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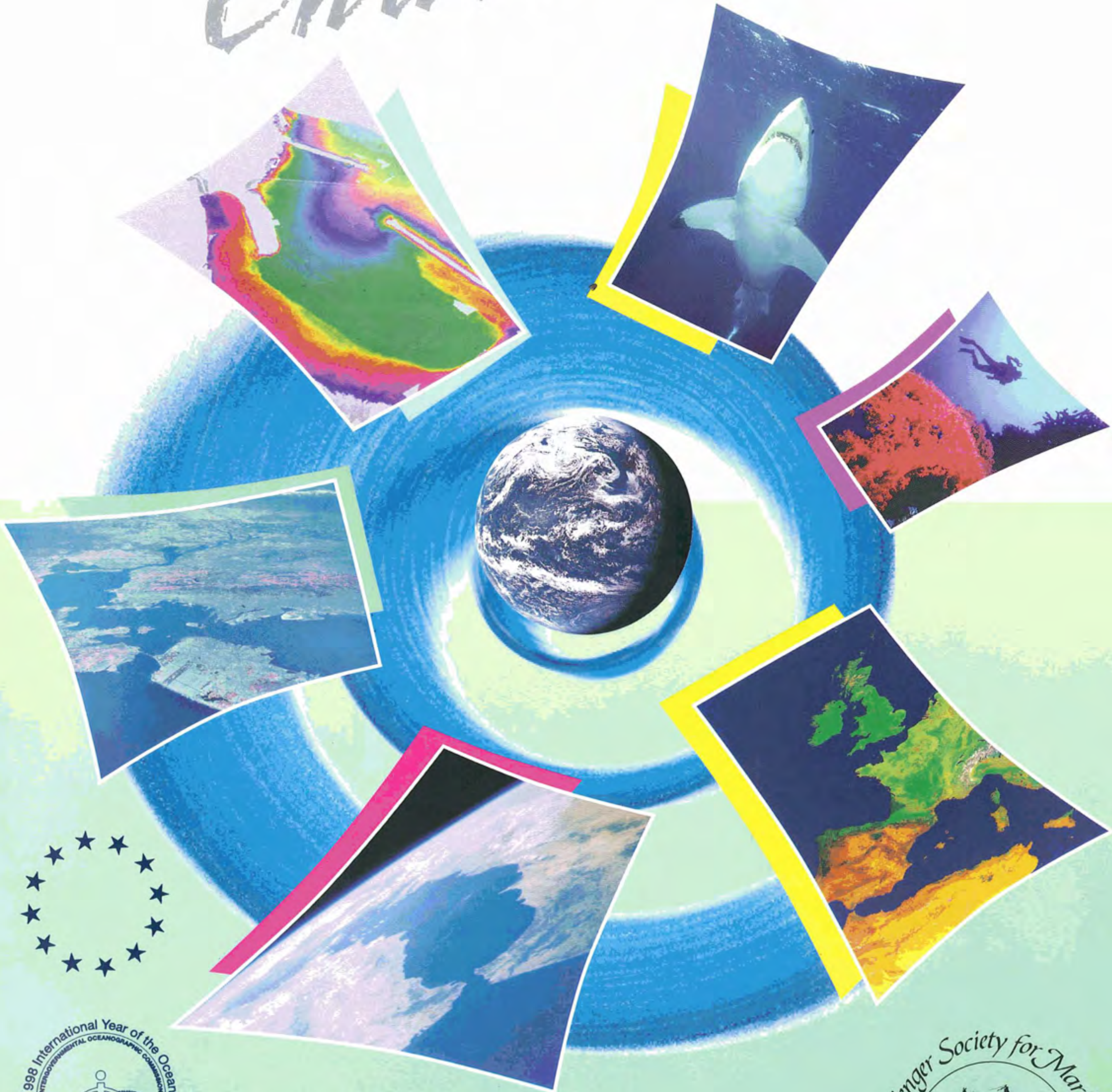

1998 International Year of the Ocean
Intergovernmental Oceanographic Commission
UNESCO

The Challenger Society for Marine Science

Volume 8, No. 2, 1998 Special European Issue

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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

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Printed in the UK by Halstan & Co. Ltd, Amersham, Bucks

ISSN 0959-0161

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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.

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A MESSAGE FROM THE PRESIDENT OF THE CHALLENGER SOCIETY

It is a great pleasure for me to introduce this first European issue of *Ocean Challenge*. The Challenger Society Council has been discussing such an initiative for several years now with a view to helping to provide a forum for discussing European concerns. We should thank Hjalmar Thiel for his patience and resourcefulness as Guest Editor for this issue. In bringing contributions together, he and the editorial team have experienced not only the generous co-operation of the authors, but also strong support for better communication between marine scientists in Europe from officers in the MAST Office and the European Science Foundation. This enthusiasm is expressed in the scope and impact of the papers that are published here. We have news items and articles from a variety of countries (Denmark, Germany, Norway and the UK, among others), covering *both* marine science of particular relevance to Europe *and* issues of global concern.

Given the lengthy gestation time of such publications, the timing of this European issue is most propitious. 1998 is the International Year of the Oceans which has triggered many international events, not least the ambitious Euro '98 celebrations in Lisbon with a strong maritime theme. There are also significant movements afoot to strengthen the links between marine scientists in Europe. As reported in the previous issue of *Ocean Challenge*, significant steps have been taken towards the establishment of a European Federation of Marine Science and Technology Societies (EFMS). A time-table has now been agreed for the build-up to a formal signing of the Articles of Federation in Paris in December of this year. Five countries (UK, Germany, France, Sweden, Finland) are already committed to establishing the EFMS, and half-a-dozen more (Italy, Portugal, Iceland, Norway, Denmark, the Netherlands) are considering the possibility of joining the founding group. The Challenger Society is making a determined effort with its partners in Europe to ensure the successful establishment of the EFMS. This European issue of *Ocean Challenge* is another step towards cementing the close working relationships that have been established in this process.

A recent editorial in *Nature* (**393**, pp.607, 614–15, 1998) has given the concept of a Federation strong support from an authoritative, if unexpected, quarter. The conclusion is summarized in the following quotation: 'In short, as long as there are some strong national societies in its discipline in Europe, a federated European Society allows the community to get the best at both national and international levels.' The reasoning behind the formation of the EFMS was presented at the European Marine Science and Technology Conference in Lisbon in May 1998 by Thomas Höpner, President of the Deutsche Gesellschaft für Meeresforschung. He indicated that 'the new Federation is prepared to act as the link between the national societies and the agencies of the European Union ... in both directions.' This European issue of *Ocean Challenge* should help to forge that link.

We intend that other European issues will follow. I therefore encourage colleagues in all the countries to which this issue is circulated to send proposals for articles and for themes for future European issues. Ours is a truly international area of science and therefore demands a strong international expression of its potential and its concerns.

New tricks for old dogs?

The Third European Marine Science and Technology Conference

John Patching

At the end of May, a wide selection of those involved in all aspects of European marine science and technology assembled in Lisbon for the Third European Marine Science and Technology conference. Previous conferences, in 1993 and 1995, were organized by MAST (the Marine Science and Technology Programme of the EU) and Euromar (an industry-led programme for the development and exploitation of Europe's advanced marine technology, which operates under the EU Eureka initiative). These first conferences were referred to as 'MAST Days and Euromar Market', a clear indication that they were intended to present the achievements of EU-sponsored R&D to potential clients. The exploitability theme was also strong at the Lisbon conference which was organized to coincide with the Expo '98 exhibition in celebration of the International Year of the Oceans. However, this time, in addition to MAST and Euromar, the range of EU sponsors was expanded to include FAIR (concerning Aquaculture and Fisheries Research), and the Environment and Climate Programme, whose responsibilities include projects on coastal zone ecosystems and climate-orientated marine research in sub-Arctic areas.

As on previous occasions, the conference featured an exhibition (mainly of posters, but also with some prototypes) made up mostly of presentations of projects sponsored by the EU, but also including national stands for Belgium, France Spain, Sweden, the Netherlands and the United Kingdom. Over 200 exhibitors were featured – a great opportunity to check on work in progress in areas other than one's own, and the possibilities opened up by developments in technology, etc. Understandably, because of the nature of the conference and the wide diversity of interests represented, most exhibitors had opted for visual impact and accessibility rather than deep scientific or technological content. Nevertheless, the displays provided a clear demonstration of the breadth and depth of European marine R&D. Equally impressive, but of more lasting value are the six (!) volumes published in connection with the conference; these contain synopses and lists of partners for all current marine science and technology projects (including AIR and FAIR) sponsored by the EU (see end* for further details). Good value for 78 ECU!

As the conference progressed, however, it became clear that its objective was not merely to act as a showcase in which to present achievements. Had this been the sole intention, the list of attendees would seem to indicate that the event was largely preaching to the converted. A major strand in both lectures and discussions concerned strategies for exchange of ideas and information between all those involved in matters marine: the scientists and technologists of various disciplines, the EU, government agencies, policy-makers and clients in the broadest sense (small and medium-sized enterprises, the European in the street, etc.). Much time was also spent considering the way forward for marine R&D, especially in the context of the Fifth EU Framework programme which will commence shortly. In this connection, it should be noted that a further sponsor of the conference was the secretariat of the European Marine and Polar Science Boards (EMaPS) which operates under the aegis of the European Science Federation. Many will be familiar with the role of EMaPS in sponsoring 'think tanks' and publishing reports on various aspects of policy and co-operation within European marine science. Several discussion sessions were accompanied by an EMaPS position paper (see pp.20–21).

The opening session consisted of a plenary presentation on the Oceans and Climate Change by John Shepherd (Southampton Oceanography Centre). This was clearly intended for a general audience and was an excellent example of how to communicate with non-experts. The importance of the oceans in creating a habitable planet, and their influence on our environment (via the atmosphere and climate), was explained, and threats to the oceans by pollution, over-exploitation and climate change described. John pointed out that the oceans are still relatively unspoilt (except in some coastal and estuarine regions) and are a dynamic biogeochemical system which is capable of coping with exploitation by humanity *if* we can study and understand the system, control damaging activities and find a balance between exploitation and protection. Some examples were given of this approach. A changeover to a hydrogen economy could reduce carbon dioxide emissions, but the generation of hydrogen by nuclear power or the gasification of coal creates its own waste disposal problems. Greater understanding of residence times, dispersal and ultimate fate, and effects on biota, are needed before new proposals for waste disposal by ocean dumping can be initiated. Cost/benefit decisions must be made on the sustainability of marine resource exploitation and its impact on the environment. These are examples of the challenges facing us, and much of the conference was taken up in considering how scientists and technologists could help policy makers meet such challenges by passing on what we already know, or will discover through future research.

Thereafter, the conference split up into parallel lecture and discussion sessions covering a wide range of topics in the fields of fisheries/aquaculture (fisheries research, genetics and pathology), marine science (extreme environments, biodiversity, large-scale projects, sea-bed mapping), technology (new instruments and platforms, monitoring, scientific ocean drilling), and research policy (the research/policy interface, disseminating the results from basic Research and Technological Development (RTD), the Fifth EU Framework Programme). Space, and my inability to be in several places at once, precludes a comprehensive report on the proceedings.

The session on infrastructure for research on biodiversity provided a good example of the tasks facing us in defining the way forward and communicating with the policy makers. As with other sessions entitled 'discussion meeting', this consisted of a series of presentations by provocateurs who then formed a panel to lead (and occa-

sionally dominate) the discussion. Jenine Olsen (the opening provocateur) took the definition of biodiversity beyond that of Rio '92 (genes, species, habitats and ecosystems) to include connections between these components. Questions should be asked as to how biodiversity influences ecosystem function and resilience. This would require both descriptive and experimental research. At this point I wondered what areas of marine biology were not classified as biodiversity studies! Problems to be faced included our relative ignorance concerning the taxonomy of marine (as opposed to terrestrial) organisms, coupled with a dearth of taxonomists and the fragmentation of biodiversity research in terms of goals and methodology. The discussion reflected these problems, with some time being spent on deciding exactly what should be discussed.

Edna Granéli pointed out some areas which could act as focal points for concentrated effort. These included relationships between biodiversity and eutrophication, pollution and commercial fisheries, and the ecological effects of the introduction of genetically modified organisms (GMOs), cultured fish and exotic species. Modern molecular techniques must be used to counter our relative ignorance of bacterial biodiversity, and also advance our knowledge of genetic variation among phytoplankton and its significance with respect to toxin production and bloom formation. It seemed clear that attempts to convince policy makers of the importance of marine (as opposed to terrestrial) biodiversity had met with limited success; furthermore, funding for marine biodiversity studies reflects (some would say correctly) immediate human concerns, with 90% of EU funding going to animals and <1% to procaryotes. The comment was made that we are good at documenting our ideas but are failing to transform them into funding.

The problems of communication outside of the scientific circle were featured in the session on the interface between marine research and policy. In her keynote address on taking research to policy-makers, Carol Turley delved into areas often ignored (to their cost) by 'pure' scientists. We must be able to communicate in the different languages of the public, administrators, and policy makers, and also understand their different perceptions of the nature of science. We must also understand the links between scientists and policy-makers and the implementation of their decisions. Other speakers provided examples of the research/policy interface in action. Edna Granéli told a salutary tale concerning Swedish coastal waters, where eutrophication produced a public outcry in the 1980s. A limitation on sewage-derived phosphorus discharge (previously introduced with little scientific justification) had proved ineffective. Subsequent research showed that the limiting nutrient for phytoplankton growth was nitrogen, and steps are being taken to reduce its discharge into coastal waters – an expensive and complex process because of the diffuse sources of this nutrient. There is some controversy as to the effectiveness of this approach, yet relatively little is being spent on scientific investigations which would shed more light on the limiting nutrient controversy.

At the last minute, the subject of Dr Bayona's talk was switched to the aftermath of the major accidental discharge of hazardous mining waste which had occurred during the previous month near the Doñana national park in south-west Spain. The scale of the disaster was alarming, with 8 million cubic ft of river water requiring treatment and 6000 ha of land polluted with untreated sludge containing a high concentration of heavy metals, and one could only sympathise with the science panel as they struggled to assess the extent and intensity of the spill and advise the decision-makers on monitoring and remediation strategies.

Finally to the session on the EU Fifth Framework Programme, a must for the pragmatists amongst us who are concerned with meeting the costs of our research. By now, everyone has surely heard of the major changes between the Fourth and Fifth Framework Programmes,[†] with MAST being subsumed into other categories which, we are told, move beyond the definitions of pure and applied research to become more focussed and 'customer-driven' with 19 'key actions'. It is clear that details of the implementation of the policies defined for the programme are still being worked out. I would advise readers (as we were ourselves advised) to 'surf' the EU web pages regularly for the latest information (see http://www.cordis.lu/). (See also p.26.)

One message was clear, however. Good science and innovation are no longer enough to ensure funding. Proposals must show *why* they are best carried out at the European level, for reasons of critical mass or trans-national complementarity. They must also be 'customer orientated', where the customer is defined as the EU citizen and his/her concerns for employment, environment, and quality of life. Dissemination and exploitation are matters which are set to become of major importance. Be warned, the stock answer that 'results will be published in refereed journals' will no longer cover requirements in this area. There is a new language to be learnt: 'users' of the 'product' of the project (scientists, policy-makers, industry and the EU citizen) must be identified and channels of communication set up. It was even suggested that PR consultants could be employed as subcontractors. Post-project activities must be addressed by a comprehensive implementation/dissemination plan. It was indicated that the performance of these activites would be monitored, though how the EU would penalise defaulters was not clear.

My overall impression of the meeting was that, once again, it is time for old (and young) dogs to learn new tricks. Communication is vital. We must make contacts at all levels, from policy-makers to the citizen in the street, not only to reach agreement on what should be investigated, but also to ensure that the results of our studies are fully exploited for the benefit of as many as possible. All we need now is a 36-hour day so that we can do science as well!

John Patching is at the Martin Ryan Marine Science Institute, National University of Ireland, Galway, Ireland.

[*] EUR 18220: *Third European Marine Science and Technology Conference - Project Synopses* (Volumes I to VI). Luxembourg: Office for Official Publications of the European Communities (1998) (ISBN 92-828-2896-4; 78 ECU)

[†]See *Ocean Challenge*, Vol. 7, No. 3, pp.22–3.

The Bergen Large-Scale Facility for Marine Pelagic Food Chain Research

Clelia Booman

In Norway, unique installations at the University of Bergen, and at the Institute of Marine Research, have been granted a Large-Scale Facility (LSF) project within the Training and Mobility of Researchers (TMR) Programme of the European Union. The EU is supporting access to these installations by European scientists with more than one million ecu during the period 1996–99. The Project is managed by Professor Dr Dag Lorents Aksnes, from the Department of Fisheries and Marine Biology.

The Large-Scale Facility for Marine Pelagic Food Chain Research, located on the western coast of Norway (Figure 1), is a set of complementary installations spanning the whole range from controlled laboratory systems to natural environments. The Facility makes possible integrated research in a number of aspects of marine biology, environmental biology, fisheries biology and aquaculture, offering an excellent opportunity to link experimental studies with field observations.

The Facility includes a specialized laboratory with continuous seawater supply, where environmental variables can be accurately manipulated. The LSF also features isolated 'cells' certified for research on fish pathogens, walk-in cool rooms with seawater supply, floating mesocosms (Figure 2), modern aquaculture installations (Figures 3 and 4) and large seawater basins equipped for production of marine fish larvae. All the experimental facilities have a stable, high quality seawater supply, ensured by deep water intakes and virtually unpolluted seawater sources.

Special topographical characteristics and hydrographic conditions in the area provide a range of unique marine habitats, including deep-sea environments. Most of these environments are accessible within one hour by research vessels from the University of Bergen. Live organisms obtained in their natural habitats can thus be efficiently transferred to the experimental facilities, allowing researchers to combine *in situ* observations with experimental work under controlled conditions.

A remotely operated submersible vessel (ROV) equipped with advanced photographic and video systems will soon also be available to TMR-supported researchers. Designed to operate at depths down to 2 000 m, the ROV will be ideal for studying fragile deep sea creatures in their own environments.

Research opportunities

The Facility is well suited for conducting basic research on fundamental processes underlying dynamics in the marine environment, and on the structure, functioning, and diversity patterns of marine communities. Excellent conditions are also provided for applied research in aquaculture and diseases of marine organisms, fish recruitment, and effects of pollutants on marine organisms.

LSF activity is grouped into the following research areas:

- Marine micro-heterotrophs (bacteria and fungi) and viruses;
- Phytoplankton and primary production;
- Zooplankton and secondary production;
- Reproductive and developmental biology;
- Larval fish physiology;
- Larval fish ecology;
- Marine juvenile production;
- Health of marine organisms;
- Environmental health;
- Marine molecular biology.

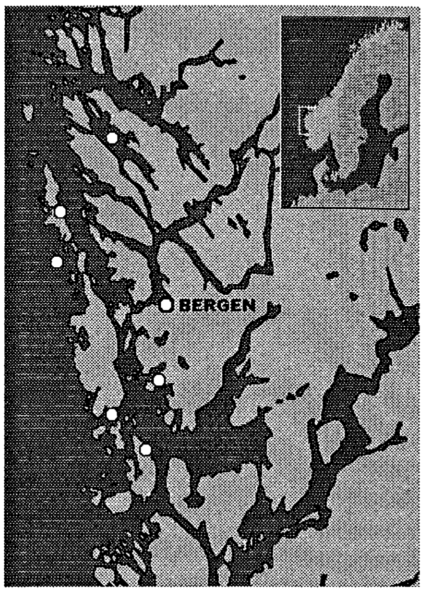


Figure 1 *Locations of the different installations constituting the Marine Pelagic Large-Scale Facility*

Research undertaken so far

More than 80 European scientists from 33 institutions in 13 European countries have had access to the

Figure 2 *Floating seawater enclosures at one of the mesocosm laboratories.*

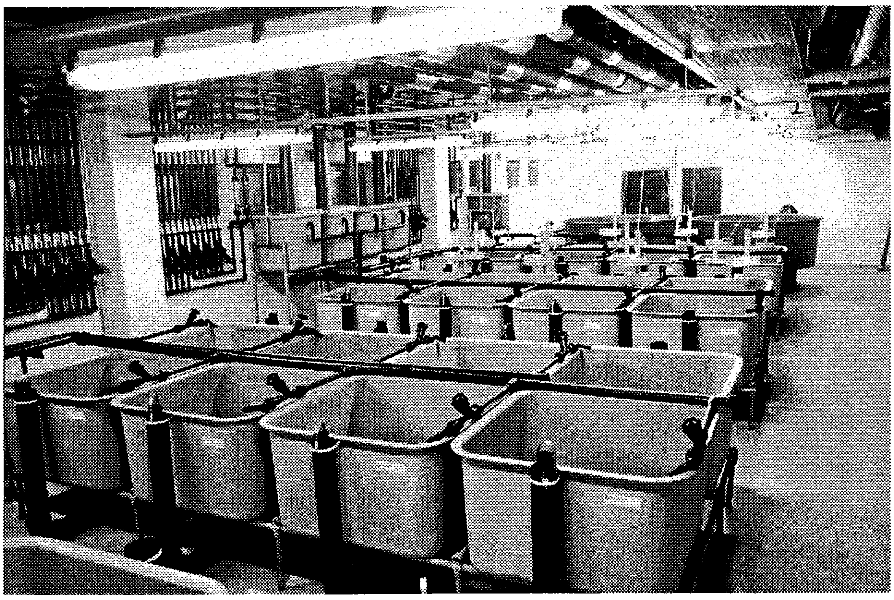


Figure 3 *Fish tanks with water quality and photoperiod control (simulating day-lengths and variations in light intensity appropriate to different latitudes).*

Facility during 1996–97, participating in more than 30 research projects. Some of these projects were conducted by individual scientists while others involved several scientists from different countries. All research areas have been represented.

Projects that have been conducted at the LSF through the European access scheme include:

o Structure and function of microbial communities in the chemocline of a meromictic lagoon.

o Nutrients and pelagic marine production: phytoplankton population dynamics.

o Overwintering, gonad development and egg production in relation to food availability of *Calanus finmarchicus* in Lurefjorden, Bergen.

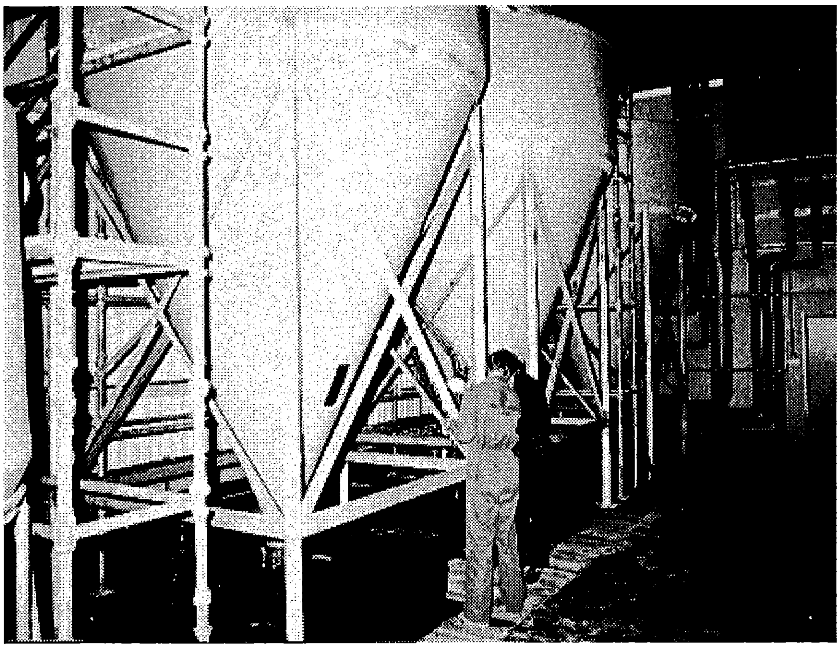
o Characterizing small pelagic fish and zooplankton for application in abundance assessments using acoustics.

o Early development of the light sensory organs, retina and pineal organ, in herring and cod.

o Daily growth and condition of Mediterranean sardine larvae under controlled environmental conditions.

o Formation, structure and function of social hierarchies in flatfish.

Figure 4 *Silos for rearing halibut yolk-sac larvae*



o Characterisation and evaluation of the microflora of intensive turbot production systems.

o The production of scallop larvae in large flow-through tanks.

o Detection of biliary PAH metabolites continuously collected by bile cannulation in Atlantic cod after exposure to benzo(a)pyrene.

What is on offer?

Access to the facility includes infrastructural, logistical, technical and scientific support, including use of research vessels, some laboratory consumables and subsistence support, and reimbursment of international travel expenses. Access is normally provided for a minimum period of three weeks, with a maximum of four months for each user.

Calls for proposals

Calls for proposals are published twice a year in specialized journals and in LSF's home page (see below) Potential applicants are encouraged to contact a scientist in their research area at the University of Bergen or the Institute of Marine Research. A list of 'Liaison Officers' together with more detailed and updated information about the project, and the application form, are available through the LSF home page.

Project proposals are selected on the basis of scientific merit through an independent peer review procedure and further approval by the European Commission. Applicants are informed of the outcome of the evaluation within two months of the closing date for presentation of project proposals.

Contact

Interested researchers should contact:

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LSF home-page:
http://www.ifm.uib.no/lsf

Water water everywhere ... and less and less to drink

96% of the water in the global hydrological cycle is in the oceans, and demand for the usable 4% is growing because of the dual pressures of population growth and rising standards of living. Those pressures will persist, in spite of water-saving measures by some industrial sectors and a still rather small proportion of domestic users.

One obvious solution to water shortages is desalination of seawater. At present, desalination is usually associated with arid countries fortunate enough to have coastlines, and the best known examples are probably those of the Middle East. However, seawater desalination is an option already being considered in regions that would not immediately come to mind as likely to suffer from lack of water. In Britain, for example, the East Anglian region receives only about as much rainfall as parts of sub-Saharan Africa (about 500 mm annually), and last year there were newspaper reports that Anglian Water was considering desalination of North Sea water as one of their options for maintaining water supplies into the coming decades.

If East Anglia, why not elsewhere in temperate latitudes too? Most of us know rather little about what desalination involves, but Thomas Höpner of the Universität Oldenburg, Germany, has researched aspects of the technology and its impacts, with especial reference to the Arabian Gulf. He presented a review of the subject at the DGM–Challenger Society meeting at Hamburg last October. An abstract featured in an account of the meeting in the *DGM Mitteilungen* (No.4/97, pp.65–6), and we are pleased to be able to provide a fuller version of the talk here.

Seawater Desalination – Global Perspectives

Thomas Höpner

The global freshwater production capacity of desalination plants, now in the region of 16 million cubic metres per day, is currently growing annually by about 2 million cubic metres per day. Desalination plants are not necessarily environmentally compatible or benign, and they should be subject to coastal management legislation and environmental impact assessments in the same way as power stations or other industrial installations on coastal sites.

There are two kinds of desalination plant: 'thermal' plants and 'reverse osmosis' plants. Thermal plants make use of sophisticated energy-saving distillation techniques which include repeated evaporation and condensation, flash evaporation at low pressure, and heat recovery. Reverse osmosis plants use less energy and need fewer additives, but the technology is less advanced and the plant units are smaller.
The number and capacity of thermal plants is increasing, while the relative proportion of reverse osmosis plants is declining. Even if this is a temporary trend peculiar to countries with plentiful cheap oil and gas supplies, it still seems sensible to focus here on the chemical emissions of thermal plants and their impacts on coastal ecosystems.

Thermal desalination plants can be considered to be heavy industry, in terms of their fuel and power consumption, use of additives, land requirements, and major coastal construction works, with large-scale waste production and chemical emissions into both atmosphere and coastal waters (Figure 1). Contrary to most perceptions, the marine environment is affected more by the additives (or their conversion products) and by corrosion products, than by the discharged brines. This is because desalination plants discharge the same load of seawater constituents as is taken in. The only difference is the increased concentration and the changed pH. A typical product recovery is 10% of the amount of 'raw' water taken in, i.e. the salinity of the concentrate is 1.1 times greater than that of the original water. For instance, seawater with a salinity of 40 (typical for the shallow southern coastal waters of the Gulf; see below) would receive a concentrate of salinity 44. In hot and arid regions, natural evaporation can result in high salinities greatly in excess of this.

Seawater desalination – the Arabian Gulf

A preliminary and general environmental impact study was made of thermal desalination plants located on arid climate coasts by myself and Jens Windelberg in 1996. We focussed on coasts of enclosed seas rather than oceanic coasts. The Arabian (Persian) Gulf serves as an

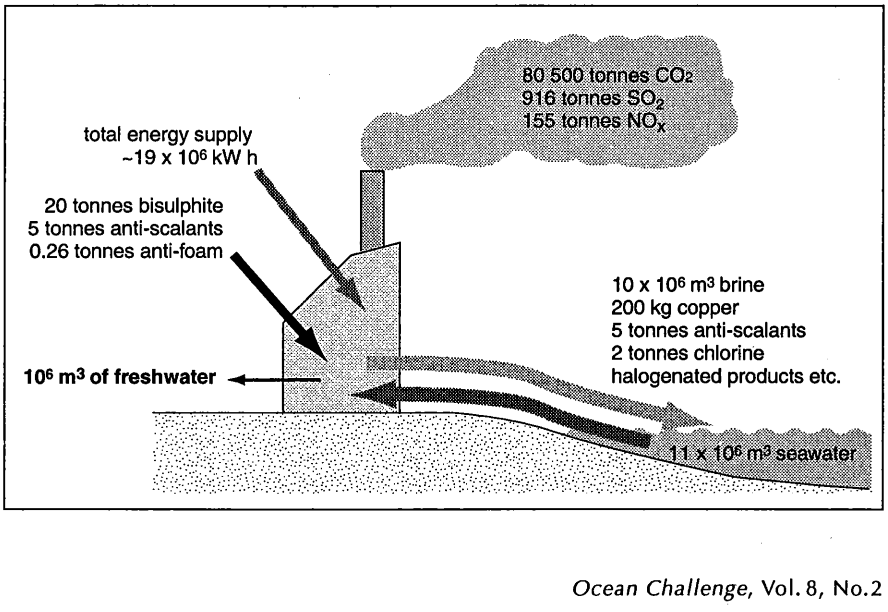

Figure 1 *The emissions from a thermal desalination plant, normalised to 10^6 m³ freshwater production. The atmospheric emissions are for an oil-fired plant, which can be considered the 'worst case' emitter. Emissions from gas-fired plants will depend upon the quality of the gas, but will in general be less than from oil-fired plants.*

example of a enclosed sea; the eastern coast of the sea is steep and rocky, and there are many more desalination plants along the flat western and southern coasts (Figure 2).

Emissions

Chemical emissions to the atmosphere are generally similar to those produced by power plants, and are not discussed further here. Chemical emissions into the sea are less well known and consist of a variety of components:

- The concentrated brine (at several degrees above ambient temperatures);
- Metallic corrosion products;
- Anti-scaling additives (polycarbonic acids, polyphosphates);
- Anti-fouling additives (mainly chlorine and hypochlorite);
- Halogenated organic compounds formed after chlorine addition;
- Anti-foaming additives;
- Anti-corrosion additives;
- Oxygen scavengers (sodium bisulphite)
- Acids

To these chemical emissions we should add the production of waste heat.

In Figure 1 the emissions from a thermal desalination plant have been normalized to production of 1 million m^3 of freshwater. Some plants achieve this production within two or three days, and along the Gulf coasts about 6 million cubic metres of freshwater are produced every day (i.e. about a third of global production).

Coastal sub-ecosystems

A comprehensive illustrated general introduction into the variety of habitats of the western Gulf was published by Philip Basson and others in 1981 (see Further Reading). Using literature studies and data from our own excursions, in 1996 Jens Windelberg and I defined 15 sub-systems which we arranged in a sequence from low to high sensitivity to desalination emissions. The basis of our sensitivity index is the scale of coastal sensitivity to oil spills which was devised by Erik Gundlach and Miles O. Hayes in 1978, following the *Amoco Cadiz* accident off Brittany in the same year. The criteria used ranged from elimination time and depth-penetration in relation to ecotoxicity, to the potential for biodegradation and recovery.

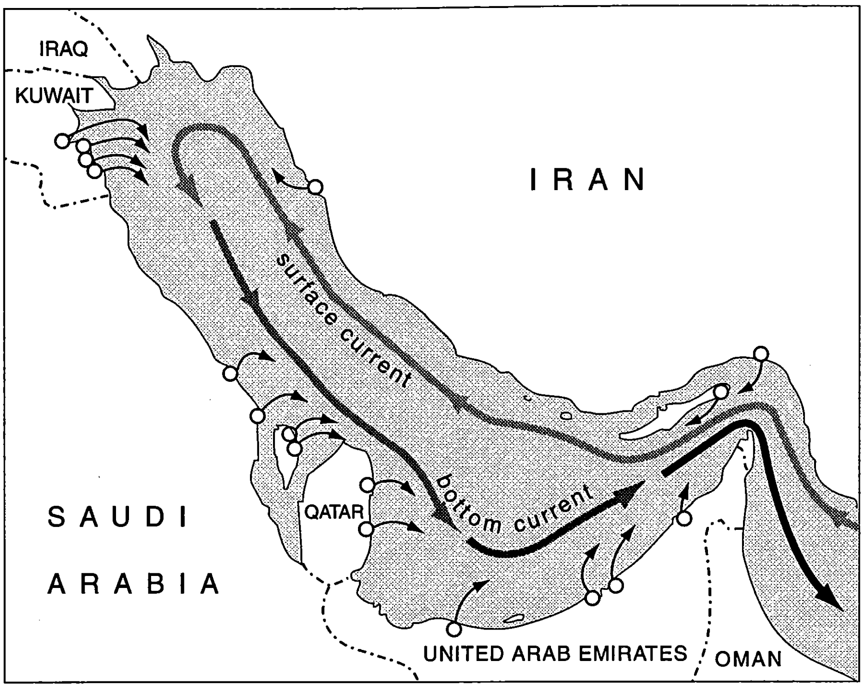

Figure 2 *Generalized map of the Persian Gulf, showing approximate locations of the seventeen largest desalination plants (where the short curved arrows originate), with production capacity of more than 50 000 m*^{3} *freshwater per day. Three are on the Iranian (eastern) coast: Bandar Abbas, Queshim, Bushein (from south to north). The remaining fourteen are on the western coast: four in Kuwait in the north (Doha, Shuaiba, Shuwaik, Az Zour); two in Saudi Arabia (Jubail, Khohar); two in Baharain (Al-Dur, Sitra); two in Quatar (Doha, Abu Fontas); and four in the United Arab Emirates (Mirfa, Umm al Nar, Taweela, Sharjah).*

In the case of the water-soluble emissions of the desalination plants, the criteria range from flushing times (exchange rates) in relation to benthic accumulation rates, to ecotoxicity, but it should be kept in mind that the sensitivity index is hypothetical because (unlike the index of Gundlach and Hayes) it is not based on field examinations at a desalination plant. The index provides a guide for investigators wishing to analyse potential effects on a variety of different marine areas, and to assess the impacts. Sub-systems with low water exchange and high accumulation potential were assessed to be most sensitive, as were soft sediment sub-systems rich in benthic organisms. Least sensitive were well-flushed rock-based benthic communities. It was assumed that heavy metal accumulation and toxicity provide the main impact, followed by the reaction cascade initiated by chlorine. It is recommended that the sub-systems present in each actual situation be determined and examined separately before attempting a synthesis.

Effects on the regional ecosystem

At first sight the Gulf seems to be an enclosed sea with limited exchange with the ocean. In fact, the exchange is high, because a Mediterranean-type current system links the Gulf strongly to the Indian Ocean. The circulation is driven by evaporation within the Gulf, enhanced by the prevailing winds, which raises salinity in the northern part to about 40. The dense water sinks and leaves the Gulf as a bottom current, being replaced by ocean water of salinity about 37, which enters the Gulf as a surface current. Because of the Coriolis effect, the surface current is deflected to the the right and flows mainly along the Iranian (eastern) coast, and the bottom current flows mainly along the Arabian (western) coast. The circulation is strong enough for about one-third of the volume of water in the Gulf to be exchanged with the Indian Ocean each year.

Figure 2 illustrates the counter-clockwise circulation in the Arabian Gulf and the locations of the seventeen largest desalination plants. As most of the plants are along the Arabian coast, discharge is mainly into the bottom current flowing out of the Gulf.

We now need to consider the number and capacity of the desalination plants and their combined emissions into this 'ring current'. Is it possible that there is a limit on the number and capacity of desalination plants within a confined area such as the Gulf? Figure 2 shows only the 17 largest plants, but in fact there are 277 thermal plants and 112 reverse osmosis plants. Their combined capacity is about 6 million m^3 of freshwater per day (data from K. Wangnick, personal communication). Figure 2 shows only the sites of plants actually producing more than 50 000 m^3 freshwater per day, but within this group the capacity ranges from 50 000 m^3 day^{-1} (at Bandar Abbas, Iran) to more than a million m^3 per day (at Jubail, Saudi Arabia).

Total production of about 6 million m^3 of freshwater per day means that total daily emissions to the waters of the Gulf are six times greater than those listed in Figure 1 – we can assume nearly all of the freshwater production is from thermal plants, since reverse osmosis plants are much smaller and less numerous. It is in fact more appropriate to consider total *annual* emissions, because marine processes are slow and it takes time for cumulative biological effects to be revealed. It might be even more appropriate to calculate all emissions which have entered the Gulf since the beginning of desalination activity (although the data would probably be difficult to obtain), because the annual emissions are considerable. Total emissions into the sea (per million m^3 freshwater per day) are:

- 440 tonnes of copper (only one of the corrosion products)
- 11 000 tonnes of antiscalants
- 4 400 tonnes of chlorine

plus several hundred to a few thousand tonnes of the other emissions listed in Figure 1.

Totals released yearly into the atmosphere are:

- 176 million tonnes of CO_2
- 2 million tonnes of SO_2
- 340 000 tonnes of NO_x

(Note, however, that these are 'worst case' values, assuming oil-fired plants, whereas most plants are now gas-fired.)

The considerable quantities of waste heat discharged into both atmosphere and coastal waters will tend to enhance any chemical effects.

Discharges of additives and corrosion products into the sea may accumulate within the counter-clockwise current, and cumulative effects on the seawater and sediments are to be expected downstream of the points of emission. At present, every desalination project is planned in isolation and without regard to existing emissions. Such a lack of coordinated development cannot be continued into the future within a small semi-enclosed sea.

Concluding remarks

The number of desalination plants will probably increase sharply in the near future, both because of economic growth, and because of climate change. It is important that planning, construction and operation of desalination plants be accompanied by properly conducted environmental impact analyses, and that such analyses be made also for existing plants and published within the next few years, to serve as models and standards. As things stand at present, each desalination plant has its own individual adverse environmental effects, and in the longer term their overall impact could be cumulative, in some cases even synergistic – to the detriment of both open oceans and semi-enclosed seas.

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The Russian Oceanographic Society

The Oceanographic Society of Russia was founded in 1994 to promote oceanographic studies, and achieved full legal status in November 1997. In December, the Society was enrolled as a member of the Union of Russian Scientific Societies, and by the end of 1997 it had more than 60 individual members.

The Oceanographic Society is a voluntary independent scientific organization representing the whole range of disciplines of marine science and its applications. Everyone actively involved in the ocean or related sciences, or who believes that they contribute to them, is eligible for membership.

The Oceanographic Society is involved in technical arrangements for the Russian National Research Programme (Comprehensive Investigations of Oceans and Seas, the Arctic and Antarctic). Some scientific projects of the Programme and of the Russian Foundation for Basic Research (RFBR) are carried out by the members of the Society.

The Society is active internationally, and communicates with oceanographers abroad. The Russian Chapter of the Pacific Congress on Marine Sciences and Technologies (PACON) is an affiliated body of the Oceanographic Society.

Annual dues are two minimum monthly salaries for individual membership, half a minimum monthly salary for students and twenty monthly minimum salaries for corporate members. For foreign members annual dues are $30 for individual membership, $10 for students and $300 for institutions.

For more information, contact:
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Fax: (095) 135-15-68 *or* (095) 124-59-83.

Changes in NADW over time – the Neodymium Connection

Derek Vance

Most oceanographers are probably aware of the significance of studies of stable isotopes of carbon and oxygen for our understanding of past changes in climate and ocean circulation. They are perhaps less familiar with the importance of radiogenic isotopes of elements such as strontium, neodymium and lead in the oceans. The study of these radio-isotopes can tell us not only about the response to changes in climate over continental areas, but also about how inputs into the oceans vary in response to changes in weathering rates on land. Moreover, variations in the isotopic composition of radiogenic elements in the world's oceans can provide information on the redistribution of terrestrial inputs by the oceanic circulation. This article summarises some recent results which illustrate the direction of ongoing research in this area and some of the insights that may be derived from it.

Radio-isotopes and residence times

The element strontium (Sr) provides perhaps the simplest (and most familiar) example of the type of information that can be obtained from radiogenic isotopes in seawater. The isotopic composition of Sr dissolved in seawater, and its secular evolution on time-scales of millions to hundreds of millions of years, is now very well established. The $^{87}Sr/^{86}Sr$ ratio of seawater is constant in the open ocean at any given time. The reason for this ocean-wide homogeneity is that Sr is highly soluble in seawater and its residence time in the oceans is about 2 million years – much longer than the mixing time-scale of the oceans. There are two unfortunate consequences of this. First, Sr supplied by local anomalous continental sources is added to an already very large reservoir, so that its impact is small. Secondly, short time-scale changes in the isotopic composition of Sr in the oceans (such as might accompany glacial–interglacial changes in continental weathering rates, for example) are smoothed out by mixing into the large oceanic reservoir, and are too small to be measurable with our present technology.

In contrast, the elements neodymium (Nd) and lead (Pb) are much more particle-reactive so that they are efficiently removed from solution in seawater by particle scavenging. The residence time of Pb is probably less than 100 years whilst that of Nd is of the order of a few millenia – i.e. similar to the oceanic mixing time. Consequently, variations in the isotope composition of Pb and Nd in the present-day oceans reflect differences in local terrigenous inputs and the redistribution of those inputs by the oceanic circulation. The implication is that a record of such variations in the past might hold information about major changes in circulation that accompany, or perhaps even drive, climate change. My research is concerned principally with the story that neodymium isotopes can tell us, and I focus here on what we can learn from them about the history of NADW over the last few million years.

North Atlantic Deep Water and ferromanganese crusts

The North Atlantic region is surrounded by old continental crust such as that of the Canadian Shield and Greenland. The result is that Nd in North Atlantic Deep Water (NADW) has an ε_{Nd} of around −13.5 (see Box, overleaf). There are four main contributors to NADW – Denmark Strait Overflow Water (DSOW), Iceland–Scotland Ridge Overflow Water (ISOW), Antarctic Bottom Water (AABW) and Labrador Sea Water (LSW). Of these, the most important for the Nd characteristics of NADW is LSW which has an ε_{Nd} of −18 (the others are −8.6 (DSOW), −7.7 (ISOW) and −8.5 (AABW) – all less negative than mature, mixed NADW). In contrast, Pacific seawater Nd is dominated by young circum-Pacific volcanism and thus has an ε_{Nd} of about −3, which is a much more mantle-like value (see Box). Whilst this inter-ocean difference is primarily controlled by local sources of Nd, it is modified to some extent by the advection of some Nd into the Pacific from the Atlantic via the thermohaline conveyor.

Studies of stable isotope variations and nutrient proxies such as foraminiferal $\delta^{13}C$ and calcium/cadmium (Ca/Cd) records have suggested that the thermohaline circulation in the Atlantic began to intensify about 3–5 Ma ago, in response to closure of the Panama gateway, which resulted in greater convective instability in the North Atlantic. Such a change in oceanic circulation should be reflected in the past record of Nd in the oceans. In recent years, much interest has centred on the Nd isotope composition of hydrogenous ferromanganese crusts and their potential as records of past Nd changes in the oceans. This research has been led by groups of isotope geochemists at Cambridge, Mainz, Michigan and Oxford. The crusts are found principally on volcanic seamounts and are similar in origin to manganese nodules. Both nodules and crusts incorporate Nd and other elements from seawater as they grow. The crusts grow in a reasonably stratiform way, so that sampling the secular evolution of Nd isotopes in ambient seawater is a relatively straightforward task. The approach has involved sampling the crusts and determining how the Nd isotope changes with depth within them. These data, in combination with a knowledge of the growth rate of the crusts, can provide a record of the secular evolution of Nd isotopes in seawater at a given site.

Foraminiferans as records of continental inputs to the ocean

Whilst crusts are clearly useful they have one rather severe limitation. Sampling is done by sequentially scraping off small amounts of material down through the crusts. The smallest thickness of material that can be scraped off in this way is generally about a millimetre and since the growth rates of the crusts are 1–10 mm per million years, the time-resolution available is generally of the order of 0.1–1 Ma. Higher resolution is clearly desirable, and essential if we are to obtain information on the time-scales of 1–10 thousand years that characterize glacial–interglacial changes. That is why Kevin Burton (University of Michigan) and I have been developing the use of foraminiferans to provide a record of Nd isotopes in past oceans. Foraminiferans incorporate metal ions from seawater as they grow (see Fig.1, overleaf) and have been used, for example, to measure Cd/Ca ratios and, by proxy, past oceanic nutrient levels.

Neodymium and the Earth System

The element neodymium (Nd)* has seven stable isotopes, one of which, at mass 143 (^{143}Nd) is radiogenic, produced by the natural radioactive decay of another isotope – in this case an isotope of the element samarium (Sm).* ^{147}Sm decays to ^{143}Nd with a half-life of 1.06×10^{11} yr (very long compared with the age of the Earth, which is 4.5×10^{9} yr). The result is that the more Sm there is present in a rock relative to Nd, the more abundant ^{143}Nd will be relative to the other non-radiogenic isotopes of Nd. Moreover, the chemical characteristics of the two elements Sm and Nd are sufficiently different for natural chemical processes – especially those involved in the formation of igneous rocks – to fractionate them one from another. As a result, rocks that acquired different Sm/Nd ratios at the time of their formation now have significant and measurable present-day variations in the abundance of ^{143}Nd relative to other, non-radiogenic, isotopes of Nd.

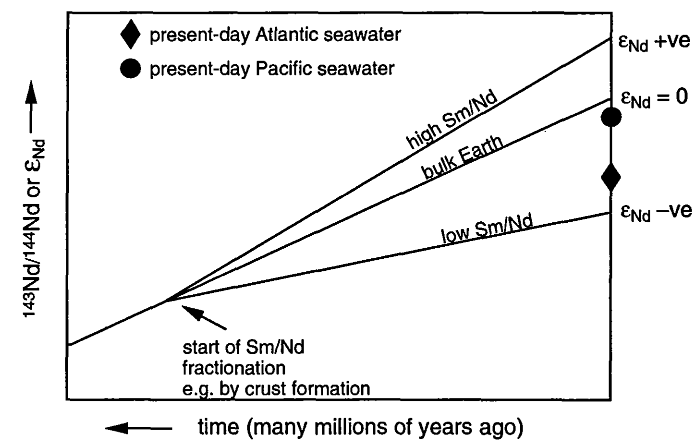
One such fractionation process is the large-scale chemical differentiation that has led, over the 4.5 Ga of Earth history, to the formation of the continental crust. The process of continental crust formation has probably been reasonably continuous up until the present-day – though scientists argue about whether or not it has slowed down over time.

The continental crust has formed by melting of the mantle. During this process, melts form in the mantle and, because they are lighter, rise, cool and solidify to form the 'scum' that is the continental crust on which we live. Residual solid phases are left behind in the mantle. Because Sm is fractionated preferentially into solid phases, whereas Nd preferentially goes into any melt that is present, Sm is depleted relative to Nd in the continental crust and enriched relative to Nd in the mantle. The present-day mantle therefore has measurable enrichments of ^{143}Nd because of the decay of the relatively abundant Sm over the long time period since crust-formation began. The continental crust, on the other hand, being depleted in Sm relative to Nd, has a corresponding depletion of ^{143}Nd.

In isotope geochemistry, variations of one radiogenic isotope, like ^{143}Nd, are expressed relative to the abundance of a second isotope of the same element whose natural abundance remains constant. For Nd, the stable, non-radiogenic isotope conventionally used is ^{144}Nd, so that variations are expressed as the ratio ^{143}Nd/^{144}Nd. The resulting numbers are awkward to deal with and variations in the numbers are quite small. It has therefore proved convenient to introduce a further simplication whereby the ^{143}Nd/^{144}Nd of a sample is expressed as a deviation, in parts per 10^4, from a bulk (i.e. average) Earth reference. Isotope geochemists call a difference of one part in 10^4 an epsilon (ε) unit and this has led to the ε_{Nd} notation (similar to the δ^{18}O notation used to describe per mil variations in oxygen isotope compositions).

Thus, as the figure below shows, the bulk (average) Earth has an ε_{Nd} of zero. Samples from old continental crust have ε_{Nd} as low as −20 to −30, because they come from a reservoir depleted in Sm and have therefore not accumulated so much ^{143}Nd. On the other hand, samples of young basaltic rocks erupted from the mantle, with its long-standing enrichment in Sm, today have an ε_{Nd} of about +10. Measurement errors using modern chemical and mass spectrometric procedures are as low as 0.2 epsilon units – or about a factor of 200 less than the total variation.

It turns out that a lot of the earliest crust, formed 2–4 Ga ago, is now found around the North Atlantic region in places like Greenland, North America and northern Eurasia. As we have seen, the Nd in these old continental crustal rocks has very negative epsilon values (−20 to −30), and so do the waters of rivers eroding them and draining into the North Atlantic. The Pacific, on the other hand, is surrounded by active volcanoes, so that a lot of the Nd reaching the Pacific Ocean came from the mantle very recently, and has higher (more positive) epsilon values.



Nd isotope evolution in the bulk Earth of a high Sm/Nd reservoir (e.g. the mantle) and a low Sm/Nd reservoir (e.g. the continental crust) assuming separation of the crust early in Earth history. Crust separated from the mantle today would evolve in similar fashion to the low Sm/Nd reservoir.

*The elements neodymium and samarium are members of the lanthanide series, sometimes called the rare earth elements, which lie between barium (Ba) and hafnium (Hf) in the Periodic Table.

The major advantage of foraminiferans over crusts is that they are geographically widespread and the sediments in which they occur accumulate at rates of 10–100 m per million years, potentially providing a time-resolution many orders of magnitude greater than Fe–Mn crusts.

In addition, as there are both benthic and planktonic species of foraminiferans, they can sample both deep and surface waters.

As with all bright ideas, there are drawbacks. This, in fact, is not the first time that the Nd isotopic compositions of foraminiferans have been investigated. About 10 years ago, a series of three papers by Martin Palmer and Harry Elderfield (University of Cambridge) attempted to use them to map Nd isotope variations in the Atlantic. They uncovered a potential problem with Nd: apparently, during diagenesis, foraminiferal remains accumulate a Mn-rich coating, which contains very high amounts of Nd as well as other trace elements (perhaps a few 1000 p.p.m. as opposed to about 1 p.p.m. or less within the shell itself) (see Figure 1). Thus the Nd isotope compositions of the foraminiferans did not reflect contemporary seawater but pore waters or local bottom water. These manganese-rich coatings have proved to be a major problem for the study of other trace elements in foraminiferans as proxies for seawater, but Ed Boyle (Massachusetts Institute of Technology) has developed a method for removing them using reductive cleaning with hydrazine. The problem which Palmer and Elderfield encountered was that, although they could apparently clean the coatings off in this way, the resulting concentrations in the foraminiferans were so low that they were unable to measure precise isotopic compositions.

My colleagues and I have recently returned to the problem with modern analytical techniques of isotope geochemistry, which now enable us to measure precisely the isotopic composition of very small amounts ($<10^{-8}$g) of Nd. The scientific motivation for the present study was twofold. In the long term, if it could be established that cleaning procedures purify the foraminiferan samples enough for measured Nd values to reflect seawater concentrations, then the available time-resolution could be used to investigate changes in the sources of Nd and the structure of oceanic convection on a time-scale of 100–1000 years, well within that of glacial–interglacial cycles. More immediately, however, a recent paper in *Nature*, by Kevin Burton and others from the Cambridge group, reports the use of Fe–Mn crusts to show that ε_{Nd} in both NADW and Pacific Deep Water has become more negative over the past 3–5 Ma. This was interpreted in terms of a greater proportion of LSW in NADW and a more intense flow of NADW after 3–5 Ma than previously. Such an increased flow has been simulated by General Circulation Models, as a response to closure of the Panama Gateway at that time, and it has obvious consequences for palaeo-climate change prior to and during the Pleistocene epoch (the last 2 million years or so). However, an alternative explanation of the Nd data from the crusts is that there has in fact been no change in the rate of formation of Labrador Sea Water at this time, but that instead the source of Nd in LSW itself has changed over the past 3–5 Ma. It has been suggested, for example, that ice-rafting during glaciation could have brought material with different Nd isotopic characteristics from further inland.

Neodoymium in foraminiferans in the Labrador Sea

Our recent work has centred around an ODP core from the Labrador Sea, which we studied in order to investigate this particular problem and the utility of foraminiferans generally for determining the Nd isotopic composition of seawater. The sedimentation rates for the core are estimated at 45 m per Ma as far back as 2.5 Ma, before which there is a long hiatus in the record. Foraminiferans are ubiquitous in the core, the main species being *Neogloboquadrina pachyderma* – a species commonly used in oxygen and carbon isotope studies. *N. pachyderma* is a planktonic species and therefore carries a record of Nd concentrations and isotopic compositions in *surface* seawater (see Figure 1).

If one were to set up some *a priori* criteria to test whether foraminiferans record Nd in seawater rather than in sediment pore waters, they might be as follows:

(1) The most obvious criterion would be that foraminiferans from the core should have Nd concentrations similar to those in modern samples from present-day seawater that have never been buried and have never 'seen' pore water Nd. Figure 2(a) (overleaf) summarises our preliminary results for neodymium concentrations both in foraminiferans from the Labrador Sea core and in the one sample of modern foraminiferans that we have managed to obtain. Although the modern sample comes from the equatorial Atlantic, its concentration of Nd is

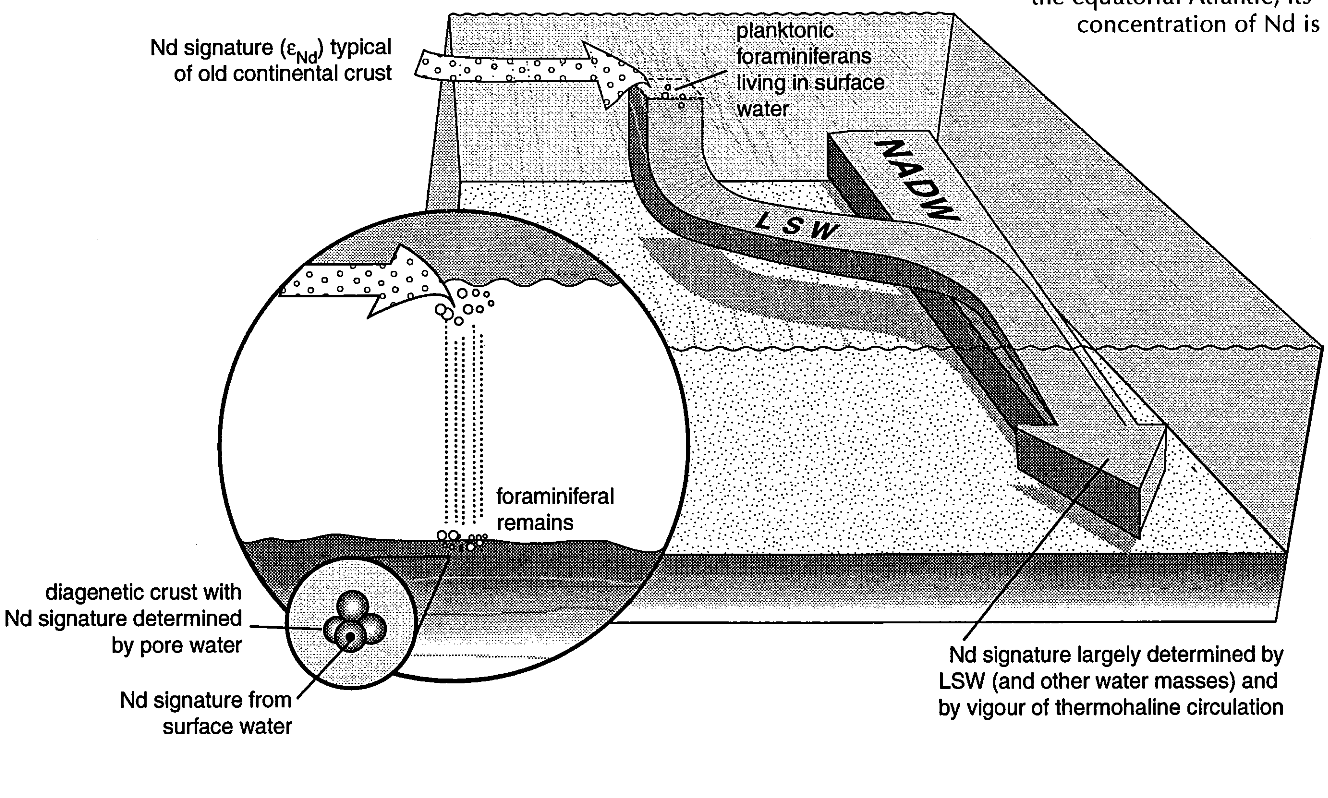


Figure 1 *Schematic diagram to show Nd contributions to the remains of a planktonic foraminiferan which originally lived in surface waters of the Labrador Sea, and the implications for the Nd signature of North Atlantic Deep Water.*

within the range measured in foraminiferans from the core. The Nd concentration in the modern sample is at the low end of the range for the Labrador Sea core samples, and this is wholly consistent with the fact that measured Nd concentrations in Labrador Sea surface water are higher than those in the equatorial Atlantic. A slightly puzzling aspect of the data at this stage is that both the modern and the core samples have Nd/Ca ratios that are a factor of about 100 higher than ambient seawater. This enrichment is much greater than that seen for any other trace element (e.g. Cd/Ca ratios of foraminiferans are typically about 1–2 times that of seawater) implying that foraminiferal tests somehow dramatically concentrate Nd.

(2) If the foraminiferans have been cleaned properly, the Nd isotopic composition of the core-top (i.e. the youngest) foraminiferans should reflect modern surface seawater (since these are planktonic species).

The Nd isotope data for foraminiferan samples from the Labrador Sea are shown in Figure 2(b). A Nd profile for modern sea water is available from very close to this site and it shows deep waters to have an ε_{Nd} of −13.5 whereas surface waters have an ε_{Nd} of −18. The planktonic foraminiferan sample from the core-top has an identical ε_{Nd} signature to surface waters and it is distinct from that in both deep waters and host sediment – the two most likely sources of any diagenetic Nd – suggesting that the samples have not been affected by diagenesis.

(3) If cleaning has been complete, then duplicate analyses of a given sample should yield the same result. In our preliminary dataset, duplicate analyses of two cleaned foraminiferan samples are indeed virtually indistinguishable from each other (Figure 2(b)). Of course, all this means is that the cleaning procedure is reproducible, not necessarily complete – but it is encouraging.

Regarding the scientific problem we set out to investigate, let us for a moment assume that we have demonstrated that Nd in foraminiferans *does* reflect Nd in contemporary seawater. In that case, it is clear from Figure 2(b) that ε_{Nd} of Labrador Sea Water became progressively more negative between 2.2 and 1 Ma ago. The observed shift is dramatic – nearly 8 epsilon units. Subsequent to 1 Ma, the Nd isotopic composition of LSW rose again almost to the present-day (Figure 2(b)). By contrast, over the same period of 3–5 Ma ago to the present, the ε_{Nd} value of NADW became more negative by only about 2 epsilon units. It thus appears that the change in NADW in the period 3–5 Ma does not necessarily reflect the closure of the Panama Gateway and intensification of NADW flow; it may simply reflect a change in the source of Nd in LSW.

But what of the possible reasons for such a change in the source? There are several observations of interest. The change to more negative ε_{Nd} values in LSW (Figure 2(b)) is correlated with a greater prevalence of coarse material in the core. In addition, it has recently been shown that ice-rafted detritus associated with Heinrich events has more negative ε_{Nd} values than material above or beneath it. So the long-term secular fall and rise of ε_{Nd} in LSW between about 2.2 Ma and the present day may simply be a reflection of greater supplies of material with more negative ε_{Nd} to the north-west Atlantic during the Pleistocene.

Future directions

While I am now fairly convinced that foraminiferans do indeed provide a high-resolution record of Nd in seawater, the marine science community at large will probably take more convincing. We have already started to look for interspecies consistency in the results since this is another obvious criterion for success, and we are finding them! The exciting prospect that these systematic studies hold out, however, is that soon we will be able to track changes in the response of the continents to glaciation and deglaciation and to relate them to well-established oceanic proxies for nutrient levels, ice-volume and temperature.

Further Reading

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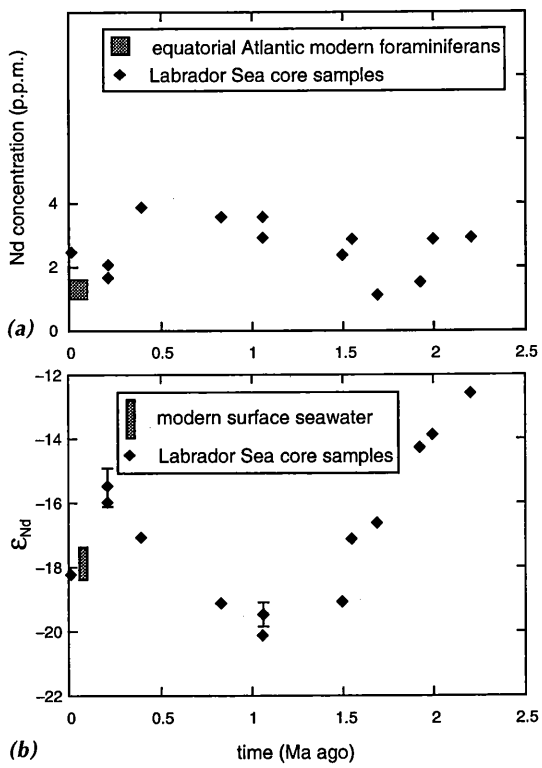


Figure 2 ***(a)*** *Nd concentrations in a Labrador Sea planktonic foraminiferan species* (Neogloboquadrina pachyderma) *compared to a modern sample (mixed planktonic species) from the equatorial Atlantic. Error bars are smaller than the symbols;* ***(b)*** *ε_{Nd} in planktonic foraminiferans from the Labrador Sea for the past 2.2 Ma. Error bars, unless visible, are smaller than the symbols.*

Training and mobility of scientific divers in Europe: a review and a look ahead

Marco Weydert

Diving is one of the most effective ways in which marine scientists can observe the environment below the sea-surface and collect samples. Scuba-diving was not easily accessible to scientists until the advent of tables for safe decompression, safe and easy-to-use scuba equipment, and appropriate training schools. In fact, both military and commercial divers have often used other techniques and have been prepared to accept some problems like bends and follow-up recompression which neither sports divers nor scientific divers are willing to accept. Then, in the 1970s, safety was substantially improved, as demonstrated by the large sports diving community which uses scuba. It can truly be said today that conscientious, well trained scuba divers run no greater risk than a pedestrian in a city or a car driver. This is shown by the statistics in the accident and incident reports for scuba divers, which are in the process of being analysed in detail, and which should be published. Of course, there will always be people who enjoy running risks – whether speeding on motorways or diving in extreme conditions – and they damage the image of all the others. But there has been a substantial change in mentality over recent years; deep diving has become less of an aim since federations of sports divers have started to change their rules and – with a few exceptions – now avoid dives deeper than 40 m.

On the regulatory side, unsafe diving practices by a few, and a history of many different types of diving, have led to a jungle of quite stringent regulations, rules and laws. This has resulted not only in different requirements for diving in different countries and at different sites, but also to differences (mostly minor) in training systems; there are many hurdles to be surmounted by a diver trained in one country wishing to get their scuba training, and training in scientific diving, recognized elsewhere. These hindrances are not always driven by real safety issues.

In the meantime, the European Union has decided on two directives aimed at free movement of professionals and recognition of their diplomas and other training or experience (see refs. 1, 2 and 3). Although they have no influence on diving rules, and although some kind of procedure still needs to be followed, the directives have recently been shown to be quite effective, and professional divers should refer to them if they have any problems concerning free movement within the European Union. The European Commission (Directorate General 15) and the European Court of Justice in Luxembourg oversee their correct and full application.

Diving is often the only satisfactory way of observing the marine environment
(Photo by courtesy of Gerd Schriever)

In order to tidy up the training issue, the author and three others (all four fully trained and experienced scientific divers, three of them instructors), undertook to develop an agreed or minimum training standard for scientific divers. (This group included the current chairman and two former chairmen of the Scientific Committee of CMAS, the World Underwater Federation.) The idea that was proposed resembled that developed by the engineers: a standard would be defined and a list of the schools and certificates which fulfil the requirements of the standard would be published by a recognized body of scientific divers. The paperwork could thus be substantially reduced, since the control body in a member state would need only to check that the certificate was on the list before issuing the recognition letter. In order to get worldwide recognition, the scientific Committee of CMAS has been approached.

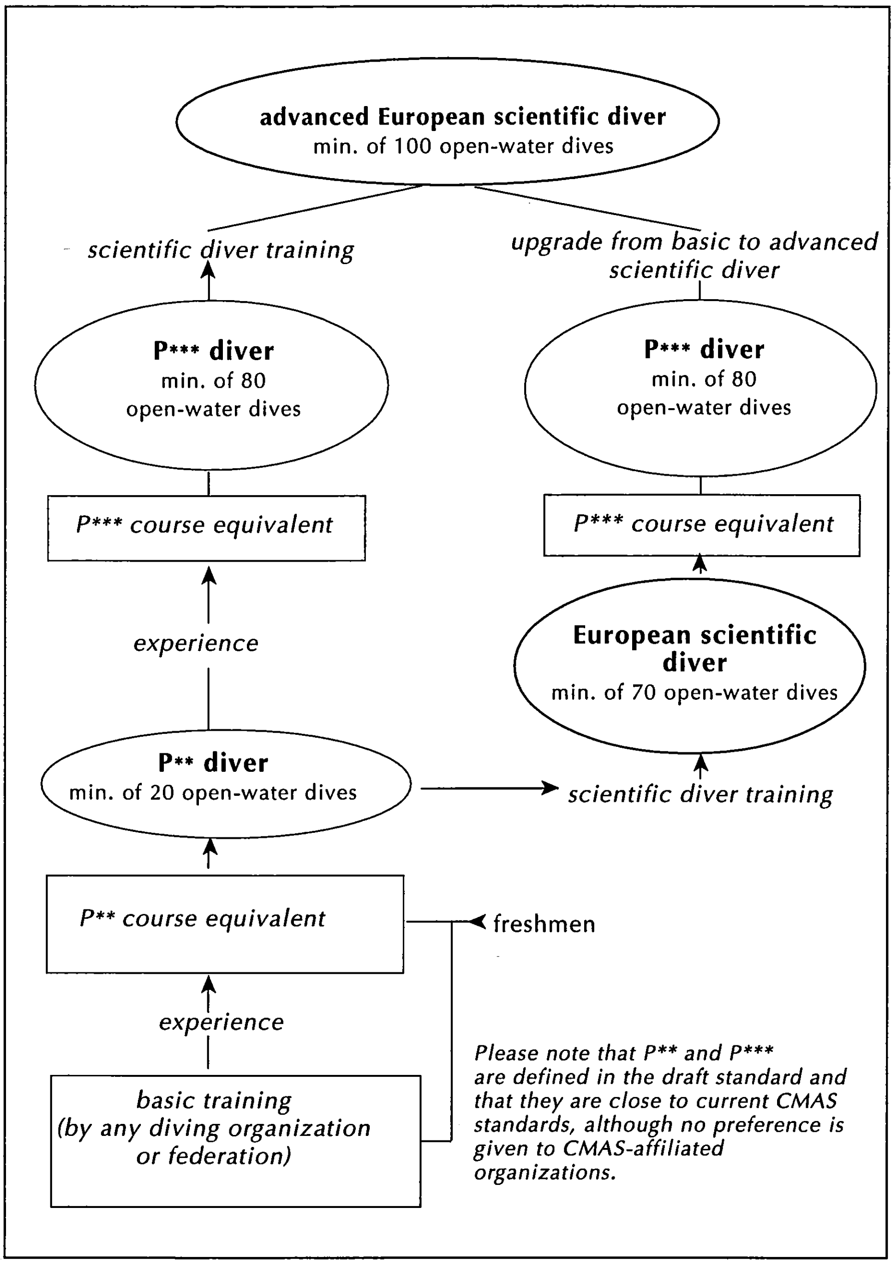
A draft standard for European scientific divers

The first requirement was some harmonization of basic scuba training up to the required level, as well as of diving and working practices (best practice). These two points have had to be the subject of special efforts by the services of the European Commission (Directorates General 15, 12 and 5). In order to achieve a proper basis, contacts were established with institutes involved in scientific diving and in the training of scientific divers. It soon turned out that there was already a largely common and comparable education of scientific divers, and two levels were identified which were later named European Scientific Diver (ESD) and Advanced European Scientific Diver (AESD).* A standard for basic training up to these two levels was drafted at a couple of workshops. Although it is not possible to go into the details here, a short discussion of some of the main points will be useful to illustrate the solidity of the standard and the differences between the two levels.

The degrees, or more precisely their equivalents, certify, among others, the following:

- For the ESD, basic scuba training with an agreed programme followed by training in scientific diving with a minimum of 70 dives (down to 30 m); for the AESD, 100 dives (down to 40 m) would be required. The complete ESD training can be done in an 8-week full time course; only experienced divers can enrol in the AESD course; the number of scientific dives must be no less than 20 in both cases (*see diagram*).
- The basic scuba training can be done by any nationally authorized school, federation or association, while the scientific diving has to be done by competent organizations.
- A European Scientific Diving Committee has been established; it will be attached to the European Marine Science and Polar Boards of the European Science Foundation.
- Transition rules for scientific divers already trained (probably valid up to 1999) were agreed.
- A safety net can be included via an entrance exam which checks physical fitness in addition to diving skills.

* European Scientific Diver and Advanced European Scientific Diver draft standards are available from the European Science Foundation (1, Quai Lezay Marnésia, FR-67080 Strasbourg Cedex; Fax: +33-388-37-05-32) and the European Commission (200, rue de la Loi, B-1049 Bruxelles; Fax: +32 -2-296-30-24).



Schematic diagram illustrating the ESD and AESD training system, showing alternative routes to becoming an Advanced (professional) European Scientific Diver. *The boxed items represent formal/semi-formal training, the ovals the stage of expertise of the diver.*

If a scientific diver fulfils the conditions for ESD or AESD, the recognition of his/her qualifications should be automatic once the system is operational. One point of caution, though: the author does not expect all countries to accept the ESD, while the AESD should be accepted everywhere. Normally, only an AESD would be expected to be capable of leading an expedition. For comparison purposes, the reader may notice that the basic scuba training required for an AESD exceeds the P*** diver of CMAS and the PADI divemaster.

It should also be noted that the standards do not include anything about insurance, medical exams, employment rules, diving limits, rules of recognition of national diving schools, etc. These are handled elsewhere. A course for instructors of scientific divers, with participants from 14 of the 15 EU member states was organized in May 1997, allowing the instructors to familiarise themselves with the standard, and to exchange teaching and working skills.

The next step will be to firmly establish the standard (including modifications to reflect experience already gained), and to implement the scheme, i.e. to abolish any administrative hurdles which might still hinder a scientist wishing to do science underwater using scuba in any member state of the EU. This process should be completed before the end of the century.

Conclusion

Scientific diving has long suffered from unsafe practices, and problems early on, including saturation diving, use of early versions of diving tables, and even lack of knowledge of (sometimes mythical) potential hazards. In particular, the numerous spectacular accidents of amateurs and adventurers has at the same time led to many restrictions on scuba diving at the local, regional and national levels. This was rather like over-reacting to stories about man-eating whales and octopuses.

But since the advent of safe scuba-diving practices, safe equipment and tables, scuba diving has become a technique used by many marine and freshwater scientists, as well as by police, firemen, photographers, etc. With the advent of the EU directives on recognition of diplomas and training for professionals, and with the establishment of minimum or agreed training standards, *and* of the imminent recognition of the newly established standards by CMAS, scientists should now be able to finally acquire complete freedom of movement within the EU and outside.

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This article reflects the personal views of the author and does not necessarily reflect those of the European Commission.

SeaNet

At present, all countries around the North Sea operate monitoring systems for proper management and scientific research of the marine environment. These systems deliver valuable data about the dynamics of the North Sea, for application in the management of the marine environment. However, they feature differences with respect to technical ideas and their application, with the result that optimum use of the existing facilities is prevented by two major stumbling blocks:

- Most systems are meant for use on a local or national scale. With the exception of meteorological parameters, there is still little exchange of data for use on a regional scale.
- In most systems, the integrated approach of real time *in situ* measurements using fixed platforms, buoy stations, satellites and operational data-assimilation modelling to produce complete and detailed information and forecasts has not yet been implemented.

Recognition is growing among agencies operating national marine monitoring networks that from an economic and operational point of view, integrated use (data exchange) and integrated system concept (integration of measurements and modelling) are necessary. In view of this, an initiative has been taken to form a European group called SeaNet, which meets at a workshop once a year.

SeaNet has focussed its attention on fixed monitoring networks in the North Sea region and has taken the initiative to start a concerted action called MMS2000+ (Marine Monitoring System 2000+) which is funded by the EU.

Participants

The countries participating in SeaNet are Belgium, Denmark, France, Germany, Great Britain, Ireland, the Netherlands, Norway and Sweden, and the workshop is open to governmental departments and institutes, dealing with monitoring activities at fixed locations.

Objectives

SeaNet's objectives are:

- A homogenous distribution of fixed monitoring sites.
- Promotion of on-line data exchange between fixed monitoring networks.
- Standardization of data collection, processing methods and validation techniques.
- Co-operation in the development of new measuring techniques and sensors, and testing of existing sensors.
- Exchange of experience in data communication and data collection, particularly in the case of fixed structures.

The long term objective is to realize a North Sea monitoring system, based on fixed monitoring networks as a contribution to an integrated European marine monitoring and forecasting system.

On the Internet

Information about SeaNet can also be obtained from the Internet. The site presents meta-data on parameter groups and specific parameters being measured in the North Sea region for all participating countries. The site can provide you with an overview of locations where specific fixed monitoring activities are taking place. Information on progress and plans with the SeaNet workshop are also available.

The address of the SeaNet site is: http://www.minvenw.nl/projects/seanet/index.html

Information

Information about the activities of the Workshop on Fixed Monitoring Networks on the North Sea is available through the secretariat:

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The EU Marine Science and Technology (MAST) Programme

Klaus-Günther Barthel

Since its pilot phase during 1989–92, the MAST programme has earned wide recognition among European oceanographers and, indeed, within substantial sectors of the international community. Although rightly considered as the central component of EU research policy in marine science and technology, it should not overshadow a vast array of contributions arising from other programmes, particularly on environment and climate, on fisheries and aquaculture, and on other resources such as renewable energy and hydrocarbons. The maritime sector (ship-building, transport etc.) is also covered to some extent in other programmes. Having said this, most of the examples of current work mentioned below will come from MAST. The second section of the article will outline opportunities offered to marine science in the upcoming Framework Programme 5.

When the European Union launched its first Framework Programme on Research and Technological Development (RTD) in 1983, no specific module on marine research was included. However, it was soon felt that marine matters needed more attention, and in 1989, during the second EU Framework Programme, MAST started as a specific programme. The financial 'volume' of MAST increased steadily with each new EU Framework, and the present programme on marine science and technology, MAST-III, will terminate at the end of this year having spent 244 million ECU, a five-fold increase on MAST-I. The ultimate objective of its research is to understand the functioning of marine systems around Europe, both in shelf waters and deep seas, and thus to help in establishing the scientific and technical basis for their exploitation, management and protection. This is being addressed by concentrating on four themes concerning the 'Health of the Oceans and Management for their Sustainable Use', 'Coastal Zone Management', 'Operational Forecasting' and 'Technological Opportunities'.

Fisheries and aquaculture research was initiated at European Community level in 1988 and since then has taken several denominations: FAR (1988–92), AIR (1990–94), and now FAIR (1994–98). The programmes have concentrated on the promotion of research in support of the Common Fisheries Policy, dealing with fisheries management, aquaculture, product development and, more recently, the interactions between fisheries, aquaculture and the marine environment.

The Environment research programmes of the 1970s and 1980s have already addressed issues of marine pollution and ecotoxicology. These topics have remained on the agenda of successor programmes: STEP (1989–92), Environment (1990–94) and the current Environment and Climate Programme (1994–98). Due to an obvious risk of overlap with MAST in the coastal zone, both current programmes are co-operating in the management of projects on coastal ecosystems, in conformity with the so-called ELOISE science plan (European Land–Ocean Interactions StudiEs). Finally, the Environment and Climate Programme also supports some marine research, especially in sub-Arctic seas, through climate-oriented projects.

In the years of MAST-I and to some extent also of MAST-II, the flagship project of the programme was the G6, then the G8, project on coastal morphodynamics. Owing to its unusual size and close integration of partners from 12 countries, it stood out as the first striking example of the potential for networking offered by a European programme on the marine environment. Leading institutes, each of them at the forefront of expertise on coastal physical processes, and normally competitors in their activities throughout the world, had agreed to co-operate in 'pre-competitive' research, and in so doing, they also brought together a large number of scientists from universities and other organizations.

The four large regional projects, MTP (Mediterranean Targeted Project), OMEX (Ocean Margin Exchange), CANIGO (Canary Islands–Azores–Gibraltar Observations) and BASYS (Baltic Sea System Study), two of which actually started under MAST-II, have since confirmed the ability of a programme such as MAST to bring together in a single project more than 50 participating institutes and several hundred scientists, thus helping to create a European community of oceanographers. Both the second phase of MTP (MATER – Mass Transfer and Ecosystem Response) and the BASYS project are adding a further dimension of co-operation with third countries by including numerous partners from North Africa and Eastern Europe, respectively. For each of these four projects, EU spending ranges from 7 to 11 MECU.

However, MAST does not consist exclusively of giant projects. MAST-III in fact supports 141 other projects of various sizes, some of which are medium-sized (in the range of 3–5 MECU EU contribution) while most others fall in the range of 1–2 MECU and have between five and ten partners. Furthermore, particular efforts are made to support advanced training in an international context, to satisfy the research needs of small and medium-sized enterprises, and to provide a better research infrastructure at a European level.

MAST has also played an important role in furthering the issue of marine data-management. MAST policy regarding data has lead to a much wider availability and thus utilization of data in Europe than before. The success is exemplified by recent publications of complete datasets on CD-ROM (e.g. from the OMEX-I project) and an increasing acceptance, for international co-operative projects, of data-management by professional data-managers instead of decentralized, uncoordinated data treatment.

MAST does not stand alone in Europe. Co-ordination with the EU member states and associated countries, and with the European Science Foundation (ESF) in particular, has contributed to creating a European dimension to marine research. In 1990, the European Committee on Ocean and Polar Science (ECOPS) was created, with financial support from MAST, to be an advisory body to the ESF and the European Commission. Since 1995, it has been succeeded by the two boards on European Marine and Polar Science (EMaPS) with whom MAST maintains a close co-operation on scientific matters. The marine technology sector, on the other hand, has profited from co-ordinated actions between MAST and the Euromar project of the Eureka initiative.*

Looking into the future

It is evident that Europe is a highly diverse continent with a multitude of interwoven cultures enabling it to be at the forefront of the scientific, social and economic development of marine issues. Europe is also a maritime continent, with a very long coastline in relation to its land surface, and with coastal seas that belong to the most exploited regions on our planet. Consequently much marine research effort has been concentrated on the coastal zone, and a relatively good knowledge base allows us to now move confidently into the field of operational oceanography and forecasting of coastal systems. As commercial operations move into deeper waters, we face at the same time the challenge of management for sustainable use beyond the shelf break, reaching across the continental slope and onto the abyssal plains. In this context, ecosystem-oriented research has to combine a natural science base, socio-economic requirements and necessary technological developments. Pertinent issues are deep-sea drilling, the deep sedimentary biosphere, living resources, and maintaining biodiversity despite exploitation. Activities must be closely integrated with one another, such that they contribute in a targeted way to the solution of the most important problems. Small and medium-sized enterprises, as well as public and private end-users, must be given a larger role in marine affairs. Hence, a wider approach will be taken by the European Union than in the past, and a new structure has been developed for its upcoming Fifth RTD Framework Programme.

The tasks in marine research and policy that lie ahead require stronger co-ordination at the European level and also with non-European partners. Implementation of marine policy is indeed beginning to move away from the national level where it has almost exclusively been in the past. The European Commission will therefore increase its activities in this field and support, or carry out itself, particular measures such as the co-ordination of the national research fleets or other large-scale infrastructure.

*For background information about Eureka and Euromar, see p.3; for details of how to find out more about MAST, see p.26.

As it currently stands after discussions in the European Council and Parliament, the proposal for the Fifth EU RTD Framework Programme comprises four 'Thematic' Programmes (i.e. the four themes in Activity 1, see below) and three 'Horizontal' Programmes (Activities 2–4 below).

First Activity *Theme I* Improving the quality of life and management of living resources.

Theme II Creating a user-friendly information society.

Theme III Promoting competitive and sustainable growth.

Theme IV Preserving the ecosystem.
Part A: Environment and sustainable development;
Part B: Energy

Second Activity Confirming the international role of Community research.

Third Activity Innovation and participation of small and medium enterprises (SMEs).

Fourth Activity Improving human potential.

A new structure has been given to the the four Thematic Programmes that focusses on:

- problem-oriented key actions which are directed towards a common European challenge or problem;
- generic activities that will complement the key actions to provide the general scientific and technological capabilities of widespread application;
- support for research infrastructure to encourage optimum use of the Union's research facilities.

Marine research will be dealt with at a number of places in Activity 1:

o In Theme IV, in the key action 'Sustainable marine ecosystems' that is devoted to developing a better management of marine ecosystems;

o In Theme IV, in the key action 'Global change, climate and biodiversity' that addresses marine issues in global change;

o In Theme III in the key action 'Land transport and marine technologies';

o In Theme I in the key action 'Sustainable agriculture, fisheries and forestry, including integrated development of rural areas';

o In infrastructure support.

The only exclusively marine key action will deal with 'Sustainable Marine Ecosystems' and address the following three core issues: (1) the capacity to understand, model and predict the functioning of marine ecosystems, both in the open sea and in the coastal zone; (2) the need to develop new environmentally-safe technologies to survey, monitor and exploit the marine environment, especially, though not exclusively, in coastal waters and over the continental shelf; and (iii) the ability to forecast environmental constraints that have an impact on offshore activities.

Another important contribution to marine ecosystem research will be made in the context of the key action 'Global change, climate and biodiversity' that concentrates on the understanding of global change processes and the mitigation of their consequences.

It may seem that marine research is somewhat dispersed in the Fifth Framework Programme, but this will allow the integration of marine issues with topics in environmental and other sciences. Obviously, there is a need to co-ordinate the marine activities in different Thematic Programmes and the European Commission will establish appropriate mechanisms in Framework Programme 5. This is also a prerequisite to establish closer links with national marine policies for better co-ordination of national, regional and European actions in marine research and ocean management.

With the new EU Framework Programme, Europe will be better prepared to tackle the problems at the turn to the next century. We hope to see many old and new researchers participating in the international and interdisciplinary research projects, thus making best use of the existing European potential for co-operative research.

Acknowledgements: Thanks are due to my colleagues in the MAST, Environment and Climate and FAIR Programmes who provided valuable input, and in particular to Jean Boissonnas who made substantial contributions to the text.

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Europe's Grand Challenge: achieving coordination in marine research

Tony Mayer and Laurent d'Ozouville

Europe might be termed the 'Peninsula' continent. With its own smaller peninsulas and islands, it has a huge coastline (over 90 000 km) in relation to its land area. The sea has been a major influence on the history and development of our continent, providing the means for development of trade, acting as a barrier to migrations (and sometimes invasions), as well as the means by which cultures and people have interacted. Even though the use of the marine environment may be perceived by the general public to be declining, it still accounts for a very major part of the economy of Europe, between 3% and 5% of European GDP. Marine activities include: the extraction of natural resources (e.g. hydrocarbons, sand and gravel for construction, fisheries and renewable energy); transport (of goods and people – EU countries rely on shipping for 90% of their external trade); and tourism. It is within the broad coastal zone that we see many of Europe's great cities. Indeed, population growth within the coastal zone provides another pressure point on the exploitation of our marine resource.

Clearly, there is a major imperative for us to understand the marine environment, both in the narrow, local sense described above and in the broader, global sense, as we recognize the importance of the global marine system, its function and the effects of changes on all our lives. This recognition has led to Europe being in the forefront of marine research, as reflected in the activities of the Challenger Society and its sister organizations within Europe.

Although oceanographic research has a laudable record of international co-operation, in the past there has been a tendency to think of national research programmes, national marine research institutes and national research resources such as research vessels. The development of European co-operative programmes through the EC Framework Programme (MAST) and within Eureka (with Euromar) has clearly demonstrated the gains to be made both intellectually and financially from European co-operation in research.

So where does the European Science Foundation (ESF) and its 'daughter' organization EMaPS (European Boards for Marine and Polar Science) fit into the picture?

The ESF is the European association of national research councils and academies supporting fundamental research from public resources. Founded in 1974, it currently has over 60 Member Organizations from 21 European countries, most having an interest in marine research; in the few landlocked countries, there is still a healthy research interest in the marine environment (e.g. Switzerland). The ESF exists to promote fundamental research by providing support for a variety of co-ordinating and networking activities through its schemes for Exploratory Workshops, Scientific Networks, European Research Conferences and Scientific Programmes. All of these mechanisms have been used to support the marine research community in Europe.

Some eight years ago, together with the European Commission, the ESF established the European Committee on Ocean and Polar Sciences (ECOPS), which was charged with identifying the key issues to be tackled at a European level over the next decade or so. The result of the brainstorming undertaken by the Committee was the publication of the 'Grand Challenges'.

The 'Grand Challenges' are:

- operational forecasting of the oceans and coastal seas;
- investigating variability of the deep sea floor;
- investigating the Arctic Ocean; and
- a European programme on ice-coring in Antarctica.

ECOPS also identified two other fields of major scientific interest:

- marine biodiversity; and
- coastal zone management.

These major issues became the basis for the design of the current MAST-III programme within the EC's Fourth Framework Programme. They not only addressed issues of concern to the EC in terms of developing industrial competitiveness and policy support, but they still remain valid for Framework Programme 5 and for the advancement of fundamental marine research in Europe.

With the completion of its task, ECOPS was succeeded by EMaPS, consisting of representatives from marine research organizations in Europe, who came together to implement the Grand Challenges through co-ordination, and to build on this base in developing a strategy for the future of marine research in Europe.

Summary of the draft report of the Committee on Science and Technology of the Council of Europe

Because of its rich maritime history, Europe has many assets in marine science and technology. Moreover, over the course of this century an active and diverse network of scientific institutions has developed, along with a well-trained workforce. European industries have been very successful in developing new technologies for the exploitation of offshore resources and the building of new ships.

This potential is, however, dispersed, and Europe lacks major programmes in marine science and technology, which might mobilize scientific and technological competence and give it a leading role in international co-operation in certain key areas.

Europe's potential in marine science and technology must be given more funds in order to be fully realized. Its competence should be used in dialogue with industry and other maritime partners and as a tool for politicians in the development of a true European maritime policy. This process will necessitate the creation of a European Maritime Agreement.

Already EMaPS has moved ahead on many of these initial issues with activities on, for example, coastal management research, ocean modelling, marine biodiversity and the deep-sea environment, as well as on strategic issues for marine science in Europe.

The European Science Plan on Marine Biodiversity

The overall objective of this plan is to develop, on a European scale, the scientific basis necessary to support management for the sustainable use of the diversity present in the marine environment, for the benefit of present and future generations. The three sub-objectives are:

To describe and characterize marine biodiversity in Europe and to quantify its role in providing goods and services in relatively pristine environments as compared to impacted environments, as a baseline for evaluating human impact. This should involve a nested approach to address patterns at a range of temporal and spatial scales.

To determine the effects of changes in biodiversity, both natural and man-made, on the goods and services provided by marine ecosystems. This should involve long-term and large-scale studies as well as experimental manipulations of biodiversity.

To provide the scientific concepts and tools for the management of marine resources, living and non-living, including modelling frameworks and rapid assessment protocols.

EMaPS, as befits an organization of research institutes – the 'doers' – needs to have regard to the infrastructure for marine science in Europe. ESF has always had a particular mandate to encourage and facilitate the use of large research facilities in Europe. While this mandate was originally considered to be concerned with facilities such as those needed for particle physics, astronomy, nuclear physics, etc., it is now acknowledged that marine research is also 'big science'. Only by ensuring that Europe has an effective infrastructure can we hope to compete globally. ESF, through EMaPS, is fulfilling its responsibility for the marine research community in this key area. For instance, in looking ahead to future science needs and technology requirements for deep sea sampling, ESF has brought together scientists and technologists from industry, to produce a position paper on future European initiatives needed in this area.

Position Paper on European initiatives in science and technology for deep-sea coring and drilling: summary and recommendations

1. General recommendations The scientific community in Europe is in an excellent position to contribute actively to science objectives and technology developments in the framework of European and international drilling programmes.

The oil and gas industry and the scientific community presently have several common interests in drilling objectives and in the development of new technologies. There is an urgent need for a more concerted European approach in the framework of future international drilling programmes. Co-ordination and co-operation have to be developed at the scientific, technological and executive levels between the parties involved in deep-sea drilling in Europe.

2. Scientific recommendations Endorsement of the Long Range Plan of the Ocean Drilling Program (ODP), which involves concentrating on:
(1) the nature of the deep ocean crust and the dynamics of the lithosphere; and
(2) evolution of the Earth's environment.

Specific European priorities are: (1) continental margins (resource exploitation; natural hazards; high resolution study of climate and sea-level changes); (2) the deep sub-seafloor biosphere.

These aims cannot be achieved with only one platform, and there is an urgent need for European scientists to gain access to additional platforms with long piston coring, geotechnical and drilling capabilities, as appropriate

3. Technological recommendations Development of new techniques, in particular riser techniques, are required before testing a number of geological and geophysical models and hypotheses. The present riser technologies used by the oil companies are close to reaching their limits and cannot be extrapolated for deeper drilling without difficulty.

Due to its high-level expertise, Europe can actively contribute to the construction of the deep penetration tools of the future (riserless drilling, slimline riser drilling).

Europe can contribute a series of down-hole exploration tools: new logging sensors, fluid samplers, pressure core samplers, microbiological samplers and *in situ* laboratories.

EMaPS must also be aware of the science policy framework in which marine scientists operate. Through ESF, it has made a significant input to the formulation of Framework Programme 5 and, more directly, by ensuring that there is a close working relationship between it and the European Commission. Another player at the European level is the Council of Europe, which has rightly recognized the oceans as an environment of concern to, and part of, the heritage of all Europe's citizens. EMaPS has been able to assist the Science and Technology Commission of the Council of Europe in producing a major report on marine matters, and has assisted in the recent Parliamentary Assembly in Paris (19 March 1998) dedicated to marine matters.

Now, in the UN Year of the Oceans, with the World Expo in Portugal devoted to marine and maritime themes, and with the report by the World Commission on the Oceans also expected shortly, the importance of EMaPS in bringing together Europe's ocean scientists needs to be reiterated.

Rightly, there is increasing public perception of the role and importance of the World's ocean system on our lives and mounting concern about the health of the oceans. Even 'El Niño' has entered into common parlance in Europe's media. Europe's scientists must continue to play a key role in research into a further understanding of the ocean system, and EMaPS, in co-ordinating national activities, provides a special added value in this respect.

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EuroGOOS: An Overview

Most people have probably heard of GOOS, the Global Ocean Observing System. EuroGOOS is the Association of European national agencies established to maximize the benefits to Europe of operational oceanography (i.e. measuring, monitoring, modelling and forecasting) within the framework of GOOS. EuroGOOS has three principal goals, long-term objectives for the development of operational oceanography and the provision of benefits to Europe:

1. To build on the scientific successes and benefits of the post-World War II era of investment in marine science and technology in Europe.
2. To create new businesses and new jobs in Europe and improve the efficiency of industries and services, through new developments in operational oceanography.
3. To develop a collaborative scientific approach to planetary environmental management, thereby enabling Europe to wield influence on a global scale.

Europe is in a strong position to lead the way in marine science and technology, but no single European country can monitor and predict all the sea areas which influence its own particular economic, environmental and social conditions. Still less can a single country make a signficant contribution to the global structure and implementation of GOOS. Achievement of the goals of EuroGOOS plainly requires collaboration between agencies responsible for maritime transport, environmental management, coastal defences and flood prevention, fisheries, harbours, offshore oil and gas, tourism, maritime research, and marine technology.

Since the Association of European agencies was formed in 1994, most countries with member Agencies have formed national co-ordination groups to plan their participation in EuroGOOS projects. Development of new European infrastructures, working across industries and across EC Directorates, will expedite applications of marine science and technology, and thus increase European competitiveness in global markets.

Thirty research programmes were already underway by 1996, conducted either at the national level or by collaboration between groups of agencies from different countries. These programmes provide a secure base of experience upon which to develop more ambitious integration of data and modelling, as well as provision of services and products, both for regional seas in and around Europe and for the North Atlantic.

Development of EuroGOOS is taking place in three phases:

Phase 1: 1996–1998

Phase 2: 1998–2002

Phase 3: 2002–2006 and beyond.

A number of Major Projects in the EuroGOOS Plan are to be implemented during the various phases of this time-table:

- The Atlantic Project will forecast fluxes of heat and water, the variabliity of currents, storms, ice and climate in the North Atlantic, all vital to a proper understanding of climate change in Europe.
- The Arctic Project will concentrate on the Eurasian sector of the Arctic Ocean and its continental shelf, and in particular on development of a three-dimensional ecosystem model for predicting ice cover, water circulation and biological processes, both as an aid to fisheries and shipping and to support long-term climate prediction.
- The Baltic Project will improve and expand existing collaboration between maritime agencies in Baltic states, so as to provide long-term modelling and forecasting of waves, ice, pollution, and biological production (including plankton blooms and fisheries).
- The Mediterranean Forecasting System, to be developed over the next ten years, will provide forecasts of sea-state and currents, as well as of biological production (especially plankton blooms) and climate variability. These bear on the management of pollution in the Mediterranean and on the incidence of droughts in North Africa, and there is to be strong collaboration with North African states.
- The European North-West Shelf Seas Project is to provide a uniform system of observation, modelling and forecasts of: tides, currents, sediment movement and erosion, primary production and algal blooms, and water quality, all of which will benefit fisheries, shipping, and offshore hydrocarbon production.
- The Global Pilot Project, conducted in collaboration with American institutions, will focus on the Atlantic and will make use of satellite data and super-computer models to support the development of global climate forecasting.

The four-year duration of successive phases of EuroGOOS operations should facilitate more efficient development of existing services and forecasts, as well as development of new technology (through trials and pilot tests), as well as training of new scientific and technical staff. It is hoped that defining new procedures and establishing new cross-boundary infrastructures and faciilities will also lead to new business opportunities for European countries.

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Marine Societies move closer together at Bolougne

The inaugural meeting and conference of the European Federation of Marine Science Societies (EFMS) took place at Boulogne-sur-Mer on 19–24 April 1998. It was a joint meeting sponsored by the Challenger Society, the Deutsche Gesellschaft für Meeresforschung and the Union des Océanographes de France. An official sub-group devoted a large amount of time and effort to setting up the Articles of Association of the Federation. In addition to representatives from the Challenger Society and the DGM, and of course members of the UOF, there were also two representatives from Turkey and one from Greece. The Nordic countries were represented by delegates from Sweden and Finland, who were mandated to speak also for Norway, Denmark, Iceland and Faeoes; in addition, there had been an expression of interest from Israel.

Broadly speaking, the aims of the Federation are to encourage a more unified and more interdisciplinary approach to the marine sciences throughout Europe, to influence government policies more effectively and thereby improve reseach funding. It is intended that there shall be an 'open-door' policy with regard to membership, so that oceanographers from any country can join, either individually or collectively (as members of their national societies). Each national society will remain responsible for its own marine science affairs, statutes, membership and meetings, but formulation of broader supranational issues is to be dealt with by the Federal Council, on a 'one country, one vote' basis. The full Articles of Association have still to be agreed and ratified, and this is likely to occur towards the end of 1998.*

Nobody pretends that it will be an easy task to achieve a fully functioning federation. In the UK alone, for example, in addition to the Challenger Society there are no fewer than five societies or associations dealing with different aspects of marine science and technology, and some of them have memberships of comparable size or larger. It would surely be in the best interests of a Federation if such groups could in some way be affiliated to it, so that their views and ideas were represented.

For such a significant meeting the somewhat limited attendance from countries other than France was noticeable. This may in part be attributable to the fact that, for practical reasons, the meeting could be announced only rather late in 1997. This was a great pity, for the overall theme was to consider and discuss 'the state of multi-disciplinary research in coastal oceanography in Europe'.

For those who did manage to reach Boulogne, however, there was much to see and learn and discuss. Although the majority of speakers were French and many of them (not surprisingly) presented their papers in French, their overheads were often labelled in English, enabling the rest of us to follow most of the arguments, especially as most abstracts were in both French and English. The discussions that followed some presentations, however, tended to become somewhat protracted dialogues between speaker and interlocutor, which many delegates could not follow.

One of the central features of this meeting was a session devoted entirely to presentations by young oceanographers. These were particularly impressive because of the efforts they made to communicate to an audience from a variety of countries. Indeed there was a prize awarded for the best 'European' communicator. This was won by Xavier Harlay (from Wimereux). The Jaques Poutiers Prize for the best science presented was won by Vincent Denis (from Caen), the second prize being won by Joëtte Paing (from Montpellier).

An important (and to us novel) feature of the conference was the round table discussions. There were four of these: on vessels and instrumentation; on publication and communication; on coastal zone monitoring; and on education and job opportunities. The value of these discussions, which could with advantage be arranged at other meetings, is that it enables different member nations to obtain an overview of what the others are doing. It depends for success crucially on a critical mass of delegates from particular nations being present, so that they can speak with authority. In this connection it was a little embarrassing that the UK delegation was below such a critical mass and so could not illuminate all of these discussions as much as migh otherwise have been possible.

Of particular interest to *Ocean Challenge* was the discussion on communication and publication. It was envisaged that eventually there might be a pan-European journal or magazine – though compiling and editing such a production would require significant resources. In the meantime, one possibility is that individual member societies would circulate 3–4 page newsletters, in the style of the DGM's *Marine Messenger* and the UOF's *La Lettre des Océanographes*. These would supplement (rather than replace) the 'home' journals of those societies that currently produce them, which for financial and/or logisitical reasons might not reach all members in the Federation (see also below).

A particularly interesting feature of the discussion on coastal zone monitoring was the suggestion that researchers should make their results commercially attractive to industry and so obtain additional financial support – otherwise their funds from more conventional sources could dry up. It was also stressed that anthropogenic influences extend from river catchment areas to the coastal zone (a fact that some of us tend to forget). The importance of long time-series measurements was repeatedly stressed, as was the need for more multidisciplinary research programmes, embracing not only the basic science, but also the social and economic aspects of the consequences of human activities.

*See also the item by Challenger Society President, Mike Whitfield, on p.8 of the previous issue (Vol.8, No.1).

The round table discussion on education established that in most European countries marine scientists are recruited from graduates whose undergraduate education has been in one or other (rarely more than two) of the main science disciplines (with or without maths). In other words, they are 'specialists' right up to graduation, and may well remain so even after they get into the marine science field proper, unless they learn early enough that in the marine (and indeed any other) environment 'Everything Relates to Everything Else', i.e. that we ignore other disciplines at our peril. However, the case for single-discipline training at pre-graduate level remains strong in many institutions (*Ocean Challenge*, Vol. 7, No. 2, p.18). The plight of contract researchers was also aired during this discussion, though it appears to be less of a problem in France than in, for example, Germany and the UK (*Ocean Challenge*, Vol. 7, No. 2, pp.19–21; Vol. 7, No. 3, p.9).

A highlight of the symposium was the guided tour round the extension to the Nausicãa marine complex, officially opened in May 1998, but still under construction at the time of the meeting. It is an aquarium plus multimedia 'eyes-in' and 'hands-on' extravaganza, offering adults and children alike the opportunity to explore several marine environments in some detail. The dominant themes are: living and non-living resources; biodiversity; fishing (including aquaculture); coastal (including harbour) communities. Two large aquarium displays feature the contrast between a tropical island (complete with real corals) and an open ocean environment (complete with fish), and there is a Californian-type sea-lion park. Similar projects are underway elsewhere in France and in some other countries, including Germany, Italy and Thailand. The staff at the Nausicãa includes no fewer than five marine scientists, to ensure that the science is right and that the 'artificial' ecosystems are true to their natural counterparts.

Running through all of the various themes and exhibits and displays is the underlying philosophy of sustainability, and there are constant reminders that humans have become a dominant part of the marine environment and must take care of it for the benefit of future generations.

Society Publications

All participants were given current copies of *DGM Mitteilungen* (1/98), *La Lettre des Océanographes* (Vol. V, No. 2, March–April 1998), and *Mer & Sciences* (Vol. 1, No. 1, 1998). Each of the three publications is aimed at a different kind of readership, so they contrast strikingly with one another.

Shortest by far was the UOF newsletter, consisting of four pages of news and views. The first item was (of course) advance notice of the meeting reported on above, but the second one was particularly eye-catching, for it concerned a story that had also featured in the British press. It centred round the mystery of several dolphins (reported numbers ranged from 14 to 22) washed up dead on France's Mediterranean coast earlier this year. All the animals had an identical ventral wound: a circular fist-sized hole just behind the head. The favoured conspiracy theory was that these were dolphins trained by the US Navy as submarine guards for military installations, and fitted with small transmitters to signal the presence of intruders. In the event that the dolphins ceased to do their job properly, for whatever reason, they could be killed by detonating a small explosive charge implanted near the head. Alternative explanations involving natural causes of death, e.g. viral infection or changing sea temperature, lack conviction as they cannot account for the identical holes in the heads. There is evidence from Scotland that some dolphins kill their own young, but that can be ruled out here, as these were all adult animals and it doesn't explain the holes either. We shall probably never know what happened.

But to return from this digression: The newsletter also carried a series of short news items from Ifremer, reporting current projects and recent activities. Finally, there was a somewhat longer piece by J.-M. Amouroux bewailing the way in which (he believes) molecular biology and genetics are nowadays seen as fashionable, not to say trendy, whereas systematic biology, especially taxonomy and ecology, have become old-fashioned 'second-class' sciences of interest only to a minority. He warns that we dispense with these subdisciplines at our peril, because only through them can we properly understand the living world around us. (Similar sentiments were expressed at the MAST meeting in Lisbon; see p.5.)

Much longer than the newsletter is the first issue of the magazine published by the UOF, with Ifremer support. In full colour on glossy paper it looks very handsome, but some might find the content a bit limited. Much of the first half is devoted to the organizational structure of French marine science and technology, with information about the relevant institutions and the research vessel fleet (also covered at the joint meeting in Hamburg, October 1997; see *Ocean Challenge*, Vol. 7, No. 3, pp.22–3). There is also a review article about oceanic water quality and how it might be monitored, the factors that can affect it, and the difficulties of reliably defining what we really mean by the term 'water quality'.

The *DGM Mitteilungen* is perhaps the 'meatiest' of these three publications, but you need to concentrate because German is not an easy language. There is the usual mixture of articles, both long and short, as well as meeting reports, news of forthcoming events, and other items, including what can best be described as personal 'policy statements' from the new management of the DGM. One very useful new addition to the DGM newsletter is that the scientific articles now have *abstracts in English*, against which less linguistically gifted readers can test their understanding of German.

A.M.C and J.B.W (Eds)

'Science and art belong to the whole world, and the barriers of nationality vanish before them.'
Goethe

'There is no national science, just as there are no national equations.'
Anton Chekov

Extreme Marine Environments

Peter Herring

What is an extreme marine environment? How do organisms cope with living in one? These were the two questions addressed by the meeting held at the University of Plymouth on 30 March–2 April 1998, under the joint sponsorship of the Marine Biological Association and the Challenger Society. Appropriately, the meeting was held in honour of Professor Alan Southward's 70th birthday. Throughout his career, Alan has been actively involved in many extreme environments, ranging from the high tide mark to abyssal hydrothermal vents – including most marine environments in between. Many of his students and/or colleagues took the opportunity to honour him and highlight his massive contribution to the science and to their education.

Most environments are regarded as extreme if they fall off the end of our measurement systems. Thus we recognize in the sea extremes of temperature, salinity, light, pressure, oxygen, heavy metals etc. Cleverly, we go further and recognize the additive effects of synergies, e.g. low temperature and high pressure in the deep sea, or high salinity and high levels of solar radiation in tropical pools. Much less easy to quantify are the behavioural traits of animals which dip into (and out of) measurably extreme environments, or the relative sensitivity of different life-history stages of the same species to the environmental stresses highlighted by our instruments. But these instruments are viewing 'extreme' from a largely inappropriate perspective; the only real perspective is that of the individual organism's sensory and physiological systems. In many cases, critical parameter(s) for the organism may be quite different from anything that we can record. We have only recently established that iron measurements may identify 'extreme' for diatoms in some localities. Perhaps biodiversity should be the criterion: low diversity is often regarded as the product of an extreme environment (e.g. with high disturbance). But high biodiversity implies a saturated, highly competitive environment. Isn't this an extreme environment too?

Happily the meeting was not too racked by these navel-gazing concerns and each presenter took their own view of 'extreme', aided by the catalytic contributions of the six keynote lecturers. These covered 'Brackish waters' (Richard Barnes), 'Hydrothermal vents' (V. Tunnicliffe), 'Polar regions' (Andrew Clarke), 'Hypoxia' (Jim Childress), 'Rocky shores' (Steve Hawkins and Guido Chelazzi) and 'Toxic metal-rich environments' (Phil Rainbow). Each keynote lecture was followed by relevant contributed papers and it was no accident, given the Southward connection, that those on hydrothermal vents and rocky shore environments were numerically predominant. The range of topics, phyla and environments covered was impressive. None of the participants will have come away quite as confident that 'their' particular environment is as uniquely extreme as they imagined when they arrived.

A list of the contributions would be of limited value here; it can be obtained from the Marine Biological Association, or from Paul Tyler or myself at the Southampton Oceanography Centre (see below). I shall simply consider some of the aspects that were covered. Socio-economic problems are associated with many of the extreme marine environments of coastal waters (e.g. halophyte communities, mangrove swamps, and estuaries heavily polluted with metals). These problems provide some financial leverage for the continuation of research in these areas.

Extreme marine environments also offer the opportunity for addressing fundamental questions that concern biological systems in general. Community limitation and succession, reproductive strategies for spatially or temporally constrained resources, the interaction between physical stress and biological competition: all these aspects can be advanced by examining the special natural experiments offered by particular extreme environments. Some extreme physical problems presented by the environment (e.g. ice scour) may be of limited geographical consequence, and the hydrothermal vent environments may seem esoteric novelties in relation to the whole area of the deep-sea floor. Nevertheless, the particular questions both environments pose about recolonization strategies have much in common. Studies on the processes occurring in environments which, like these, are difficult and/or expensive to access, can be accelerated if more local analogues can be found. Thus the lightless chemosynthetic communities most strikingly found at deep-sea hydrothermal vents have an analogue in the dark submarine caves with enclosed sulphurous springs that are present in parts of the Mediterranean.

Rocky shores offered scope for many of Alan's colleagues to emphasize his contribution to their science and to describe continuing work on zonation and competition. Barnacles and winkles provided predictable vehicles for analysis of the stresses in this environment and the observed phenotypic and genotypic consequences. The occurrence of zonation has recently been challenged and the debate continued within the meeting, with the zonationists in the apparent ascendancy, ably marshalled by Steve Hawkins' keynote address. Much of the interpretation of the controlling processes depends on the data generated by distributional analysis and experimental manipulations. These can then be transferred to models and the models driven through simulations of specific stresses. To me, this still requires an act of faith in the links between the statistics of distribution, the equations of the models and the behaviour of individual organisms, as opposed to virtual populations. I still await conversion. At the cellular level, the techniques now available can be skilfully exploited to dissect the sequence of messages that determine the response of fucoid algal zygotes to, for example, osmotic shock, with the consequent effects on their survival in the osmotically extreme conditions of rocky shore zones. The stress in these environments is not only physical at the upper shore levels but also biological in the predation or grazing pressures coming from lower levels.

The success of mussels in coping with this ecological and evolutionary squeeze was highlighted. Rocks and hard places are not the only challenging environments inshore. Extremely soft sediments present their own problems; perhaps 'marine slurries' would be an appropriate environmental description.

The organisms that do succeed profoundly modify their environment for others. The same applies in conditions of high tidal flow rates and here the plasticity of growth form is a key factor.

Other contributions came in the form of a lively poster session whose numbers rapidly outgrew the organizers' initial expectations. With the aid of the MBA help-desk all were successfully accommodated. Meetings are as much about encounters outside the lecture hall as what goes on within it. This was no exception and the interactions were given added encouragement by a reception at the MBA (which generated a rumour that unprecedented quantities of wine had been consumed) and a splendid conference dinner in Alan Southward's honour. In practice, of course, it honoured both Alan *and* Eve for their mutual contributions, not least in that they were probably the only participants to have been present for *every* paper. The informal success of the meeting was demonstrated later that night by the quantity (if not the quality) of a 3 a.m. rendering of 'Ilkley Moor', which had your correspondent feeling his age and searching for the fire hose.

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Contract Researchers' Plight

The position and prospects of post-doctoral researchers seems to be as dire in Spain as it is elsewhere in Europe (*Ocean Challenge*, Vol. 7, No.3, p.9), according to a feature in a recent *Nature* supplement entitled 'Science in Spain' (pp.4–5). Although no mention is specifically made of the situation in the marine sciences, there is no reason to suppose it is any different from that in other scientific fields. In some respects it might be encouraging to learn that scientists elsewhere are protesting about their situation, but there seems to be little incentive for people to try their luck elsewhere in Europe. *Ocean Challenge* readers would be very interested to learn directly from scientists on the ground how post-docs fare on the Spanish oceanography scene.

Want to know more about MAST?

For information on projects, calls, events, publications, etc., visit the MAST Web site:
http://europa.eu.int/comm/dg12/marine1.html

For follow-up actions from the Third European Marine Science and Technology Conference (see this issue, pp.3–5) visit:
http://europa.eu.int/comm/dg12/marine/lisbon-g.html

A useful booklet published by the MAST Office is:

Major European Marine Research Institutes and Centres – Address List (1997) EC, Directorate General, Science, Research & Development

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- Practical ways to integrate East European research communities; and
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News and Views

Pleistocene sea-farers

Until relatively recently it was thought that the first hominids to acquire the ability to make sea voyages were modern humans (*Homo sapiens*), and the earliest of such voyages was believed to have led to the colonization of Australia from what are now the Indonesian islands between about 40 000 and 60 000 years ago. It now seems that communities of the ancestral species (*Homo erectus*) living in the Indonesian islands as long ago as 800 000 to 900 000 years ago, were not only capable of making tools, but also of travelling over water between the islands. Some of the islands may be been connected when continental shelves were exposed at times of low sea-level during glacial maxima, but the straits between others were too deep. To reach Flores Island, for example, where a rich haul of mid-Pleistocene artefacts was recently discovered (*Nature*, **392** (12 March) 1998, pp.173–6) would have required a crossing of nearly 20 km even when sea-level was at its lowest.

One of the fascinating aspects of early hominid history is the initially very low rate of technological advance. *H. erectus* learned to navigate and make stone tools nearly a million years ago (if not earlier), was using fire and wooden spears at least 400 000 years ago (cf. *Ocean Challenge*, Vol. 8, No.1, p.8), but never progressed beyond that. Even our own direct ancestors, appearing barely 150 000 years or so ago, remained in the Stone Age for about another 140 millenia. Then somebody discovered farming, somebody else discovered how to use metals, we came out of the Garden of Eden – and it has been downhill ever since. But isn't it amazing: *H. sapiens* has become 'industrial man' only during the last 5% of the period that our species has been on the planet. There's progress for you.

Sea mammals and sound bites – update

In the April Newsletter from SAMS (the Scottish Association for Marine Science) is a short article on the effect of loud low-frequency sounds on marine cetaceans (cf. *Ocean Challenge*, Vol. 8, No.1, p.12), especially when emitted at regular intervals (e.g. during oil exploration). The author joins the growing band of scientists urging caution in the deployment and use of equipment that produces such sounds, until the effects on the animals can be properly evaluated.

An interesting recent variation on this theme is a new radio channel called ORCA FM, which began broadcasting in July this year, from a remote location on the coast of British Columbia, claimed to be the best place in the world for finding killer whales. An underwater microphone will relay the clicks, pops and squeaks of killer whale 'language' to interested listeners (and there is also a phone link to the Vancouver Aquarium, which should increase the audience). Apparently each family ('pod') has a distinct dialect, which the young learn from their mothers. Attractive though whale 'language' is to hear, it seems that it is little more than a rudimentary system of sharing information on practical matters, along the lines of: 'I am here, where are you?', 'Hey, I've found breakfast, come and get it!'

The British Columbian coast is understandably a favourite haunt of whale watchers, and the noises made by the local flotilla of whale watching boats, as well as by passing cruise ships, will also be broadcast. Scientists monitoring the transmissions claim that the underwater environment already sounds as if a crowd of paparazzi is following the whales round all the time, and they are concerned that the extra noise could eventually drive the whales away – it looks like there's a market for a whale-watching boat that's silent.

To clear fog, use a greenhouse gas ...

In winter, airports can be paralyzed by freezing fog. Such hold-ups may become a thing of the past, once airport managements get to know of the no doubt serendipitous discovery that spraying CO_2 on runways can clear the air in a matter of minutes. At –80°C, liquid CO_2 droplets make good condensation nuclei as they evaporate, and accelerate the growth of ice crystals, which fall out as snow or ice.

It has a pleasing, not to say ironic, symmetry: In order to expedite the movement of air traffic which expels vast amounts of extra CO_2 into the atmosphere, we can now clear runways by supplying the atmosphere with additional doses of CO_2 – well, at least it's cheap.

... and to clear oil, use hair

Pictures of oiled seabirds are familiar to most people, pictures of oiled sea mammals less so, chiefly because most of them are not noticeably hairy. Sea otters are an exception, and their fur takes up oil as efficiently as the feathers of any bird. The oil is not actually absorbed into the fibres, rather it is *ad*sorbed onto their surfaces and can be shampooed out – indeed, part of the reason why many de-oiled seabirds don't survive is because the natural oils that coat their feathers have been removed along with the mineral oil. The same would appliy to the fur of oiled seals and otters.

Another serendipitous bit of lateral thinking around this topic has suggested a practical use for the many tonnes of human hair that accumulate in hairdressing salons and barbers' shops across the globe, and are presently dumped as waste. Hair adsorbs oil, so use it to clean up oil spills. Large bundles of human hair enclosed in nets are apparently far more effective and much quicker at getting rid of spilled oil than the conventional chemical methods presently used – and of course they don't damage the marine biota. They are also much cheaper, especially as they can be 'shampooed' and reused. There is, of course, the small question of what to do with the many tonnes of detergent–oil–water mix that results, but that, as we say, is not our problem.

The idea of using human hair in this way is credited to a small-town barber in the southern US, and by a quirk of technological convergence, scientists at the University of Bangor have patented a very similar technique, using specially treated plant fibres that selectively remove oil from water. This may prove to be a more costly way of clearing oil spills than simply using sweepings from the floors of hairdressing salons, but it should find uses for industrial processes where cleanliness is important, and any old hair would not be acceptable.

NOW There's a FUNNY THING...

Global Warming Outrage – humans not to blame

So Piers Corbyn, the maverick meteorologist (*Ocean Challenge*, Vol. 7, No.3, p.18), may have been right all along. Scientists in Denmark recently established a good correlation between global cloud cover and cosmic ray activity. The inference is that cosmic rays can 'seed' the atmosphere with ionized particles, thereby encouraging the formation of clouds. Clouds reflect solar radiation back to space, so the more clouds there are, the cooler the Earth will be. The solar wind 'blows' cosmic rays away from the Earth, and the intensity of the solar wind increases with increasing solar activity, as indicated by the number of sunspots on the Sun's surface. It follows that when there are more sunspots there are fewer cosmic rays and fewer clouds, so the Earth warms up. Conversely, fewer sunspots means more cosmic rays, more clouds, and global cooling.

It is a lovely idea, and the proposed mechanism of cloud formation by cosmic rays is particularly appealing, although it has yet to be confirmed by experimental observation in a 'cloud chamber' of the kind used during the 1920s and 1930s in the early days of the search for subatomic particles. The chamber contains rarefied water-saturated air, and the charged particles leave tracks of condensed 'cloud droplets' as they travel through it.

The appeal of this new Theory of Global Warming is immense, although of course it is simply a modern variation on an old theme. It has long been supposed that there is a link between sunspots and global climate – sunspot minima characterized the Little Ice Age of the 17th and 18th centuries, for example. But there were also fewer sunspots during the temporary reversal of this century's global warming trend that occurred between the 1940s and the 1970s (when scientists began to warn about the onset of a New Ice Age). The subsequent reversion to global warming can then be attributed to a secular increase in sunspot activity.

Wouldn't it be wonderful if we could now conclude that the folk who attribute global warming to greenhouse gases have for years been talking so much Hot Air? The oil companies wouldn't need to waste their time messing about with developing solar energy technology, we wouldn't need more wind farms, and we needn't feel guilty about using our cars and turning up the central heating.

Yes, but ...

I seem to recall that not all clouds are net reflectors of solar radiation. There is evidence that in some circumstances increased cloud cover insulates the Earth, trapping out-going radiation and keeping us warm (*Ocean Challenge*, Vol. 7, No.3, p.7). If cosmic rays produce charged particles, would they not produce them mainly in the upper atmosphere, i.e. seeding cirrus clouds? Some scientists claim that cirrus clouds reflect incoming solar radiation, others that they trap outgoing terrestrial radiation. Could this lovely new theory fail because of the Wrong Sort of Clouds? In case you were wondering, by the way, charged particles *in the solar wind* don't provide cloud condensation nuclei because they don't penetrate beyond the ionosphere, where they produce the spectacular auroral displays of ionizing energy above the poles.

The burst of publicity these results received in April has been followed by silence. It would be mischievous to suggest that too much has been invested in conventional climate change models based on greenhouse warming, making us reluctant to contemplate alternative explanations. Somehow it seems unlikely that increased solar activity can be responsible for the warming trends of the 1980s, when sunspot numbers actually *declined* for most of the decade. But what of the 1990s, with three of the hottest years ever, and mountain glaciers shrinking at record rates all over the world? Sunspot numbers began to rise again in the early 1990s and indeed some people did blame solar activity for the horrendous heat wave that hit the south-eastern Mediterranean in late June and early July of this year.

Meanwhile, down in the forest ...

All this scientific stuff can be tiring, so let's have some good old mysticism, some metaphysical intervention in phenomena we still don't fully comprehend. Take the case of the rainforest fires in the Roraima region of the northern Amazon basin. For five months they raged out of control, helped along by local landowners so that they could claim compensation from the Brazilian government (which makes an interesting approach to environmental management). Firefighters were in despair. Their best efforts were ineffective, only rain could end the drought and extinguish the fires. As a last resort, two tribal forest Indians were asked to intercede with their ancestral spirits. They performed the necessary rituals (the nature of which they kept private), and said simply that it would rain soon. Within hours heavy rain was falling on the fire-ravaged forests, and the fires petered out.

What a refreshing change from arguments about climate models and cosmic rays! Perhaps these wizards could have been called in to help with the drought-driven forest fires raging through Florida and the record-breaking heat waves affecting large parts of the USA.

I wonder if teleconnections can have a spiritual component ...

Stop Press

We appear to have had a bit of occult intervention in the weather on this side of the Atlantic too, albeit rather unsuccessful as it turned out. There has been no shortage of anomalous weather over the last few months in various parts of the world, and the UK was no exception: our April and June were the wettest for over 150 years, May was one of the driest, and there was some decidedly unsummery wet and windy weather early in July. It seems that for this last we can blame the Druids, whose Sun-dance at the summer solstice was (on their own admission) shorter than usual and performed with less than the accustomed zest. The reason? Well, the weather was a bit dodgy at the time ...

Goodness me, how La Niña has grown!

Various parts of the world experienced unusual, and sometimes severe, climatic conditions over the past several months, and it seems to be widely held that the principal culprit is the 1997–98 El Niño, allegedly the strongest on record.

But now, would you believe, we have dire warnings of the potentially catastrophic effects of La Niña. I was amazed. There in a broadsheet newspaper were the standard text book cross-sectional diagrams of the Pacific Ocean, illustrating (left) normal conditions, and (right) El Niño conditions. The big difference was that the diagram illustrating the normal (i.e. non-El Niño) conditions was labelled La Niña, implying this is some kind of unusual phenonemon that must from time to time be suffered, especially after an El Niño event. Yet historically speaking, it is surely the norm: under the influence of the South Pacific High and the Indonesian Low, easterly Trade Winds, drive warm water westwards in the Equatorial Current System, depressing the thermocline in the west, elevating it in the east, allowing upwelling to bring nutrient-rich water into the Peru/Humboldt Current so that the birds and fishes in the eastern Pacific grow fat on the plankton.

Now we are being told (and not only in the newspapers – I've heard it over the radio too) that this state of affairs is some deadly climatic nemesis, threatening storms and heavy rains in Indonesia and environs, droughts along the western seaboards of North and South America, and Atlantic storms and snow (*sic*) for north-west Europe. Insurance companies are reported to be gearing up for a whole set of new claims based on the disastrous consequences of what I have always understood to be the normal state of affairs in the Pacific.

I suppose all this hype is because the recent ENSO event was so strong that return to normal conditions appears by contrast all the more dramatic. Also, drama makes for better copy – nobody wants to hear about conditions reverting to *normal*, that's boring, it's no way to sell newspapers or attract listeners and viewers. It has to be said too that the cross-sections I saw were quite accurate, so there should be some improvement in public understanding, a touch incomplete and distorted, perhaps, but better than nothing.

Suckers for satellites

Al Gore, the 'greenest' US Vice-President in history, has worthy but distinctly nutty ideas for saving humanity from itself, as anyone who has read his book (*Earth in the Balance*, 1992) can testify. His latest wheeze suggests he has not lost his zany touch. He wants NASA to launch a satellite whose principal purpose willl be to beam back to the Internet an image of the Earth floating in space, to provide 'a natural beacon for environmental awareness and science education'. It is intended to sit in a geo-stationary orbit about a million miles up between the Earth and the Sun. Equipped with an 8-inch telescope, it will transmit an image of the Earth's sunlit disk every few minutes. One estimate has placed the cost of all this at 50 million bucks. Golly. Wouldn't it be a whole lot cheaper to post on the Internet an array, even a sequence, of photos of Earth in Space taken by astronauts during the lunar missions of the early 1970s?

Zany maybe, and possibly a huge waste of taxpayers' money, but at least it is harmless. Equally dotty but far more dangerous is a Russian plan to put a large mirror in space that will reflect sunlight down onto large tracts of Siberia, to lighten its skies and shorten its winters.

The idea is not popular with astronomers, who feel there's already enough light pollution in the sky, and don't want a gigantic aluminium foil 'sail' upsetting their own space-observing satellites. Environmentalists aren't too keen either. Turning night into day and winter into summer may be fine for the crops and even for some of the local citizenry, but it can hardly be ecologically sound. Plants and animals adapted to the harsh steppe conditions will not survive for long if the steppes become subtropical literally overnight.

Thankfully, it transpires that there are insufficient funds to finance this mad venture, which would in any case require several experimental runs to test the technology. Latest reports say that the plan has been shelved indefinitely. It is too much to hope that indefinitely means forever in this context. Politicians seem to be fond of techno-fix projects with apparent benefits in the short term, because they will have retired well before any adverse long-term consequences come to light.

Keep beaches dirty

A dirty beach is less prone to erosion, so leave it alone. If that seems like nonsense to you, read on. It is in the nature of beaches that anthropogenic debris (glass, plastic, paper, cigarette ends, rags and so on, not to mention bits of raw sewage) gets mixed up with the sand, shingle, seaweed, shells, driftwood and the associated biota (sandhoppers and the like). Local authorities keen to promote tourism want their beaches free of the unpleasant consequences of humanity's chronic inability to cope with its wastes. But they cannot afford to pay for selective removal of glass, plastic, condoms, etc., so they send in a bulldozer to scoop up everything and take it away to their landfill site. Environmentalists claim that this removes not only the rubbish but also a lot of sand and/or shingle and makes the beach more vulnerable to erosion. Whether this is a valid argument or not must surely depend upon the frequency with which the bulldozing is done.

At the other extreme are people who wish to discourage the collection of shells and driftwood, even seaweed, for ornamental or practical purposes (e.g. firewood, garden fertiliser). They claim that – you'll never guess – it makes the beach more vulnerable to erosion and can adversely affect the beach fauna. Presumably this is for beaches not yet being bulldozed. When the bulldozers arrive there will be nothing to collect anyway. Blue Flag beaches are evidently set to become not merely clean but positively sterile – until they've been eroded away, that is. Not that there are all that many Blue Flag beaches anyway, at least not in Britain: only 45 at the last count, and a significant proportion of the remaining 470-odd are polluted enough to pose serious risks to public health.

John Wright

Sustainability is Dead – Long Live Economic Growth

Anyone seeking a Millenial Sign for the death of sustainability need surely look no further than Hong Kong's new international airport. Inaugurated in early July, its construction involved flattening a small island and using the rubble to increase the original area four-fold before building the airport itself. The terminal building is said to be the largest covered structure in the world, a triumph of design and engineering and aesthetic appeal. It has also been described, by the architect himself, as 'environmentally friendly'! How can anything associated with an *airport* – especially an international airport – be environmentally friendly? How can anyone regard aviation as compatible with sustainability?

Sustainability versus economic growth

True sustainability (sustainable development if you prefer) requires that humans must eventually learn to live in equilibrium with their environment. Even my shaky grasp of history tells me that humans have been incapable of developing anything in a truly sustainable manner ever since they ceased being hunter-gatherers and became farmers some 10 000 years ago. For centuries, if not millenia, and especially since the Industrial Revolution, nearly all of us have been locked into economic growth. Look around you: tourism, air travel, overfishing, coastal development, road networks, fossil fuel extraction on continental shelf and slope, the arms trade, deforestation, mechanized agriculture, urban growth and consumerism (to name only a handful of examples), continue inexorably to grow. In several cases, growth is reinforced by massive governmental subsidies to the industries concerned. None of those activities can by any stretch of the imagination be considered compatible with sustainability. Nor do our puny efforts at recycling, energy-saving, wildlife conservation and the like, make any serious impact on these activities – we are indeed fiddling while Rome burns.

There are two chief reasons why we allow, even encourage, these environmentally unfriendly practices to continue. First, very few people, even in the developed richer nations really know what is meant by sustainability; and politicians, financiers and industrialists habitually equate 'sustainable development' with 'sustainable economic growth' – they are *not* synonymous terms! Second, and much more important, any serious attempt to move society towards true sustainability would being the entire global edifice of economic interdependence crashing down. For example, scientists who understand these matters know full well that global cuts of something like 60% in fossil fuel use are needed even to start bringing atmospheric carbon dioxide concentrations into equilibrium. That is plainly out of the question.

So it was quite brave of the EU to sign a legally binding agreement to make a cut of 8% in total greenhouse gas emissions by 2010. It was brave because of the potential adverse impact on the economies of the countries concerned. However, I was slightly less impressed to see that the objective is to be achieved by some of the richer 'northern' counties (including the UK and Germany) making bigger cuts (about 12%), whereas some of the poorer 'southern' countries of the EU will actually be allowed to *increase* their emissions. The effects of implementing these policies will of course be miniscule in the global context, especially as most of the rest of the world will continue to increase its greenhouse gas emissions in the coming decade. Nonetheless it is a small step in the right direction, even though it means that an increased proportion of electricity must henceforth be generated by nuclear power. Wind farms may be beautiful – especially offshore – but literally thousands are needed to make up for even one conventional power station. Other alternatives are not serious options. For example, tidal power requires huge capital investment, and there are major technical problems with wave power, which, like wind, has 'low energy density'. Incidentally, this agreement jeopardises the UK Government's commitment to keep Britain's coal industry alive by curtailing development of new gas-fired stations (coal emits significantly more CO_2 per unit of energy than either gas or oil); which makes me wonder why Germany continues to subsidise its coal industry. I also wonder why, having just agreed to curtail its fossil fuel emissions, Britain then proceeded to negotiate an £8 billion deal with the Azerbaidjan government for rights to exploit oil in the Caspian Sea.

What should scientists do?

When I look at the literature I sometimes wonder how many scientists, including marine scientists, are really interested in sustainability and related issues, how many focus only on their field of science and rarely (if ever) consider the global setting in which science perforce must operate.

A few years ago, a well known international journal of science canvassed some 'visions of the future' from eminent scientists of its acquaintance. Here are edited extracts from the correspondence that ensued.

'None of [the eminent scientists] dealt with the truly revolutionary issue of bringing the human population into some kind of sustainable long-term balance with the capacity of the Earth to support it.'

'Poverty, the gap between rich and poor, economic instabilities, environmental degradation, violence on all scales, will continue to grow ... but [the journal] will not publish articles on these subjects unless they are related to cell function, viruses, mathematical theories of chaos, stellar events, superconductivity, elemental isotope ratios and so on ... Copious pages of reports, most about small increments in arcane knowledge, many written by scientists at the frontier and their students, will fill [the journal's], but will continue to be too difficult for anyone but specialists to understand.'

Apocalypse Delayed

Our small attempts to 'green the planet' by recycling, energy conservation, saving endangered species, etc., are local (at most regional) rather than global in scope. They serve only slightly to slow the gradual but inexorable trend towards the ultimate global desert, especially as they are practised only by the rich fifth of the world's population (the remaining four-fifths are too poor to afford such luxuries). The unsustainable way of life that characterizes modern industrial societies is bound to continue, even increase in scale, if only because of the relentless growth of humankind and its unremitting search for *Lebensraum.* and for continual 'improvements in living standards'. Nor should we forget that *Homo sapiens* is the only species for which there are no natural limits to population growth – unless a large comet or asteroid comes along to cause another mass extinction.

Meteorite impacts excepted, however, there is no immediate cause for alarm. Sustainability may be dead, but I reckon economic growth is safe for at least a few more centuries yet. Nor need we be concerned that future generations might condemn us for our profligate ways (a theme popular with Prophets of Doom). I know of no historical precedent for such condemnation. In any case, it is my impression that the young are mostly concerned more with becoming good consumers than with the future of humanity.

Perhaps they have the right idea ... carry on consuming.

Reflections on Sintra

The British Government certainly seems to be putting itself about in its attempts to look environmentally correct. A meeting on the marine environment, attended by ministers from 15 European nations and held at Sintra in Portugal this July, was told that Britain will by 2020 reduce to 'virtually zero' its radioactive emissions into the sea. That means discharges from Sellafield; and I presume that the French have agreed to similar reductions from their nuclear reprocessing plant at La Hague. It was interesting to note that Greenpeace hailed these developments as sounding the death knell of nuclear reprocessing in the UK, an interpretation refuted both by BNFL and by the Deputy Prime Minister. I have little doubt who will prove to be right. If we are to rely increasingly on nuclear power for our electricity to keep down CO_2 emissions, we need nuclear fuel – which needs reprocessing. In any case, the words 'virtually zero' are already being interpreted to mean 'as low as possible with available technology'. The trouble is, however small the emissions, however great the dilution, there are still 'artificial' radio-isotopes that can be progressively concentrated in successive trophic levels. Lobsters, for example, can concentrate technetium to levels 50 000 times those in the ambient seawater.

Another agreement reached at Sintra was to stop dumping redundant oil rigs at sea. Since the estimated cost of this operation will total some £8 billions over the next thirty years, I assume this means that all the rigs and platforms in British waters will be brought ashore for disposal. It seems to me that '*Brent Spar* Paranoia' (to coin a phrase) has become well established in the minds of our rulers. Whatever happened to all those proposals on the feasibility of removing just the superstructure of rigs, leaving the lower parts in place to form artificial reefs for fish and benthic communities? The positions of these installations are already known with great accuracy and would be notified to fishing fleets and to any other interested parties as necessary. It seems to me an eminently pragmatic and sensible solution, but I expect the politicians will reject it anyway.

John Wright

Ego at the Helm?

We were recently sent this mini-story by Email from someone who claims it was an actual radio conversation that took place at sea recently and which has been released by the US Chief of Naval Operations.

#1: 'Please divert your course 15°161' to the North to avoid a collision.'

#2: 'Recommend you divert YOUR course 15° 161' to the South to avoid a collision.'

#1: 'This is the Captain of a US Navy ship. I say again, divert YOUR course.'

#2: 'No. I say again, you divert YOUR course.'

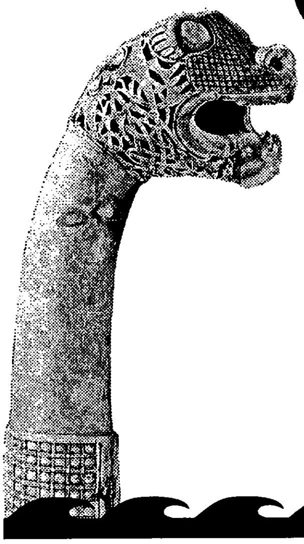
#1: 'THIS IS THE AIRCRAFT CARRIER 'ENTERPRISE' – WE ARE A LARGE WARSHIP OF THE US NAVY. DIVERT YOUR COURSE NOW!'

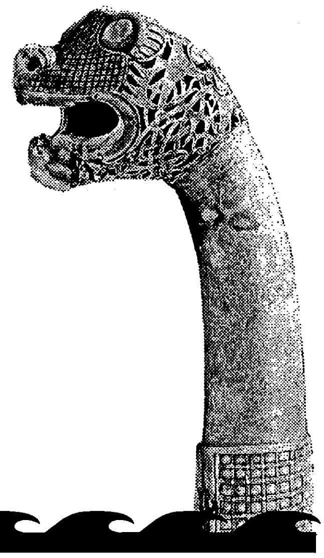
#2: 'This is a lighthouse. It's your call!'

The Viking Sea revisited

New investigations into benthic fauna around the Faroe Islands and Iceland

Ole Secher Tendal





Over the last ten years, Nordic taxonomists have collected hundreds of bottom samples all over the exclusive economic zones of the Faroe Islands and Iceland. The sorting work has been done in specially erected laboratories (initially temporary, but now permanent), and numerous specialists in many countries have received material of their respective animal groups for identification and further work. Results have begun to accumulate – in print, in the bulging files of two large databases, and as extensive museum collections. The general outcome is a revised and detailed picture of the composition and distribution of the fauna of a marine region of great current interest – the transition area between the Arctic seas and the temperate North Atlantic.

The Faroes and Iceland: cornerstones in northern Atlantic research

Estimates of the amount of water transported over the Greenland–Scotland Ridge vary considerably, but oceanographers all agree that this area has a key position in the circulation and exchange of heat between the Arctic Seas and the North Atlantic (Figure 1). Two small nations occupy the middle region of the Ridge – the Faroe Islands and Iceland – both economically dependent on fisheries and scientifically and politically highly aware of the importance of hydrographical and biological changes going on in their waters.

In the 1970s both countries declared extensions of their exclusive fishing zones to 200 nautical miles (or to the nearest median line). Not only did this result in the responsibility for control and regulation of fisheries over much larger areas than before (144 000 km² for the Faroe Islands, 578 000 km² for Iceland), it also implied an obligation and need to carry out comprehensive scientific research of various kinds. Here, we focus on investigations into the benthic fauna.

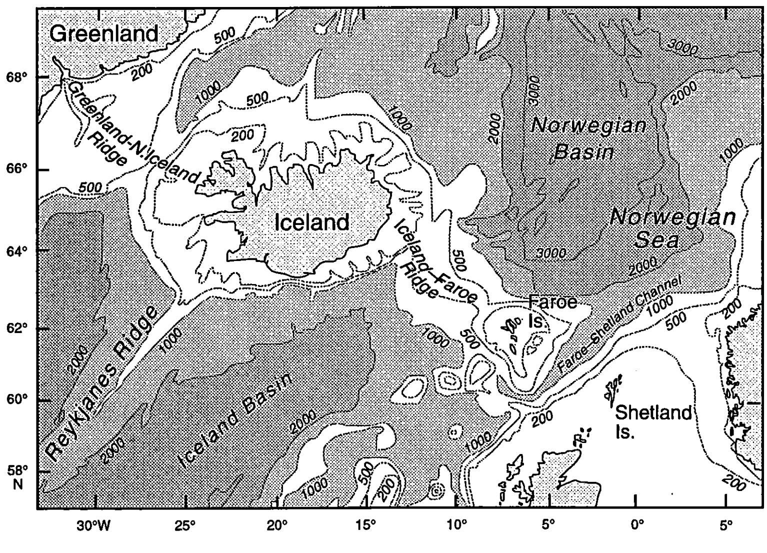


Figure 1 Iceland and the Faroe Islands lie on the Greenland–Scotland Ridge between the Arctic seas and the temperate North Atlantic.

Early faunal investigations around the Faroe Islands and Iceland

The systematics and biogeography of marine fauna have a long and respected tradition in all the Nordic countries. The earliest descriptions and collections of fauna and flora in the Faroes and Iceland date from the late 1700s and early 1800s and were often made by interested doctors, teachers and priests.

The first more extensive investigation of the Faroese marine fauna was carried out during the latter half of the 1920s by specialists from the Zoological Museum in Copenhagen. Their results, together with a compilation of the older reports, were published in the series *The Zoology of the Faroes*, mainly during the years 1928–42 (with some parts as late as 1971), financed by the Carlsberg Foundation. For depths shallower than about 300 m (the greatest depth within the old 3 n.m. territorial sea limit) more than 900 animal species were listed.

A similar investigation was carried out into the Icelandic marine fauna during the late 1920s and the 1930s by Danish and Icelandic zoologists. The results were published during 1937–59 in the series *The Zoology of Iceland*, also financed by the Carlsberg Foundation. Close to 1500 marine animal species could be listed for the region from the shore down to about 400 m.

Nordic concern about taxonomic expertise

In the 1980s there was great concern among Nordic marine zoologists about decreasing systematic expertise in the wake of a series of cutbacks in the staffs of the natural history museums and many university laboratories. No longer did any single country possess enough taxonomists to handle the larger part of their own fauna.

The establishment and recognition of exclusive economic zones (EEZs) meant that, in addition to their relatively well-known northern and southern shelf areas, scientists in both the Faroe Islands and Iceland now needed to be concerned with regions with Arctic as well as North Atlantic deep water masses, in depths down to about 3500 m, with the corresponding bathyal and abyssal faunas.

In this situation, a fortunate combination of professional biological requirements, financial possibilities, and political inclination emerged. A group of marine taxonomists and biologists saw the need to combine Nordic taxonomic expertise into a team effort aimed at solving larger challenges and creating education and training opportunities for students and younger scientists. The Nordic College of Marine Biology, already a most effective inter-Nordic state foundation, decided to transfer a larger part of its financial support from projects run by single individuals into programmes involving combined Nordic scientific and training efforts. Politically, at that time there was a strong tendency in the Scandinavian communities to treat growing EEC influence with hesitation and suspicion, and this led to many initiatives being channelled into programmes involving some kind of inter-Nordic cooperation and management. It was widely felt that this approach gave more freedom, more room for spontaneity, more opportunity to change in response to changing situations, easier access to some certain financial sources, and a more efficient use of resources, than would be possible under the auspices of the Brussels bureaucrats.

The Inter-Nordic BIOFAR Programme

Under the circumstances, the Faroes, with their rather independent status within the Danish kingdom, were considered a suitable area for a combined research effort, and the programme known as BIOFAR – Investigations into the Marine Benthic Fauna of the Faroe Islands – was initiated in 1987. Responsibility for implementation of the programme lay with a steering committee whose members represented the Nordic Council of Marine Biology, the Faroese Government, the Natural History Museum (Tórshavn), the Zoological Museum, Copenhagen (Denmark), the Institute of Fisheries and Marine Biology, Bergen (Norway), the Trondhjem Biological Station (Trondheim, Norway), and the Kristineberg Marine Biological Station (Fiskebäckskil, Sweden).

The aims of BIOFAR were formulated as follows:

- To increase within the Faroese community, knowledge of, and interest in, their local marine fauna.
- To establish a local basis for further research.
- To create the inter-Nordic network of contacts necessary for such research.
- To promote further investigations in the Faroese marine territory, which is scientifically interesting (1) with respect to biogeography, (2) as a basis for important local fisheries, and (3) as a target area for investigating human influence on the marine environment.
- To encourage a coordination of Nordic taxonomic expertise which could then be used in other scientific projects.
- To train students and young scientists in practical work at sea.
- To arrange inter-Nordic taxonomic and biological courses for students and young scientists.

Looking back over the last ten years, how much of all this has been achieved? The simple answer is: all of it, although there is still much work to be done. A comprehensive invertebrate collection has been built up, the main part of which will subsequently be placed under the curatorial responsibility of the Natural History Museum in Tórshavn. This collection was achieved through nine cruises of one to two weeks (four cruises on a Faroese research vessel, three on a Norwegian vessel, one each on a British and a German vessel), plus a number of shorter cruises on Faroese coastguard vessels.

Collecting methods included use of various dredges, an epibenthic sledge (for collecting hyperbenthic fauna), a detritus sledge (Figure 2) and a trawl (Figure 3). From the outset, detailed planning of the work and its execution, sample treatment and sorting, along with contact with specialists and other organizational matters, centred around a new permanent institution, the Kaldbak Laboratory, which was erected for BIOFAR near Tórshavn. Support from the Nordic Council of Physical Oceanography made it possible to compile a hydrographical database containing the measurements from 11 000 stations, leading to accurate classification of the biological sampling sites according to water mass; Figure 4 (opposite) shows the positions of the sampling sites in relation to bottom water temperature.

Likewise, a database for all animal identifications is being built up, at present containing about 1500 species and a great many details on local distribution. More than 50 scientific and popular articles have so far been published, and several more are at various stages between manuscript and publication.

Taxonomic workshops on the collections of polychaetes, molluscs and crustaceans have been held in the Faroes, Denmark and Norway. It was, however, evident that the Nordic countries alone could not handle all groups, a situation which naturally led to wider international cooperation, involving specialists in Australia, France, Germany, Great Britain, Holland, Iceland and USA. All together, about 60 scientists, covering all but

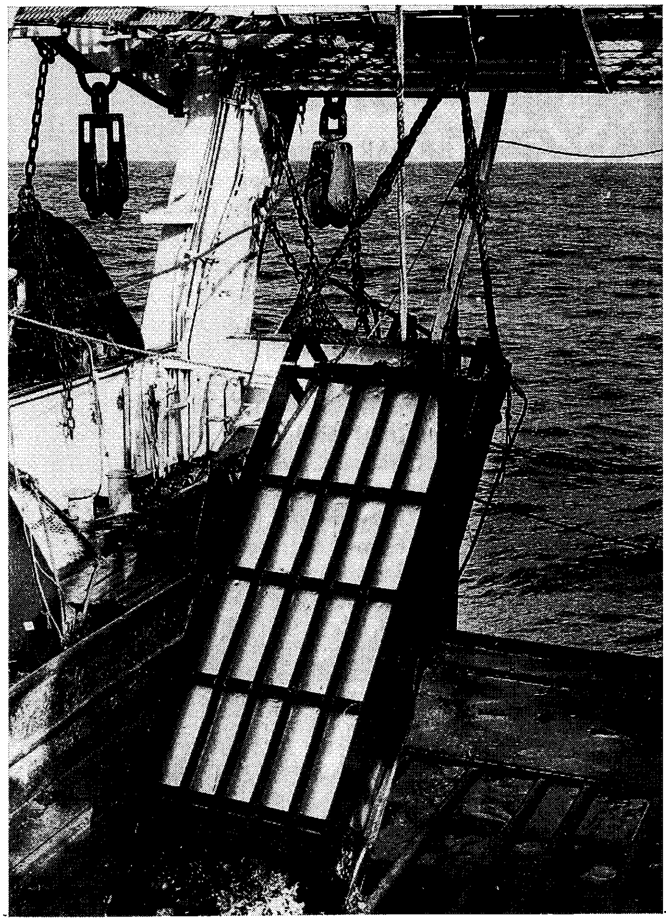
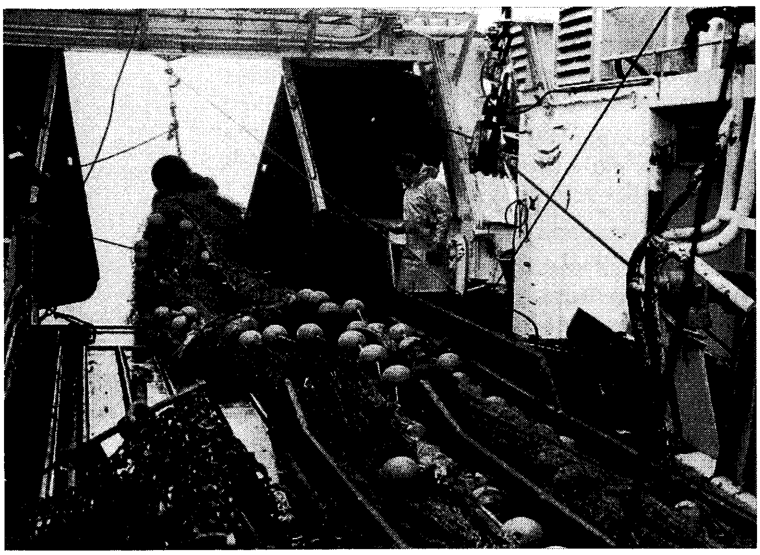


Figure 2 *The 2-m long detritus sledge is emptied onto the deck of the Faroese Fisheries Investigations research ship* Magnus Heinason.



(a)

(b)

(c)

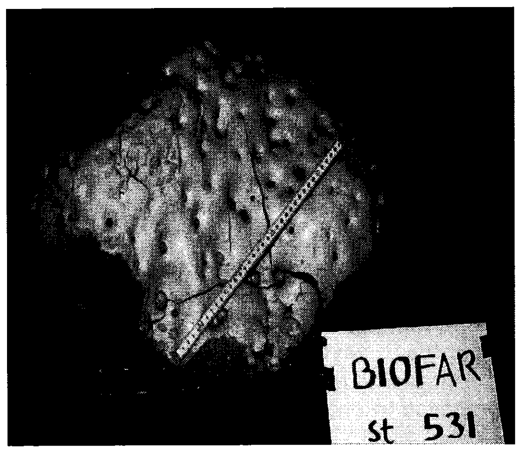


Figure 3 (a) *The bottom trawl is made ready on board the* Magnus Heinason. ***(b)*** *A trawl catch consisting mainly of large sponges, from about 360 m depth, west of the Faroe Islands (BIOFAR station 531).* ***(c)*** *The large demosponge* Geodia barretti *from the trawl catch in (b). (Photographs: Ole Tendal)*

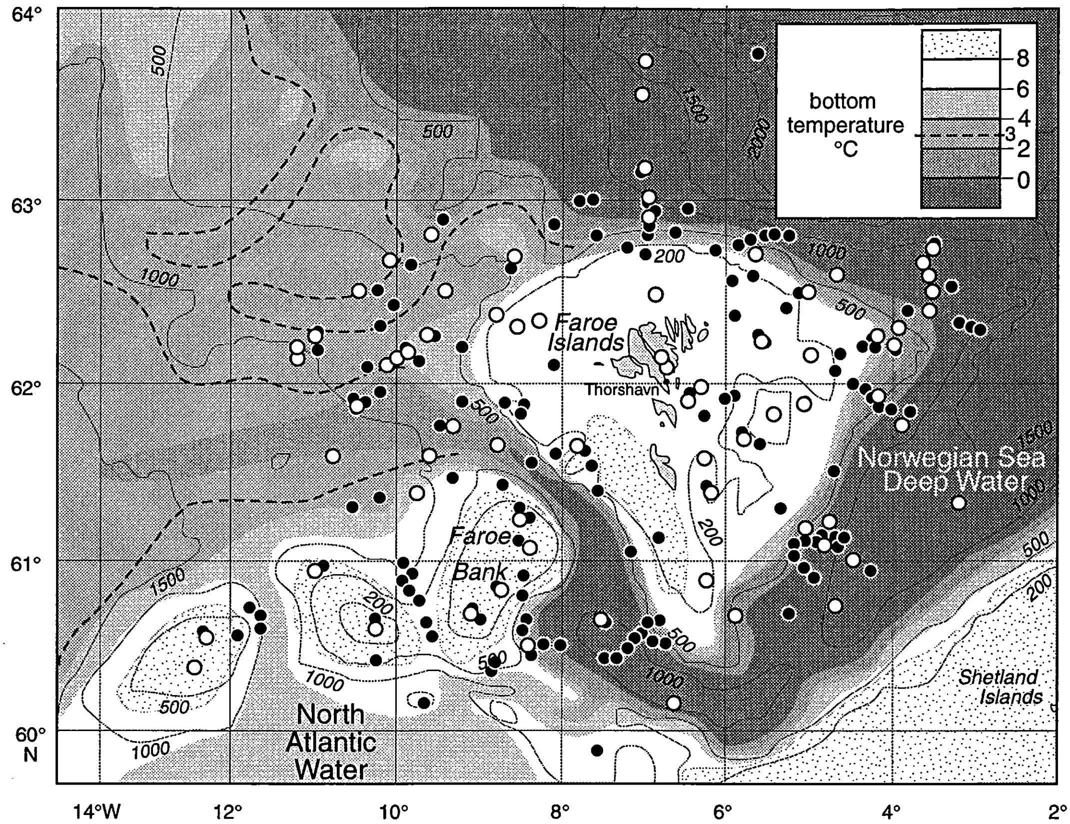


Figure 4 *Bathymetric map with bottom water temperature distribution, showing locations around the Faroe Islands sampled during the BIOFAR programme with the detritus sledge (black dots), and the epibenthic sledge (open circles). (Isotherms are mostly at 2°C intervals, but the 3°C isotherm is also shown, as – – –. Bottom water temperatures are by courtesy of Dr H.Westerberg, Göteborg, Sweden.)*

a few animal groups, have been working on the BIOFAR collections. They nearly all met during a successful symposium in Tórshavn in 1991, arranged and paid for by the BIOFAR Programme in order to 'improve the team spirit' and to discuss preliminary results and further joint projects.

A BIOFAR II programme, initated in 1995 and running through 1998, aims at a re-investigation of the shallow waters around the Faroe Islands, including the fjords and sounds.

The inter-Nordic BIOICE Programme

With a very high proportion of the species found in the Faroese samples newly identified in the area (30–60% depending on the animal group), and the EEZ median line between the Faroes and Iceland being a biologically meaningless boundary, a natural next step was to establish a project on fauna in Icelandic waters. It was named BIOICE – Benthic Invertebrates of Icelandic Waters – and was initiated in 1991. Implementation of the programme was carried out by the Marine Research Institute, the University of Iceland and the Icelandic Museum of Natural History (all in Reykjavík, Iceland), and was supported by a Nordic Contact and Advisory Committee with representaives from the Zoological Museum (Copenhagen, Denmark), the Natural History Museum (Tórshavn, Faroe Islands), the Institute of Fisheries and Marine Biology (Bergen, Norway), Trondhjem Biological Station (Trondheim, Norway), and Swedish Museum of Natural History (Stockholm).

The main objectives of the BIOICE Programme are:

- To gain basic knowledge of the composition and abundance of the benthic invertebrate macrofauna in Icelandic waters.
- To map the distribution of the species in relation to environmental factors.

The information obtained will be used in two further projects studying:

1. Benthic communities in Icelandic waters and the effects of fishing activities on these communities.
2. Trophic relations of benthos and fish stocks.

The sea around Iceland was arbitrarily divided into sectors of a size suitable for proper sampling over a 10–14 day period. One or two sections have been made each year, and the last cruise will be in the summer of 1998 or 1999. So far, 12 cruises have been completed (six on an Icelandic ship, one on a Faroese ship, and five on a Norwegian research ship). Sample-processing and sorting are done in a new institution, the Sandgerdi Marine Centre (SMC), which was erected for BIOICE near Keflavík, some 40 km from Reykjavík. In 1988, this institution was granted the status of Large-Scale Facility under the Training and Resources Programme of the European Commission.

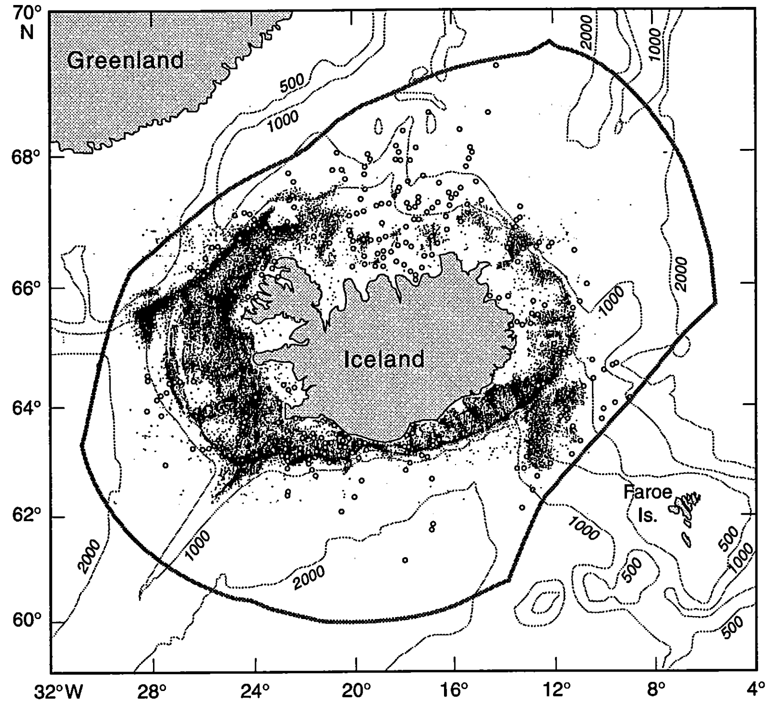


Figure 5 Localities around Iceland sampled during the BIOICE programme 1992–95 (open circles), and localities where commercial trawling took place in 1991 (small dots). (By courtesy of Dr S.A. Sleingrimsson, Fisheries Research Institue, Reykavík, Iceland)

A very large collection has been built up and a substantial part has been sorted and sent out to about 70 specialists. The collection is under the curatorial responsibility of the Icelandic Museum of Natural History in Reykjavík. Up to now there has been only modest reporting of results, but nevertheless more than 1300 species have so far entered the database, and about 10 scientific and popular articles have been published. Once the BIOICE results are available, the Icelandic rule of reporting all trawl catches will allow for statistical evaluation of the effects of fisheries on benthic invertebrate communites.

In order to promote the identification work and to build contacts between specialists and students, three taxonomic workshops, relating to the collections of polychaetes, molluscs and amphipods, have been held at the SMC.

Financing BIOFAR and BIOICE

Economic support for both programmes has come from a combination of sources. The Faroese and Icelandic governments financed the erection and running of their respective laboratories. In Iceland, the local community of Sandgerdi also played a most important role by placing building facilities at the project's disposal. Marine Research Institutes (Fisheries Investigations) of both countries provided ship time, as did the University in Bergen. Other very substantial funding came from the Nordic Council of Ministers and the Nordic College of Marine Biology. It should also be mentioned that both programmes have been immensely well received by the local communities and their institutions as well as by national private foundations.

Next on the horizon: BIOGREEN and BIOMAINE

The goal for the groups of marine taxonomists and biologists organizing the BIOFAR and BIOICE programmes is to achieve a revised detailed survey of the composition, distribution and history of the benthic macrofauna in the whole transition region between the Arctic seas and the temperate North Atlantic. Thus, an obvious next step for Nordic efforts is to promote and take part in investigations around southern Greenland and off parts of East Greenland. Preliminary initiatives have been the participation of project scientists in fisheries research cruises where some collection of invertebrates has been possible, the formulation and carrying through of some local projects, and the development of contacts with relevant Greenland and Danish institutions and authorities. The seeds of a BIOGREEN Programme have been sown.

On the other side of the North Atlantic, the comparatively small region centred around the Gulf of Maine, home to a northern temperate fauna, has aroused public interest because of the disastrous collapse of the fisheries on the Newfoundland Banks. Important biological work is carried out by several institutions in the area, and a strong sense of the need for a full survey of the fauna has emerged in recent years. The concept of a BIOMAINE Programme was created by scientists of the Darling Marine Center (Walpole, University of Maine) and their co-workers in local and foreign institutions. Faunistic data – a spin-off from a number of specific projects as well as from local faunistic investigations – are currently accumulating at the Darling Marine Center, hopefully contributing support for the further flow of resources necessary for a full-scale investigation of the outer parts of the Gulf of Maine.

Ole Secher Tendal is Associate Professor at the Department of Marine Invertebrates at the Zoological Museum of the University of Copenhagen. He is a member of the Steering Committee and the Advisory Board of the BIOFAR Programme and the Kaldbak Laboratory, and of the Nordic Contact and Advisory Committee for the BIOICE Programme. His interests are sponges of the Arctic, northern boral and Antarctic regions, and xenophyophores (Protista) of the world. He is currently working on Faroese, Icelandic and Greenland sponges, and the fauna of the Gulf of Maine.

Publications from the BIOFAR and BIOICE programmes may be obtained the author on Email: ostendal@zmuc.ku.dk

Fingerprinting air masses using aerosol chemistry

Lucinda Spokes

Chemical interactions between the oceans and the atmosphere are critical controls on global climate, but are poorly understood. In 1994 NERC initiated a new Community Research Project – Atmospheric Chemistry Studies in the Oceanic Environment, ACSOE (see box overleaf) – with the overall aim of obtaining a clearer understanding of natural processes in the remote marine atmosphere and the modification of these processes by anthropogenic emissions. The first major field campaigns of ACSOE were conducted in the spring and summer of 1996. This article focusses on the Marine Aerosol and Gas Exchange (MAGE) component of the project.

The study of marine aerosols and gas exchange across the air–sea interface is important because, once in the atmosphere, trace gases produced in seawater (and through anthropogenic activity) can affect:

- the oxidizing capacity of the atmosphere;
- the acidity of rain and aerosols;
- the atmospheric radiation balance.

The atmospheric radiation balance is affected through the uptake or release of gases such as CO_2, N_2O and CH_4, and through the formation of cloud condensation nuclei from oxidation of anthropogenic SO_2 and from phytoplankton-derived dimethyl sulphide (DMS).

In addition, deposition of aerosols and rain onto the surface ocean provides a source of trace nutrients (such as iron and fixed nitrogen) to marine biota.

The Eastern Atlantic Experiment

The Eastern Atlantic Experiment, conducted in June 1996, was the first field campaign of the MAGE component of ACSOE (Figure 1). The principal aims were to investigate the oxidation of DMS and its reaction with nitrogen species, but the experiment also sought to determine how the chemistry of the clean marine atmosphere is perturbed when marine and continental air masses mix within the coastal zone. Measurements were made on land at the Mace Head Atmospheric Research Station on the west coast of Ireland, operated by University College, Galway; at sea, aboard the NERC RVS operated RRS *Challenger* which worked in waters up to 200 nautical miles off the west of Ireland; and in the air using the Cranfield 'Jetstream' Research Aircraft and the Meteorological Research Flight C-130 'Hercules' Aircraft.

The region where aerosols were sampled

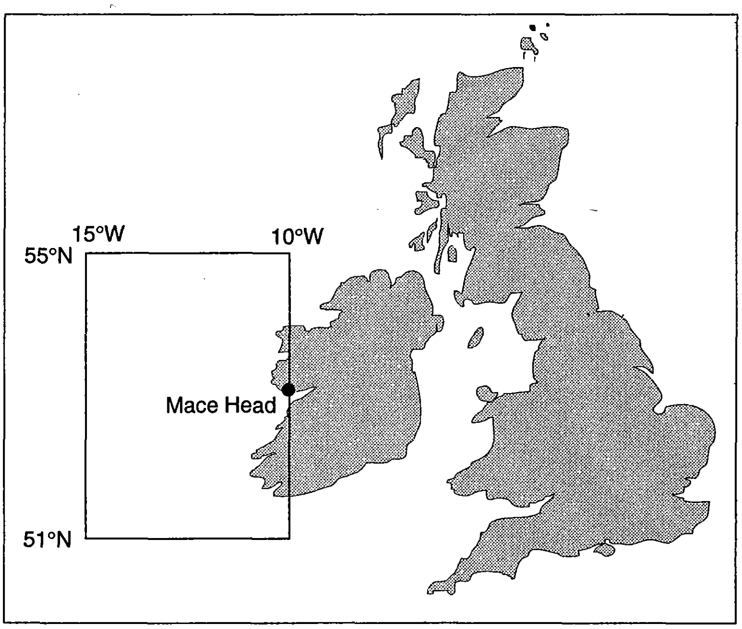


Figure 1 *Operational area of the Eastern Atlantic Experiment*

Atmospheric Chemistry Studies in the Oceanic Environment

ACSOE is a five-year NERC Community Research Project which aims to investigate:

- the chemical processes responsible for controlling the concentration of many trace gases (especially ozone and other oxidants) in the boundary layer and the free troposphere.
- the production of condensation nuclei and aerosols from oceanic and terrestrial emissions of gaseous sulphur compounds and their direct and indirect impact on the radiation balance in the troposphere.

The project consists of three components ('consortia'):

1. **OXICOA** (**OXI**dizing **C**apacity of the **O**cean **A**tmosphere), a study of oxidant, radical and related gas chemistry within the clean and moderately polluted marine atmosphere.

2. **MAGE** (**M**arine **A**erosol and **G**as **E**xchange), a study of aspects of air–sea exchange relevant to atmospheric chemistry and aerosol production.

3. **ACE** (**A**erosol **C**haracterisation **E**xperiment), a land-based study of gas and aerosol processing through hill-cap clouds and subtropical marine stratocumulus.

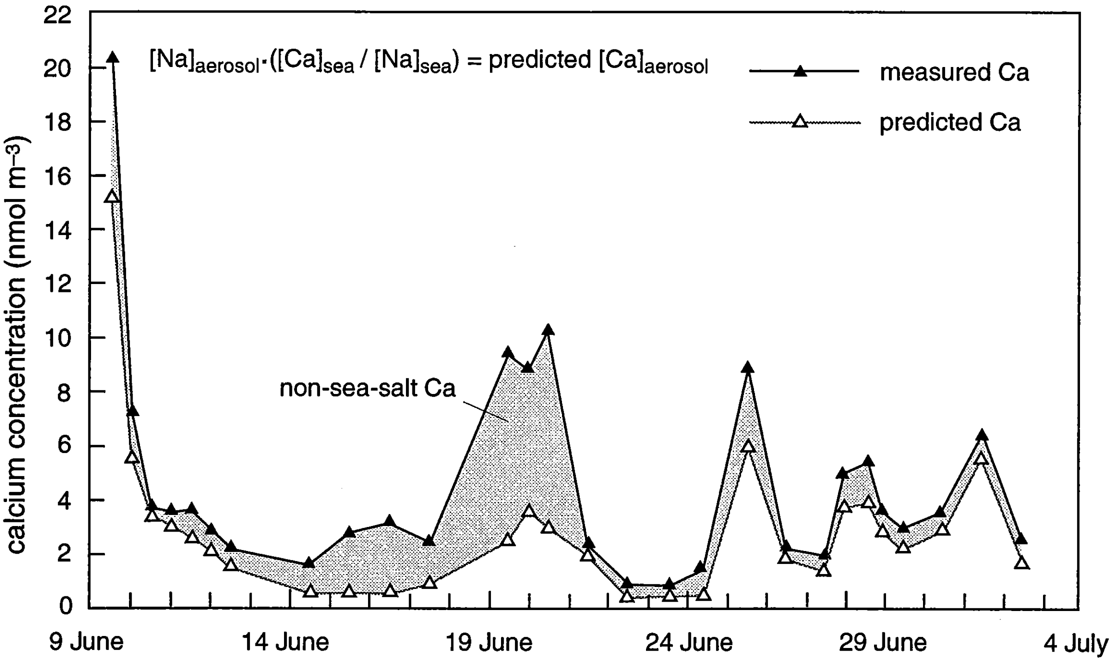
ACSOE is co-ordinated primarily at the University of East Anglia and involves funded groups from the Universities of Birmingham, Bristol, Cambridge, East Anglia, Lancaster, Leeds, Leicester, Newcastle and Sunderland, AEA Technology, the British Oceanographic Data Centre, the British Atmospheric Data Centre, Imperial College London, the Institute of Terrestrial Ecology, Plymouth Marine Laboratory, UMIST, University College Galway and University College Wales.

To examine the oxidation of DMS and its reaction with nitrogen species in the atmosphere, we needed to make a series of measurements within the same air mass over a period of time. Use was made of forecast five-day air parcel back-trajectories (modelled paths of air masses for the five days prior to arrival at the site of interest) which were provided by the British Atmospheric Data Centre (BADC), and meteorological data from the UK and Irish Meteorological Offices.

In the event of continuous air flow between the ship and the land site, the ship was positioned approximately 8–9 hours air transit time from the land station at Mace Head (between 100 and 200 nautical miles offshore, depending on the wind speed). Sampling times were adjusted at the land station to enable samples to be matched. The sampling delay allowed changes in composition as a function of time within a particular air mass to be determined. The very limited aircraft time was used to take measurements between the ship and Mace Head, and to quantify, to some extent, the loss of species through mixing of air from the marine boundary layer (the first stable layer of the oceanic atmosphere) into the free troposphere above.

***Figure 2** Comparison between measured aerosol calcium concentrations and predicted values based on aerosol sodium data.*

Calcium from terrestrial sources peaked in the middle of the experiment



Our contribution to this experiment was the collection of both aerosol and rain samples at sea and on land. At Mace Head, aerosol sampling was conducted throughout the experimental period, and rain samples were collected using manually deployed rain funnels. As atmospheric sampling and surface water surveying are in practice incompatible, RRS *Challenger* operated in two modes throughout the experiment. Half the time was devoted to atmospheric measurements, and the ship operated head to wind to prevent contamination of samples from the ship's stack. For the remaining time the ship operated in survey mode to assess the spatial and temporal variability of DMS concentrations in surface seawater, so that a flux of DMS into the atmosphere could be determined. In the event of rain, the ship was stopped, positioned head to wind, and the rain samplers deployed.

As expected, we saw very good correlation between the concentrations of sodium, potassium and magnesium in the aerosol phase, with all these being high during periods of rough weather. Aerosols originate from seawater and are ejected into the atmosphere through the process of bubble bursting during wave breaking. We can confirm that potassium and magnesium are indeed from seawater by calculating predicted concentrations based on the aerosol sodium concentration (which we assume is all from seawater) and known ratios for the elements in seawater. On the other hand, calcium, which has mixed seawater and continental sources, shows a much lower Na/Ca ratio during the middle period of the experiment than that predicted on the basis of a seawater source alone. During this period, therefore, we see a significant non-sea-salt ('nss') calcium component (Figure 2), which we suggest is continental in origin. This is confirmed using data on ammonium which in this area is also terrestrially derived, resulting mainly from agricultural activity. Ammonium levels were low at all times, except when nss-calcium was high. The results of the aerosol analyses from this period, however, also show high levels of the seawater tracer, sodium.

So how can we reconcile both continentally and marine derived species within the same air mass? At this point we turn to meteorology. At the beginning and end of the experimental period, when sea-salt-derived species are high, we see a low pressure area to the north of the UK, a high to the south and resultant westerly winds. We can confirm longer range transport using five-day air mass back-trajectories (Figure 3) which show that during this period the air is marine in origin, generally westerly or south-westerly in direction, and has a small North American (i.e. continental) component.

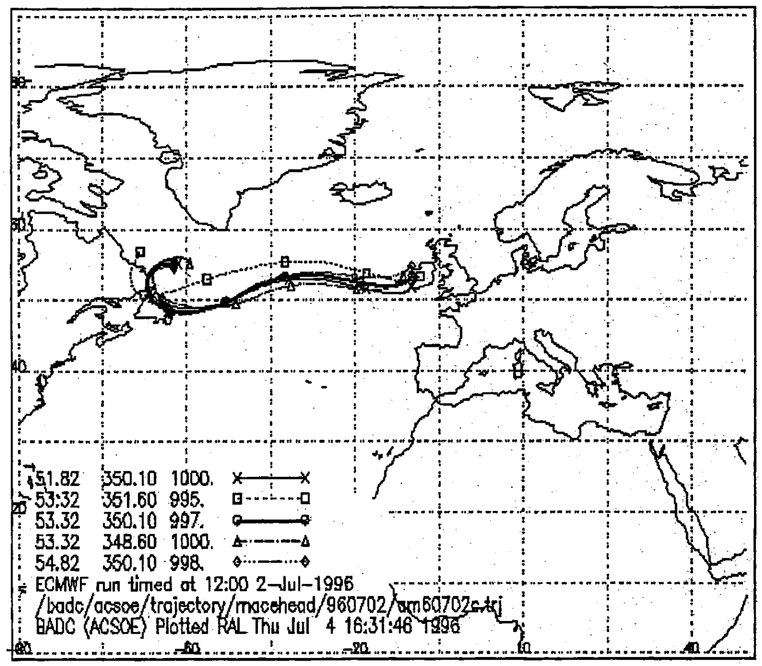


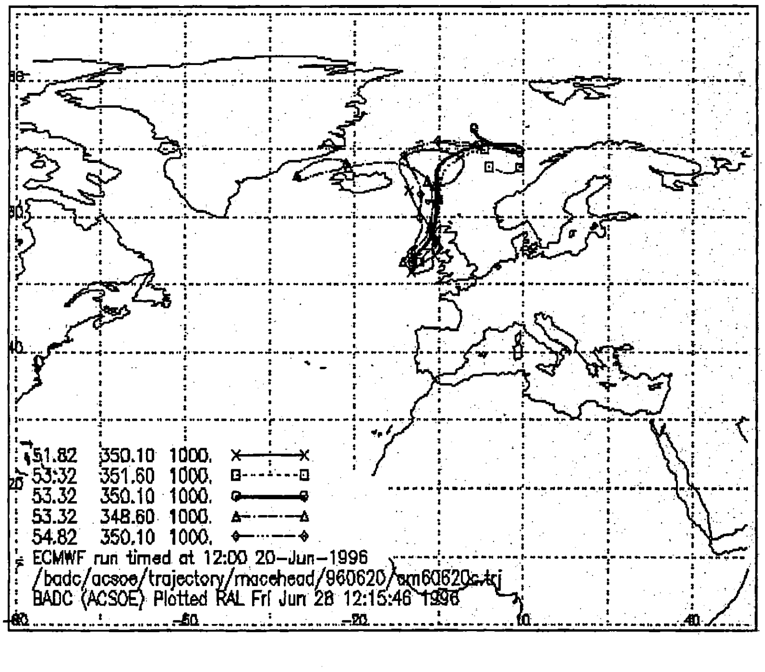
Figure 3 *Five-day air mass back-trajectory for 2 July 1996 (at the end of the experiment). Winds arriving at the ship site aboard RRS* Challenger, *and at Mace Head on the west coast of Ireland, are from the west and therefore have a strong marine signature. The air mass also has a small North American component.*

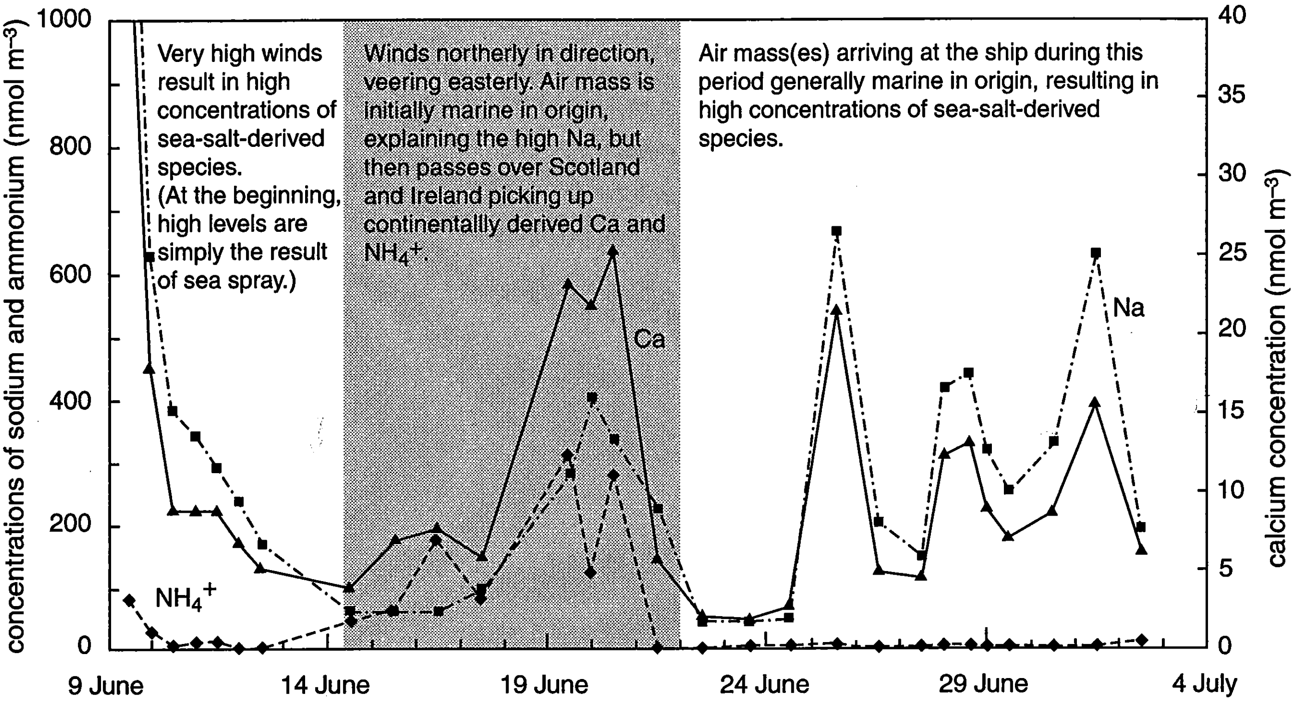
On 2 July, most of the air reaching the study area has a strong marine signature

During the middle period of the experiment, the meteorological conditions change and we see a high pressure region to the north of the UK and a low to the south which results in winds initially northerly in direction which then veer round to easterlies. Back-trajectory analysis (Figure 4) shows that the air arriving at the ship site has a marine component,

On 20 June, air reaching the study area is initially marine in origin, but then swings over Scotland and Ireland picking up continentally derived species

Figure 4 *Five-day air mass back-trajectory for 20 June 1996 (in the middle of the experiment). Winds are originally northerly, but veer easterly over Scotland and Ireland before arrival at Mace Head and RRS* Challenger.





From 18 to 22 June, high pressure to the north of the UK results in an air mass with a mixed marine and continental signature

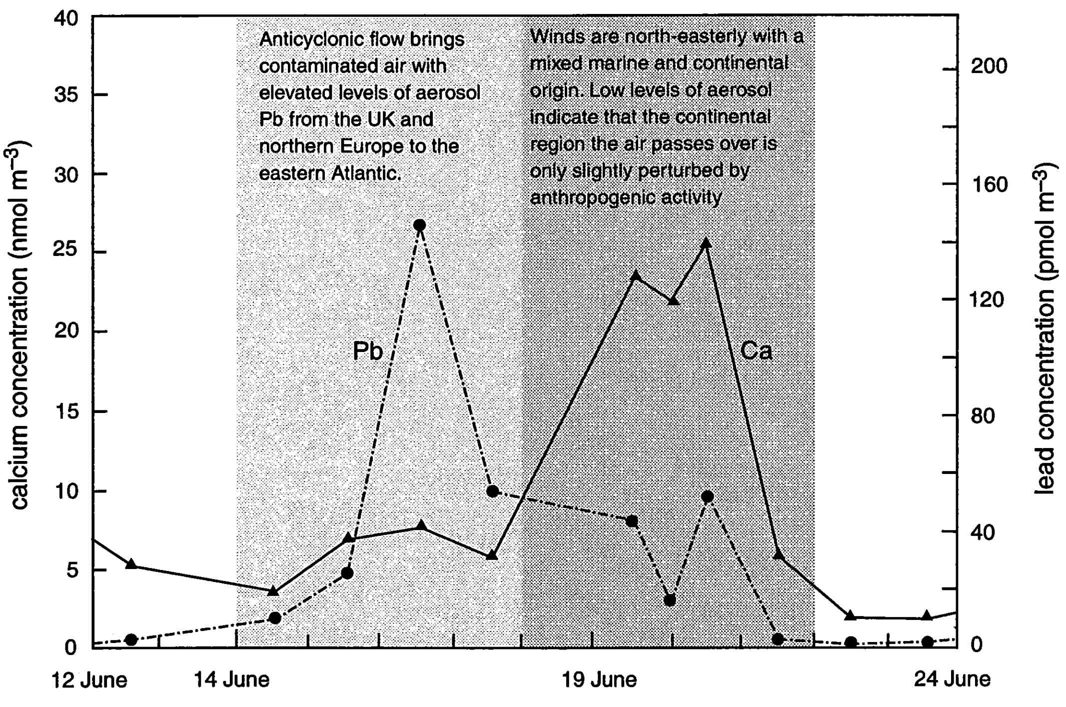
Figure 5 *Initial classification of air masses based on sodium, calcium and ammonium aerosol data.*

explaining the high concentrations of sodium in the aerosols. However, after moving south, the air mass then swings to a more easterly direction, crossing Scotland and Ireland and picking up local continentally derived 'nss'-calcium and ammonium (Figure 5).

So it looks as though simple analysis of the major components within the aerosol phase allows us to distinguish the differing air masses experienced throughout the campaign. From this information we know that the beginning and the end of the experimental period were characterized by south-westerly and westerly winds, and the middle period by winds with both marine and continental characteristics. But is this the entire story? Further analysis of the aerosols for anthropogenically derived lead, emitted into the atmosphere primarily through the high temperature combustion of leaded fuels, shows fairly low concentrations associated with the period we have classified so far as mixed marine and continental in origin. High levels of lead are however seen prior to the peak in 'nss'-calcium and ammonium (Figure 6). So it looks as though with just

Figure 6 *Refinement of the aerosol classification for the middle period of the experiment, on the basis of calcium and lead concentrations.*

From 14 to 18 June, easterlies bring anthropogenically derived lead from the UK and northern Europe



one more piece of information we can now identify another distinct period which appears highly perturbed by anthropogenic activity. Back-trajectory analysis confirms this deduction (Figure 7), showing anticyclonic flow bringing UK and North European pollutants to Ireland and the eastern Atlantic Ocean.

Thus, with just a few of the components which will eventually be measured, we have identified three distinctly different periods. The beginning and the end of the experiment were characterized by high winds from a westerly or south-westerly direction resulting in an aerosol phase with a strong marine signature. During the middle period of the experiment, anticyclonic flow was set up resulting in a short period of highly polluted easterly winds which were subsequently followed by low velocity north-easterlies. The chemical characteristics of this north-easterly air mass indicated that the air had both a marine and a continental signature but that the continental region that the air passed over was largely unperturbed by anthropogenic activity.

Our next step is to compare these results with those collected on land within the same air mass and look for changes in composition as a function of time. Using these data along with measurements of the thickness of the marine boundary layer, and the model being developed for this area, we aim to determine rates for reactions of interest and, through calculation of the wet and dry deposition fluxes, to determine whether the atmosphere is a significant source of metals and fixed nitrogen to the surface ocean biota.

Atmospheric deposition of biologically essential elements such as nitrogen and iron may stimulate the phytoplankton which produce DMS. Once DMS enters the atmosphere, metals such as iron and copper may influence the rate of sulphate aerosol production. The resulting acidity that is generated increases the solubility of atmospheric iron and perhaps also the subsequent solubility of iron in seawater. Thus the linked cycles of sulphur and nitrogen are not only important in climate control but also affect other elemental cycles, including those of the metals.

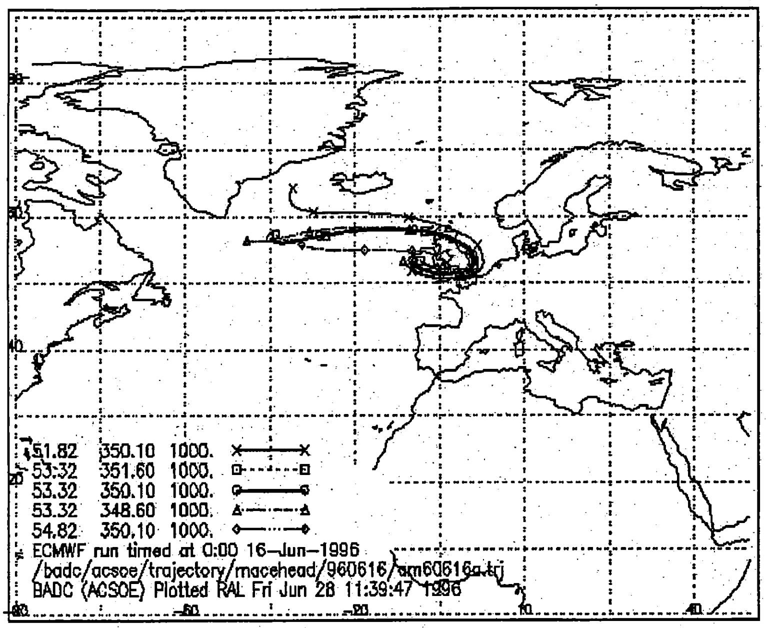


Figure 7 *Five-day air mass back-trajectory for 16 June 1996 (in the middle of the experiment). Northerly winds veer easterly over Scotland and Ireland before arrival at Mace Head and RRS* Challenger.

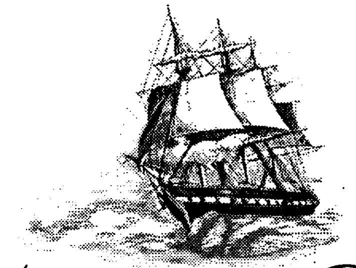
On 16 June, easterly winds bring polluted air from over the UK and northern Europe

Thanks go to everyone involved in this experiment, in particular the officers and crew of RRS *Challenger,* and Gerry Jennings, Gerry Spain and Mick Geever from University College, Galway, Ireland. Thanks go also to Paul Berrisford, University of Reading, the ECMWF, the UK Meteorological Office and BADC for trajectory information.

More details regarding the ACSOE project can be obtained from Bill Sturges, the ACSOE Project Manager, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK.

Lucinda Spokes is a Post-Doctoral Research Associate at the University of East Anglia, working with Tim Jickells on the Rain and Aerosol Component of ACSOE/MAGE.

Email: l.spokes@uea.ac.uk



The German Challenger of Neptune

the short life and tragic death of Rudolph von Willemoes-Suhm

Gerhard Kortum

Much has been published about the preparation, execution and results of the *Challenger* Expedition, and all accounts of the history of oceanography agree that this famous circumnavigation inaugurated a new period in the study of the sea. HMS *Challenger* left Britain on 21 December 1872, and returned on 24 May 1876, having covered 68 700 nautical miles and worked 362 oceanographic stations in all oceans of the world. Many readers will be aware that a young German zoologist had joined the scientific staff of the *Challenger* shortly before she departed. His name was Rudolph von Willemoes-Suhm, from the small port city of Glückstadt on the northern bank of the River Elbe. He was never to return home, for he died on 13 September 1875, on board the *Challenger* in the Pacific Ocean, and was buried at sea.

For a number of reasons, Willemoes-Suhm's contribution to oceanography in general, and to the *Challenger* cruise in particular, has not been fully recognized, even in his native Germany. For one thing, as he did not return, he was not involved in editing the reports. However, he was greatly valued by his colleagues, particularly John Buchanan. In a letter of condolence to Rudolph's mother in Rendsburg, then the place of residence of his parents, Buchanan wrote:

> 'In him I lost my best friend on board the ship and even after so many months the whole extent of the loss, which the expedition has sustained by his untimely death, has not been realized. Had he only lived a few years longer, there can be no doubt, that he would have handed down his name to posterity amongst the foremost of those, who rendered Germany famous in science; but even as it is, no man of his age has left a more indelible mark on the science of zoology.
>
> Montevideo,
> February 22, 1876'

This assessment is confirmed by a quick look at Rudolph's list of publications, as listed in an annex to the last 'Challenger-Brief' sent from Hawaii to Professor Carl von Siebold of Munich University for *Zeitschrift für wissenschaftliche Zoologie* (Vol. 26, 1876) (see later). The references to Suhm in the narrative volume of the *Challenger Report* are numerous, including ten notes on different species. Some new species were named for or by him (e.g. *Willemoesia leptodactyla*, Suhm; *Polycheles crucifera*, Suhm), as were some minor islands (the Suhm Islands in Royal Sound, Kerguelen Island, and a coral island east of D'Entrecasteaux in the Nares Harbour area of the Admiralty Group in the Pacific Ocean). As he mentioned in a letter to his friend and tutor Professor Carl von Kupffer of Kiel University (sent from Mindanao on January 30, 1875), he hoped, after his return to England to help Wyville Thomson in editing the results, and to stay in England for a couple of years. But it is clear that he would have accepted a professorship at a German university, probably in Kiel where he would have succeeded his friend von Kupffer, who left Kiel for Königsberg University in 1877. So a brilliant career was waiting for Willemoes-Suhm at home. But he did not return, and after a time his contribution to the *Challenger* cruise was forgotten.

With the help of von Kupffer, Rudolph's mother Mathilde edited the letters she had received over the years, and in 1877 gave them to the Engelmann publishing house in Leipzig. Another important source of information is the set of *Challenger* letters (Challenger-Briefe, alluded to above), which Rudolph sent to his Munich teacher and friend Professor Carl von Siebold, for publication in his *Zeitschrift für wissenschaftliche Zoologie*. These notes were intended to inform the German scientific community about major results of the cruise, and paralleled the reports Wyville Thomson regularly supplied to *Nature*. As Director of the civilian staff on board the *Challenger*, Thomson had given his consent that Rudolph should keep the German scientific community informed by this series of notes. The last letter Rudolph sent to von Siebold (No. VI) was written on board the *Challenger* in July 1875, on the way from Japan to the Sandwich Islands.

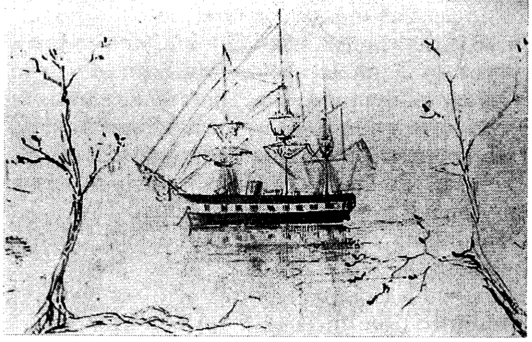
More important in the present context are the letters von Siebold published in 1877 (*Von der Challenger-Expedition: Nachträge zu den Briefen*). Like the letters Rudolph sent home, these communications were not intended to be published, so they contain many interesting personal and private details that give us a better idea of Rudolph's character and personality. Nobody had looked at these sources again, until recently. In 1984, the biologist G. Müller of Saarbrücken University re-edited the family letters, and some of the communications sent to von Siebold, for a more popular series *Alte abenteuerliche Reiseberichte*. In his introduction he tried to integrate some facts about Willemoes-Suhm that he had found in the Detlefsen Museum in Glückstadt, the place Rudolph was born. Obviously, no more sources were available locally with the exception of some photographs and books about the *Challenger* cruise given to the museum in 1907 after Rudolph's mother had died. Thanks to Muller's efforts, however, a modern edition of the letters is readily available today.

This was not the case in the early 1970s, and the oceanographic historian and *Challenger* scholar Daniel Merriman confessed that he had difficulty in getting hold of a copy of the 1877 edition and had to use a microfilm from the British Museum for his fascinating study of Wyville Thomson and Rudolph von Willemoes-Suhm, the most senior and the youngest of the 'Challengers of Neptune' on board the *Challenger*. His appreciation of the life and work of the young German zoologist is moving in its warm understanding of

Photograph of Rudolph von Willemoes-Suhm, from the Challenger-Briefe.

Rudolph's circumstances. It can be read in the report of the *Challenger* Expedition Centenary held in Edinburgh in 1972, on the occasion of the Second International Congress on the History of Oceanography. Merriman also translated parts of some of Rudolph's letters to his mother and included a reproduction of the portrait of Willemoes-Suhm from the 1877 Challenger-Briefe.

We know the main facts of Rudolph's life and career, short as they were, from the contemporary obituaries by Carl von Kupffer, Carl von Siebold, and Wyville Thomson. To understand his *curriculum vitae* it is useful to distinguish three periods. The first is the 'local and regional' period until he left school with the Abitur from the respected Johanneum School in Hamburg, on 20 March, 1866. This period is restricted to different places in Schleswig-Holstein in northern Germany. The second phase involves his time as a student and Privatdozent, until he first met Wyville Thomson in Edinburgh on 14 October, 1872. The third 'global' phase is his time on board the *Challenger* until his death.



HMS Challenger
(Sketch drawing by Prince Ludwig von Battenberg, Bermuda, April 1873, by courtesy of the Detlefsen Museum, Glückstadt)

In this article, new light will be thrown upon the first phase. This is where the story begins – and, as will be shown later, also ends. It was clearly a task for local historians of oceanography to find out more about the family background and Rudolph's childhood and youth, as all the places where he lived are in Holstein and quite close to Kiel. Furthermore, it seems that, although never a student of Christian-Albrechts-University in Kiel, Rudolph had closer relations with academic circles there than was known previously. So he fits quite well into the long and successful tradition of marine research in this Baltic port city, which was shortly to become a leading naval establishment, following the foundation of the German Empire in 1871.

According to the *Narrative** of the *Challenger Report*: 'Rudolph von Willemoes-Suhm, son of the Kammerherr Landrath von Willemoes-Suhm, a native of Schleswig-Holstein, was born September 11th, 1847.' Although the *Challenger* files clearly state that he was German, many contemporaries and later authors sometimes were not sure whether he was German or Danish, or more a Dane than a German. This is a complex matter for those unfamiliar with European regional history of that time. It is connected to the political problem of Schleswig-Holstein in 1848, which was so complicated that even the British Prime Minister negotiating a truce and treaty between Denmark and the German states was driven mad by it. This national ambiguity of the Willemoes-Suhm family might partly explain why Rudolph's participation in the *Challenger* cruise had a low profile in a country that was to evolve into a leading rival to British sea power in the next few decades, and was more concerned with organizing its own national cruises on the *Gazelle*, *National* or *Valdivia*.

** Challenger Report, Narrative,* Vol. I, 2nd Part, 1885, p.769.

A member of the Willemoes-Suhm family, probably Rudolph's paternal grandfather Martin, was a leading figure in the defence of Copenhagen against the British in 1807, and was admitted into the Danish nobility in 1820. This is why there is a Willemoesgade (Willemoes Street/Lane) in Copenhagen.

The career of Rudolph's father, Peter Friedrich, determined the localities where the future zoologist grew up. Peter Friedrich was born in 1816 on the island of Fyn in Odense, but grew up in Holstein where Martin had military assignments (in Plön and Itzehoe). From 1838 until 1843 he studied law at Kiel University, and started an administrative career in the Duchy of Holstein, which had a very peculiar constitutional status. The Danish king was the sovereign of this Duchy between the Eider and Elbe, although it remained a German territory with its own administration. In 1846 Peter Friedrich was married to Mathilde Ida Albertina von Qualen. She had been born in 1824, daughter of the last Danish envoy to the court in Eutin, then an independent church territory.

Rudolph's father had moved to Glückstadt in 1844, where he was active until 1852 as Stadtpräsident and, from 1850 onward, Bürgermeister. Afterwards he was transferred to Wandsbek (1852–56) and Altona to direct the police affairs in both cities (later to be incorporated into Hamburg). In 1864, after the German–Danish War, he had to resign because of his evident Danish sympathies. For two years he went to Leutersdorf on the Rhine. In 1866, however, Peter Friedrich Willemoes-Suhm came back to Holstein as a respected regional administrator and served as Landrat (Chief District Magistrate) in Rendsburg (1866–77) and then Segeberg, where he died on 19 December, 1891. Like many others, he had accommodated himself with the new Prussian order in the province.

So, despite his Danish family background, Rudolph von Willemoes-Suhm was a German from a formal and constitutional point of view. And he held a German passport when he travelled with the Danish Expedition to the Faroes on board the *Phoenix*, which in 1872 called at Leith to take on coal, allowing Rudolph to meet Wyville Thomson.

It is said that Rudolph's early and keen interests in natural history were fostered by Dr Pfingsten of the Schleiden educational establishment in Wandsbek. Rudolph started to publish and lecture about ornithology before he left the Johnneum School in 1866, and his early papers appeared in the journal *Der Zoologische Garten* in Frankfurt.

Rudolph first went to Bonn University to study law, but obviously did not wish to follow in his father's footsteps. A year later he went to Münich and began to study zoology with Professor Carl von Siebold (1804–85), who very soon realized that Rudolph would become a good scientist. From April 1869 onward, Rudolph was a student in Göttingen, where he obtained his doctor's degree with a thesis about the anatomy and development of certain parasites. Afterwards Rudolph specialized in marine biology. He went to the Mediterranean and visited Genoa and La Spezia.

Then, in the summer of 1870, he came to Kiel, met Professor Carl von Kupffer (1829–1902), and under his guidance started to collect marine samples in the Kiel Bight. The result of his Baltic studies was accepted in Munich as his Habilitationsschrift ('dissertation') and published under the title *Biologische Studien über niedere Tiere.* Professor von Siebold asked him to come back to Munich and be his assistant. At the very young age of twenty-four, on 18 December 1871, Rudolph von Willemoes-Suhm was promoted Privatdozent at Munich University, and began lecturing. This, in brief, was the promising early academic career of the German participant on the *Challenger* cruise.

The minutes† of the decisive meeting of the *Challenger* Expedition Circumnavigation Committee (7th meeting, 17 October, 1872)

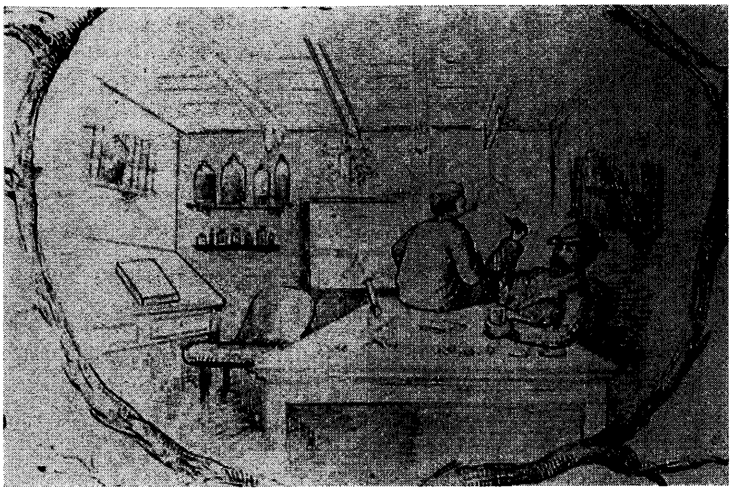
† By courtesy of a private communication from the late Professor Ron Currie.

read: '... Admiral Richards informed the committee that the appointments of the gentlemen named in the minutes of June 5 had all been made by the Admiralty with the exception of Dr. Stirling who had previously withdrawn. Professor Wyville Thomson proposed and Dr. Carpenter seconded a motion that the name of Dr. von Willemoes-Suhm be proposed to the Admiralty in lieu of Dr. Stirling who had withdrawn. This motion was adopted ...'

Rudolph von Willemoes-Suhm died on 13 September, 1876. The *Challenger Report Narrative* (Vol. 1, First Part, 1885, p.20) says: 'On the voyage to Tahiti, Dr. R. von Willemoes-Suhm died after a short illness from erysipelas [an infectious disease]'. Thomson informed the family from Tahiti. The Challenger-Briefe (1877, pp.177–79) incorporates a letter Buchanan sent to Rudolph's father from Valparaiso on 25 November, 1875, explaining the circumstances of the death of his 28-year old son:

'... He was buried at sea on the morning of the 14th with the customary ceremonies. I need hardly say that his death caused the greatest grief among all on board, where his personal merits and scientific eminence had secured the respect and love of all. Every one joins me in the expression of their sympathy for you in your present severe affliction, and as some slight mark of respect for his memory we wish to send a memorial tablet, to be put up in the church or burial place of his home ...'

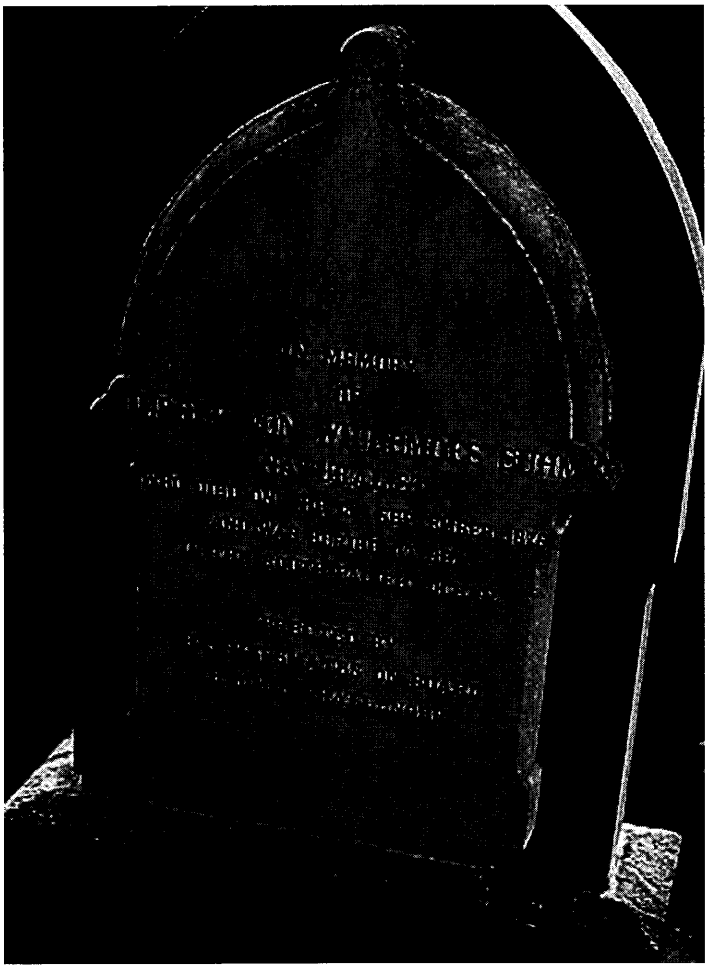
It was to be Rudolph's last voyage that led back home to Holstein again. We know from the *Challenger Narrative* (Vol.1, 2nd Part, 1885, p.771) that 'a tablet to the memory of Rudolph von Willemoes-Suhm has been erected in his native place by his colleagues in the *Challenger*'. Obviously, this was done some time after the *Challenger* returned to England, because the Challenger-Briefe edited by his mother and published in 1877 has a photograph of this memorial stone ('Grabmonument') at the end. This photograph was probably taken on the day it was erected, because there is a fresh wreath on top of it. Local sources indicated that the tablet was at the entrance ('gleich neben dem Eingang') of the graveyard of a church in Itzehoe, as the local newspaper reported in a commemorative article about Willemoes-Suhm on 13 September, 1900 (Büchner, 1973). According to the local church register, Rudolph's mother was living there in Klosterweg 3 and died on 11 January 1907. At Itzehoe Kloster (Monastery), the Schleswig-Holstein nobility had a foundation and facilities to support unmarried and widowed female members, and that is where she went after her husband's death. But, as Büchner stated in his 1973 paper, nobody knew anything about a memorial stone. Glückstadt and Rendsburg were other possible places where the stone might have been, but all efforts to find it were in vain.



Rudolph von Willemoes-Suhm and Prince Ludwig von Battenberg in the laboratory on board Challenger in Bermuda in April 1873.
(Sketch by Prince Ludwig von Battenberg, by courtesy of the Detlefsen Museum, Glückstadt)

Then, in January 1996, on a casual visit to the provincial town of Bad Segeberg, about 30 miles south of Kiel on Route 404, the author was successful. The minister of St Marien Church, who was questioned about this matter after the Sunday service, knew nothing about Willemoes-Suhm, marine biology or a vessel named *Challenger*, but remembered an English inscription on one of the tombstones of his four extensive graveyards in the vicinity of the church. He described the way and site, and there it was, still intact and in good condition, although weathered and no longer as white as it once was. The vanished *Challenger* memorial stone with the tablet given to the family by Wyville Thomson, John Murray, John Young Buchanan, Henry Nottidge Moseley and John James Wild, had survived on the family's grave (Graveyard No. II, south-east section close to the fence). The present location certainly is different from that on the 1877 photograph, so it is likely that Rudolph's mother, who had such an intimate relationship with her son (there are no letters to the father), took the stone with her from Segeberg to Itzehoe when the father died, so as to have Rudolph's memorial near by. Perhaps Rudolph's brother Josef, who had lived with his mother in Itzehoe until her in death 1907, or maybe somebody else, later arranged that the *Challenger* memorial stone be transferred back to the family burial place in Segeberg. So the history of this stone 'document' in a way still remains a mystery.

The important thing is that it still exists and this fact is now made known to the international marine community. Meanwhile, the Institut für Meereskunde at Kiel University has approached the church committee in Segeberg and offered help with restoration work. Furthermore, it has been suggested that this memorial monument, not being a



The memorial to Rudolph Willemoes-Suhm in the graveyard of St Marienkirche, Bad Segeberg, Germany.
(Photo: Gerhard Kortum)

tombstone, be transferred again, in case the burial place of the Willemoes-Suhm family should one day be abandoned. The museum in Glückstadt, or a marine research institution near the present site, would be appropriate locations for a memorial to remind future generations of oceanographers that there was a German participant on board the *Challenger*, who died under tragic circumstances 123 years ago. The impressive memorial stone, measuring about 1.6 m x 1 m, is certainly a symbol of the fact that marine research has been an international affair ever since the *Challenger* set sail to study the seas as a common heritage of science and mankind.

Obituaries

Carl von Kupffer in *Willemoes-Suhm* (1877), and in *Kieler Zeitung, Abendausgabe* of 25 November, 1875, p.4764.

Carl von Siebold in *Zeitschrift fur wissenschafliche Zoologie*, Vol. 26, 1876, pp.XCI–XCIV.

Charles Wyville Thomson in *Nature*, Vol.13, 1875, p.88–9; cp. *Challenger Report, Narrative* Vol.1, 2nd Part, 1885, pp.769–71.

The inscription of the tablet reads:

IN MEMORY
OF
RUDOLPH VON WILLEMOES- SUHM
NATURALIST
WHO DIED ON THE 13TH OF
SEPTEMBER 1875
AND WAS BURIED AT SEA
IN THE SOUTH PACIFIC OCEAN
ERECTED BY
HIS MESSMATES ON BOARD
H. R. M. S. CHALLENGER

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Gerhard Kortum is Provost of the Institut für Meereskunde at the University of Kiel, Germany. His main interests are marine geography and the history of oceanography.

Law of the Sea and development of marine resources
A Challenge for Scientists

Philomène A. Verlaan

The 1982 United Nations Convention on the Law of the Sea (LoS Convention) entered into force on 16 November, 1994. Now, with 126 states as full parties, virtually universal acceptance is anticipated. The LoS Convention establishes a comprehensive, global, binding legal framework to govern both marine activities and those activities on land and in the atmosphere affecting the marine environment. Designed to be a living instrument, responsive to changing circumstances and new knowledge, the LoS Convention is to be complemented by international mechanisms to review and update ocean law in light of environmental changes and progress in science and technology. Planning the development of marine resources should take the LoS Convention into account, and will require substantial input from marine scientists.

This article discusses the implications of the LoS Convention for marine scientists in two contexts:

- development of marine resources;
- reviewing and improving regulation of activities associated with such development.

Development of marine resources

Under the LoS Convention, coastal states may control virtually all activities connected with marine resources, including marine scientific research, in most of the ocean. Coastal state jurisdiction over marine resources starts (roughly) from shore; it potentially extends seaward for 200 nautical miles (n.m.) in an 'exclusive economic zone' (EEZ), and at least to the edge of a 200 n.m. legal continental shelf (which may differ from the actual geological continental shelf) (see Figure 1, overleaf). Under certain circumstances, jurisdiction over shelf resources may extend even further.

The affected resources may be living, non-living, traditional and new; an example of 'new resources' is energy production in the EEZ from water, currents and winds. Resources are covered by the LoS Convention regardless of their location – in the water column, in or on the sea-bed or subsoil, or in the overlying atmosphere. The coastal state has exclusive control over construction, operation and use of artificial islands, offshore structures, installations and drilling in the EEZ, on the continental shelf, and in its territorial waters, which may extend out to 12 n.m.

Consequently, development of marine resources is now likely to be subject to substantial state-imposed constraints. For example, under Part XIII of the LoS Convention (on marine scientific research), coastal states essentially have the power of veto over requests to conduct marine research throughout their proclaimed EEZ and on their legal continental shelf. Research proposals by scientists from developed countries are often designed to avoid large parts of otherwise scientifically relevant ocean off the shores of coastal states who are known to be uncooperative.* This situation shows no signs of improving.† One consequence of the provi-

* The chilling effect exerted on marine scientific research by the LoS Convention (even though it was not yet then in force) is addressed in detail in Verlaan, P.A. (1990), 'Marine Scientific Research and the Law of the Sea: Implications and Consequences for Marine Scientists' in *Proceedings, Pacific Congress on Marine Science and Technology*, Tokyo, Japan.

† Roach, J.A. (1996) 'Marine Scientific Research and the New Law of the Sea' in *Ocean Development and International Law*, **27**, 59–72.

States-parties to the LoS Convention in Europe include: Austria, Bosnia and Herzegovina, Croatia, Cyprus, the Czech Republic, Finland, France, Georgia, Germany, Greece, Iceland, Ireland, Italy, the Former Yugoslav Republic of Macedonia, Malta, Monaco, Netherlands, Norway, Portugal, Romania, the Russian Federation, Slovakia, Slovenia, Spain, Sweden, the United Kingdom, and Yugoslavia. The EU is a party pursuant to Annex IX on international organizations.

sions for marine research in the LoS Convention is that less information about marine resources is potentially available, because much of the coastal ocean, particularly near developing countries, has been placed out of bounds to even the most basic marine research. The implications of restricting marine research, as far as our knowledge of climatological and other regional and global natural processes is concerned, are perhaps even more worrying than their potentially detrimental effects on the development of marine resources.

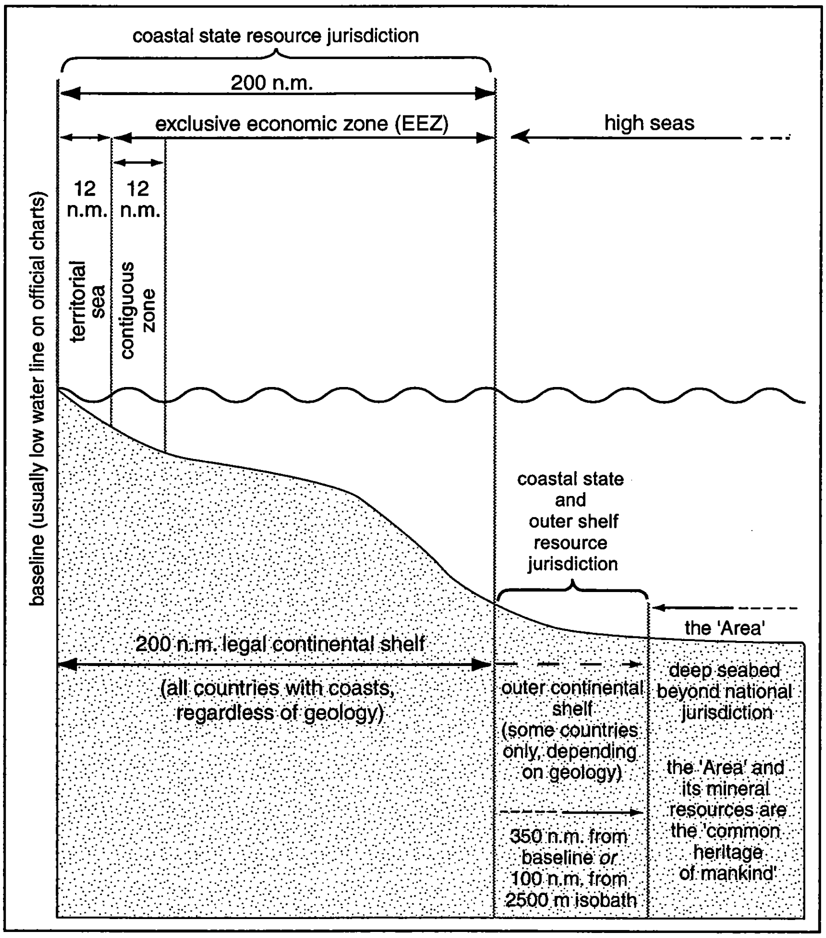
In addition to the EEZ (Part V of the LoS Convention) and the legal continental shelf, the geographical extent of state control over marine resources may now often also extend even further seaward to include the outer continental shelf, the deep sea-bed and the high seas. An example of each follows.

Under Part VI of the LoS Convention, if a coastal state has a geological continental shelf extending beyond 200 n.m., it may, under certain circumstances, control activities on the sea-bed and subsoil and the resources thereof, for up to (usually) a further 150 n.m. seaward. This is the outer continental shelf, whose definition for coastal state jurisdictional purposes under the LoS Convention is not yet settled. The outer shelf issue has important scientific, technological and commercial implications beyond the scope of this article.**

The deep sea-bed lies seaward of the ocean floor over which coastal states may assert resource rights under EEZ or shelf criteria. Called 'the Area' in Part XI of the LoS Convention, it is defined as 'the sea-bed and ocean floor and subsoil thereof beyond national jurisdiction'. The Area is controlled by a multi-state organization known as the International Sea-bed Authority (the Authority), whose headquarters are in Kingston, Jamaica. The Authority governs activities in the Area related to exploration and exploitation of its solid, liquid or gaseous mineral resources. Other resources (e.g. living or non-mineral energy resources) in the Area, or in its overlying waters and atmosphere, are not within the Authority's purview. Part XI of the Convention is substantially amended by the Agreement of 28 July 1994, which prevails over Part XI where the two are inconsistent.

The rather small part of the ocean remaining outside the jurisdiction of the coastal state is known as the high seas (see Figure 1). However, under Part VII of the LoS Convention, the concept of 'high seas freedoms' – which refers to certain activities that may be engaged in by all states in that part of the ocean – has been transmuted into a concept of high seas duties and obligations. On the high seas,

Figure 1 *Diagrammatic cross-section (not to scale) to illustrate the maritime zones defined and described in the LoS Convention.*



Under Article 87(1), high seas freedoms include navigation, overflight, laying submarine cables and pipelines (qualified by Part VI), constructing artificial islands and other installations permitted under international law (qualified by Part VI), fishing (extensively qualified by Section 2 of Part VII and the 1995 straddling and highly migratory fish stocks agreement) and marine scientific research (qualified by Parts VI and XIII).

These implications are addressed in detail in Verlaan, P.A. (1997), 'New seafloor mapping technology and Article 76 of the United Nations Convention on the Law of the Sea', *Marine Policy*, **21, No.5, 425–34.

states-parties must comply with a variety of conditions circumscribing these freedoms, including other rules of international law and those laid down in the LoS Convention itself. The latter include the duty to: reserve the high seas for peaceful purposes; conserve living resources; protect the marine environment; and have due regard for the interests of other states and activities in the Area. Thus any state under whose auspices activities related to marine resources are being carried out on the high seas must ensure that these activities comply with the LoS Convention.

Before it may impose controls within an EEZ, the coastal state must proclaim an EEZ, submit charts showing the outer limits of its EEZ, with the appropriate geographical coordinates, to the Secretary-General of the United Nations, and otherwise publicize these limits. However, a coastal state's claimed territorial sea, EEZ and shelf may overlap with claims by its opposite or adjacent coastal neighbours, which will complicate the work of marine scientists still further. The LoS Convention addresses any unattributed rights or jurisdiction within the EEZ which might give rise to a conflict between states. It provides various approaches to these situations, but all require prolonged negotiations between the states involved. Without an agreed resolution between the states concerned, marine scientists cannot proceed with confidence. It would be wise for marine scientists to investigate the jurisdictional status of waters where they plan to work.

Promulgation, review and improvement of regulations

The foregoing section described the pervasive and comprehensive rights to control activities related to marine resources throughout the ocean assigned to coastal states or to groups of states under the LoS Convention. These rights may be exercised either to promote or inhibit development of marine resources. An instructive lesson is offered by experiences relating to marine scientific research so far under the LoS Convention: if a coastal state does not understand the marine activity proposed, it is likely either to forbid it, or to surround it with so much regulation that it becomes uneconomical. The LoS Convention offers an approach to this situation which would benefit from the cooperation of marine scientists concerned with marine resource development, as explained below.

The LoS Convention is designed to ensure the promulgation of effective, iterative international mechanisms which enable ocean law to be updated in the light of developments in science and technology, and changes in the marine environment. Although not stated as such in a single article, this is the operative effect of those articles in the LoS Convention that impose precise and unqualified obligations on states to regulate their use of their marine resources.[††]

Examples of such obligations include:

- Using the best scientific evidence available in conserving living resources in the EEZ and on the high seas.
- Regular exchange of this information between states and competent global, regional and sub-regional international organizations in the EEZ and on the high seas.
- Cooperation with states and competent global, regional and sub-regional international organizations to manage living resources in the EEZ and on the high seas.
- Cooperating in harmonizing approaches to manage resources generally, in enclosed or semi-enclosed seas.
- Protecting and preserving the marine environment in general and involving global and regional competent international organizations in this work.
- Developing, harmonizing and enforcing international and national laws and regulations to protect the marine environment.
- Setting scientific criteria to formulate these rules.
- Developing and promoting contingency plans for responding to marine pollution incidents.
- Promoting and participating in research on marine environmental pollution and exchanging information and data.
- Monitoring risks and effects of marine environmental pollution, and of activities which states permit or engage in; and reporting on the results to competent international organizations.

The practical upshot is that states have an ongoing duty under the LoS Convention to develop and review comprehensive regulations for sustainable development and use of marine resources, on the basis of the best scientific evidence available, and in harmony with other states. The requirement of sustainability may be derived from, and is consistent with, the over-arching and unqualified duty of states under the LoS Convention to protect and preserve the marine environment.

Considerable financial and expert resources will be necessary for states to perform this regulatory duty adequately in such a highly complex area. Lack of resources to regulate imaginatively and appropriately will usually be invoked by a state as the reason for not regulating well, but does not usually prevent the state from regulating at all. As has already

[††] The IUCN/World Conservation Union (1995), provides an extensive, detailed analysis of the relevant articles in the LoS Convention, their resulting obligations and institutional consequences in: *The Law of the Sea: Priorities and Responsibilities in Implementing the Convention. A Marine Conservation and Development Report*, vi + 155pp., IUCN, Gland, Switzerland.

been seen with marine scientific research, absence of money and expertise in a state may result in regulations that are unnecessarily restrictive. This is unsatisfactory for all concerned, but arguably most of all for the state, which bears not only the immediate financial and administrative burden of its restrictions, but also the long-term losses of income, skills and information that might otherwise have been available in the absence of such constraints.

The LoS Convention offers marine scientists an excellent opportunity to participate in designing acceptable regulations from the very beginning. Scientists should take advantage of this opportunity, in light of the LoS Convention's emphasis on scientific and technological advancements and environmental change as important factors driving regulatory development. Given that regulation of many marine activities is now mandatory under the Los Convention, marine scientists could seize the initiative by ensuring that the best scientific evidence is available, and by joining in promulgation of appropriate regulations.

States are generally receptive to proposals by interested, well qualified parties for the administration of an area of common concern. A detailed regulatory draft from such parties for a new area of interest can be especially persuasive, particularly when it is likely to be the only one on the table, and when the state's time and resources to prepare alternatives are limited. It is from the marine scientific constituency that the scientific basis for proposals for the optimum development and use of marine resources could, and should, emanate. Perhaps such a resource-driven initiative by scientists might eventually even lead to an improvement in the unsatisfactory treatment of marine scientific research under the LoS Convention – but that subject is for another issue of *Ocean Challenge*.

Conclusion

With the coming into force of the LoS Convention, marine scientists concerned with marine resource development are advised to bear in mind that:

- States may now control development of marine resources nearly everywhere in the ocean.
- Since regulation is likely, a useful approach is to promote adoption of the best possible regulations by participating in their design.

Success in developing marine resources will depend substantially on efforts by the marine scientific community to combat state ignorance and its usual, sad consequence: inhibition, if not prohibition, of exciting and imaginative marine activities. But if these efforts are made, sea, land and science will benefit.

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The Case of the Swimming Scallops

"An instructive case, Watson, but not one, I think, for your collection, since it involves little or no bloodshed and its solution hangs upon a matter of when the law deems a marine animal to be able to swim. I do not myself know the answer, so can only put before you the facts as I see them.

There are not many nations that can claim a legal continental shelf outisde their EEZs, only those having a natural extension of their actual (geological) shelf beyond the 200 nautical mile limit. Canada is one such nation.

In 1996, Canadian fisheries patrol vessels arrested two US boats fishing for scallops on the shelf outside her EEZ. Now, every country with a coastline automatically has a legal continental shelf as part of its EEZ, and inside that boundary is entitled to exploit any and all resources both in the water column and on as well as under the sea-bed. However, on the legal continental shelf *outside* the EEZ boundary, the country has rights to exploit *only* what is on and under the sea-bed. The overlying waters are part of the high seas, where anyone is entitled to go and catch fish.

It appears that under Canadian law scallops are not considered to be capable of swimming, therefore scallops are legally part of the sea-bed and in consequence fishing for them on Canada's legal continental shelf is an offence against the law.

Are the Canadian authorities correct in claiming that scallops cannot swim? Anyone who has visited an aquarium may well have seen scallops 'clapping' about in the water. In common with many others I had always thought that scallops moved rather like squid and cuttlefish, squirting jets of water 'backwards' out of the partly opened shell. It seems intuitively most likely. However, movement is in fact 'gape-first.', because the water jets are expelled either side of the hinge region. While the jets are indeed produced by 'clapping' the shells together, the shells never open more than about 13°, to maintain the lift provided by the aerofoil-like cross-section of the two shells, and prevent stalling. Initial 'rotation' for take-off is provided by a downward jet from the front of the gape, but 'flight' becomes more or less level once a height of a metre or two above the the bed is reached, with an upward tilt in the 'flight' direction of less than 5° – and this attitude is maintained for landing too. Speeds of a metre or two per second can be achieved, but as swimming lasts only a few seconds, the range is no more than a few metres at most. Moreover, scallops are not carnivores, so they only jet about to avoid predators.

I rather fancy, Watson, that the Canadians may have been right. I suspect scallops spend more time on the sea-bed than in the water column, and cannot therefore be harvested, save by trawling at the sea-bed."

How do we evaluate environmental consequences of large-scale activities in the deep ocean?

Hjalmar Thiel and Tony Rice

Many marine scientists are involved in studies of the actual or potential impact of human activities on the deep ocean. But little thought has been given to whether the research techniques themselves significantly affect the environment. Conventional intrusive research techniques, such as those using tow-nets and trawls, have not changed significantly in scale since the *Challenger* expedition some 125 years ago. Although the recent realization that the deep ocean is much more variable than was previously thought has resulted in temporally and spatially more intense sampling, the global effect of such traditional methods must be trivial. Typically, for example, deep sea-bed samples range from a few square centimetres for small corers to a few thousands of square metres for the largest trawls. The environmental impact of such sampling is small. The total area of sea floor sampled 'destructively' by all the gears used by oceanographers since the *Challenger* amounts to no more than a few square kilometres, a tiny fraction of one per cent of the more than 300 million km^2 of deep ocean. But in recent years oceanographers have begun to question whether this 'traditional' approach is adequate to answer some of the questions about the oceans that are now being posed.

It is clear that to understand how the natural system functions, more intense spatial and temporal sampling and data-gathering is necessary. However, a much more difficult problem is that of predicting the likely environmental consequences of anthropogenic impacts. The effects of general impacts such as global warming or the build-up of atmospheric carbon dioxide are, of course, of great potential importance. Detecting or predicting them may require very precise data-collection and analysis, but these would not be significantly different in kind from the techniques used in conventional research. In contrast, predicting the impacts to be expected from direct human intervention in the deep sea – such as metal extraction or sludge disposal – by extrapolation from conventional research results, including recolonization experiments on the scale of 1 m^2, is difficult if not impossible. Accordingly, some deep-sea scientists believe that in order to make such predictions it may be necessary to conduct much larger scale experiments.

Large-scale experiments

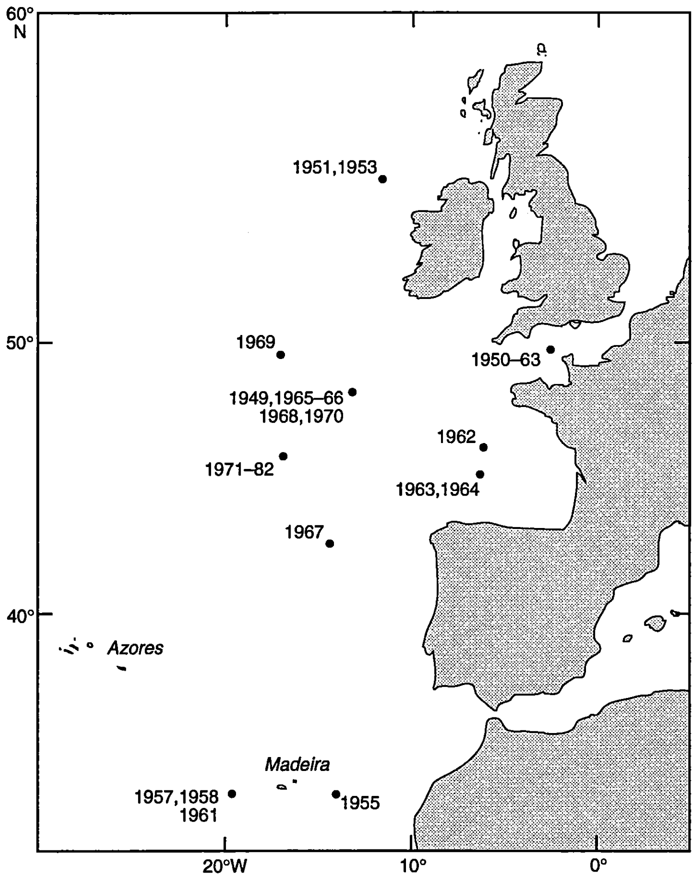
One such experiment, DISCOL (Disturbance and Recolonization experiment), is an attempt to simulate at least some of the probable effects of manganese nodule mining. In this experiment, some 10 km^2 of the sea floor at a depth of 4150 m in the south-eastern Pacific was physically disturbed by ploughing, using a modified farm harrow, and the resulting recovery of the area has been monitored at intervals ever since. Although the data obtained during this project will certainly be valuable, their relevance to the much larger scale physical disturbance to be expected from a commercial operation, of 1 km^2 of sea-floor destruction every day for up to twenty years, is questionable. Moreover, even if these results were useful, DISCOL simulates only part of the potential impact of commercial mining and does not, for instance, address the effects of the large mud plume which would inevitably be produced. In order to address this impact further, large-scale experiments have been conducted by blowing large amounts of sediment into the water column and observing its resettlement and its influence on the fauna. These experimental studies influenced several square kilometres of sea floor. In other possible areas of activity – either of resource extraction or of waste disposal – no impact experiments have yet been conducted.

RISKER

A recent desk study, RISKER (Environmental Risk from Large-scale Ecological Research in the Deep Sea), funded by the European Union under the MAST-II programme, has investigated this general area.

In 1993, the European Union published a call for proposals (93/C203/19) asking for 'the assessment of any possible risk likely to affect the marine environment in association with research, monitoring and surveying in marine sciences and technologies'. Funded under this programme, RISKER's overall objective was to identify the types and scales of research that would be needed to predict the impact of a range of deep-sea activities and to assess the likely environmental impact, and therefore acceptability, of the research itself. As a result of the RISKER study we suggest that future scales of ecological research will range from conventional corer, grab and trawl samples for the benthos, and water bottle, pump and plankton net sampling for the mid-water realm, to the experimental creation of large-scale impacts for risk-evaluation of commercial uses of the deep sea. These potential industrial activities include both waste disposal and resource extraction, and assessment of their environmental impacts will require research at a variety of scales.

Sites in the north-east Atlantic used for the disposal of radioactive waste between 1949 and 1982 *(Information courtesy of the the Nuclear Energy Authority)*



Deep-sea waste-disposal

The use of the deep ocean for the disposal of waste is rather different from most potential large-scale activity. The wastes considered range from sewage sludges and dredge spoils, through radioactive wastes and munitions, to large structures such as redundant offshore oil and gas installations, and finally to excess industrial carbon dioxide in liquid or frozen form. Each of these categories would probably involve the use of unique technologies, and would certainly result in quite different impacts, depending upon the consistency and volume of the waste, as well as its toxicity. Because of these differences, and varying socio-political attitudes towards them, we suggest that the types of research required to investigate their environmental impacts would also have to be different.

Radioactive wastes

In some cases, for instance the disposal of radioactive waste, a realistic *in situ* experiment would be unthinkable in the current socio-political climate, any more than would renewed deep-sea disposal of such waste (this is true despite evidence that some deep-sea sedimentary conditions might provide adequate long-term isolation of emplaced radio-nuclides). Instead, therefore, we suggest that the existing emplacements of such wastes should be regarded as scientific experiments, and should be monitored using current conventional research techniques, or even ones yet to be developed, though still at scales similar to those traditionally used in the past. Close-up observations of the storage containers, and targeted sampling in their immediate neighbourhood, seems essential, and the most appropriate technique would be the deployment of remotely controlled vehicles (ROVs) or manned submersibles. The results could certainly be of considerable interest purely scientifically, but might also be relevant to other anthropogenic impacts: for example, transport rates could be elucidated using the radioactive wastes as tracers. In the context of RISKER, the environmental impacts resulting from such research activities would remain rather limited, although ROVs and submersibles may have an impact on several square metres of sea floor by working close to it.

Munitions

A similar situation applies to munitions disposal, but in this case dumping localities have been kept confidential because of their highly political nature. However, oceanographers *should have access* to these sites to inspect and measure impacts on the environment. Nevertheless, the research techniques needed would be of the conventional scale and therefore, we believe, would have no significant and unacceptable environmental impact.

Large structures

Recent events have placed the disposal of large structures in much the same situation as radioactive waste and munitions disposal. The controversy surrounding the *Brent Spar* suggest that any attempt within the foreseeable future to carry out a similar operation, either commercially or 'experimentally', would encounter very strong opposition. We therefore suggest that in order to investigate the possible impacts of such events (unlikely though they may be), it would be necessary to study existing natural or artificial analogues. These range from natural oil and gas seeps, through hydrothermal vents, to existing (or future) shipwrecks. Again, the research techniques needed, either currently available or to be developed in the future, would be at traditional research scales, including the use of ROVs and submersibles, and therefore would again have no significant environmental impact themselves.

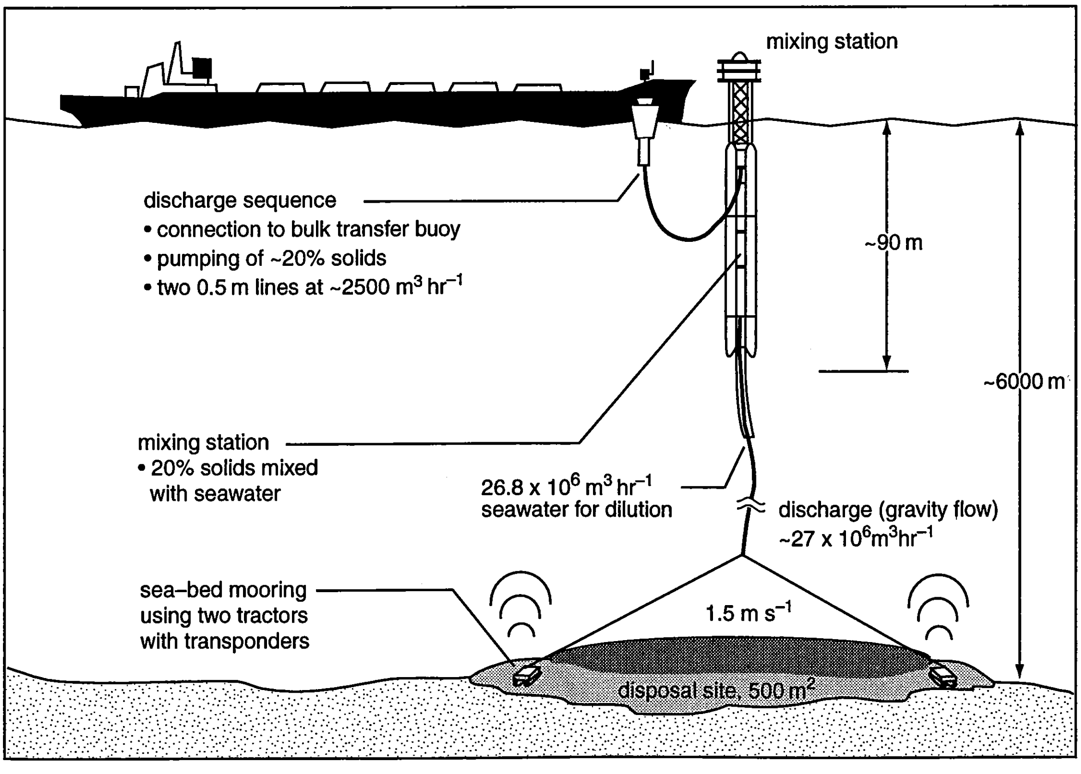
Large-volume wastes

For the deep ocean disposals considered above, environmental impacts can be deduced from earlier experience or disasters, but this is not the case for other potential candidates for deep ocean storage: sewage sludge, dredge spoils, and carbon dioxide. Sewage sludge from the city of New York has been dumped at the so-called Dumpsite 106 in the western North Atlantic Ocean at a depth of 2000 m. The settlement of the particulate matter, its transport and distribution on and along the sea floor have been monitored, and the results published. Although the data from the continental slope situation cannot be applied directly to the abyssal context, they may nevertheless help in predicting dispersal in abyssal environments.

Therefore, the large-scale experimental approach is a *conditio sine qua non.* Only such experiments will allow appropriate environmental impact assessments. Techniques of transport, deep-sea emplacement, and monitoring programmes are likely to be similar for sewage sludge and dredge spoils, and the same large-scale experimental design (e.g. the method illustrated below) may be sufficient for both types of waste materials. In contrast, the introduction of carbon dioxide into deep water layers or into sea-floor depressions will need specific research efforts.

But for both situations a step-wise scaled approach is necessary to evaluate effects at different ecological levels and to avoid excessive costs. In evaluating the effects of carbon dioxide at the species, population, and community levels, four steps should be involved: (1) laboratory tests on the reactions of individual organisms to increased CO_2 concentrations under aquarium conditions; (2) similar tests under 'mesocosm' conditions; (3) tests under natural conditions with a medium-scale experiment contaminating a fjord system for a restricted period; and finally (4) the ultimate large-scale experiment, the disposal of a large volume of carbon dioxide into the deep ocean.

Steps 3 and 4 should be based on extensive modelling of the oceanographic conditions, so that the experiments can be designed at scales likely to produce results with predictive value for economic scale disposals. The steps suggested for sewage sludge and dredge spoil should also involve four stages. The first of these would be a pre-experimental and design phase in which a prospective disposal

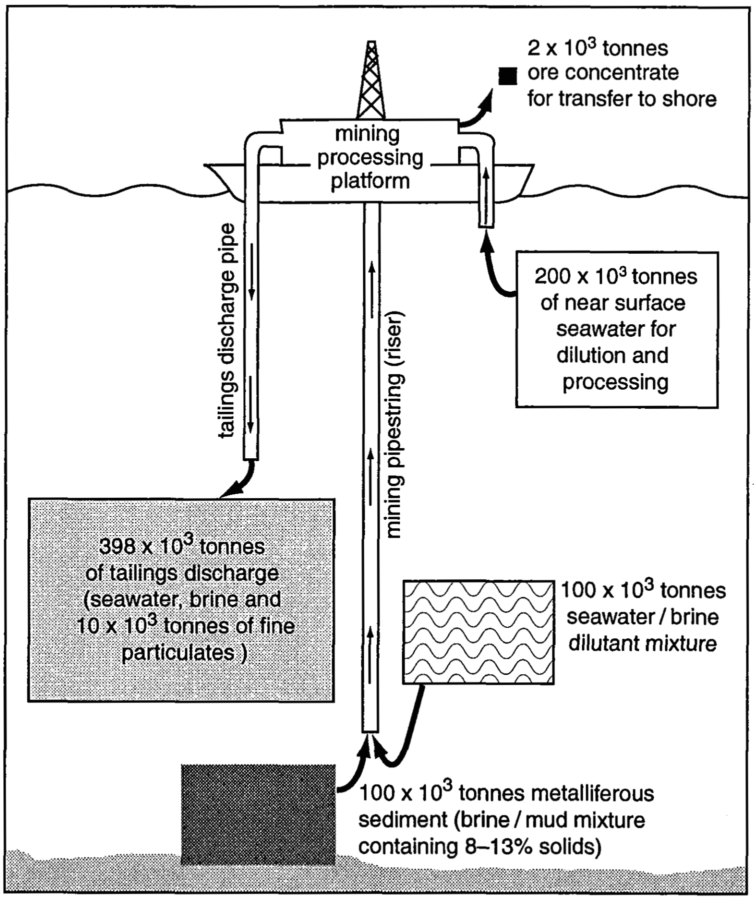


One possible method for disposing of sewage sludge and dredge spoils in the deep sea *(Reproduced, with permission, from the RISKER report)* site and a control site would be surveyed, the disposal technique selected and some preliminary modelling work undertaken. The second phase would be a relatively small *in situ* experiment in which the equivalent of a single load of a bulk carrier would be emplaced within an area with a radius of about 1 km and monitored for about one year. If the impact at this stage is acceptable the third phase would involve the emplacement of about 1 million m^3 of waste in a similarly restricted area over a period of about one year and then monitored for a further year. Again, if the impact at this stage is still acceptable the fourth phase would involve annual emplacements of about one million tonnes each year for ten years.

Resource extraction

Possible exploitable resources in the deep sea include manganese nodules and crusts, phosphorites and massive sulphides, and metalliferous muds. Although the scales of operation and the technologies needed to recover these resources vary, they share a number of common features. They would all involve severe physical disruption of the sea floor over relatively large areas, and they would all also result in extensive mud plumes in the water column. While plume phenomena can to some extent be modelled using available data, we suggest that in order to assess the likely environmental consequences it will also be necessary to conduct and monitor relatively large-scale *in situ* experiments. The result from a single experiment may provide data relevant to a range of different activities, but it may be necessary to conduct several large-scale experiments in order to cover the full range of possible impacts.

Daily intake and discharge requirements for a (hypothetical) operation to mine metalliferous mud in the Red Sea. (The sizes of the boxes indicate respective volumes)



Techniques for mining manganese nodules and metalliferous muds are available, although if and when mining starts in a few decades, more effective methods may be employed. So-called 'Prepilot Mining Tests' have already been conducted (in the late seventies), and were accompanied by environmental studies. The results led to the new approach of conducting the large-scale experiments already mentioned. No techniques have been designed for mining other ore types, but suitable methods may be developed from those already known. However, the resulting environmental impacts are likely to vary according to the ore type and local oceanic conditions. Therefore, specific large-scale experiments must be planned in association with each industrial intrusion into the deep sea. Moreover, the mining of phosphorites and the associated environmental impacts must be considered separately from other ores since they occur in relatively shallow areas of the deep sea and on continental shelves, specifically in upwelling areas. Plumes created by mining activities, particularly in these regions, might be transported large distances by the prevailing currents, and they might reach highly productive surface waters or interact with fish stocks and their larvae.

Careful impact predictions are of importance for all these mining activities. Only large-scale experiments, which allow extrapolation of the results to commercial-scale mining, will provide adequate information.

Is large-scale research in the deep sea acceptable?

We believe that conventional deep sea research has not had, and will not have, an unacceptable impact either on the bottom or in mid-water. The disturbance by conventional methods of sampling, observing and recording remains so small in relation to the large areas and volumes available that even the slow pace of life in the deep sea will repair any damage relatively quickly. 'Normal'-scale biological deep ocean research is therefore excluded from further consideration.

However, deep-sea ecologists are faced with new dimensions of their research as people penetrate the most remote and inaccessible space on Earth. Ethically there appears to be no difference between exploitation of terrestrial or extra-terrestrial realms and exploitation of underwater space. Nevertheless, it is justifiable to ask whether approaches to large-scale research would result in unacceptable risks for sustainable development. The new experimental approaches have already involved deep sea areas of 10 km^2 or more. Such sites have received additional sediment cover of a few millimetres from material disturbed in their immediate neighbourhood or from some distance upstream, but still from the same general ecological setting. In other places the sediment surface has been severely disturbed, and the benthic community has certainly shifted markedly to lower standing stocks and different dominance ratios. Although re-establishment of communities does occur, this takes considerable time. In the case of severe habitat change, the original fauna may not be able to return. For example, when manganese nodules are buried below the sediment surface, hard substrate epifauna and crevice fauna cannot return, but their ecological space will be occupied by species of the soft-bottom sub-community, which can now spread.

What does 'acceptable' mean?

No specific criteria are available to distinguish between acceptable and unacceptable environmental impacts. This poses problems even in environments which are much better known than the deep sea. Nevertheless, even for this rather poorly known environment, some rather general principles of 'acceptability' can be proposed:

- Persistent adverse effects on regional biodiversity should not be accepted.
- No species should be driven to extinction.
- Ecological processes should not be impaired. This pertains specifically to those processes with climatic relevance and the transport of toxic substances.
- Living resources should not be adversely affected.
- There should be no interference with other ocean uses.
- Risks to keystone communities and/or processes, and even to human safety, must be excluded.

Large-scale experiments may be undertaken as purely scientific investigations, or they may be conducted in conjunction with industrial developments and tests. In deep ocean mining the Pilot Mining Operation (PMO) phase is the first developmental step which, probably under reduced scales, will lift ore and tailings to the surface in larger amounts than in the Prepilot Mining Tests. Whereas scientific experiments causing of the order of 10 km^2 of disturbance may easily meet the above criteria of acceptability, this may not be true for a PMO. During this phase, large amounts of material will be transported from the sea floor to the ocean surface and the tailings will be discharged at a depth to be determined by local conditions. Although the techniques to be employed are not known, the extent of this pre-commercial phase should also meet the acceptability criteria. The duration of such PMOs would be limited to a few months, and they will probably be executed at only about one-fifth of the scale of subsequent commercial mining. It seems likely, therefore, that the acceptability criteria will be met by such activity. However, oceanographers of all disciplines must carefully monitor such PMO events to ensure that the environmental impacts, and therefore acceptability, of commercial scale mining can be predicted accurately.

Analogous to the PMO concept for mining, the RISKER study introduces the term Pilot Disposal Operation (PDO). As indicated above, a stepwise experimental design should be the approach to waste disposal, with the acceptability at each stage demonstrated unequivocally before proceeding to the next stage.

Conclusion

The RISKER study concludes that traditional scale research activities and large-scale scientific experiments, as conducted recently, meet the environmental acceptability criteria. Because of their limited extent in space and time, it is believed that PMO and PDO commercial tests would also be acceptable, although the specific techniques which are likely to be used for mining and disposal cannot yet be predicted. Careful consideration in the early phases of any future developments will be essential before decisions are made to proceed with PMOs and PDOs.

But despite these assesments of 'acceptability', any deep-sea research involving impacts significantly longer-lasting than those resulting from 'conventional' approaches should be preceded by widespread consultation to ensure that it is also acceptable to the public at large.

Further Reading

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Hjalmar Thiel and **Tony (A.L.) Rice** were both deep-sea biologists. Both have now retired and can therefore discuss future research with impunity!

EWOC99 – The Fifth International Conference on School and Popular Meteorological and Oceanographic Education

At previous international conferences on school and popular meteorological and oceanographic education there have been ideas aplenty on how to excite interest in the atmosphere and the oceans. If you missed these events, you should consult *Weather Education* (Walker 1985) and the preprint volumes prepared for the second, third and fourth conferences (AMS 1989, 1993; RMS 1996). Meteorological and oceanographic education can certainly be fun.

The Fifth International Conference on School and Popular Meteorological and Oceanographic Education, called 'Education: Weather, Ocean, Climate' (EWOC99), will be held in Australia from 5 to 9 July 1999. Like its predecessors, this conference will focus upon the rôles of meteorology and physical oceanography in science education and the benefits to be gained from improving environmental awareness and literacy.

There will be particular reference to weather and ocean studies in primary and secondary schools, professional development programmes for teachers, use of the Internet in schools, and ways and means of explaining El Niño, ozone depletion and other environmental issues to children and the public.

The conference is intended primarily for teachers, educationists, meteorologists, oceanographers, equipment manufacturers and science communicators. The format of the conference will be mixed, with poster displays, workshops, oral presentations of papers and 'hands-on' demonstrations of equipment and teaching aids. A feature of the conference is that three venues will be used: the University of Ballarat on 5 and 6 July, the Bureau of Meteorology, Melbourne, on 7 July and the Glen Waverley Secondary College, Melbourne, on 8 and 9 July.

Summaries of papers and descriptions of demonstrations must be received by 30 November 1998. The official language of the conference is English. Summaries and descriptions must not exceed 500 words and authors should indicate the preferred format for presentation (oral, poster or workshop/demonstration). Those who wish to demonstrate equipment must provide details of special requirements. Authors will be notified of acceptance by 31 January 1999. A preprint volume will be prepared, for distribution at the conference. All correspondence should be addressed to: acceptance by 31 January 1999.

All correspondence should be addressed to:

DWOC99
Cooperative Research Centre for Southern Hemisphere Meteorology,
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Victoria 3168,
Australia

Abstracts may be sent by Email to ewoc99@vortex.shm.monash.edu.au in plain ASCII form or sent by Fax (+61-3-9905-9689). The address of the conference web site is http://www.shm.monash.edu.au/ewoc99.

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Book Reviews

Sea-Level Changes: The Last 20 000 Years by Paolo Antonio Pirazzoli (1996, reprinted 1998). John Wiley & Sons, 211pp. £24.95 (flexicover, ISBN 0-471-96913-3).

This is a nicely produced book which attempts a review of research into sea-level changes from the last glaciation to the present. The author, Paolo Pirazzoli is well known for his research into the geological record of sea-level change, author of the *World Atlas of Holocene Sea-Level Changes,* and leader of the International Geological Correlation Programme (IGCP) Project 200.

The book is said to be aimed at post-graduate students, young researchers and teachers in various branches of the Earth sciences. However, I would say that the standard is nearer to 'researcher' than 'student', as several of the middle chapters contain more research detail than one would expect in a student text. Also, in student material one expects a Glossary (how many students know what a 'phreatic level' is, or what 'foraminifera' are?) and the information has to be carefully ordered (here, by contrast, oxygen isotope ratios are first introduced on p.9 but one has to wait until p.64 for a partial explanation of what they are).

Chapter 1 consists of an interesting essay on the many causes of sea-level change. This would be useful for either students or researchers to read, although similar chapters can be found in other text books. However, it is from Chapter 2 onwards that Pirazzoli's personal style becomes evident. Anyone who has heard his conference presentations, based on fieldwork along many of the world's coastlines, and especially in the Mediterranean, will recognize the material of these middle chapters. In particular, this chapter (and the remainder of the book), make use of the author's extensive collection of photographs of palaeo-sea-level indicators, most of which he obtained himself. Chapter 2 is concerned with many different types of evidence for former sea-level stands (biological, geological, archaeological) and is probably the best chapter in the book.

Chapters 3 to 5 are concerned with particular geological epochs and are equally well illustrated. Chapter 3 discusses the 'Ice Age Earth' and covers O^{18} ratios and inferred sea-level changes since the last interglacial, fluctuations in sizes of ice caps, palaeo-shorelines, land bridges and the evidence for changes in North Atlantic climate. Chapter 4 focusses on 'Deglacial Sea Level Changes' with case-study examples from various areas indicating the construction of 'sea-level curves' from the usually dispersed evidence. The fact that the curves from the different case-study areas are not the same emphasizes the complexity of the geological evolution of the Earth and the 'non-eustatic' character of real sea-level change before and into the Holocene.

Chapter 5, concerned with changes in the late Holocene, again contains many case-studies, in particular from deltas and corals. Corals are mostly late Holocene, as present day reefs developed primarily as the rate of post-glacial sea-level rise was attenuated. Again, there are excellent demonstrations of how 'sea-level curves' are constructed for areas that are suitable for such computations. Several references are made to work in the UK, which is a rich source of palaeo-sea-level data. Then there is a section on areas subject to rapid vertical displacements of the coastline caused by seismic events (e.g. in the eastern Mediterranean). These areas are clearly less suitable for constructing 'sea-level curves'. This section is also particularly well illustrated.

One minor complaint: I would have preferred these middle chapters to have had more research conclusions, summarizing the overall status of the field and pointing to future priorities. Of course, case-studies are important as there are many different types of coastline and sea-level indicators, as Chapter 2 showed. However, a succession of case-studies, interesting as they are individually, needs some synthesis for the reader's benefit. Some of these strands are brought together in the Conclusions.

Chapter 6, on present day sea-level changes, is the one I liked least. It contains a review of the global tide gauge dataset (the Permanent Service for Mean Sea Level), its limitations, and the geological and oceanographic signals to be found in the records. Most of the discussion is based on publications by the author many years ago. For example, I do not think it is acceptable to show sea-level time-series which end in the late 1970s in a book published 20 years later. The chapter makes no mention of GLOSS (the Global Sea Level Observing System) and the section on 'land and ocean levelling' does not discuss the use of GPS and absolute gravity in any detail. These new technologies are now central to sea-level research. Mentions of altimetry are illustrated with plots from *Seasat,* and any student could learn more by surfing the many web pages of *TOPEX* information now available. The chapter concludes with an interesting section on areas at risk from a future sea-level rise.

In summary, it seems to me that the interests and considerable experience of the author are reflected primarily in the chapters presenting case-studies of geological evidence for former sea-levels around the world, while for a couple of the chapters the book would have benefitted from having a co-author. However, I can strongly recommend the book to anyone interested in long-term sea-level changes.

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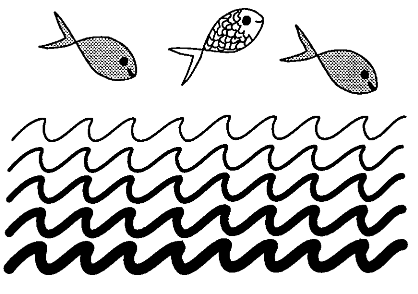

Molecular Approaches to the Study of the Ocean edited by Keith E. Cooksey (1998). Chapman & Hall, 549pp. £110 (hard cover, ISBN 0-412-72960-1)

Being a chemist, I was enthused by the title of the book, as I had a text in my hands that specifically dealt with molecules used to study the ocean. But after browsing through the contents, and reading the back cover, I realized that I had misinterpreted the title, probably because my background is not in biological sciences. As the editor quickly tells the reader in the foreword, the intent of this volume is to deal with organisms at the base of the marine food web, the area of study where molecular techniques originated. So, as such, this book is a good compilation of molecular technology.

What is this technology? The answer, basically, is: microbiological techniques. And which are the molecules the text primarily addresses? The editor refers to any chemical markers, that is organic components, whatever their molecular size, i.e. from lipids to proteins and nucleic acids. However, there is a strong bias towards the latter. The techniques described are not applied to the complete study of the ocean, but are used to address basic ecological questions: How many organisms are there? How can they be named? And what are they doing? Concerning these topics, I found the book very interesting, but I would have given it another title which more closely reflected its content, something on the lines of: 'Biomolecular techniques for studying marine organisms at a microbial and cellular level'.

This book is primarily about methods, and not a description of molecules in the oceans (no 'stamp-collecting'); nor is it about ways of understanding oceanic processes (e.g. carbon export to the sea-floor). Instead it deals with molecular methods for characterizing organisms and their activities, with an emphasis on the ecological implications of the results.

The book contains 27 chapters, written by one or more of the 55 contributors, each dealing with a specific topic, generally in the form of a review paper. I failed to see any logical and consistent distribution of the topics and the papers, probably because they are too diverse, although there is a progression in the size of organism under discussion, from virus to macroalgae, but finishing with biofilms, bacteria, toxins and databases. There are several papers on the applications of phylogenetics, and then molecular approaches to studying biomass, activity of marine organisms, and phytoplankton physiological status, virus ecology, fungi, phytoplankton growth; also immuno-assays, nitrogen fixation, copepod production, lipids in zooplankton, invertebrate development, growth and biodiversity, sponge cell cultures, cnidarian/algal associations, bio-films, microbial ecology, study of bacterial growth, marine toxins; and finally the use of databases in molecular ecology. Certainly a diverse melting pot, difficult to group in areas or parts.

So, this is certainly not a textbook, nor is there such a claim in the book. It often seemed to me more like a volume of conference proceedings, suitable for the initiated or even specialist. However, as an illustration of the power of some molecular biological techniques to aid the study of marine organisms, the volume offers a good and effective compilation of papers. The first chapters/papers in the volume also provide the best review of some of the methods, for example on the application of phylogenetics to marine phytoplankton, copepods, macroalgae, invertebrate and fungi (extended in later chapters, with some overlap). Anybody who wants to get to grips with this powerful technique will be well served by reading the book.

For me, one of the most complete papers in the volume, and one which justifies the title of the book, is a review of molecular approaches to microbial biomass estimation, and this I fully recommend. However, some of the chapters are disappointing from a molecular standpoint, and have little to offer in terms of molecular approaches not dealt with in other papers – for instance, in the chapters on marine virus ecology (a summary of research in this field) or sponge cell cultures, where the emphasis of the discussion is on how to establish culture media.

In my opinion, the most important topic left out of the book, although fitting with the aims of the editor, is a thorough description and discussion of the role and occurrence of lipids and photosynthetic pigments in marine organisms. The only contributions of substance which I found on this were papers on the 'Ecophysiology of lipids in pelagic crustacean zooplankton communities' (Chapter 16), and on the use of molecular biomarkers (i.e. ATP, chlorophyll-*a*, phospholipid phosphate and fatty acids, ergosterol, lypopolysaccharide, muramic acid and DNA) in biomass estimation (Chapter 16), which were fine in themselves. Unfortunately, I could find only scattered references in a few papers to lipid and pigment biomarkers for bacteria and phytoplankton. In fact, the reader is told in the chapter on 'Methods for the study of marine fungi' that 'the use of lipids in marine research has been discussed in detail in Chapters 2 and 16'. Not really. I am sure that the amount of research that is reported in the literature on these compound classes shows that they can also provide some good answers on the basic ecological questions posed by the editor in the foreword, beyond that presented in this volume, which amounts to very little.

I would recommend this volume to someone who wants a good introduction to the state-of-the-art application of molecular biological techniques to marine organisms. Before buying the book, I recommend reading the contents list in detail, as the diversity of the papers compiled may not justify its cost. But this is a personal opinion of course, and many people may be as interested in improving their knowledge about phytoplankton phylogenetic analysis and molluscan adhesive protein genes as they are in learning about modelling marine biofilms, and marine toxins, each topic occupying a chapter. If this applies to you, but you are not especially interested in marine lipids and pigments, then go ahead and get the book.

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Currents of Change: El Niño's Impact on Climate and Society by Michael H. Glantz (1996). Cambridge University Press, 194pp. £14.95 (flexicover, ISBN 0-521-57659-8).

Torrential rain and storm damage in America, droughts and epidemics in Indonesia, crop failures in Asia – scarcely an evening passes without news reports of various natural catastrophes wreaking havoc around the globe, all blamed on 'the weather phenomenon known as El Niño'. With the British media's interest in El Niño reaching an almost unprecedented level, there seems to be a need for a basic explanatory text that might explain to the general public what is happening. The dramatically titled *Currents of Change* aims to fill this niche; in the author's own words, he hopes '... to provide a user-friendly account of what El Niño is, what it does, and why we ... need to have more than a passing intermittent interest in it'. Worthy aims indeed, and ones which the book goes some way to achieving, though not without some hiccups along the way.

The book's moderate length and affordable price square nicely with its bid for the popular science shelves. It also benefits from putting as much emphasis on the social science aspects of El Niño as on the physical science. As Glantz points out in a number of places, considerable research effort has been put into understanding and trying to predict El Niño events, but comparatively little effort into determining how best to actually use the information. Most people have a vague understanding that 'forewarned is forearmed', but the book asserts that to actually gain significant tangible benefits requires considerable understanding of the way *societies* work as well as understanding of the way El Niño works.

The introduction is largely just a short summary of the rest of the book, presumably to serve as an appetiser for the reader. It is perhaps most noteworthy for its inclusion of an El Niño crossword, the rationale for which, apparently, is to persuade the reader to persevere with the book so that the answers can be extracted. I thought this a rather peculiar idea, with the inclusion of this additional incentive to read the book giving it the uncomfortable feel of a school textbook.

After the introduction, the book is divided into three main sections. The first of these, 'Emerging interest in El Niño', briefly covers the basics of what actually constitutes an El Niño event, and gives an interesting history of humanity's interest in such episodes, dating back to the 1800s when their adverse effects on guano bird populations were being felt in Peru. This section also describes the early days of interest in the Southern Oscillation, and Jacob Bjerknes' subsequent identification of the physical mechanisms linking it with El Niño. This is the section that will probably be of most interest to scientists already acquainted with El Niño, and those with an interest in the origins of scientific research. From a purely selfish point of view, I would have liked this section to have been greatly expanded with more detail included, but that would perhaps have been getting away from the original concept of the book.

The next section, 'The life and times of El Niño episodes', gives a solid and comprehensible description of the main physical mechanisms of El Niño. The author wisely steers away from more difficult concepts out of consideration for the readership; indeed he sounds almost apologetic when introducing the concepts of Rossby waves and Kelvin waves. The 1982–83 El Niño (an 'anomalous anomaly') is taken as a case study, and there is a discussion of the efforts made to forecast El Niño events and how their effects are felt around the world via teleconnections.

The final part of the book, 'Who cares about El Niño – and why', features an outline of modern research into El Niño, including an interesting section on the trend towards funding 'usable science'. It also contains a lengthy section by various leading lights in El Niño research, each of whom wrote a paragraph or two about their experiences and thoughts on their work. The contributions naturally vary widely in their success in interesting the reader.

The most insight to be gained from this section does not come from any single contributor, but from groups of them presenting conflicting ideas. In fact, the whole range of optimism and pessimism about El Niño research is represented here, from those who regard the development of an accurate prediction capability to be a *fait accompli*, to those who believe it is an unattainable goal. The inclusion of these short contributions is an unusual idea, and I'm not completely convinced it works – there are simply too many of these contributions (thirty-six in all), and the majority of them are too similar. Rather than including everything he was given, it would have been better for the author to have included just the most interesting points, and edited them down to just a few pages.

The diagrams are generally very clear, and add substantially to the text. The inclusion of photographs in addition to schematics is especially praiseworthy, since they are chosen well, and really bring home the point that El Niño is important as more than just an interesting scientific problem. There are, unfortunately, a few notable exceptions to this high standard. Figure 2.2 on p.20 is a whole-page world map, with just six arrows on it demonstrating the locations of, for example, Australia and the United States. All the relevant information is contained in the figure caption, which takes up the entire following page. It gets even more bizarre when the caption is repeated verbatim in the main text on pp.61–63. Also poor are Figures 7.4 to 7.7, a series of four maps illustrating the climatic impacts of the 1991–92 El Niño. Such a series of maps is no bad thing in principle; but the problem is that they come straight after each other, and take up a total of 14 pages, with the accompanying captions being up to three pages long. Whilst perhaps appropriate for a reference text written for other scientists, it's hard to imagine even a very interested non-scientist wading through all that.

My major criticism of the book is that it is rather poorly organized. Admittedly, and as the author himself confesses in the introduction, it is difficult to write a book covering the various different physical and societal aspects of El Niño without involving some repetition. Furthermore, with such interrelated topics it is not immediately obvious where best to start the description. Even allowing for this, the sections and subsections presented in the book are often too short, which serves to interrupt the flow rather than give it structure. Sections sometimes appear to have little relevance to the preceding ones, and the choice of what warrants a whole section is occasionally strange (for example, the various different uses of the word 'complex' gets a section to itself). This actually makes certain parts of the book quite difficult to read, a distinct flaw in a book which sets out to be user-friendly.

To sum up, this is a quite an interesting introduction to El Niño, though somewhat spoilt by a few disappointing aspects which a second edition (if such a thing should ever happen) would do well to address. Non-scientists and new undergraduates will find it reasonably rewarding, but scientists already familiar with El Niño should go straight to a weightier text.

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Meteorology Today: An introduction to Weather, Climate and the Environment (5th edn) by C. Donald Ahrens, Fifth Edition, West Publishing Company, 591pp. £21.50 (hard cover, ISBN 0-314-02779-3).

The declared target audience of this American textbook is 'college-level students taking an introductory course on the atmospheric environment ...' and its main aim is 'to convey meteorological concepts in a visual and practical manner, while simultaneously providing students with a comprehensive background in basic meteorology'. It requires no special scientific prerequisites.

For me, the book started off well when I read that the publisher prints 70% of its college books on recycled, acid-free paper – thoroughly appropriate for a text that is set to explain all about the atmospheric environment.

I enjoyed reading this book – a great deal of careful work has gone into its completion, particularly with the wealth of good, clear colour diagrams and photographs; in fact, all the illustrations are in colour. Each of the nineteen chapters is written to be self-contained and includes at least two 'focus' sections within which an item of particular interest is explained in more detail. In the 'Precipitation' chapter, for example, these focus sections are entitled: 'Does cloud seeding enhance precipitation?', 'Are raindrops tear-shaped?', 'When is it too warm to snow?', 'Sounds of silence' and 'Aircraft icing'. At the end of each chapter there is a summary, a list of key terms (which the student is expected to define as an act of revision), questions for review, questions for thought, and problems and exercises. The questions and problem/exercise sections are well thought through and typically contain a dozen to twenty questions and three to six problems/exercises respectively.

For those who like to get dynamical/physical in a small way, there are thoroughly worked examples of how to calculate the magnitude of the geostrophic wind and how to use the hydrostatic balance to estimate the pressure depth of a layer. These are useful illustrations for non-specialist students who may be averse to the use of any mathematical expressions.

The text covers the whole range of meteorological science and tackles modern issues of global consequence succinctly. Global warming is covered, as is artificial ozone depletion and ENSO – although the book was of course published before the most recent dramatic example of the latter. The case studies are North American, but there is no harm in that for European students – tutors can always add local examples anyway. So far as ocean people go, there is a small section on atmosphere–ocean interaction that briefly covers wind-driven surface currents, upwelling, surface ocean temperatures and, as mentioned above, ENSO.

The book contains a number of appendices ranging from temperature conversions to weather-map plotting conventions, and from humidity tables to worldwide mean monthly data – it even includes a hurricane-tracking chart. This may be useful for those UK readers planning visits to the Florida Disneyworld!

On a serious note, I recommend this book for those involved in teaching a University introductory course in weather and climate – in the UK (or anywhere). My impression is that it will satisfy the needs of students majoring in Ocean Science or in Geography who want a broad, mainly qualitative knowledge of modern meteorology. Ahrens' book should persuade undergraduates that the atmosphere and its phenomena really are in themselves interesting and exciting. With, it seems, physical science slipping down the popularity ratings year by year, I applaud any text that successfully shows students the value of science in understanding what makes this aspect of the natural world 'tick'.

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But where have all the oceans gone?

Physical Oceanography by Alan Strahler and Arthur Strahler (1997). John Wiley & Sons Ltd. 638pp. £23.95 (hardback, ISBN 0-471-111299-2).

For something like three decades the name of Strahler has been one to conjure with in the field of physical geography – Arthur N. Strahler's textbooks have been classics of their kind. For students of the marine sciences they have always been mines of useful information and explanation about atmosphere and climate.

In this new work Arthur Strahler is joined by his son (or so I must presume, for even the biographical notes 'About the authors' do not tell us!), and the coverage is expanded and up-dated and much more spectacularly colourful, with an easier-to-read typeface.

The book is subtitled 'Science and Systems of the Human Environment', and reflects the Strahlers' attempts to reach more non-scientists and tell them about how the world works and about the ways in which humans can (and do) damage it.

As Mike McCulloch wrote in his review of Neil Wells' book, *The Atmosphere and Ocean* (*Ocean Challenge*, Vol. 8, No.1, pp.44–5) we are adjured to regard the oceans and atmosphere as a single system when it comes to discussions of the factors controlling climate and climate change, but old habits die hard, and most of us still tend to treat them separately. The Strahlers are no exception, and the oceans get distinctly short shrift in this book.

Much of the first half (250-odd pages) is devoted almost entirely to classical Strahlerian descriptions and explanations of weather and climate, in which the oceans figure somewhat marginally, in the contexts of the hydrological cycle and global surface heat transport. Three full chapters of this part are devoted to a detailed description and classification of climate types – did you know there are *thirteen* climate types? The rest of the book is mainly about geology and especially geomorphology (the development of landforms, including coastal ones) There's also a quite detailed discussion of soil classification, which leads into two final chapters on biogeochemical cycles and global ecosystems – in which the oceans do figure, since it is hard to see how they could be left out!

As the now almost obligatory systems approach is adopted throughout the book, purists might well argue that virtual omission of the oceans cannot allow complete descriptions of global climate systems. I believe that for students at this level the balance of the book is awry: there should be a bit less on detailed classifcation of (mainly terrestrial) climate types, more on how the oceans work.

In this context it is interesting to note the omission of some physical concepts and principles that were in earlier Strahler books. Two examples will suffice: first, the Coriolis effect is here explained using that hoary old rocket fired at the North Pole (which doesn't explain how zonal flows are deflected equatorwards), whereas in earlier editions it was explained using the 'Earth-tracks' of satellite orbits – which is more difficult to understand but more reliable. Second, there is nothing about tides at all, whereas early Strahler works gave a fair account of tide-generating forces. It was interesting, too, to recognize several illustrations from the earlier editions, albeit now in glorious full-colour, but otherwise not altered at all. It is all a reminder that the basic principles don't change – though the omission of some shows that our perceptions of their relative importance plainly does change.

Perhaps I'm being a bit curmudgeonly. OK, so the book goes a bit over the top in places, but it is written by geographers for geographers, and oceanography isn't a compulsory subject – not yet, anyway. It is, to be sure, a handsomely presented work and there are a number of good educational features.

For the non-scientists each chapter has a number of boxes headed 'Focus on Systems', in which topics such as atmospheric convection, climate feedbacks, glaciers, and energy budgets, are briefly discussed, chiefly to illustrate the importance of cycles and the effects of perturbations upon them. For the weakly numerate there are other boxes headed 'Working It Out', which give guidance on quantitative aspects of the subjects under discussion. There are numerical problems at the end of each chapter, enabling students to apply their understanding of these boxes. Alas, I'm not totally convinced of the efficacy of this approach, especially as (i) the questions are necessarily several pages away from the related boxes; and (ii) the explanations in some of those 'quantitative' boxes are not as clear as they might be. On the positive side, however, answers to these problems *are* provided at the end of the book.

There are also (of course) more discursive end-of-chapter questions, for which suggested answers are (as usual, alas) not provided. Instead there are lists of key terms (with Glossary), appendices on maps, information systems, and soils. There is also a vast array of supplementary materials: Exercise Manual, Student's Companion, Instructor's Manual and Test Bank, Test Bank ASCI Files for Mac and Windows, Full-Color Overhead Transparencies, Full-Color Slides; and finally readers are invited to visit Wiley's website at: ftp://ftp.wiley.com/public/college/geography

It is a worthy attempt to communicate the inter-relationships of the Earth's systems to students with little formal background in science, not least because there are also sections headed 'Eye on the Environment', which relates the subject matter of the book to peoples' daily lives, touching on issues such as pollution, global warming and El Niño (the oceans again!), in which the notion that ENSO events could be caused by sea-floor volcanism is mentioned – but you read it here first! (*Ocean Challenge*, Vol. 8, No.1, p.10).

This will be a useful book for teachers trapped by the National Curriculum into sticking to a geography syllabus which does admit of some meteorology and geology – *but see the next review before making up your mind whether to obtain it.* It may even be more student-friendly than other texts, judging from the blandishments of the Student to Student open letter at the front of the book, telling you how wonderful it is – yes, really, it is from a self-proclaimed 'science-skeptic (*sic*) phobic' who was apparently invited to 'test-drive' the book, by reviewing chapters during production But alas, the book has no place for marine science as such, so if you seek an introductory text for oceanography, go elsewhere.

Introducing Physical Geography by Alan Strahler and Arthur Strahler (1996). John Wiley & Sons Ltd, 565 pp. £25.95 (flexicover, ISBN 0-471-113569-0).

Well, I dunno. This is effectively the book I just reviewed above, cut down a bit for students at a slightly lower level or taking a shorter course in the subject. Virtually all of the illustrations in this book can be found in the larger work (the reverse is not true however). And it is in paperback, so how come it costs *more*?

It is sub-titled *Environmental Update*, and retains only the 'Eye on the Environment' boxes of the larger work. Instead there are chattily jolly introductions to each chapter ('What Is This Chapter All About?'), which purport to drive home the relevance of the subject matter to the reader. I'm not convinced they are wholly successful. On the plus side, however, there is a collection of reprints at the back of the book, under the heading 'Science News'. It's simply a collection of articles from recent issues of the journal of that name, but it makes interesting reading. Could copyright costs for such extracts have put up the price? It seems unlikely. Such extracts date rather quickly, however, and this, together with the paper binding and the word 'update' in the sub-title, incline me to suggest that prospective buyers might consider waiting for the next (millenial?) edition – except of course that the format and content will be much the same, since (as I remarked above) the basic principles don't change.

Even though this version costs a fraction more than the larger one, it may be a better investment for teachers – but not, I repeat, if your students want to find out about marine science.

Stop Press: We have just learned from the publishers that this volume is out of print as at Feb. 1998. See, I was right to suggest waiting for the next edition!

Earth Science (8th edn) by Edward J. Tarbuck and Frederick K. Lutgens (1997) Prentice-Hall, 638 pp. £25.50 (hardback, ISBN 0-13-570839-7).

This is a standard text with a difference. If you don't adopt the 'now obligatory systems approach' (see previous reviews) to teaching earth sciences, then you use 'a relatively nonintegrated format to allow maximum flexibility for the instructor'. The four parts to this book (Solid Earth, Oceans, Atmosphere, and Astronomy) are written as 'stand-alone' units, so that they can be taught in any order, and one or more units can be omitted 'without appreciable loss of continuity'. It is a pragmatic approach to teaching such a wide-ranging topic, but it does sit oddly with the opening discussion about the Earth as a system in which 'A change in any one part can produce changes in any or all of the other parts'. If you then treat the different components of the system independently, it becomes more difficult to show how change in one part affects other parts. The authors of this book get round that with several dozen 'Special Interest' boxes (e.g. sea-level rise, ozone holes, air pollution, earthquakes, tsunamis, floods, landslides), to demonstrate interactions between different parts of the Earth system. Amazingly enough, though, there's no mention of El Niño!

The Oceans get a bit more coverage than in Strahler and Strahler but it's still not a lot: two chapters (about 50 pages) out of the total of 22 chapters. The Atmosphere gets five (about 130 pages), while the Solid Earth occupies almost all of the first half of the book (over 300 pages). The remainder is about the rest of the Solar System and our place in the Universe. There are (of course) appendices, a glossary, and end-of-chapter questions (without answers), and there's also an array of supplementary and supporting materials, Study Guide, Tests, Transparencies, Web site, just as with the Strahler and Strahler books (but if anything bigger and more varied).

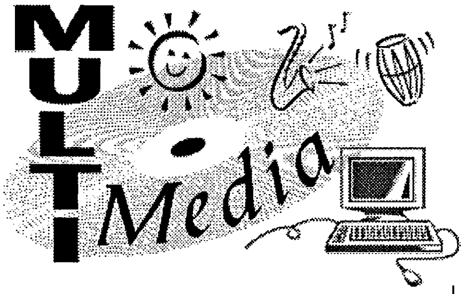
Despite its rather compartmentalized approach, this is yet another 'nontechnical survey for undergraduate students with little background in science, who are taking an earth science course to meet a portion of their university's general requirements'. The illustrator (Dennis Tasa) has his name on the flyleaf, and I have to say that while the pictures in Strahler and Strahler are good, the ones in this book are better. It is indeed most attractively illustrated – which has the subliminal effect of increasing your desire to read it.

I have to confess that I was also drawn to this book by a statement from the authors that for their eighth edition they 'have improved readability by reducing sentence and paragraph length, omitting unncecessary details, examining chapter organisation and flow and writing in a more personal style.'

All the same, making science more accessible carries with it the requirement that the science be reliable. Readers of this book will come away with the notion that ocean currents are 'rivers in the sea', a concept that even I abandoned some 20 years ago (and I'm a late developer). What is more, marine chemists will not be pleased to learn that the seawater solution contains salts like sodium sulphate and fluoride, and calcium and strontium chloride. So far as I know, those are not produced when seawater is evaporated. Moreover I have been ear-bashed for years by a colleague telling me that 'seawater contains dissolved ions, not dissolved salts'.

Finally, then, like the Strahler and Strahler books, this one could also be useful for science teaching within the National Curriculum. Indeed it might even be *more* useful, because it provides greater opportunities to 'pick-and-mix' topics and to use your own initiative in relating them to other parts of the Earth system.

John Wright



Earth on Line: An Internet Guide for Earth Science by Michael E. Ritter (1997) International Thomson Publishing, £12.95 (ISBN 0-534-517072).

I was very impressed with the simplicity of this book, in the way that it has set out to demystify some of the complex jargon surrounding computers and computing. This type of book is liable to use so many unfamiliar terms that it becomes unintelligible and therefore unuseable, which is most certainly *not* the case here.

However, we do have to remember that *Earth on Line* is an American book, and as such it caters for an American audience, which is notoriously parochial in its outlook. There are some pointers to European/British pages, but they are quite few and far between; because of this it may very well have a limited application in this country.

Generally, it sets out by showing the reader how to use the Internet from very first principles – always assuming that you know your way round a computer. It even goes into how to use the electronic mail systems.

By far the most useful chapters were those about searching for Internet resources and the 'Educational and Professional' activities. All the addresses of the American universities are there, but it isn't until Chapter 10 that other useful sites such as NASA, the National Climatic Data Center, and the Global Climate Perspectives System (GCPS) Climatological Products appear. This chapter has about fifteen pages of useful Earth Science addresses, which are subdivided into topics such as Astronomy, Climatology, Earth Science education, Earthquakes and Seismicity, Vulcanology and Oceanography.

In summary, this book could be useful, as long as it is used selectively, and the American bias is allowed for.

Polly Rhodes
Open University
Geological Society

Forthcoming Events

Events in 1998 The Year of the Ocean

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

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

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

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

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

Technology for deep sea geological investigations: developments, applications and results (Joint meeting of the Marine Studies Group of the Geological Society and the SUT Ocean Resources Committee). 11–12 November, Geological Society, Burlington House, Piccadilly, London. The meeting will cover topics that relate to the development and use of technology for geological investigations in deep water. Subjects to be covered include sea-floor sampling and drilling, ODP drilling advances, sampling of hydrothermal waters, seabed imaging and seismic methods. The programme will be posted on the MSG Web page at the end of August: http://www.geolsoc.org.uk/msg/msgindex.htm Those wishing to attend are asked to notify the convenors by October. The registration fee, to be paid on arrival, will be £10 per day (£5 for Geological Society Fellows, SUT members and students). *Contact* Dan Evans, British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA; Tel. 0131 667 1000; Fax: 0131 668 4140; Email: dan.evans@bgs.ac.uk *or* Keith Harrison, BRIDGE Programme Manager, School of Earth Sciences, University of Leeds, Leeds LS2 9JT; Tel. 0113-2335241; Fax: 0113 2335259; Email: BRIDGE@earth.leeds.ac.uk

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

Events in 1999

Oceanography – Satellites in Action 14 January, 6.15 p.m. Lecture by Trevor Guymer at London Heathrow Airport, for the Royal Aeronautical Society.

Coastal Management for Sustainability: Review of 1998 and Future Trends 19–21 January, University of London, Russell Sq., London. The conference will provide a briefing on a wide range of topical marine and coastal environmental issues, included integrated coastal management, marine nature conservation (biodiversity, pollution, fisheries). Practical application of sustainability in the coastal environment, including risk indicators, risk assesment, management systems and assessment will feature prominently. Fee £65. *Contact* Bob Earll, Tel. 01531-890415.

Knowledge and Information for the Coastal Zone Feb./March, Noordwijk, The Netherlands. Coastal planners and managers need pertinent and readily available information. Plenary and workshop sessions will be used to examine the stages of information transfer from data-acquisition to the provision of expert advice, drawing on experience from different parts of Europe. *For more information contact* Linda Bridge, European Union for Coastal Conservation-UK, 6668 AP Randwijk, The Netherlands. Fax: +31-488-491252; Email linda@bart.nl

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

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

Education: Weather, Ocean, Climate (EWOC99) (Fifth International Conference on School and Popular Meteorological and Oceanographic Education) 5–9 July, Australia. For details see p.56.

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

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

MEMBERSHIP SUBSCRIPTIONS

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

ADVICE TO AUTHORS

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

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