramic vistas of 'Thunderball' and 'The Abyss', we get the idea that water mainly turns things a shadowy blue–grey, but one can still see for miles. In fact, even the brightest light we know (sunlight) can only penetrate a few hundred feet in the clearest water, and under most conditions our feeble attempts at illumination only serve to push our visibility to a few dozen feet at most. Add sediment or algae to the mix, and most light gets scattered right back, like a car's headlights in the fog. So although underwater cameras and high-intensity lights are common, they are quite limited at search tools. Under the most generous assumptions, it would take several days to completely search a single square mile with an underwater video camera – and someone has to be carefully watching the monitor at all times (an excruciatingly boring task). When the search area is tens or even hundreds of square miles, optical methods are hardly effective.

Laser line scanners are a new technology that use laser light, working on the principle that certain colours are transmitted better in seawater than others (it is those wavelengths that are *not* absorbed that give the ocean its characteristic blue–green hue). An intense laser beam of the right colour is scanned over the bottom in a back-and-forth pattern, painting a 'raster' image similar to a television picture. The device has a range of between about 10 and 100 ft (depending on water clarity) and can image areas larger than 100 ft across at high resolution. This is still rather small compared to typical search areas, and there are only a few of these devices currently in existence.

The most widely used sensor in the business of ocean search and mapping is the side-scan sonar, of which the example most familiar to *Ocean Challenge* readers will be Britain's *GLORIA*. A side-scan is typically a cigar-shaped instrument with fins (commonly called the towfish) that is towed underwater and behind a ship using a special cable capable of carrying electrical power and sonar data. The cable also provides the strength needed to pull the sonar through the water at survey speeds of up to 5 knots.

To work, the side-scan sonar relies on a device called a transducer. Transducers have a unique ability to convert electrical energy into sound, and sound energy (pressure) back into electrical energy. The transducer is used to create a sound pulse in the same way as a depth-finding echo-sounder operates. Unlike such an echo-sounder, which sends sound energy directly down to the sea-floor, the side-scan sonar directs its transducers out to the side of the instrument to 'illuminate' a strip of the ocean bottom. When this sound hits objects (whether natural or manufactured), an echo is reflected back to the transducer. The intensity of the returned signal, carefully timed, is used to 'paint' a line on a paper or video monitor. After a short time, the transducer stops listening for echoes and sends another pulse, painting another line on the display. This process is repeated at a rate of several times each second, forming over time an 'acoustic image' of the ocean floor along a broad 'swath' on one side of the towfish. By adding a second beam, pointing to the opposite side of the towfish, a second 'swath' along the bottom can be imaged on the other side of the track. The resulting images must be corrected for geometric distortion and the actual path of the ship to produce a 'rectified', or geographically correct map.

Also, image-enhancement techniques, many of them exploited by NASA for planetary imaging, can greatly improve the picture. The nature and quality of these images are similar to the familiar ultrasound images used by doctors to examine unborn babies. Although great detail will sometimes appear, the reflective properties of different materials, the angle that the sound wave strikes the bottom, and distortions in the sound as it passes through the water, all make side-scan images difficult to interpret.

There is a trade-off between range and resolution. Systems with wide swaths (measured in miles) have poor resolution (measured in feet) and cannot detect small targets. They also must operate several hundred feet above the bottom (like *GLORIA*) so the sound wave doesn't strike the sea-floor at too shallow an angle at the edges of the swath. So, we can't use them in shallow water when looking for small objects. Higher resolution systems, typically used in this sort of search, can image swaths of around 600 feet at better than 1-ft resolution while skimming tens of feet from the bottom (like *TOBI*). Such a system, using overlapping swaths to improve the chances of detecting targets, could search a square mile in under six hours.

Mother Nature is notoriously uncooperative – if not downright malicious! – with sailors, and search teams are no exception. Bad weather can keep even the larger ships from operating, and high, noisy seas can severely degrade the quality of sonar images. The shallow water is actually a hindrance, as wave effects, noise, and surface reflections are closer to the sensor and 'targets'. Most search systems operate at slow speeds (a few knots), so significant coastal and tidal currents can make it difficult to space search lanes evenly.

Complications

The wreckage of TWA 800 was not the only debris on the continental shelf off Long Island. Sunken barges, lost fishing gear and dumped refuse compete with trawler scars and natural rock outcroppings to give false signals and mask the ones we are looking for. Contacts must be identified before risking divers and wasting salvage efforts in difficult conditions. The Navy operates several Remotely Operated Vehicles (ROVs), equipped with cameras, lights and manipulators, to help identify wreckage and even pick up small items. Then, Navy divers must be sent in to do the real dirty work. With visibility of as little as 3 ft, tangled wreckage, leaking fuel, and other hazards, the work can indeed be quite dirty and dangerous.

But divers' biggest concern is the pressure of the water itself. Even at these shallow depths, water pressure approaches 50 p.s.i. Prolonged breathing of pressurized air can lead to narcotic effects from nitrogen, lethal oxygen toxicity, and nervous system disorders. Decompression illness (known as 'the bends') is a complicated collection of related ailments that can strike anyone, and occurs once every 500 to 1000 dives among commercial divers.

Recreational SCUBA divers are limited to only 13 minutes in the water when descending to a depth of 120 ft, after which a 'surface interval' of over two hours must be spent before the dive can be repeated (even then, successive dives should be limited to 100 ft). Beyond that, recompression chambers must be used to keep gases from boiling out of divers' tissues too quickly. Specially-trained 'saturation' divers can spend days or weeks living and working at elevated pressures breathing specially mixed gases (mainly helium or other high item gas with small amounts of oxygen). A few hardy souls (known as 'mechanical divers') willing to spend $10 000 on equipment, will dive to depths of 300 ft or more for recreational purposes, breathing mixed gases and spending several hours slowly returning to the surface (for decompression) after only 30 minutes on the bottom.

To all this has to be added the danger from cold. Even in the summer, water temperatures are low enough to be a real hazard, sapping energy and numbing the mind. Obviously, the divers working the TWA site could only spend limited amounts of time in the water each day. When out of the water, they were constant prisoners in their recompression chambers. Under pressure from the ocean, and under pressure to return.

Quite an achievement

Considering the scope of the task, the dangers, the stressful interaction with families of the victims, and the need to collect evidence before it ages, the achievements of the TWA search and recovery team have been quite remarkable. In barely three weeks, a fleet of equipment was mobilized, a team of specially-trained divers assembled, most of the victims found, the flight recorders retrieved, and nearly half of the aircraft recovered (subsequently increased to more than three-quarters). If the mystery of the crash is never solved it will not be for lack of effort and accomplishment by the NTSB search and recovery team.

Further Reading

Moon, R.E., Vann, R.D. and Bennet, P.B. (1995) The physiology of decompression illness, *Scientific American*, August, pp.54–61.

Also of interest: Navy Public Affairs Library (wwwnavy.mil/navpalib)

David W. Jourdan
Meridian Sciences, Inc.
Columbia, Maryland, USA

Carbon cycle shock – oceanic residence time slashed!

Well, that headline was just to catch your attention, but this is a serious issue. If you read standard texts and the works of eminent marine chemists such as those of our very own Challenger Society President, you either see no residence time quoted for carbon in the oceans, or you see a figure in the order of 10^5 years. That figure is arrived at by the simple expedient of dividing the river flux to the oceans into the total dissolved carbon in the oceans: in round figures it is 0.5 Pg yr^{-1} into 38 000 Pg (Pg = 10^{12} kg), which gives 76 000 years, near enough to 10^5 years.

However, when I look at the atmospheric fluxes of carbon into and out of the ocean, I notice that they dwarf the rate of supply from rivers. About 100 Pg yr^{-1} are exchanged across the air–sea interface. When you look at carbon cycle pictures, that exchange is shown diagrammatically as occurring more or less at the same place, but we know that is not the case. Again roughly speaking, polar regions take in atmospheric CO_2 (particularly in the North Atlantic) and send it to the deep ocean in sinking water masses. Equatorial latitudes return the stuff to the atmosphere by upwelling, warming and degassing. At intermediate latitudes, the ocean is (roughly) a sink for CO_2 in winter and spring, a source in summer and autumn.

Moreover, that two-way flux of 100 PgC yr^{-1} has different components, which only show up when you start to look closely at these carbon cycle pictures. First, there is the flux into and out of the biota, which is mostly in the surface ocean, indeed, mostly in the mixed layer, but certainly above the main thermocline. Best estimates of marine biomass are of order 2 Pg, and the fraction of CO_2 in the surface ocean that cycles into and out of that is generally given as about 40 PgC yr^{-1}. That is a turnover rate of 0.05 yr, or a little under three weeks. That sounds about right, given that oceanic biomass is dominated by phytoplankton.

Second, there is the flux into and out of the surface ocean itself, which I will for present simplified purposes take as being the bit above the thermocline. That is generally estimated to contain about 1000 PgC in solution. Now, we are told that 100 PgC yr^{-1} are exchanged between atmosphere and surface ocean, so at first sight we might suppose that to give us a residence time of something like 10 years (1000 PgC/100 PgC yr^{-1}). But hold, that sum is for the flux into and out of the surface ocean *at the top*. What about the fluxes into and out of the surface ocean *at the bottom* – namely, the downwelling (water mass formation) and upwelling fluxes? That figure is of the order of 35 PgC yr^{-1} in each direction (there's a slight imbalance because of 'leakage'into sediments, but it's trivial in this context). That gives us a residence time of something like 30 years (1000 PgC/35 PgC yr^{-1}) for carbon in the surface ocean, which isn't all that reliable either, because upwelling and downwelling occur in different parts of the surface ocean. Whether you choose 10 years or 30 years doesn't really matter a lot – the time-scale here is a few decades.

Third and finally, we come to the deep ocean, which receives the downwelling flux from the surface ocean, and returns it thither as the upwelling flux. Best estimates of the total carbon in the deep oceans is 38 000 PgC, and we've seen that the downwelling and upwelling fluxes are about 35 PgC yr^{-1}. That gives us a residence time for carbon in the deep ocean of a little more than a thousand years. And since the deep ocean is the biggest part of the whole, it would be fair to quote an oceanic residence time for carbon of ~1000 years. Wouldn't it?

But what about that figure of 10^5 years, commonly quoted as the 'standard' carbon residence time? I suspect that this comes from the fact that the amount of carbon 'leaked' annually from the marine carbon cycle and preserved in sediments is of the same order as the supply of carbon entering the ocean from rivers each year, *viz* about 0.5 PgC. The number has its own internal logic, i.e. it is the amount of time a carbon atom can be expected to spend in the ocean before it is taken out of the cycle and removed into sediments (where it will stay for up to perhaps 200 million years or so, or even more, though admittedly sometimes a lot less).

But it isn't a real residence time from the point of view of controlling atmospheric CO_2 concentrations. That must surely be determined by the 1000-year cycle. If you pump more CO_2 into the atmosphere, some of the excess is removed into biota, both as organic carbon and calcium carbonate, and a small fraction of that is removed permanently from the cycle. But most of it is returned to solution in the deep ocean and will come back to the surface in about 1000 years, to exchange with the atmosphere once more. This is not without some relevance to the future of humanity (assuming it lasts that long): if there is less CO_2 in the atmosphere some hundreds of years hence, could not upwelling and degassing of CO_2-rich waters from the deep ocean cause atmospheric concentrations of the gas to rise again?

It seems to me to be statistically a lot more likely that most of the carbon atoms locked away in marine sediments have actually entered the ocean direct from the atmosphere rather than via the weathering cycle and rivers. Indeed, how can an individual carbon atom decide which of the oceanic subcycles it will go into? I mean, one atom might come into the ocean from a river, get fixed into an algal cell and then be consumed and respired back into the atmosphere within days. Another might dissolve at the air–sea interface, get incorporated into a planktonic carbonate skeleton, and sink to the ocean floor to be buried and preserved.

It further seems to me that the only certain way of locking away atmospheric carbon dioxide in the long term is to increase organic production, especially if it is associated with calcum carbonate precipitation. Increased production of coral reefs and other shallow-water carbonates on continental shelves would be a good long-term mechanism for removing CO_2 from the atmosphere. That is true, even if the limestones are then uplifted, because we must remember that weathering of limestone followed by precipitation of carbonate has no net effect on atmospheric CO_2 concentration:

$$\begin{array}{c}\text{atmosphere}\\ \downarrow\uparrow\\ CaCO_3 + CO_2 + H_2O \rightleftarrows Ca^{2+} + 2HCO_3^-\end{array}$$

Some geologists are fond of positing that increased weathering rates will draw down extra CO_2 from the atmosphere and transfer it to the oceans, where it will be removed from the cycle for tens to hundreds of millions of years. As a mechanism of climate change this is fine, but *only provided* that there is a concomitant increase in the rate of organic production and/or of carbonate skeletal material, especially shallow-water carbonates (which are above the carbonate compensation depth and so less likely to redissolve). Otherwise, I don't see how increased weathering can be a significant long-term agent of climatic change.

It would not surprise me to learn that the foregoing is based upon a major misconception, that I have forgotten some crucial aspect of the marine carbon cycle, that the standard texts are right, and that the true oceanic residence time of carbon really is a hundred thousand years. Perhaps somebody out there can give our readers the *real* story about how carbon behaves in the ocean!

John Wright

The CFC story

CFC's are jolly useful tracers, and physical oceanographers have cause to be grateful to industry for inventing and liberating them. But they are also stratospheric ozone-destroyers as well as being powerful greenhouse gases – though their concentrations are so small that their climate warming effect is negligible. The Montreal Protocol of 1987 decreed that CFCs should be phased out. That's the good news. The bad news is that a flourishing black market in CFCs has developed, not least because they continue to be made in Russia, India and China (who have evidently not implemented the Protocol), to replenish supplies in old fridges and (especially) in the air-conditioning systems of older, chiefly American, cars. Hundreds of millions of dollars worth are allegedly smuggled annually into the US alone, because it is expensive to fit systems which can use the new CFC substitutes. On a more parochial domestic note, it appears that asthma inhalers available in the UK nearly all still have CFC propellants; there are a few with the new substitutes, but they are about four times the price.

Further bad news is that, while the new CFC subsitutes may be 'ozone-friendly', they are not without their problems too. They are varieties of hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) whose breakdown products include trifluoroacetic acid (TFA), which is resistant to abiotic degradation processes (hydrolysis, photolysis), is virtually unmetabolizable by most plants and animals, and tends to accumulate in wetlands and shallow groundwaters. However, as nobody seems to know for sure yet just how toxic (or not) TFA will turn out to be, this bit of news might not be so bad after all.

It's far more worrying that CFCs continue to be manufactured, distributed and used in large quantities, because more CFCs means more ozone-depletion. The 'ozone hole' above Antarctica isn't getting any smaller and the rather newer one over the Arctic seems to be developing apace. Admittedly, more CFCs also means that physical oceanographers can go on using them to trace water movements. Environmentally conscious cynics (is that an oxymoron by the way?) might comment, however, that elucidating the detailed circulation in the oceans with the help of an agent that could seriously (albeit indirectly) damage marine life might be seen as a funny way of doing science.

Meanwhile, another organic halide in the atmosphere, methyl bromide, CH_3Br, is in the frame as the chief source of stratospheric bromine, where, atom for atom, it is about 50 times more effective than chlorine at converting ozone to oxygen and enlarging the ozone hole. Unlike CFCs, methyl bromide has natural sources. It is produced in surface and near-surface oceanic waters, probably by algae, including seaweeds (which also generate methyl iodide, CH_3I). The other natural source is biomass burning in wildfires, while industrial sources include the biomass-burning that accompanies deforestation, and emissions from leaded petrol (so emissions from that source should decline, should they not?). The compound is also used as an industrial fumigating agent, but production is beginning to be phased out. As the lifetime of CH_3Br is less than two years – it is not stable in oxygenated environments, so the ocean is a major sink as well as a source – phasing out production should thus produce rapid results. But what about the biomass- burning that accompanies deforestation? So long as that continues, the stratospheric ozone concentration must slowly but surely continue to rise, must it not?

Now test your understanding of the previous item by attempting this simple question: *What is wrong with the following quote from a newspaper?*

'A world-wide drop in demand for the lead anti-knock compound which is extracted from seawater and used in four-star petrol, has led to redundancies being announced at the Associated Octel plant at Amlwch [Anglesey].'

Here is the answer:

The article implies that the lead compound is extracted from seawater, which is plainly impossible, as lead concentrations in the oceans are comparable with those of gold (i.e. they are minute). It is of course bromine that is extracted from seawater (and in fact is used to make ethylene dibromide, which is converted to methyl bromide during combustion of leaded petrol). Two years ago the plant was expanding, now they are announcing redundancies. Perhaps there really is a downward trend in methyl bromide emissions from motor vehicles.

UK Oceanography 96

This is the first year that we have not provided detailed accounts of each session of the Conference. Instead, you have been supplied with two highly readable 'personal views' of the meeting (pp.28–30). You may recall that we offered a £50 prize for the best such personal account. It was a little disappointing that so many participants yielded so few offerings, but these two were so good that we decided to publish them both and award two prizes.

Here are a few additional observations on the Conference.

The number of participants was most impressive: some 380 in all, compared with the 120 or so who were at the first of these gatherings (POG '84), also at Bangor. The numbers were most agreeably swelled by a substantial contingent from other parts of Europe, especially Germany, and the inclusion of contributions on biological oceanography provided encouraging signs of a trend towards multi-disciplinarity. There also seemed to be an increase in the proportion of female marine scientists, another encouraging trend. The whole event was superbly run, and Ed Hill, Steve Mudge and their colleagues on the Organising Committee fully deserved the praise and bouquets that they received. None of what follows should be interpreted as being critical of their achievement; it is certainly not meant to be so.

Sessions Is there some way of avoiding parallel sessions? Dare one consider accepting fewer offerings for verbal presentation? On the other hand, it is possible to have more posters? Can one be more selective there too, and if so, what criteria should be used? Is it possible to have two lots of posters, one for research students and another for established professionals, including institutions and commercial outfits?

Whatever the outcome, if parallel presentation sessions are to be retained, then strict time-keeping is of the essence. This time it was very nearly faultless. The great majority of speakers structured their talks to fit the allocated time, there were very few over-runs, and most of the session chairs were also vigilant in this respect.

Inevitably, though, if you have parallel sessions, you have meeting rooms of differing quality. That's nobody's fault, but in this case it meant sessions in Powys Hall which – despite its amazing mural – was less user-friendly than the lecture theatre.

A heartfelt plea Will future organising committees of this event please try and ensure that Friday mornings are kept for lectures (such as the Buckland Lecture, see later) and presentations (even keynote lectures) by senior scientists who are not eligible for the Norman Heaps Prize? It took the edge off the presentation ceremony at the Conference Dinner that the Norman Heaps award had to await the judging panel's assessments of qualifying speakers on the last morning. It probably did not help the nerves of these last speakers a great deal either.

Presentations

We covered the subject of presentation quality after UK Oceanography '92 (*Ocean Challenge*, Vol.3, Nos.2/3, pp.23–4), and were astounded at the improvements at Stirling two years later. We thought we detected some signs of slippage at this meeting. Although we may be mistaken, a few points are worth making here:

1. The proportion of equations on overheads seemed to have increased again – more of what one of our Editorial Board colleagues calls 'flute music', fine for musicians, less intelligible to the rest of us. Could this trend be related to our other perception that there seemed to be more theory and modelling (hence more equations), at the expense of observation and measurement? Could that in turn be a consequence of reduced funding for research?

Conversely, where we did have observation and measurement, we seemed to be presented with lots of data, but not a lot of analysis and interpretation. It appears that the huge and rapid improvements in instrumentation enable phenomena and processes to be more closely observed than ever before. Clearly such improvements are important in fields such as environmental monitoring, but were we alone in feeling that at times there was more emphasis on the instruments than on the data, that we were studying the means rather than thinking about the ends? In short, does improved technology provide us with fundamentally *new* information?

2. Whether or not you have more or less equations on your overheads, it seem to us as impartial observers that there are two basic relationships here:

First, the scale and print-size of information on an overhead must of necessity be *inversely* proportional to the amount of such information. Less information and bigger print *has* to be preferable to more information and smaller print.

Second, the amount of information on an overhead should be *directly* proportional to the time allowed for the audience to absorb and understand that information. There was a tendency for some speakers to put up a crowded overhead, say a few words, and whip it off before anyone had a chance to see it properly. And it has to be said that several quite economical overheads (i.e. with low information density) had print too small to be seen further back than about the third row.

3. The great advantage of overheads is that you can point to them on the projector. To be sure, the quiver of nervous fingers is then magnified on the image, but this is on the whole preferable to speakers turning their backs on the audience and addressing the screen. If there is a fixed microphone – or (especially) if there is no microphone at all – the result is that audio-reception is weak beyond about the third row.

4. Many talks began with a 'contents list': the problem, the method, the results, the discussion, the future work. Is that really necessary, given that time is short? In any case, (a) we know you're going to do it more or less like that, and (b) even if we didn't, we would have forgotten what you said you were going to do after the first couple of minutes. It may be unconventional, not to say radical, but you *could* start by telling your audience, 'This is what I've found out, and here's how I did it.' Not always feasible, of course, but worth considering?

5. Perhaps most seriously of all, as the days passed, it seemed that there was more anxiety and less enthusiasm among young presenters than had been evident at previous gatherings. There seemed to be less buzz, less excitement, not so many people saying 'Hey, look what I found, isn't this fascinating?' Was this our imagination, or a real reflection of the

uncertain climate in which science nowadays must operate? Either way, we can offer a suggestion for generating a sense of enthusiasm.

These days, science is beleaguered by a lack of proper public understanding, not to say suspicion about what scientists get up to. Part of the mission of *Ocean Challenge* is to make marine science more accessible to people, and we would like to encourage more young scientists to do the same. So next time you are scheduled to present a paper, think about your audience. Whom do you want to reach? If it's a specialist group, read no further. But if your audience comes from diverse backgrounds, imagine that it contains also the Science Correspondent from a quality broadsheet paper – or even, who knows, from local or national TV or radio. You think your research and results are important, and you want them to be understood by as many people as possible. How best might you present your talk to achieve that?

Our two prize-winning authors have plainly grasped this message: there can be little doubt that *they* would be able to make their science interesting and comprehensive. So as a preliminary guide, you could do worse than read what they have written; and the citation for the Normal Heaps prize might be worth a look too.

Prize-winners

The Norman Heaps Prize for Best Verbal Presentation by a Young Scientist

Stephen Marsh of the University of East Anglia carried off this award with his paper 'Bedforms and suspended sediments beneath waves: a comparison of field and laboratory data.' The citation read: 'He not only provided an exceptionally clear exposition of the measurement and analysis of shallow-water bed forms, but also brought a charismatic lightness of touch to his presentation that many more experienced speakers might envy.'

The Cath Allen prize for Best Poster Presentation by a Young Scientist

This was won by Mark Brandon of the British Antarctic Survey for his poster 'A shelf-break front around South Georgia' (jointly authored with Eugene Murphy, Phil Tratham, Doug Bone and Julian Priddle). The poster layout used captions cleverly so as to draw out the main points of the scientific argument, and the whole effect was visually very pleasing.

Challenger Prize for best OU Oceanography student in 1995

The winner, who unfortunately could not be there to receive his certificate, was Stephen Sheard from Stockport, Cheshire, who 'decided to study oceanography, since it looked like the most interesting course on the syllabus'. His background in maths and physics and his work in the field of computational fluid dynamics as an aerodynamics engineer are all highly relevant to oceanography. He also commented that oceanography comes across as a youthful and rapidly developing field of science.

Presidents' Photographic Competition

This was only the second time that this competition, sponsored by past and current Presidents of the Society, had been run. The winning photograph, by Sandrine Charrier of Southampton Institute, is reproduced below, sadly without the dramatic colours of the sky behind the silhouettes. Second prize was won by John Humphery of Proudman Oceanographic Laboratory, for his distinctive shots of equipment-preparation. We also greatly liked a number of well-constructed compositions by Helen Mitchener of Hydraulics Research, Wallingford, and some evocative black-and-white photographs by Pam and Laurie Draper.

'Day and night: Part 2', the winning photograph by Sandrine Charrier

Science, Sun and Scenery: UK Oceanography '96 in Bangor

Heike Langenberg

What is the essence of UK Oceanography '96 in my – personal – memory? This is what I asked myself, when thinking about a theme for this account. Well, for me, it is three things.

First of all, naturally, there is the science. This is probably not surprising when writing about a conference on oceanography, and I dare say many would share this choice with me. But there was such a wide variety of oceanographic subjects covered, so many topics mentioned, and generally so much effort put into the quality of presentation that there was a lot to learn for all participants – and after all that's what these conferences are all about.

One of the highlights was Henry Charnock's lecture on the life of John Swallow. Not only did he succeed in conjuring up a vivid impression of a man I – and probably most of those present – had never met, but he also managed to give his talk an end so dramatic and yet so well measured, that true feeling was conveyed without kitsch. Many a film director would be well advised to learn from him.

Another treat was the talk by Ed Hill, who told the long story (with a happy ending) of the search for the spill of dense water over the shelf edge of the North Sea – a quest that went on in spite of three equipment calamities on three consecutive cruises, spaced over ten years. Encouragingly, the successful observations of the fourth attempt to measure hydrography at the shelf-edge were presented – in brilliantly coloured pictures – to prove that stamina is a most important quality in an oceanographer ...

Needless to say, many other amusing, interesting, intelligent, novel and provocative talks and posters would merit mention. But, alas, only 1000 to 1500 words were asked by the editors and a week's talking plus 160 posters cannot be accounted for within those limits.

Secondly, there was the sunshine. This came as a surprise to me: September in Wales does not exactly have the connotation of heat and sunshine, but there it was. Maybe not so much heat – although it seemed hot enough when walking up Snowdon: some people crossing our path were even seen bare-chested! But sunshine persisted throughout the week.

The organisers had already done a perfect job in arranging the technical equipment, from microphones to video display. They had provided excellent catering, from abundant tea, coffee and biscuits during breaks to a spectacular conference dinner. And they flooded us with information leaflets on everything from the best Indian restaurants to an introduction into the Welsh language. But finally they seemed to have transcended the human sphere and lured the gods of meteorology into a favourable mood.

Thirdly, I was impressed by the scenery. Leaving my room on the way to breakfast to see the faraway hills in the morning mist was the first pleasure of the day; the scenery from the path up Snowdon was even more impressive, and on crossing the Menai Bridge on Friday afternoon, the glimpse of the Menai Straits with its two bridges delighted the visual sense.

Unfortunately, I had to give the intended walk to Bangor pier on late Thursday afternoon a miss: after surmounting Snowdon's heights and an evening's dancing in Ffriddoedd Bar to the swinging music of Tom Rippeth's jazz band (where the German/Swedish delegation made up a largely over-proportional fraction of the dancers) I was so stiff that I was only just able to make it from my chair in the audience to the podium for my talk, and the mere thought of walking any additional distance hurt my legs.

Finally, the University building could not have been more suitably situated: it provided a terrace with a great view over Bangor that was happily used for lunching in the sun by those who had not booked the marquee facilities. Of course, in spite of the nearly perfect organisation there were a few minor calamities and unintentional jokes, too.

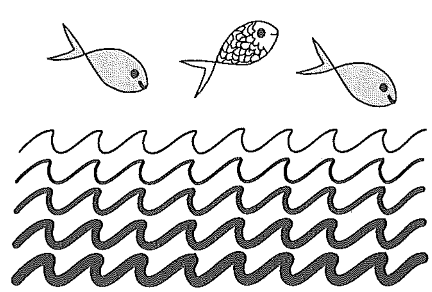
As in all science conferences I have attended so far, inertia interfered with time-tables in that sessions tended to start and end late, which occasionally caused difficulties for those changing between the two parallel series of lectures. With all those prizes presented on the conference dinner evening so charmingly by the Challenger Society's President John Simpson (who mentioned that the number of prizes has been increasing from year to year since the first UK Oceanography meeting) I suggest that an additional trophy be awarded to the best chairperson, to be elected by the non-keynote speakers.

There was the endless struggle with the microphones in the main lecture theatre, and the difficulty of fixing the mike to the speaker recurred after every talk, while in Powys Hall it seemed next to impossible to speak into the desk microphone when pointing to the figures on the wall.

And there was the confusion about the overpowering technical equipment with all these remote controls on the speakers' desk, so that Henry Charnock ended up directing them all with both hands to the wall like a gun-slinger.

But what remains now of UK Oceanography '96 for me back in front of the good old computer screen in my office in Hamburg are a lot of new views on oceanography, a slight sunburn on my right shoulder, and the determination to come back for holidays in North Wales in the not too distant future.

Heike Langenberg is at the Institut für Meereskunde, Hamburg



UK Oceanography '96: a delegate's perspective

Andrew Brierley

Croeso i Cymru!– Welcome to Wales! proclaimed the Vice Chancellor of the University of Wales, Bangor, at the beginning of UK Oceanography '96. As Professor John Simpson, the serving President of the Challenger Society for Marine Science, then went on to point out in his opening address, by returning to Bangor the conference was in a way coming home: the first of this now well-established series of biennial meetings was held at the University's Menai Bridge marine laboratories in 1984.

If UK Oceanography was coming home then so too, as a former graduate of the University's School of Ocean Sciences, was I; returning to my marine-science roots (or should that be holdfasts?) for the first time since graduating in 1988. As in the summer's European Championship (when, as the song said, football was also coming home) the amassed delegates, some 400 in all, also included a strong European and notably German contingent, expanding and enriching the scope of this meeting (in contradiction to its title) well beyond the bounds of solely UK-based oceanographers.

For me, UK Oceanography '96 began with some arduous but exhilarating pre-excursion field work: an aerial (well almost) survey of the Glaslyn estuary from an impressive, if awkwardly gained, vantage point at the summit of a rock face above the seaside village of Tremadog to the south of Bangor. After a five-hour drive from the flat and oceanographically challenged lands of East Anglia, my colleague and I tackled a climb called 'Christmas Curry'. The name could quite easily have been plucked from the night-shift breakfast menu aboard RRS *James Clark Ross* during the previous winter's cruise – a cruise in which we had both participated, and about which we were to speak during the coming week. Watching the light fade over the estuary below provoked in my mind a question I was to hear reiterated by others on more than one occasion during the course of the meeting – why did I leave Wales?

Arriving in Bangor at the Friddoedd (I couldn't pronounce that even before the welcome party) residence site, I saw a hive of building activity, apparent confirmation that a state of well-being is not restricted to the School of Ocean Sciences – the School continues to be very highly rated in research assessments and has on order a new research vessel to replace the ageing *Prince Madog* – but is symptomatic of the University as a whole. The new halls of residence in which we were accommodated (adjacent to the one in which I was interned as a student 11 years ago) are now so luxurious that even the cold taps gush a seemingly endless stream of hot water.

The following morning, after the last of the opening remarks by Professor Naylor, Head of the School of Ocean Sciences, the first parallel sessions were set underway and the meeting continued with a very full programme throughout the week. An astounding diversity of oceanographic topics were covered, ranging from measurement of deep-ocean currents to estimation of rates of coastal erosion, and from zooplankton and larval distributions to ocean–atmosphere interactions.

The importance of modelling in modern oceanographic studies was evident from the number of papers adopting this approach, an approach which has perhaps grown in prominence because of the difficulty now associated with procuring ship-time. Some relatively simple models were able to make predictions that were borne out in nature, although there was mention of one model so computationally demanding that it ran at only half real time! The scale at which reported oceanographic studies had been conducted also varied enormously. On a small scale, sand-ripple formation was described in great detail, whilst at the ocean-basin scale controversy surrounding the origin of warm-core rings was discussed, and at the global scale there were papers describing the influence of oceans on global warming. Remote-sensing played a key role in many of the studies presented, and many authors expressed the pressing need for data from a new generation of ocean colour imaging satellites. The venues for oral presentations included the highly ornate Powys Hall, and the illusory '3-D' mural there was only occasionally more interesting – and seldom more comprehensible – than the lectures.

In addition to oral presentations, posters were displayed for most of the meeting, with the Tuesday evening being dedicated to them. Displays had also been mounted by several manufacturers of oceanographic equipment, and by a publisher of some of the increasing number of journals now disseminating results of oceanographic studies. These commercial companies had in most instances also sponsored the meeting in some way.

In keynote lectures we learnt, among other things, how short-term anthropogenic activities, for example oil-extraction, can have far-reaching long-term implications for marine systems: sediment transport around the coast may alter on a century scale in response to short-term financially driven ventures. Such projects should not be allowed to jeopardise long-term coastal stability. The opinion was expressed that a long-term approach to research funding needs to be adopted if loss of skills vital to monitoring changes within the marine environment is to be avoided. Short-term funding regimes are not conducive to retention or further development of the taxonomic skill base often essential for assessments of environmental change. Last, but not least, the eulogy by Professor Charnock to the inventive and pioneering work of Dr John Swallow was enthralling and inspirational.

The overall success of the conference was due in no small part to the organisational skills of Dr Ed Hill and the rest of his organising committee. The meeting progressed almost as smoothly as the stealth condoms described in such an animated fashion by the after dinner speaker, Professor Dennis Woods, in a speech which was perhaps too biological for the majority of those present. The conference dinner amidst the grandeur of the University's Pritchard Jones Hall, the largest in North Wales, was also the occasion for presentation of prizes to the winners of the poster and photographic competitions.

The following morning the 1996 Buckland Lecture given by Professor John Gray illustrated how, in many instances, scientists are providing exactly the data required to reduce the potential impact of industrial processes on the marine environment, but that a lack of legislation enabling enforcement of the recommendations can result in otherwise avoidable large-scale environmental degradation. Professor Gray also emphasised that much greater statistical rigour needs to be applied to environmental studies, pointing out that, at present, conclusions of numerous monitoring programmes could legitimately be refuted because of inadequate sampling strategies.

The conference on the whole was, for me, greatly informative and provided an excellent opportunity to meet colleagues and discuss ideas with them. My only disappointment was the relative scarcity of biological papers, and the fact that, as is often the case with meetings of a size necessitating parallel sessions, I could not be in two places at once. As for future UK oceanography meetings, my personal sentiments would be well expressed in the words of a man not widely recognised for his contribution to oceanography, Arnold Schwartzenegger – 'I'll be back.'

Andrew Brierley is at the British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK; Tel: 01223-251613; Email: A.Brierley@BAS.ac.uk

The Buckland Lecture

The Buckland Lecture took place on the last morning of the conference. The Lecture was introduced by Professor Stephen Lockwood of MAFF Fisheries Research, who is a trustee of the Buckland Foundation. Professor Lockwood gave a brief talk about Frank Buckland, reproduced opposite.

The Buckland Lecturer, Dr John Gray of Oslo University, is a graduate of Menai Bridge where he studied for his PhD under the late Dennis Crisp. John Gray's research was amongst the earliest to demonstrate that many interstitial fauna of sandy beaches feed on marine bacteria. The Zoological Society of London ranked his thesis the best zoology PhD in 1965, and awarded him the prestigious Thomas Huxley Prize.

From Menai Bridge he moved to the Robin Hood's Bay laboratory of the University of Leeds where he studied the effects of Rio Tinto Zinc company discharges on the fauna of Tees Bay. With Professor Bob Clark and David Bellamy he founded a newsletter which grew into the internationally respected journal *Marine Pollution Policy*. In 1976 he moved to Norway as Chair in Marine Biology at Oslo University, where he studied the problem of coastal eutrophication. As the Norwegian oil industry grew, he developed an expertise in identifying the subtle effects of incipient pollution of marine communities. He has been both member and chairman of a wide range of international marine pollution committees, including GESAMP (Group of Experts on Scientific Aspects of Marine Pollution) and GEEP (Group of Experts on Effects of Pollution). He also sat on Britain's NERC Council for six years and held a similar position in Sweden, also for six years, and continues to sit on Swedish and Danish committees studying environmental issues in the Oresund.

Professor Gray's subject was 'Protecting the Seas: Using Science for a Better Environment'. A major theme of his address concerned the need, before embarking on major industrial projects, to allow sufficient time in which not only to inform the public about the project, but also to make environmental impact assessment sufficiently rigorous that protection measures can actually be enforced where necessary. Using examples from his own experience in Scandinavia (from which our own government could learn a great deal), he showed that it is possible actually to halt high-cost major industrial developments for up to several months, so that natural populations and ecosystems are not irreversibly damaged. The most significant adverse effect of human activities is habitat destruction, with consequent loss of biodiversity. Politicians and industrialists (and quite a few academics) pay lip-service to sustainability, but in practice pay little heed to the maxim that it is more important in the long run to protect the environment than to exploit it – especially given the pressures of a growing world population.

Deutsche Gesellschaft für Meeresforschung

The DGM Newsletter is a very interesting publication. The October issue (Mitteilungen No. 3/96) carries an account of UK Oceanography by Thomas Höpner, the DGM Chairman. There is also a piece about the recent re-discovery of the gravestone of a German member of the *Challenger* expedition, who died and was buried at sea during the voyage. He was Rudolph von Willemoes-Suhm (1847–75). Historically minded readers can locate the gravestone near the south-eastern boundary of the perhaps somewhat unimaginatively named Cemetery No. 2 at the St Marienkirche in Bad Segeberg. The inscription in English states simply that the stone was erected by his 'Messmates', who of course included (among others) Wyville Thomson, Murray, Buchanan, Moseley and Wild. The DGM account provides a brief biography of Willemoes-Suhm and we are pleased to say that we will be carrying an English version in the next issue of *Ocean Challenge.*

There is also a short meeting report (Changing Times – historical perspectives on science, including marine science), by no less a person than one of our prize winners; a discussion of the *Brent Spar* controversy (by Thomas Höpner), and an account of plans for a new marine biodiversity centre in Germany, both of which make pointed reference to Agenda 21 of the 1992 Rio Conference. There is also a short article about the Institute of Marine Chemistry and Biology at the Carl von Ossietzky University in Oldenburg; and there are *two* discussions of the Waddensea 'black death' outbreak, one of them decidedly scathing about ministerial disclaimers. In addition there's a book review;.and, last but not least, an item describing proposals for a working group on marine science education.

Wider dissemination of the DGM Newsletter is limited by the fact that it is (quite understandably) written in German. However, any Challenger Society member wishing to receive a copy of the latest issue should contact the Editor of *Ocean Challenge.*

The following morning the 1996 Buckland Lecture given by Professor John Gray illustrated how, in many instances, scientists are providing exactly the data required to reduce the potential impact of industrial processes on the marine environment, but that a lack of legislation enabling enforcement of the recommendations can result in otherwise avoidable large-scale environmental degradation. Professor Gray also emphasised that much greater statistical rigour needs to be applied to environmental studies, pointing out that, at present, conclusions of numerous monitoring programmes could legitimately be refuted because of inadequate sampling strategies.

The conference on the whole was, for me, greatly informative and provided an excellent opportunity to meet colleagues and discuss ideas with them. My only disappointment was the relative scarcity of biological papers, and the fact that, as is often the case with meetings of a size necessitating parallel sessions, I could not be in two places at once. As for future UK oceanography meetings, my personal sentiments would be well expressed in the words of a man not widely recognised for his contribution to oceanography, Arnold Schwartzenegger – 'I'll be back.'

Andrew Brierley is at the British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK; Tel: 01223-251613; Email: A.Brierley@BAS.ac.uk

The Buckland Lecture

The Buckland Lecture took place on the last morning of the conference. The Lecture was introduced by Professor Stephen Lockwood of MAFF Fisheries Research, who is a trustee of the Buckland Foundation. Professor Lockwood gave a brief talk about Frank Buckland, reproduced opposite.

The Buckland Lecturer, Dr John Gray of Oslo University, is a graduate of Menai Bridge where he studied for his PhD under the late Dennis Crisp. John Gray's research was amongst the earliest to demonstrate that many interstitial fauna of sandy beaches feed on marine bacteria. The Zoological Society of London ranked his thesis the best zoology PhD in 1965, and awarded him the prestigious Thomas Huxley Prize.

From Menai Bridge he moved to the Robin Hood's Bay laboratory of the University of Leeds where he studied the effects of Rio Tinto Zinc company discharges on the fauna of Tees Bay. With Professor Bob Clark and David Bellamy he founded a newsletter which grew into the internationally respected journal *Marine Pollution Policy*. In 1976 he moved to Norway as Chair in Marine Biology at Oslo University, where he studied the problem of coastal eutrophication. As the Norwegian oil industry grew, he developed an expertise in identifying the subtle effects of incipient pollution of marine communities. He has been both member and chairman of a wide range of international marine pollution committees, including GESAMP (Group of Experts on Scientific Aspects of Marine Pollution) and GEEP (Group of Experts on Effects of Pollution). He also sat on Britain's NERC Council for six years and held a similar position in Sweden, also for six years, and continues to sit on Swedish and Danish committees studying environmental issues in the Oresund.

Professor Gray's subject was 'Protecting the Seas: Using Science for a Better Environment'. A major theme of his address concerned the need, before embarking on major industrial projects, to allow sufficient time in which not only to inform the public about the project, but also to make environmental impact assessment sufficiently rigorous that protection measures can actually be enforced where necessary. Using examples from his own experience in Scandinavia (from which our own government could learn a great deal), he showed that it is possible actually to halt high-cost major industrial developments for up to several months, so that natural populations and ecosystems are not irreversibly damaged. The most significant adverse effect of human activities is habitat destruction, with consequent loss of biodiversity. Politicians and industrialists (and quite a few academics) pay lip-service to sustainability, but in practice pay little heed to the maxim that it is more important in the long run to protect the environment than to exploit it – especially given the pressures of a growing world population.

Deutsche Gesellschaft für Meeresforschung

The DGM Newsletter is a very interesting publication. The October issue (Mitteilungen No. 3/96) carries an account of UK Oceanography by Thomas Höpner, the DGM Chairman. There is also a piece about the recent re-discovery of the gravestone of a German member of the *Challenger* expedition, who died and was buried at sea during the voyage. He was Rudolph von Willemoes-Suhm (1847–75). Historically minded readers can locate the gravestone near the south-eastern boundary of the perhaps somewhat unimaginatively named Cemetery No. 2 at the St Marienkirche in Bad Segeberg. The inscription in English states simply that the stone was erected by his 'Messmates', who of course included (among others) Wyville Thomson, Murray, Buchanan, Moseley and Wild. The DGM account provides a brief biography of Willemoes-Suhm and we are pleased to say that we will be carrying an English version in the next issue of *Ocean Challenge.*

There is also a short meeting report (Changing Times – historical perspectives on science, including marine science), by no less a person than one of our prize winners; a discussion of the *Brent Spar* controversy (by Thomas Höpner), and an account of plans for a new marine biodiversity centre in Germany, both of which make pointed reference to Agenda 21 of the 1992 Rio Conference. There is also a short article about the Institute of Marine Chemistry and Biology at the Carl von Ossietzky University in Oldenburg; and there are *two* discussions of the Waddensea 'black death' outbreak, one of them decidedly scathing about ministerial disclaimers. In addition there's a book review;.and, last but not least, an item describing proposals for a working group on marine science education.

Wider dissemination of the DGM Newsletter is limited by the fact that it is (quite understandably) written in German. However, any Challenger Society member wishing to receive a copy of the latest issue should contact the Editor of *Ocean Challenge.*

Who was Frank Buckland?

Frank Buckland was the eldest son of the very Reverend William Buckland, Dean of Westminster, and was born on 17 December 1826. He later wrote:

'I am told that soon after my birth, my father and godfather, the late Sir Francis Chantry, weighed me in the kitchen scales against a leg of mutton, and that I was heavier than the joint provided for the family dinner that day.'

From these few words we can see that Frank Buckland was born into a world of pre-Victorian middle-class privilege, a contemporary of Darwin and Thomas Huxley. Also, he was the son of a cleric, the profession which, arguably more than any other, contributed so much to our knowledge of British natural history.

Frank Buckland, 1826–1880. Here he is posing dressed for action. As usual, he has his notebook within easy reach.

After school and Christ Church, Oxford, Buckland studied surgery and was gazetted assistant surgeon to the Second Life Guards in 1854. Notwithstanding the potential grandeur of this appointment and the entrée it might give him to society, Frank continued to pursue the love of wildlife he developed as a boy. For example, in his journal for 7 June 1855, he recorded that after attending the funeral of Dean Gaisford at Windsor, he 'went to the pond and caught some fine lizards for the Zoological Gardens' [the London Zoo].

It was about this time also that he began to develop an additional passion, a lifelong obsession almost – communicating his enthusiasm for wildlife to the public at large. He published frequently in *The Field* and in due course many of his articles were amalgamated to form a series of four wonderful books entitled *Curiosities of Nature*.

By 1863 his enthusiasm for wildlife and writing exceeded his interest in the farm and surgery; he resigned his commission. From this time on he was wholly committed to communication. He became the Victorian equivalent of David Bellamy – even down to the sartorial style!

Just as Bellamy's medium for communication is TV, Buckland's was the pen and printed word. Within his general interest in natural history, Buckland developed a keen specialist interest in anything and everything to do with fish and fisheries – including their environment.

In 1866 he was appointed Her Majesty's Inspector of Salmon Fisheries, an appointment which both required and enabled him to indulge his passion for matters piscatorial the length and breadth of the British Isles. It also heightened his awareness of interactions between fish and industry. Weirs constructed for industrial purposes frequently blocked the salmon spawning runs and contributed to a general decline of this species.

Throughout this period, Buckland delivered lectures at every available opportunity and published a continuous succession of detailed anecdotal observations, serious articles, and official reports on the state of British salmon, herring and shellfish stocks. Unfortunately his enthusiasm did not extend to taking good care of himself when away on fieldwork. His work came to an untimely end in 1880, when he died of TB at the comparatively young age of 54.

Even in death, however, his commitment to communication was maintained, particularly in making fish and fisheries information accessible to all who care to listen. He bequeathed a sum of money in trust to fund the annual appointment of a peripatetic professor to deliver three public lectures and provide the text for publication. The lecture delivered at UK Oceanography was the first for 1996.

Our thanks go to Professor Stephen Lockwood, for kindly allowing us to reproduce his talk here.

A European view of the future of palaeoclimate research

Mark Maslin and André Berger

In May 1996, a two-day meeting was held in Brussels to celebrate the achievements of European environmental scientists. Entitled 'Climate and Ozone at the Dawn of the Third Millenium', the meeting was organised by the European Commission, the Georges Lemaître Foundation, the Belgian Royal Academies, and the Catholic University of Louvain.

The four invited keynote speakers were all winners of international awards in 1995: Professor Paul Crutzen had won the Nobel Prize for Chemistry, Professor Bert Bolin the Blue Planet Prize, and Professor Willy Dansgaard and Professor Nick Shackleton were co-recipients of the Crafoord prize. Two of the prize winners are famous for their study of past climates. Professor Dansgaard (University of Copenhagen, Denmark) has had a long and distinguished career working with ice-cores, and recently led the highly successful European drilling expedition to Greenland (for the GRIP project). Professor Shackleton (Cambridge University) is one of the most distinguished and innovative palaeoceanographers in the world and is presently extending detailed age modelling of deep-sea sediments back to over 14 million years ago.

The aim of this European meeting was not only to review successes but also to investigate priorities for future research. One of the most interesting points raised by the conference was that despite the huge advances in understanding climate, the unknown still far outweighs the known. This point is particularly pertinent in the European context, as it is now essential to highlight the most urgent areas of environmental research that need to be covered by the Framework V programme. Professors Dansgaard and Shackleton, as well as the other delegates at this meeting, suggested a number of ways in which these priorities can be decided.

Setting priorities for the future

One of the best ways of predicting future global climate is to use climate models, but because of the limitations of historical climate records, the models can only be calibrated with modern data. However, climate modellers have found palaeoclimate data an extremely good way of testing the robustness of their models. For example, in the late 1970s and early 1980s an international team of palaeoceanographers (the CLIMAP Group) produced maps of global ocean surface temperatures at the Last Glacial Maximum (LGM), 20000 years BP. Advances in the last twenty years have been so fast as to make parts of this dataset obsolete; in addition, it is now possible to estimate past surface salinities. It is important for climate modellers to set new priorities for the palaeoclimatic community and specify what types of data they need to test their models and thus improve prediction of future changes. Some datasets which the modellers would like to have are much more difficult to obtain from the geological records – volumes of the LGM ice-sheets or global estimates of precipitation, for example.

There needs, of course, to be a feedback: the palaeoclimate community must in turn set priorities for the modellers, because they require models to understand changes in past climates – models such as those used to investigate changes in deep water formation or the links between changes in the Earth's orbital characteristics and glaciations.

A priority that was stressed particularly by Nick Shackleton is the need for pure or non-directed research within the palaeoclimatic community. This is essential for two reasons. The first, esoteric, aim is to increase our knowledge of the world, to improve our appreciation of the global environment and how it has changed. Examples of questions that are being addressed at present are:

- Did a meteorite impact cause the extinction of the dinosaurs?
- Did tectonic uplift of the Himalayas trigger onset of the Northern Hemisphere glaciations and thus the great Ice Age?
- Did global climate change affect human evolution?

The second, more practical, reason for pure research is that it can turn up many surprises, which are not obvious from contemporary studies, and can change the way climatologists view the planet. Among the many examples are:

1. The study of gases trapped in air bubbles in the Antarctic Vostok ice-core have provided evidence that during the last glacial period the atmosphere contained nearly 30% less carbon dioxide than in pre-industrial times, and also much less methane. These data confirmed the important role of atmospheric CO_2 and methane in influencing the surface temperature of the Earth.

2. The Vostok ice-core and Chinese dust (loess) records suggest that the last glacial was very dry, with high atmospheric dust loadings. This led John Martin (Moss Landing, California) to suggest that iron from continental dust may have fertilized the ocean during glacial periods, stimulating productivity and drawing down atmospheric CO_2. Iron fertilization has also been suggested as one of the 'technofixes' which could be used to decrease atmospheric CO_2 and ameliorate global warming. (These matters are given an airing on p. 6.)

3. Oxygen isotope measurements from benthic foraminiferans indicate that the deep waters were at least 2 °C colder during the last glacial period. This finding is supported by proxy data ($\delta^{13}C$) from other deep-sea sediments, and suggests that this cooling was caused by massive changes in ocean circulation, including the reduction of deep-water formation in the Nordic (Norwegian and Greenland) Seas and/or a shift to the North Atlantic. This has been successfully simulated in models of ocean circulation, and has led climate modellers to investigate whether deep-water shut-down could occur in the future due to an increased fresh-water flux into the Atlantic.

4. Palaeoclimatologists have also been surprised by the speeds at which climate change can occur. The work on ice-cores and deep-sea sediments has demonstrated that climate change, both regional and global, can be very rapid – climate can switch into a new state within a few years.

One example is provided by the 'Heinrich events', semi-periodic failures of the huge North American ice-sheet during the last glacial period.

What palaeoclimatic data are required?

The biggest problem is that we would like palaeoclimatic data with a global coverage at a spatial resolution similar to that of contemporary data. This laudable aim will never be achieved. For example, there are many thousands of modern surface water temperature measurements, compared with perhaps two hundred estimates for the Last Glacial Maximum. The global cover of palaeoclimatic data is being addressed by international programmes such as PAGES (Past Global Changes) and IMAGES (International Marine Global Change Study; the main regions in which these projects will concentrate are indicated in Figure 1.

Figure 1 Global map of planned and continuing palaeoclimate studies. The programmes include the PAGES Pole–Equator–Pole (PEP) transects, the Arctic and Antarctic programmes, and IMAGES (indicated by the ocean ellipses). Another major international undertaking which contributes greatly to palaeoceanography is the Ocean Drilling Program, ODP.

Palaeoclimatic data are required on three different time-scales:

1. For the last 200–500 years, in a resolution of at least monthly and preferably shorter, to test present climate models and to investigate rapid natural climate changes as in El Niño–Southern Oscillation events. This time-scale also covers the main period of anthropogenic effects on the global environment.

2. For the last 2000 years in at least yearly resolution. This is required to look at long-term trends and climate changes (such as the Little Ice Age) within the last part of a relatively stable interglacial period.

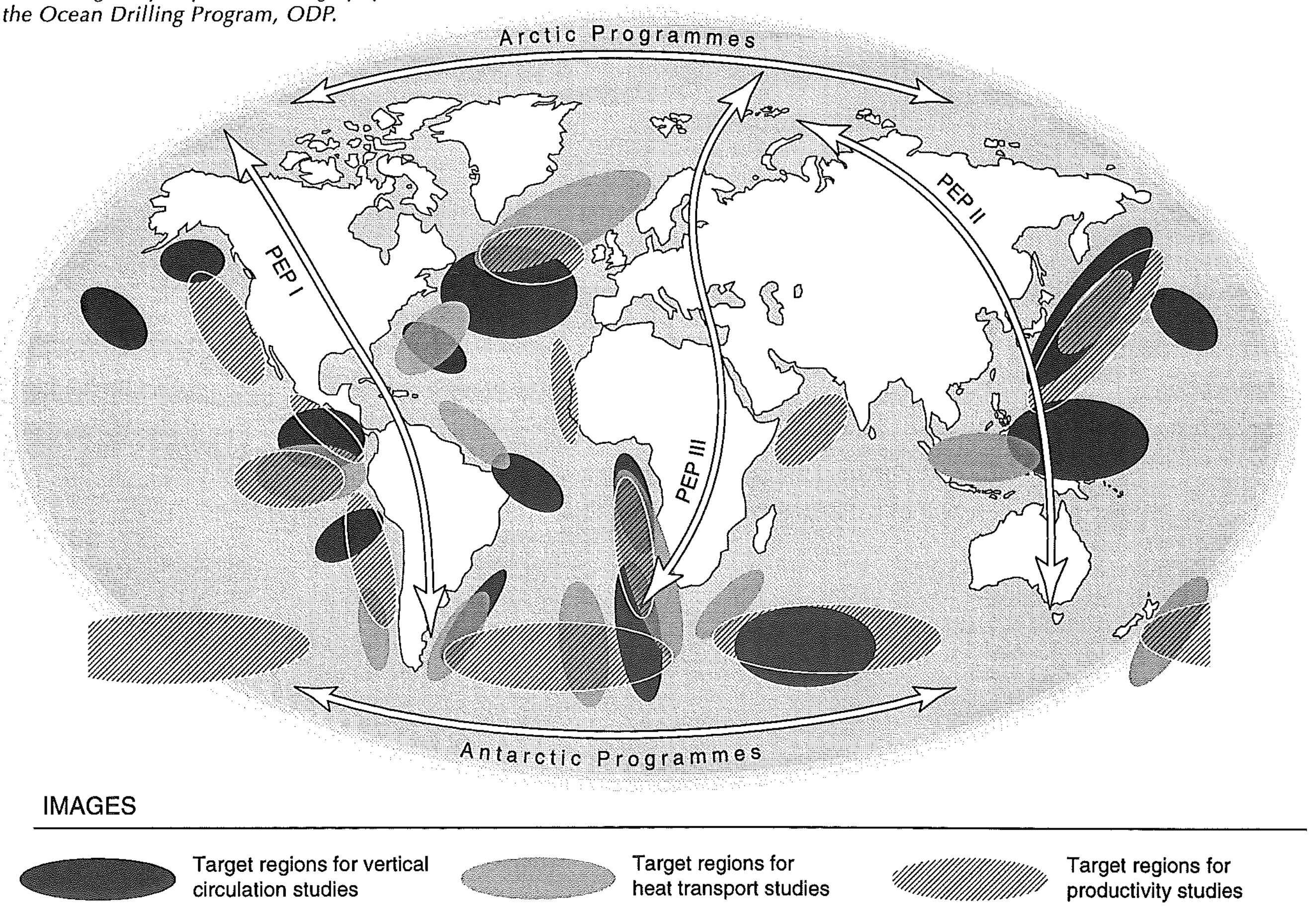
3. Longer term palaeoclimatic studies of a large range of climatic conditions. The most useful may be periods when global climate was similar to or milder than at present, such as the last interglacial (Eemian) period, when (it is believed) sea-levels and atmospheric CO_2 were both slightly higher than in pre-industrial times. Other geological periods which would also provide information on the global climate system under still warmer conditions are the Miocene or Cretaceous, both of which were apparently also characterised by significantly higher atmospheric CO_2 concentrations.

Conclusions

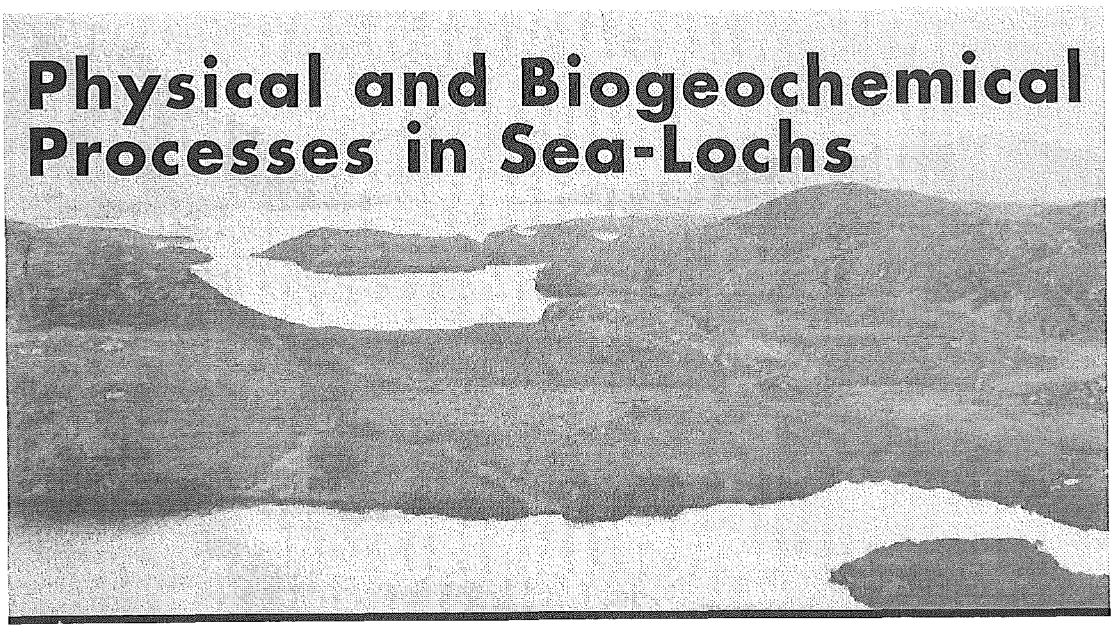
We have a long way to go before we can truly say we understand and can predict the implications of human activities on the global climate. The last few decades have seen an amazing increase in our knowledge of climate, and we hope that the planning which occurred at the European meeting and is taking place at national level, will enable the palaeoclimatic community to achieve its aims into the twenty-first century.

Mark Maslin is at the Environmental Change Research Centre, Department of Geography, University College London, 26 Bedford Way, London WC1H 0AP, UK.

André Berger is at the Institut d'Astronomie et de géophysique G. Lemaître, Université catholique de Louvain, 2 Chemin du Cyclotron, B-1348, Louvain-la-Neuve, Belgium.



Physical and Biogeochemical Processes in Sea-Lochs



Louisa Watts

Along the west coast of Scotland there are approximately 50 fjords, commonly known as sea-lochs. Like all estuaries, sea-lochs are zones between land and open oceans: a seaward flux of fresh water entering the loch at the head is compensated for by a saline inflow at the mouth, giving rise to strong physical and chemical gradients. Sea-lochs have characteristic topographic features, with deep, steep-walled basins and submarine sills, and they encompass a number of distinctive oceanographic environments which make them particularly interesting sites for estuarine research.

During the past decade, attention has been given to sea-loch systems because of growing concern over observed changes in the nutrient composition of the waters resident in them. These have been linked to observed changes in algal growth in coastal waters of the Scottish west coast, changes which have had implications for public health, natural populations of fish, and the viability of the aquaculture industry in the area.

In 1990, for example, a number of shellfish farms had to be closed along the west coast of Scotland due to the presence of a toxin known as Paralytic Shellfish Poison (PSP). This toxin is produced by certain species of dinoflagellate algae and can accumulate in the host organisms (e.g. mussels) without danger, but may cause diarrhetic and paralytic shellfish poisoning in human beings. In addition, localised phytoplankton blooms of the diatom *Skeletonema costatum* can physically damage the gills and intestines of farmed fish simply through impacts with the silicate frustules.

Since the predominant algal species in a bloom depends in large measure on the nutrient composition of the local water, it is important to understand the processes that determine this composition. Part of my PhD study was to try and identify, isolate and quantify these processes in the sea-loch system of Loch Linnhe.

This article is based on a talk presented at UK Oceanography '94, Stirling, September 1994

Processes Controlling Nutrient Composition

The nutrients considered in this study are nitrate, phosphate and silica, whose distribution is governed by (i) physical processes – the circulation and the hydrography of the system, which control physical transport of the nutrients – and (ii) biogeochemical processes, the biological and chemical activity within the system, which recycles nutrients between solid and dissolved phases.

Physical Processes

The basic physical processes described here are common to all fjords but their relative importance in any one system depends upon the individual characteristics of the environment, especially the detailed topography and its effects on circulation, and on local meteorological conditions and prevailing tidal regime. Figure 1 (*opposite*) illustrates how the type of circulation set up in a fjord can be split into two basic components, with a surface system overlying a less dynamic basin system.

The surface system has an estuarine-type circulation, with saline water entering at the mouth and fresh water at the head of the loch. The river discharge initially causes a hydraulic head so that the fresh water effectively runs downhill towards the sea. To balance the salt that leaves the loch entrained in the seaward-flowing surface layer, saline water enters the loch over the sill (a

Cross-section of a fjord or sea-loch

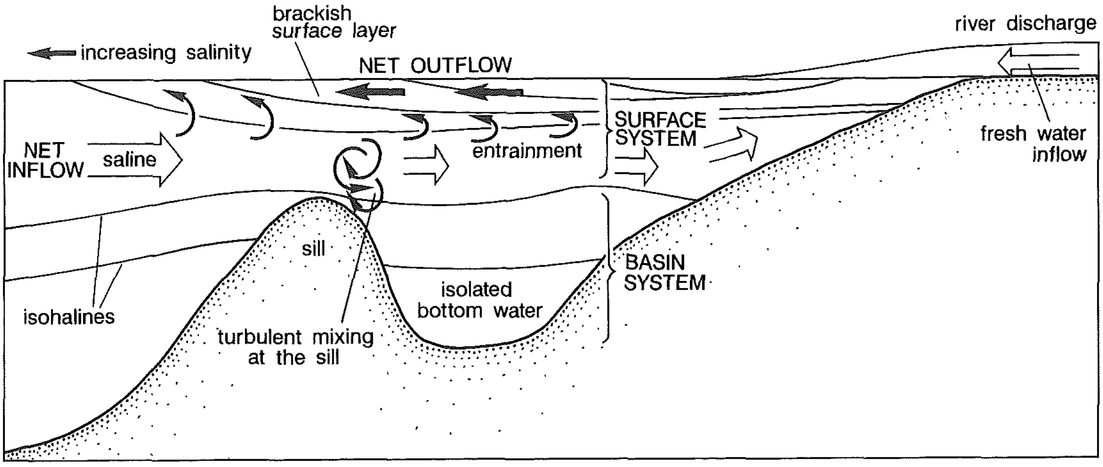


Figure 1 *Schematic cross-section (with greatly exaggerated vertical scale) of two-layer estuarine circulation in a sea-loch.*

'compensation current'), so providing a landward flux of salt. In lochs with sufficiently deep sills, the surface system has a two-layer circulation comprising brackish outflow above a simultaneous saline inflow (as in Figure 1). But in Loch Linnhe, where the sill is shallow (~15 m), the strength of the compensation current is reduced, so that the saline inflow is actually blocked on an ebb tide, but augmented on a flood tide. This phenomenon is referred to as 'tidal throttling'.

If protected by a sufficiently shallow sill, dense saline waters in the underlying basin system may be isolated, and even stagnant, for periods of days to years. Such isolated bottom water can only be displaced if incoming saline water is denser than bottom water and has sufficient volume to replace it. The frequency of these deep-water renewal events will depend on factors such as tides, winds, variations in fresh-water runoff, and sill-depth, as well as on variations in the density structure of adjacent coastal waters. The capacity of sea-lochs to retain water isolated at depth for significant periods of time allows biogeochemical processes to have a measurable effect on bottom waters, and the strength of the resultant chemical signal will depend on the isolation period. Any changes in the nutrient composition of bottom waters may affect algal growth in the sea-loch when bottom waters are displaced upwards into the euphotic zone.

Biogeochemical Processes

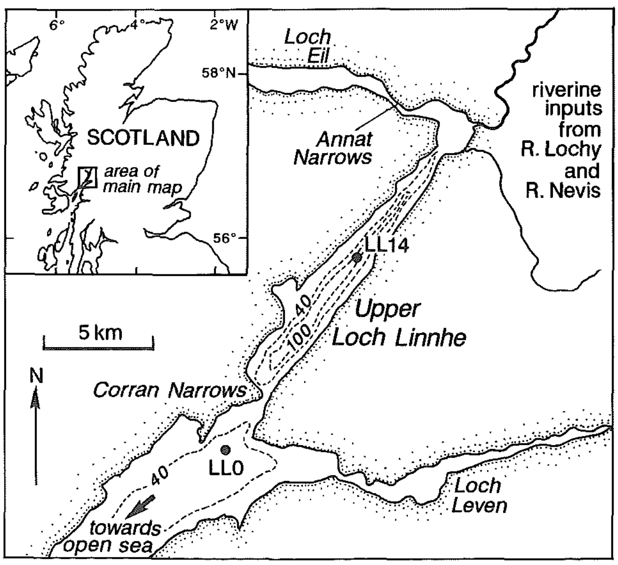
These include redox reactions (e.g. $NO_3^- \leq NH_4^+$) as well as reactions that (a) remove nutrients from solution (*sinks*) or (b) add nutrients to solution (*sources*). Examples of (a) are biological activity (uptake of nutrients by phytoplankton for growth), and also adsorption and/or incorporation of nutrients onto or into particulate matter, such as the reactions of phosphates with clays and colloidal aggregates. Examples of (b) include release of regenerated nutrients from sediments into porewaters, by microbial oxidation processes within the sediment, and ultimately to the overlying water column via disturbance of the sediment and/or upward diffusion from the porewaters; and also release of nutrients via desorption from particulate material. The latter process is particularly important for phosphate which can be released from particles under certain pH, salinity and redox conditions. For example, phosphate bound to iron(III) compounds can be released to the water column under reducing conditions due to reduction to more soluble iron(II) compounds.

The Survey Area

The upper basin of Loch Linnhe is part of a sea-loch system on the west coast of Scotland (Figure 2). The saline input to the loch consists of ~ 75% Irish Sea/Clyde water and 25% Atlantic water, which enters via the Firth of Lorne from the west. The main fresh-water input to the loch is from the rivers Lochy and Nevis which feed into the top of

Location of the survey area: LL0 and LL14 are sampling stations occupied during the 1992 field season

Figure 2 *Map of the upper basin of Loch Linnhe, and its link to the lower basin through the Corran Narrows. Also shown are the links to Loch Eil and Loch Leven, and the main fresh-water inputs. Bathymetric contour values are in metres.*



the upper basin. Loch Eil also drains into the upper basin through a channel of water called the Annat Narrows.

The data were collected during a three-month field season from February to May in 1992. Sampling took place weekly and during flood tides when possible, using the Dunstaffnage Marine Laboratory research vessel, RV *Calanus*. Results from only two stations LLO and LL14 (Figure 2) are considered here, since data from these stations were used in the numerical model. Station LLO is in water about 40 m deep in Lower Loch Linnhe, i.e. seaward of the sill at the Corran Narrows, and was chosen to represent saline end-member conditions (see below) for the upper basin. Station LL14 is in water 110 m deep and is the most central station, where currents generated from riverine input and density currents developed in the sill region are weakest. On each sampling date, temperature, salinity, depth and fluorescence measurements were made throughout the water column at each station, using a CTD with a fluorometer sensor attached. Water samples for nutrient analysis were collected immediately afterwards at depths of 0, 5, 10, 20 and 40 m for station LLO, and 0, 5, 10, 20, 40, 60, 80, 100 and 110 m for station LL14.

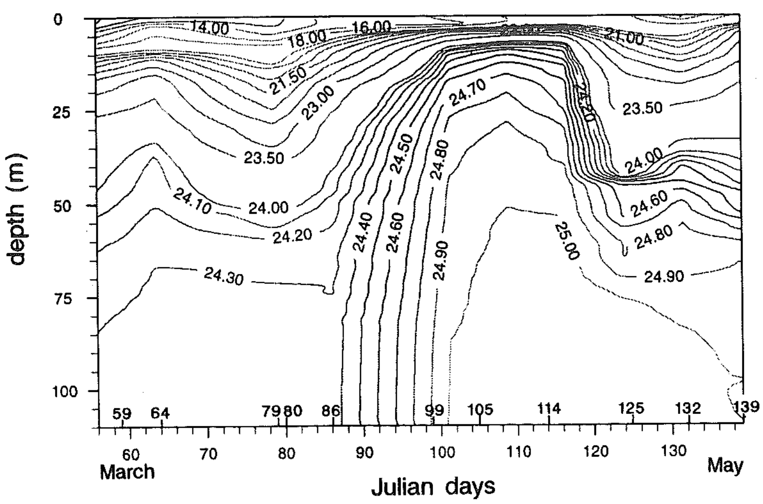
Observational Results

Hydrography

Figure 3 illustrates the temporal variations in the density structure of the water column at station LL14. It should be noted that in temperate estuarine systems in general, density structure is determined by salinity rather than by temperature, because salinity gradients are relatively large compared to temperature gradients, and a salinity change of only 1 will bring about the same change in density as a temperature change of 5 °C.

Figure 3 shows the water column at station LL14 to have been stratified for most of the period, except between Julian days 86 and 99 where there is evidence of vertical mixing throughout the water column. This was caused by a deep-water renewal event resulting in the upward displacement of resident water from all depths. This upward displacement of high density bottom water explains the increased densities observed at all depths after the event. Coincidentally, river flow was low during and just after the renewal event, but increased again around day 115, re-establishing the stratification.

Deep-water renewal occurred some time between days 86 and 99 at station LL14



Study of wind data and hydrographic measurements suggests that the deep-water renewal was most likely caused by wind-driven upwelling seaward of the sill, allowing high salinity seawater to enter the upper basin. Data from station LLO suggest that upwelling of high density water up to sill level (15 m depth) occurred between days 86 and 99. The occurrence of spring tides around day 95 would also have contributed to deep-water exchange by increasing the volume of saline water entering the upper basin on the flood tide.

The timing of this renewal event cannot be more precisely pinpointed because it was not always possible to make observations at weekly intervals, and there was a hiatus in the measurement routine between days 86 and 99. This is a clear example of the operation of Sod's Law, well known to all scientists to occur at the time when a significant event needs to be documented – in this case a deep-water turnover event!

Despite these difficulties, it is possible to state with some confidence that water deeper than 75–80 m at station LL14 was isolated from day 56 up to at least day 86 (and possibly for a few days thereafter), allowing biogeochemical changes in these deep waters to be determined.

Nutrients

If the only process to affect the concentration of nutrients is physical mixing of two end-member concentrations (in this case the fresh-water and the saline inputs), then a plot of nutrient concentration against salinity will result in a straight line, the theoretical dilution line (TDL). If, however, biogeochemical processes give rise to sources or sinks of nutrients within the system, then nutrient concentrations will plot away from the TDL, indicating *non-conservative behaviour.* However, this approach to the identification of non-conservative behaviour relies on the existence of no more than two mixing types in the system (the end members for the TDL on a mixing diagram). In a sea-loch system such as Loch Linnhe this is not the case, because (a) the end-member nutrient concentrations vary within the flushing time of the system, and (b) vertical mixing of

Figure 3 *Temporal variations in the density structure (σ_t, kg m^{-3}) of the water column at station LL14 during the 1992 field season, from February to May (Julian Day numbers 56 to 139, where Julian Day number 1 is 1 January). The contours are interpolated from the weekly observations to provide a continuous time-series.*

water in the basin is restricted by the shallow sill such that more than two water types of different ages, and hence of different nutrient concentrations, may be present in the basin at any one time. In consequence, even if nutrients were behaving conservatively (which is not the case in most aquatic systems), the presence of more than two mixing types on a mixing diagram will also give rise to deviations away from a TDL as a consequence of *apparent* non-conservative behaviour.

Figure 4(a), (b) and (c) show all the 1992 nutrient measurements collected at stations LL0 and LL14, along with available riverine nutrient data, plotted against measured salinity. For each nutrient, the line of best fit has been used to define a TDL (which assumes conservative behaviour), and the gradient of this line indicates the source of the nutrient, while the regression coefficient (r^2) indicates the degree to which nutrient concentration varies with salinity. The gradients in Figure 4 suggest that the main source of nitrate and phosphate to the system is seawater and that of silica is fresh water. Values of r^2 are very low for all three nutrients, and imply that only 1.5%, 9.9% and 12% of the variation in nitrate, phosphate and silica concentrations respectively, can be attributed to variations in the salinity, i.e. to conservative behaviour. However, as explained above, deviations from a TDL in a sea-loch system will represent not only real non-conservative behaviour caused by biogeochemical processes but also apparent non-conservative behaviour caused by temporally varying end-member nutrient concentrations.

Differentiation between 'real' non-conservative and apparent non-conservative behaviour of nutrients was achieved to a limited extent for Loch Linnhe with the help of the numerical model described overleaf. The model was developed with the following rationale: if the density structure (determined by salinity) of the upper basin could be correctly simulated over the observational time-period, then the model could be further adapted to incorporate nutrients as conservative tracers with salinity and hence to predict nutrient distributions By subtracting results of the modelled conservative behaviour from the observed distributions, a measure of the apparent plus real non-conservative behaviour would be obtained.

For the isolated bottom waters of the upper basin, however, lying at depths of >80 m between days 56 to 86, the only way of changing the observed nutrient concentrations would have been through biogeochemical processes (real non-conservative behaviour) and/or diffusive processes. The latter can be accounted for in the model by assuming that the nutrient diffusion rate is equal to that of the salt. Hence any difference between the model-predicted nutrient concentration and observed concentrations in bottom waters must be due to biogeochemical processes, and some measure of the real non-conservative behaviour occurring in these waters can thus be obtained from the model.

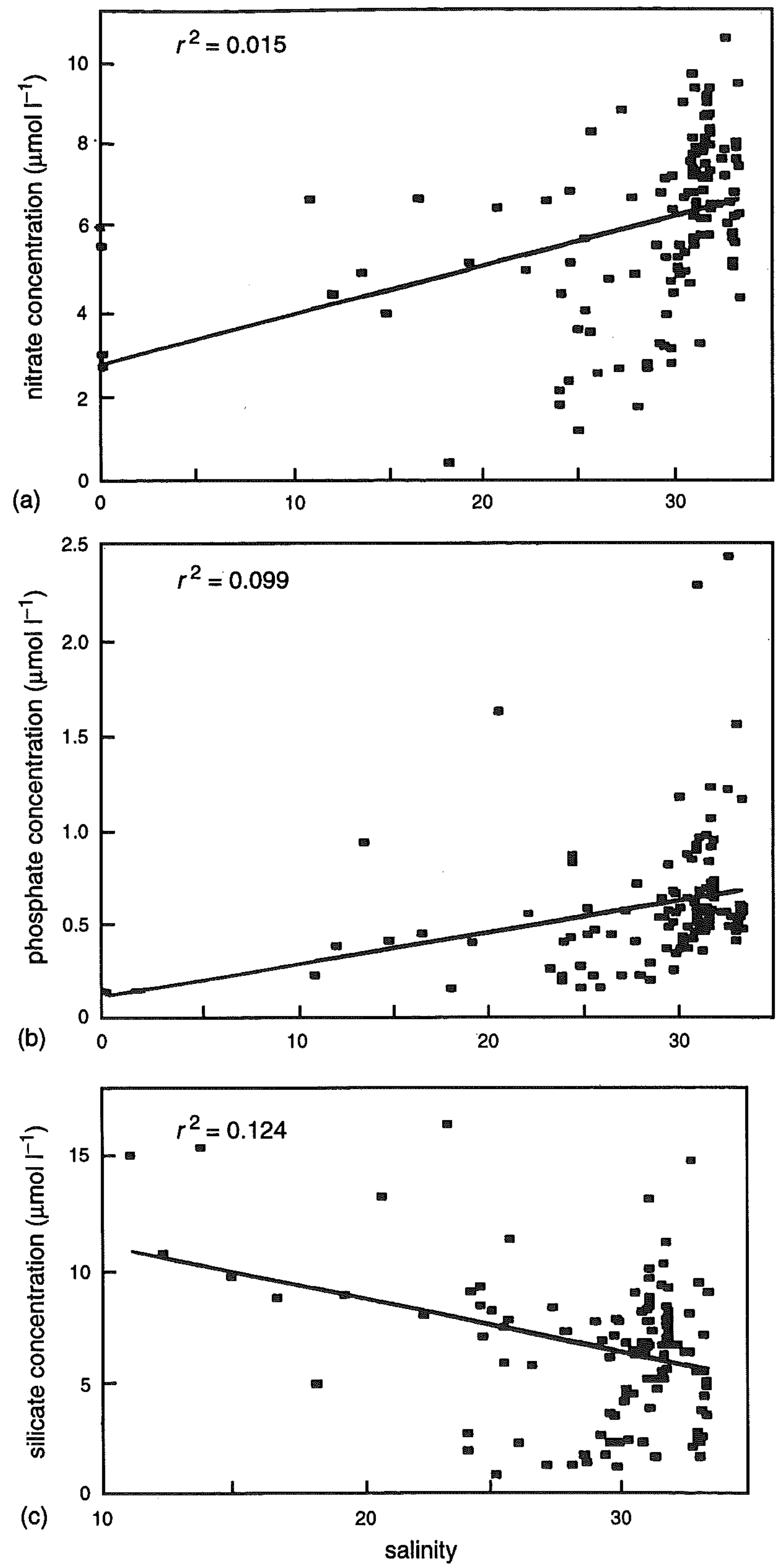
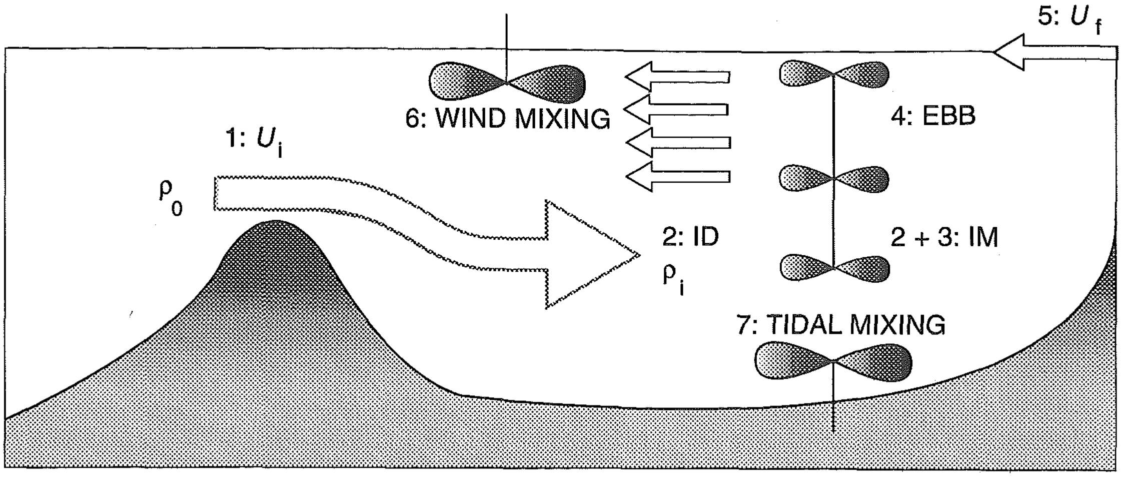


*Figure 4 Concentrations (micromolar) of **(a)** nitrate, **(b)** phosphate, and **(c)** silica plotted against salinity, using measurements made at stations LL0 and LL14, as well as data for riverine inputs (silica excepted), obtained by courtesy of the Highland River Purification Board.*

The mixing diagrams show a lot of scatter of data about the TDL, because of real and apparent non-conservative behaviour



The commands carried out per time-step in the filling-box model

Figure 5 *Principal features of the filling-box model used, with numbers showing sequence of input operations. Key to symbols:* U_i *= rate at which saline water enters the loch;* ρ_0 *= density of saline inflow;* ρ_i *= density of water at inflow depth;* ID *= inflow depth;* IM *= inflow mixing (to sill depth) + upward displacement and mixing of resident water;* EBB *= mixing of water displaced upwards from sill depth to surface + ebbing (outflow);* U_f *= rate at which fresh water enters the loch.*

Model Description

The model used (Figure 5) was an adaptation and continuation of one developed by John Simpson and Tom Rippeth in 1993 for the Clyde Sea area. The model is described as a 'filling-box model' and uses a one-dimensional depth-resolving grid. It uses energetics equations to consider the interaction between basic stratifying processes (buoyancy) and stirring processes (wind-stress, tidal forcing and convective motion). The effect of temperature on density is neglected since observations show this to be small. A central assumption that the water structure in the upper basin is horizontally uniform is justified by observations such as those shown for the upper basin on day 64 in Figure 6. The model is driven using daily saline and freshwater flow data (in this case observed at station LLO and provided courtesy of the Highland River Purification Board, respectively), and observed meteorological data. For the present study, the starting condition was the hydrographic profile measured at station LL14 on day 56.

Horizontal uniformity in the water structure of the basin is central to the model

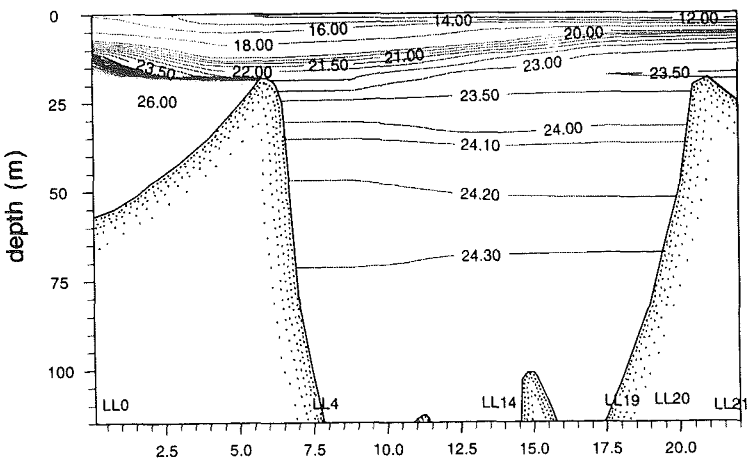


Figure 6 *Longitudinal (north-east–south-west) density structure (σ_t, kg m^{-3}) in the upper basin of Loch Linnhe on Julian day 64.*

Output from the model is in the form of daily temperature, salinity and density profiles with a 1 m depth interval. Because the model is one-dimensional these profiles apply to a fixed position in the loch which can then be taken to apply to any location given the assumption of horizontal invariance made above. Time-series data can be compiled using the model output and these predictions can then be tested against observations. Data from station LL14 were used for this purpose, as this station provided the best average representation of water column properties.

Model Results: Hydrography

Figure 7(a) (*opposite*) shows a plot of the density time-series as predicted by the model for station LL14 over the field season, compared with the observational density data in Figure 7(b), which is the same as Figure 3. Deep-water renewal is shown by the model to start on day 94, thus narrowing down the timing of this event, which could only be placed between days 86 to 99 from the observational data.

This is also illustrated in Figure 8, a comparison of observed and model-predicted salinity data for the bottom waters (110 m) at station LL14. The model prediction of day 94 for the start of the renewal event corresponds well with the increasing tidal range around this time, with spring tides peaking on day 95 as previously noted (tidal range = 3.3 m). The presence of isolated bottom waters between days 56 and 86 is also supported by the model, as is the presence of stratification throughout the water column during this period. The model does, however, predict too high a salinity for the surface layers (Figure 8), which would make them denser than the observed data allow. This discrepancy has been attributed to the directional effect of the wind increasing the proportion of river water in the surface layers, which cannot be replicated in this one-dimensional model. In fact, winds were predominantly north-easterly until about day 86, then became predominantly south-westerly until about day 95 (thus contributing to the renewal event), before swinging back to the north-east.

It should be noted that the model was also run and tested using hydrographic data collected in 1990 and was found to simulate conditions, and the timing of the renewal, as accurately as for the 1992 data.

Model Results: Nutrients

Once the density variations at station LL14 had been successfully simulated (within limits), nutrients were then incorporated into the model as conservative tracers with salinity. Observed nutrient profiles measured at station LL14 on the first day of the field season (and interpolated linearly to give concentrations at 1 m depth intervals) were used to initialize the model.

Between days 59 and 94 the model predicted conservative behaviour for phosphate with salinity in the isolated bottom waters, such that regression analysis gave $r^2=1$ (Figure 9(a), *overleaf*). When we compare this with the observed data for the isolated bottom waters between days 58 and 86 (Figure 9(b), *overleaf*), the corresponding regression analysis gives $r^2=0.09$ – as expected, phosphate is behaving non-conservatively. However, the discrepancy between predicted and observed values cannot be due to *apparent* non-conservative behaviour, since the bottom waters remained isolated during this period – no new water penetrated them, i.e. the end-member compositions did not change. Hence, the discrepancy can only be the result of *real* non-conservative behaviour in the bottom waters. Nitrate and silica exhibit similar relationships with salinity (Figure 9(c) and (d)), yielding r^2 values of 0.03 and 0.17, respectively. The observed (real) non-conservative behaviour must be the result of biogeochemical processes occurring at the sediment–water interface at the bottom of the loch.

The model can thus account for *some* of the scatter of points away from the TDLs in Figure 4 resulting from real non-conservative behaviour. The next step was to use the model to try and identify *apparent* non-conservative behaviour. To do this, the model was initialized with conservative nutrient profiles, and then run to predict how they would change with time, given only conservative behaviour. We might expect the end results also to yield $r^2=1$ with salinity. However, they do not: r^2 values for predicted data below 60 m are 0.97, 0.90, and 0.89 for the relationship of phosphate, nitrate and silica, respectively, with salinity. Since the model cannot predict real non-conservative behaviour, we may therefore conclude that *at least* 3%, 10% and 11% of the total scatter in the respective concentration plots in Figure 4 is due to apparent non-conservative behaviour.

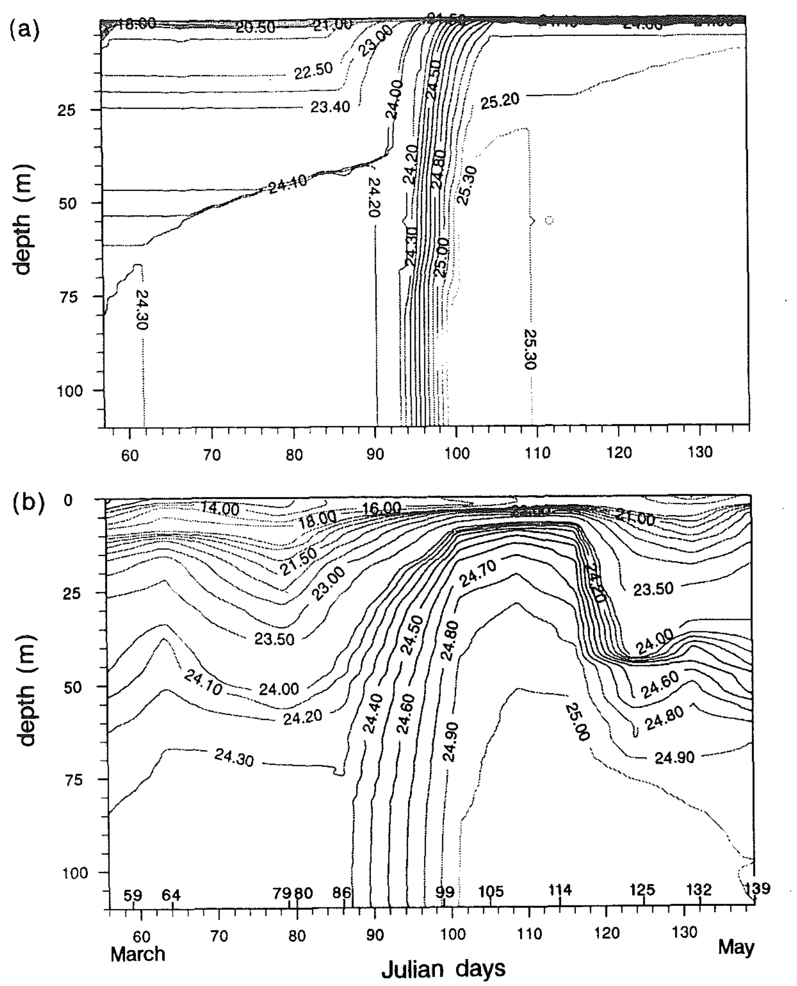
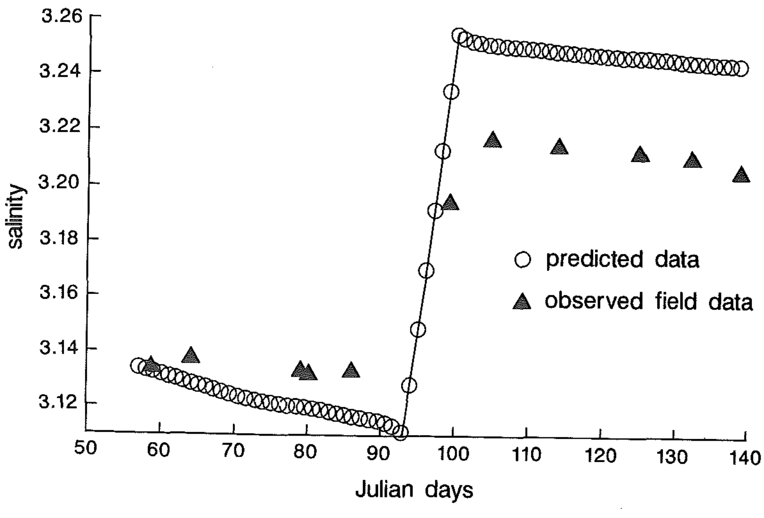


Figure 7 *Comparison between **(a)** model-predicted and **(b)** observed density structure (σ_t, kg m^{-3}) at station LL14. (Part (b) is the same as Figure 3.)*

The model successfully simulated the hydrographic features of the basin over time

Figure 8 *Comparison between model-predicted and observed salinity data for bottom waters (110 m) at station LL14. Note the gap in observations between days 86 and 99.*

The model predicts displacement of bottom water on day 94



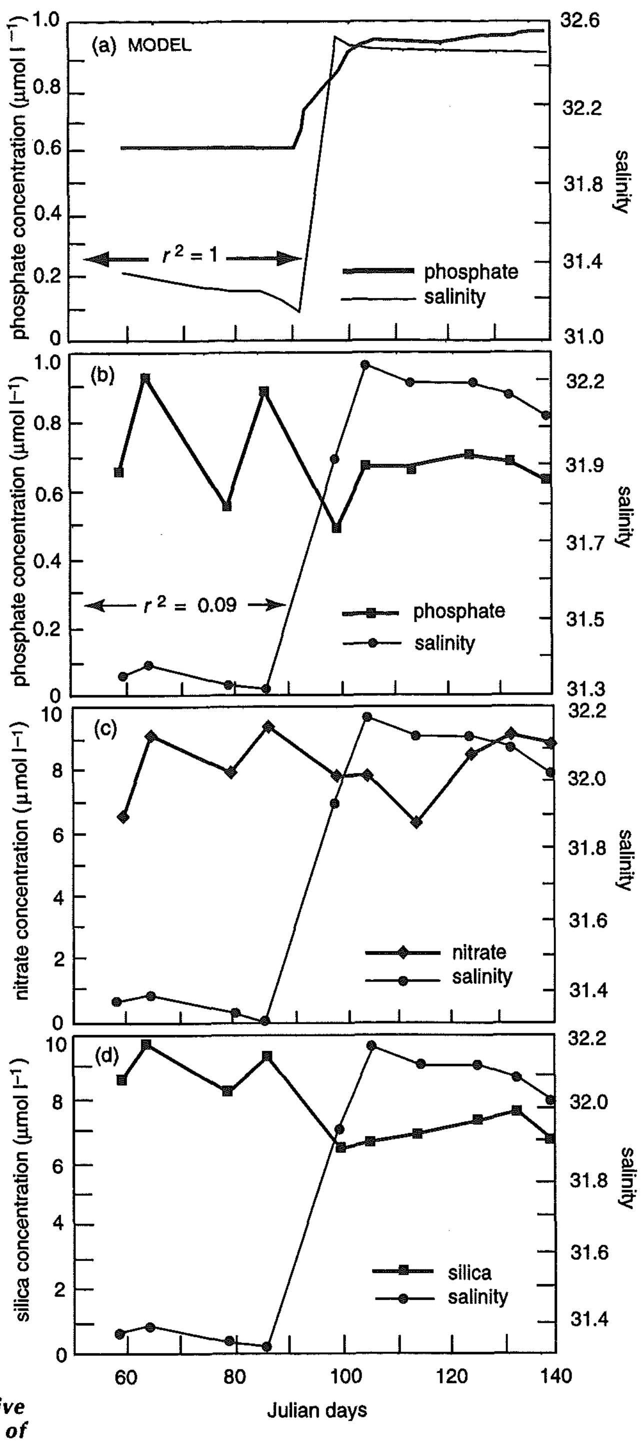


Figure 9 *(a) Predicted changes in phosphate and salinity with time.* ***(b)*** *Observed changes in phosphate and salinity over the same period.* ***(c)*** *and* ***(d)*** *are analogous plots for observed nitrate and silica.*

The non-conservative behaviour of nutrients is not easily modelled

What next?

Results from the study have shown how a simple 1-D model can reproduce major hydrographic features in a sea-loch system. The model accurately predicts the timing of deep-water renewal, given only an initial hydrographic profile, end-member compositions and meteorological conditions over the field-season. As has been described, deep-water renewal events are an important mechanism by which nutrients accumulating in isolated bottom-waters can be transported to the euphotic zone, where they can have an effect on the primary productivity and possibly the initiation of a phytoplankton bloom.

Although the model provides a tool for the study of processes affecting nutrient distributions, some limitations are evident. The most important is that the starting condition of the model must involve a conservative nutrient profile ($r^2 = 1$). Such a profile can be simulated but in a real world situation such linear variation with salinity is likely to be observed only when the system is well-mixed, for example after a deep-water renewal event. Such events, however, are a continuous feature of the hydrography in Loch Linnhe.

Despite these limitations I feel much has been achieved through this model development. We have been able to examine the role of physical processes in the distribution and behaviour of nutrients within the system. In doing so, we have highlighted the importance of correctly representing those physical processes in ecosystem models, something which has been somewhat neglected in past studies. Understanding the roles of such processes will help in the next step, which is to elucidate the primary controls on biological productivity and the timing of phytoplankton blooms in such areas.

Acknowledgements

The author would especially like to thank Dr Tom Rippeth and Professor John Simpson for their help and collaboration during this study; Professor Dennis Burton and Dr David Hydes at Southampton Oceanography Centre for their help and support; and the Dunstaffnage Marine Laboratory for the provision of excellent facilites and technical and moral support throughout the PhD..

Further Reading

Simpson J.H. and Rippeth T.P. (1993) The Clyde Sea: A model of the seasonal cycle of stratification and mixing, *Est. Coastal Shelf Sci.*, **37**, 129–44.

Thompson R.E. (1981) Oceanography of the British Columbian coast, *Can. Fish. Aquat. Sci.*, **56**, 1–291.

UNESCO Technical Report in Marine Science. (1981), No.36.

Watts L.J. (1994) *The roles of hydrographic and biogeochemical processes in the distribution of dissolved inorganic nutrients in a Scottish sea-loch system.* A PhD thesis submitted to the University of Southampton, UK.

Louisa Watts is presently based at the Dept of Marine Sciences and Coastal Management, University of Newcastle.* Her recent research has extended her interests, as she is now studying nitrogen assimilation by phytoplankton in the NW Indian Ocean using ^{15}N stable isotope techniques. She is presently modelling new production through the incorporation of remote-sensing techniques.

*Ridley Building, University of Newcastle, Newcastle Upon Tyne, NE1 7RU. Email l.j.watts@ncl.ac.uk

Sir Richard Grenville's *Revenge* ~ the last battle

Gordon R. Williamson

In September 1592, off the island of Flores in the Azores, a battle was fought between the English Royal Navy ship *Revenge,* commanded by Sir Richard Grenville, and 53 Spanish warships. On that day Sir Richard Grenville deliberately sailed his ship right into the centre of the Spanish fleet that had been sent to destroy him. A violent battle ensued, during which the *Revenge* was reduced to a floating ruin, and a number of Spanish ships were destroyed. Sir Richard was finally forced to surrender, and died of his wounds a few days later. He was instantly a hero in England. For centuries, English schoolboys were told his tale, to encourage daring and courage – as Scottish lads were taught of Bruce and the spider, and Spanish boys the bravery of El Cid.

Years later, Tennyson wrote a ballad about the battle. Here are the first lines of *The Revenge: A Ballad of the Fleet:*

At Flores in the Azores
        Sir Richard Grenville lay,
And a pinnace, like a flutt'ring bird,
        came flying from far away:
'Spanish ships of war at sea! We have
        sighted fifty three!'

What exactly happened? What was the background? Was Sir Richard Grenville incredibly brave, or mad, or on a suicide mission – or a combination of the three?

Spain the Greatest

In 1592, Spain was *the* power. Spain was strong because she was favoured by the Catholic Church, she was a large and united (whereas Italy and Germany, indeed most of the countries of Europe, were then made up of dozens of small states), and she was *rich*. One hundred years earlier, Christopher Columbus had sailed from Seville, in Spain, and discovered the Americas. Looting of the gold from the Incas had meant instant wealth for Spain – but had dried up. But big silver mines were discovered in Mexico and Peru, and soon the Spaniards were reaping a harvest of silver which became the economic life-blood of Spain, the wealth supply on which all Spain depended. The silver bullion – called 'plata' by the Spanish – was shipped from the Mexican port of Vera Cruz. The silver-bearing ships sailed to Havana, Cuba, then crossed the wide Atlantic to the verdant island of Flores in the Azores, and finally on to Seville.

England wants a slice of the pie

But, unfortunately for Spain, to the north lay a troublesome little country, England. England had opted out of the Catholic Church. England did not accept the Pope's declaration that all the New World belonged to Spain and Portugal. In 1558, a tough 25-year-old redhead became Queen of England: Queen Elizabeth was familiar with every trick in the book and was determined to hold power by guile, flirtation, or beheading opponents.

In 1572–73, Sir Francis Drake, Queen Elizabeth's favourite pirate, attacked the Spanish port of Panama; later, Drake sailed his *Golden Hind* through the Straits of Magellan, attacked the Spanish ports in Peru, and then circumnavigated the world. In 1583, Queen Elizabeth claimed Newfoundland as her first colony, and in 1584 English colonists settled on the coast of America, calling it Virginia. All this time, English 'private adventurers', known as 'privateers', attacked Spanish ships wherever they could find them. When King Phillip II of Spain complained to Queen Elizabeth, she replied that they were outlaws, beyond her control; she was very sorry but she could not stop them. She quietly helped her privateers.

King Phillip's reaction

King Phillip II of Spain was almost the opposite of Queen Elizabeth in character – modest, religious, methodical. From his Escorial Palace near Madrid he ruled not only Spain but Flanders, parts of France and parts of Italy. He became increasingly irked by the continued English attacks. To avoid individual Spanish plate-carrying ships being captured by English privateers, he ordered that the annual production of Mexican silver be carried to Spain only once a year in a special well-escorted convoy. This annual 'plate-fleet' – very difficult to attack – immediately became the ultimate 'jackpot' for English pirates and privateers.

As far as Philip was concerned, the bullion from Mexico *had* to reach Spain safely. All Phillip's European expenditures were paid for with this silver and during the 1570s and 1580s Phillip gradually came to the conclusion that he would have to attack England. The result was 'La Empresa de Inglaterra' – 'The Enterprise of England' – what the English call the Spanish Armada (Armada means 'navy' in Spanish).

The aim was to conquer England and install a Spain-friendly monarch instead of Queen Elizabeth. This was to be achieved by:

- assembling an army of 30 000 soldiers in Flanders, then a Spanish possession.
- ferrying this army across the English Channel in barges, protected by a 130-ship taskforce of the Spanish Navy – a D-day landing in reverse.
- marching the army to London and deposing Queen Elizabeth.

How the enterprise was launched in 1588, how the 130 Spanish Navy ships reached the coast of Flanders two weeks before the army was ready to embark, and how the Spanish Armada ended up sailing around the whole British Isles only to be pounded to pieces on the west coast of Ireland by the September gales, how the army never left Flanders and how England never got invaded – is another story.

Although the Spanish Armada failed in its mission, Queen Elizabeth knew a state of war now existed between England and Spain

1591

So frequent did the English attacks on the Spanish annual plate-fleet become that in 1591 King Phillip II ordered the fleet not to sail, but for two years' worth of silver to be accumulated at Vera Cruz, Mexico, and a heavily armed 'double plate-fleet' to sail in 1592. There were to be about ten plate-ships – a double jackpot – and sixty escort ships. Queen Elizabeth decided, for the first time, to send English Royal Navy ships to attack the plate-fleet.

The best place to attack the plate-fleet was in mid-voyage, off the Island of Flores in the Azores, 1 000 miles west of Portugal (see map on p.13). The island of Flores was – and still is – an exquisite island of verdant vegetation and wild hydrangeas, and only a tiny population. For sailing ships coming from the west, *en route* for Europe, it was the first landfall, where ships could get shelter, food and water.

Elizabeth ordered an English naval taskforce of six battleships to proceed to Flores, lie in wait for the plate-fleet, and then capture as many plate-carrying ships as possible. Sir Thomas Howard on the *Defiance* was the commander of the taskforce, and his second-in-command was Sir Richard Grenville on the *Revenge*. In addition, there were six victualling ships that came and went between London and the fleet bringing food, and four pinnaces for scouting and general purposes.

Sir Richard Grenville and the *Revenge*

Sir Richard Grenville was of the landed Norman family of Grenvilles in north Cornwall. Their land was poor, and for generations the family had made their fortunes at the King's court in London and by adventuring. Sir Richard may have been the wildest of them all. For various reasons, Sir Richard had not participated in any of the Anglo-Spanish battles till now, and it was Sir Frances Drake who had won all the glory. But now Sir Richard had his chance to shine.

The *Revenge* was a small but powerful galleon, 92 feet long, of 500 tons, and armed with 40 cannons. She had been built in Deptford 15 years previously, and was now packed with 190 Devon sailors. By contrast, the biggest Spanish galleons each carried 500 men and 90 cannon.

Three fleets come together

Queen Elizabeth's taskforce sailed from Plymouth in April 1592 and soon reached the island of Flores – it is 1400 miles, about ten days' sail, from Plymouth. Sir Thomas Howard, the commander, had no idea when the plate-fleet would arrive – only that, sooner or later, it would arrive. The six fighting ships – ships of the line as they were called – anchored off the north coast of the island while the pinnaces patrolled to the west, ever watching for the white sails of the Spanish fleet.

Back in London, news spread of the dispatch of the taskforce to Flores, and before long reached the ears of the Spanish ambassador, who immediately wrote warning King Phillip of Spain that his precious plate-fleet was going to be ambushed. On hearing this news, King Phillip decided that he would ambush the ambushers. With grim determination, he ordered a maximum-strength fleet of warships to assemble at Lisbon (Portugal was under Spanish control in those days). Soon they were ready. He appointed Don Alonzo de Bazan as fleet commander. In early September the Spanish fleet sailed west from Lisbon. Fifty-three warships made up the fleet.

So now the stage was set: six English battleships quietly waiting off Flores, the seventy vessels of the Spanish plate-fleet sailing slowly eastward toward Azores, and the 53-ship fleet of Don Alonzo heading out to destroy the English ships.

The Spanish fleet arrives off Flores

The prospect for Sir Thomas Howard was definitely not good. But, very luckily for him, he received a warning. An English naval pinnace – a small, fast spy-ship patrolling the coast of Spain – saw the Spanish fleet sailing out of Lisbon, guessed its destination and purpose, put on all sail and arrived at Flores about one hour before the Spanish fleet of Don Alonzo. As described in Tennyson's poem, he reported: 'Spanish ships of war at sea! We have counted fifty three!'

Before he could say more, the first of the Spanish ships came in sight. The Spanish fleet had divided into two and had come round opposite sides of Flores intending to catch the English ships in a pincer movement. All six of the English ships were at anchor; they had been waiting for five months. Sir Thomas Howard took one look at the oncoming pincer points, did some quick mental arithmetic, and hoisted the order 'All ships cut anchors. Sail north for England.' Five of the six ships obeyed his order.

... but the *Revenge* stayed put

The *Defiance* and four other ships escaped to the north before the Spanish pincer closed. But the *Revenge* did not move. Sir Richard Grenville's ship had about ninety men ashore, convalescing from a wave of sickness that had run through the crew. He was not going to desert his men, and ordered that all men ashore should be brought back on board. Rowboats busily ferried the men from shore, and finally the *Revenge* was ready to sail. The anchors were raised and Sir Richard ordered all sails except the mainsail to be set. He might still narrowly escape the closing Spanish pincers. The crew thought this was what he would try to do.

Instead, he ordered 'Load with bar-shot!' and steered the slowly-moving *Revenge* into the heart of the Spanish fleet. 190 English seamen *versus* 4 000 Spaniards. Forty English cannon *versus* 1 000 Spanish cannon.

The leading Spanish ships were mighty galleons of 1 500 tons, three times bigger than the *Revenge*. The Spanish technique of sea warfare had long been to run their galleon close to any enemy ship, fire a single broadside, steer right alongside the enemy ship, grapple on with grapnel hooks and, in a 'land-battle-on-ship', send soldiers on board the enemy ship to capture it by hand-to-hand combat. This the leading Spanish ship now prepared to do. 'Fire!' shouted Grenville. The vicious bar-shot hurtled outward and felled the masts of the adversary. Score 1 : 0 to Grenville.

How the battle went until sundown

Then came the 1 500-ton *San Felipe*. The *Revenge*, downwind, became becalmed as the wind was blocked by the massive Spanish ship. The *San Felipe* threw grappling hooks onto the *Revenge* but the ropes broke. Next came another huge ship, the *San Barnabe*, which successfully grappled on, then another galleon grappled on to the *Revenge*'s stern; soon two more galleons grappled on. The *Revenge* was boxed in by four giants. There was no escape.

The battle started about three in the afternoon. It was as if the *Revenge* was in a smoke-filled boxing ring, in a hollow between the great Spanish ships. Cannon fired at almost zero range. Soon the *Revenge*'s masts and sails were all flat on deck. The Spanish soldiers tried to climb on board but the English sailors kept them back. Sir Richard strode about the debris thrusting his sword, yelling and encouraging. From musket-men overhead, a hail of shot rained down.

Grenville's Devon gunners jammed wedges under the breeches of their cannon to depress the muzzles so that the 32-pound cannon balls would go into the lower parts of the Spanish ships, holing them below the waterline. Several ships were sunk this way, but always new vessels replaced the sunken ones. Sir Richard was shot in the arm, but continued fighting.

Now at sunset, the *Revenge* was like some wounded dinosaur. Nobody was alive or visible on deck, but no Spaniard dared to go on board. The Spanish had captured the exterior of the ship. The interior was death to enter.

In the night

Night came, and Spanish cannonballs still thundered into the English ship. The *Revenge* only fired occasionally, most of her guns having been dismounted by Spanish shot. Every red hot cannon ball ignited a fire where it lodged, and in the swirling darkness and smoke, sailors with buckets of water tried to quench the flames that glowed on her deck and 'tween-decks. The *Revenge*'s gunners still fired occasionally – punishing shots to below the waterline; many a Spanish ship left the fight – but always a new ship grappled on. So many dead, so many dying, so many wounded men.

Next day

Soon after dawn, the *Revenge* ran out of shot and the English cannon fell silent. Grenville ordered his men to fight hand-to-hand to the last man, no surrender. But shortly afterwards, he was struck in the head by a musket ball, and was carried below deck mortally wounded. From the *San Barnabe*, the mighty Spanish galleon lashed on to the *Revenge*, Captain Bertandona called for Grenville to surrender, promising honourable and safe conveyance to England for all his surviving crew. On hearing this ultimatum, Grenville sent for his Master Gunner and asked 'Have we enough gunpowder to blow up the *Revenge* and all these Spanish ships around us in one huge bang?'

'We have,' replied the Master Gunner.

'Ignite the magazine!' ordered Grenville.

Outside the Captain's cabin the crew waited to hear their leader's decision. When they heard what it was, they tied up the Master Gunner and, instead of obeying the order, sent a messenger to the *San Barnabe* to inform Captain Bertandona that *Revenge* was finally willing to accept his surrender terms. Thus, after about twenty-four hours of fighting, the *Revenge* was finally defeated.

After the battle

The mortally wounded Sir Richard Grenville was transferred to the *San Paul,* the Flagship of the Spanish fleet, commanded by Don Alonzo de Bazan. Many Spanish captains came to see this amazing English warrior – but Don Alonzo refused to do so. A few days later Sir Richard felt death approaching and spoke: 'Here I die, Richard Grenville, with a joyful and quiet mind, for I have ended my life as a true soldier who has fought for his country, his Queen, religion and honour.' He was buried at sea.

Spanish sailors were put on board what remained of of the *Revenge,* augmenting the few surviving English sailors. Two days later the plate-fleet arrived and beheld, in amazement, the evidence of the battle: the battered dismasted Spanish ships, the lifeless flattened hulk of the once-deadly *Revenge,* and wounded men by the hundred.

Finale

The combined Spanish fleets sailed for the island of Terceira, but an unprecedented storm arose and raged for a week. Many ships foundered or were smashed on the rocks of the islands. *Revenge* herself struck a rock close to Terceira and sank with all hands, save one solitary English sailor who struggled ashore, climbed the cliffs, informed the local people what had happened, and died.

And that is the story of the *Revenge* and of Sir Richard Grenville and his men – four hundred years ago on 13 September, 1592. The English and Spanish fought with equal valour and honour, and the tale is worthy of remembrance in both countries.

Further Information

If you wish to visit Flores, you need to fly via Lisbon to Ponta Delgada on the island of San Miguel.

You can visit Buckland House, Sir Richard Grenville's Devon home, where he lived during his seafaring days. Buckland House is a converted former abbey at Buckland Monachorum in the beautiful Tavy valley, ten miles north of Plymouth.

Books which relate to the *Revenge* story include:

Sir Richard Grenville of the Revenge, by A.L. Rowse, published by Jonathan Cape.

In Search of Spanish Treasure, by Sydney Wignall, published by David and Charles (Chapters 7 and 8).

Finally, since Sir Richard's time, the British Royal Navy have given the name *Revenge* to many other ships. The latest bearer of the name *Revenge* is a 7 000-tonne nuclear-powered submarine, whose crew, incidentally, is only 147. This submarine has recently been retired from service and is at Rosyth in Scotland, waiting to be cut up for scrap.

You could therefore even buy the submarine *Revenge*! I think Sir Richard would have preferred his old model.

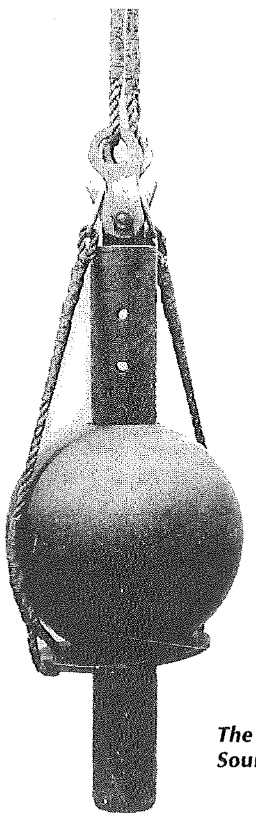
Gordon Williamson is a marine biologist who is keen on history and lives in Inverness, Scotland.

Book Reviews

Catalogue des appareils, d'océanographie en collection au Musée océanographique de Monaco. 5: Instruments de Sondage by Christian Carpine (1996). Fondation Albert, Prince de Monaco, 208pp.
(soft cover, ISBN 2-7260-0178-5).

Note This book is Volume 75, No. 1441, of the Bulletin de l'Institute Océanographique Fondation Albert, Prince de Monaco. The text is in French.

For the past dozen years or so, staff at the Musée Océanographique de Monaco have been striving to complete a comprehensive listing of the great mass of material which has been deposited within the Museum since its establishment by Prince Albert I in 1910. Responsible for enumerating the depth-sounding instruments within the collection has been Christian Carpine whose work has now been published in Volume 75 of the *Bulletin de l'Institut Océanographique* here under review.



The Brooke Sounder

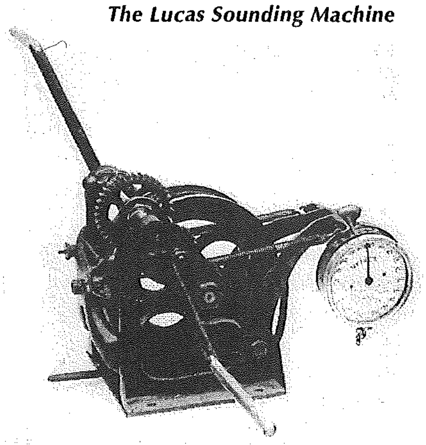
Depth-sounding at sea may be considered as the earliest navigational technique. Indeed, the first among 72 items of equipment listed in this catalogue is the 'galet troué' – a large stone with a hole bored through it to enable it to be used as the weight at the end of a sounding rope. The final item listed is the British Admiralty Echo Sounder model MS XII built by Hughes and Sons of London about the year 1937, with which I was shipmates in HMS *Franklin* in 1939! Many of the items listed were employed by Prince Albert in his yachts *Princesse-Alice*, *Princesse-Alice II*, *Hirondelle I* and *Hirondelle II*, and others have been presented to the Musée.

There is a photograph of each invention on the left-hand page, whilst a full description of its working appears on the facing page, together with an exhaustive list of references to other publications concerning the history of the instrument. It is not surprising that Anita McConnell's name appears frequently; in fact her book *No Sea Too Deep* forms an excellent companion to this catalogue. The bibliography extends to 25 pages, and there is also an index of names cited in the work.

A number of copies of sounding devices have been specially constructed by various instrument-makers over the years so that the originals, of which only descriptions remained, could be included in the collection. A replica of an intriguing apparatus which employed a propeller to register the depth and a float to bring it to the surface when its weight had been deposited on the sea-bed, was made by Max Marx of Berlin on the basis of a description by someone calling themselves 'Joe Soundings', published in the *Nautical Magazine* in 1832. It seems likely that this is the only one of this apparatus ever made.

The various types of depth-sounders which have been used by seamen, cable-laying engineers and oceanographers over the years have been divided by Christian Carpine into different categories with an introductory essay for each section. There are those that release their weights on the sea-bed to activate a sampler; one such was the sounder developed by Midshipman Brooke under the guidance of Matthew Maury in 1852. There are others without wires or lines which return by flotation to the sea surface after releasing their weights, the depth being calculated from double the time of travel. Then there are the sounding machines using thin wire such as the Lucas Machine invented by the Chief Engineer of the 'Telegraph Construc-

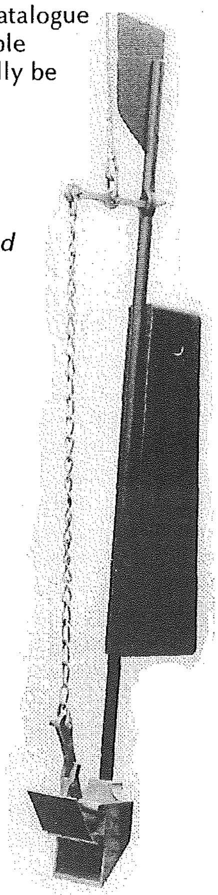
The Lucas Sounding Machine



tion and Maintenance Company', which was used in the *Great Eastern* in 1856. Finally, there are the echo-sounders of which the continuous recording apparatus developed by the 'Service Hydrographique de la Marine Français' under the guidance of their 'igénieur hydrographe' Pierre Marti must be considered as the first to be introduced after the end of the First World War.

The author explains that the next catalogue in the series will be devoted to thermometers, with further publications dealing with laboratory and meteorological instruments. If these catalogues maintain the standards achieved in Catalogue No. 5 then a valuable series will eventually be available to oceanographic historians.

G. S. Ritchie
Collieston, Scotland



The Lightning Sounder (here in descent mode) as used by Wyville Thomson on HMS* Lightning *in 1868

Concepts in Biological Oceanography: An Interdisciplinary Primer by Peter A. Jumars (1993). Oxford University Press, 348pp. £45 (hard cover, ISBN 0-19-506732-0).

One of the current challenges in marine science is to incorporate biological processes into national and international oceanographic programmes. This can sometimes be difficult to achieve because of the particular way in which biologists approach the subject. Biologists tend to focus on small differences whereas physicists, for example, look first at similarities and then focus on differences. For this reason, physicists often lose patience with biologists. While the marine ecologist will make a specific study of the life form, biological oceanographers may have training or experience in a number of disciplines and so are likely to combine many types of processes (physical, chemical or geological) in their approach to research. Furthermore, the jargon of biology is complex, often involving latinized words, and to workers in other disciplines may therefore seem exclusive. Even at graduate level, biological oceanography may be impenetrable to non-biologists.

To try to address such problems, this book is written as an interdisciplinary primer for physical, chemical and geological oceanographers, to encourage communication and collaboration between oceanographers and biologists. It is less full of facts than of principles and approaches, with the minimum amount of jargon and peripheral detail. For example, instead of describing reproduction and feeding by considering physical characteristics of an organism, the determinants described are the principles of foraging and encounters between individuals.

The book is divided into three sections: an introduction to ecological principles; a description of issues central to biological oceanography; and a number of short essays on interdisciplinary topics. The introduction to ecological principles describes classification by feeding, and not by the more traditional method of taxonomy. Energy acquisition is used to develop foraging theory, and feeding efficiency is considered along with encounter rates and types of feeding. Population kinematics are discussed and considered in fluctuating environments, along with appropriate population models. This leads naturally on to the current debate in the ecology of communities concerning whether competition or predation is the more important in determining community structure. The final part of the first section considers ecosystems and the weaknesses and strengths of energy or mass flow models. The section closes by considering how newer ecosystem models based on tracking of individual organisms may be more realistic than those using statistics alone.

'Central issues in biological oceanography' form the subject of the second section of the book, which begins by describing the horizontal and vertical structure of the biology in the oceans; this is then followed by temporal change; the magnitude and time variation of primary, new and exported production are then superimposed on this background, and this progresses to a discussion of grazing, but in both cases considering causes of variations; microbial loops, closely interlinked, are then described. The dispersal and recruitment of planktonic larvae is considered in relation to primary production.

The third section introduces a number of biological oceanographic subject areas to non-biological oceanographers. It is intended to stimulate their interest and also to stimulate growth at the edges of the disciplines. The subjects covered are marine optics, physical oceanography, particle dynamics, sediment transport, fouling, stratigraphy, diagenesis and geophysics. For someone approaching one of these subjects for the first time these chapters will be useful, although after the depth of the first two sections they may appear rather shallow. It might have been better to take one or two of these subjects and to discuss the interconnection of the biology with other disciplines more deeply, rather than attempting to deal with so many topics. After reading the final section of the book it seems that the author has resorted to the type of classification criticised in the Introduction, although in this case he has chosen to fit biological processes into a series of physical, chemical and geological subject areas. Surely, in a truly interdisciplinary approach, the boundaries of discipline in oceanography are not relevant and so should disappear? The final section of the book appears to focus on these boundaries rather than to attempt to break them down.

Taken as a whole, the book is a useful introduction to biological oceanography for both the undergraduate and the graduate oceanographer. Since biological oceanographers often develop their interest in biology after studying and researching in other disciplines, it may even be useful further on in the career of a researcher. There is little doubt that it will be one of the texts used in an undergraduate biological oceanography course. It will also be a useful book in any university library, and the excellent list of references will encourage further reading.

Alison Weeks
Southampton Institute

The Oceans and Climate by Grant R. Bigg (1996), Cambridge University Press. 266pp. £55 and £18.95 (hardback, ISBN-0 521-45212-0; paperback 0521-58268-7).

A book emphasising the role of the oceans in climate and climatic change is very timely and to be welcomed. The oceans are too often poorly modelled or given minimal attention by meteorologists investigating the global climate system, and it is for oceanographers to draw attention to the important part which they play.

This textbook starts with a general account of the climate system and then considers in turn physical, chemical and biological interactions between the atmosphere and ocean; it proceeds to discuss large-scale air–sea interaction with particular regard to El Niño and the Southern Oscillation, and after examining the role of the ocean in climatic variability from Palaeozoic times up to the present century it concludes with a look to the climate of the future.

It is not clear just what level of student this book is intended for. To cover such topics, which are complex and multifaceted, in a book of about 260 pages is an ambitious project. A reader without an existing knowledge of oceanography and/or meteorology, or at least a very sound background in the basic scientific disciplines and a familiarity with Newtonian mechanics – not to mention a willingness to work hard to apply them to the atmosphere and ocean – is unlikely to cope with the early chapters, and these provide an essential foundation for the latter part of the book. The very nature of the subject matter, involving numerous interrelationships and feedbacks, leads to constant references back and forward in the text, and to a certain amount of repetition.

There is a Glossary which is very useful, though the explanation of terms in it is generally rather brief. Of the appendices, I could see little justification for the longest (B) setting out the Periodic Table and electron orbital configuration, but the visible part of the electromagnetic spectrum could well have been enlarged in A to enable the reader to relate colours mentioned in the text to wavelength.

Perhaps one of the most disappointing aspects of the book is the figures. There is a profusion of these, but most seem to have been taken almost directly from other sources (often poorly computer-generated); sometimes it appears that colour illustrations are reproduced in black and white and/or have been reduced from their original size, and in very many cases it is difficult to identify features to which the text draws attention. There are also some errors in the figures and the captions; for example, in Figure 2.31(b) the arrows represent horizontal pressure gradients, not velocities; in Figure 3.4 the flux between the surface and deeper waters is incorrect; an arrow is missing out of dissolved nutrients in Figure 4.3; the left and right panels appear to have got transposed in Figure 5.32; two dates seem to be transposed in Figure 6.16; and 1790 in the caption to Figure 7.10 should presumably read 1990. I found the physical approach to explaining the Coriolis effect a refreshing alternative to the mathematical approach so often used, but I do just wonder how many readers will be convinced that Figure 2.13 shows paths curving to the right.

There are also a significant number of points in the text which are erroneous or could lead to confusion. Salinity is stated to be essentially identical to a measure of parts per thousand by *volume* (p.15). Equation 2.15 has frequency where period should be. Whilst some eddies may be associated with vertical movement, it is not a requirement; in particular Gulf Stream rings do not require vertical movement and the high nutrient content of cold-core rings results from their origin and not from upwelling as stated on p.78 and p.121. Productivity is a rate not a total mass (as stated in the Glossary), and predators affect the amount of phytoplankton present rather than the productivity (as suggested on p.121). The feedback from ice-melting on climate due to the increase in absorption of radiation is surely positive, not negative as stated on p.185. These, and other points, should be corrected in a reprint of this book, and in the meantime perhaps the author will be able to provide an errata sheet – those of us involved with the Open University are well-accustomed to these, and not just for the OU oceanography course!

In conclusion, my report would be: an excellent piece of work, but needing some corrections and improvements to the figures. With these, I could recommend it wholeheartedly to those concerned with the oceans, with climate, and with global change, as long as they have an adequate background to cope with the complexities of the systems and interactions which the book explores.

John Harvey
Tarbet House, Loch Lomond

Introduction to Physical Oceanography by George L. Mellor (1996). AIP Press (Woodbury, New York), 260pp. £45 (flexicover, ISBN 1-56396-210-1).*

Oceanography has been one of the growth areas in science over the last 15–20 years. The recognition of the ocean's role in climate, concern over the growing pollution of beaches, the depletion of fish stocks, rising sea-levels – all of these factors have contributed to the expansion of a branch of the Earth Sciences previously regarded by some as rather peripheral. Accompanying this expansion has been a proliferation of marine science courses in universities, with their concomitant textbooks.

Finding a distinctive niche for a new book on basic physical oceanography has thus become a difficult task. This new title by George Mellor, developed from a course taught at Princeton University, is aimed at the American Senior/early postgraduate with a mathematical bent. It largely succeeds in giving a fresh approach to the derivation of the major equations of the physical oceanography of both the deep and coastal ocean. In research papers, these basic equations are now largely skipped over and so this book provides an up-to-date, insightful reference source for the incipient researcher.

After beginning with a general introduction to the ocean and the presentation of the basic equations of oceanic dynamics, Mellor then proceeds to explore different simplifications. The starting point is the key balance of geostrophy, which is followed by boundary-layer processes and how energy gets into or out of the ocean. The intrinsic mechanism for supply of momentum is set up, and leads into barotropic and baroclinic ocean flows. Waves in their various manifestations as surface, inertial and tidal features follow, with a final discussion of the concept of vorticity and its links to previous discussions. At the end of each chapter there are a set of problems of varying difficulty to enable the student to reinforce that chapter's theory.

While the book is intended for people with some familiarity with partial differential equations, the steps in each derivation are generally well explained, and in some cases give the more experienced reader a new perspective on an old topic. This mathematical treatment is very much the book's strength. The initial sections on general oceanography, and later parts commenting on observational data, are more tentative, and sometimes misleading – yet another author who neglects to remind students that water vapour is the dominant greenhouse gas. There are also somewhat more than usual typsetting errors, which sometimes creep into the equations or units. However, these drawbacks are minor. Taken in its entirety, this text forms a good basis for leading the new postgraduate into the mysteries of ocean dynamics.

Grant Bigg
University of East Anglia

*It seems that there is some prospect of a paperback edition, but it is unlikely to appear in the immediate future.

Ocean Acoustic Tomography by Walter Munk, Peter Worcester and Carl Wunsch (1995). Cambridge University Press, 433pp. £45 (US$59.95) (hard cover, ISBN 0-521-47095-1).

I wonder how many book reviewers actually read every word on every page of the books they are sent to review – and check all the mathematics as well? People are so busy these days dealing with the everyday demands of their jobs that finding the time to review a paper – let alone a book – can sometimes seem impossible. So how welcome, therefore, to find a text which even after only a cursory inspection, leaves one feeling convinced of its merits as a genuine and scholastic contribution to the scientific literature – and not just another attempt by someone to boost their publication rating for a research assessment exercise. This is just such a book; produced to a very high standard and with excellent diagrams and figures – some in colour. The authors, various reviewers and Cambridge University Press have done an outstanding job in adding this book to the ranks of other distinguished treatises in the Cambridge Monographs on Mechanics series. I remember only too well as a research student dipping into other books in this collection, in particular J. S. Turner on buoyancy effects and A. S. Townsend on shear flows, to understand something of the vagaries of ocean turbulence. And that is how I imagine *Ocean Acoustic Tomography* will be used by a generation of students and engineers, in the process looking at the pioneering contribution of Munk, Worcester and Wunsch in this field over the past 15–20 years.

Ocean acoustic tomography is all about using sound to probe the interior of the ocean. Although satellite remote sensing has made enormous strides in revealing the complexity, we are still stuck when it comes to getting below the surface to see what is going on underneath the waves. The oceans remain opaque to all but the longest wavelength electromagnetic radiation. On the other hand, sound energy, at low frequencies, is known to travel long distances with little attenuation. Moreover, it travels on fairly well defined pathways so that if the effect of changes in these pathways on sound propagation can be understood, then, from a relatively simple estimate of the initial state of the ocean, it is possible to work backwards to recover information on features in the ocean (e.g. eddies and fronts) and other processes which are only glimpsed from the surface by satellites. That these features exist is in no doubt – two decades of measurements from drifting buoys, moored current meters and satellites have told us that – but we are still lacking techniques that can routinely monitor the interior of the ocean over long periods of time. Ships are costly and not always in the right place at the right time. Some other method was needed and this – finally, after 10–15 years of what some might regard as principally technological development – is where ocean acoustic tomography may begin to pay off, with both long and short baseline transceiver arrays being set up to monitor change in the ocean.

So back to the book. This is not for the mathematically shy – although it can be read with interest by dipping into the various chapters. Any account of ocean acoustic tomography inevitably involves discussion of the forward and inverse problems. And that is largely how this book is organised, with Chapter 1 defining the tomography problem from a classical ocean acoustics point of view and proceeding through rays and travel-time differences to the forward and inverse problems that define the technique. The forward problem, i.e. how from a knowledge of the sound speed profile in the ocean can we deduce the arrival structure of the signal at a distant receiver – is dealt with at greater length in Chapter 2 for the range-independent case using ray and normal mode treatments. At this point, readers need to appreciate that tomographic techniques are essentially spatially averaging – good, therefore, for measuring things like the heat content change in a volume of ocean – and it is only by careful design of transceiver arrays and from an *a priori* knowledge of sound propagation paths, that it is possible to infer structure on scales smaller than the array separation. Surprisingly, it is only comparatively recently (1994) that this largely forward problem has been solved with sufficient accuracy to enable reliable and meaningful estimates of integral properties and mesoscale variability to be extracted using inversion techniques.

This is dealt with in more detail in Chapter 3. Reciprocity is a fundamental tenet of acoustic tomography – basically, sound has to be able to travel forwards and backwards over more or less the same path for changes in the space between a transmitter and a receiver to be detected. Current shear means that this doesn't happen and that ray paths may separate vertically by a few tens of metres. On the other hand, the rays are not infinitely thin and provided the width of the wave front is greater than the ray separation the method works – and the authors show how. This brings me to an important point. There is a lot of good basic physical oceanography in this book and I particularly like the way the authors do little 'back of the envelope' calculations to illustrate a point. So in Chapter 3, in addition to ray width and reciprocity, the relative contributions of geostrophic shear and sound speed perturbations are assessed. In a similar vein, the book is good at illustrating the practical significance of circulation, vorticity and divergence – concepts that will be familiar to physical oceanographers at least.

The discussion of reciprocity reminds us of course that the ocean is not just a quiescent body of water, with conditions everywhere the same. The real ocean is populated with eddies and fronts and demonstrates variability on a wide range of spatial and temporal scales. To map these using acoustic tomography we have to be able to do the forward problem in a truly range-dependent environment, i.e. one where the conditions change along the ray path. This is addressed in Chapter 4 which introduces the concept of adiabatic transformation of ray paths in sound channels which change with range. Calculations of the travel-time perturbations due to Rossby waves, mesoscale variability and internal waves are examined here also. Even chaos creeps in. Range-dependent environments are characterised by rapid exponential-like divergence of rays from their nearest neighbours with increasing distance down-range – and with a similar dramatic reduction in intensity; this behaviour is termed ray chaos. Also dealt with here are modal representations of range-dependent profiles and, finally, horizontal refraction due to the temperature changes associated with mesoscale eddies and bathymetric effects.

The success of acoustic tomography in recent years is founded very much on improvements in the accuracy and reliability of measurement techniques and signal-processing. Chapter 5 gives a useful resumé of the sonar equation before dealing with pulse-compression, accuracy of travel-time measurements, time-keeping, Doppler effects, positioning and data treatment. In common with other inverse methods, acoustic tomography depends on having a good initial guess or estimate of the state of the ocean. Two approaches to this are possible: one based on data or observations and the other on the use of models. Chapters 6 and 7 deal with these two approaches. In terms of mathematical content, Chapter 6 is probably the most demanding – but even here it is possible to glean much by reading between the lines of equations and matrices. This is the 'hard stuff', as it were, of ocean acoustic tomography, and I am sure that for the specialists this gives a good account of inverse methods.

One area where acoustic tomography has begun to show promise and which is also highly topical, is basin-scale tomography. Promoted very much by Munk himself, the proposal here is for nothing less than a global array of acoustic tomography sensors to measure climate change in the ocean on decadal time-scales by measuring small differences in travel time and arrival structure over long distances. The term 'acoustic thermometry' has been coined by the exponents of this idea and seems particularly apt given the basis of the method. This chapter is beautifully illustrated with colour plates, as is the Epilogue which – for my money – is one of the most interesting chapters in the book, detailing the contributions that have been made by acoustic tomography to our understanding of subjects as diverse and fundamental as mesoscale variability, convection and the basic equations of state for seawater and the speed of sound.

Science is done by people and it is therefore nice to find a really personal touch at the end of this book where there is an account by the authors of the development of their subject and details of the principal scientific and technical contributions made by various groups around the world. If all you do is read this you'll get a flavour of the excitement and come away a lot wiser about ocean acoustic tomography. The book is littered with anecdotes and interesting footnotes – which only add to the personal touch – this reviewer, at least, detected the hand of Walter Munk in many of these.

This is an excellent book – a classic in my opinion – marking the important observation that much of the ocean's interior is not quiescent and that like the Earth's atmosphere it is frequented by 'weather' and 'storms' on scales that are determined by rotation and stratification. The efficacy (or rather the lack of it) of ocean sampling strategies prior to the '70s and the advent of tomographic techniques – is amply illustrated by the statement in the Preface that earlier methods under-sampled the ocean and missed some 99% of the kinetic energy! It seems obvious now, but how are we going to tackle this problem in the future? Ocean acoustic tomography may be the answer – particularly if it can be combined with satellite remote sensing. There is no doubt that this will represent major technological challenges but with people of the stature of Munk, Worcester and Wunsch to give us the benefit of their insight into the problems, we are surely well placed to begin the development of acoustic tomography as a means of routinely monitoring the ocean interior.

Tony Heathershaw

Defence Evaluation and Research Agency (DERA)
Southampton Oceanography Centre

Any views expressed are those of the author and do not necessarily represent those of DERA/HM Government.

MICROTEST to accompany **Exploring Ocean Science** (2nd Edition) by Keith Stowe (1996). Wiley College Software, John Wiley & Sons Inc. £22.50. (ISBN 0-471-13695-6).

I referred to this software when I reviewed the accompanying book in the previous issue of *Ocean Challenge* (Volume 6, No. 3). I suspected it might merely be the rather simple-minded set of mutliple-choice type questions and answers provided in Stowe's own supplement entitled *Instructor's Manual & Test Bank*. So it has proved.

The single disk (somewhat unusually, for use on Apple Macintosh systems) comes in a smart plastic box with a User's Guide, a pamphlet that provides simple instructions for computer semi-literates (like me). It enables you to select questions (and answers) from an extensive range (of the order of 2000 questions in total) covering all aspects of oceanography, including Law of the Sea, and to compile your own bank of test and examination material. You need 'at least 1 Mb of RAM and a hard disk or two 800K disk drives. The program needs at least Systems Tools 5.0 (System 4.2/Finder 6.0)'.

It seems to me, however, that the facility to 'pick 'n mix' is the limit of the advantages conferred by this package because, as noted above, the material is not intellectually demanding. The problem is that a high proportion of the questions require you simply to recall information in the book from memory – or to look up the answer, if uncertain. Many others offer such unlikely alternatives to choose from that the right answer is obvious (example: A change in pressure from one place to another is called a(n):
A instability; B Brummer effect;
C Coriolis change, D typhoon;
E pressure gradient). Often, however, the right answer is not unambiguously obvious (example: The ocean's surface waters are saltiest where .... is greatest.
A the speed of surface currents; B wave activity; C wind speed; D evaporation; E precipitation).

All the same, we do keep banging on about the need to introduce marine science into schools. While Keith Stowe's idea of what constitutes tests of understanding strikes me as somewhat naive, I can see that his huge bank of questions might be useful for teachers introducing their pupils to 'science and the sea' for the first time. They could well find this software of interest.

John Wright

Ocean Challenge Advertising Information

Circulation of the magazine includes over 550 individual subscribers, mainly in the UK but also in Europe and the United States, plus libraries and Industrial Corporate Members of the Challenger Society.

Advertising rates

Full page £250 Half page £130 Third page £85 Sixth page £50

The corresponding rates for industrial corporate members are: £200, £100, £70, £40.

There is a discount of 20% for advance orders for adverts or inserts (see below) for three or more successive issues. Cheques should be made payable to the Challenger Society for Marine Science. Rates are not subject to VAT.

Copy information: Please supply the Editor (address below) with black-and-white camera-ready copy *or* electronic files importable into PageMaker for Apple Mac (TIFF or EPS), at following final sizes:

Full page	180 mm wide × 255 mm deep	Third page	115 mm wide × 125 mm deep
Half page	180 mm wide × 125 mm deep	Sixth page	55 mm wide × 125 m deep

Inserts

Commercial publicity material provided for distribution with an issue £200 per sheet
Rate for Industrial Corporate Members: £160 per sheet
Maximum weight 25 g; for heavier inserts contact the Editor (see below).

Closing dates

The magazine is published three times a year in April, August and December. Advertising copy/disk for Apple Mac should arrive with the Editor by the first day of the preceding month. Inserts should be posted to arrive by 25th day of the preceding month.

Enquiries

For information about advertising and/or subscribing to the magazine, please contact:

Jenny Jones,
Executive Secretary for the Challenger Society for Marine Science
Room 251/20, Ocean Technology Division
Southampton Oceanography Centre
Empress Dock
Southampton SO14 3ZH

Tel. 01703-596097 Fax: 01703-596097 Email: jxj@soc.soton.ac.uk

For information about supply of advertising copy, please contact:

Angela Colling
Editor, *Ocean Challenge*
Department of Earth Sciences
The Open University
Milton Keynes MK7 6AA

Tel. 01908-653647 Fax: 01908-655151 Email: a.m.colling@open.ac.uk

How to obtain back-issues of *Ocean Challenge*

If you would like to obtain back-issues of *Ocean Challenge*, write to Jenny Jones, the Executive Secretary of the Society, at Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, UK.

Issues are priced at a standard rate of £2.50. Please send a cheque payable to the Challenger Society for MarineScience.

Below are brief summaries of the content of those issues currently available.
All issues contain news items, meeting reports and book reviews.

Volume 1, Spring 1990 (the first ever issued – a collector's item!) *Dennis John Crisp, CBE, FRS, 1916–90.* Feature articles: *A Short History of the North Sea Seal Epidemic* by John Harwood; *Modelling the Tides for the 1988 Olympic Games* by Roger Proctor and Judith Wolf; *RRS* James Clark Ross*: A New Vessel for the British Antarctic Survey* by David Drewry; *Community Research Projects – The North Sea Project: A Progress Report* by John Huthnance. (36pp.)
(A few copies only)

Volume 1, Summer 1990 Feature articles: *What Use for Ocean Science? A Personal View* by Steve Thorpe; *International Affairs in Marine Science* by Tony Laughton; *Estuaries: The Sensitive Fringe of the Ocean* by Keith Dyer; *Ocean Modelling in Britain* by Peter D. Killworth (36pp.)
(A few copies only)

Volume 1, Autumn/Winter 1990 Feature articles: *James Clark Ross: The Man Behind the Name Behind the Ship* by Tony Rice; *The Irish Sea: NOT the Most Radioactive Sea in the World* by David Assinder; *Investigating the Deep Sea Floor in the 1990s* by Colin Summerhayes; *Sharing an Atlantic Resource for Oceanography* [about the Bermuda Biological Station] by Matthew L. Doty; *Biological Light in the Sea* by Peter J. Herring; *Oceanographic Fame and Fortune: The Pay of Scientists and Sailors on the* Challenger by Tony Rice. (52pp.)
(A few copies only)

Volume 2, Spring 1991 *Job Security and a career in research: the New Oxymoron* by Tim Jickells and Karen Heywood; *James Rennell: the Father of Oceanography* by Raymond Pollard and Gwyn Griffiths; *Long-term Sea-level Changes: Their Measurement and Prediction* by Philip Woodworth; *Biodiversity in the Oceans* by Martin V. Angel.
(A few copies only)

Volume 2, Summer/Autumn 1991 *Consultation between Marine Scientists and the Inter-Agency Committee for Marine Science and Technology* by Nick Flemming. Feature articles: *The Royal Research Ship* Discovery*: a Marine Platform for the 90s* by Frank P. Verdon; *Monitoring Decadal Variations in the Ocean* by John Harwood; *The Artificial Reef in Poole Bay* by Peter Lockwood, Antony Jensen, Ken Collins and Andrew Turnpeny; *The IAPSO Standard Seawater Service* by Fred Culkin and Paul Ridout; *Bragg Reflection and Sand Bar Formation* by Tim O'Hare. (52pp.)
(A few copies only)

Volume 2, Winter 1991 *The Southampton Centre for Deep Sea Oceanography* by Howard Roe; *Young Scientists for the Future* by Penny Hollow; *Drift Bottles from the Past* by Jim Adams, Eric Henderson and Bill Turrell; *The Ups and Downs of Life in the Ocean: Vertical Migration of Pelagic Animals* by Martin V. Angel. (64pp.)
(A few copies only)

Volume 3, No.1, 1992 *Challenger Society Affairs in 1991/92.* Feature articles: *A New Approach to Assessing the Quality of the North Sea* by Jean-Paul Ducrotoy; *A Sound Idea for Estimating Sediment Thickness?* by Neil Mitchell; *The Impact of Mining on Deep Sea Organisms: The DISCOL Project* by Hjalmar Thiel *et al.* (52pp.)

Volume 3, No, 2/3 1992 *Oceanography at Liverpool.* Feature articles: *The Effects of Fishing Disturbance in the Northern North Sea* by Mike Robertson and Steve Hall; *Whaling: the Present Position* by Ray Gambell; *Tracking Wales by Satellite* by Tony Martin; *The Voyage that Changed the World* by Malcolm Walker; *The Politics of Scientific Moves: the transfer of the British Museum scientific collection from Bloomsbury to South Kensington* by Tony Rice. (64pp.)

Volume 4, Nos. 1/2, 1993 James Rennell Special Issue: a collection of articles on the 'Father of Oceanography', by Raymond Pollard,Gwyn Griffiths, John Gould, Michael Bravo, John Phillips and Margaret Deacon. (64pp.)

Volume 4, No. 3, 1993 (pub. 1994) *Marine Science for All?* (marine science education and training). Feature articles: *Something for (almost) Nothing: the Quest of Data Assimilation* by Rebecca Woodgate; *Letter from* Discovery by Jane Read; *Pulling the Plug: the Ocean Floor Revealed* by Anthony S. Laughton; *Krill: the Ecology of Aggregation* by Julian Priddle, John Watkins and Eugene Murphy. (52pp.)

Volume 5, No.1, 1994 *Coasts and Shelf Seas: no longer marginal?* Feature articles: *Persistent Chemicals: Controlling their Input to Marine Waters* by Jan Pentreath; 'Quid pro Quo' – the start of a series of articles on Oceanography and Defence: *Defence Oceanography – An introduction* by Tony Heathershaw; *The Royal Navy's Interest in Oceanography* by Commander Ian Gallett; *Civil Research Programmes: the Defence Connection* by Colin Summerhayes; *Developments in Oceanographic Computer Forecasting for the Royal Navy* by Tony Heathershaw and Steve Foreman. (56pp.)

Volume 5, No.2, 1994 (pub 1995) *Dr John Crossley Swallow FRS: Physical Oceanographer 1923–1994* by John Gould; *Changing Attitudes to Coastal Defence* by Keith Clayton; *The Great Eel Mystery: Is the Solution in Sight at Last?* by Gordon Williamson; *Now, There's a Funny Thing!* (first of new series) *Eating Research Assistants is Wrong* by Martin Angel; UK Oceanography '94; Hydro '94. Feature articles: *The Deepest Depths* by Rear-Admiral Steve Ritchie; *Stamps of*

Approval for Edward Forbes by Tony Rice: *From Dittmar to Diagenesis: 40 Years of Chemistry at IOS* by Sarah Colley and Roger Wilson. (51pp.)

Volume 5, No.3, 1994 (pub. 1995) *All Change at* Brent Spar by John Wright; *Plus ça change ...* by Tony Rice; *Rarity: a Biological Conundrum* by Martin Angel; *Professor Ray Beverton, CBE, FRS, Fisheries Biologist, 1922–1995*; *Now, There's a Funny Thing! 'Full Many a Gem ...'* by Tony Rice. Feature articles: *The Oceanography of the Eastern Mediterranean Sea* by Michael D. Krom; *Southern Ocean Fisheries: Present Status and Future Prospects* by Paul Rodhouse, Martin White and Inigo Everson; *The Discovery Collections: 70 Years of Sampling the Ocean's Fauna* by Martin V. Angel; *Bioacoustics and Bio-luminescence: Living Clues for the Naval Strategist* by Howard Roe, Gwyn Griffiths and Peter Herring. (48pp.)

Volume 6, No.1, 1995 A special Volume consisting of articles arising out of a symposium on 'A century of Hydrographic Work in the Faroe–Shetland Channel', held in Aberdeen in 1993, and involving the ICES Oceanic Hydrography Working Group and the ICES Data-Management Working Group. Among the topics covered are: the history of research in the region, from Danish and Scottish perspectives; the hydrography of the north-east Atlantic; long time-series; tidal oscillations; salinity anomalies; fish migration; and studies of the shelf-edge. (68pp.)

Volume 6, No.2, 1995 (pub. 1996) Feature articles: *The History of Wave Research at Wormley: a personal view* by Laurence Draper; *Dive 3000: A Milestone of Deep Ocean Research* by *Alvin* pilot, Pat Hickey (40pp.)

Volume 6, No.3, 1995 (pub. 1996) *'Sea Bat' Bonanza at Lochinver* by Gordon Williamson'; *The Maury Project* by Sue Greig; *Waves from Westminster* by Stephen King; *Coastal Management in Wales* by Rhoda C. Ballinger and Madeleine S.C. Havard; *Closure of Geevor Tin Mine – Not the Environmental Disaster Once Predicted* by Ben Williamson *et al.*; *Professor Rob Kidd – An Appreciation* by Simon Wakefield; *Professor Ron Currie CBE* by Jack Matthews and Martin Angel; *The Trouble With Imia* by Michael Tsimplis. Feature articles: *Mud Glorious Mud: Morphology and Development of a Coastal Resource* by Keith Dyer; *New Marshes for Old: Saltmarsh Creation in Essex, England* by Laurie Boorman and John Hazelden. (44pp.)

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

MEMBERSHIP SUBSCRIPTIONS

The subscription for 1997 will cost £25.00 (£12.00 for students in the UK only). If you would like to join the Society or obtain further information, contact The Executive Secretary, Challenger Society for Marine Science, Room 251/20, Ocean Technology Division, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

ADVICE TO AUTHORS

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

For further information, please contact the Editor: Angela Colling, Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, Bucks MK7 6AA, UK. Tel: +44-(0)1908-653647; Fax: +44-(0)1908-655151; Email: A.M.Colling@open.ac.uk

CONTENTS