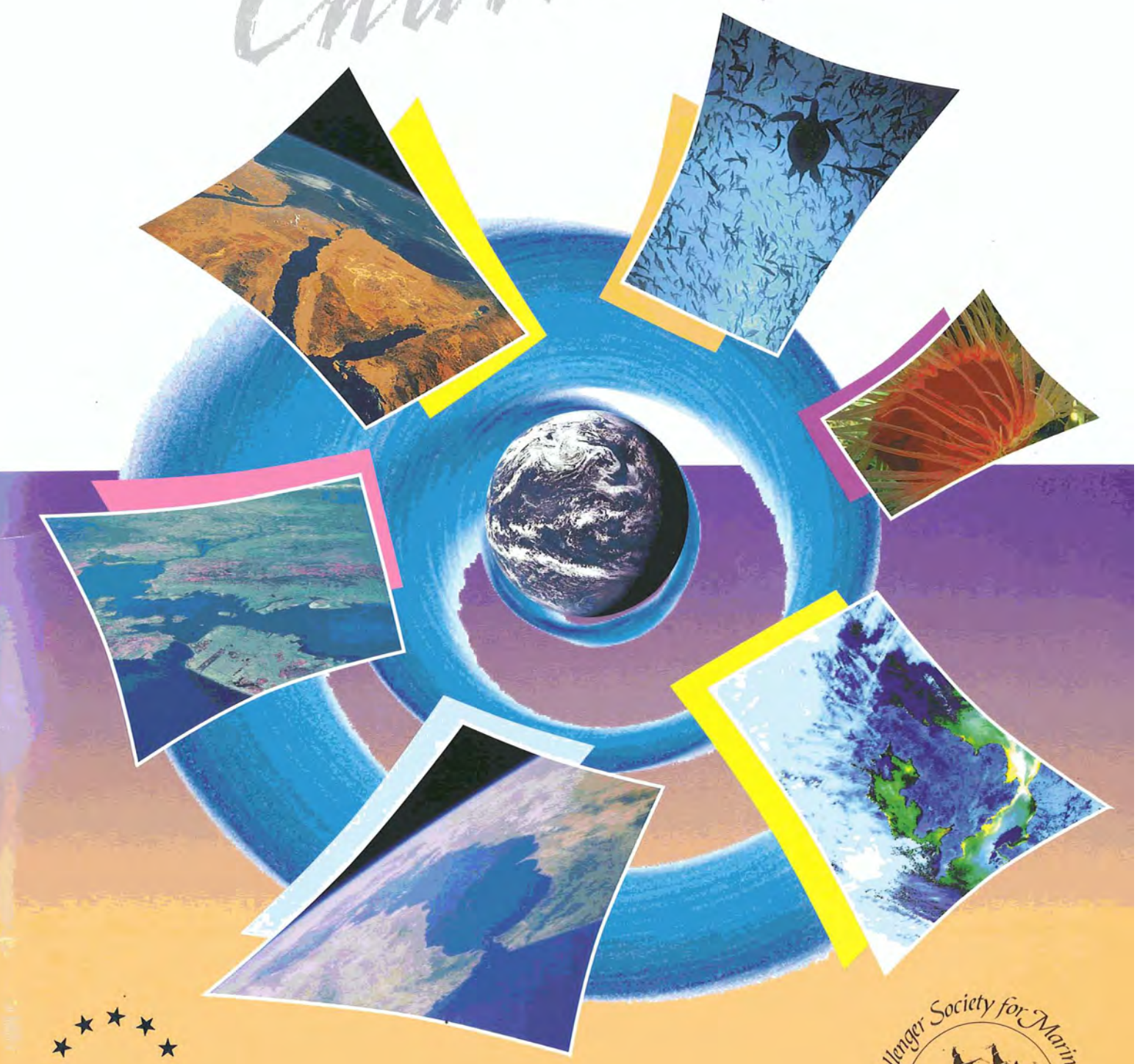
OCEAN Challenge



The Challenger Society for Marine Science

Volume 9, No. 2, 1999 Special European Issue

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Special European Issue

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and 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.**
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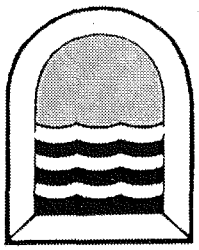
Most of the figures and maps for this issue were drawn by John Taylor of the Cartography Office of the Department of Earth Sciences at the Open University.

The cover was designed by Ann Aldred Associates.

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

EFMS

The European Federation of Marine Science and Technology Societies will be a year old in December. On the next few pages, in alphabetical order of acronym, are brief profiles of the societies making up the EFMS; the four UK societies are given at the end.



Italian Association for Oceanology and Limnology (AIOL)

The Italian Association for Oceanology and Limnology was established on 27 June 1972 in Bologna by a number of researchers in marine and freshwater geology, chemistry, and biology.

AIOL's members include honorary members, full members and junior members. It is currently composed of 400 associates and it is governed by an Executive Board and the Assembly of Members.

The aim of the Association is to promote collaboration among scientists working in the fields of Oceanology and Limnology in the broadest sense, thus contributing to the progress of these sciences.

A national Congress is held every two years, with oral presentations and poster sessions. Its proceedings are submitted to referees and published in one or two volumes.

The topics of the last Congress, which took place in Ancona (28–30 September 1998), included:

- Ecosystem variability on micro-, meso- and macro-scales,
- the Adriatic Sea,
- the Antarctic Seas.

A six-monthly Bulletin is sent to all members, informing them about the activities of the Association.

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Email:
bianchi@estosf.santateresa.enea

The AIOL website is:
http//www.iii.to.cnr.it/aiol

DGM

Deutsche Gesellschaft für Meeresforschung

The DGM is the society of German marine scientists and technologists as well as individuals from other professions working in universities, oceanographic institutes and industry. The DGM was established in 1980 and has 550 members.

- DGM offers an organizational framework for the exchange of information and opinions regarding marine research and research policy.
- DGM supports contacts among its members by member assemblies, conferences and workshops.
- DGM provides information to members through its quarterly *DGM-Mitteilungen*, the *Marine Messenger,* and by the internet home page.

President: Prof. Dr Thomas Höpner,

Contact address: Deutsche Gesellschaft für Meeresforschung
Bundesstrasse 55
D-20146
Hamburg

The DGM website is:
http://www.rrz.uni-hamburg.de/DGM

The Association of Greek Oceanographers (GOA)

The Association of Greek Oceanographers was established in 1986 by a team of post-graduate oceanographers from the University of Athens. Today there are 250 members, all of whom possess an M.Sc or Ph.D degree in oceanographic studies. The Association, which is run by a seven-member executive board, has 72 biological oceanographers, 50 chemical oceanographers, 74 geological oceanographers and 54 physical oceanographers.

Its objectives are:

1. To contribute to the advancement and dissemination of oceanography in Greece.

2. To contribute to the promotion, improvement and dissemination of oceanographic studies at all levels (BSc., MSc., Ph.D).

3. To develop and protect professional activities of oceanographers, to allow them to participate in all fields that concern the marine environment (planning, research, protection, management, education).

4. To cooperate with the State, and with Governmental and Non-Governmental Organizations, in specific subjects and projects and in tasks relating to the study, protection and management of marine environment policy.

5. To help oceanography students to finish their studies successfully and to help unemployed oceanographers find a job suitable to their speciality.

GOA's activities include:

- Organizing scientific seminars, meetings, conferences and conventions related to the science of oceanography.
- Participation in scientific research in cooperation with universities and research centres.
- Participation in scientific conferences.
- Intervening and exerting pressure on the Government in order to solve problems that threaten the marine and coastal environment.
- Social activities such as excursions, dancing nights, and presentations.

An 8-page leaflet, *Messopelagia*, is published by the Association every three months to inform members about matters that may concern them. This leaflet is also distributed to many Governmental and Non-Governmental Organizations of Greece.

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Athens GR-10035
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Instituut voor Zeewetenschappelijk Onderzoek

The Institute for Marine Scientific Research (IZWO) is an independent non-profit-making organization, established in 1970 following a proposal from a group of professors from the various Flemish universities, working in marine sciences. The Institute was created with the support of the Government of the Province of West Flanders (bordering the North Sea), the Francqui Foundation, and the Belgian National Science Foundation.

The association has approximately 140 members, mainly scientists working in oceanography and marine sciences at the various Flemish universities and governmental departments.

The President of IZWO is the Governor of the Province of West Flanders, one of the founders of the association, who presides at the annual General Member Assembly and takes a keen interest in the Institute's activities. The management of the Institute is taken care of by the Board of Directors, presided over by a member of the Permanent Deputation of the Province of West Flanders. The Board consists of representatives of the six Flemish universities, governmental scientific institutions, the Belgian National Science Foundation, regional authorities, and industry. The Scientific Committee consists of delegates of all the scientific research groups and is responsible for all marine science-related matters and policies.

Thanks to the diversity of disciplines practised by IZWO members (biology, ecology, chemistry, physics, geology, etc. and applied marine research such as aquaculture and pollution), the Institute constitutes a multi-disciplinary forum for cooperation, coordination, planning and execution of marine projects, and for interfacing with concerned authorities.

Annually, the results of the scientific investigations of the IZWO members are grouped together in the *IZWO Collected Reprints*. This publication is exchanged worldwide with the publications of marine centres in all continents. As such, the results of Flemish marine research are made available to the international community and acquisitions to the IZWO marine scientific 'Halewyck' library can be sustained. This library is the largest in Belgium and serves the scientists as well as the public at large. Any new proposals for exchange of publications are welcomed. Contact between members is maintained by publication of the *IZWO Newsletter*, published in Dutch.

In the near future, the activities of IZWO will be incorporated into the newly established Flanders Marine Institute (VLIZ – Vlaams Instituut voor de Zee). The new institute will have a key role in international cooperation and act as an interface between the marine research community and governmental public authorities. One of its main tasks will be to set up a Marine Data Centre. Until further notice, all correspondence for VLIZ should be forwarded to IZWO.

Contact address: Institute for Marine Scientific Research, IZWO
Victorialaan 3 – B-8400
Oostende, Belgium

Tel. +32-(0)59-32 10 45
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Email: izwo@unicall.be

Website: http://user.online.be/~izwo

Marine Science and Technology Society of Finland (SMTSR)

The Marine Science and Technology Society of Finland was founded in 1989. Its main objective is to be a forum for people from different areas of marine science and technology to meet each other and exchange experiences. The background for this is that in the 1980s Finland built a lot of marine research vessels and it was considered important to have this kind of forum, where both science and technology issues may be discussed and people can meet in an informal environment.

The Society's main activity is to arrange meetings of its members on various subjects in the field of marine science and technology. Normally there are one to three lectures and free discussion in the meeting. In the last two years subjects have included: sea-ice research during Finnish Antarctic Research expeditions; the *Estonia* disaster; the effect on the Baltic Sea ecosystem of bridge-building in the Danish Straits; diving for marine archaeology in the Baltic Sea. Every year, there are two to four such meetings, plus the annual meeting of the Society.

The Society has 80 members and includes people from marine science, marine technology (including the shipbuilding industry and suppliers of marine equipment), marine archaeology and seafaring. Most of the members are professional marine scientists. About 10% of members are students.

As yet there are no permanent publications or website. However, all kinds of additional information on current topics is delivered to the members along with material relating to the meetings.

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Fax. +358 9 7638
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Union des Océanographes de France (UOF)

The Union of Oceanographers of France is a non-governmental, non-profit-making scientific society. It includes approximately 200 researchers in Marine Science and Technology belonging to the various French organizations for private or public research (INSU/CNRS, IFREMER, universities, IRD (ORSTOM) and INRA).

The objectives of the Society are:

- To bring together all individuals (researchers, students, technicians, sailors etc.) concerned with teaching oceanography, oceanographic research, and ocean management;
- To let its members' views and needs be known.
- To inform its members about research programmes and about the development of specialized organizations.
- To promote the coordination of oceanographic activities in teaching, research, and development, mainly by organizing periodic meetings of working groups or of the entire Society, along with national and international symposia, the Young Oceanographer's Forum, etc.;
- To create the necessary advancement of oceanographic structures.
- Within the limits of its statutes, to ensure its members representation in any legal actions, and organize contacts with national and international organizations concerned with oceanography or related activities

The Society organizes symposia, and publishes the *Journal de Recherche Océanographique*, and a bulletin, *Lettre des océanographes.*

It has created a Directory and a database of French-speaking marine and freshwater scientists. In 1998, it created a Unit of Reflection and Research for the Prospects of Oceanography Students.

The UOF is a member of the Ifremer Instrumentation Committee, and a member of the Environmental Committee of the National Council of French Engineers and Scientists.

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F-75005 Paris, France

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Email:100670.615@compuserve.com

Website:
http://www.oceano.org/uof

UK Societies

Challenger Society for Marine Science

The Challenger Society was founded in 1903 as a society of professional oceanographers, but evolved to become a society whose aim is to provide a link between workers in the various fields of marine science on the one hand, and between oceanographers and the interested lay-person on the other. The Society was formally reconstituted and modernised in 1988. For more about the early history of the Challenger Society, see *Ocean Challenge,* Vol. 7, No. 2, 3–7.

The Objectives of the Society, and the contact details of the Executive Secretary are set out on the inside back-cover of *Ocean Challenge.* It currently has about 560 members (including 160 students), mostly from the UK, but also about 25 from continental Europe (including Scandinavia), and about 20 from the USA and other countries.

Marine Biological Association

The Marine Biological Association was founded by a group of far-sighted scientists and men of affairs who were interested in fisheries and the study of marine life. They got together at the International Fisheries Exhibition in London in 1883, when it was proposed to form a society to build a laboratory on the British coast. The most active member of this group was E. Ray Lankester who became honorary secretary of the Association when it was formally constituted on 31 March 1884, with T. H. Huxley as the first President. It was decided to build a laboratory at Plymouth, where there was a great variety of marine life. The Treasury was persuaded by the famous radical politician, Joseph Chamberlain, to provide a capital sum towards building costs and an annual grant towards running expenses. In return for this government aid, the Association pledged itself to pursue practical research into fisheries. The laboratory was opened in June 1888, and from the start the investigations were multidisciplinary, ranging from fishing to physics. (See *JMBA,* **67**, 463–506 (1987) for a fuller account of the MBA's history.)

There are currently about 1500 members, the majority from the UK, continental Europe, and North America. Membership consists of professional scientists, marine biology students who come to use the library, and lay-people interested in marine biology, such as fishermen and divers. Student membership is available to students registered for first or higher degrees.

The Association was established to promote the investigation and to disseminate knowledge of marine biology (in its widest sense) for the benefit of the public.

The *Journal of the Marine Biological Association* was started in 1887 and has appeared without interruption ever since. It is an international scientific journal with a world-wide circulation and six issues are published yearly. A Newsletter, *MBA News,* is published twice yearly. An Annual Report is published in the spring each year.

MBA educational activities include the award of various bursaries for young scientists to work at the laboratory at the discretion of the Director. An open day is held every year for schools to have hands-on experience of the type of research currently undertaken.

A *Physiology Workshop* is held annually at the laboratory and a scientific meeting is arranged each year, often resulting in the publication of the abstracts and papers submitted.

In collaboration with major holders of marine biological data and information, the Marine Biological Association is developing a project known as 'The Marine Life Information Network (*MarLIN*)'. *MarLIN* will provide an interactive system improving access, display and interpretation in support of marine environmental management, protection and education.

Contact: Professor Steve Hawkins (Director as from 1 October 1999)
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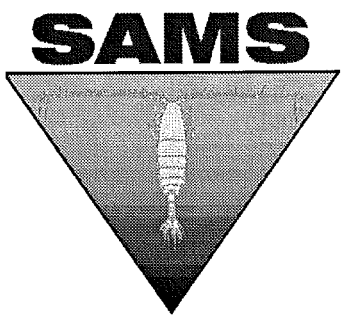
Website: http://www1.npm.ac.uk/mba



Scottish Association for Marine Science

SAMS was founded in 1884 as the Scottish Marine Biological Association, and the name was changed in 1993 to better reflect the wider scientific interests of the Association. The corporate, individual and student membership (525, including 80 students) covers the full spectrum from universities, private and other organizations, to members of the public.

Publications include an Annual Report and a twice-yearly Newsletter.

The Society's aims and objectives are the promotion of marine research and education in Scotland through:

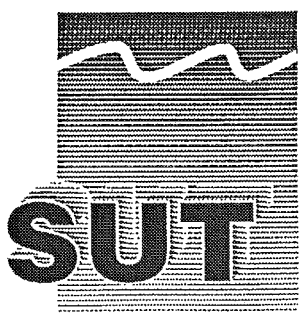
- An in-house research programme at the Dunstaffnage Marine Laboratory near Oban, utilizing grant-in-aid from NERC and other funding sources. Particular focus is on scientific issues relevant to Scottish waters.
- Encouraging external research through the award of Bursaries, Fellowships and Grants.
- Organizing meetings on contemporary marine scientific issues.
- Maintaining and strengthening links and involvement with national and international marine science programmes.
- Bringing the importance of marine science to the attention of a wider public through schools visits, open days, and seminars, and hosting the marine science degree of the University of the Highlands and Islands.
- Providing an independent view on marine scientific issues in Scotland and elsewhere.

Contact: Dr Graham Shimmield (Director),
SAMS
Dunstaffnage Marine Laboratory
PO Box 3, Oban,
Argyll, PA34 4AD.

Tel. +44-(0)1631-562244;
Fax: +44-(0)1631- 565518
Email: mail@dml.ac.uk

Website: http://www.nerc-oban.ac.uk/dml

Note: The website is being updated and will become separate from the nerc-oban address in the autumn. Links will be provided between the two sites.



Society for Underwater Technology

The SUT is an international body actively promoting the development, dissemination and exchange of ideas, information and technology arising from or related to the underwater environment. Founded in 1966, the Society brings together organizations and individuals from over 30 countries with a common interest in underwater technology, ocean science and offshore engineering.

Benefits of membership and SUT activities include:

- A forum for networking and communication between members through a newsletter, a members' directory, branch membership and events.
- Technical publications such as: *Underwater Technology*, the members' quarterly journal comprising technical papers and reports covering the wide range of marine science and technology interests; and more than 35 conference proceedings volumes and collected papers.
- Programme of events including an extensive schedule of conferences, seminars, evening meetings and training courses.
- Substantial discount on all publications, events and advertising for members.
- Specialist interest groups covering: ocean resources, environmental forces and physical oceanography, underwater science, robotics, diving and manned submersibles, subsea engineering and operations, offshore site investigation, Government liaison, and education and training.
- Subsea engineering register of specialists.
- Student sponsorship through Educational Support Fund scholarship grants.
- Careers information in a folder of fact sheets (*Oceans of Opportunity*).
- Comprehensive Services via the internet.
- Reference facilities in the IMarE Marine Information Centre and Library with adjacent SUT Office.

For further information about membership, publications or general enquiries contact:

SUT Head Office, 80 Coleman St, London EC2R 5BJ, UK; Tel. +44-(0)207-382-2601; Fax: +44- (0)207-382-2684.

Concerning events, contact: SUT Aberdeen Office, Innovation Centre, Exploration Drive, Bridge of Don, Aberdeen, AB23 8GX, UK; Tel. +44-(0)1224-823637; Fax: +44-(0)1224-820236

Website: @ www.sut.org.uk

Accreditation for Oceanographers?

Steve Hall

Readers may wish to ponder on the issue of 'accreditation' for oceanographers. The biggest question is whether it is needed at all. However, the private sector in particular does seem very interested, so the marine science community needs to give this issue some thought.

The following text originated as background material for discussion at the Education and Training Committee of the Society for Underwater Technology (SUT). This committee exchanges minutes with the Challenger Society's Education Committee and the two enjoy a close working relationship.

Why is accreditation of oceanographers worth considering?

The purpose of accreditation would be to demonstrate that an individual has the necessary suite of skills, and the academic training, to be relied upon to deliver work to a specified standard. At present, there is a groundswell of opinion among some private sector employers that it would be helpful to have a uniform standard against which candidates for employment could be measured. Private sector employees are also voicing concerns over the need for continued professional development training and associated accreditation.

There are several reasons why employers want to see accreditation, including:

- A BSc. degree may no longer be enough to satisfy the core-skill requirements of employers – further training is almost always needed.
- The proliferation of modularized university degree courses causes confusion for employers, in that it is not clear from the title of the degree exactly what modules a student will have studied.
- There is concern over a marked fall in the general numeracy and, to some extent, literacy, of candidates.
- The expectation that new employees will begin generating revenue very soon after starting employment.
- The lack of training time available from smaller employers.
- The need to show customers that staff deployed on a project are able to deliver high quality results.
- The need for a yardstick for comparing candidates from different nations.
- Today, oceanography is a compact community, but this will change in the 21st century. As a result, word-of-mouth references will not be as valid as they are now.

Accreditation is not yet a major issue, but there is a belief that starting an accreditation scheme now will bear useful fruit in several years' time.

Do oceanographers want *an accreditation scheme?*

At present, probably not. In particular, for the majority of oceanographers who are employed in the university and government sectors there is no evidence that accreditation would make the slightest difference to their employment prospects or career development. The only exceptions could be oceanographers who are undertaking commissioned research for customers who have specified that they want to see accredited oceanographers working on the project – not the case now, but it could happen if accreditation takes off in the private sector.

Are there alternatives?

For many sub-sectors within oceanography, there are already accreditation schemes available. Examples would be Chartered Meteorologist, Chartered Chemist and Chartered Surveyor. For many employers the holding of a Doctorate by the candidate may be enough to satisfy the need for evidence of professional competence.

It can be argued that a comprehensive CV ought to be able to address the concerns of employers, as could the instigation of high quality, well structured in-service training, instead of relying on others (universities, government-funded labs, the armed services), who at present effectively subsidise the training costs of the private sector.

Who would pay?

This would depend on what kind of accreditation scheme we're talking about. If you look at a model such as Chartered Engineer, the candidate could pay the relevant fees but it's more likely that an employer would cover these costs as part of an employment package. So, in some cases the individual oceanographer would pay any relevant fees; in others, the employer would. Doubtless there would be variation across the industry, with those employers who really wanted to see accreditation offering fee-payment as an employee benefit. Whoever pays (and at this stage, the likely level of fees is impossible to estimate), the scheme should be fully transferable between employers, especially since many junior level jobs are short-term contracts.

Are we talking Chartered Status?

Ultimately, that would be the aim. But it's a long and difficult road that can involve setting up a company to administer the scheme. It's only worth doing if a large section of the community supports the idea. In the shorter term, a simpler accreditation scheme such as 'registered oceanographer' would be more appropriate.

'Registered oceanographers' would have satisfied their peers that they are competent to practise in a number of core skill areas. A panel of senior oceanographers would need to convene to consider applications. Existing experienced oceanographers would quickly be able to attain Registered status.

It is unlikely that a single scheme would work for all oceanographers. There are certain core skills, but these are common to almost all scientists. Members of the SUT Education and Training Committee have suggested that initial efforts concentrate on a scheme aimed at physical oceanographers.

Initial administrators of a Registered Oceanographer Scheme could be the SUT and the Challenger Society, or perhaps all of the UK members of the EFMS.

What next?

The SUT has suggested that a workshop should be convened during 2000, perhaps during UUV Showcase 2000 (Southampton), or UK Marine Sciences 2000 (the Challenger Society's biennial conference, to be held at the University of East Anglia). These issues can be discussed and a decision can be made either to go ahead or put plans on hold if there is insufficient demand.

It's up to the oceanographic community to decide.

News and Views

DNA Profiling and a New Taxonomy?

Ever since Carl von Linné (or Linnaeus, as he is remembered) pioneered the systematic classification of living organisms in the late eighteenth century, it has been tacitly assumed that the possession of similar characteristics signifies a shared ancestry. This may be about to change. DNA profiling suggests that convergent and divergent evolution are more widespread than was previously thought. Thus, organisms of widely differing ancestry can evolve to look alike if put into similar environments; while organisms from the same stock can evolve to look very different if they get into contrasting environments. So, for instance, African and North American cactus plants look the same but have different origins, whereas the (to us Europeans) exotic pawpaw is closer to the humble sprout and cauliflower than to the exotic passion fruit, with which it was previously linked.

Is traditional taxonomy therefore in need of drastic revision? If the whole basis of the Linnean system were shown to be unsound, the painstaking elucidation of lineages from fossil evidence must surely become suspect – because it is of necessity based on the possession of shared characteristics that are nearly always identifiable only from skeletal remains, since soft tissue (never mind DNA) is rarely fossilized.

By way of an example, it appers that DNA profiling relates whales and dolphins more closely to pigs and hippos than – as previously supposed – to cows and camels. Could that affect understanding of the family tree of marine cetaceans and the taxonomic relationships among them? This is not a trivial question. A proper understanding of biodiversity must be based upon sound taxonomy (see *Variety is the Spice of Life: Biodiversity in the Ocean* by Angelika Brandt, pp.34–9).

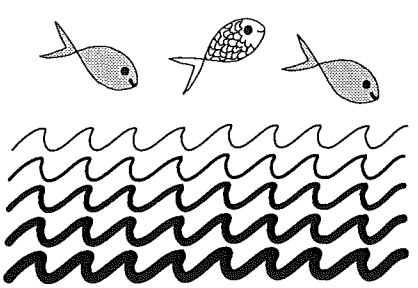
Genetic Engineering and a New (reduced) Biodiversity?

Could disruption to traditional taxonomy (see previous item) also result from the effects of genetic engineering, which holds at least the potential, if not the promise, for development of new variants of plants and animals? The technology is still in its infancy of course, and so far is applied only to land plants of agricultural importance, and to a few farmed fish species (salmon, carp and tilapia; cf. *A Vision of the Future*, p.18). But already there has been well publicized concern about 'artificial species' escaping from their farm enclosures and mingling with wild populations. Might the present progressive decline in natural biodiversity be offset by an increase in anthropogenic biodiversity?

In fact, if anything, the opposite seems more likely. Genetic engineering has not so far been used to create new species, merely variants of existing ones. 'Artificial' mutants that escaped into the wild would very likely modify existing ecological relationships, but might not significantly accelerate speciation. All in all then, biodiversity seems set to go on decreasing, with or without genetic engineering.

MPAs and Fish Stocks

Can Marine Protected Areas (see pp.14–15), by acting as 'no-take' zones, provide a means of replenishing populations that have been depleted by over-exploitation? The answer is yes, but only if they are large enough. The marine reserves and sanctuaries that have so far been set up are too small to provide significant replenishment outside their boundaries (*Science*, 1999, **284**, p.49). It would seem to be wise to supplement no-take zones with breeding of threatened species in aquaria (the marine equivalent of zoos) and then to release them to the wild when numbers have increased enough to make a viable population.



Whales, Fish and Humans

The Makah Indian tribe in north-western USA began their series of attempts to kill a whale by traditional methods in October last (*Ocean Challenge*, Vol. 8, No. 3, p. 11). They eventually succeeded in May this year, in spite of efforts by environmental protestors to stop them, though they had to use guns as well as harpoons, and nearly lost the whale when the carcase started to drift out to sea. The 1982 IWC moratorium on whaling exempted 'whaling by indigenous peoples for subsistence purposes'; but whatever this was, it plainly was not subsistence whaling.

All the same, the incident is insignificant in comparison to the hundreds of whales killed annually by Japanese and Norwegian whalers, who have for years been defying the IWC moratorium (with their governments' approval). Japanese whaling is ostensibly for scientific purposes but some whale meat undoubtedly finds its way to market (*Ocean Challenge*, Vol. 5, No. 2, p.19). The Norwegians now justify whaling on the grounds that whales eat too many fish and must be culled. They plan to kill around 750 minke whales this year, claiming that the minke population has risen to around 20 000 since the 1920s (when the species was almost extinct and hunting was banned). International trade in whale meat and blubber is forbidden by CITES, but since the Japanese pay up to £200 per kilo for certain cuts, it would not be surprising if some Norwegian whale meat ended up in Japan.

Cruel and barbaric though whaling undoubtedly is (the animals take up to 30 minutes to die in agony), whales that eat fish are taking food from the mouths of an expanding human population. Culling seals is cruel too, but seals also eat fish, and seal populations in, for example, Canadian waters, have grown enormously in recent years, further reducing fish stocks already depleted by over-fishing. The culls will continue. But as long as these marine mammal/cetacean competitors remain off the endangered species list, culling will not adversely affect their chances of survival.

The Colder it Gets, the Bigger they Grow

Gigantism is a well-known feature of the deep ocean benthos and is generally held to be a consequence of slow metabolic rates and slow turnover of populations because bottom waters are so cold. Crustaceans in polar seas grow bigger than their tropical cousins, and it has recently been suggested that this is because of higher dissolved oxygen concentrations in the colder water there (O_2 concentrations are even higher in cold fresh water, because gas solubility is also inversely related to salinity). Is there any evidence that the proportion of benthic 'giants' in the deep sea is greater where bottom waters are better oxygenated?

Polar Bears become Whalers

The northward progress of global warming and the consequent thinning of Arctic ice-cover (*Ocean Challenge* Vol. 9, No.1, p.4) has affected the top predators of the north polar regions in a disturbing way. Less ice means a smaller harvest of ice algae for plankton and small fish, which means less food for Arctic cod and hence for seals. Polar bears prey chiefly on the seals, of which there is now a shortage. Recent eyewitness accounts describe polar bears congregating around holes in the pack ice, and attacking beluga whales when they surface to breathe '.... clawing away chunks of flesh and blubber ... Many of the whales were terribly maimed ... some were so badly hurt the bears were able to haul them out of the water and devour them. The open sea was too far away to be reached by the whales without surfacing again and being attacked once more.

Explosion of jellyfish

Fishermen and tourists off France's Côte d'Azur suffered earlier this summer from an invasion of fist-sized jellyfish equipped with stinging tentacles, identified as *Pelagia noctiluca*. They clog up fishing nets, and the welts they leave on human skin take more than a week to heal; their decomposing bodies carpet the shoreline. There is no obvious reason for the appearance of these animals in plague proportions, but the most likely explanation is a favourable combination of oceanographic factors, culminating in an ample supply of plankton. An additional reason could be the declining populations of turtles, their only natural predator. French naval divers were apparently called in to help clear the jellyfish, but it is difficult to see what they could have done. Would it have been more sensible to let the outbreak run its course, and to hope that it will not turn out to be an annual event?

Noah and the Comet

The biblical flood that Noah and his family survived in their Ark may not have been related to a 'Black Sea Waterfall' at all (*Ocean Challenge*, Vol. 8, No. 3, p.6). An alternative and even more spectacular explanation is that a comet hit the Mediterranean around 3000 BC. The resulting tsunami presumably caused the flood, but what about the rain? Could an impact in the sea throw enough debris into the atmosphere to provide enough condensation nuclei to last 'forty days and forty nights'?

Danish Wind Power Goes to Sea

Two rows of five wind turbines are soon to be built three miles off Denmark's North Sea shore. They will be giant structures, over 50 m high, and with 60 m diameter blades. Each will generate up to 3 MW of electricity. That is a total of 300 MW from a single wind farm. The Danes have plans to build a total of 5000 wind turbines, of which 2000 are to be 3 MW giants, the rest smaller machines (1 MW or less). Together they will generate as much power as eight medium-sized conventional power stations, which is getting on for a total of 10 000 MW. Since they cannot *all* be sited offshore, large tracts of countryside as well as territorial sea will be required to accommodate them. Offshore wind farms cost half as much again to build as wind farms on land, but they are 50% more efficient, as winds are steadier offshore. Future offshore installations will be on both the North Sea (west) side and the Kattegat (east) side, where they may present some problems for migrating bird flocks. The aim is to generate half of Denmark's electricity needs by early in the new millenium, and there are even plans to export the electricity to neighbouring countries.

Other EU members could learn from the Danes, who have a head start because they never embraced nuclear power. Wind energy is therefore one of the few alternatives to fossil fuel electricity available to Denmark, which is a world leader in the technology.

Lobster Conservation

A new and very simple way to conserve Cornish lobsters has recently been devised. A small notch is made in the tail of any immature lobsters that are caught, and the animals released, to grow and breed. The notch is eventually lost when the lobsters moult, of course, but since it is now illegal to sell notched lobsters, the scheme can do nothing but good.

Face-lift for Mont St Michel

Plans are afoot to restore this famous French monument to its ancient island status by replacing the causeway and car parks with a mini-rail bridge that will take visitors across on little trains. The reason is that the causeway, built at the end of the nineteenth century, has over the years blocked tidal flows in the Coueston estuary, leading to accumulations of sand and preventing high tides from reaching the base of Mont St Michel, which lies a short distance east of St Malo.

Cornwall's equivalent, St Michael's Mount off Penzance, has a causeway that can only be negotiated at low tide, and visitors' cars are not allowed on the island; during high tides small boats shuttle visitors between island and mainland. There is thus no permanent obstacle to tidal flows, and sediment accumulation is not a problem.

A Catastrophic Drop in the Ocean?

The death of the Aral Sea in Uzbekistan (formerly part of the USSR) was a consequence of years of disastrous Soviet planning policies that were initiated in the 1920s. It has been well documented, with harrowing tales and pictures of abandoned fishing ports and stranded trawlers rusting in a desert landscape a hundred kilometres from the present shoreline. Attempts to reduce the rate of shrinkage of what was once the world's fourth largest lake are underway but progress is both slow and costly (*Science*, 1999, **284**, p.31).

A sudden and unexpected, not to say catastrophic, contribution to refilling the Aral Sea could come from high in the Pamir mountains of Tajikistan, about a thousand kilometres to the south-east. Lake Sarez formed there when debris from an earthquake in 1911 blocked a mountain valley and dammed the river flowing through it. Another earthquake could destroy that dam, and the ensuing flood could reach the Aral Sea. Unfortunately, Lake Sarez contains only 17 km^3, quite enough to cause disastrous flooding, but not enough to improve the situation for the Aral Sea, even assuming that most of the water actually arrived there.

Doñana Aftermath

Little more than a year ago, coastal waters off the Atlantic coast of south-west Spain were threatened by a potentially huge influx of acidic metal-rich waters and toxic sludge. These pollutants were released into the Guadiamar River (a tributary of the Guadalquivir) and parts of the Doñana National Park, as well as onto agricultural land, when a large dam holding back waste water and mine tailings burst. Copper and other heavy metals have been mined in Spain's so-called Pyrite Belt for more than two thousand years, so rivers and coastal waters have always been more or less polluted – but the dangers are now much greater because of greatly increased production in recent decades. Teams of scientists have been monitoring the pollution, particularly in the Mediterranean, which receives the pollution directly from mining activities in south-eastern Spain, but also indirectly via the flow of Atlantic surface waters into the Mediterranean via Gibraltar.

The threat to the Doñana National Park made headlines for two or three months but then faded from the news – attempts to clean up pollution are typically of less interest to the media than the disasters which cause them. The use of heavy-metal-tolerant plants has apparently featured prominently in the remediation programmes, but contamination by acid soil waters and heavy metals (especially arsenic and zinc) appears still to be extensive. However, there have been no recent reports of increased pollution levels offshore.

Eliminating Endocrine Disruptors

Both natural and artificial oestrogenic endocrine-disrupting substances get into the natural environment via waste-water and effluents from sewage treatment works. There now appears to be a simple technique for eliminating these chemicals, thereby mitigating mammalian reproductive dysfunction. It consists simply in irradiation with ultraviolet light (already practised in many sewage treatment plants) and mixing with powdered titanium oxide (TiO_2), which catalyses decomposition of the oestrogens. This must surely be good news.

Reducing Acid (rain) Emissions is Not Enough

In western Europe and North America, anthropogenic emissions of SO_2 – the main cause of acid rain – reached a peak in the 1960s–70s and have progressively declined since, thanks to increasing use of low-sulphur fossil fuels. However, as overall fossil fuel use has continued to grow, so has the contribution of nitrate (resulting from oxidation of atmospheric nitrogen during combustion) to acid rain.

But what of basic ions in the atmosphere? Time-series measurements on both sides of the Atlantic have revealed that the atmosphere is becoming progressively depleted in non-sea-salt Ca^{2+}, Mg^{2+}, Na^+ and K^+, i.e. there are progressively fewer base cations to counter the acid rain deposition, especially inland. Coastal regions are less affected, for they are supplied with sea-salt cations from aerosols in marine air.

There has been no obvious secular decline in either wind strength or rainfall, so the supply of 'marine' cations has not changed. It turns out that removing the particulates in smoke from power stations and factories (e.g. slag dusts from smelters, Ca-rich dust from cement works) in western Europe and North America has been a mixed blessing. It has made the air much clearer, but it has greatly reduced the fall-out and wash-out of the cations needed to neutralize acid deposition. Creeping urbanization is progressively eliminating other potential sources of cations, such as unpaved roads, agricultural tillage, forest fires and wind erosion of dry soils – all of these are in decline.

Thus, in reducing both sulphate and dust emissions, we in the industrial societies have effectively caused our rainfall to become gradually more acid with time – except at sea, of course, where there's enough buffering capacity to soak up a good deal of acid rain. (Though the sea does have its own source of sulphate, via DMS – but that's another story.)

... and don't forget the trace metals

Humans have become the most important agent of global biogeochemical cycling of trace metals. Industrial mobilization of As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Tl, V, and Zn into the biosphere is of the order of tens of thousands to millions of tonnes (depending on the element) each year. It has been estimated that the annual total toxicity of all these mobilized metals together exceeds that of all radioactive and organic wastes combined. Can that be right? Perhaps it can. After all, millions of tonnes of 'new' trace metals are produced by metal mining and industrial processes, and subsequently circulated through soils, water and air and hence inevitably redistributed into food chains throughout the biosphere.

We should not be surprised that this is happening, but surely the news is not necessarily all bad, if only because several of these trace metals are essential to life in small concentrations (e.g. As, Cr, Cu, Mo, Se, V, Zn), though others are indeed toxic (e.g. Hg, Tl). Moreover, iron is among the metals that are mobilized by industry – and on a huge scale. It is not regarded as a trace element by geologists and soil scientists, but occurs only in very low and biologically limiting concentrations in natural waters, including seawater. Wind-blown dust carries iron to ocean surface waters in some regions, where it 'fertilizes' biological production – could some of that iron nowadays be of anthropogenic origin?

The Hydrate Family and Global Climate

There are three members of the hydrate family. Two are naturally occurring, and of these, one is very much more abundant than the other. The third hydrate is artificial, and so far is only known from small-scale experiments.

Gas hydrates, formed of methane and water and known to science for nearly 200 years, are a feature both of continental slope and rise sediments (where bottom water is cold), and of high latitude permafrost regions. They occur in vast quantities, making them a huge potential source of methane, though whether as a fuel or as a potent greenhouse gas will depend upon how human society decides to conduct itself in the coming decades (cf. *A Vision of the Future*, p.19).

The less abundant, and much less well known, hydrate is *ikaite*, discovered barely 60 years ago. It is a calcium carbonate hydrate ($CaCO_3.6H_2O$) that precipitates when bicarbonate ions combine with calcium ions in cold water (less than about 4°C). It can therefore form in seawater (which already contains calcium ions), but only where bicarbonate is being supplied from springs on the seabed, which happens in rather few places. Ika Fjord in south-west Greenland is one such place – hence the hydrate's name – and Mono Lake in California is another. The ikaite forms irregular tufa-like columns that can grow to heights of several metres. When warmed, the hydrate rapidly loses water and turns into ordinary calcium carbonate (usually calcite, sometimes aragonite).

The relative newcomer is *carbon dioxide hydrate*, $CO_2.6H_2O$, as yet unnamed. It forms when carbon dioxide reacts with water at low temperature and high pressure. It does not occur naturally, because CO_2 is not especially abundant, even in the high pressure environment of the cold deep sea. However, experiments to test the feasibility of oceanic disposal of anthropogenic CO_2 (*Science*, 1999, **284**, 943–5) have shown that the hydrate forms quite readily when liquid CO_2 is injected into the deep sea. It does decompose slowly after formation, chiefly because the deep oceans are not (yet) saturated with CO_2, and since oceanic turnover times can be as long as 10^3 years, it would be many centuries before the injected CO_2 could get back to the surface.

The topic of deep-sea CO_2 disposal has come up in previous issues of *Ocean Challenge* (e.g. Vol. 7, No. 2, pp.22–3), but few of us knew about CO_2-hydrate formation at the time. So, have these experiments changed the picture at all? Well, yes and no. They haven't made it seem any easier to collect and compress and condense and pump the CO_2 into the deep sea, a horrendous task when you realize that hundreds of millions of tonnes of the gas must be got rid of to make a dent in the global warming effect – and that doesn't include the additional CO_2 produced in generating all the extra energy needed to drive this enterprise!

On the other hand, at temperatures below 2 °C and depths greater than 2700 m, liquid CO_2 is denser than seawater – and the hydrate is denser still. So the CO_2 should stay down there if injected deep enough. However, in forming the hydrate, liquid CO_2 expands to between four

and seven times its original volume; and the reaction is strongly exothermic, liberating 271 kJ for each kg of water combined with CO_2. The specific heat of seawater is less than 4 kJ kg^{-1}, so the heat of hydrate formation is enough to raise the temperature of 1 kg of ambient seawater by nearly 70 °C. Moreover, almost by definition, hydrate formation is accompanied by salt rejection. Taken together, all this suggests that pumping large quantities of CO_2 onto the deep sea-bed would dramatically change the temperature and salinity regimes of deep and bottom water masses, with interesting consequences for ocean circulation and global climate, not to mention the abyssal biota. At first sight, a picture emerges of large hot low-pH brine pools sloshing about on the deep sea-bed. Would such a picture be confirmed by modelling studies?

Ernest Shackleton to replace *Bransfield*

This summer, RRS *Bransfield* is being retired after 28 years of Antarctic service and is being replaced by the Norwegian ship *Polar Queen*. The ship is to be renamed *Ernest Shackleton*, flagged in the Falkland Islands, and is awaiting a Royal Warrant before sailing to the Antarctic in October.

The *Polar Queen* was built in 1995 by Kvaenner Kleven in Norway and is owned by Rieber Shipping. She is an ice strengthened, special-purpose vessel and has previously been operated in the Antarctic by several other national Antarctic programmes for both logistic and science work. Funding for the ship has been obtained through the Government's Private Finance Initiative (PFI) via a 15-year charter.

The *Ernest Shackleton* will be operated by a Natural Environment Research Council crew for 245 days a year, and under commercial charter with a Rieber Crew for the remaining time. Rieber Shipping have significant experience with polar shipping and supplied the current HMS *Endurance* (formerly *Polar Circle*) to the Royal Navy. The *Bransfield* is being sold to Rieber Shipping as part of the contract.

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The Future of Ocean Drilling

At the end of May, a meeting was held in Vancouver the purpose of which was to agree key scientific problems that need to be addressed by ocean drilling after the Ocean Drilling Program (ODP) comes to an end in 2003. The meeting was attended by over 300 people from countries already participating in ODP, the majority of whom were Americans.

We were told to let our minds roam unfettered by cost or technological limitations so that a shopping list of ideas would emerge to guide the design of a proposal for a 'daughter/son of ODP' for which international funding would be sought. A new international programme will enable areas of the ocean floor to be investigated that are not accessible to the current ODP ship. This vessel, the *JOIDES Resolution*, employs riserless drilling* and so must avoid sites where hydrocarbons and overpressured zones might be encountered, and as it does not use dense drilling mud, borehole conditions cannot be controlled, making wireline logging difficult. The new drilling programme will, it is hoped, be 'multi-platform'. It will still need a riserless ship, especially to obtain long continuous piston core records for palaeoceanographic and palaeoclimatic studies – fields in which the UK has particular strengths.

The big new development is the commitment by the Japanese to build a very large ship with riser capability. They will spend up to $400 million to build the ship, their Parliament having been convinced that drilling the seismogenic zone adjacent to Japan will aid the understanding of earthquake mechanisms and so contribute to methods of earthquake prediction. The ship will be ready in 2006 and will be very expensive to run, so international funding will be needed to enable it to be used to drill around the world.

*Riser drilling enables borehole conditions to be controlled by recirculating drilling mud via a 'riser' that encases the drill string.

During the meeting, the case was also made to drill in shallow waters over continental shelves that are not accessible by a *Resolution*-type ship or the new Japanese vessel. Drilling in such regions would address palaeoceanographic and palaeo-climatic issues and the roles of tectonism, sea-level change and fluid flow in the formation of continental margin sedimentary wedges. It was hoped that stronger partnerships could be forged with industry in this field. A clear need to drill in Arctic regions was demonstrated – the climate card is writ large here. Existing drilling barges could be adapted for drilling in such regions, and to reach other targets beneath shallow seas.

The ideas presented at the meeting ranged from rather routine 'cottage-industry' type proposals, to some exciting new science which could only be done using the multi-platform approach. The case for continuing access to riserless drilling was made persuasively by many hard and soft rock geologists.

An underlying theme in discussions outside the scientific sessions was concern about the design and costs of the new Japanese ship. The international community will not have to meet the capital cost of constructing it, but its high running costs are worrying because they could make future participation in an international multi-platform programme difficult to justify to national funding agencies. At times there was a slight feeling that superpower politics was being played out. The Japanese, having unilaterally committed to build a big new ship, may have ruffled American feathers. This could bring new and larger funding, but will the European countries be able to afford to join the club?

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RV *Valdivia* decommissioned – history repeats itself after 100 years

Hjalmar Thiel

In early July, the German research vessel *Valdivia* retired from science, having supported 181 research cruises. Built as the deep sea trawler *Viking Bank* in 1961, she fished for cod and other commercially important species in the North Atlantic, the Norwegian Sea and the North Sea up until 1970. During this period, fishing techniques developed considerably and by standards of the time the ship became inefficient.

The *Viking Bank*, for historical reasons re-named *Valdivia*, was reconstructed to function as the first German research vessel dedicated to exploration of commercially exploitable deep-sea resources, particularly polymetallic nodules in the Pacific Ocean and metalliferous muds in the Red Sea. Along with the explorative investigations conducted on board *Valdivia*, studies were undertaken into the potential environmental impacts of deep-sea mining.

Valdivia was then replaced by a larger ship, RV *Sonne*, and the German Research Council bought *Valdivia* for the University of Hamburg and she was remodelled in 1981. Since 1982 she has been cruising in European seas, ranging between the ice edge in the north, the Mediterranean in the east and the seas of the north-east Atlantic. Although the remodelling in 1981 removed her capability for deep-sea work, scientists from all disciplines and from many institutions throughout the world used the *Valdivia* during the 1980s and 1990s, until she was decommissioned in July 1999.

100 years ago, on 1 May 1899, another *Valdivia* was decommissioned. This reconditioning marked the end of a charter contract between the shipping company Hamburg-Amerika-Linie and the German government, which over the previous nine months had been funding an expedition for the exploration of the eastern Atlantic Ocean, Antarctic waters and the Indian Ocean – the *Deutsche Tiefsee-Expedition.*

The expedition left Hamburg on 1 August 1898 under the leadership of Carl Chun, Professor of Zoology at the University of Leipzig. The first port of call was Edinburgh, for a meeting with *Challenger* scientists at John Murray's home, Challenger Lodge. *Valdivia* then sailed south in the eastern Atlantic Ocean. From Cape Town the expedition headed south-east to search for Bouvet Island, originally sighted by Lozier Bouvet on 1 January 1739, but still with its existence unconfirmed. On 25 November 1898 the island was rediscovered to the west of the position originally determined.

The southernmost position was reached off Enderby Land at 64°S – it was decided not to press further south because of the ice conditions. The subsequent track crossed the Kerguelen Islands and passed across the Indian Ocean in a large loop, taking in regions not visited by the *Challenger*. The last stations to be visited were in the Arabian Sea off the Horn of Africa. Without undertaking further work *Valdivia* returned to Hamburg via the Red Sea, where the Austrian *Pola* had been sampling down to great depths, and the Mediterranean, already studied by the *Pola* and by the *Hirondelle*, which was owned by Prince Albert I of Monaco.

Many of the results are published in 25 folio Volumes (1902–40), and on scanning through these books, one gets the impression at first glancethat the *Valdivia* Expedition had been an appendix to the *Challenger* expedition. The phrase 'already described in the *Challenger* reports' comes up repeatedly. But the *Valdivia* Expedition aimed to supplement the *Challenger* collections regionally and taxonomically, and succeeded well in both objectives, as indicated by the description of many new species and genera and by other morphological and histological data.

Strange though it may seem to modern oceanographers, the *Valdivia* Expedition appears to have had no central scientific goal. At least, if it it did, it is nowhere strongly expressed. Water masses were described, sediments characterized and sea-floor topography

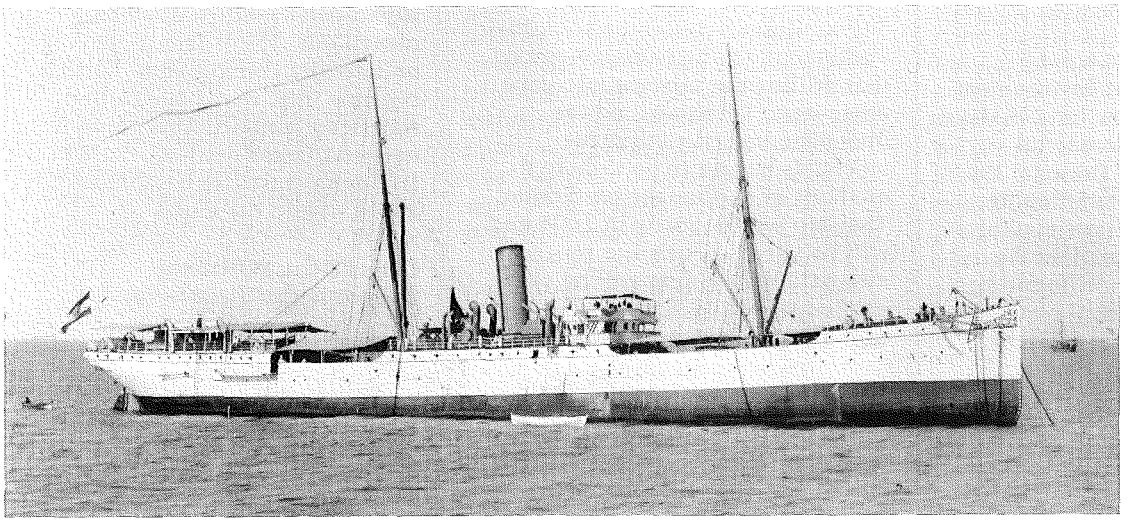

Figure 1 *The merchant ship* Valdivia *was chosen for the Deutsche Tiefsee-Expedition because of its size and its behaviour under severe weather conditions. It was built in 1886 by W. G. Armstrong, Mitchell & Co in Newcastle upon Tyne.*

was sounded. A detailed description is given of searching for, and finding, the Bouvet Island. Yet, most of the papers cover taxonomical, morphological and histological work, all characteristic of the biological sciences a century ago. Only Hans Lohmann related his data on the Appendicularia to the Plankton Expedition of Victor Hensen on RV *National* (1889), which studied the quantitative distribution of plankton predominantly in surface waters.

Even Carl Chun, in a lecture delivered to the influential *Gesellschaft Deutscher Naturforscher und Ärzte* in 1897, and in a popular description of the expedition *Aus den Tiefen des Weltmeeres* (1900 and 1902), presented the specific aims rather weakly. The introduction says: 'Conviction blazed the trail that Germany could no longer with honour evade obligation to participate in the exploration of the deep sea in competition with other cultured nations.' All this is particularly remarkable, since Chun had been studying the bathy- and abyssopelagic fauna of the Mediterranean off Naples and in the area of the Canary Islands, and in opposition to Alexander Agassiz, believed he had discovered a special pelagic deep-water fauna. Agassiz, working in the Atlantic and the Pacific Oceans was not able to prove the existence of such a fauna, but Chun, collecting with an opening / closing net (both functions operated by a propeller winding along a spiral axis while hoisting), assumed that the phenomenon existed ocean wide. Why did he not elaborate on this broad complex of ecological problems when arguing for the *Deutsche Tiefsee-Expedition*?

However, in the context of the distribution of deep-sea fauna the *Valdivia* Expedition was certainly different from the one by the *Challenger*. The importance placed on this problem is expressed by Chun in *Aus den Tiefen des Weltmeeres* when he writes:

'Never did we neglect to study the content of the closing net immediately after its recovery and to record those forms which were found still alive and with fully intact soft tissues, or showing no traces of degradation. Since all (6) zoologists, together with the botanist, participated in these observations and the results were always intensively discussed, because of their high biological interest, it can be assured that the sharpest criticism was applied to the material collected and to the faultless functioning of the net.'

Well prepared by Chun's earlier work, the *Valdivia* proved the world-wide existence of a specific bathy- and abyssopelagic fauna, and Chun's observations of the Canary Islands had already indicated the existence of seasonal vertical migration of planktonic and nektonic species.

On 1 May 1899 the original *Valdivia* was returned to her owner, and in early July 1999 the younger *Valdiva* was transfered to her new owner. She has been sold to a Scottish company and in her third career will further cruise the North Sea. Whereas the old ship is no longer well known, the newest one will be well remembered by scientists from many German institutions, and from other countries, participating in cruises in 'European waters'. Many university students first became aquaintanted with the sea on board *Valdivia,* in both calm and stormy weather.

Further Reading

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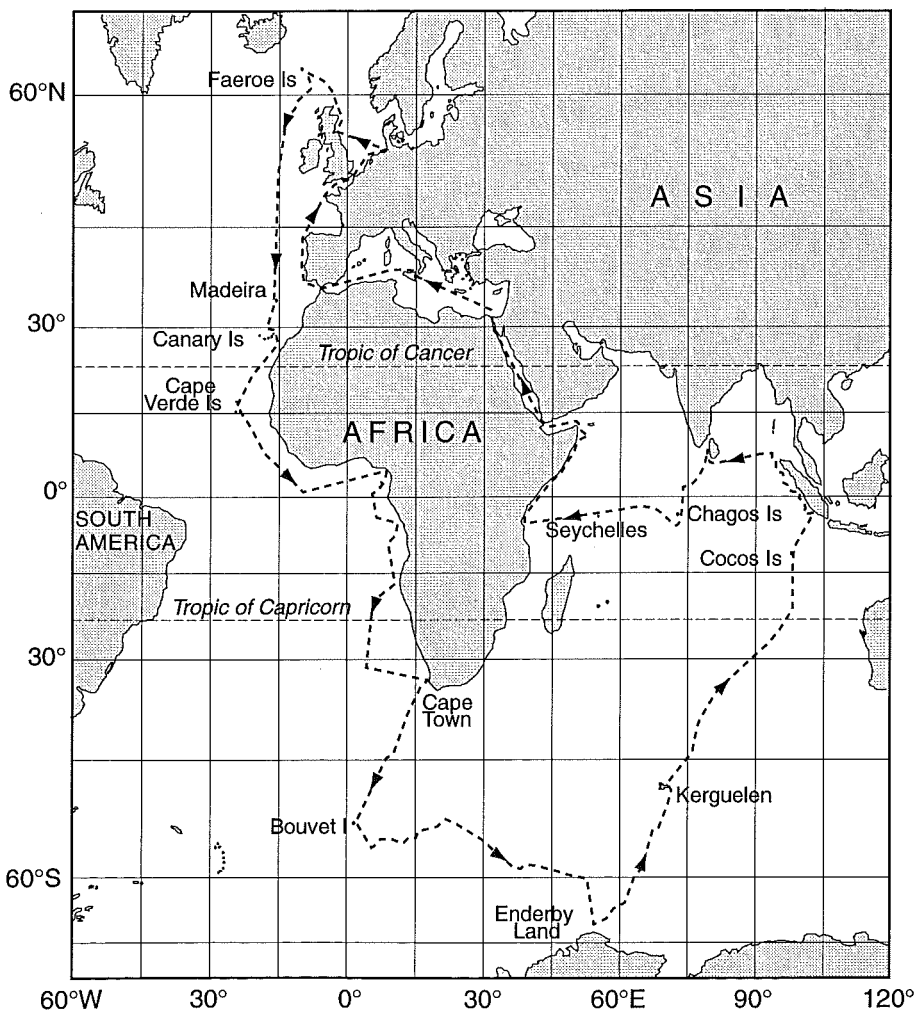


Figure 2 *Map of the* Valdivia *cruise, from 1 August 1889 to 30 April 1899. The cruise track was chosen to supplement the earlier cruises by HMS* Challenger *and other research vessels used for deep-sea trawling.*

Do we need oceanic MPAs?

Hjalmar Thiel and Tony Koslow

In recent decades, a number of countries have established Marine Protected Areas (MPAs) in their coastal and, to a lesser extent, offshore regions. The International Union for the Conservation of Nature (IUCN) has established generally recognized criteria for the selection of an MPA, such as the extent to which the site is in a natural state and its biogeographic, ecological, economic, social and/or scientific importance. To date, MPAs have all been in territorial waters (12 nautical miles from the coast) or Exclusive Economic Zone (within 200 n.m.) of particular states, and thus fall within national jurisdictions. But is it also necessary to establish MPAs in oceanic waters beyond any nation's jurisdiction?

This question was first raised within the IUCN, and a working group, chaired by Maxine McCloskey, was formed. Recently, the problem was discussed in a small group of scientists, chaired by Tony Koslow, with the participation of representatives of the IUCN and the IOC (Intergovernmental Oceanographic Commission) of UNESCO.

Humanity's impact on high seas marine environments is not widely recognized; nor is it given the high priority assigned to problems in the coastal zone. There is, perhaps, a general perception that processes that might threaten the high seas are a concern of the distant future, that there is little of interest in the deep sea, and that, in any case, deep sea ecosystems are vast and populated by species with wide distributions. Therefore, foreseeable disturbances should have little impact. In fact, localized areas beneath the high seas contain rich living and non-living resources and may be particularly vulnerable to human activities, because of the greater fragility of their ecosystems.

The most immediate cause for concern regarding humanity's impact on the deep sea is associated with deep-water fisheries, such as that for orange roughy (*Hoplostethus atlanticus*). Deep-water fishes are far less productive and more vulnerable to overfishing than species living on the continental shelf, because of their slow growth and extreme longevity (the orange roughy, for example, lives to well over 100 years). Some species also congregate on seamounts, where they are highly vulnerable to fishing. Benthos on seamounts, which is trawled up along with the fish, often consists of cold water corals that may be restricted to the seamount habitat and have highly localized distributions. If a seamount is heavily fished, such corals are almost completely removed.

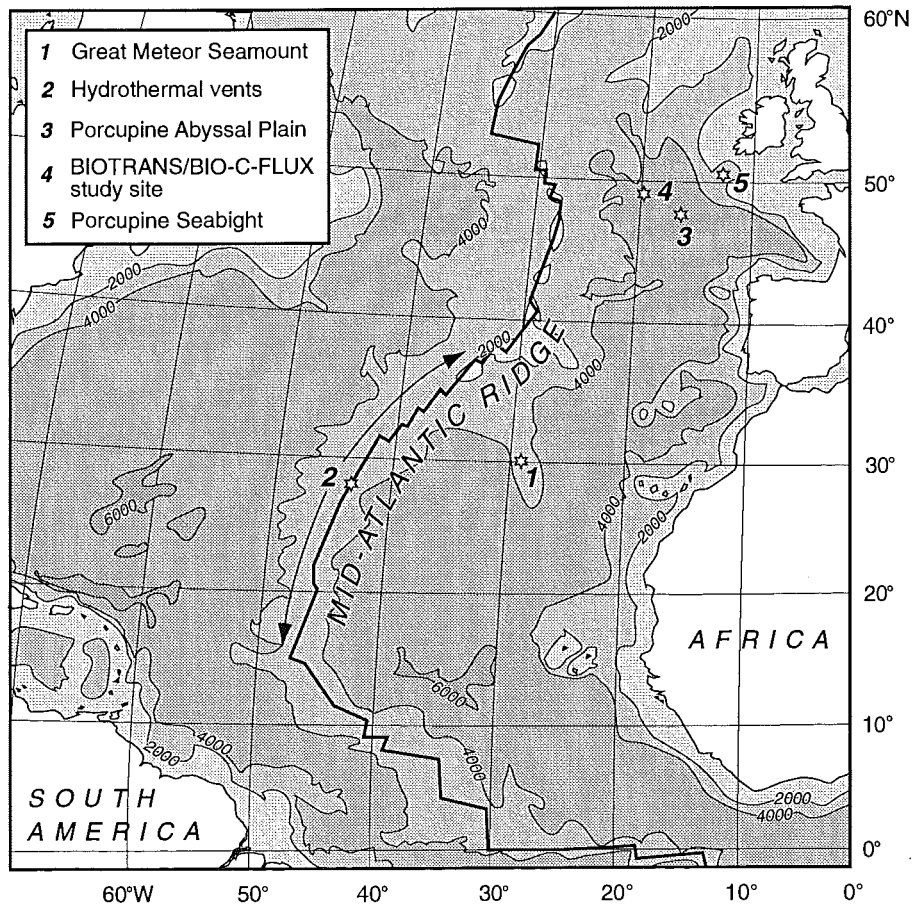
At the recent IUCN/IOC-sponsored meeting, several habitats with their specific faunas were identified for potential protected status:

- seamounts;
- deep water vents and cold seeps; *plus*
- regions of particular scientific interest.

Seamounts, deep water vents and cold seeps support unique faunas. All could be severely threatened by uncontrolled fishing, mining or waste disposal. Consideration needs to be given to establishing a network of MPAs to protect representative deep water communities in these special habitats throughout the world's oceans.

Regulations for the use of the deep sea are only just beginning to come into existence. The International Seabed Authority, established as recently as November 1994, is developing a code for mining polymetallic nodules; guidelines are under discussion to regulate environmental assessment obligations for the mining contractors. These will include the establishment of stable reference zones in the various mining claims to study natural community change in undisturbed areas, as well as the recovery of the fauna after mining ceases. The legal background for these areas will be established in the foreseeable future, but for all other areas no legal framework is available and needs to be devel-

Potential deep-sea MPAs in the North Atlantic



oped. Thus, the problem of instituting MPAs in waters outside national jurisdictions involves complex legal issues, as well as scientific ones.

Within the North Atlantic, for example, several special areas should be considered as potential MPAs:

- Great Meteor Seamount in the central North Atlantic (around 30°N, 28°W), where various ecological investigations have been conducted (see the following article).
- Hydrothermal vent areas on the Mid-Atlantic Ridge between 14°N and 38°N, sites of many recent vent studies.
- The extensively studied areas of:

1. The Porcupine Abyssal Plain station (around 48°N, 16°W), where British and European (MAST-funded) programmes have concentrated much of their activity during recent years, and

2. The BIOTRANS/BIO-C-FLUX study site (around 47°N, 20°W), where ecological long-term investigations have been located since 1984, and which became the central JGOFS station in 1989.

These latter two sites should be joined with the Porcupine Seabight area (a British long-term study site in Irish national waters) to establish (as already proposed), the European Deep-sea Transect (EURODEST), as a basis for long-term studies on ecological variability and climate change. Studies of deep-sea communities require substantial investment of technical, financial and personnel resources; it is vital that such long-term datasets are not rendered useless by uncontrolled use of the sea floor close to such special scientific study sites.

The recent group meeting proposed a multidisciplinary workshop. However, funds need to be raised for the support of participants before progress can be expected.

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Complex trophic interactions around ocean islands

Franz Uiblein and Fernando Bordes

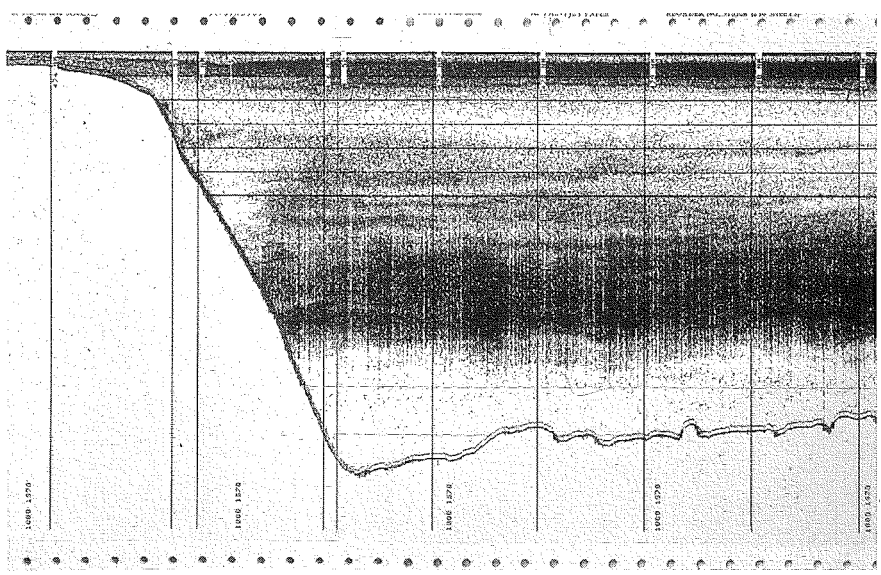
Oceanic islands of volcanic origin – e.g. the Canaries in the eastern central Atlantic – typically have a narrow shelf and a steep slope down to the surrounding sea-floor (cf. Figure 1). One consequence of this particular topography is that coastal areas are space-limited and oceanic conditions can be encountered only a few miles offshore. Such a 'boundary' situation is of particular ecological interest, as there are manifold trophic interactions between various ecological groups of neritic, oceanic, benthic and benthopelagic organisms, all in close proximity to one another.

Recent studies of fish community structure and fisheries-related problems in the eastern central Atlantic suggest intensive trophic interactions between mesopelagic animals and the bottom fauna in such environments. For instance, several so-called 'pseudoceanic' species (e.g. *Diaphus adenomus*, Figure 2(a) overleaf) are known to impinge on steep slopes and feed there on benthopelagic slope-dwelling prey.

In several cruises undertaken around the Canary Islands, financed by the local government (Gobierno de Canarias), mesopelagic fishes have been found to form a major component of dense scattering layers at 400–700 m during both day and night, and also at less than 150 m depth at night (cf. Figure 1). During their nocturnal residence in the epipelagic realm, vertical migrators may be carried towards the shelf by upwelling events or horizontal drift, and then become 'trapped' in shallow waters before they have a chance to migrate downwards. Such trapping effects can be observed above deeper seabeds (300–400 m) and in non-migratory midwater fishes (e.g. *Argyropelecus aculeatus*, Figure 2(b) overleaf) too, as revealed by recent collections on the plateau of the Great Meteor Seamount (see map opposite) during cruise M42/3 with the German RV *Meteor*.

The studies around the Canaries further showed that many larvae and juveniles of slope-dwelling

Figure 1 *Typical night-time echo-sounder record off the shelf of Fuerteventura in the Canaries, showing both shallow and deep scattering layers. The shallow scattering layer continues towards the shelf as a result of spatial interaction between migratory mesopelagic fauna and neritic shelf fauna; the deep scattering layer (at ~400–650 m) impinges on the steep slope. (The maximum depth covered by the transect is about 850 m; the length of the section is about 5 km.)*



oped. Thus, the problem of instituting MPAs in waters outside national jurisdictions involves complex legal issues, as well as scientific ones.

Within the North Atlantic, for example, several special areas should be considered as potential MPAs:

- Great Meteor Seamount in the central North Atlantic (around 30°N, 28°W), where various ecological investigations have been conducted (see the following article).
- Hydrothermal vent areas on the Mid-Atlantic Ridge between 14°N and 38°N, sites of many recent vent studies.
- The extensively studied areas of:

1. The Porcupine Abyssal Plain station (around 48°N, 16°W), where British and European (MAST-funded) programmes have concentrated much of their activity during recent years, and

2. The BIOTRANS/BIO-C-FLUX study site (around 47°N, 20°W), where ecological long-term investigations have been located since 1984, and which became the central JGOFS station in 1989.

These latter two sites should be joined with the Porcupine Seabight area (a British long-term study site in Irish national waters) to establish (as already proposed), the European Deep-sea Transect (EURODEST), as a basis for long-term studies on ecological variability and climate change. Studies of deep-sea communities require substantial investment of technical, financial and personnel resources; it is vital that such long-term datasets are not rendered useless by uncontrolled use of the sea floor close to such special scientific study sites.

The recent group meeting proposed a multidisciplinary workshop. However, funds need to be raised for the support of participants before progress can be expected.

Hjalmar Thiel
Hamburg
Tony Koslow
Hobart and Monterey

Complex trophic interactions around ocean islands

Franz Uiblein and Fernando Bordes

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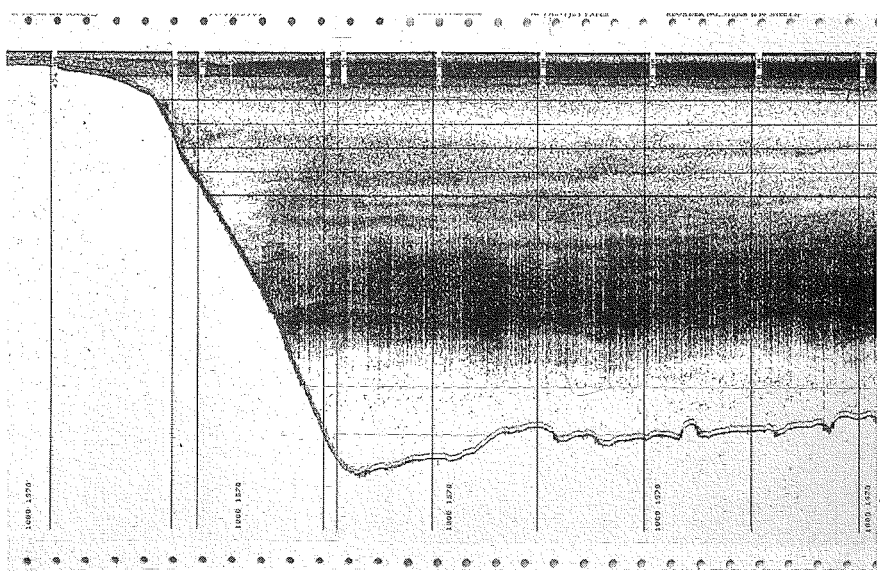
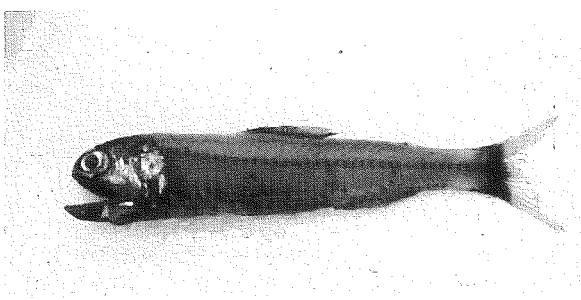
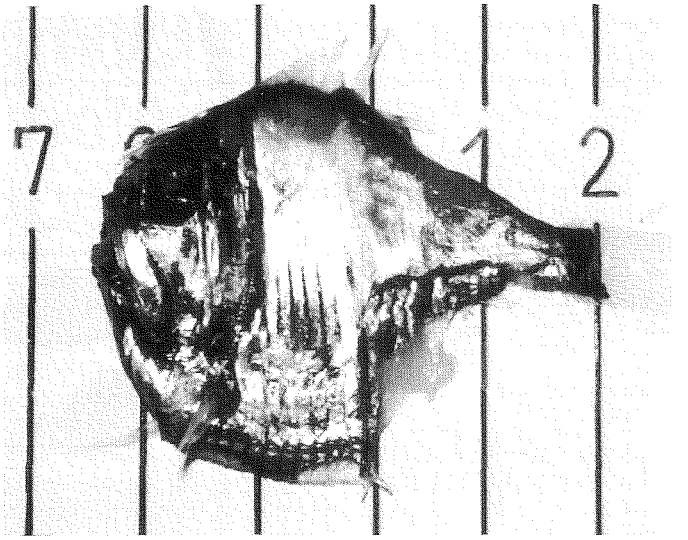




(a)



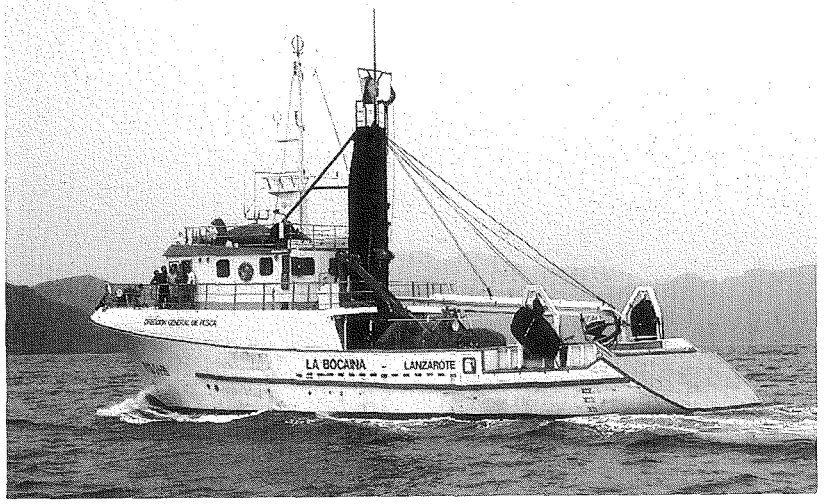
(b)

Figure 2 *(a) A specimen of the myctophid* Diaphus adenomus, *a typical pseudoceanic species, caught with a pelagic trawl at 624 m, close to the slope off eastern Fuerteventura. This specimen is about 11 cm long.*

(b) A specimen of the non-migratory fish Argyropelecus aculeatus *(Sternoptychidae). Several individuals of this species were collected by bottom trawl over the plateau of Great Meteor Seamount at depths of 266–426 m. This specimen is about 3.5 cm long.*

fishes including anguilliform and trichiurid species (the latter including the black and silver scabbard fish, *Aphanopus* sp. and *Lepidopus caudatus*), undergo a pelagic stage during which they may act as prey of mesopelagic fishes, competitors for food, or even their predators. On the other hand, mesopelagic fishes themselves are frequently preyed upon by the adults of benthopelagic slope-associated species. Because mesopelagic fishes also serve as prey of epipelagic fishes such as mackerel, tuna, or swordfish, they represent an important trophic link between slope-dwelling and epipelagic fishes in areas close to ocean rims.

Figure 3 La Bocaina, *the Canary government's research and navigational school vessel, undertaking an acoustic survey off eastern Fuerteventura.*



For a deeper understanding of the food web at ocean rims we need to undertake detailed investigations of the species composition and biomass of the scattering layers. These should allow us to estimate their trophic potential for slope-dwelling or epipelagic predators. At the same time, the habitat and diet selection of pelagic, benthopelagic and benthic predators have to be studied to determine the extent to which midwater resources are utilized. The methods currently applied in the Canaries include: acoustics (cf. Figure 3) combined with pelagic and epibenthic trawling to study epi- and mesopelagic fishes; bottom and vertical longlines to investigate large demersal fishes; examination of stomach contents; hydrographic measurements; and satellite imagery. It is intended that these studies be carried out over a longer time period at regular intervals, to allow monitoring of possible climatic influences and development of predictive food-web models.

Further Reading

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Research Vessels – the People Factor is Important Too

I disembarked from the *RV Celtic Voyager* (it was then flying a green, white and orange tricolour) in Galway on Sunday 30/5/99 and returned to Dublin to find *Ocean Challenge*, Vol. 9, No. 1 awaiting me. I was surprised to find that, according to Dr Hill's article, *Celtic Voyager* was now a vessel of the British research fleet.

Apart from this oversight, I must agree with Dr Hill's major thesis. In Ireland we learned long ago that the work a vessel can carry out depends on much more than its size. The recently retired RV *Lough Beltra*, 21.1 m LOA, carried out a great variety of operations during the twenty odd years of its career. It was not always comfortable, and there were tasks which its size made difficult, in a few cases impossible. However, it operated from the Porcupine Bight to the Isle of Man and from Malin to the Scilly Isles and was commended by the EU as the most efficient and cost-effective vessel in Europe. Based on experience with the *Lough Beltra*, the *Celtic Voyager* was designed by Marine Technology Ltd and the Marine Institute to overcome many of the shortcomings experienced with the former vessel. In the opinion of many users, it has been a great success.*

An item not mentioned by Dr Hill in his consideration is the matter of the crew. While personnel have changed over the years, the long service of the crew of the *Beltra/Voyager* as a body and their interest in the work of the vessels, has enabled an extremely high level of operational efficiency to be reached and maintained. The crew are all multifunctional. Their seafaring backgrounds are mixed: fishing, merchant shipping, and other services such as Irish Lights.

Being a single-class ship, with one mess room, has assisted in developing a strong relationship between the crew and regular users, which helps greatly in the acclimatisation of students and newcomers. It is noticeable that when a cruise is aborted due to bad weather or other mishap, the disappointment of the crew is equal to that of the scientists. All scientific workers are signed on the ship's log as supernumerary crew members, a simple matter which has a considerable psychological effect on first-timers.

It is possible that British seafaring and social traditions would be an impediment in this area.

However it must be emphasized that the successful management and manning of a small vessel is a very different matter from the somewhat remote personnel management techniques often necessary where a multi-vessel fleet of large ships is involved. A much higher level of personal involvement and tolerance of inconvenience and discomfort is necessary on a small vessel.

Back in the 1960s I served on board the RV *Prince Madog* when Prof. Taylor Smith and Dr Bill Bailey carried out their pioneering work in the Porcupine area. It was noticeable that even within the confines of the structured British system the rapport between crew and scientists was much greater than on larger vessels.

The above may appear to be a minor point to members of a high level committee charged with the allocation of funds for ship-building, but at an operational level it is of fundamental importance.

Raymond Keary
Senior Marine Geologist
Geological Survey of Ireland

* For more about *Celtic Yoyager*, see *Ocean Challenge*, Vol. 7, No. 3, p.14.

OI 2000 and OI 2001

Oceanology International 2000 (OI 2000) is already well on track. Companies have booked their space even earlier than usual for the show that will take place in Brighton during 7–10 March 2000. According to Spearhead*, the company that organizes OI events, many new companies will be exhibiting (including many from Europe), and existing exhibitors have increased the size of their stands. In addition, companies that previously chose to share a stand have now decided to sign up on their own.

As always, the main focus of the show is technology. *OI 2000 will* continue the tradition of being a forum for the exchange of information between the industrial and scientific communities. Emphasis will be on demonstration and discussion of the latest products, developments and ideas in the marine science and ocean technology industries.

OI 2000 is sponsored by the Society for Underwater Technology and supported by the Intergovernmental Oceanographic Commission, European Marine and Polar Science Board, World Meteorological Organization, and the Hydrographic Society.

Professor Jacqueline McGlade, Director of the Natural Environment Research Council's Centre for Coastal and Marine Sciences, is chairing the Conference Committee.

OI exhibitions are being launched in the USA, with Oceanology International Americas 2001 planned for 3–5 April, in Miami, Florida. Spearhead say that more than 40% of companies see the US as the geographic destination for their products and services, and almost 30% of those companies were targetting the USA for sales growth.

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A Vision of the Future

European marine science and technology in the 21st century

Laurent d'Ozouville and Pierre Papon

For millennia, exploration and exploitation of the sea were important ventures for Europe, and contributed to some European states becoming great powers. However, after the major European oceanographic expeditions at the end of the 19th century and the beginning of the 20th, the impetus for oceanographic research gradually disappeared from Europe and leadership in the field crossed the Atlantic to the United States. Up until the early 1980s, cooperation in marine research in Europe tended to take place via trans-Atlantic links.

A new approach to European cooperation in marine science was created with the establishment of the first Marine Science and Technology (MAST) programme of the European Commission (EC) in 1984, as a result of which a dynamic European community of marine scientists has emerged. In the early 1990s, the former ESF/EC European Committee for Ocean and Polar Sciences (ECOPS) identified major grand challenges in marine and polar sciences and proposed the formation of a European 'forum' for marine and polar science. The marine and polar research organizations also recognized a need for improving collaboration between one another, and this resulted in the creation of the European Boards for Marine and Polar Science (EMaPS) in October 1995. In the case of marine science, the structure is now known as the ESF (European Science Foundation) Marine Board.

The main scientific challenges

Today, the oceans play an important role in global geopolitics, and many important scientific, economic and social issues have a maritime dimension. It is expected that marine science and technology will bring new knowledge of the ocean as well as new tools to obtain greater wealth from its exploitation in a sustainable manner. In this perspective, the authors intend to present some main challenges for the future.

This article covers material presented at the Wilton Park Conference, 'Sustainable Oceans in the Twenty-First Century', 30 March–1 April 1998.

Origin of life, evolution and exploitation of living resources

The discovery in the deep Pacific Ocean in 1982 of hydrothermal systems with thermophilic life forms (which can withstand temperatures of more than 100 °C) has provided us with insight into a primitive form of life, the 'archaebacteria', and has led to scientific conjecture about the role of these bacteria in the origin of life. Sequencing the genome of one of these microbes in 1996 was a fundamental breakthrough for molecular biology and brought new questions to the fore. Bacteria have also been recovered from sediment cores obtained by drilling at depths of more than 800 m below the sea floor at temperatures greater than 100 °C. If we want to understand the evolution of Life on Earth from primitive unicellular organisms to more complex multicellular organisms, we must understand life in the ocean and its role in biodiversity.

Marine fisheries have enormous importance for the economy of European regions, but fish stocks for many species have been depleted. In 1997, the FAO estimated that 60% of fish stocks are fully or over exploited, and since 1990, fish catches have levelled off or declined. The scientific knowledge required to forecast the evolution of resources is, in many cases, insufficient, and it is thus essential to maintain research activities in this area.

Models on which scientists are working have to be more sophisticated – they have to take into account the interactions between fish species, and the impact of fishing, and they need to integrate physical parameters (temperature, salinity, hydrodynamic factors, availability of solar energy at the sea-surface, etc.). Parameters such as species vulnerability and fish recruitment (numbers of young fish which are incorporated annually into the exploited fraction of the fish population) remain the basis for scientific studies of fisheries through population dynamics. However, some of these models might be considered as describing a 'chaotic' situation in the physical sense: total biomass might be considered as stable in well-defined conditions, but the biomass of a specific fish species (cod, for example) might vary unpredictably and would thus not have an equilibrium value. Identification of relevant biological and physical parameters is necessary to improve the models predicting evolution of fish stocks (e.g. climatic factors might play a role).

Mariculture is important in countries such as Norway, UK and France, but faces problems, such as the need for healthy coastal species to be resistant to disease. Genetic engineering can be applied to fish farming, and research on gene transfer between species (fish, molluscs) might produce varieties with more rapid growth potential or resistance to viral infection or severe temperature fluctuations. However, application of genetic engineering to aquaculture raises important ethical and legal questions for which it will be necessary to have appropriate answers.

More generally, the biodiversity of marine species is an asset which has to be protected. Following the 1992 Rio Conference, efforts to understand the implications of biodiversity have been supported by the international programme Diversitas. Marine biodiversity is a broad topic, and research in this area can only progress through a large multidisciplinary effort in which modern techniques such as genetic engineering play an important role.

Marine organisms are also sources of biologically active compounds, and utilization of molecules of marine origin is an important field, although not a new one – already some 6500 natural products of marine origin have been isolated. Several deep sea species have developed chemical arsenals involving molecules which signal their presence, attract prey, or can be used to defend themselves. Some of these substances are of pharmacological interest as analgesics and antibiotics, as well as anti-inflammatory and anti-tumoral agents. Cephalosporin, one of the antibiotics developed in recent years, was extracted from a marine fungus; and AZT, a drug active against AIDS, is extracted from herrings. Similarly, the thermophilic bacteria that live around hydrothermal vents synthesise enzymes and polysaccharides which can be used as chemicals active at

high temperature. Research in this field requires a strategy based on identifying species, screening active molecules and synthesising some of them or, alternatively, cloning potentially interesting bacteria to produce industrial quantities of useful compounds.

Global ocean modelling and forecasting

The ocean works as a vast heat engine which, with the atmosphere, redistributes over the surface of the planet the energy which is absorbed from the Sun. Currents play an important role in this redistribution, but the coupling between ocean and atmosphere is also important, as it affects the climate and its variability. Thus, the interaction between the atmosphere and the tropical ocean is the source of a pressure oscillation between the western and eastern Pacific which drives the El Niño phenomenon. The study of such interactions, as well as of the ocean circulation, is at the very heart of ocean modelling and thus of climate forecasting. The ocean as a global system has been the subject of international programmes such as the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmosphere (TOGA) experiment. We should also note that the thermal and water exchanges between the sea floor and the oceans are still poorly understood and need to be quantified.

We also need to establish the role of the ocean in absorbing and storing carbon dioxide, thereby moderating global warming. One of the objectives of the Global Ocean Observing System (GOOS), and in particular of EuroGOOS, is to monitor the oceans globally in order to improve our ability to detect and to predict, with accurate and efficient models, the effect of climate change (see later). Modelling and forecasting the ocean is a real scientific challenge which has to be carried out on an international scale, particularly through European cooperation. It requires the development of new measurement and monitoring techniques (sensors, automatic buoys, etc.) and the construction of important research infrastructures (satellites and computing networks, for example).

Exploring the deep sea floor

The exploration of the ocean floor has led to important discoveries, and the modern theory of plate tectonics has been verified through undersea exploration. However, oceanographers and geologists need to develop better models of the structure of the oceanic crust to improve understanding of subduction and accretion phenomena, of the origin of oceanic earthquakes, and of the mechanisms which drive hydrothermal sources with their emission of mineral compounds.

Furthermore, there is considerable interest in the study of continental margins, both in terms of exploitation of resources (living and mineral) and natural hazards (instability of slopes). For example, large slide-induced flood waves could devastate stretches of coastal plains, while potential failures of unstable sediments along the north-west European continental slope could be a direct threat to the exploitation of Europe's offshore energy resources.

We need to pay special attention to the gas clathrates (gas hydrates) which are crystalline compounds in which water forms a cage-like structure around smaller 'guest' gas molecules (generally hydrocarbons). They form below and above freezing point, at elevated pressure, and occur 300–450 m beneath the sea floor at water depths of 500–2200 m in the slope–rise region. There are three main reasons for interest, but also for concern, regarding oceanic gas hydrates. Firstly, as a resource, they could represent twice the total estimated reserves of oil, gas and coal in the world, but their exploitation, with the present state of knowledge, would be very difficult. Secondly, the accumulation of free gas at the lower boundary of the hydrate stability zone in marine sediments, usually a few hundred metres below the sea-floor, considerably decreases the shear strength of the sediment, and might be a potential cause of slope instabilities. Lastly, the sudden destabilisation of thousands of km^3 of hydrate-bearing sediments would release enormous quantities of methane into the ocean and atmosphere and might contribute to climate change and global warming. A better knowledge of gas hydrates is necessary to understand their formation and distribution, and their possible impact on the environment.

Ocean drilling is a key technology for achieving these objectives, for it can help to resolve fundamental questions about the evolution of Earth and its climate, as well as providing useful information about the sea floor, the continental margins, oil and gas reserves, and so on. Ocean drilling has been pursued through ODP, the Ocean Drilling Program, a large international project in which European countries participate along with the USA, Japan, Australia and Canada.

Integrated Coastal Management

Coastal regions, from catchment basin to shelf edge, form a highly complex and dynamic environment governed by both natural processes and transformations due to human activities. Research into integrated coastal zone management requires a joint approach between natural scientists and socio-economists. For example, proliferation of algal blooms (some toxic) are a nuisance to fish farming and tourism, and their causes need to be clearly identified.

Water quality models, used to predict consequences of pollution from estuaries, coastal discharges or waste dumping at sea, require knowledge of processes involving physical dispersion and chemical reactions in the water, along with biological phenomena in the water column and in the sediments. Substantial efforts are still necessary to improve understanding of phenomena in the coastal environment, to collect data, and to test and improve forecasting models.

Development of marine technologies

We can identify three major technological issues which call for greater European cooperation, to be supported in some cases by specific European programmes.

1. **Ship-building** is facing severe difficulties in Europe, although it has retained a high level of technical competence.

Technological research is necessary:

- to improve tools to design and produce ships using, in particular, new materials and information technologies (e.g. expert systems);
- to develop techniques for new ships (high speed ships, vessels for environmentally friendly short-distance shipping) and to enhance ship safety;
- to increase automation of ships.

2. **Maritime transportation** has been increasing steadily during recent decades and, in parallel, so has traffic in harbours. This trend calls for the development of specific technologies:

- to improve multimodal transport (sea–road–rail);

- to develop high-speed sea connections between European harbours for passengers and freight;
- to supply new techniques for traffic control and management and provide new services for shipping (ocean forecasting, for example);
- to modernise harbour logistics (including automation of freight operations).

3. Undersea exploration and exploitation of hydrocarbon and mineral resources require the development of appropriate technologies. The possibility of exploiting deep-sea offshore oil and gas fields (at depths of more than a 1000 m) represents a real technological challenge which has to be met. It is thus necessary to develop:

- remotely operated vehicles to work undersea for scientific and industrial purposes and, more generally, undersea robotics for industrial operations;
- automatic undersea vehicles to perform bathymetric surveys and make scientific measurements;
- new acoustic and seismic techniques to transmit information and explore the ocean bed and sea-floor sediments;
- new drilling techniques and particularly deep penetration tools.

Deep-sea offshore hydrocarbon fields will certainly require the building and operation of specific floating production, storage and offloading systems (ships or platforms) with networks of lines and pipelines; these new types of facilities require important technological developments to be achieved in the coming years. In parallel, it will be necessary to introduce new techniques for harbour dredging.

Besides these three major issues there are other areas that call for technical progress and breakthroughs. Marine instrumentation is certainly one of them: we need to develop new sensors for scientific research and ocean monitoring (biosensors, automatic buoys, systems for detection of chemicals or toxins, etc.). Wave energy and desalination of seawater are other areas that need to be pursued.

Increasing interdependence between marine science and technology

Ocean science opens new opportunities for technological developments and maritime services, and scientific research relies increasingly on high technology for better measurements and observations of new phenomena. Moreover, the development of marine technology relies more and more on new technology – computing and information technology, for example.

Marine research is, in many cases, *interdisciplinary*: the scientific approach to problems involves bringing together complementary disciplines and techniques. Furthermore, it is important to recognize the relevance of social sciences (economics, sociology, history, etc.) for many problems related to ocean management. Coastal management and policies for sustainable fisheries are typical of areas which deserve such an interdisciplinary approach.

GOOS – the Global Ocean Observing System, mentioned above – embodies the concept of *operational oceanography*, which represents a real change for ocean science and technology. Operational oceanography involves the continuous application of numerical models supported by networks supplying data for the prediction of marine parameters, by routinely collecting, disseminating and interpreting measurements of the ocean and atmosphere (as already occurs in the case of meteorology and weather-forecasting).

GOOS was proposed by the Intergovernmental Oceanographic Commission, and its development was recommended in 1992 by Agenda 21 adopted at the Rio Conference. It will provide new operational marine services based on forecasting in the following areas: climate monitoring and forecasting; coastal zone management; living resources; health of the ocean (i.e. monitoring of pollution); ocean services for shipping and offshore operations. GOOS requires world-wide organization but on a regional basis, hence EuroGOOS, which was established in 1994 by 25 marine and meteorological agencies of Europe. The EuroGOOS consortium provides the mechanism for European cooperation in operational oceanography (see *Ocean Challenge*, Vol. 8, No. 2, p.22).

Finally there is the broad area concerned with information collection and data management. Means of communication are steadily increasing, offering completely new opportunities for the transfer of information. Reliable and up-to-date information and data are increasingly in demand by different groups – scientists, the public and decision-makers – and there is still a major challenge to provide the end-users with information and data in the most appropriate form.

European potential in marine science and technology

Europe's many assets in marine science and technology are a heritage of its rich maritime history. An active and diverse network of scientific institutions has developed throughout the century (academic laboratories, mission-oriented national institutes, marine stations) with a well trained workforce; European countries have built important facilities (50 oceanographic vessels longer than 50 m, two scientific submarines, ocean observation satellites); European industry has been very successful in developing new technologies for offshore resource exploitation and the building of new ships. The European Space Agency (ESA) has played a critical role in building and launching two ocean observation satellites *ERS-1* and *ERS-2*, which are very important tools for ocean forecasting.

As far as the funding of Research and Development (R&D) of marine sectors is concerned, although there is no recent overall survey available, one can roughly estimate that EU countries are investing, at most, 2 billion Euro per year in these sectors (excluding investments by ESA for ocean satellites). This funding includes state-funded expenses for marine science and technology (civil and military sectors), EC-funded programmes (100–120 million Euro per year on average from programmes such as MAST, FAIR, etc.) and company-funded R&D. The R&D expenditure of private companies is difficult to estimate; it is low in sectors such as shipyards and fisheries, but relatively high in offshore technologies in countries such as France, Italy, Norway and the UK. Globally, privately-funded R&D represents at most 20% of the total expenditure in marine science and technology. At the national level, apart from countries where maritime activities play a major role (e.g. Iceland and Norway), funds devoted to marine science and technology probably represent on average 1.5–2% of the total national expenditure on R&D (all sectors being taken together), which could be considered as insufficient given the importance of the ocean for Europe, and of the challenges which have to be met.

Based on analysis of scientific publication indicators, the marine science publications of the EU represented 28% of the world publications of this domain in 1995. In comparison with 1990, there was an increase of 20%, which may be interpreted as a beneficial result of the EU marine research programmes initiated in 1988.

Meanwhile, we must recognize that Europe's marine science and technology suffer from a number of weaknesses:

- the potential, although large, is dispersed;
- there is no real coordination for the building and operation of oceanographic fleets and of large facilities such as hydrodynamic flumes;
- Europe lacks large programmes in marine science and technology which would mobilise its scientific and technical competence and give it, in some areas, a leading role in international cooperation. Europe needs to strengthen the coherence of its strategy in marine science and technology, as it has just entered into the process of defining long-term common objectives and priorities: deep-sea drilling might be a good case in point.

The future of European marine science and technology

European marine research should pursue three main goals:

- to increase our knowledge of the marine world;
- to illuminate the economic, social and political importance of the ocean, and bring scientific and technical expertise to policy-makers in ocean-related activities;
- to enhance technological competitiveness of European maritime industry. Marine research is an indispensable tool for a European maritime policy, and it should provide a vision of the challenges to be met and of the potential provided by marine science and technology for the sustainable exploitation of ocean wealth.

Furthermore, we must not forget that in marine technology Europe faces severe international competition from the United States and Asian countries. European countries urgently need to adopt common strategies so as to be able to face up to such competition. European cooperation in marine science and technology is certainly a most effective means to this end.

Europe must find ways to meet these challenges of world competition by:

- the mobilisation of scientific and technological competence;
- the constitution of research networks associating academic laboratories, national institutes and private companies;
- the building and operation of a large common research infrastructure (oceanographic vessels with high technology equipment, ocean observation satellites, supercomputers etc.).

To achieve these objectives, it is timely to promote a true European policy of the sea, and to investigate the best means to implement it so as to catalyse and synergize the efforts of the various national agencies and European institutions with responsibility for maritime activities.

Laurent d'Ozouville is Scientific Secretary to the Marine Board of the European Science Foundation (ESF).

Pierre Papon is a Professor at the Ecole Supériere de Physique et de Chimie Industrielles and President of the Observatoire des Sciences et des Techniques.

Making Ecological Excellence Available to All

The series 'Excellence in Ecology' consists of 10 books (and three in preparation), published by the international Ecology Institute. Authors of these books are the recipients of the Ecology Institute Prize, awarded once a year to an outstanding ecologist. The laureates are required to serve science and society by writing a book of their choice. They are thereby offered the chance 'to present their personal experiences, insights and visions, to critizise freely and to courageously formulate new scientific concepts ... to show new ways into the future'. The director of the international Ecology Institute, and editor of these books, is Professor Dr Otto Kinne, formerly Director of the Biologische Anstalt Helgoland, Germany. On the basis of nominations, each year's jury selects the recipient, rotating between marine, freshwater and terrestrial ecologists.

So far, four of the books (1, 4, 7, 10) have been written by marine ecologists, with a fifth on the way from the 1998 winner, Richard Barber. All present fascinating viewpoints, a breadth of knowledge, historical perspectives, summaries of various topics, and personal, highly stimulating or provocative views, all in the field of general ecology, as well as human impacts on the Earth, including social aspects. Certainly, authors have their areas of personal interest and expertise, where they have gained the experience from which they draw their examples.

It is difficult to give a general view on ten books written by ten top ecologists. But I can highly recommend this series, both to ecologists who can scan the contents of the older and newly published volumes for their own pleasure, and to non-ecologists because the books' multidisciplinary perspectives will help them to realize what ecology is all about. The books are magnificent for teaching courses and seminars, and students should get acquainted with them. They are different from textbooks and will stimulate individual thought. Certain chapters will lead into good seminar discussions in the fields of science, administration, sociology and politics.

The books written by prize winners in the field of Marine Ecology are as follows (all have the ISSN 0932-2205):

Book 1: *Ecology – potentials and limitations* by Tom Fenchel (Copenhagen, Denmark) (1987) 186 pp. DM 67 or 34.26 Euro.

Book 4: *Marine rocky shores and community ecology: an experimentalist's perspective* by Robert T. Paine (Seattle, USA) (1994) 152 pp. DM 59 or 30.17 Euro.

Book 7: *Towards a science of recruitment in fish populations* David H. Cushing (Lowestoft, United Kingdom) (1996) 175pp. DM 58 or 29.66 Euro.

Book 10: *Our biosphere*, 1997. Roman Margalef (Barcelona, Spain): 176pp. DM 48 or 24.54 Euro.

Book 13: *The Response of Oceanic Ecosystems to the Climate of the 21st Century* by Richard T. Barber (1998 prize winner – in preparation)

Hjalmar Thiel

Marine Research and the Policy-Makers – The Need to be Understood

Scientists are being increasingly urged, even forced, to get involved with governments and with the wider public. The words 'relevance' and 'applied research' are more and more widely heard. There is a growing trend towards asking scientists (including marine scientists) the question: who will benefit, and in what ways, from the thousands/millions of dollars that are granted for their researches? Equally (perhaps more) important is the question of whether knowledge on complex scientific issues is properly taken into account by those who make policies and implement them; and if not, what should be done to improve matters?

Traditionally, rather few people – small select groups of scientists and administrators – have been engaged in policy-making and implementation. But there is now a growing need to involve the wider community, including those with commercial and industrial interests, as well as the public at large. Moreover, until quite recently, communication tended to be one-way, with decision-makers 'taking scientific advice' and dealing with different issues more or less in isolation. But with the growing realization that 'everything relates to everything else', the decision-making process nowadays involves many more individuals, representing a great variety of interests. Those who possess scientific information and understatnding must communicate to a much wider audience than heretofore. Such changes in policy-making procedures have begun to evolve fairly recently, and are still the exception rather than the rule in Europe.

In an effort to promote greater understanding and cooperation between marine scientists and the rest of the community, a conference was held in Lisbon in May 1998, to coincide with the opening of Expo. The proceedings were published in a small booklet (see end for details), and we present here some edited extracts from the convenors' overview of the conference.

The Nature of the Information

Most crucially perhaps, scientific results need to be processed into a form that can be used as a common language between parties concerned with resource issues. This involves amalgamation and synthesis of data and simplification in the interests of intelligibility. However, that can lead to loss in quality of the information and hence to misinterpretation, and there is the additional danger that information may be used out of context, which can lead to costly and ineffective actions. An example is the construction of urban waste-water treatment plants to reduce phosphorus emissions to Swedish coastal waters, based on the assumption that eutrophication processes would be the same as those occurring in fresh waters.

Two things in particular need to be made clear to parties involved in policy-making: the complexity of marine ecosystems and their relationships with human activities on the one hand; and the uncertainties attached to scientific knowledge on the other. Indeed, scientific evidence may not always be pleasant to hear, and decision-makers often hesitate to discuss some issues, let alone to take action, unless returns can be perceived to be immediate rather than long-term – long-term being more than a few years.

The Problems of Problem-Solving

Scientists are frequently called upon to help solve problems, which commonly have the character of an emergency (e.g. the recent mine-tailings dam breach which threatened Spain's Doñana National Park). If the necessary scientific knowledge is not readily available and usable, research must be conducted, and publication of the results in an appropriate (i.e. accessible) form must accompany and inform the decision-making process. Consultation mechanisms must also be in place to ensure that the scientific knowledge is fully exploited, and scientific monitoring of progress is essential, both to permit adjustments where necessary and to refine peoples' understanding of the problem.

Marine scientists are not bound to be simply reactive, however, responding only to a succession of urgent problems requiring instant solutions. Prevention is obviously better than cure, and it is well to be prepared for issues that are not yet politically 'hot', but might become so in the future. An example is environmental impact assessments of possible large-scale future exploitation of the deep oceans (e.g. for mining, waste disposal, or even greater fishing effort). There is a need for the scientific community to produce 'anticipatory' documents, articles and papers, presenting the current state of knowledge on marine issues, with conclusions and likely outcomes of possible future policies.

Improving Knowledge and Communication

More effort needs to be put into disseminating information, through documents, conferences, articles, policy briefs, and so on, and the information needs to be tailored to the requirements of different audiences. In addition, the education system should put more emphaisis on the 'systems approach', so that future partners in policy-making dialogues may be aware of the complex nature of environmental and societal systems – as well as of the uncertainties and limitations of scientific knowledge. Now more than ever before, scientists in different disciplines need to be able to understand each other and to work together.

Although both fundamental and applied research are necessary, it is becoming increasingly important for research to be targetted, in order to minimize controversies and to clarify the criteria for implementing specific policies. Multidisciplinary projects are often indispensable for providing the kinds of information that decision-making requires. However, there are barriers to

setting up and executing multi-disciplinary projects (e.g. inconsistency and incompatibility of data, models and approaches), and these difficulties need to be addressed by the scientific community.

Improved communication and dissemination of scientific knowledge is essential if disasters are to be avoided. For example, mine-tailings dams in southern Spain continued to be filled with toxic wastes even when the risk of rupture had been identified; and a policy to reduce by half the eutrophying emissions into the Baltic was implemented on a time-scale known *at the outset* not to be feasible.

On the other hand, for political reasons the necessary information may not always be available. Thus, it was not until the fall of the Iron Curtain and the changing relationships between the Baltic states that it was possible to make use of data on Eastern European sources of eutrophication.

And finally ...

The conference brought out the need for improved dialogue between marine scientists and policy makers. The case studies came mostly from northern Europe and thus complemented those presented at a similar meeting concerned with the Mediterranean, which was held in Rome in 1997. It is anticipated that there will be another conference with the same theme, to be held at Hanover next year.

Eds

Details of the publication are as follows:

Marine Research and Policy Interface: Links, Interdisciplinary Co-operation, Availability of Results, Case Studies (Report from a session of the Third European Marine Science and Technology Conference) edited by Michael Cornaert and Elisabeth Lipiatou (1999).

(Research in Enclosed Seas Series: ISBN 92-828-5902- 9.)

Published by EC Directorate-General (Science, Research & Development); DGXII/D.3)

Major themes of IYO

Martin Angel

The International Year of the Ocean was an initiative launched by the UN with the purpose of increasing public awareness of marine and maritime issues. Several of those issues, highlighted during IYO, are of great importance to all maritime nations, especially (but not exclusively) those nations that belong to the EU – and that includes countries with representatives in EFMS!

The choice of 1998 as the International Year of the Ocean was timely. In addition to presaging the Millennium, it also fell shortly after the *United Nations Convention on the Law of the Sea* came into force (November 1994). UNCLOS has been described as one of the most significant pieces of international legislation ever devised. Responses to UNCLOS are developing slowly and IYO has helped these to emerge.

IYO also came at a time when scientific evidence was inceasingly showing the influence of human activities on the open ocean as well as coastal seas. The role of the oceans in ameliorating climate change and buffering the effects of emissions of greenhouse gases to the atmosphere has become a progressively more important area of research.

The principal conflicts of ocean use are related to maintaining clean seas as a contribution to the quality of life, while still exploiting marine resources as a contribution to wealth generation and economic well-being.

Seven Threats to Seven Seas

Throughout 1998, Britain's Deputy Prime Minister (and Secretary of State for the Environment), John Prescott, spoke of the 'Seven Threats to the Seven Seas'. Here are some of the key questions associated with those Seven Threats:

1. Shipping

As world trade continues to increase, the vast bulk of goods and materials traded internationally will be transported by sea.

- How can we best develop and modernize existing ports, while still maintaining other coastal amenities and environments?
- How can cargo-handling, ship movements and port operations be made safer, cleaner and more efficient?
- How should coastal and short-distance shipping be developed as a contribution to an integrated transport policy, and what is the right balance between movement of containers and roll-on, roll-off (ro-ro) ferries?
- Will increased control of ports improve safety, minimize environmental impacts, and improve co-ordination between port stakeholders and local and regional planners?

2. Fishing

The fishing industry is fast approaching a state of crisis. Many stocks are over-exploited, yet new technologies make the capture of fish more efficient. Local and often isolated communities, dependent on fishing, are under severe threat. Management of most fish stocks under the EU's Common Fisheries Policy is clearly failing to be sustainable.

- How can fishing mortality of the currently over-exploited fish stocks be reduced without causing severe and unfair socio-economic distress to fishing communities?
- How can fisheries science predict stocks more accurately in a changing environment?
- How can fishing regulations best be implemented, and should local fishermen be empowered to regulate the exploitation of their own local stocks?
- Can newly exploited deep-sea stocks sustain fishing pressures, and if so, how can these fragile fisheries be regulated?
- Can a more precautionary approach be adopted in fisheries management without causing unacceptable hardship in the short term?
- Can the concept of 'no-take' zones prove an effective solution to fishery management problems, and if so, how large should the zones be and how will they be enforced?
- What are the limits to mariculture in European waters? Can additional species be farmed?
- Are existing regulatory mechanisms adequate to prevent undesirable environmental impacts emanating from fish farms, such as escape of exotic genetic strains, the stimulation of toxic algal blooms, and the excessive use of chemicals?

3. Pollution

Run-off and discharges from land-based activities are the major sources of pollution in coastal waters. With increasing distance from the shore, fluxes from the atmosphere become progressively more significant.

- Is enough being done to minimize anthropogenic inputs?
- Do existing investment plans for sewage treatment go far enough, and are they cost-effective?
- How can run-off containing nutrients, agricultural chemicals (including hormone disruptors) and bacteria from agricultural land be controlled?
- How much should be done to restore coastal seas and habitats?
- How can the fluxes to the seas of pollutants via the atmosphere be reduced?
- Is there a stage at which diminishing returns place economic limits on further attempts to reduce emissions?

4. Dumping Waste at Sea

Currently the international trend is to ban all waste disposal into the oceans. The methods used for ocean dumping in the past are now unacceptable, but improvements in technology could lead to such dumping having minimal impact on ocean ecosystems.

- Taking a holistic view of global problems, could ocean disposal ultimately become an option that is preferable to disposal on land?
- Is the policy of banning all dumping at sea sustainable in the longer term?
- Should old dump sites (for munitions, radioactive waste, and industrial wastes) be cleaned up?

5. Sea-bed minerals

In European waters the only sea-bed minerals currently being exploited are marine aggregates and hydrocarbons.

- Is the exploitation of marine aggregates preferable to use of land sources?
- Are environmental impact assessments of offshore developments adequate?
- Does it make environmental sense to remove completely all offshore installations and drill-cutting piles when the installations are decommissioned?
- Is enough known about how to predict, control and clean up oil leaks and spillages from tanker and operational accidents?

6. Coastal Zone Management

In many places there are major conflicts of interest about how coastlines are managed. This is an area in which greater efforts at consensus-building are likely to result in the best dividends.

- Local consultation and decision-making processes often prove ineffective. How can they be improved?
- How can national and European directives be better reconciled with local and regional requirements?
- How can the best balance be achieved between commercial needs (ports, outfalls, coastal defence) and environmental needs (conservation, recreation and the human environment)?
- Developments exploiting renewable energy (wind, tides and waves) will produce more demands on coastal resources and facilities. How can these be integrated into planning procedures?
- How are coastal defence and/or coastal retreat to be managed, and can policies be evaluated solely on economic grounds?
- How can the aesthetic, spiritual and cultural values of coastal environments be evaluated?
- At present, heritage and archaeological sites receive relatively poor safeguards. How is this to be remedied?

7. Climate change

The problems of accounting for natural variability in natural processes are now accentuated by the effects of anthropogenically induced climate change. There is considerable uncertainty about how best to respond to the impending changes.

- What role can the EU play in developing a better understanding of the likely responses of the oceans to climate change?
- Should greater efforts be made to stimulate increased exploitation of renewable marine energy sources (wind, tides and waves), as a major contribution towards reducing emissions of greenhouse gases?

What is to be done?

The Seven Threats listed above correspond well with the concerns identified by the Independent World Commission on the Oceans, in *The Ocean: Your Future*, published in 1998 by Cambridge University Press. Several countries are making significant contributions internationally, for example to scientific research into the role of the oceans in climate change, and in seeking the means of ameliorating the potential effects of emissions of greenhouse gases. Some are also active in developing the concepts of marine reserves and no-take zones. Others are State Parties to the *United Nations Convention on the Law of the Sea*, and participate actively in the work of the Commission on Sustainable Development, which is monitoring the progress made on the *United Nations Convention on Environment and Development* and the Conventions on Climate Change and Biodiversity.

About thirty international organizations have marine interests, ranging from the International Maritime Organization (IMO) to the International Whaling Commission (IWC), the Washington Convention on Land-based Discharges, and the Oslo and Paris Commission for the Prevention of Pollution in the Maritime Area of the North East Atlantic (OSPAR). The work of these international organizations continues. For example, Quality Status Reports are being finalized for the five subregions of OSPAR, and are due to be published at the beginning of 2000.

Television programmes, films and well-illustrated articles often stimulate public interest in the marine environment. Even so, the democratic process of ocean debate and decision-making is poorly served because no politician is elected to represent an offshore constituency (islands apart). Developing public awareness of ocean issues, and improving the ways in which awareness of the seas is introduced into school curricula, are matters of continuing concern.

Here are some general questions about how to resolve the challenges resulting from the Seven Threats:

1. What new marine technologies are needed to deal with the threats?
2. What scientific programmes are most urgently needed to underpin the decision-making required?
3. How can improvements in scientific understanding and technical capability be rapidly and effectively applied to solving marine problems?
4. How can the general public be better informed, so that people's participation in the debates on relevant issues can be more effective and more democratic, and so lead to greater compliance with the necessary controls and regulations?
5. How can marine topics and issues best be introduced into schools?
6. Is present EU legislation so inflexible as to inhibit adoption of the best solutions?

Although the general theme of the International Year of the Ocean emphasized the holistic nature of ocean issues, there is a great diversity of local interests and priorities. There can be no universal (or even national) strategies* for meeting Mr Prescott's Seven Threats.

A report of the UK's contribution to IYO will be presented in the next issue of *Ocean Challenge.*

*See also the review of *The Ocean Our Future* (pp.50–51), in which our reviewer argues that conflicts of interest will make it difficult to devise, let alone implement, such strategies. Ed.

Dealing with the Cousteau Factor

Impressions of the IACMST National Open Forum on Education and Training in Marine Science and Technology

This all-day meeting held on 10 June 1999 at the Royal Society featured presentations by providers and employers of graduates and post-graduates in the fields of marine science and technology (MST). The meeting was well attended, by some 60–70 people, though academia probably out-numbered industry by about 2 to 1. We consider the main themes of the meeting here, because we think the issues raised are likely to be of interest and relevance to colleagues in the rest of Europe.

The UK has about 6000 MST undergraduate students and 1000 post-grads, distributed among about 20 higher education institutes (HEIs) that teach marine science, and 12 teaching marine technology.

Both presentations and discussions inevitably revealed broad consensus on some key issues, less agreement on others. It was almost taken as read that everyone expects graduates (and post-docs) to have IT/computer skills, to be numerate and to be able to write and communicate clearly. There was a welcome emphasis on the acquisition of understanding and transferable skills – a great improvement on the bad old days of rote-learning and regurgitation. Who knows, the 'open-book' exam may become the norm rather than the exception.

There was uncertainty about the extent to which modularization of the syllabus is a Good Thing. In the present financial climate, where students are increasingly self-funded (whether by loans or parental benevolence), they must increasingly be seen as customers, which can be interpreted as meaning that they must be provided with the courses they want, rather than what the HEIs think they should have. Hence the notion that by providing more course modules you increase the opportunities to 'pick-'n-mix' and thereby attract more students.

This is surely relevant to the concepts of Continuing Personal Development (CPD) and Lifelong Learning. We are now well and truly in the Information Revolution and the need to keep up-to-date grows continually. Institutions that offer arrays of short course modules on a wide variety of subjects can benefit from the resulting demand – especially where that demand extends to in-service training for employees in companies and organizations too small to mount their own programmes.

On the other hand, modularization presents horrendous staffing and time-tabling problems. It also conflicts with the other principal requirement of nearly all MST employers, namely a proficiency in maths and/or physics. There's no getting away from the fact that about 80% of students opt for so-called 'soft' natural sciences, especially biology, whereas 80% of the *demand* is for graduates with qualifications in 'hard' physical sciences. Modularization may thus bring 'bums on seats', but when the bums have graduated they won't get jobs in the marine field. That problem might be overcome by a policy of excluded combinations for undergraduates, while allowing in-service trainees to 'pick-'n-mix' as required. Underlying it all is the over-arching and long-standing problem that there are woeful shortages of good maths and physics teachers in Britain's schools – and the problem isn't going away.

One way to counteract the misconception that marine science is about whales, dophins and coral reefs (the Cousteau Factor) is to arrange school visits to MST departments of HEIs. This can be highly effective, but the influence can be ephemeral, plus which it is necessarily confined to relatively small catchment areas. Another way is to introduce attractive-sounding courses (e.g. Meteorology and Oceanography at UEA, Electronics and Music at Glasgow). Such strategies attract students, but do not eliminate the need for maths and/or physics – and their relevance to MST may not always be obvious! The media route, especially marine-related TV programmes, is a much less promising way of attracting recruits to marine sciences than many people might believe. It is one thing to devise a stunning TV series, even to write an outline that will wow your colleagues..It is quite another thing to sell it to a network. Few commissioning editors have backgrounds in science or technology, and they all have to consider the viewer ratings. Two brilliant recent series were 'Earth Story' and 'The Planets' – good science, well told, and they were in prime time slots. Another prime time series was 'Supernatural', which – in my opinion – was complete garbage: shoddy science, slickly told, dressed up with flashy electronic gee-whiz gimmickry that fooled people into believing it was brilliant. Try the TV route by all means, but be prepared for weeks of wasted effort. And if you want to tell prospective students that the study of maths-related subjects brings rewards, don't rely on TV to do it!

However, once prospective students have been made aware of the value that can eventually accrue from studying physics and/or maths, they could well become sufficiently motivated to put in the necessary work. Motivation is also increased by student-placement schemes, which expose students to how businesses work; and by sponsorship schemes, which provide both financial support and incentives, especially if the sponsorship is likely to lead to employment. This is evidently a useful strategy for dealing with the fact that the 'T' component of MST has much greater problems of recruitment than the 'S' component. There is nothing mysterious about that, it arises out of our peculiarly British tendency to associate words like 'technology' and 'engineer' with big smelly and/or dangerous machines, oily rags, greasy overalls, and low intellectual attainment. The rest of Europe has no such hang-ups, the title 'engineer' carries as much status there as does the title 'doctor'. The UK situation might be improved if it were possible to work towards Chartered Engineer status in the marine technology field (discussions in the Challenger Society suggest that criteria for the analogous title of Chartered Oceanographer would be more difficult to define). There is also a perceived need for more awareness among all kinds of MST graduates of the basic legal and economic and administrative framework within which all businesses (and government departments) must operate. At what stage in the educational process should these topics be inculcated?

Another aspect of the 'T' component of MST is the continuing acute

shortage of the qualified technical personnel who are needed to operate and maintain the ships and equipment used by marine scientists and engineers. The National Vocational Qualification (NVQ) route seems to be the best way to acquire the necessary qualifications, but it won't alleviate the shortage of suitable people, unless ways are found to persuade school leavers that there is a career in sea-faring. In at least some UK institutions, academics feel themselves superior to technicians, which is not a sensible attitude – especially when things go wrong with the often complex equipment upon which the academics depend for their career advancement.

All of which brings us back, albeit obliquely, to students as paying customers, and the old cliché that 'the customer is always right'. In fact, (unlike some academics that I know) students don't expect to be right all the time (especially at exam time!), but they quite legitimately expect Quality Assurance, namely that they will get good teaching, fair treatment and sound advice, not least about what courses to follow. In this context, how much does it matter that the undergraduate science curriculum should consist of one (at most two) so-called traditional or 'core' disciplines, or of multidisciplinary science? How you answer that question depends upon your own educational background, and up to a point it doesn't matter a lot. What does matter though – and here I write from bitter experience – is the danger of increasing specialization that attends a growing obsession with the Research Assessment Exercise. It can destroy successful teaching units (e.g. at Cardiff) whose priorities lie more with educating students than with hunting grants. It also creates specialists who are obsessed with staying at the 'cutting edge' of their own particular field and become so blinkered (and in some cases so arrogant) as to be incapable of communicating with anyone in a different field – still less of doing any effective teaching. I suspect that similar problems beset schools of technology and engineering.

The ultimate irony of this situation – which will get worse before it gets better – is that an insitution's RAE rating comes last in the list of requirements by prospective employers of MST graduates.

John Wright

Postscript: Here is a question: Why do so many institutions still require their students to write essays? What are essays *for*, exactly? How many people write essays when they leave university? Does essay-writing really prepare them for writing reports and syntheses and summaries, even papers for publication? It sure as hell didn't help me any.

Issues in scientific research and teaching

Topics discussed at the IACMST meeting reported above cannot be seen in isolation from two other pressing problems that nowadays face university scientists: One, the relationship between academics and administrators; and two, the relationship between pure and applied research. Employers of university graduates should also be interested in these issues, because they affect the nature and quality of prospective employees. If the teachers cannot operate effectively, their students are disadvantaged.

The passages which follow are based upon a recent speech to the Geological Society by a distinguished Earth scientist, and a short item in a recent *Nature* supplement. We would welcome comment and opinion on these matters from *Ocean Challenge* readers.

Academics and administrators

A general problem facing all academic endeavours is takeover by accountants and lawyers and other bureaucrats of mean understanding, who know the value of nothing and are obsessed with accountability, assessment and review. Universities are becoming businesses. In the ambitious scramble for funds and recognition, scientists are forgetting the traditional values of scholarship, the seamless integration of research and teaching that generates knowledge and understanding. In these days of overheads, 'value-added', 'wealth creation' and 'quality of life', the basic concepts of curiosity-driven research are diminishing. Some things can never make a profit, especially the finest traditions of basic research and scholarship.

Also on the increase is a 'bean-counting' attitude to research productivity, the notion that 'more means better', that number of publications correlates with quality of research. It is nonsense. A single seminal paper that breaks new ground is worth much more than any number of pot-boilers describing different aspects of the same thing. More insidiously, in these days of increasing specialization those charged with promotions and appointments commonly have little idea of what constitutes quality research outside their own circumscribed fields. Consciously or subconsciously there is an attitude that says: 'The only papers which count are those published in journals I've heard of.'

Pure and applied research

Here, the challenge is to combine high-quality basic research with a mission to address wider national needs. Important contributions to understanding made in basic science are not necessarily accompanied by corresponding technological improvements. Some people think that scientists are too preoccupied with striving for academic excellence to pay attention to applied research, that they may even believe applied research is not good for science. On the other hand, many scientists have had little or no experience of applied research, and an apparent lack of interest in applications is in fact a reluctance to undertake applied projects that do not have a solid grounding in fundamental research.

Another problem is that those in charge of research funding tend to believe in 'proactive' research design. They would rather tell scientists what to do within prescribed patterns, instead of allowing them to behave in responsive mode and thereby generate the innovative ideas of the future that will benefit humankind. No-one, however clever, has the wisdom to know what research will prove to be important and what will not.

Challenger Society Awards and Prizes

The awards system of the Challenger Society has been revised. Here is a summary of the new situation.

The Challenger Medal

This is the premier award of the Society, and will be awarded at the major biennial meeting of the Society. The medal will be next awarded at the Marine Sciences 2000 meeting at the University of East Anglia on the occasion of the Challenger Lecture by the recipient. The award is for a distinguished UK marine scientist or other person who has made a single major contribution, or a sustained contribution, to the development of marine science, or whose innovation has opened up new perspectives. The recipient need not be a member of the Society.

Honorary Membership

This award recognizes substantial contributions to the work of the Society and to the national and international development of marine science. Honorary membership is restricted to a total of 2% of the membership of the Society. There are currently four Honorary members. There are no restrictions on the nationality of nominees. The recipient need not be a member of the Challenger Society.

Fellowships

The Society is initiating the award of four Fellowships biennially to young marine scientists under 40 years old who are members of the Challenger Society, for their achievements and promise in a branch of marine sciences (marine biology, marine chemistry, marine geology or marine physics). The Fellowships will be first awarded at the Marine Sciences 2000 meeting.

Prizes

Two Challenger Society Prizes are awarded at each biennial Marine Sciences meeting: The **Norman Heaps Prize** for the best verbal presentation by a young (under 35) non-established researcher and the **Cath Allen Prize** for the best poster. The **Presidents' Photographic competition** will also be judged at the meeting. There is also a **Challenger Prize** for the best student of the Open University's Oceanography course.

Travel Awards

Travel awards to assist graduate students attend scientific conferences or participate in cruises/fieldwork will be offered annually. Priority will be given to graduate students who have had a paper or poster accepted for a recognized conference. The awards will be modest and amounts will depend on numbers of applications. The Society cannot guarantee that an award will be made and this should not be assumed in applying for funding elsewhere. Applicants must be members of the Challenger Society.

Nominations and Applications

Nominations and applications will be considered by a sub-group of the Council of the Challenger Society. They should be submitted to the President (see end) before the deadlines shown below. Nominees should be members of the Society or supported by a member.

Nominations for the *Challenger Medal* and *Fellowships* should be by letter explaining the reasons for the nomination, quoting where appropriate relevant references to scientific publications or other contributions. A short *curriculum vitae* of the nominee is required. The nomination should be submitted by a single proposer with support by one or preferably two others. The next deadline for nominations is *10 January 2000* and biennially thereafter.

The *Honorary Membership* will be awarded only very occasionally because statutes of the Society limit the numbers of Honorary Members. Nominations should be as for the Challenger Medal and Fellowships. Nominations may be submitted at any time.

Applications for *Travel Awards* should take the form of a statement of the reasons for travel (if for a conference, it should detail its scientific value and confirmation that a paper/poster has been accepted) accompanied by details of the total budget for the travel involved, and an explanation of how most of the costs will be covered. A letter of support from the student's supervisor must be included. The deadline for applications is *10 January* annually.

Current Council Members of the Society are ineligible for any award or prize.

Submissions should be sent the President of the Challenger Society (from whom advice may also be sought). Until September 2000, the President is Harry Elderfield, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK (Email: he101@esc.cam.ac.uk).

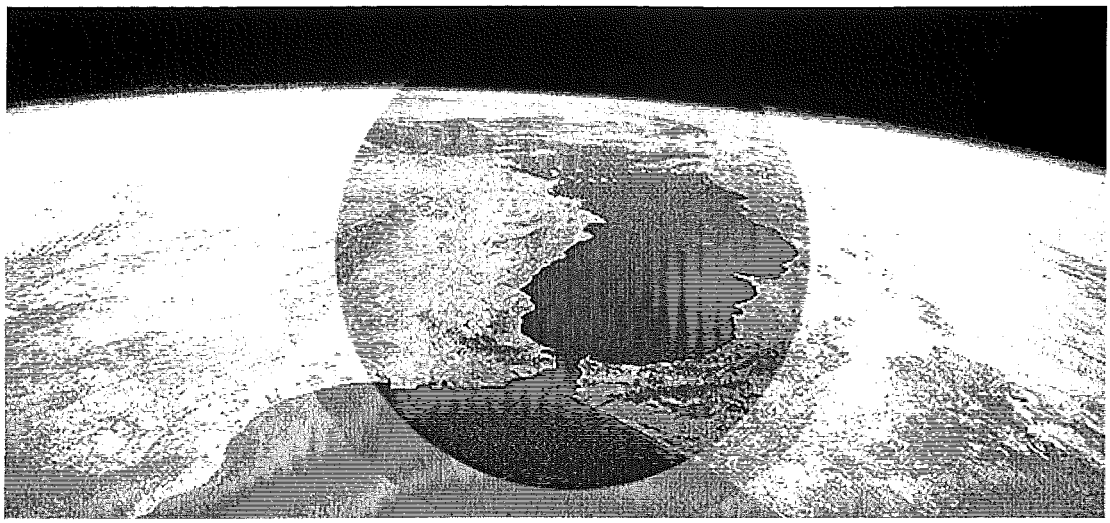
DGM Mitteilungen No.1/99

The helpful abstracts in English that characterized some earlier issues of *Ocean Challenge*'s German counterpart do not appear in this number. This is a pity, because it carries a good variety of articles and features.

Longer articles include a bicentennial account of Alexander von Humboldt's trans-Atlantic voyage to South America (1799). There is also a description of a fascinating astronomical venture that involves placing a neutrino detector 4000 m down in the Ionian Sea; also a historical review of some of the problems and difficulties that have beset students of marine biology and ecology in the past sixty years or so. Two substantial features describe and discuss the history and the future of ICES – the historical review, partly in English, describes controversies that arose in Germany when ICES was founded.

Shorter pieces cover a range of topics, including: results and achievements of the WOCE project; the feasibility of extracting useful products from bacteria in polar seas; a global 'millenial' cruise that will take teams of scientists and science journalists on a 65 000 mile circumnavigation to visit important oceanographic areas and retrace voyages of early explorers; and some observations on the pitfalls of research into marine biological resources.

The Changing Environment of the



Mediterranean Sea

insights from the Mediterranean Targeted Project

André Monaco

During the last five years, important scientific observations have resulted in a change in our understanding of life in the Mediterranean Sea. Some of the most significant data have originated from the Mediterranean Targeted Project (MTP) which is currently the largest environmental research project of the European Commission and the largest project in the Mediterranean Sea in general.

A large-scale oceanographic project

For decades, the Mediterranean Sea has been over-run by tourists (158 million in 1996 in the 22 Mediterranean states – one-quarter of world tourism) and crowded with ships. It has also been bombarded with scientific and policy initiatives. Along with other international organizations, since the mid-seventies the European Commission has been pursuing the goal of scientific and policy co-operation focussed on the socio-economic and ecological issues of the Mediterranean region as a whole.

The first phase of the MTP project began in 1993 and was co-ordinated by the European Commission (under the Marine Science and Technology Programme); it combined 10 smaller projects, involving 70 institutions, and 250 scientists from 14 countries. For the first time, experiments were carried out at a number of different scales in both the western and the eastern Mediterranean. Techniques were compared and exchanged among participating laboratories, and people were trained in new approaches. The fact that leading scientists from different countries and various disciplines (physicists, chemists, statisticians, geologists) cooperated at a level never before achieved in this area, was in itself an important achievement (see also Further Reading).

Today, the project is in its second phase (MTP-II). This involves 53 research institutions (including the Joint Research Centre of the European Union), and a total of 335 scientists from 13 countries in Europe as well as Morocco and Tunisia, and is running until the end of 1999. It is headed by a co-ordination unit which includes a scientific co-ordinator and a technical manager liaising with the EC.

The pilot phase

During its pilot phase (i.e. the period 1993–96), MTP produced important scientific results, in three main areas:

Global change

The temperature of deep waters in the western Mediterranean has increased by 0.13 °C over the last 40 years (a rate of 3.2×10^{-3} °C yr^{-1}). The observed warming was accompanied by increasing salinity. Information about these trends allowed calculations of the probable changes occurring in water and heat fluxes across the sea-surface. The recently observed increase in temperature took place over a very brief period of time, whereas past climatic changes typically occurred over periods of several thousand years.

Evidence for climatic changes was also detected in the deep water masses of the eastern Mediterranean basin. These changes were revealed by an increase in temperature of the deep layers during the last three to four decades and an increase in salinity of the intermediate waters (specifically, Levantine Intermediate Waters) with a corresponding increase in their density (cf. *Ocean Challenge*, Vol. 6, No. 2, p.10). These water mass changes could have a profound influence on the functioning of the ecosystem over the next few decades (see also Further Reading).

Humanity's impact on the Mediterranean system

The most obvious negative trends have been increases in nutrient discharges (phosphate and nitrate) according to deep-water measurements. They result from human, industrial and agricultural activities around the sea, which began to increase markedly in the early 1960s.

There have been positive trends too. Lead concentrations in surface waters halved in the early 1990s following the application of European regulations on lead additives in gasoline (cf. *Ocean Challenge*, Vol. 8, No. 3, p.8). This result suggests that the marine system may also respond quickly to other chemical land-based emissions.

Structure and functioning of the Mediterranean ecosystem

During the pilot phase, the overall structure and functioning of the Mediterranean Sea ecosystem were shown to be variable on seasonal and interannual time-scales. Furthermore, seasonal changes in atmospheric inputs to the marine environment could be detected at water depths of 1000 m. Pioneering work has been directed at producing models which couple water circulation and ecological processes. These models could lead to the development of valuable tools, both for managing coastal zones and for forecasting the impact of climatic change (see Further Reading).

As mentioned above in the context of lead, MTP improved our ability to understand the capability of the Mediterranean to absorb input materials such as contaminants. It also improved our ability to evaluate their impact on trophic relationships by estimating mass balances and exchange rates across its boundaries, and understanding the functioning of the euphotic zone. Amongst the small-scale trials conducted was an experiment in the Adriatic Sea, which is a semi-enclosed basin. Nutrient discharges from the Po River to the Adriatic were evaluated, and the river's annual fluctuation in nutrient supply to the shelf was shown to be an important control of primary productivity and biomass in the Adriatic Sea (see Further Reading).

MTP results strongly support the hypothesis of phosphorus limitation for phytoplankton growth in the north-western Mediterranean Sea. On a very broad scale, it was found that recycling of organic matter increases from oligotrophic (nutrient-poor) to mesotrophic (moderately nutrient-rich) areas.

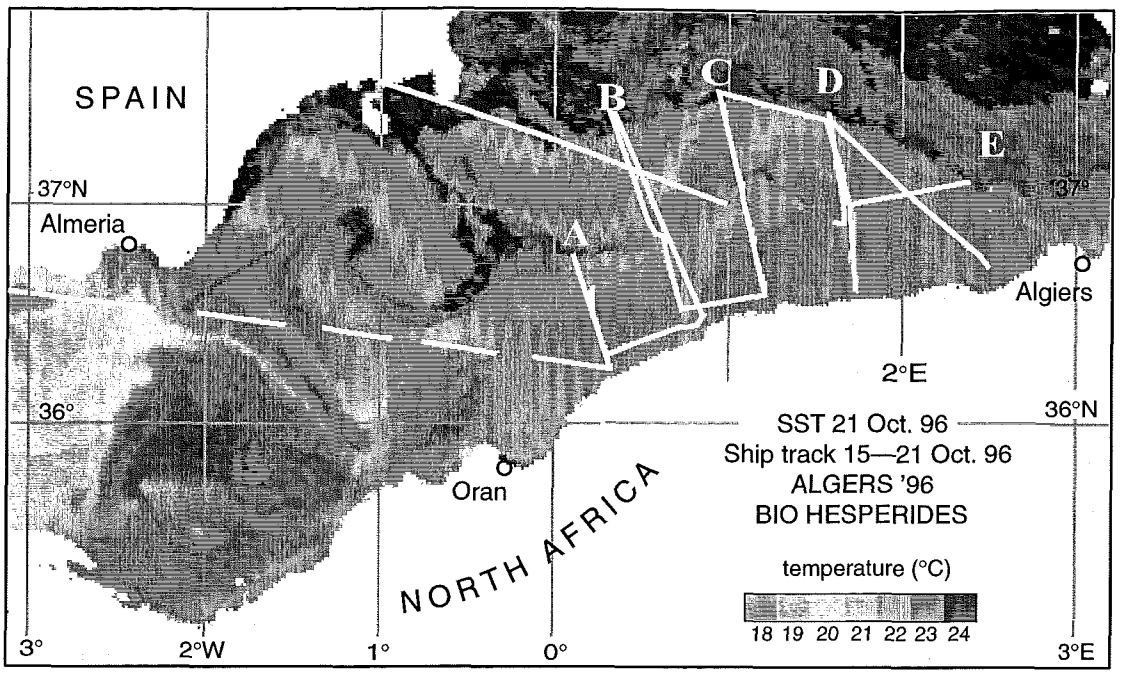
A special research effort in the Eastern Mediterranean

During the MTP pilot phase an important research effort was carried out in the eastern Mediterranean Sea in order to fill some basic gaps in our knowledge of this region. For the first time, acquisition of reliable primary production and microbial production estimates was achieved on a seasonal basis in the open waters of the Aegean Sea. The southern Aegean Sea is one of the most oligotrophic regions of the world, as bacteria account for more than 56% of the organic particles in near-surface waters. And because the bacteria consume nearly all the sinking waste matter, the deep Aegean is one of the poorest habitats of the world ocean. However, important changes – such as nutrient enrichment in conjunction with the onslope movement of the deeper and more nutrient-rich water masses of the Cretan Sea – have been observed; these are influencing the extremely oligotrophic character of the South Aegean Sea, and will have a direct effect on the biology of the region. As a consequence, benthic productivity and fish recruitment over the continental margin is expected to increase in years to come.

A synthesis of all the scientific results is currently being prepared and it will be published as a Special Issue of the international journal *Progress in Oceanography* (to appear at the end of 1999).

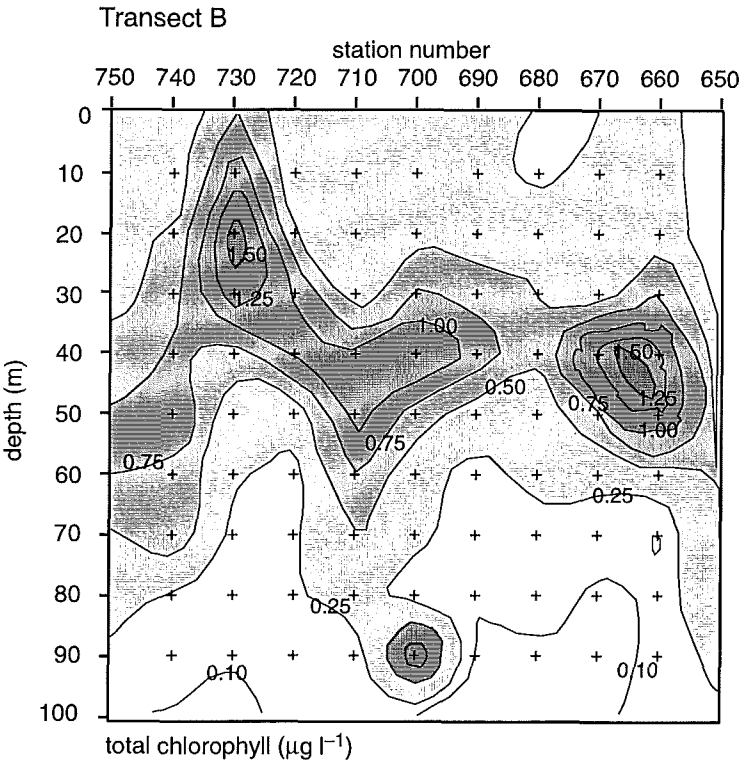
The MTP II–MATER phase

The second phase of the MTP project, named MATER (MAss Transfer and Ecosystem Response) led to improved connections among different disciplines and research activities throughout the whole Mediterranean basin. During this phase of the project, the participating institutes benefitted from extensive ship-time provided by the countries bordering the Mediterranean (France, Greece, Italy and Spain) through the organization of two 'trans-Mediterranean' cruises. Other benefits included the standardization of methods and the creation of common pools of equipment among the participants. To date, a complete information dissemination system has been established, along with a database organized from three regional data centres: Systèmes d'Informations Scientifiques pour la Mer (SISME) in France; the Hellenic National Oceanographic Data Center (HNODC) in Greece; and the Osservatorio Geofisico Sperimentale (OGS) in Italy. This coordinated approach led to an overall understanding of how the ecosystem functions and to a more coherent scientific community.



(a)

A combination of satellite images and in situ measurements allows detaile studies of mesoscale features such as eddies



(b)

Figure 1 *Recent oceanographic cruises in the western Mediterranean (from the Alboran Sea to the Algerian Basin) were focussed on the study of mesoscale structures in one of the most energetic areas of the Mediterranean.*

(a) *Remote sensing imagery (here, an infrared image from AVHRR/NOAA) was used in combination with information about dynamic surface structures and physical and biochemical* in situ *measurements (total chlorophyll).*

(b) *Transect B (cf.(a)): In this particular case, the chlorophyll was not homogeneously distributed but follows the eddy structure in the upper 100 m.*

(J. Font ICM/CSIC, C. Millot and I. Taupier-Letage) COM/CNRS).

In MTP I and, in particular, during the MTP II – MATER project, fieldwork was structured on the basis of the overall oligotrophic (nutrient-poor) character of the Mediterranean Sea and its east–west productivity gradient (higher in the west, lower in the east). This approach yielded a consistent dataset and has allowed us to answer questions about the functioning of the ecosystems in the western, central and eastern basins of the Mediterranean.

The comparative experimental work carried out in these areas also indicated a north–south gradient (higher in the north, lower in the south) driven by nutrient input from the largest Mediterranean rivers in the western and central basin and, in the Aegean part, by the inflow of Black Sea waters.

Another relevant point is represented by the mesoscale dynamics having space- and time-scales that allow direct application of the techniques to global ocean studies. It was demonstrated that the features studied play an important role in the general circulation of water masses and ecosystem-response mechanisms. MATER has addressed several topics in mesoscale dynamics and regional scale circulation through *in situ* measurements and processes and regional modelling studies, most of them concentrated in the western basin (Figure 1).

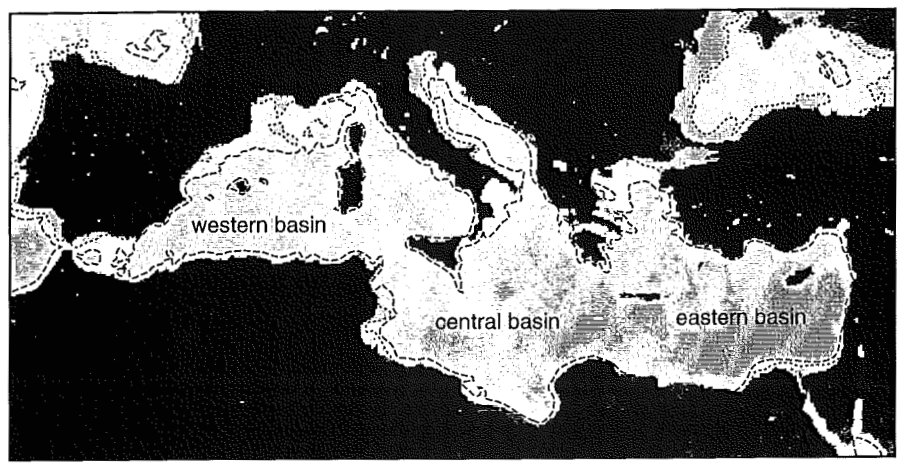
There were also new insights into the close relationships between the different sub-basins and the effects of water mass redistribution. In particular, evidence was obtained on the effect on the Ionian and Adriatic Sea circulation of formation of new deep water in the Aegean Sea changing the deep water regime. The great effort undertaken in the study of the straits (Gibraltar, Otranto, Sicily and Cretan) is contributing significantly to the knowledge of the real connections between the different basins, and it is likely that there are important implications for the ecology.

Figure 2 *Relationship between primary productivity and particulate organic carbon (POC) fluxes measured by use of sediment traps at shallow and deep levels. This unique experiment represents the result of the combined effort of several teams (University and CSIC of Barcelona, CEFREM University of Perpignan, Istituto di Geologia Marina-CNR Bologna, NCMR Athens).*

(a) *Surface primary productivity of Mediterranean waters as it appears on CZCS images (Nimbus 7). Areas of relatively high primary productivity are enclosed by dashed lines, areas of highest primary productivity are enclosed by dotted lines.*

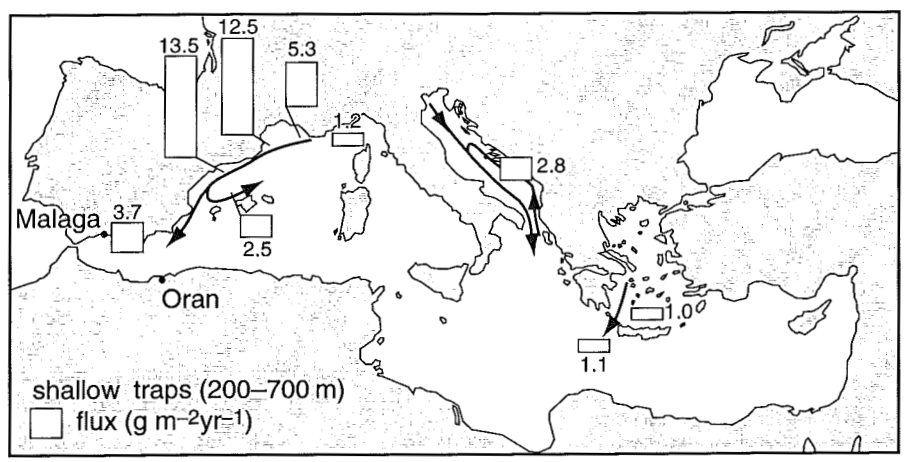
The distribution of primary productivity relates quite closely to ***(b)*** *the annual average POC fluxes measured between 200 and 700 m depth.* ***(c)*** *The fluxes at depth (1000–1500 m) are generally greater. The exact mechanism whereby material is transported from the surface to the bottom remains hypothetical: advection, organomineral aggregation, etc. What is certain is that a strong hydrodynamic component is involved in the phenomenon. (Arrows indicate surface current systems.)*

Prepared by S. Heussner (CEFREM, University of Perpignan).

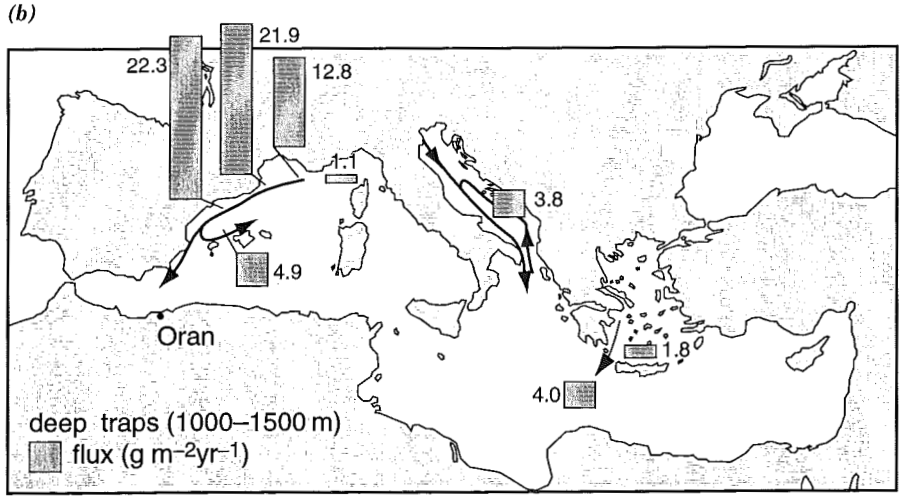


(a)

Fluxes of POC to deep water correlate well with primary productivity levels inferred from satellite images



(b)



(c)

The MATER project allowed the monitoring of three of the major Mediterranean basins with several mooring lines equipped with sediment traps and current meters. The purpose of these experiments was to measure and characterize downward fluxes of particles (marine snow) to highlight seasonal and interannual variability in relation to climate, water circulation and trophic level (Figure 2). A central innovative effort also consisted in approaching the spatial and temporal variability of mass and carbon fluxes through high resolution studies (High Frequency Flux Experiments) conducted both in geostrophic environments (along the Northern Current, which flows along the south coast of France and Spain; cf. Figure 2) and in ageostrophic environments (upwelling off Malaga and the Almeria–Oran front in the Alboran Sea).

Given the evidence of interannual temperature and salinity changes and the recent discovery of areas of deep water formation in the Aegean Sea (see Further Reading), it is now clear that the Mediterranean environment is a highly sensitive and reactive system; the trend of increasing temperature would constitute the first measured effect of enhanced greenhouse warming. It is also clear that the Mediterranean could potentially play a role in the evolution of large-scale world climate change. The strong response to the interannual variability of atmospheric/climatological forcing makes the Mediterranean Sea an ideal test area for studying air–sea interactions. In this context, it would be interesting to verify if a relationship can be established between the variability of the current transport across the channels and the North Atlantic Oscillation.

To date, there are several key components of the Mediterranean system that have been identified from modelling studies within the frame of the MTP II–MATER project: thermohaline circulation, interannual variability in relation to atmospheric circulation, interactions with topography, exchanges through the straits, vertical turbulent mixing. Concerning the ecosystem studies, two kinds of models are being developed: one type simulates the basin-wide three-dimensional variability of the first trophic level; the other type focusses on process studies and pelagic/benthic coupling in sub-basins, solving problems related to biogeochemical cycling in phosphorus-limited environments, or in population dynamics.

Towards sustainable manangement of the Mediterranean ecosystem

Although there were many other outcomes of the Mediterranean Targeted Project, the above examples should be enough to illustrate the change in current understanding of research issues in enclosed seas. The results are interesting not only from the purely scientific point of view – they can also be used to monitor changes in the whole Mediterranean environment (the sea itself, and the population and activities in its catchment) and socio-economic studies (e.g. tourism, fishing). Because of them, the Mediterranean Sea is even more useful as a natural full-scale system for monitoring environmental and climatic evolution in general and that of the Mediterranean region in particular.

The EC MTP II–MATER project has increased the visibility of scientific activity carried out by the European scientific community with the support of the European Commission in this region. This visibility finds expression in the creation of different project Web sites, the publication of an *MTP Newsletter*, a project brochure and an electronic information bulletin.

The project has also opened the doors to a larger public through the production of a television film and an educational TV series 'Méditerranées' broadcast on the European channel 'ARTE', and the participation of MTP leading scientific groups at several conferences over the last six years, especially during 1998, the International Year of the Ocean.

Finally, the MTP project went beyond the regional dimension, and its experience and organization inspired other large-scale projects oriented towards the sustainable management of regional ecosystems like the China Sea and the Japan Sea.

Further Reading

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Nigel Williams (1998) The Mediterranean beckons to European oceanographers, *Science*, **279**, January, pp.483–4.

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The MATER Website is:
http://www.cetiis.fr/mtp/mater

André Monaco is a research scientist at the French CNRS. He is the scientific coordinator of the MTP II-MATER project. Elisabeth Lipiatou, Scientific Officer in EC DG XII/D 1-3 and coordinator of the pilot phase of the MTP Project, also contributed to this article.

Biodiversity in the Ocean

Angelika Brandt

Biodiversity can mean many different things, depending on who is using the term. However, a useful definition is: 'Biodiversity is the totality of genomes, species, communities, and ecosystems in space and time.' In the marine realm it encompasses bacteria, ice-algae assemblages and phyto- and zooplankton, down to pelagic organisms and benthic assemblages. Biodiversity in general has a hierarchy of levels, namely ecological diversity, genetic diversity, and biodiversity at the level of the organism. The population is the fundamental unit linking these components.

Biodiversity research is an integral part of conservation: if you do not know the species, assemblages and communities of a certain area, you cannot protect them. Moreover large-scale patterns of biodiversity underpin theoretical ecology and paleoecology; furthermore, it was recognition of diversity gradients that led to early works on resource partitioning.

Carefully curated collections are essential for accurate recognition and classification of organisms in biodiversity research

Up until now global studies of regional diversity patterns ('γ diversity') have not yet been undertaken and we are still far from the international goals of the Systematics Agenda 2000, 'Charting the Biosphere' (see Box, opposite). Even in the late 1980s, Robert M. May was able to pose the basic question: 'How many species are there?'

The importance of taxonomy

Study of biodiversity involves several different biological disciplines. Evolutionary biology provides explanations for the origin of biodiversity, and of processes like speciation (development of new species) and extinction, by which it is continuing to change. Biological systematics and taxonomy focus on similarities and differences arising from evolution. Ecology deals with structural and functional relationships between organisms and the biotic and abiotic environments in which they occur; it also provides a classification of the different types of habitat. Genetics, on the other hand, tries to understand the basis of variation through heredity and evolutionary change at all levels, and finally population biology collects information about the genetic structure, spatial, age and size structure of the individuals of a population, as well as the population dynamics.

Of all these disciplines, the most fundamental is taxonomy, being a reference system for biology and the underpinning for all other biological disciplines. The fundamental step in any biodiversity research must be the accurate recognition and classification of variation, both within and between species and also between assemblages. Such information is essential for identifying patterns of biodiversity and for understanding how these patterns change over time and space. However, taxonomists are themselves a vanishing

Figure 1 *Part of the author's collection of peracarid crustaceans occupying just one of the thousands of shelves of preserved specimens at the Zoological Museum of the University of Hamburg.*

species, and in the future only a very small number of people will be able to identify species accurately. It is therefore very important to conserve this knowledge, as is presently done by the Expert Centre for Taxonomic Identification (ETI) in Amsterdam, in a series of CD-ROMs. Moreover, in order to make identifications, taxonomists will continue to be dependent on extensive museum reference collections (Figure 1).

When considering marine biodiversity we have to remember that more than two-thirds of the Earth's surface is covered by ocean; of this area less than 10% is coastal or shelf, and more than 90% is deep sea. It is probable that there are a tremendous number of taxa here, especially among the smaller invertebrates, and most of these are still unknown. This short review therefore focusses mainly on biodiversity on the deep sea floor.

Biodiversity in the deep sea

In several classic studies in the 1960s, Howard Sanders found that benthic marine biodiversity is higher (for many taxa and areas) in the deep sea than on the shelf or on the continental slope. However, for some taxa – including the Isopoda from the Arctic Ocean – conflicting results have been found.

In 1993 Svavarsson and colleagues reported a steady decrease in species number with depth down to 4000 m, while some families showed different patterns with depth and geographic area. Their results suggest that some true deep sea species have their maximum diversity in the South Atlantic at about 5000 m depth, while in the North Atlantic more species (of, for example the genus *Haploniscus*) occur around 3000 m depth. In the Pacific we find almost the opposite pattern, with a higher number of species occurring deeper than 5000 m in the north, while in the south most species seem to be eurybathic (i.e. they are found over a large range of depths).

I have myself investigated the composition and abundance of peracarid crustaceans at 75°N in the Arctic Ocean by means of an epibenthic sledge. My study showed that here diversity does not increase with depth down to 2700 m, but abundance is higher in the deeper samples, especially down to 1500 m, but also at 2700 m. Nutrient supply in terms of chlorophyll equivalents was very similar at all stations down the slope and this might explain the high number of Peracarida at about 2700 m depth. These samples were taken in the area of the Greenland Sea gyre, close to the ice edge where ice dynamics (downwelling etc.) are high. Therefore it is possible that both the blooms of phytoplankton and ice-algae in July and early August were quickly transported into the deep sea by convection linked with deep water formation. However, in that case one would also expect higher abundances at shallower depths.

There are a number of possible reasons for these phenomena. There is a clear dominance of sessile filter-feeding organisms at about 800 m depth, and these animals might have reduced the amount of organic debris before it reached the sea-bed so that the peracarids could not find sufficient food at these stations. Also, the high frequency of filter feeders might reduce the availability of 'ecological niches', especially for burrowing species.

Systematics Agenda 2000 Charting the Biosphere

MISSION 1: Discovering biological diversity (☆)

MISSION 2: Understanding biological diversity

MISSION 3: Managing systematic knowledge (★)

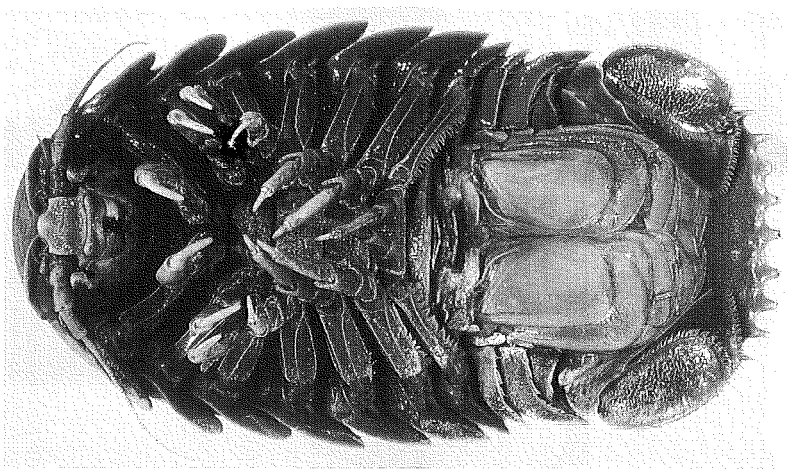
☆ **Primary uses of systematics**

- Discovering species and making inventories
- Making comparisons among species and inferring phylogenetic history
- Using phylogeny, and classifications derived from it, to integrate basic and applied biology
- Providing basic data to underpin sustainable use of biological diversity

★ **Fields in which understanding of systematics is used**

- Applied health and medical sciences
- Biotechnology
- Agriculture and fisheries
- Forest products and forest-related industries
- Conservation and resource management
- Ecotourism
- Basic biological science

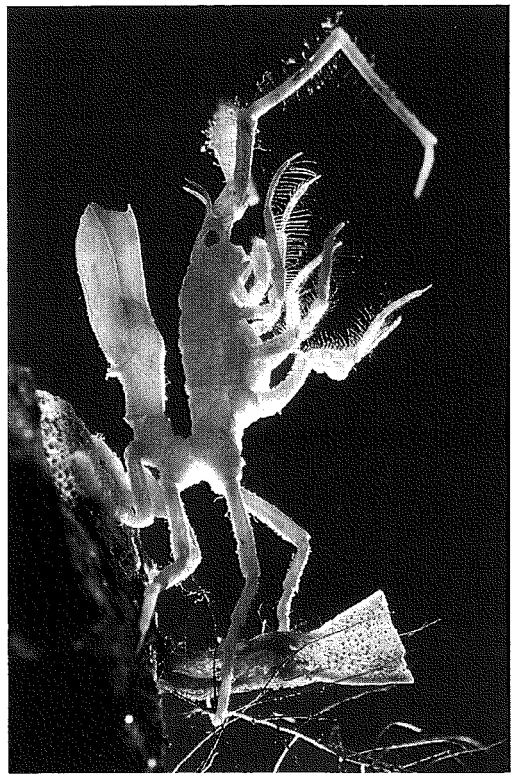
Figure 2 *Ventral view of* Bathynomus giganteus, *the largest known isopod of the family Cirolanidae, the adults of which can reach lengths of 40 cm or more.* Bathynomus *is a typical deep sea genus. This specimen was collected in the Atlantic at a depth of 800 m.*



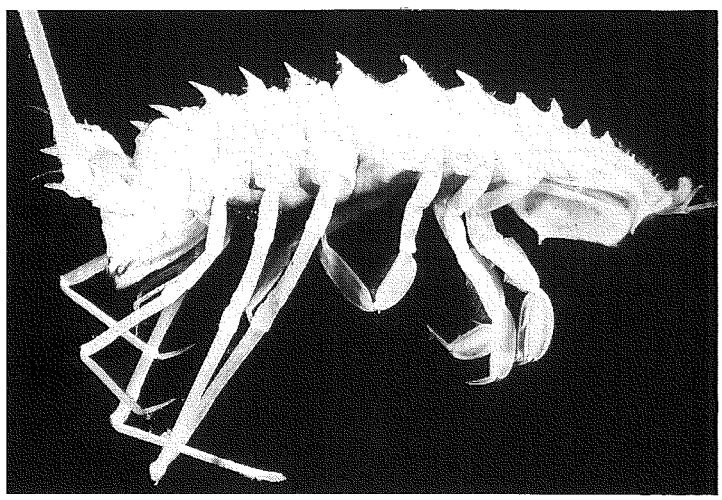
The largest deep-sea isopods can be more than 40 cm long

Isopods come in glorious variety and have a range of life-styles

Figure 3 *A selection of isopods from the Antarctic.*
(a) Dolichiscus meridionalis *(Family Arcturidae), found in the Weddell Sea and eastern Antarctic. It is about 5 cm long and is a passive filter feeder.*



(a)



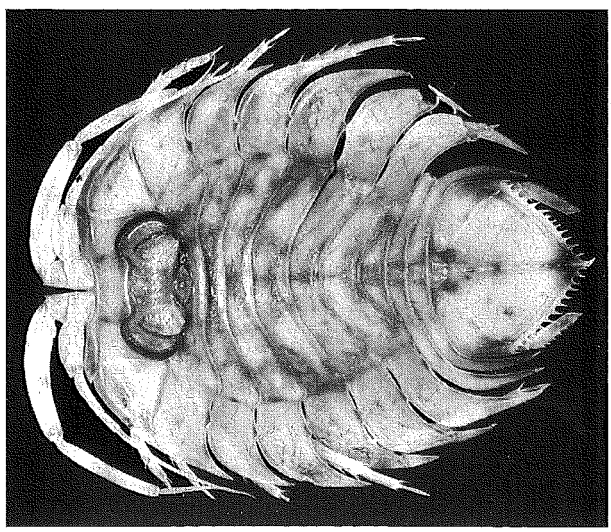
(b)

(b) Munnopsis australis *(Family Munnopsidae), found in the Weddell Sea at depths > 1000 m. It is about 2–3 cm long and feeds on detritus and perhaps also foraminiferans.*

(c) Ceratoserolis trilobitoides *(Family Serolidae). It is found all around the Antarctic and is a predator.*

(d) Glyptonotus antarcticus *(Family Chaetiliidae), in ventral view. It is also found all around the Antarctic, and is a predator and scavenger. The largest Antarctic isopod, it may grow up to 17 cm long.*

(Photos: (a) Martin Rauschert, (b) Kuno Lechner)



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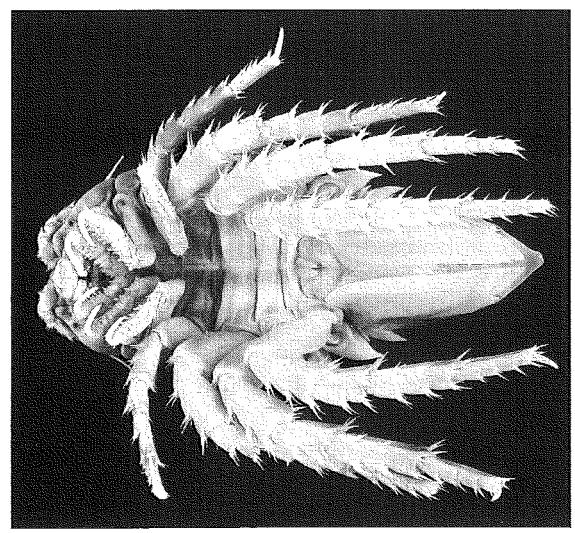


(d)

Another reason for these results (suggested by Klaus Schnack) might be the fact that the percentage of predatory and surface-feeding polychaetes is highest at 200 m and 400 m depth, where the competition between these animals and the peracarids might be much stronger than in the deep sea (at depths of 1500 m and 2700 m), where the number of exclusively benthic infauna and sub-surface-feeding polychaetes is much higher.

A number of hypotheses have been used in the past to explain high deep-sea species diversity. These include: (1) Howard Sanders' stability–time hypothesis, that the deep sea is characterized by environmental stability which leads to development of a highly diverse community; and (2) the biological disturbance theory involving processes of contemporaneous disequilibria (meaning, for example, that habitat change or heterogeneity as well as biological disturbance in terms of inter- and intraspecific interactions leads to faunal diversification).

Predation and competition are also disequilibrium explanations of high species diversity, and might be as important as dietary specialization or food availability due to production in general.

Latitudinal effects

Life in the oceans is underpinned by primary production. Productivity is directly dependent on solar energy and this is of course much lower at the poles than in the tropics (due to the oblique angle of the incoming sunlight, and the large area over which this energy is spread).

Away from upwelling areas, vast areas of the tropical ocean are nutrient-poor. By contrast, polar areas are generally more eutrophic, even if only in short seasonal bursts, related to upwelling and cold water production. Nevertheless, productivity (terrestrial and marine) does generally increase from poles to tropics. Given that overall abundance of animals is usually correlated with diversity, the diversity gradient from poles to tropics may be a result of higher productivity leading to a greater abundance of animals.

Whatever the true cause, there is no doubt that a latitudinal gradient in species diversity exists in many deep-sea taxa. In 1993, Gary Poore and George Wilson calculated the expected numbers of all species from both literature data and their own samples, and found that species numbers varied with latitude from the tropics to the poles, especially in the Northern Hemisphere. In the same year, this hypothesis was supported by Michael Rex and colleagues on the basis of epibenthic sledge samples from several locations in the Atlantic Ocean (depths between 500 and 4000 m). However, it should be noted that Rex's southernmost sample was taken in the deep Argentine basin, at only 40° S. In these studies a latitudinal gradient was shown for Isopoda, Gastropoda, and Bivalvia, with all three taxa demonstrating lower species numbers in higher latitudes, especially close to 80°N. Thus species diversity appears to increase with decreasing latitude.

In a response to the publication by Rex and colleagues, Brey and others tested whether this general hypothesis would prove true for the southern Weddell Sea. These authors demonstrated that, at least within the bivalves, gastropods and isopods, the expected number of species in the Weddell Sea lies in the same range as that of tropical regions at about 20° S. There seem to be more distinct latitudinal gradients in species diversity in the Northern Hemisphere; clearly other factors play a part in the Southern Hemisphere, where we find more heterogenous regional variations. These might be universal global patterns in both surface and deep sea ecosystems.

Geographical differences

We also have to keep in mind that there are significant differences in species diversity between ocean basins. Although a latitudinal gradient can be shown in all oceans (especially in the north), the Indo-West Pacific has a prominent peak of shallow-water diversity, especially in the species associated with coral reef habitats. This is due partly to the great habitat heterogeneity of the coral reef areas, which simply allows a higher number of species to coexist. However, it could also be related to geological age, as the Pacific is the oldest of the oceans. Age may also be a factor affecting latitudinal gradients in biodiversity, as the Southern Ocean is of demonstrably greater antiquity than the Arctic Ocean, whose marine fauna is certainly much younger and comprises only few endemic species. The Antarctic, by contrast, has a high percentage (up to 90%) of endemic species for many taxa (e.g. for sponges, some taxa of the peracarid crustaceans, and fish).

Since the establishment of the Antarctic Circumpolar Current, and later the glaciation in the Northern Hemisphere, the polar regions have played a crucial role in the formation of large-scale diversity patterns. Work done at several large Antarctic research institutions, e.g. the British Antarctic Survey, suggests that in the Arctic Ocean, perennial sea-ice cover was established only between 2 and 0.7 million years ago, meaning that modern Arctic biogeography is very largely the product of events that occurred over the last 2 million years. In the Antarctic, by contrast, extensive coastal glaciation can be traced back at least 38 million years.

So we can also postulate a close correlation between species richness, speciation rate and geological (i.e. evolutionary) time. Areas of high diversity, be they in low or high latitudes, may also be centres of origin of new species rather than the destinations of mass migration of species, or refuges for formerly widespread species now extinct elsewhere. My own research on, for example, the Antarctic isopod families Arcturidae and Serolidae (cf. Figure 3(a),(c)) demonstrates this, as does that of Les Watling and Mike Thurston, on the Antarctic amphipod family Iphimediidae (see Further Reading).

Changes in biodiversity through time

In 1997, Jack Sepkoski of the University of Chicago illustrated the variation of biodiversity at generic and family levels through geological time (Figure 4, overleaf). The fossil record allows us to distinguish periods of origination and extinction, and in general it seems that mass extinction events are followed by evolutionary diversification. The Cambrian explosion of biodiversity was followed by a tremendous decline in diversity due to the mass extinction at the end of the Paleozoic. A subsequent steady increase in diversity was followed by another extinction and rapid diversification event between the Cretaceous and Tertiary. (In the fossil record, the horizon marking this event is known as the K/T boundary.) Sepkoski distinguishes three great evolutionary faunas through Phanerozoic time: Cambrian, Palaeozoic, and Modern (cf. Figure 4).

A recent observation by Thomas Cronin and Maureen Raymo (1997) on *Poseidon amicus*, an ostracod characteristic of interglacial periods, is very interesting. On the basis of the occurrence of this species in the vicinity of the Rockall Trough (3 427 m) in the north-east Atlantic these authors demonstrated that *Poseidon amicus* shows cyclical changes through time. These can be correlated with vatiations in bottom water temperature (measured in Mg : Ca ratios), and changes in ice volume (i.e. glacial and interglacial

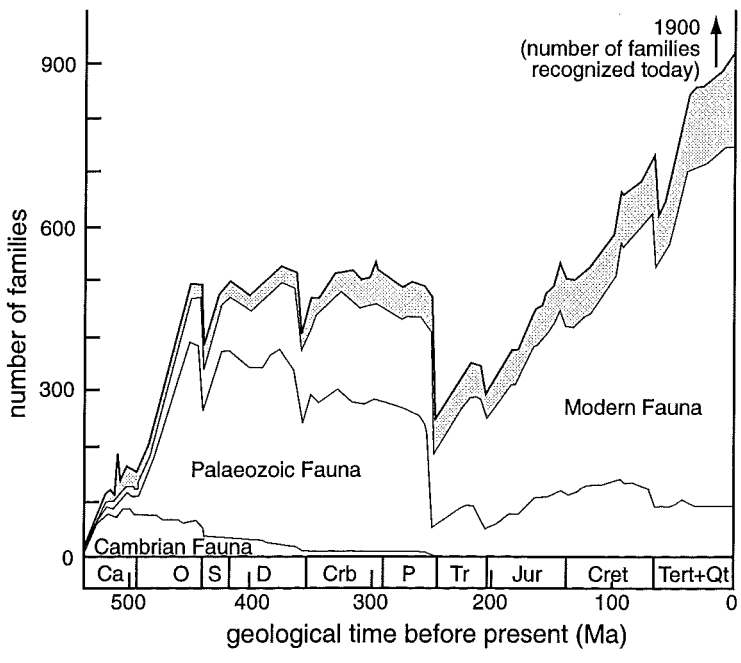
periods, as shown on the basis of oxygen isotope ratios). They went on to show that the control of deep-sea benthic diversity by cyclic climate change at time-scales of 10^3–10^4 years does not support Sanders' widely accepted stability–time hypothesis, because it shows that the deep sea is a temporally dynamic environment. These diversity oscillations probably reflect large-scale responses of the benthic community to climate changes as a result of the effect of climate on the thermohaline circulation and hence bottom water temperature, and/or on food availability (production) plus a coupling of benthic diversity to surface productivity.

What one can deduce from such studies is that faunas in the past have obviously been able to cope with periods of global warming (and cooling). In addition, Sepkoski has suggested that environmental changes which caused extinctions may even have provided strong stimuli to evolution and diversification. Therefore, Clarke and Crame think that 'in the long-term view, perhaps global change, at least on the scale experienced by the marine realm so far, is no bad thing after all'.

Most scientists working on present-day diversity patterns believe that we are facing a biodiversity crisis caused by species becoming extinct at an alarming rate. Estimates of extinction rates range from 5.5 to 41 species per day. Assuming 10^7 species, this would mean that between 640 and 4 800 years from now, 96% of species presently identified would have been lost.

Extinction and diversification/ speciation are related to biodiversity

Figure 4 *Changes in the numbers of families of marine animals over the last 540 million years, on the basis of fossil evidence, according to Sepkoski. The topmost toned region represents only those families known from instances of exceptional preservation. The rest is based on the fossil record of skeletal hard parts, and is made up of three evolutionary faunas, Cambrian, Paleozoic and Modern.*



Conclusion

Marine biodiversity obviously depends on a variety of factors. Among the most important of these are the number of individuals in a certain habitat, the size of this habitat or ecosystem, and also the size of the animals themselves.

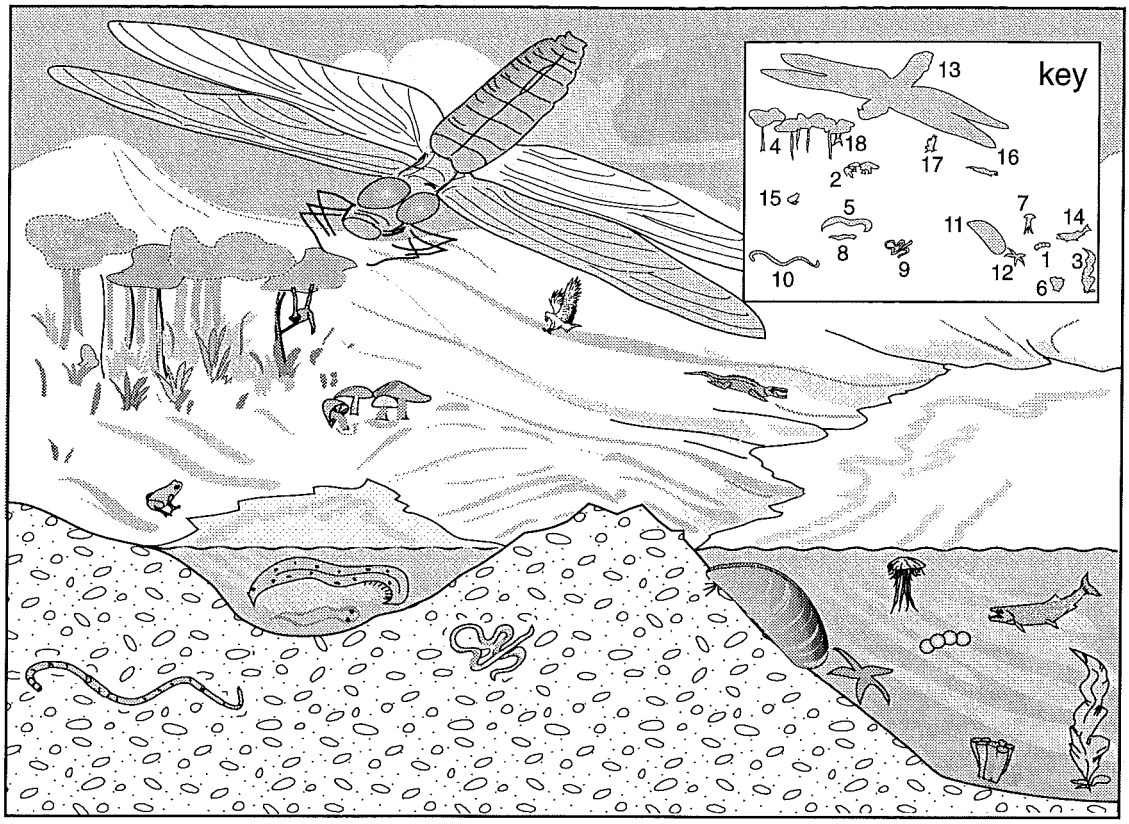
Moreover, depth, productivity, sedimentology and hydrography, and also intra- and interspecific relations of species, can have an influence on biodiversity. So too can habitat heterogeneity, which may vary greatly; for example, the habitats of the Arctic and Antarctic are strikingly different, with the result that the Southern Ocean is characterized by huge amounts of sessile suspension-feeding organisms, which are far less numerous in the Arctic Ocean.

Because of the complexity of biodiversity research, we demand multidisciplinary assaults. As Sepkoski said, 'There must be fine-scale studies of extinctions and recoveries using every appropriate biostratigraphic, sedimentological, geochemical, and geophysical means of temporal resolution. There must be paleoenvironmental and paleoclimatological understanding of the context of extinction and recovery. In essence, we must expand our cooperation among both biological sciences and Earth sciences if we want to make vital contributions that are within our grasp, to the societal problem of declining biodiversity in the modern world.'

Though long-term changes in biodiversity are not necessarily a disaster, as explained above, some workers have estimated, conservatively, that almost 25% of the total world primary production is appropriated by a single species – humans. For that reason much more effort has to be made to conserve marine biodiversity and also biodiversity in general. Much of the total diversity of marine life is yet unknown, and many species might vanish before we even get to know them. We therefore have to try to conserve both the species and their environments, and avoid habitat destruction, fragmentation and degradation. Moreover, some of these species might also provide more sources of drugs and other products, and we might all come to depend on them one day.

We need laws (and many are already used) to protect both biodiversity and the species' habitats. Introductions of ecologically potent species may cause local extinctions and a homogenization of the world's marine biota, and therefore have to be avoided.

And, finally, in order to fulfil these conservation aims we urgently need more taxonomists and more financial support for biodiversity research projects. Many scientists already see the urgent need for international cooperation in this field, in order to approach the goals of the Systematics Agenda 2000.



Schematic diagram in which the size of a representative organism is approximately proportional to the number of described species in the major taxon; 13 = arthropods, of which insects are the most abundant; this group also includes the crustaceans.

Other groups:
1 = bacteria, blue-green algae etc.
2 = fungi
3 = algae
4 = multicellular plants
5= protozoans
6 = sponges
7 = jellyfish, corals etc.
8 = flatworms
9 = nematodes
10 = annelids (earthworms etc.)
11 = molluscs
12= echinoderms
13 = see above
14 = fish
15 = amphibians
16 = reptiles
17 = birds
18 = mammals

Acknowledgements

I am very grateful for the invitation by the Deutsche Gesellschaft für Meeresforschung and the Challenger Society for Marine Science for the invitation to present the talk on marine biodiversity on which this article is based. My thanks also to Dr Alistair Crame who kindly read and commented on an earlier draft of this manuscript.

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DRIFTING and DREAMING

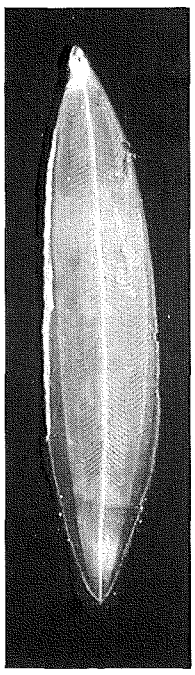
Is this how baby eels cross the Atlantic Ocean?

Gordon Williamson
Sinclair Stammers, Wann-Nian Tzeng, Jay C. Shiao
Galina Prokhorchik, Raymonde Lecomte-Finiger

The European eel, *Anguilla anguilla*, is believed to spawn in the Sargasso Sea. At this very moment, millions of delicate leaf-shaped baby eels are travelling across the Atlantic Ocean towards Europe. How do they make this long journey from the Sargasso Sea? Some fascinating observations have suggested to me that these baby eels – properly called leptocephalus larvae (leptos for short) – are not swimming across the Atlantic, but drifting in the current in a vertical orientation, head-up; and that furthermore they are 'asleep' or 'in a trance'.

These conclusions about how eels make their long migration are completely the opposite of those of Dr Friedrich-Wilhelm Tesch of the Heligoland Biological Station, Hamburg, who believes that eel leptocephalus larvae adopt a horizontal orientation and actively swim toward Europe. By contrast, I believe that leptocephali beat their tails not to swim but to prevent themselves from sinking. Observations – detailed later in the text – have suggested to me five new theories (Box 1, opposite) about the lives of European eel larvae, and these are the subject of this article.

Leptos are leaf-shaped, and completely transparent apart from their silvery eyes



Studying leptocephali is not easy

It is the marine life of eels that has always fascinated me. How do the adult eels get to the Sargasso Sea? How do the baby eels get from the Sargasso Sea to the coasts of Europe or of North America?

The journey of the adult eels will be discovered in due course, when radio-tags small enough to be put on an eel are invented. But leptocephali are tiny creatures – much too small to have a tag attached. So how to study them? The problem with leptos is not only that they are delicate and difficult to catch alive, but even when you *do* get some into an aquarium, the environment is so different from their natural one – brightly-lit, vibrating, noisy, etc. – that they do not behave normally.

Figure 1 *Leptocephalus larva of the European freshwater eel* Anguilla anguilla. *This photo shows a lepto life size, 75 mm long.*
(Photo: Norman Nicholl)

One advance has been made, regarding the depth at which leptos swim. By towing plankton nets at different depths, Tesch has discovered that over or near the continental slope, leptos live by day at about 300 m below the surface of the ocean in twilight, and by night, live about 50 m below the surface, in complete darkness. They ascend at dusk and descend at dawn.

The depth at which leptos swim when in mid-ocean is not known for certain. Is it possible that leptos 'float in the thermocline', i.e. allow themselves to sink until they reach a depth where the cooler, denser water is of exactly the same density as the lepto's body? Here, presumably, the lepto need not move its tail at all; it can remain effortlessly floating at the same depth, neither rising nor sinking.

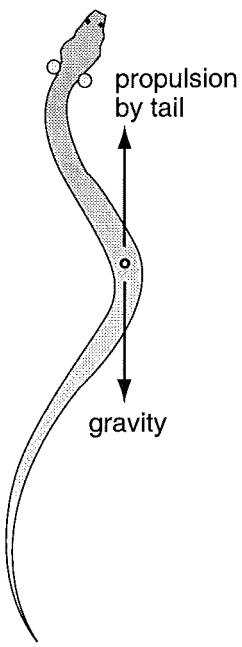
It seemed that there could be no more advances until someone made a new observation. By good luck, the man who made the new observation was me.

My lucky observation off Newfoundland

Thirty-six years ago, in 1963, I was busy in my first job at the Newfoundland Fisheries Research Station, Canada, and one weekend went to one of the rugged rocky bays to do a bit of SCUBA diving. It was July – the month during which glass eels migrate into rivers in Newfoundland. Cruising a few feet below the surface I came upon two beautiful transparent glass eels (elvers), both in a vertical orientation, head up, tail waving below. Next day I saw another one. All three glass eels were in a vertical position. Their heads pointed

upward, and their tails lashed from side to side continuously. No movement was made in any direction. The upward propulsive force generated by the tail exactly equalled the downward force of gravity, with the result that the tiny creatures kept a constant position in the water (Figure 2) The water temperature was about 7 °C. I caught one of the glass eels and counted its vertebrae: it had 106. This proved that these were American freshwater eels, *Anguilla rostrata*.

Figure 2 *Sketch of a glass eel or elver of the American eel,* Anguilla rostrata, *in a vertical orientation, as observed off Newfoundland.*



Thus started my longest-ever-by-far research project, which has lasted 36 years so far – more than half of my life. I immediately thought that this must be the tip of an iceberg. With this vertical head-up orientation, a glass eel would survive with the absolute minimum expenditure of energy. This is just what you want if you are drifting for months or years toward some distant coast. And if glass eels drift in a vertical position, why not leptocephali too?

Many years passed and my notes on the 'vertical' glass eels lay safe and remembered in a file – but wife, children, house and other research took all my energy. All the time I was keeping my ears open in case I might hear of more observations. But I heard of none. Finally, in 1985, I published a short note on the Newfoundland glass eels in the *Journal of Fish Biology*.

What we saw in the Bay of Biscay

Then in 1988 I had the good fortune to meet Dr Eel of Europe – Friedrich-Wilhelm Tesch himself. He said that his research ship, the *Friedrich Heincke* was going fishing for leptocephali in the Bay of Biscay. He invited me to join him, and to observe any leptocephali that were caught. I gladly accepted, and some months later we were on the deep swells of a sunny calm November in the Bay of Biscay. The leptos in the Bay of Biscay are ones that have been carried southward via a branch of the North Atlantic Current that turns south as it approaches Europe (see Figure 3, overleaf). Later, as glass eels, they will enter the rivers of western France (e.g. the Loire).

Some eel terminology

• Eels of the family *Anguilla* are the so-called **freshwater eels**. They live part of their lives in the ocean, part in freshwater. All other families of eels spend all their lives in salt water. World-wide there are fifteen species of *Anguilla*.

Two species of *Anguilla* inhabit Europe and North America. The European freshwater eel ***Anguilla anguilla*** is found in the fresh waters of Europe, and the American freshwater eel ***Anguilla rostrata*** is found in the fresh waters of the Atlantic coast of North America. To the non-expert, these species look identical, and it is believed that they evolved from a single ancestral species, as a result of the Atlantic Ocean getting forever wider, due to continental drift. This article relates principally to the European eel, but most features probably apply to a lesser extent to the American eel.

• An **eel larva** is any stage of a young eel from the newly-hatched yolk-sac larva to the leptocephalus to the glass eel.

A **leptocephalus** is the transparent, delicate, larva of an eel. As a tadpole is to a frog, so a leptocephalus is to an eel. Leptocephali live in the plankton, are almost invisible and are extremely difficult to catch alive. When a lepto approaches the coast, it shrinks and becomes ...

... a cylindrical **glass eel**, or **elver**, a miniature eel, completely transparent except for its silvery eyes. The glass eel stage ends when the first gas appears in the swim-bladder of the young eel, some time after it enters fresh water and after its body has become pigmented. Glass eels turn into the small eels found in rivers.

The five new theories

1 On their long journey across the Atlantic, leptocephalus larvae of the European eel travel most of the time in a vertical head-up position. Any lateral movement is achieved by drifting with the current, and not by actively swimming.

2 These drifting leptocephali are 'asleep' or 'in a trance'.

3 On the otoliths ('earstones') of European glass eels or elvers, the 'diffuse zone', where no daily growth rings can be seen (see overleaf), is deposited during the long drift across the Atlantic Ocean, when the eels are obtaining very little food and growing very slowly.

4 This 'diffuse zone' is made up of many daily growth rings which are so narrow that they cannot be distinguished.

5 While drifting across the Atlantic Ocean, leptos remain at a depth of about 300 m for many months and do not perform a daily vertical migration to the surface.

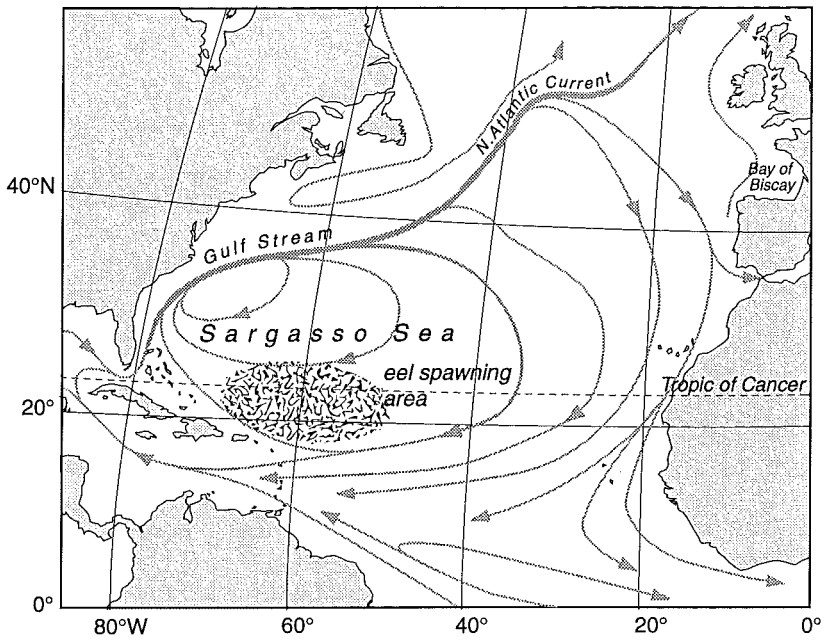


Figure 3 *Schematic map to show how the spawning area of the European eel in the Sargasso Sea relates to the gyral current system of the North Atlantic.*

Atlantic currents carry eel larvae to European coasts

We fished at night because (as mentioned earlier), leptos migrate up towards the surface at dusk and descend to deeper levels at dawn, and we used a 6 m^2 mouth-size Isaacs–Kidd Midwater Trawl net. 'Leptocephali were much more abundant some years ago,' said Tesch, 'Now we only catch about one-tenth of the former number of leptos – and the number is declining every year.' On average, we caught four leptocephali for each one-hour haul of the net. Most were dead when hauled on deck in the big cod-end container, but occasional specimens were alive. Put in an aquarium, these all, after a few minutes of prowling around the tank, settled down to swim in a vertical head-up tail-down position! They looked just like gently flickering candle flames, but upside down. Tails beating continuously at a steady 75 beats a minute in water of 19 °C. At each beat of its tail, a lepto's mouth would open and its pectoral fins make one circle of movement. But within 12 hours all the leptos died. We also caught some glass eels, and these adopted a vertical head-up position, but after some minutes or hours sank to the bottom, became bottom-living and remained in good health for the rest of the voyage and beyond. I got seriously excited. So here in the Bay of Biscay, leptocephali and glass eels were adopting a vertical position – the same as the Newfoundland glass eels. I concluded that any eel larva that wishes to conserve energy will adopt a vertical head-up position.

So I conceived a scenario (Figure 4, opposite) of how innumerable leptocephali might drift across the Atlantic Ocean to Europe. And I invited Tesch to be joint author of a paper with me, titled 'The swimming behaviour of eel leptocephali'. To my surprise, he declined because he felt that my conclusions were incorrect. In previous years he had seen many leptocephali swimming – healthy leptocephali – and they swam in a horizontal position, like any normal fish. The leptocephali on this cruise were all dying; they swam in vertical position only when they were half-dead.

I was in a quandary. With my own eyes I had seen many leptocephali 'swimming' in a vertical position, and yes, they had all died within 12 hours. But Tesch had observed healthy leptocephali swimming in a horizontal position.

Finally, after years of heart-searching, I decided to trust my own observations. Sure, weak and dying leptos swim in vertical head-up position, but that is no reason why healthy leptos should not also swim in vertical position. After all, we humans adopt the same *horizontal* position both when dying and when healthy, sleeping.

More evidence to support a vertical orientation for eel larvae

In the past ten years I have discovered two further pieces of evidence that suggest that leptos may adopt a vertical position. First, newly-hatched eel larvae (yolk-sac larvae) *all* swim in vertical head-up position (this information is by courtesy of Dr Hirohiko Kagawa of the Mie Eel Breeding Centre in Japan). Secondly, just about all elongate mesopelagic fishes swim in vertical head-up position (observations from submersibles are discussed in E.G. Barham's 1970 paper, 'Deep sea fishes; lethargy and vertical orientation'). I have also learnt of two occasions when observers in submersibles saw leptos swimming in a horizontal position at a depth of 500 m. So, Tesch and I are both wrong and both right.

My belief is that healthy leptocephali, when in daylight or in the presence of the lights of a submersible, adopt a horizontal position, but that undisturbed leptocephali on their long drift across the Atlantic Ocean, in the near-darkness of perhaps 300 m depth, probably travel in vertical head-up position (Figure 4). As the leptos approach Europe they detect land-derived chemicals in the water and are stimulated to change into glass eels, which swim in a horizontal orientation towards the source of the river water. Big changes in body shape must be accompanied by big changes in behaviour.

However, the three glass eels I saw in daylight off Newfoundland were in a vertical position. Could this be because glass eels have a horizontal orientation at night and adopt a vertical position by day?

Asleep? In a trance?

A most curious feature of the vertically-oriented leptocephali observed in aquaria on the *Friedrich Heincke* was that they appeared to be 'asleep' or 'in a trance'. If lightly touched with a pencil point, the leptos made almost no reaction – they just kept on beating their tails. The ceaseless rhythmic movements

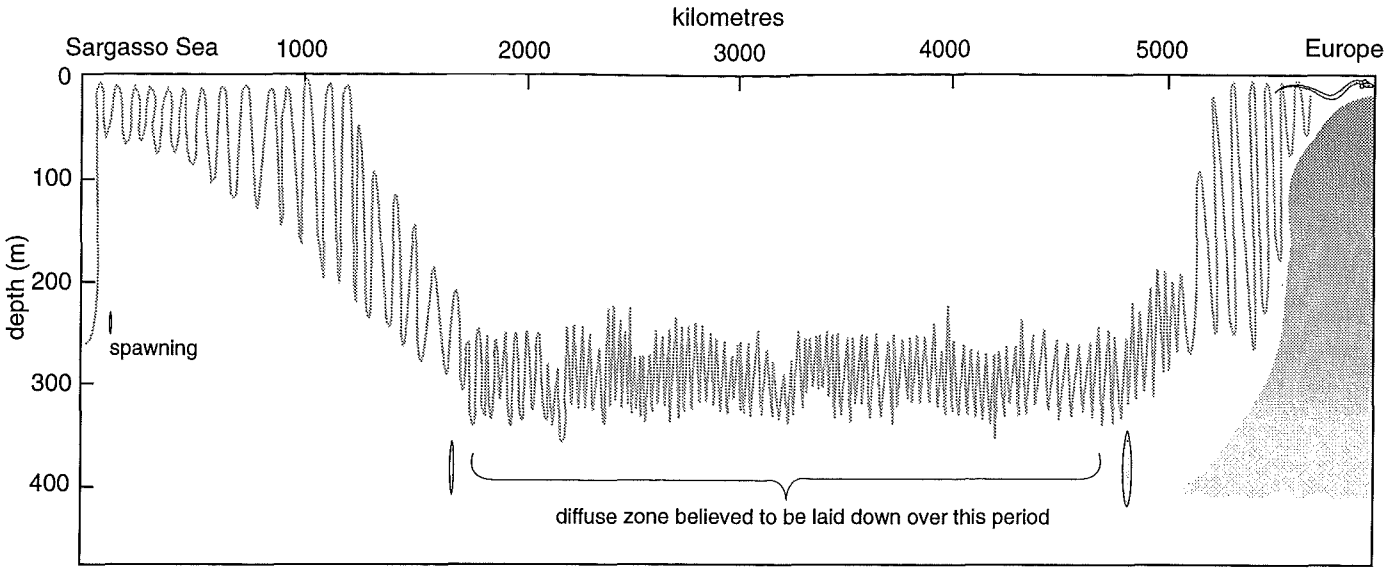


Figure 4 *Sketch showing possible vertical migrations of larvae of* Anguilla anguilla *from hatching in the Sargasso Sea to arrival at the coast of Europe. While the diffuse zone is being laid down, leptos may grow from about 50 mm to about 75 mm in length.*

appeared to be unconscious, as are the movements of the diaphragm of a sleeping human.

The conclusion that leptos are asleep, or in a trance, is supported by the submersible observations mentioned above, that many mesopelagic fish and squid were apparently 'asleep' and remained so until the submersible came very close to them when, suddenly, they 'awoke' and swam rapidly away. Whether 'asleep' or 'in a trance' is the best description of this behaviour, requires further study. The 'asleep' swimming of mesopelagic fish raises the intriguing possibility that this habit may conserve *mental* energy even in tiny leptocephali.

Evidence from otoliths

Like other fish, leptocephali and glass eels have in their skulls ear bones or 'otoliths'. These are tiny – smaller than a pinhead – but can be extracted, polished and viewed under a scanning electron microscope (SEM). Believe it or not, under a magnification of × 2000, *daily* growth rings can be seen on these otoliths. When the SEM technique was discovered, biologists eagerly examined the otoliths of glass eels, keen to discover – at last – how many days the larvae had taken to journey from the Sargasso Sea to Europe. The biologists were disappointed. They found that clear daily growth rings occurred near the centre of the otolith and less-clear rings of a different appearance on the outer part of the otolith – but that between these two sets of rings was a zone of diffuse appearance in which no daily rings could be distinguished at all (Figure 5). The inner rings become narrower as one counts away from the centre and beyond about the 70th ring no further rings can be seen. The rings at the edges of the otolith number about 50.

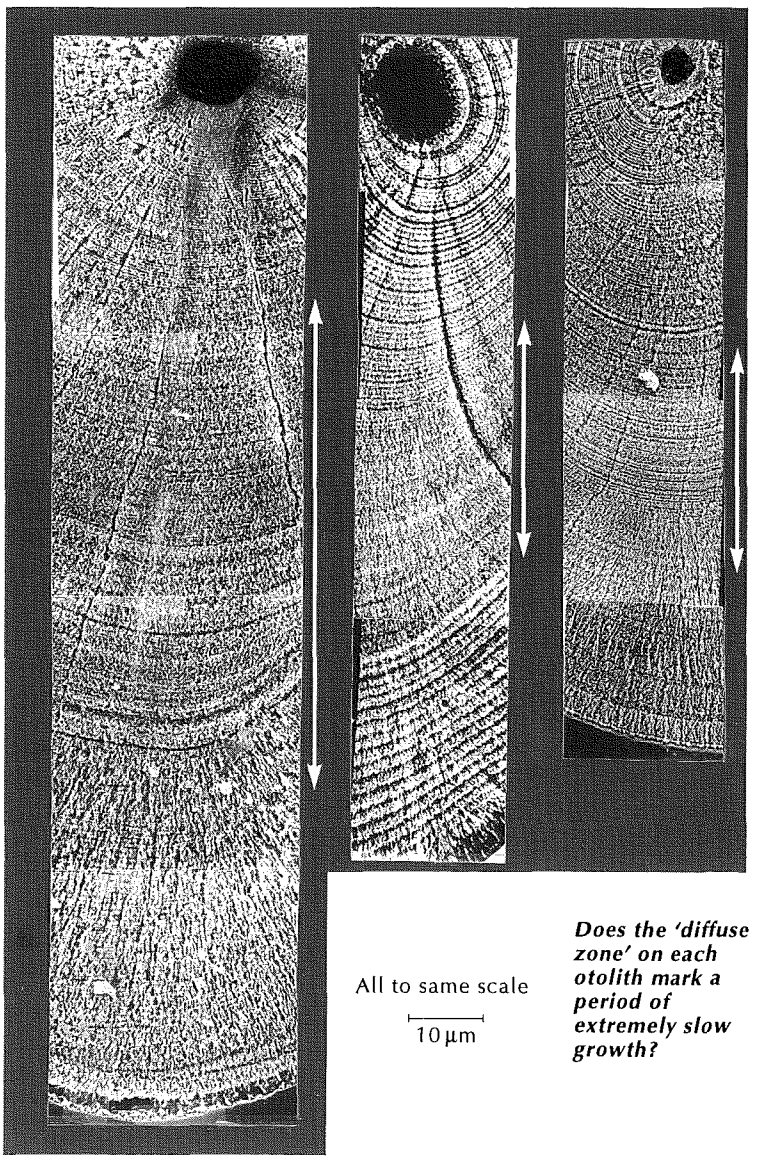


Figure 5 *Otoliths of glass eels of* (from left to right) Anguilla anguilla *from Portugal,* A. marmorata *from Taiwan and* A. rostrata *from Haiti (all × 1000). Brackets mark the approximate limits of the 'diffuse zone'. (These otoliths are < 1 mm in diameter.)*

(Photos: Wann-Nian Tzeng, Chia-Hei Wang and Jay C. Shiao)

I believe that the 'diffuse zone' is almost certainly made up of daily growth rings, which are too thin to be counted. The extreme thinness of these growth rings suggests that leptos in mid-Atlantic grow very slowly, and have a very small daily food intake. Plankton hauls and satellite images of chlorophyll distributions show that in mid-Atlantic organic material is sparse, and this could mean that, to conserve energy, leptos may remain at a depth of ~300m for many months or even years, and in mid-Atlantic may not perform diel vertical migrations (cf. Figure 4).

So, the diffuse zone on glass eel otoliths may mark a long period of very slow growth. The fact that the otoliths *are* growing shows that the leptos are obtaining food each day, but only very little. This fits well with my theory that leptos drift for months or years in the almost food-starved central North Atlantic, where they can only find enough food to barely survive and to move their tails, and grow very slowly.

Figure 5 (on previous page) shows the otoliths of glass eels of *Anguilla anguilla* from Portugal, *A. rostrata* from Haiti and *A. marmorata* from Taiwan. Up till now, biologosts have failed to agree how to interpret the otolith structure of eel larvae. How do *you* interpret these otoliths?

It is not surprising that no-one can count rings in the 'diffuse zone'. If eel larvae take (say) two years and ten months to reach Europe, a diffuse zone 0.2 mm wide may be made up of about 1000 daily growth rings.

In all larvae, the number of rings near the centre of the otolith is fairly constant, but the width of the diffuse zone, the number of outer rings, and the body length and weight vary greatly. This is to be expected because during their early life all larvae inhabit the Sargasso Sea but, after that, get carried into different environments. Some reach Britain, others get carried to the Bay of Biscay; some even reach the River Nile in Egypt.

What do leptos feed on? Even this elementary fact is not known. One theory is that they eat the slowly downward-drifting faecal pellets of copepods. If leptos eat anything that drifts down from above, as some researchers have suggested, for an eel larva to drift in a vertical head-up position would be an advantage. Why? Food particles would fall directly into its mouth. Can leptos feed while they sleep?

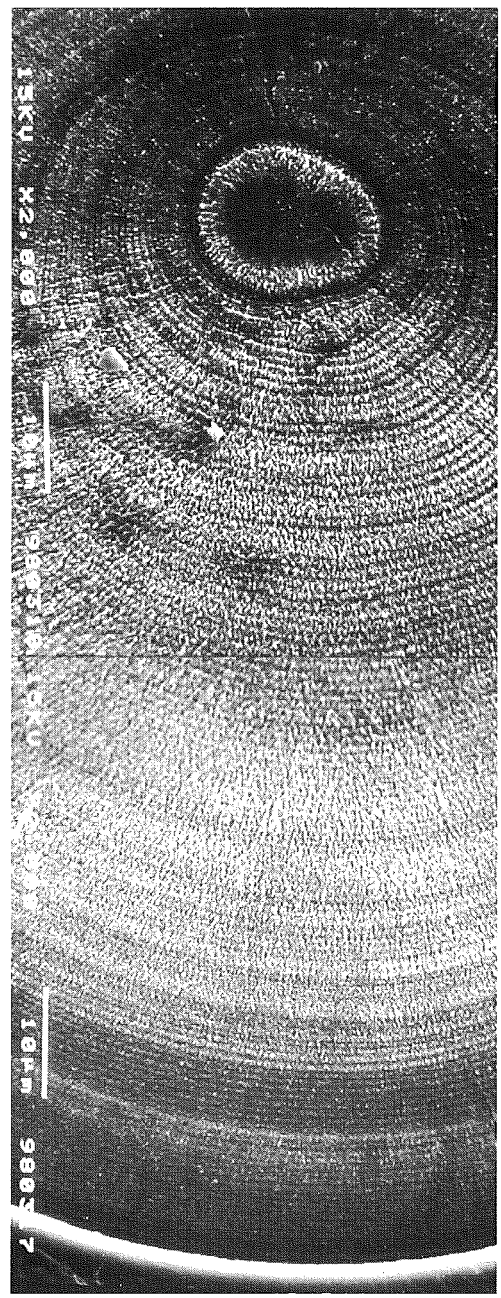
Ideas for future research

I recommend that research on eel larvae be undertaken at Bermuda, a landmass past which leptos of both *A. anguilla* and *A. rostrata* drift – one of the few solid objects between the Sargasso Sea and Europe, and one with a well-equipped biological research station, the Bermuda Biological Station for Research. The first thing I would attempt to discover is: how many daily growth rings are on the otoliths of *Anguilla* larvae when they pass Bermuda?

Conger eels deserve further study. As shown in Figure 6, the otoliths of a *Conger* eel have a continuous series of daily growth rings and no 'diffuse zone'.

In a study of eels, one does not expect to meet up with whales. Yet here is a case of convergent behaviour between eels and sperm whales. Dr Jonathan Gordon of Cambridge University, sperm whale biologist, has just discovered that sperm whales sleep in a vertical position, exactly like eel yolk-sac larvae. Both float completely motionless (Figure 7). But surely sperm whales and yolk-sac larvae must at least keep their tails moving, like a lepto? Answer: it is not necessary. A yolk-sac eel larva, thanks to the oil droplet in its head, has neutral buoyancy. A sperm whale – thanks to the huge volume

Figure 6 *Otolith of a glass eel of* Conger myriaster *from Japan (× 2000). Note that no diffuse zone is present. (Photo: Noritaka Mochioka)*



of oil in its head, plus, probably, an ability to keep exactly the right volume of air in its lungs – is also neutrally buoyant. Both, therefore, can float motionless. Yolk-sac larvae always float in vertical head-up position, but sperm whales, believe it or not, sleep both in head-up position and head-down position. (How the head-down position is achieved remains to be discovered.) If you are ever SCUBA-diving off the Azores and think you are entering a forest of grey-barked trees, it is not a forest, just a family of sperm whales having a snooze!

The nearest other fish to leptocephali in behaviour are the other elongate serpent-like inhabitants of the twilit depths of the ocean, e.g. the black scabbard fish *Aphanopus*, and the oarfish *Regalecus*. Many of these species have been seen from submersibles swimming in vertical head-up position (cf. Figure 7).

It will take many years and clever technology to prove exactly how leptocephali do travel. I believe that, as soon as a submersible approaches close to a lepto, the lepto awakes and change from vertical to horizontal swimming. Flash photos taken at five minute intervals by cameras lowered a few hundred metres below the surface may get exposures showing how undisturbed leptocephali swim.

'The next to lighten all men may be you'

All this enjoyable science came from that littlest clue – my sighting of the three glass eels swimming in vertical position off Newfoundland – from good luck and from patience. I greatly look forward to learning of new observations which prove or disprove my theory about the swimming/drifting position of leptocephali and whether or not they are asleep. If any reader can supply me with new information, please will he/she contact me? Or take the study further yourself.

Drifting and dreaming ...

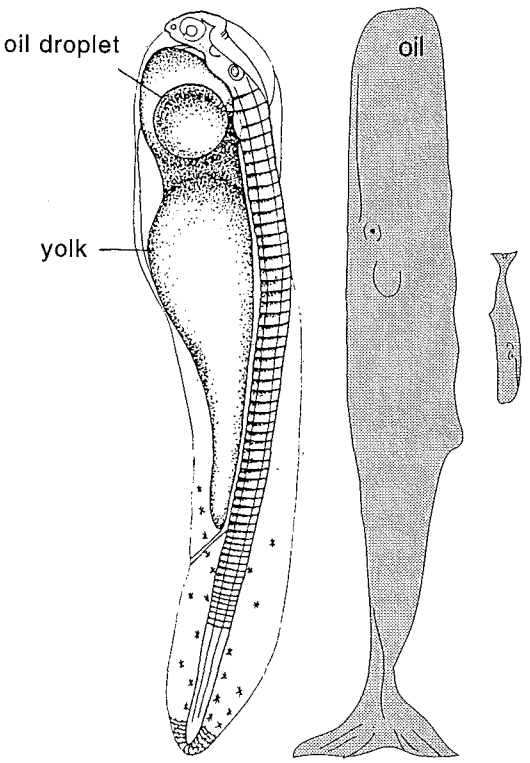
To all my colleagues – thank you for your help to date, and may your own researches be as exciting and brain-teasing as mine ...

... and while you were reading this story, the invisible invading force of sleeping leptocephali has silently drifted 200 m nearer to Europe. All in vertical head-up position ... if my theory is correct. Drifting – yes. Dreaming – who knows?

So journey on companion, when you find
No highway more, all being blind
The way to go shall glimmer in the mind.
For from the very smallest, littlest clue
Came all worth mankind ever knew.
The next to lighten all men may be you.

John Masefield

Gordon Williamson studies eels and deep-sea octopi. He lives near Inverness in Scotland. He warmly thanks the many people who help his research.



Eels 'n sperm whales

Figure 7 *A yolk-sac larva of an eel and a sleeping sperm whale both float motionless in a vertical position.*

Further Reading

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Acknowledgements
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Book Reviews

Marine Science from the Geological Society

Modern Ocean Floor Processes and the Geological Record edited by R. A. Mills and K. Harrison (1998). Geological Society, London, Special Publication 148, 303pp. £69, GSL Members £35 (hard cover, ISBN 1-86239-023-1).

The Geological Society seems to be bringing out Special Publications at an ever-increasing rate. Usually these comprise chapters based on the presentations given at a meeting. This book is no exception, the 'trigger' meeting being a two-day affair held in May 1997 under the sponsorship of the Geological Society's Marine Studies Group, BRIDGE and the Challenger Society. Inevitably such a volume ends up being a somewhat eclectic mixture. No-one is ever likely to read such a book from cover to cover, as one might a textbook written by a single author, so its value lies in bringing together related pieces of work into a single binding. Of the fifteen chapters, only three have lead-authors based outside the UK, so the book presents a predominantly British view of the state of the art. This is not necessarily a drawback, as I think we in Britain are still quite good at this sort of thing.

The first five chapters concern the configuration of the oceanic crust. Notable here is a further nail in the coffin of large magma chambers, even on fast spreading ridges, hammered home by Jenny Collier and Satish Singh on the basis of seismic inversion techniques; also a study by Simon Allerton and Chris MacLeod linking asymmetrically distributed seamounts near segment ends on slow-spreading ridges to the presence of gabbro along mantle shear zones in the Lizard ophiolite.

Next come four chapters to do with hydrothermal alteration of the crust. One is about the 2-km ODP hole 504B near the East Pacific Rise (still keeping the geochemists occupied after all these years), one about the Juan de Fuca Ridge, and two about the Troodos ophiolite. The next four chapters deal with mineralization, ranging from active massive sulphide formation on the Juan de Fuca/Gorda ridge back to the structure of vent chimneys associated with Silurian-age massive sulphides in the Urals.

The Urals feature again in the penultimate chapter that looks at the fossil record of communities at hydrothermal vents. Although vent macrofauna from the Silurian to the present looks similar (with the exception of arthropods, which are known only in modern settings) ancestor–descendant relationships are absent. This leads C. T. S. Little and co-workers to conclude that modern vents are not refuges for ancient communities and that macrofaunal taxonomic groups have moved in and out of vent ecosystems during geologic time. However, in the final chapter A. G. McArthur and Verena Tunnicliffe recognize that while many groups endemic to vent communities have recent origins, others may well be refugial remnants that have survived extinction events.

All in all, there is much food for thought in this volume. Although we know vastly more now than we did only twenty years ago, there is still much about geological processes in the ocean basins awaiting discovery or clarification.

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Tectonic, Magmatic, Hydrothermal and Biological Segmentation of Mid-Ocean Ridges edited by C. J. MacLeod, P.A. Tyler and C.L. Walker, Geological Society Special Publication No. 118, Published by the Geological Society of London, (1996). 272pp. £65, GSL Members £32 (hard cover, ISBN 1-897799-72).

This volume describes recent research on aspects of tectonic, magmatic, hydrothermal and biological processes associated with segmentation of mid-ocean ridges. Much of the work was carried out as part of the British mid-ocean ridge BRIDGE programme, and the papers were originally presented at a Geological Society meeting.

What do you get for your money? Put bluntly, 272 pages making up fifteen fairly heavy-going chapters. The papers are generally well illustrated, though the reproduction of some of the photographs is a little murky (this could well reflect the quality of the originals). Some of the photographs do stand out, however, particularly those included in the chapters on the 'Mid-Atlantic Ridge north of Kane transform' by Kate Lawson *et al.* and 'Boundary-wall faults along the Mid-Atlantic Ridge' by Eddie McAllister and Joe Cann. Both present images obtained using the then new Southampton Oceanography Centre's deep-towed side scan sonar system (*TOBI*).

The purpose of the book is stated in the preface to be '... to explore the causes and consequences of... ridge segmentation from the tectonic, magmatic, hydrothermal and biological viewpoint'. How well does it succeed in the stated objectives? Well, the papers are fairly well balanced between the disciplines, with approximately equal numbers covering physical, geological/geochemical and biological aspects of ridge segmentation. It is certainly a brave attempt to present a multidisciplinary approach to the subject, and the thematic linking of the papers will undoubtedly draw attention to the extent to which cause and effect can involve the different disciplines.

Sadly, there is little evidence of a truly interdisciplinary work. I would have welcomed some discussion of whether it is magmatic or tectonic processes which control ridge segmentation. The interrelationship of tectonic and hydrothermal activity, and the way in which they may control biological activity and its distribution is rather better described. Perhaps, being further down the information (food?) chain, it is the biologists who will ultimately provide the synthesis of cause and effect of ridge segmentation. This has not been done in this volume, nor has any attempt been made to consider the implications of the differing scales on which the various disciplines have dealt with segmentation.

So who is the volume targeted at? From a look at the references, much of the scientific information appears to have been presented elsewhere. For the academics, therefore, this is largely a re-presentation of data that would be already be available to them. On the plus side, most academics would tend to work

within their discipline, so perhaps this volume will encourage more interdisciplinary work. For the general student, the volume is somewhat dry, though there are some more general papers. The review of 'Magmatic segmentation of mid-ocean ridges' by R. Batiza is a competent synthesis. The paper by V. Tunnicliffe *et al.* 'Plate tectonic history and hot vent biogeography' may well point to the need to re-examine some concepts of past biodiversity and faunal distribution.

For this reviewer, the most thought-provoking paper is that by E. G. Nisbet and C. M. R. Fowler, 'The hydrothermal imprint on life: did heatshock proteins, metalloproteins and photosynthesis begin around hydrothermal vents?'. The concept that life as we know it may have started around hydrothermal vents, themselves the consequence of declining magmatic processes, puts us well and truly in our place.

So, is this Special Publication worth buying? For the specialists, probably not, as they will already have access to the information from other papers. For general students, there are only a couple of more general review-type papers, which nevertheless merit a read. For the interested general scientist, there is insufficient synthesis of the material to make the work of the various disciplines more accessible. For the last two groups, I feel that a library copy would suffice. Your reviewer (interested general scientist) will wait until the Geological Society publishing house has one of its periodic sales!

In summary, my initial response to this volume was that it was merely another conference volume. Subsequent re-reading mellowed this view, and, aided by an excellent preface, I took on-board the inter-relationship of the various physical, geological and biological processes which are linked, at various scales, by ridge segmentation. To make it into a benchmark publication, I still feel the need for more synthesis of the data to make the information more accessible to the student or generalist. I would also have preferred to see evidence of interdisciplinary work, rather than just multidisciplinary work. Perhaps it points the way for the development of the oceanographic sciences though?

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Geological Evolution of Ocean Basins: results from the Ocean Drilling Program, edited by A. Cramp, C. J. MacLeod, S. V. Lee and E. J. W. Jones (1998). Geological Society Special Publication 131, 336pp. £69, GSL Members £35 (hard cover, ISBN 1-86239-003-7).

This book is dedicated to Robert Kidd, who died shortly after receiving the Geological Society's Coke Medal in 1997 in recognition of his oceanographic research and his contribution to the development and success of the Ocean Drilling Program (ODP).

The editors state that the book 'attempts to provide a snapshot, circa 1995/1996, of recent scientific output' from ODP. To some extent, the content of the papers, and the division of the book into two parts dealing with 'palaeoceanographic issues', and 'structural, tectonic and sedimentary issues', reflects ODP's key scientific themes. These are the dynamics of the Earth's environment (understanding changing climates, the causes and effects of sea-level change, and sediments, fluids and bacteria as agents of change), and the dynamics of the Earth's interior (exploring the transfer of heat and materials within the Earth, and investigating deformation of the lithosphere and earthquake processes). The introduction to the book by the editors does little more than provide a summary of the abstracts of the papers that follow, and offers no comment on how the content relates to ODP's scientific themes.

The first part of the book begins with three linked papers dealing with Southern Hemisphere palaeobathymetry and Miocene bottom-water circulation, with some interesting comments on the waxing and waning of proto–Antarctic Bottom Water flow and the input of dense Tethyan outflow water. Two papers on Mid-Cretaceous and Plio-Pleistocene Radiolaria follow, the first of which discusses how nutrient supply, sea-level changes and dissolved oxygen concentrations may have influenced the evolution of this group of plankton. The second of these papers has a biostratigraphic focus.

To this biassed reader, the next three papers dealing with the record of millennial and sub-millennial scale climate changes are the highlight of the book. Maslin *et al.* compare the oceanic and ice-core records of cold events during the present and last interglacial. They find no evidence to support the interpretation of one of the Greenland Summit ice cores as indicating rapid cooling and warming during this period of time. In 1993 the ice-core workers made rather spectacular claims that the isotopic records in their material indicated major climatic instability during the last interglacial, and implied that we might face similar changes today. There is now general agreement that basal parts of the ice cores are disturbed by ice tectonics, and so we can relax – or can we? Maslin *et al.* show good evidence for a ~400 year 'cold snap' during the last interglacial in the North Atlantic area, so might the same happen during our interglacial?

A key contribution of ODP has been to provide high-resolution records of climate change through the use of piston coring techniques. Schaaf and Thurow describe two high-resolution records for the last 30 000 years from the Santa Barbara Basin off California and the Guaymas Basins in the Gulf of California. They analysed changing grey-scale values obtained from digital colour scanner records of the cores, and found various periodicities within them. A clear 1500-year cycle is present in both records. Since their paper was written, this has been found in a variety of proxy climate records from oceanic and lake sediments. They also demonstrate the presence of 86-, 22- and 11-year cycles related to solar activity, and 3–9-year El Niño cycles. A second paper by Maslin proposes that the influence of Heinrich events (short periods when armadas of icebergs advanced into the Atlantic; see *Ocean Challenge*, Vol. 7, No. 3, pp.34–9) can be discerned in the sedimentary record within the Amazon Fan. The first part of the book ends with a paper discussing the age of mass transport deposits on the Amazon fan, and another describing the mineralogy and geochemistry of distal sediments of the Bengal Fan.

The mix of papers in Part 2 is much more eclectic than that in Part 1. The first paper describes what has become the *de facto* reference section for the upper oceanic crust. Four cruises of ODP and its predecessor DSDP (the Deep Sea Drilling Project) progressively drilled deeper to provide a 2111 m record beneath the Costa Rica Rift. Two papers deal with volcaniclastic gravity flow sediments and the role of hydrothermal fluxes into these and associated pelagic sediments drilled in the Lau Basin in the south-west Pacific. These are followed by a review of drilling results south of Cyprus which document what happens when

a seamount and associated carbonate platform are subducted. This paper also describes the occurrence of mud volcanoes less than one million years old that were probably the result of the release of gas from overpressured zones caused by plate collision. A paper on Rare Earth element anomalies in the accretionary prism off Japan is followed by a valuable overview of how borehole images, obtained by instruments measuring resistivity at the millimetre scale around borehole perimeters, can be used to obtain stratigraphical, sedimentological, and structural information. These imaging techniques are particularly useful when core recovery is low. The book ends with a statistical review of hydraulic piston-coring of sediments undertaken during ODP legs 101–149, showing that results of this coring method could be used to determine the load-bearing properties of sediments.

In summary, I would liken this book not so much to a snapshot of ODP activity, as to a random sample of frames from contact prints of films taken on a number of cruises. It is, therefore, difficult to recommend the book to any particular group of readers, be they geoscientists who would like to learn more about the achievements of ODP, or aficionados wishing to learn in depth. Both would be faced with the problem that the apparent random sampling has resulted in a book with no underlying scientific theme save that the data discussed were largely obtained from one unique ship – the world's largest floating geological laboratory.

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Beach Management by Eric Bird (1998). John Wiley & Sons, 292pp. £45.00 (hard cover, ISBN 0-47196-337-2).

There can be no doubting the importance of beaches: they form a buffer between sea and land, limiting the rate of coastal erosion; and, especially if wide and sandy, form a universally attractive recreational environment whenever the weather is reasonably warm. Thus beach-management is interdisciplinary, covering as it does both sand and people.

In an earlier book, the essence of which reappears here in Chapter 3, Eric Bird has shown that beaches worldwide are losing volume – becoming narrower and lower and less and less valuable, especially at high tide. Couple that with the intense recreational use of many beaches and the need for beach management becomes clear. This is a book that summarises the context in which beaches might be managed so as to fulfill the two roles better than in their unmanaged state.

The book is comprehensive, and like other books on the coast by this author, generously provided with examples from all over the world, especially Australia, the UK and the USA. These are of great value, given the scattered international coastal literature; the bibliography here includes some 400 references. The book is pitched at the general reader, with little quantification and few formulae, and in that sense may disappoint some of the more scientific of our coastal managers. On the other hand, it is likely that most managers are primarily concerned with public use of the beach, and consult experts for advice on beach nourishment or such structures as groynes and sea walls.

The first two Chapters cover the geomorphology of beaches: the sediments themselves (and their sources) in Chapter 1, beach processes and morphology in Chapter 2. With Chapter 3 on the persistence and causes of beach erosion (where Bird lists 20 reasons why beaches erode), these make up just under half the text. Long books have been written on these topics, but the approach here provides a suitable context for the more applied chapters which follow.

One-third of the book (Chapter 5) covers beach nourishment – the addition of sediment (usually sand) to eroded beaches to restore their volume and thus their value. The conservatism of British coastal engineers (and, in the past, the funding rules of the MAFF) mean that UK experience is limited, so it is particularly valuable to have the evidence from 90 of the many hundreds of schemes worldwide as the basis for a study of the problems that may be encountered in beach nourishment. It is not a panacea, but if the twin aims of the needs of coastal defence on the one hand, and of the holidaymaker on the other, are to be met, it is about the only effective remedy available where beaches are eroding.

This point is made briefly but persuasively in Chapter 4 (the shortest in the book), which reviews coastal engineering structures and their limitations. The problem is that in building structures to stabilise the coastline, engineers almost invariably accelerate the existing loss of beach sediments, by steep walls which reflect wave energy and speed up beach loss, or groynes which divert longshore drift from the beach into the sea. I liked the author's comment on a picture of Seaford: 'by mid 1980s the shore was little more than a museum of unsuccessful coastal engineering'. He surely says too little about the huge cost of coastal engineering structures and the cost/benefit analyses used to justify them.

The last chapter covers the behaviour of people on beaches and the legal environment of beach management. Hazards range from litter or algal blooms to nudists, and again it is the examples of bizarre behaviour and equally bizarre management that provide interest – the City of Bayside near Melbourne has a sign on the beach prohibiting eight activities, from cycling to drinking alcohol, and with the legal requirement, either to secure your beach sunshade with a 5 kg bag, or to bury the shaft attached to a 30 cm ply disc 30 cm deep in the sand! But the commercially managed evening parade of fairy penguins (*sic*) viewed from a concrete grandstand on the beach at Summerland Bay, Victoria, shows where the RSPB may yet be heading.

I have a few other quibbles which could be met in a second edition. The ϕ scale of sediment size is used in Chapter 1, but there is no explanation about why this scale is of value. Bird's advice on grain size for nourishment is not consistent: generally he advocates 'the same as before', but at one point suggests the more common 'preferably a little coarser'. He does not cover the various funding arrangements that utilize central taxation to subsidise local expenditure on coastal engineering, and may make it easier to build in concrete or dump huge boulders than to work with nature in a sustainable way. And his brief look to a future with increasingly rapid sea-level rise (pp.210–11) deserves expansion.

In recent years, important advances have been made in the management of beaches. Sand nourishment began early in the USA (California had three schemes prior to 1940) but has only been widely adopted in the second half of this century. The Dutch have shown how their low-lying country can be protected along most of the coast by sand (in beaches and dunes) and on the landward side by a clay bank – no hardwoods from the rainforest or reflective concrete walls. Yet in the name of coastal protection, horrors abound. Bird has a picture of

the narrow depleted beach at Minehead protected by sheets of roofing iron against wave attack! As he comments, in the understatement of the book, it may have helped, but the recreational value was reduced! He also shows the shore at Littorale di Pellestrina, near Venice, where persistent erosion has led to the replacement of the beach by a slope of large limestone blocks. The current predilection of British coastal engineers to place ten and twenty ton boulders of imported rocks on our holiday beaches is equally distasteful. Yet how many of us have objected when we have met such inappropriate material at our local seaside resort? Perhaps through this book our coastal managers will learn how to do better in future.

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Blind Man's Bluff: The Untold Story of Cold War Submarine Espionage by Sherry Sontag, Christopher Drew and Annette Lawrence Drew (1999). Hutchinson, London, 353pp. £15.99 (hardback ISBN 0-09-180075-7).

One of the first things that drew me into oceanography was Dr Robert Ballard (then at Woods Hole Oceanographic Institution) finding and photographing the wreck of the RMS *Titanic*. I thought it was incredible that you could do such a thing in the depths of the Atlantic Ocean. As I got more interested in science and understood how it worked, I began to wonder what you could achieve if you invested sums of money similar to, say, the American space programme, in oceanographic research. This book has shown me the answer to that question.

Perhaps the best example is the story of operation 'Velvet Fist', described in great detail. In 1968 American intelligence services figured out that the Russians had lost a submarine in the Pacific Ocean – and, more importantly, that the Russians did not know *where* they had lost it. The Americans then used acoustic data from a network of fixed acoustic hydrophones on the sea floor (the SOund SUrveillance System or SOSUS network) to determine where they thought the submarine had sunk. Once they had a search area they sent out a special operations nuclear submarine – USS *Halibut* – to find it. *Halibut* had received a special refit in 1965 that cost $70 million then, and involved the fitting of a 6000-m cable on a unique winch system with a complex camera and sonar 'fish'. With a search area and such a platform, the Americans found the submarine in over 5000 m of water and took more than 22000 photographs. It turned out to be a Soviet GOLF carrying three nuclear missiles. That really is worth thinking about. *Titanic* was 270 m long, 46000 tons and in 3800 m of water, and Ballard started with a position. The GOLF was just under 100 m length, about 2800 tons and lay at over 5000 m depth. The story gets a bit more surprising when the CIA decided, against scientific advice, that recovering the whole submarine was possible. They funded the building of the *Glomar Explorer* at a cost of something like $500 million and, ultimately, mostly failed. But there are the astronomical sums of money I had speculated about – NASA estimated that the entire Mercury space programme cost something like $400 million. Finding, photographing and trying to retrieve this submarine had probably cost more.

The book details several such 'intelligence' stories and along the way I learnt why there was funding in the 1980s for oceanographers to work between Iceland and the UK, and on Arctic sea-ice. In both cases, of course, without the sums of money I have mentioned! I also learnt a reasonable amount about submarine warfare. I don't think I feel as confident as I used to about how such things work.

Of course, this book is heavily skewed towards the American experience and Cold War politics, but there are also two accounts of named British submarines being involved in underwater collisions with Russian submarines in the 1980s.

I recommend this book, but it made me feel a little naive. I know that the SOSUS network is now providing data on seismic events and cetacean tracking. Also that the Americans have been running retired attack submarines as research platforms in the Arctic (SCICEX). Even the *Glomar Explorer* has been recommissioned and converted to a drilling ship at a cost of $200 million (interestingly this is what the Russians always assumed she was). It does leave me wondering about other Cold War activities that may yet be publicized, and also sad at the thought of what it takes to really bump up research funding.

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Rigs, Lies, and (bits of) Videotape

Decommissioning the Brent Spar by Tony Rice and Paula Owen (1999). E. & F. N. Spon (Routledge). 182pp. £14.99 (flexicover, ISBN 0-419-24090-X) and £45 (hard cover, ISBN 0-419-24080-2).

How long ago it seems. The *Brent Spar* first entered my life via a TV news item in which a Greenpeace spokesman was describing the 'obscenity' of sinking a huge piece of ironmongery (plus quite a bit of concrete I learned later) in the deep sea, along with its petroleum residues, not to mention heavy metals and – shock horror – radionuclides. I was deeply impressed, especially as the *Spar* belonged to Shell, who seemed to me to be behaving rather badly in Nigeria at the time, if media reports were even halfway believable. My sympathies thus lay with the protestors for quite a while. Then somebody remarked that there were tens (hundreds?) of millions of tonnes of shipping all over the ocean floor, mostly (but by no means exclusively) sunk during two World Wars; and a letter in *Nature* pointed out that black smokers pour millions of tonnes of heavy metals into the deep sea every year. I began to wonder if Greenpeace and their allies were overreacting.

This racy little book confirms that they were, and it reminds us also that the saga only began four years ago – golly, how time flies! Be that as it may, do you like stories about chicanery, vested interests and political expediency, all seasoned with large sprinklings of bumbling incompetence? Does this book tell such story? To quote the immortal (though fictional) Francis Urquhart, 'You might think that – I couldn't possibly comment.'

However, I *can* reveal that phrases like 'monumental errors of judgment' and 'blunders, confusion and misinformation' appear in the book, and there are several amazing vignettes (including Tony's own 'worms story', featured in *Ocean Challenge* Vol. 6, No. 2, pp.7–9) that together make a fine case study of how scientific advice can be distorted or ignored or both.

I was pleased when the book confirmed my suspicion that the 'radioactivity' side of the scare stories was grossly exaggerated: radionuclides leached from clay minerals come up boreholes with the oil, dissolved in formation water. They are then

precipitated in the scale (or 'fur') that forms wherever water flows through pipes or into tanks. Clay minerals are not renowned for their lethal radiation levels in the first place (would we use bricks and ceramics if they were?), so the scale gives you about as big a dose as you might get living in a city built on granite.

I shall also reveal that the book tells us what the final resting place of the *Spar* will be – or at least what it was intended to be at time of writing. Go on, admit it, you'd not given the matter any thought, had you? It's been out of the news for at least the last couple of years! After all its wanderings as a redundant piece of junk that nobody wanted (a grotesque picture, like being completely unknown when alive and only becoming newsworthy as a corpse!), *Brent Spar* will eventually end up as part of a ferry terminal in Norway. If you want to know how that will be done, buy the book and read it – the paperback price isn't that high, and you will learn a great deal about the interaction between Science and Government. The *Spar* may be largely history, but BSE and GMOs are very much with us still, and there are lessons to be learned.

At 14 500 tonnes, the *Brent Spar* was 'about as big and dirty as a fairly average ship', so it really is astonishing that so much fuss was made over it, given – as I remarked above – the vast numbers of 'average ships' that litter the sea floor. Among many other things, the *Brent Spar* story helps to explain why the oceans haven't been grossly polluted by centuries of seafaring activity, especially warfare and especially since the Industrial Revolution. Thus, even in an area like the North Feni Ridge (the chosen dump site that was never used), where bottom currents are quite fast (about 0.5 $m s^{-1}$) and the sea-bed is quite hard in consequence (i.e. not muddy), the scientific concensus was that mobile pollutants leaked or leached from the *Spar* would have affected a roughly 2 km^3 volume of ocean for ten years or so, even if the structure had broken up on hitting the bottom. Of course, lots of ships are much bigger than 14 500 tonnes (supertankers, bulk carriers, aircraft carriers, the *Titanic*, and the like), but rough and ready back-of-envelope sums suggest to me that all of the sunken ships in all the oceans together would affect no more (and perhaps less) than a thousandth of a percent of the total volume of water in the oceans at any one time.

There is quite a lot of discussion about BPEO, and it took me some time to work out that this means Best Practicable Environmental (not Economic!) Option. The various options for disposing of the *Spar* are set out in enthralling detail, and you realize why it would have been horrendously costly, not to say risky, to turn the thing on its side and tow it ashore for dismantling on land.

The problem of what to do with redundant drilling and storage rigs will be with us for some decades yet. In exploring this issue the book reinforces my own doubts about the present British Government's endorsement of policies that prohibit deep-sea disposal under all but the most extreme circumstances. Actually, most rigs are in shelf waters, and their superstructures are made of metals that can be re-used and recycled and are too valuable to dump, so they'll be recovered anyway – and some rigs could even be *re*commissioned (*Ocean Challenge*, Vol. 8, No. 3, pp. 6–8). But what of the (largely) concrete bases? Why can't they be left as artificial reefs? It's a strategy that's been advocated by many experts over the years (e.g. *Ocean Challenge*. Vol. 7, No. 2, p.22). It would be a sorry state of affairs if the legacy of the *Brent Spar* were to be a moratorium on all deep-sea dumping. That would indeed be a triumph of earnest bureaucratic dogma and/or of environmental extremism over pragmatism and common sense; but it should occasion no surprise, for such scenarios recur time and again in this book. They would make depressing reading if they were not so entertainingly described. Enjoy.

John Wright

(Marine) Scientists of the World Unite, You Have Nothing to Lose but your Funding

The Ocean Our Future (The Report of the Independent World Commission on the Oceans) (1998). Cambridge University Press. 247pp. £12.95 (flexicover, ISBN 0-521-64465-8) and £35 (hard cover, ISBN 0-521-64286-8).

This is such a *worthy* work, but who (or indeed what) is it *for*? I have to confess that my attitude to the book is schizoid. It is overwhelmingly bland, even though it is well-written for the most part, in places even quite interesting. It expresses statements with which I wholly agree, yet presents them in a way that suggests there will be little concerted international action to rescue the oceans from what many perceive to be a progressively worsening plight.

Its initial launch was at Expo 98 in Lisbon, to celebrate the official Year of the Ocean. The Independent World Commission on the Oceans was formed in December 1995, as a result of initiatives from the UN, UNESCO and several governmental and non-governmental organizations. The Commission was charged with investigating the state of the oceans from an integrated multidisciplinary perspective. This book is the result of the ensuing three-year investigation by the Commission (chaired by Mario Soares, one-time President of Portugal), and it has been translated into eleven languages. The report addresses the following major concerns:

- promoting peace and security in the oceans
- the quest for equity in the oceans
- ocean science and technology
- valuing the oceans
- public awareness and participation
- movement towards effective ocean governance.

The six main sections addressing those concerns occupy the first 161 pages, the rest is Annexes of useful information and statistics about marine and maritime issues. The Annexes cover aspects as diverse as marine biology, history of ocean exploration, coastal and island populations, major naval forces, marine protected areas, sources of pollution, the work of the Commission (including a list of the Commissioners), a bibliography and list of acronyns (essential!), plus an index. The level of information is fairly rudimentary, but useful nonetheless.

The main part of the book is packed with quotes that are either unexceptionable but almost wholly anodyne; or incomprehensible:

'Ocean science will have to become more holistic, more interdisciplinary and more international.' (p.77)

'Full advantage should be taken of regional organisations and programmes for the sustainable management of marine and coastal areas, including regional mechanisms for dispute settlement and prevention and regional "upwards harmonisation" (*sic*) and implementation of standards.'(p.154).

'The oceans must be regarded as a common resource to be used and managed in the interests of all people. In this respect, 'all people' should not be considered as an abstraction, but

rather as an expression of the rich diversity inherent in the human adventure (*sic*)' (p.56).

'The right to participate in ocean governance thus implies the acceptance of, and compliance with, the duty to respect the rights of others, neighbours, humanity as a whole, and future generations.' (p.130)

'Worldwide the value of ocean resources ignored in market transactions is very high, and the potential cost to humanity when markets for coastal and marine resources fail is serious enough to warrant serious international concern.' (p.104)

In short, the book tells us what we already know to be wrong with the oceans (pollution, overfishing, piracy, declining biodiversity, effects of human-induced climate change, inequitable exploitation of marine resources). Its message is that 'All shall be well, and all manner of things shall be well', provided we unite in becoming decent, caring and responsible human beings and set about taking proper care of the oceans, thereby Saving the Planet.

The Commission's nine vice-chairmen and over 40 members came from nearly as many countries, and additional input to the Commission's deliberations was provided by 100 or so 'experts', probably drawn from another couple of dozen countries at least. How can you reach consensus on anything when so many national vested interests are represented? Silly question, you have only to look at the UN to see the answer. No wonder the book contains so many uncontroversial and largely predictable platitudes. No wonder I am schizoid about it.

Take just a couple of the burning issues that affect the marine environment.

The book does actually say that states should look to reducing CO_2 emissions before thinking about disposal in the deep sea (p.90). Yet the writers must be well aware that the nearest most nations will get to reducing emissions is to participate in emissions trading. That's the international scam which allows developed countries emitting lots of CO_2 to buy 'carbon credits' from developing countries, whose emissions are perforce lower – thus enabling the rich countries to continue 'business as usual', while the poor use the money to develop their industries and thus increase their own emission levels. Oil companies are busier than ever, and although BP has started to invest in solar technology and recently announced they'd stop flaring gas in their Alaskan fields, they nonetheless confirmed that they'll continue extracting as much oil as they can from their fields. Another oil giant, Esso (Exxon), does not even acknowledge that humans have anything to do with climate change. None of this gets mentioned in the book, perhaps because it's difficult to invent the right sort of meaningless political statements that won't upset somebody.

One obvious way of reducing CO_2 emissions is to expand nuclear energy production, even though there are already vast tonnages of radioactive waste sloshing around the world – some of it in the oceans. All the same, not long ago I heard a British politician say that nuclear energy could be a 'green solution to the world's energy problems'. Are you there, Dr Strangelove? On this subject, the book provides only the startling revelation that the oceans are threatened by several sorts of waste, including radionuclides.

One of the latest examples of a rich nation exploiting a poor one was the contract (signed in May) between a US fishing company and the Pakistan government to take 400 000 tonnes of fish a year from coastal waters off Baluchistan. Local fishing communities are naturally upset, claiming their livelihoods are threatened. Nobody will intervene, any more than they did when millions of hectares of mangrove swamps were destroyed to set up prawn-farming enterprises in Central and South America and the Far East. 'The Quest For Equity in the Oceans' briefly describes such situations, but the tone is 'Oh dear, isn't it dreadful'. No suggestions are made about how 'traditional fishing communities' might be helped or protected from exploitation and environmental despoliation.

Meanwhile thousands of albatross continue to be killed in the Southern Ocean by long-line fishing; similar numbers of marine mammals and turtles die in Pacific drift nets each year; declining seabird populations in the North Sea are attributed to industrial fishing for sand eels. The book tells us that modern fishing practices are wasteful – don't quite a lot of people know that already?

Or do they? In mid-June of 1999, it was reported in the press that the EC was launching a new £150 000 (EUR 230 000) study of why fishermen throw so many dead fish back into the sea to rot (hundreds of thousands of tonnes each year). The Commission seems to be unaware that the EU's very own Common Fisheries Policy requires fishermen to discard all fish of species for which no EU quota has been allocated; and if they do have a quota they must discard any excess. All EU bureaucrats should be required to study selected works of the late great Franz Kafka.

Three years of effort and probably large sums of money went into this book – and for what? A number of people will read and no doubt approve the sentiments (as indeed I do), nod sagely and agree that Something Must Be Done. Sadly, I believe that's all that will happen. That is not to denigrate (far from it) the numerous monitoring and conservation initiatives of the kind described elsewhere in this issue (and in other issues) of *Ocean Challenge*. It is simply that – even taken together – they are not enough to make a difference; and the reasons for that are fairly obvious.

As globalization grows apace, everything relates to everything else more than ever before. So, immediately enforcing, say, a 50 per cent cut in mechanised fishing effort, to conserve seabirds, marine mammals, and/or artisanal fisheries, would wreck the fishing industries of several industrialised countries. Worse, imposing, say, a moratorium on further offshore oil exploration to curb greenhouse gas emissions, would destroy the global economy. The immediate result of such draconian measures would be far worse than the effects of continued gradual climate warming or of running out of fish at some future date. The very fabric of global society could crumble almost overnight.

Which brings me back to my (mock) rallying cry at the head of this review. Scientists are as much a part of the fabric of global society as anyone else, with careers and prospects, families to support and standards of living to maintain, not to mention their research funding. There are several threats to Life on Earth arising from the way we live now, but they will take years, perhaps decades, to materialise. If scientists did indeed unite and campaign successully for implementation of drastic measures to avert one or more of these threats, they would lose a whole lot more than their funding in the ensuing economic collapse – what's more, nobody would thank them.

John Wright

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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.

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

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