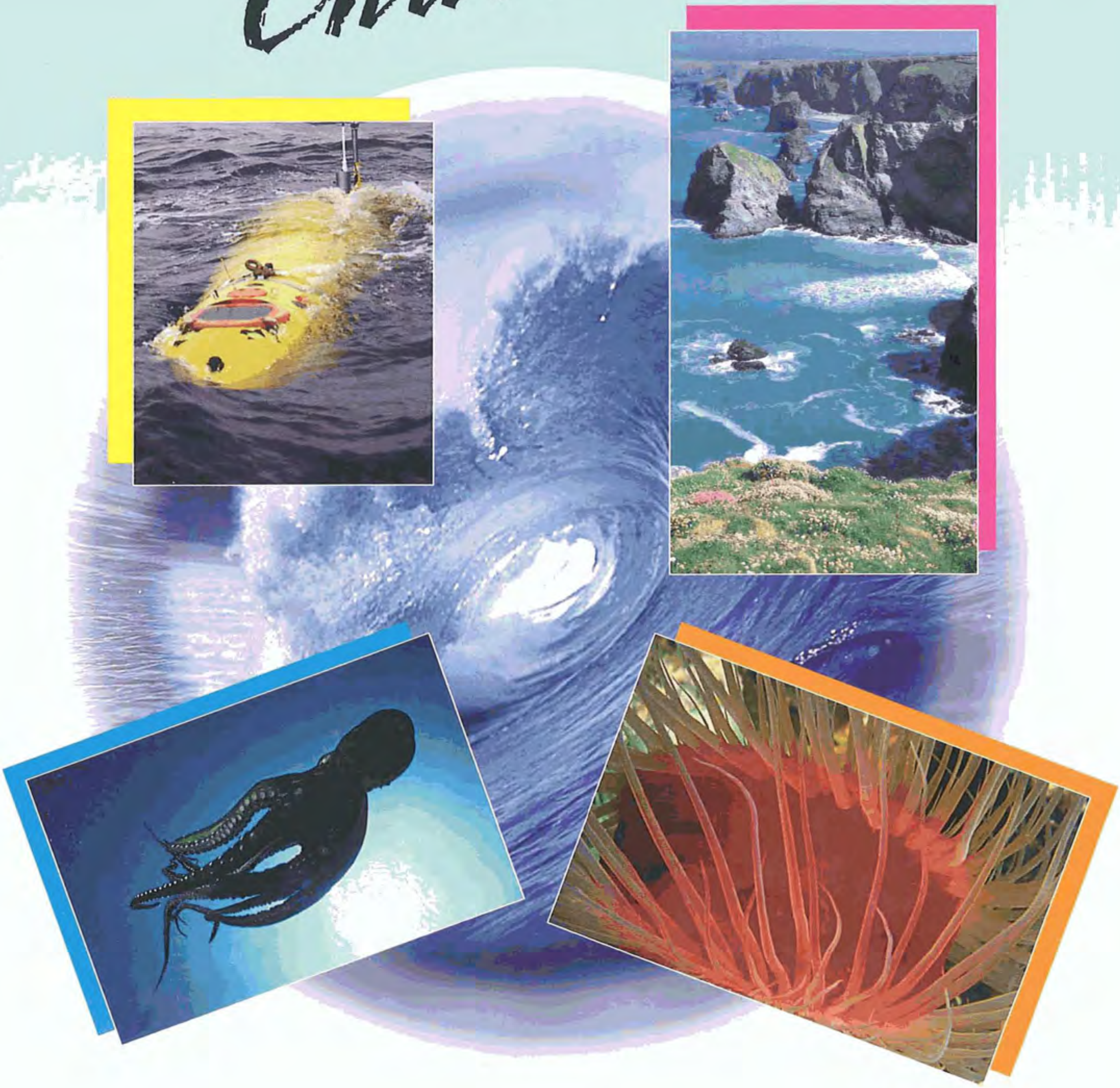
OCEAN Challenge



Volume 12, No. 2

The Challenger Society for Marine Science

Volume 12, No. 2, 2002
(published 2003)

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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

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Ocean Challenge is published three times a year. The subscription (including postage by surface mail) is £80.00 ($US 152) 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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Cover printed by Albanian Press, St Albans.
Text printed by Halstan & Co. Ltd, Amersham.

ISSN 0959-0161

CONTENTS

The cover was designed by Ann Aldred Associates.

The maps and illustrations were drawn by John Taylor of the Cartography Office of the Department of Earth Sciences at the Open University.

Message from the Editor

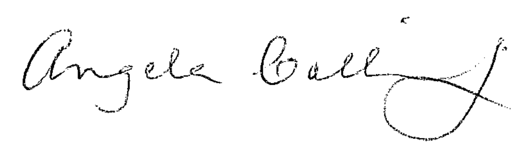
Dear Reader

We hope you will enjoy this issue of *Ocean Challenge.*

Amongst the news items is an interesting follow-up to one of the articles in the Special European issue, 'Ocean sequestration of CO_2' by Helge Drange and colleagues. There are also reports and impressions from both the Challenger Centenary Conference, and the first scientific conference of the European Federation of Marine Science and Technology Societies (EFMS), held in Athens in late September. Along with these reports is discussion of changes affecting the Challenger Society – the developing role of the EFMS, and interest by IMarEST (Institute for Marine Engineering, Science and Technology) in closer links with the Challenger Society. Do please let us have your views on these issues.

The two feature articles are very different from one another. The first is an overview of current developments in an area of science that is become increasingly important – marine biotechnology. The second is an account of the early days of wave research, during the Second World War, by someone who actually played a crucial role in that work.

Happy reading!



News & Views

The hydrogen economy

Does the answer lie in the rocks?

'Hydrogen in Earth's crust an endless fuel supply' ran the headline. It seems that bacteria in the deep biosphere, kilometres below the land surface and sea-bed, use hydrogen as an energy source to convert carbon dioxide to methane and other organic compounds. The hydrogen is reported to 'come from water molecules trapped inside molten rock, which break down to produce hydrogen', and some types of rock may contain 'as much as 1000 litres per cubic metre' – which seems rather high, since a cubic metre is 1000 litres.

In the late 1970s it was proposed that hydrogen can form by dissociation of seawater circulating in hydrothermal systems at ocean ridges (hydrothermal vents had not yet been found at this time), and that it might be tapped as an energy source (cf. *Ocean Challenge*, Vol. 9, No.1, p.16). The geothermal gradient ensures that rocks deep in the crust will be at high temperatures, possibly high enough to dissociate water and release the hydrogen – which the bacteria can then use.

Hydrogen at 'Lost City' vents

The recently discovered 'Lost City' vents are a much more likely source of 'crustal hydrogen'. Chimneys and mounds of calcium carbonate were recently discovered in an off-axis setting some 15 km west of the Mid-Atlantic Ridge (*Nature,* **412**, pp.127–8, 145–9). The carbonate is precipitated from highly alkaline (pH > 9) but relatively low-temperature (40–75 °C) vent waters that also have high concentrations (>200 μmol kg^{-1}) of hydrogen and methane. Where fracture zones permit access to deeper oceanic crustal layers, hydrothermal fluids circulate through mantle peridotite, transforming it to serpentinite and leaching calcium, which is then precipitated as carbonate on contact with ambient seawater. The origin of the hydrogen and methane is less clear, however, although thermophilic bacterial is an obvious possibility.

Pros and cons

A strong advocate of the hydrogen economy is Jeremy Rifkin, whose book and articles on the subject encapsulate his belief that 'hydrogen will make oil companies obsolete and let people generate all their own energy'. The biggest selling point of the hydrogen economy is that the by-product is water rather than carbon dioxide. That's fine if the water is liquid – as it is when hydrogen is 'burned' in fuel cells – but what of hydrogen burned in motor vehicle or aircraft engines, whence it would escape as water vapour? Does Rifkin know that water vapour is also a greenhouse gas?

The fuel for the hydrogen economy would normally come from electrolysis of water using renewable energy supplied by Sun, wind, waves and the like. The logistics and cost of tapping the hydrogen at vents like 'Lost City' must surely be prohibitive. But if there really is hydrogen available for use by bacteria in the deep biosphere, is it also possible that there could be 'hydrogen fields' analagous/similar to natural gas fields, where hydrogen is trapped by impermeable sedimentary layers, having migrated up along cracks and fissures from 'hot rock sources' deeper in the crust? If any such reservoirs have been discovered, they have not been publicised, and the hydrogen would probably be mixed with natural gas anyway. Separating the two would be neither simple nor cheap – but burning both would produce two greenhouse gases!

Nitrate on the rocks

A significant proportion of the nitrate transported to the sea in rivers is probably derived from weathering of bedrock, not – as commonly supposed – from anthropogenic sources such as industrial emissions, fertilizer runoff, sewage and so on (*Nature*, **385** (1998) pp.785–8). The principal bedrock sources are sediments (as well as metamorphosed sediments), which is not altogether surprising, since most sediments are of marine origin and therefore likely to contain organic matter. Rock weathering combined with the decomposition of organic matter and production of nitrogen oxides in the atmosphere by lightning, must presumably have kept the oceans well supplied with nitrate before humans came along.

On the early Earth, however, with an oxygen-poor or oxygen-free atmosphere, fixed nitrogen recycled from organic matter and from sediments might perhaps have been in the form of ammonia or even of hydrogen cyanide (HCN) rather than nitrate. In conditions of low or zero oxygen, oxidation of atmospheric nitrogen by lightning discharges is likely to have proceeded via liberation of oxygen from carbon dioxide and water vapour. The scientists who developed this scenario (*Nature*, **412** (2001). pp.26–7 and 61–4) have suggested that the decline of atmospheric CO_2 concentrations through silicate rock weathering and sequestration in carbonates (cf. *Ocean Challenge*, Vol.11, No.1, p.14) occurred before atmospheric oxygen concentrations had increased enough to provide the oxidizing environment needed for direct formation of nitrogen oxides by lightning discharges. Biological fixation of molecular nitrogen (N_2) might not have evolved until around 2 billion years ago. This is strange, because there are abundant cyanobacteria-like fossils in ancient rocks, and it is well known that cyanobacteria can fix atmospheric N_2 directly, and do not depend on nitrate or ammonia.

Oil on the Costa del Muerte

In November last, high-sulphur fuel oil from the sunken Gibraltar-bound tanker *Prestige* contaminated some 300 kilometres of the scenic rocky coastline of Galicia in north-western Spain, oiling thousands of seabirds, closing down local fish and shellfish industries, and keeping tourists away. The 70 000 tonne cargo was about twice that aboard the *Exxon Valdez* which came to grief in Alaska in 1989. Even in temperate latitudes, fuel oil – which has been refined – breaks down less readily than unrefined crude oil. There was also fuel oil aboard the *Erika* which ran aground off Brittany in 1999.

The Bahamas-registered *Prestige* was a single-hulled tanker of the type that can more readily break up – especially in heavy seas – than ships of double-hull construction. It seems, however, that neither the ship's owners nor the Swiss-based consortium that owns (owned?) the oil are legally responsible for this disaster, and nor are they liable for helping defray the cost of clean-up operations, let alone for compensating local communities that have been deprived of their livelihood.

In fact the disaster need not have happened, had the Spanish (and Portuguese) authorities not refused to allow the *Prestige* a safe haven, where the oil could have been offloaded. Instead, they insisted the tanker be towed west into deep Atlantic waters, where winter storms virtually guaranteed that she would break up and sink, releasing the cargo of fuel oil.

Following this disaster, in early December the EU issued an order banning single-hulled tankers from ports and coastal waters of member states. That can at best be a partial solution to the problem, for such vessels can presumably still navigate through EEZs *en route* to destinations outside Europe – what happens if an accident happens just outside the 12-mile territorial limit of an EU member state? And with eastwards expansion of the EU, will new members enforce the ban as rigorously as they should?

Dolphin-friendly seabass?

Between the beginning of December and the end of March, 104 dolphins were washed up along the south coast of Britain, and several times this number were washed up along the French coast in the Bay of Biscay. These strandings, which occur to some extent every year, are being blamed on pelagic pair-trawling (in which a trawl net is stretched between two vessels) for seabass and mackerel. There is compelling evidence for this. In 2001, observers on UK pair-trawlers in the winter seabass fishery, recorded a catch of 53 dolphins in 116 hauls. Furthermore, a study for the EU by the Irish Sea Fisheries Board showed that in a single season, four pairs of trawlers killed 145 dolphins – but nevertheless concluded that pair-trawling was a viable alternative to drift-netting. Yet more evidence is provided by the carcases of the dolphins themselves, which show marks made by fishing nets, as well as mutilations intended to make them sink rather than get washed up. This must mean that the number of dolphins actually killed is considerably more than the number quoted above.

Pair-trawling, which is used mainly by French vessels, but also by a few Scottish and English boats, has become more common since the EU completely banned drift-netting on 1 January, because of the enormous by-catch – including seabirds, seals and turtles, as well as dolphins. The by-catch from pelagic pair-trawling has not so far been studied.

Britain's Fisheries Minister, Elliott Morley, has stated that plans to stem the growing number of dolphin deaths will be revealed shortly. However, the Whale and Dolphin Conservation Society, which has repeatedly called for urgent action, comments sadly that such plans have been promised since 1999.

A spokesman from Britain's Department of Environment Food and Rural Affairs (DEFRA) has stated that 'The way to protect dolphins is through a European agreement.' If EFMS member societies are going to play a role in advising and lobbying governments about issues such as pollution, overfishing, loss of biodiversity, coastal degradation and so on, this might be a suitable problem to address. Why should Greenpeace, WWF and other conservation-oriented NGOs make all the running? (See p.16 for discussion of the role of the EFMS.)

The Whale and Dolphin Conservation Society website is: http://wdcs.org

North Sea White Fish Crisis

Cod stocks in the North Sea seem likely to go the way of those off Newfoundland a decade ago. In mid-October, the EU decreed that cod-fishing grounds in the North and Irish Seas should be closed, along with those in waters west of Scotland (cf. p.13)

In mid-November, haddock and whiting were included in the ban, which had now become partial rather than complete, with quotas reduced to about 50% rather than to zero. It was claimed that this compromise would doom the fishing industry just as effectively as would complete closure of the fishing grounds. Announcing the compromise, the EU's Fisheries Minister (Franz Fischler) expressed great sympathy for fishing communities, while his British counterpart (Elliott Morley) claimed that the scientific data on fish stocks must be 'carefully evaluated' before policy decisions could be reached – so there wouldn't be a complete ban just yet. But fish stocks are unlikely to recover if quotas aren't reduced to zero – i.e. unless fishing grounds are completely closed. There is bound to be some by-catch of immature cod (not to mention haddock and/or whiting), since industrial fishing will continue – as it must to sustain aquaculture industries. The by-catch will be dead on arrival, the immature fish will not survive to mature and breed, and then what ...? The decline in cod stocks due to overfishing is compounded by gradually rising sea temperatures round Britain, which can lead to reduced recruitment (cf. *Nature*, **404**, p.140), partly because of northward migration of zooplankton species that are the staple food of fish such as cod (*Ocean Challenge*, Vol.11, No.2, p.15).

An obvious solution to the shortage of wild stocks is cod farming, which is well advanced in Norway, where supplies are forecast to reach 400 000 tonnes in a couple of years. Misgivings about the project centre around food and wastes. The cod fry must be fed live phytoplankton and small zooplankton, which have to be produced locally, and live food must continue to be provided as the fish grow – because unlike farmed salmon, they won't eat fish meal. Then there is discharge of nutrients and potentially toxic wastes, while some fish may escape and transfer parasites and diseases to such wild stocks as remain. But cod farming will continue, if only because there aren't enough wild stocks left.

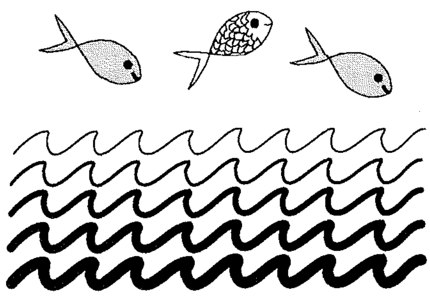
Fisheries Farce at Jo'burg

At the so-called Sustainable Development Summit, 189 nations signed up to an agreement to protect global fish stocks and enable them to recover by 2015. A key feature of the agreement was to stop illegal 'pirate' fishing by vessels flying flags of convenience (i.e. of countries without fleets of their own, e.g. Liberia, Panama), and to set up Marine Protected Areas (MPAs) as nurseries for young fish.

There is little chance of 'pirate' fishing being stopped. Despite a possibly imminent ban on cod fishing in some northern seas, EU countries continue to subsidise their already huge fishing fleets and to renew deals with West African countries (using £100s of millions of our money as taxpayers), so that their fishing boats can continue (over)fishing in the EEZs of Senegal and Mauritania. They use factory ships like the *Atlantic Dawn*, which is owned by Ireland (*Ocean Challenge*, Vol.11, No.2, p.3; Vol.11, No.3, p.2) but is flying a Panamanian flag and fishing off Mauritania under a 'private agreement'. There's over-fishing in the Mediterranean too, where, for example, trawling off the coast of Sicily was banned in 1989, so that stocks could recover. In fact, recovery seems to have been confined to smaller fish, with only negligible growth in size and stocks of commercially valuable larger fish such as Mediterranean hake and red mullet (*New Scientist*, 19 Oct., p.18).

As observed previously in these columns (*Ocean Challenge*, Vol.11, No.2, p.9), setting up MPAs on the high seas requires international agreements, which are extremely difficult to negotiate. As for MPAs established within EEZs of individual countries, the difficulty is to police them, especially since countries where rich fishing grounds remain are mostly in the underdevoped world, and cannot affort the necessary naval forces.

Local or regional fishing bans notwithstanding, overfishing will continue as it has done for the last decade and more. The lesson of Newfoundland's cod stocks is not likely to be heeded. The need for jobs, coupled with human avarice, may well ensure that within decades there will be no more commercial ocean fishing – and the drastic decline in fish stocks can hardly fail to be accompanied by adverse effects on marine food webs and biodiversity. Mariculture would then provide humanity's only source of protein from the sea. Prices will rise as demand for fish goes up, and the impact is most likely to be felt in those developing countries where fish provide an important part of the staple diet (cf. *Science*, 8 Nov. 2002, p.1154).



CO_2 sequestration experiment blocked

Lars Golmen

In August 2002, a research project involving the experimental release in the ocean of 5 tonnes of pure CO_2 was blocked by the Norwegian Ministry of Environment. The Norwegian State Pollution Control Authority (SFT) had already issued the experiment permit to the Norwegian Institute for Water Research (NIVA) and its international partners. At the time of the decision, which followed protests from two environmental groups, the international team, consisting of research institutions in Japan, USA, Canada and Norway, were ready to go to sea and conduct the experiment.

The environmentalists claim that the experiment may pave the way for future implementation of CO_2 ocean sequestration (storage) on a large scale, which may facilitate the continued use of fossil fuels. They are against this, and so argue the experiment should not be performed at all. (As it is at such a small scale, the experiment itself and the predicted environmental impacts thereof, were not real issues of concern among the protesters.)

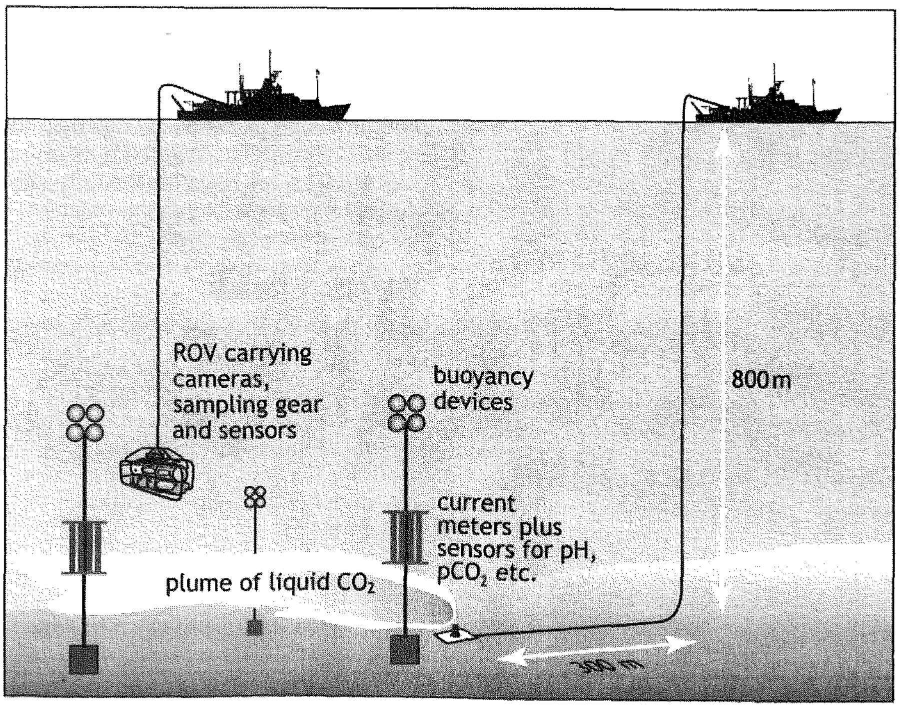
In response to the protests, the Ministry of Environment has stated that CO_2 ocean sequestration should first be thoroughly discussed internationally and the legal implications, including relations to the 1992 OSPAR convention, be clarified, before any permit to do experiments in Norwegian waters can be reissued. The Ministry is waiting for an evaluation by the OSPAR Commission's legal group, which is scheduled to meet in June 2003.

Numerous feasibility studies over the last 10–15 years have shown that ocean sequestration of CO_2 captured from powerplants etc. may have huge potential to reduce the greenhouse effect and thus mitigate climatic changes (see article by Helge Drange *et al.*, *Ocean Challenge*, Vol. 12, No.1). The method is an alternative to, for example, geological and terrestrial storage (forests, soil) of CO_2. The ocean already holds about 40 000 GtC, compared for example to the annual anthropogenic carbon emissions of about 6–7GtC. The residence times of the deep waters of the ocean are several hundred years, so sequestering the CO_2 in the deep ocean should ensure that the CO_2 will stay away from the atmosphere for an equally long period.

The experiment was the main part of a project initiated at Kyoto in 1997, as an agreement under the Climate Technology Initiative to undertake ocean sequestration trials. The project involves experimental *in situ* work to study near-field distribution and dispersion of a CO_2 plume emerging at about 800 m depth, where liquid CO_2 would be emitted from a nozzle assembly (see figure below). Results from the experiment would be available to all participating institutes for evaluation and publication, and for further use to calibrate/upgrade numerical plume models and to prepare for follow-up experiments. The experiment would also shed light on issues related to potential future leakage of CO_2 from storage under the sea bed, which is an alternative method.

The design of the proposed CO_2 sequestration experiment

(from *Environmental Assessment Report, Ocean sequestration of CO_2 field experiment, Rep.1336, USDOE-NETL, March 2001*)



The reason for selecting Norway for the experiment was that Norway has a large pool of suitable heavy-duty vessels and ample equipment/logistics, and there is abundant offshore/marine theoretical and engineering expertise in this and related fields. Additionally, the 'Deep Spill' experiment,* successfully performed in 2000, with releases of natural gas offshore Norway at 800 m water depth, had significant similarities to the planned CO_2 experiment.

The researchers involved in the project were very unhappy with the decision by the Ministry. They claimed it was illogical and that the Ministry had overturned the open process of the permitting agency, under political pressure from a few interest groups. Politicians will eventually have to decide what methods to use to mitigate climate change, but the research on the possible alternatives should be independent and purely scientific. Given the scale of the challenge, it is imperative to explore as many potential mitigation options as possible, on the basis of which informed political decisions can be made. When looking at prospects for future global energy consumption it is hard to see how renewable energies can replace fossil fuels to any significant extent in the next 50–100 years. So a realistic scenario is the steady increase in the burning of fossil fuels over this period and, if no storage methods are employed, increased releases of CO_2 to the atmosphere.

* Johansen, Ø., H. Rye and C. Cooper (2002) DeepSpill – Field study of a Simulated Oil and Gas Blowout in Deep Water. *Spill Science & Technology*, Vol. 8.

The international project is still running, and the scientific team recently successfully completed an oceanographic survey at the Loihi Seamount near Hawaii, where natural CO_2 leaks from the sea bed at 1200 m depth at a rate of about 100 000 tonnes per year. Data were obtained on the diffusion of the CO_2 and on impacts of the gas, although the setting was quite different from what was planned for Norway. Meanwhile, a number of countries will continue to investigate various methods of ocean CO_2 sequestration, and results will be communicated both to the science community and to the public, so that sound debates on the options can be maintained.

Further Information

For more on the subject matter of this article see: Golmen, L.G. (2002) *The international project on CO_2 ocean sequestration. A summary of the experiment permitting process in Norway, 2002.* Report No. 4619-2002, NIVA, Oslo, 43pp.

A useful website on the Climate Technology Initiative of the *UN Framework Convention on Climate Change* (and related topics) is: http://www.climatetech.net/links/ocean.htm

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News Nuggets

Energy-Saving Detergents?

The microbial decay of blubber-rich whale carcases in the deep sea, where temperatures of 0–3 °C prevail, has led lateral-thinking chemists to explore the enzymes that decompose fats at low temperatures, with the aim of developing 'cold-wash' detergents that cope with grease.

Volcanic hazard to shipping

Effects of volcanoes on civilian populations and on aircraft are well documented, effects on shipping less so. They include ash falls, pyroclastic flows, floating rafts of abrasive pumice fragments, gas release from submarine volcanoes (which can reduce water density enough to sink ships), and formation of new islands. Research into these hitherto poorly documented dangers forms the subject of a novel Ph.D thesis at the Open University.

Bureaucracy strikes again

Last summer, a Scottish fishing boat breached EU regulations by having plastic ropes and rungs on its boarding ladder instead of the statutory manila rope and hardwood. The owner had changed to plastic because manila rope rotted and wooden rungs became covered in dangerously slippery slime. He was fined £5000 all the same.

Strong Young Sun – another paradox?

If Mars was warm enough for surface water 2–3 billion years ago, a 'faint young Sun' couldn't have produced enough heat to support an active hydrological cycle, according to some North American scientists. An insulating CO_2-rich 'greenhouse atmosphere' wouldn't have provided enough warmth either. But there's a snag: a 'bright young Sun' obviates the need for the CO_2-rich atmosphere needed to explain many features of the early Earth.

Venetian floods

Not regional subsidence but a combination of heavy rain plus approaching spring tides put Venice under nearly a metre of water in mid-November. The combination of subsidence and sea-level rise may not have been the cause this time, but the long-term outlook is not promising.

Protection for basking sharks

It will soon be illegal to catch basking sharks in British waters, or to sell parts of them for food or other purposes.

Argo undertakes a Herculean task

Alex Sen Gupta

Together, the ocean and atmosphere control the Earth's climate system. Our understanding of ocean dynamics is however severely constrained by a lack of long-term data from a significant portion of the oceans. Difficulties with access, problems caused by harsh conditions and the high costs involved with ship-based observations, mean that the extensive observing systems in place to provide high-resolution, global atmospheric data for weather forecasting were, until recently, impossible in the ocean.

This deficiency is being addressed by the international Argo Project. Started in September 2000, Argo aims to deploy and maintain a global array of 3000 floats, collecting data in the upper 2 km of the world's oceans. This will provide a high resolution, quantitative description of the upper ocean that can be used to help interpret satellite measurements, provide initialization and validation data for ocean models, and assist in assessment of climate variability and predictability. The project's name highlights the close link with the *Jason* satellite project: one of Argo's primary goals will be to enhance the interpretation of *Jason*'s synoptic altimeter measurements of sea-surface topography.

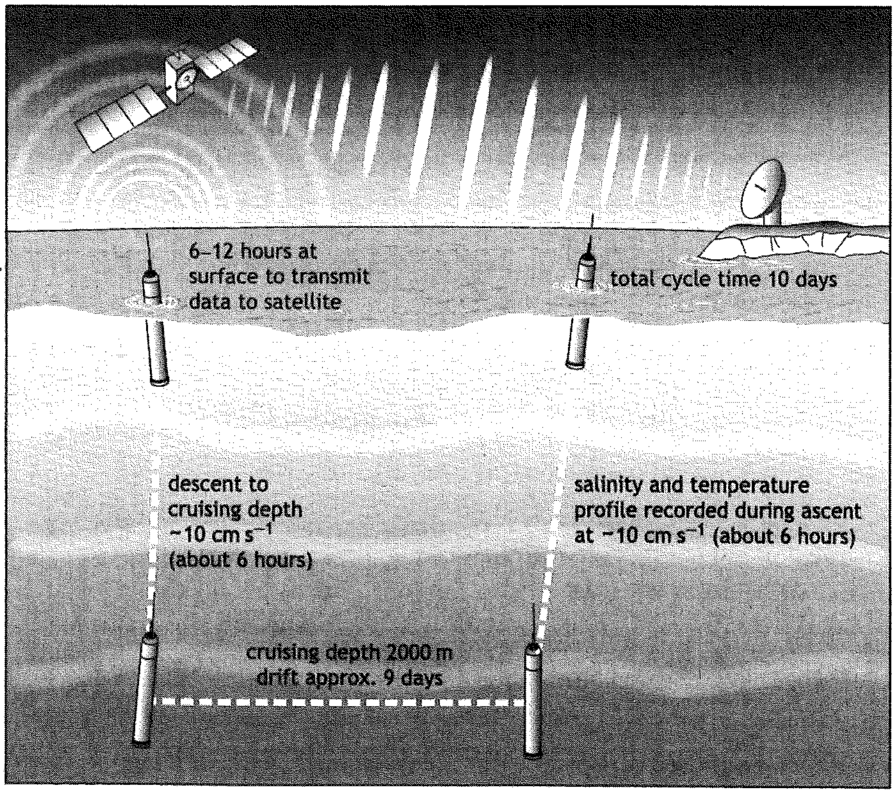
The idea of using free-floating, neutrally buoyant instrumentation to measure oceanic properties dates back to the mid-1950s when Henry Stommel and John Swallow independently developed floats that were designed to be tracked by an accompanying ship. These floats demonstrated for the first time that the interior ocean was far more dynamic that previously believed. In the 1970s, Tom Rossby and Doug Webb developed SOFAR floats; these no longer needed an escort but instead transmitted acoustic signals to land-based listening stations through the SOFAR channel (the water layer of minimum sound velocity that acts as an acoustic waveguide). These were huge instruments in the region of 8 m in length and weighing a quarter of tonne. Rossby later went on to develop the far smaller and cheaper RAFOS float (RAFOS = SOFAR backwards) that received, rather than transmitted, signals. Data was stored internally and consequently information was only retrieved at the end of a mission. Results from these floats demonstrated the prevalence of mesoscale eddies in the open ocean and their importance in the transport of ocean properties.

The modern profiling float design originated in the late 1980s. Profiling floats incorporate an external pneumatic bladder that can change in volume, thus affecting the float's buoyancy and in turn, the depth at which it floats. The floats sink to a pre-set depth and drift with the prevailing current for a number of days. When the bladder is inflated, the float resurfaces and transmits position data to the overhead Argos satellite system. Finally, the bladder is deflated again and the float returns to its operating depth. The significant enhancement to these floats is the addition of CTD instrumentation that provides the ability to measure water column profiles of pressure, temperature and salinity during the floats' ascent.

The Argo project is an international venture bringing together teams from Australia, Canada, Denmark, France, Germany, Japan, the Republic of Korea, New Zealand, the Russian Federation, the UK and the US. The ultimate goal is to maintain a network of 3000 profiling floats distributed evenly across the world's ocean. This would correspond to an average spacing of 3°, equivalent to 300 km. It is planned that the full network will be up and running by 2006. Once at full strength, maintenance of the network will require approximately 700 new float deployments each year to replace the floats that have come to the end of their life.

As of February 2003 there were over 675 Argo floats worldwide. The UK contribution to this is just over 65 floats (see map overleaf). The floats are normally programmed for a cruising depth of 2000 m with a total cycle time of 10 days: the floats take about 6 hours to descend or ascend; they float at depth for 9 days and spend 6 to 12 hours transmitting data at the surface (*see digram below*). The battery capacity provides the floats with an operational lifetime of approximately 5 years, in the region of 150 profiles. The float body is just over a metre in length with an antenna of approximately one metre protruding from the top. Its weight of 25 kg means that it can be handled by a single person.

Floats usually have a cruising depth of about 2000 m, but may also be programmed to drift at ~1500 m depth, then sink to 2000 m before beginning the rise to the surface.



The floats can be deployed in a number of ways. To date, most floats have been released by research vessels, with the float being gently lowered into the water. When deployment needs to be speedy, however – for example during merchant vessel deployments – specially packaged floats can be released down a slide to free-fall into the water. Floats can even be deployed by aircraft, again using special packaging and parachute descent.

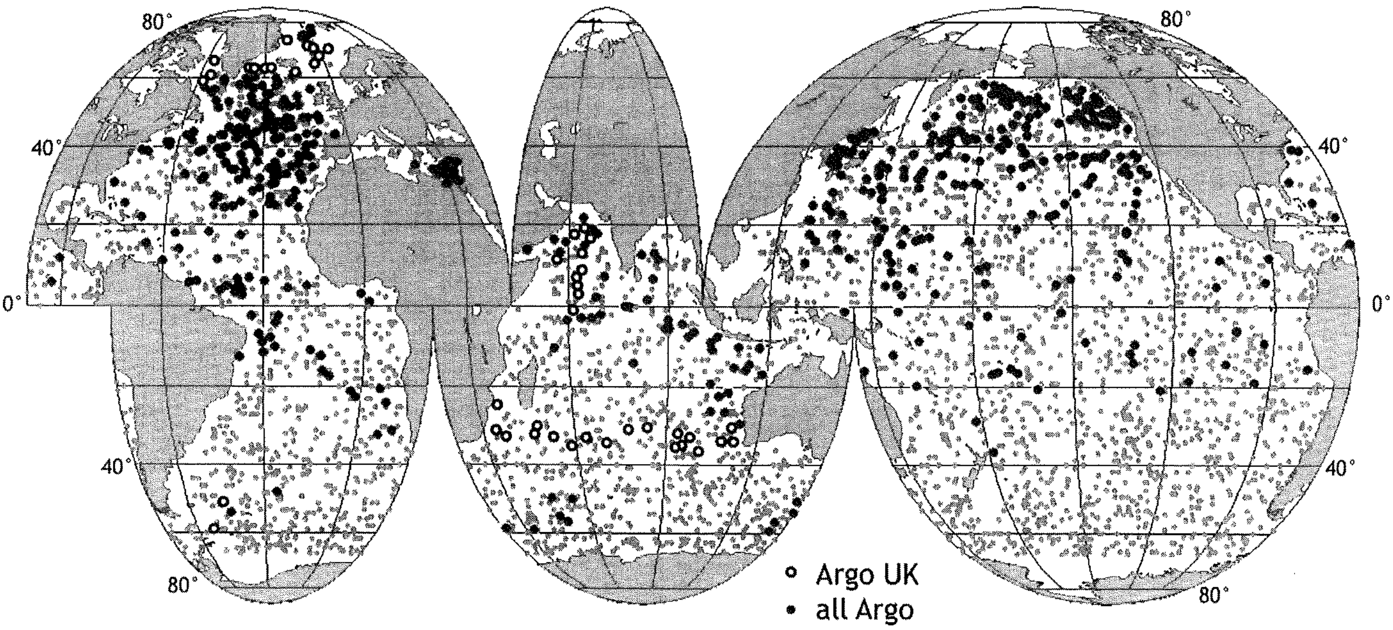
At full strength, the Argo network will produce in the region of 100 000 temperature and salinity profiles each year, far in excess of what is possible by conventional means and at a cost much lower than that of equivalent research-vessel-based measurements (the total capital and running cost of a float over its lifetime is in the region of US$25 000). The data are distributed via the Global Telecommunication System (GTS), a network linking meteorological telecommunication centres around the world. A number of data centres provide freely available Internet access to all the data, both in near real time, in an unprocessed form, and in a quality controlled form a few months later.

Project Argo represents a significant step forward for oceanography and promises important results both in terms of scientific understanding and in the economically important arena of weather and climate forecasting. When it is used in conjunction with satellite sea-surface height measurements from altimeters carried on *Jason,* along with high-resolution ocean models, we should be able to make far better predictions of climatic variations. We know that coupled ocean–atmosphere events like El Niño, generated in the tropical Pacific Ocean, and closer to home the North Atlantic Oscillation (NAO), are closely associated with ocean circulation patterns. These events can have serious consequences and are associated with anomalous temperature and rainfall conditions and with stronger and more frequent extreme events, such as storms. Greater preparedness for these phenomena can save money and lives. In the longer term, it is only through the increased coverage afforded by projects such as Argo that we will be able to assess the effects of global warming and improve our ability to predict the consequences of climatic variations.

For more information on Argo UK see http://www.soc.soton.ac.uk/JRD/HYDRO/argo/ or for the international Argo information centre see http://argo.jcommops.org/

Alex Sen Gupta is currently doing a Ph.D in global ocean modelling at the University of New South Wales in Sydney.

Current positions of Argo floats (black circles, with UK floats indicated by open circles). The grey dots give an indication of what the array will look like when it is at full strength.



Availability of *Prince Madog*

RV *Prince Madog* will be available for commercial charter for large parts of the spring and summer season. The University of Wales block allocation has now been loaded onto the *Prince Madog* website at http://www.vtplc.com/ocean/reservations.asp?viewdate=01/01/2003 This means that it is now easy to identify the vessel's availability against your requirements. All requests for charter will be processed on a first come, first served basis.

The quickest and easiest way to make a request is to use the on-line facility at the website given above. Please note that the University programme is loaded towards the Autumn. This leaves a number of slots in the summer season open for your research cruise or commercial survey. Ring +44-(0)2393-354774 to discuss your requirements. There is some flexibility in the booking system, so if you need a longer slot than seems to be available, you may well be able to be accommodated.

Thor Heyerdahl and Easter Island

We read the piece on this subject in 'Now there's a funny thing', Vol. 11, No. 3. We have long taken an interest in the island, and are sorry to see you take the now-prevalent line that old Thor was mistaken. We have been to Easter Island and conclude that what everyone seems to overlook is that there can now be no DNA evidence available to support Thor's theory, and the lack of non-Polynesian DNA in the present population is used to condemn his theories.

According to Metraux (see below), as recently as 1862 nearly a thousand able-bodied islanders were forcibly enslaved by Peruvians and taken to islands off the Chilean coast to dig guano under terrible conditions, from which many died within a few months; additionally, many contracted European diseases such as smallpox and tuberculosis. It was ironic that, by then, the islanders sent to dig guano had a bird-based religion; it was the ultimate insult.

As a result of an international outcry, those who had survived were sent back to Easter Island but, because of the European diseases picked up in Chile, many died *en route,* and only 15 regained the island; the infections spread rapidly and killed many of the remaining islanders. Civil wars and famine then further reduced the vulnerable population. Soon, the largely empty island was populated by Polynesian incomers, including their descendants from visiting seamen, who had swamped the island population, thoroughly mixing the genetic pool.

It is obvious that now there can be little chance of finding whether or not there were any original European or South American genes in the statue-building islanders. A recent television programme on the subject mentioned a study of the genetic ancestry of a group of (apparently) undated skulls recently found buried on the island; the claim that, because these were all of Polynesian origin, the statues must have been carved by Polynesians, is a non-sequitor. There must have been many thousands of people who once lived on tiny Easter Island (about six miles in diameter) over a period of a thousand years (one estimate was of a population of up to 11 000 at its maximum, far too many for a viable population); a very small modern sample cannot provide conclusive proof. It is also likely that as there were the two classes of islanders, the Haves (long ears, who master-minded the statues) and the Have-nots (short ears, the slaves), they would have been buried in their separate enclaves. From which was the sample drawn?

We inspected the massive and beautifully-hand-carved stone walls and found that it really was impossible to get a penknife between them, just as it was in the Inca and other civilisations in South America. It is claimed that nowhere in Polynesia was stonework of such quality produced.

Our interest began because one of us had the privilege of meeting Thor himself at a Pacific Science Congress in Tokyo nearly forty years ago, and found him to be an absolutely charming man who was happy to talk about his ideas, even to a lowly young scientist.

So please be careful before condemning the fellow who sadly now can't answer back – undoubtedly he would put up a vigorous case for his hypotheses! It now seems unlikely that there will ever be a definitive solution to the age-old problem as to who built the statues.

An interesting book, not now easily obtained, is *L'Ile de Paques* (Easter Island) by Alfred Metraux, first published in 1941 by Gallimard, Paris and re-published in English in 1941 by André Deutsch.

Laurie and Pamela Draper
Culbokie, Dingwall, Ross-shire

John Wright replies: I am properly humbled, claiming in my defence only that I wasn't really joining in the criticism of Heyerdahl, merely recording it. As you point out, he's not here to defend himself.

Mercury in Tuna

I noted with interest the news item on this topic in *Ocean Challenge*, Vol. 11, No. 3. You are quire correct in your last comment. This story is more than 25 years old, and thus has been forgotten.

It never ceases to amaze me that scientists seem incapable of doing literature searches before 'discovering' new facts.

The first papers on the bacterial conversion of inorganic to organic mercury species in the environment appeared in 1970 in USA (from Wood and his co-workers), and almost simultaneously in Sweden (from Jensen and Jernelov). For the next 10–15 years this was an active research area as scientists tried to untangle the various problems.

More than 95% of the mercury in fish is in methylated form, and probably always has been, as a result of natural processes. Naturally occurring mercury is converted by bacteria and accumulated, probably via food chain transfer, in top predators. This is still a hypothesis because the actual mechanism remains unknown: there are lots of theories, but few facts.

Cartilaginous fish have been known since the 1970s to contain Hg concentrations in excess of 1 mg/kg wet. wt and often significantly above that figure. Analysis of museum specimens has indicated no change since pre-industrial revolution days.

I made similar points in a short communication that I produced five years ago (see reference below*).

David Taylor
Brixham, Devon

*D.Taylor, *Letter to the Editor* Comment on: Trace element intake in the Faroe Islands. II. Intake of mercury and other elements by consumption of pilot whales, *Science of the Total Environment*, Vol. 72 (1988), 235–7.

John Wright comments: The recycling continues: I saw the 'new' stories in May last year. They reappeared in November, and again in February this year. Why?

NOW There's a FUNNY THING...

It's deja vu time again!

Five years ago I wrote about a counter-intuitive inverse correlation between evaporation and global warming (*Ocean Challenge*, Vol. 7, No.3, p.7): contrary to expectation, terrestrial evaporation has on average actually *decreased* over the past half-century of global warming; as has the diurnal temperature range (DTR). New work with pan evaporimeters has confirmed these decreases (*Science*, 15 Nov., 2002, pp.1345–6, 1410–11), and ascribed them to the same cause, namely a decrease in solar radiation consequent upon greater cloud cover and/or aerosol loading in the Earth's atmosphere.

In this connection I rediscovered a report about sulphur emissions from ships, which may be heavy users of the high-sulphur fuel oil carried in tankers such as the *Prestige*, which recently sank off north-west Spain (p.3). Most of us probably think that the marine atmosphere gets most of its sulphur from the DMS produced by plankton and then oxidized to sulphate. But according to this report (*Nature*, 19 August 1999, pp.713–14. 743–6), ships put about the same amount of sulphur into the atmosphere as is produced by the plankton – how many people know that, I wonder. I also wonder what the (presumably) increased cloud cover does to rates of evaporation from the sea surface in a warmer world. The account in *Science* was not especially forthcoming about marine evaporation rates, which are difficult to measure anyway.

Another rediscovered article describes an additional factor that could contribute to increased cloud cover (*Nature*, 18 Sept. 1999, pp.223–5, 257–9): water-soluble organic materials in industrial emissions tend to lower the surface tension of water droplets, which therefore tend to coalesce into larger droplets and make more clouds.

Sea-level rise to accelerate, shock horror

Hard on the heels of Mark Maslin's fascinating article in the last but one issue of *Ocean Challenge* (Vol. 11, No.3, p.12) I found an equally enthralling piece in *Science* (**286**, pp.1061–2 and 1132–5) on a similar subject. In brief, Maslin and his co-workers established that formation of deep water round Antarctica is more sensitive to 'capping' by a freshwater lid – which would result from ice melt in response to climate warming – than is the formation of deep water at high northern latitudes. The implication of this finding is that should formation of Antarctic Bottom Water (AABW) slow significantly, then North Atlantic Deep Water (NADW) could replace it as the principal deep ocean water mass. As NADW is about 5 °C warmer (and therefore less dense and occupying more space), the spread of NADW throughout the deep oceans would significantly increase the rate of sea-level rise. In the *Science* paper, Wallace Broecker and colleagues propose that the rate of formation of AABW is only about a third of what it was at the start of the last century; while rates of NADW formation have changed relatively little. If Broecker and Maslin and their mates are right, global sea-level should surely be rising at rates much greater than the couple of millimetres per year or so that characterized the last century?

Nuclear flight?

Airliners of the distant future may be powered by fuel cells or liquid hydrogen, but not by nuclear reactors. That last isn't as daft as it sounds. In the late 1950s a nuclear propulsion unit was actually installed in a converted US bomber. The nuclear reactor behaved like a conventional jet engine, heating air taken in at the front and expelling it at the back, providing thrust. What a great idea. At a stroke you could put an end to the vast tonnages of CO_2 expelled from present-day jet aircraft. However, it would be less easy to attract passengers, never mind aircrew, who already experience considerable levels of cosmic radiation at high altitudes. Protection from nuclear radiation requires effective shielding, which put paid to the original project, because something like 20 tonnes of shielding was needed to protect the crew alone; and it was estimated that another 30 tonnes – minimum – would be needed for the passengers. Somehow I don't think this concept will take off, however much demand there may be to reduce greenhouse gas emissions.

Global warming: the ultimate remedy?

Following on from the previous item, we actually can't stop using fossil fuels and causing the emission of greenhouse gases, so maybe it's time to start tinkering with radiation from the Sun. It's not a new idea. The Russians thought of it about five years ago (*Ocean Challenge*, Vol. 8, No. 2, p.29, also Vol. 9, No. 1, p.19), albeit as a means of modifying day–night and winter–summer cycles. But now it's the Americans' turn (*New Scientist*, 9 Nov., p.19). There appear to be two main options. One is to deflect/reflect some 2% of incoming solar radiation away from Earth, which would reduce the average radiation received by the Earth–atmosphere system from about 240 to about 235 $W\,m^{-2}$. Less solar radiation would reach the Earth and the warming effect of the 'greenhouse blanket' would be reduced. The alternative option is to meet future energy demands by arrays of collectors orbiting either Earth or Moon and capturing the higher intensity solar flux available in space, then beaming the energy to Earth by microwave transmitters. Such a scheme would perforce be linked to greatly reduced reliance on fossil fuels for transportation systems. Motor cars and aircraft would have to 'go electric'. I am reminded of Mark Twain's observation to the effect that he was amazed at how scientists '... can construct such complicated edifices of speculation on so small a foundation of fact.'

I am also reminded of an exchange of letters published five years ago under the crisp headings 'Space can wait' and 'Space can't wait' (*Nature*, **387**, p.340; **388**, p.823). I wonder how those correspondents would react to the proposition that orbiting arrays of solar collectors may solve humanity's future energy needs. It's a drastic solution, but what alternatives are there? Despite – or even with – the resolution formulated at the Johannesburg Summit (15% of energy from renewables by 2015), it's obvious that 'green' energy sources can't keep us warm or drive our cars and aeroplanes. Nuclear energy not only cannot be used to power aircraft (see the previous item), it also has a waste mountain that grows larger each year and remains manageable only because of its high density, and hence low volume. Conventional fossil fuels won't last more than four or five decades at most, leading to drastic shifts in the global economic balance. Countries that are presently rich in oil and gas (e.g. Saudi Arabia) will be a lot poorer, and countries like Afghanistan, that stand to make billions out of pipelines across their territories, will also lose out. On top of that, getting usable fuels from tar sands or oil shales will prove not only complicated but also costly. Perhaps orbiting solar collectors will be the answer after all – though preferably not with the focussing power of the device in the latest Bond movie, 'Die Another Day'.

Surfing degree not a doddle

Plymouth University's new degree course in Surf Science and Technology, which started in 1999, proved to be much more of an intellectual challenge than supposed by scornful academics in other institutions – but not in these columns (see *Ocean Challenge*, Vol.11, No. 3, p.20). For one thing, any student hoping to be taught how to surf was disappointed (though there were opportunities for surfing when field classes finished); for another, the course requires at least three good passes at A-level, including one or more science subjects. Materials technology and business studies are covered in the course, as well as oceanography, and there is plenty of scope for graduates to enter the UK surfing industry, which turned over about £160 million last year and is expanding fast.

OSCAR

No, not a variant of wave-measurement by radar – it's a novel sea-bed energy source (Ocean Sediment Carbon Aerobic Reactor). The basic principle is simple, the ingenuity lies in getting electricity out of it. Microbial decomposition of organic matter at the sea-bed occurs under oxic conditions and uses up electrons, while in sub-seafloor sediments, microbial decomposition is anoxic and proceeds by reduction of oxidizing agents (nitrate, sulphate), which releases electrons. The resulting EMF across the sea-bed can be tapped by putting one electrode just above the sediment–water interface, another about 10 cm below it. The energy generated amounts to 50 milliwatts per square metre, but since microbial decomposition never stops, the potential difference is a permanent feature, and would obviate the need for batteries – which have to be replaced – in sea-bed sensors. The description that appeared in *New Scientist* (6 Oct. 2001, p.24) was somewhat marred by the headline 'Plankton power' and a sub-head about 'microbeasts producing the juice'. Every year we have students who regard phytoplankton and/or bacteria as animals – I would expect a reputable science journal to recognize the distinction. And since when were bacteria in sediments planktonic?

Coral gardening – with electricity

Here is a novel way to replace coral reefs being killed by pollution and possibly by global warming (cf. *Ocean Challenge*, Vol. 11, No. 2, p.4). The principle is relatively simple, but only a genius could see how to apply it for growing coral reefs.

A steel frame is erected in shallow sunlit water and an electric current passed through it – no more than 300 watts, easily achieved with photovoltaic cells. Gas bubbles off the steel frame, as electrons combine with hydrogen ions to form molecular hydrogen; and bicarbonate (HCO_3^-) dissociates to form more hydrogen ions (which produce more hydrogen gas), as well as carbonate ions (CO_3^{2}). The latter combine directly with dissolved calcium ions in the water (which is now less acid because hydrogen ions are being electrolytically removed), precipitating aragonite upon the steel framework. This so-called 'bio-rock' provides a substrate which coral polyps can colonize.

A minor snag is that brucite ($Mg(OH)_2$) is also precipitated and, being softer than aragonite, tends to weaken the substrate. The remedy is to switch off the current and allow the brucite to dissolve again. As the artificial reef grows, fish and other organisms are attracted to it. Energy provided by the current in forming the ready-made substrate is claimed also to render the corals in reef 'gardens' more resistant to the thermal and other stresses that afflict corals in 'natural' reefs. Growth rates of up to 5 cm per year are claimed for these reef gardens, which have already been 'planted' in several sites throughout the tropical–equatorial ocean (*New Scientist*, 5 July 2002, pp.38–41). The project has been going for at least ten years, and seems to have a bright future, provided that anthropogenic loadings of CO_2 don't make ocean surface waters too acidic and inhibit carbonate precipitation (cf. *Ocean Challenge*, Vol. 11, No. 1, pp.19–20).

Earlier in the year it was reported that marine biologists at the Boston meeting of the American Association for Advancement of Science (AAAS) had identified the world's ten most diverse and threatened coral reefs. Potential snags notwithstanding, it is perhaps as well that this way of developing coral 'gardens' has come along, for the AAAS scientists went no further than recommending that Marine Protected Areas be established to protect the threatened reefs. Reef 'gardens' were not mentioned. Perhaps they should have been.

Dimpled skipping stones

If you want your pebble to bounce lots of times on a water surface when you indulge in a bit of 'stone skipping', you need to ensure that you impart both high speed and high spin rate to your pebbles. That's the finding of some recent important research on the subject, possibly by someone looking to scoop an Ignobel Prize (*New Scientist*, 19 Oct., p.19). The pebbles skip even better if the surface is dimpled like a golf ball's, because dimples disrupt the viscous sublayer that clings to the surface and slows the pebble down. Sharks and other fish evolved a similar sort of trick some tens of millions of years ago (cf. *Ocean Challenge*, Vol. 10, No. 1, p.4).

John Wright

Challenger Centenary Conference

Marine Science 2002 – effectively the centenary Challenger Society Conference – was held in Plymouth, on 9–13 Sept. Belated congratulations to Fauzi Mantura, Carol Robinson and the rest of the team at Plymouth who made the meeting such a success. All were agreed that standards of presentation and of posters were as high as ever, if not higher. Session chairs nearly all stuck to time so well that it was easy to move up and down between the two lecture theatres (on adjacent floors, another bonus) to catch talks in different sessions. Most presenters used Powerpoint, which has the great advantage that 'split-screen' images and video clips can be shown. Another brilliant move was to put email addresses in the list of participants – a great help to commissioning editors! The food and accommodation were excellent too, and we all felt well cared for.

It was a good idea to have at least one keynote talk each day, in plenary session, ideal for exposing everyone to new ideas and developments in different fields of marine science. Novelties included the expanding areas of microbial and molecular biology and genetics, about which many of those present were wholly ignorant. So the talks by Paul Falkowski, Mikhail Zubkov and David Wolff opened up whole new vistas for many of us. One of the keynote lectures was by Mike Fasham, this year's Challenger Medallist, and we hope to feature a version of his talk in a later issue. We also hope to include Margaret Deacon's fascinating account of the history of the Challenger Society.

There were mixed reactions to the innovation of Poster Overviews. Although it drew peoples' attention to the poster sessions, such overviews are perforce subjectively selective, which could lead to accusations of bias or favouritism by those whose posters are left out. It would be good to learn that every poster was at least named, if not discussed. Much praise is due to Louisa Watts and all the others who diligently judged awards for the Norman Heaps and Cath Allen prizes. The judges for the Norman Heaps prize for the best presentation by a young scientist had a very hard task and eventually decided to award three joint prizes, as follows: Alex Mustard from the Southampton Oceanography Centre (SOC), who spoke on 'The interaction between mesoscale physical processes and zooplankton at the Iceland–Faroes Front'; Ian Walkington (Dept of Mathematics, Keele), 'The impact of topography on the steady state wind- and buoyancy-driven subtropical gyre'; and Katharine Woods (Plymouth Marine Laboratory), 'A seasonal study of primary production in the western English Channel'.

The Cath Allen Poster Prize was also shared, the joint winners being: Katy Shannon (SOC and University of Wales) 'Gauging the rain'; and Will Le Quesne (SOC) 'Stable isotope study of the importance of intertidal marsh primary productivity'.

This year, the subject of the President's Photographic Prize was 'Colour and the Sea'. The winning photo, 'Breaking Wave' (below – sadly not in colour) was taken by Alex Mustard. The prize for the best student of the Open University Oceanography course was awarded to David Angus.

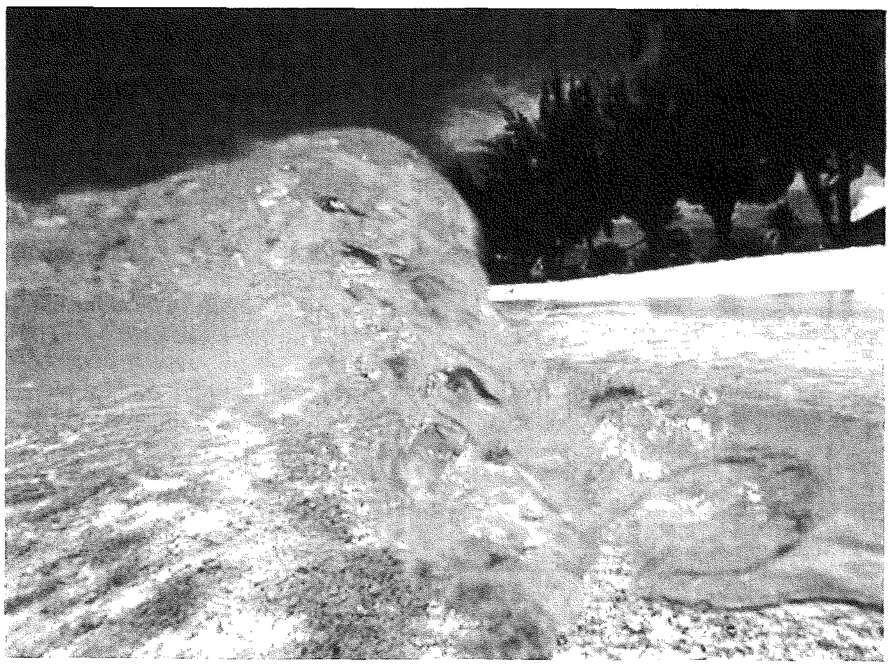
The prize winners were announced at the Conference Dinner by outgoing President, John Shepherd. John also delighted the company by announcing some unexpected prize-winners: Mike Whitefield, for the most interesting 'deflowering of a Powerpoint virgin' (i.e. for the most entertaining presentation by a speaker tackling Powerpoint for the first time); Andy Watson, for having the most entries in the index of the Conference Proceedings; and Mike Krom and Harry Bryden, who received honourable mentions for excellent posters from experienced 'old hands'.

On a more serious note, Mike Fasham was awarded the Challenger Medal for exceptional contributions to the development of marine science, notably for his pioneering work in biogeochemical modelling. Presentations were also made to the new Challenger Fellows: Carol Robinson (PML), Chris Hughes (POL), David Marshall (Reading) and Toby Tyrrell (SOC).

(For information about the award of the new *Prince Madog* prize, which was advertised at the Conference, see opposite.)

The Leslie Cooper Memorial Lecture

A new event this Conference was the Leslie Cooper Memorial Lecture. The lecturer, Bob Duce (Texas A&M University), began by explaining that, although not now generally well known, Leslie Cooper played a signficant role in the development of marine biochemistry. He refined Redfield's original seawater analyses that gave the 'Redfield ratio' for the proportions of nitrogen and phosphorus in plankton. This ratio, which is



The prize-winning photo 'Breaking Wave' by Alex Mustard. The wave has been photographed from within.

the same as that in seawater generally, is fundamental to many aspects of marine science.

Bob then introduced a new international programme, the Surface Ocean – Lower Atmosphere Study (SOLAS), which is 'a multi-disciplinary global-scale research programme' developed by the international scientific community with the aim of achieving 'quantitative understanding of the key biogeochemical–physical interactions between the oceans and atmosphere, and how the coupled system affects, and is affected by, climate and environmental change.' SOLAS is an integral part of the second phase of IGBP (the International Geosphere–Biosphere Programme). It will tackle topics like exchange of gases, aerosols and energy across the air–sea interface, and should greatly advance our understanding of climate change.

The Buckland Lecture

The Buckland Lecture was held (appropriately enough) in the Maritime Museum, and was given by Dr Dick Ferro, Head of Fishery Technology at the Aberdeen Marine Laboratory. It dealt with the problems facing the fishing industry today, and was a sobering experience. We did learn, however, that overfishing is not a new phenomenon. For more than 800 years there have been scares about it, along with legislation to limit size and type of gear, size of fish caught, mesh size of nets, even to set up closed areas and seasons. Dumping of surplus or undersized fish isn't new either, but nowadays there are no new fishing grounds to exploit, so overfishing is a global phenomenon. The situation is dire, and the audience heard some horror stories – e.g. on average, from 1992 to 2001, 75 000 tonnes of North Sea haddock were caught, 75 000 tonnes were dumped.

Dr Ferro was not optimistic. There is little debate/discussion about overfishing within the industry, which might agree to changes in net design (to allow escape of immature fish), but would oppose decomissioning on any scale (cf. *Ocean Challenge*, Vol. 11, No. 3, p.2), and is not likely to police legislation aimed at conserving stocks. The matter was partly resolved in the autumn, when the EU partially closed cod fishing grounds in the North and Irish Seas.

Aquaculture and mariculture are perceived as ways of making up the shortage of 'wild' fish. But these industries depend in large measure on the fish meal produced by industrial fisheries, which use small mesh nets and can catch any immature fish that escape the nets of 'conventional' fishing boats. It's hard to see how sustainable marine fisheries can ever be achieved, let alone by 2015 (cf. 'Fisheries Farce at Johannesburg', p.4).

IMarEST and professional recognition

The launch issue of *Marine Scientist,* a new journal from the Institute of Marine Engineering, Science and Technology, was made available to participants. After the Challenger Society AGM, IMarEST's Director General, Keith Read, spoke about the Institute and his hope that the Challenger Society would join with IMarEST to form a larger 'marine lobby'. IMarEST is considerably bigger and wealthier than the Challenger Society, and clearly has a different ethos. The pros and cons of a possible federation (consisting of IMarEST, the Society for Underwater Technology, the Challenger Society and perhaps other societies) will have to be carefully weighed.

In his talk, Keith Read emphasized the development of two new professional titles: Chartered Marine Scientist and Chartered Marine Technologist, which would 'enable marine scientists and technologists to have their qualifications, experience, competence and commitment officially acknowledged and their professional status formally recognized.' The issue of professional recognition for oceanographers was discussed by Council early in 2000 (at its 50th meeting), and Steve Hall provided a short feature on the matter in *Ocean Challenge* (Vol. 9, No.3, p.7). The outcome was inconclusive, chiefly because of the diversity of disciplines in the marine sciences, but the IMarEST initiative may encourage oceanographers to acquire professional titles.

A sustainable future – for the oceans as well as research funding?

UK Marine Science 2002 opened only a few days after the end of the Johannesburg Summit on Sustainable Development. *Sixty five thousand people* went to Johannesburg, yet at Plymouth only one speaker menioned sustainability, and that was only a passing reference on the Thursday morning. NERC evidently believes in the concept though, because everyone was invited to take a copy of *Science for a sustainable future 2002–2007,* dealing with topics like 'sustainable economies', 'investment in research and training', and 'sustainable solutions to environmental problems'. NERC is planning to spend some £40 millions annually on projects to monitor climate change, biodiversity, water quality, ecological and biogeochemical cycles, and so on.

Of course, it is only by measuring and monitoring that scientists can collect the evidence to convince politicians of the need for action to curb pollution and mitigate the effects of climate change. However, it would be good to hear more about scientific initiatives intended to address such problems directly.

Prince Madog Prize

The Prince Madog Prize, put up by Vosper Thorneycroft, has been won by Brett Lyons and Grant Stentiford of CEFAS. Under the terms of the competition (which requested proposals for scientific programmes and training programmes) their proposed Integrated Marine Monitoring Workshop for Cardigan Bay will be made reality. The prize is five days' ship time on the new *Prince Madog* – which is based at Menai Bridge – complete with crew, victuals and fuel.

The scientific assessors said that the entry addressed the difficult problem of pollution in Cardigan Bay with 'a thorough combination of research and training', and noted that it was 'a well thought-out programme with a strong interdisciplinary theme'. The Environment Agency particularly liked the collaborative nature of the project, and the idea for training and development alongside modern research techniques.

The runner up was Alberto Borges, Postdoctoral Researcher at the University of Liège Chemical Oceanography Unit.

Vosper Thorneycroft would like to thank the science review panel at the School of Ocean Sciences, University of Wales, Bangor; the National Marine Service at the Environment Agency; also Fauzi Mantoura, Richard Burt and the Challenger Society.

For information about booking ship time on Prince Madog, see p.8.

'Going Foreign'

Finlo Cottier

A century for Challenger, a debut for me. After several years in marine-related fields, the Challenger Society Centenary Conference in Plymouth was my first brush with the greater UK marine science community. As I'm based at the Scottish Association for Marine Science (SAMS) near Oban, this was a welcome opportunity to travel south to the balmy, cosmopolitan, English Riviera. Though SAMS does not exist in total geographic isolation (we are closer to both Rockall and the Faeroe Islands than to Plymouth) this conference certainly had a foreign, almost overseas, feel to it.

On arrival, it felt very much like joining a research cruise and throughout the week I encountered numerous parallels with shipboard life. At the most basic level, thoughts initially revolved around the essential trinity of: Where am I working? Where am I sleeping? Where is the bar? Once these were established, each day then fell into a fairly predictable routine involving varying proportions of work, rest and play.

Inevitably the other folk joining this 'cruise' fell into one of a number of categories. First were those from whom you never seem to escape, the omnipresent characters who are part of the fixtures and fittings. Then there were the 'haven't I sailed with you once before?' types where there was a vague recognition of a face followed by a sudden recollection of the name and the reputation. A variation of this is to know the name and the reputation but meet the face for the first time. Another group are those who are initially a completely unknown quantity but rapidly attain soul-mate status. Finally, there are the 'disembarkation characters', the ones you notice for the first time on the final day. For me, there were many in each category.

As far as the representation of institutions went, the geographical spread showed a distinct exponential decay as a function of latitude. Populations from Plymouth and Southampton were close to saturation whilst those from the extremities of Scotland were at barely detectable levels. One would hope that this is not a true reflection of the distribution of funding and support.

I hadn't ever appreciated fully just how many UK research departments are engaged in marine science. Besides the obvious big guns housed in their 'littoral zone' laboratories, there were also the 'landlubbers' from the likes of Keele, Cambridge and Reading. Academic, government and commercial – they were all there, lending their own distinct flavour to this scientific cocktail.

With any conference or cruise there are highlights and lowlights, with the intervening periods being rather akin to routine CTD stations. The keynote talks were quite definitely *the* highlight, something to engage every individual: a breadth of talks that spanned the extremes of scientific disciplines, set in an historical perspective by Margaret Deacon's, 'Origins of the Challenger Society'. It's a humbling experience to listen to a lecture by a true polymath like Paul Falkowski, who effortlessly shifted from palaeoceanography to genetics to microbiology to climate models to ocean turbulence and back. I was totally left for dead in places and could only listen with a sense of awe.

'Interdisciplinarity' is ubiquitous in scientific parlance these days. Unfortunately it is more likely to be paid lip service than to feature in real projects. So it was particularly refreshing to hear and read the series of presentations and posters from the British Antarctic Survey, which wove together results from a brilliantly planned observational programme and ocean models to create a representation of the fluctuating krill populations in the Scotia Sea.

It was another Southern Ocean project that caused a mass population displacement of 'physicists' to join the 'biologists' in the lower lecture theatre for the latest in CTD surveys by fur seal. A bit of lateral thinking, the latest in inductive sensors and a cooperative seal combine to provide a unique hydrographic platform. It seems the only catch was the need to have a calibration curve for your seal!

Another bold and brilliant performance that caught my attention was introduced by the speaker as 'not so much a scientific talk, rather a moral tale'; he then proceeded to expand on how the variations in a measured oceanic 'signal' were probably just an effect of his mooring swaying in the East Greenland Current.

And then there were the posters, with the unusual creation knocked up on brown paper with crayon being as eye-catching and memorable as the stunning graphics in the glossy displays. As on a well-organized ship, much can be achieved with a seemingly continuous supply of beverages and biscuits. The poster display area in the Main Hall was both mess room and working space, as ideas, collaborations and arguments were developed, criticised and resolved.

The lowlights must have been few, far between and trivial, because I can't recall a single significant disappointment. Often there is dissent over the scheduling or grouping of talks, chronic cases of over-run, or complete overhead overload. Here, however, the diversity in the presentations and the organization of the programme kept most people happy most of the time. Rather uncharacteristically, the individual sessions kept closely to the timings so that it was quite easy to switch between halls and cherry-pick the talks. A significant factor in keeping the show on the road was the superb support given to speakers by the technical team who ensured that changeovers were slick and who prevented any potential 'PowerPoint prolapses'.

And what of those routine CTD stations I talked of, the myriad of presentations that form the body of the conference? Well, like any cruise, the unique observations and gems of data which form the highlights, have to be interpreted in the context of the local hydrography. At Plymouth, the local hydrography was represented by the wide range of presentations about the great variety of marine science projects being undertaken across the UK. For the sheer spectrum of emotion and performance, this conference was hard to beat. Genuine enthusiasm and excitement blended with frustration, despair and outright terror. There was eloquence, showmanship, humour and great technical expertise alongside hesitancy and trepidation. The old hands gave guidance and the occasional grilling to the greenhorns, but always with a supportive tone and real camaraderie.

But where were the most intense, opinionated discussions held? True to form, when you have a gathering of marine scientists, much of the verbal jousting was conducted at the bar. Only on this occasion you didn't have to remember, 'one hand for the ship, the other for your pint!'

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European oceanographers work towards a sustainable Mediterranean

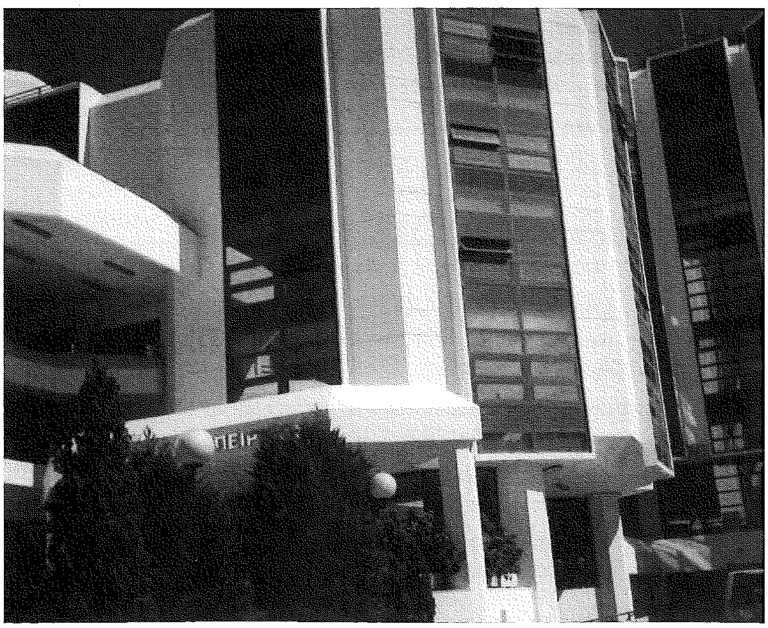
In late September, the EFMS – the European Federation of Marine Science and Technology Societies – held its first scientific conference in Athens, hosted by the Hellenic Oceanography Association. The conference, entitled 'oceanographical aspects for a sustainable Mediterranean', provided a forum for discussion of the challenges facing marine science and marine scientists in the particular context of an almost entirely enclosed body of water, bordered by more than a dozen states.

The main conference was preceded by an EFMS workshop (held in the Propyleon in central Athens, *right*), focussed on training and employment prospects for young marine scientists, a crucial topic for EFMS. Environmental conservation, integrated coastal zone management, and – following the Johannesburg Summit – sustainable development, are all becoming prominent in the syllabus at university level. The inculcation of transferable skills (including languages!) is considered important too, while the physics/maths deficit recognized among school leavers in Britain appears to be a Europe-wide problem.

The main scientific sessions were held in the modern university campus at the port of Piraeus (*below*). For delegates from northern Europe, the format of the conference was unusual: the presentations were all invited lectures, and after each, generous time was allowed for debate. The debates brought out interesting points, and often involved delegates who were not from member societies of the EFMS, including Morocco and Spain. This suggests that there is scope for increased membership of EFMS.

The classical facade of the Propyleon university building, in the centre of Athens

Restricting the talks to eminent speakers meant that less experienced researchers were relegated to the poster room. The posters were of a generally high standard, but as the formal sessions devoted to them tended to get curtailed, a number did not get the attention they deserved.



The modern campus at Piraeus, where the main conference sessions were held

Two invited lectures were given each morning and afternoon, and each pair of lectures was followed by discussion. In the first talk, Artemis Nicolaidou explained how the rich diversity of species in the Mediterranean is a result of its tectonic history, and its wide range of climatic and hydrographic conditions. She then summarised present-day threats to this diversity. One of these threats is the accidental transport of non-endemic 'alien' species, into areas where they may wreak havoc on local populations. Some of the issues arising were later elaborated by Charles Bouderesque.

The rich diversity of species in the Mediterranean and the wide range of habitats, along with historical and cultural factors, have led to a wide diversity of fishing methods and gears. A corollary of the large species diversity is the general lack of large monospecific shoals, and associated fisheries. These topics were addressed by Guilio Relini, who also described the increasing role of aquaculture in the area, particularly around the eastern Mediterranean.

One fish that *is* found in large shoals is the blue fin tuna. Guy Imbert outlined the problems faced by the artisanal *'thonaille'* fishery, and its advantages. It is much more selective than the commercial drift-net fishery (less by-catch), with the only cetaceans caught unintentionally being young striped dolphins.

Meriwether Wilson discussed different approaches to sustainable coastal management. She favours a 'large ecosystem approach' that does not focus on specific uses. Haris Coccossis stressed the need for integrated management, and a process-oriented approach, with rationalised decision-making and increased participation by local communities and scientists.

Interestingly, the Mediterranean has no exclusive economic zones and no high seas. Since 1978, issues relating to the protection of the marine environment have been covered by the 'Barcelona Convention'.* Professor Wilson (who has career experience in administation as well as science) stressed how important it is for administrative bodies to include scientists, and urged young marine scientists to consider this (often overlooked) career path.

Since the 1992 Earth Summit in Rio, prevention and control of land-based pollution has moved up the agenda, and the MEDPOL programme has been in place in the Mediterranean. However, 45% of industrial effluents still go directly into the sea, and the 'action-oriented' MEDPOL initiative Strategic Action Programme, described by Francesco Civili, is badly needed.

Gerd Leibeziet compared the Mediterranean Sea with the Baltic – in some ways similar, but with a positive freshwater balance, whereas the Mediterranean has excess evaporation. This difference, and a longer flushing time in the Baltic, affects the behaviour of pollutants. The states around each of these seas have agreed upon common measures to monitor and control marine pollution (under the Barcelona and Helsinki Conventions, respectively).

Certain topics recurred in the talks. The poulation around the Mediterranean is expected to double by 2003, with 'growth hotspots' along the eastern Adriatic and around the eastern Mediterranean. Although the Mediterranean Sea is in a better state than many parts of the ocean, the marine environment throughout the Mediterranean is under threat; and the many conflicts of interest within and between individual states become more pressing and more numerous each year, as both tourist numbers and populations increase. Where new developments require relocation of communities, the profits go to the developers, and the costs are borne by the displaced. Quarrying and land reclamation for new developments may muddy coastal waters, killing fish and smothering corals.

*Properly, *The Convention for the Protection of the Mediterranean Sea against Pollution.*

In theory at least, conservation measures in the Mediterranean are well established. There are 122 Marine Protected Areas, all coastal and mostly designed for specific animals (e.g. cetaceans). In reality, conventions, agreements and MPAs have had limited effect because they are not properly policed and enforced. That is partly through lack of political will, partly because – as one of the participants trenchantly observed – of the high levels of corruption throughout the EU (cf. *Ocean Challenge*, Vol. 11, No. 3, p.2). Moreover, such conventions and agreements are difficult (if not impossible) to police or enforce along the northern shores of Africa because those states don't belong to the EU anyway. We heard that gill nets that had become illegal in European waters were being sold to fishermen working off Morocco, Tunisia and Cyprus, where they are not illegal.

A key requirement is educating and/or communicating with politicians and officials, who don't fully understand the terrestrial environment, and find the marine environment largely incomprehensible. Thus, the Greek government minister invited to open the proceedings spoke briefly about increasing pollution in the Mediterranean and the importance of scientific research, then abruptly turned on his heel and left.

The scientists' contribution to all of these problems and conflicts is the same as in Britain. Large amounts of money are spent on research grants to investigate and catalogue the levels of pollution from aquaculture and tourism, the decline of biodiversity, the invasion of alien species, and so on. We have conferences and we talk among ourselves, but we lack the means properly to communicate with the public at large, the voters who (in theory at least) may have some influence on the behaviour of governments and public bodies. Even when we talk among ourselves, however, the audience is limited. As one speaker caustically pointed out, the invited lecturers didn't all stay to hear the other lectures!

A final Open Meeting was held almost literally in the shadow of the Acropolis, at the headquarters of the Hellenic Society for Protection of the Environment and Cultural Heritage. During discussion it became apparent that there is rapid turnover among Brussels officials and bureaucrats and therefore no continuity of experience. Equally worrying was news that civil servants at Brussels have heard of fish and phytoplankton, but not of zooplankton; so they see little point in funding long-term plankton surveys! (Hence the need for more scientists to get involved in administration.)

Perhaps the time-keeping was not as crisp in Athens as at Plymouth but there were many excellent features – the talks and posters were of high quality, the food and drink were great, and most of all there was the opportunity to exchange information and ideas.

At the formal General Assembly of the EFMS, ably chaired by the President (Graham Shimmield), it was agreed that the next Assembly will meet at Nice in 2003. The next EFMS conference will be in 2004.

Defining the Role of the EFMS

The EFMS represents 8 societies and about 5000 marine scientists, but to be useful it must be more than the sum of its parts. At the conference there was, naturally, extended discussion about the role of the EFMS, both within Europe and within individual member countries, and the role of individual societies within the EFMS.

Here are suggestions for key roles for the EFMS, which arose during discussion:

- It should facilitate coordination of research and co-operation between European marine scientists generally.
- It should work to make the relationship between marine scientists and Brussels more productive.
- It should have an interdisciplinary outlook, and have a special role with respect to pollution, coastal zone management, offshore development, fisheries, Marine Protected Areas, aquaculture and biotechnology.

What do Ocean Challenge readers feel that the role of the EFMS should be?

And what practical help should the EFMS offer national societies in promoting fruitful interactions with their governments?

Please write and let us know your views, about the EFMS and marine science in Europe generally.

Challenger Society for Marine Science

ANNUAL REPORT 2001–02

Message from the President, Professor John Shepherd

The end of the 99th year of the Challenger Society is imminent, and our centenary celebrations will commence with the Centenary Conference which is being held in Plymouth, just a few months early. We are planning other events during 2003 itself, and we especially hope to encourage local groups to organise events to mark the occasion. There will of course also be one of the new Challenger Lectures, and nominations for the speaker (and the venue) are now invited. This year's Challenger Lecture will be given during the Plymouth meeting by Prof. Mike Fasham, who has been awarded the Challenger Medal for 2002, and to whom we offer warm congratulations. Congratulations also to the four members newly elected as Fellows of the Society, as reported below.

Membership of the Society still remains low by comparison with the number of scientists professionally trained and employed in the field, and even more so in comparison with the number of people who are just generally interested in marine science. We need new ways to promote our society, and to a wider audience. My exhortations to you to recruit your colleagues have not been sufficient, but I remain convinced that personal recommendation can be very effective and encourage you to continue. An important development this year is the emerging possibility of a formal relationship with the newly reconstituted Institute of Marine Engineering, Science and Technology (IMarEST). This is dealt with in more detail below.

During the year we have streamlined the work of Council by discontinuing its committees (which recently have rarely met in the flesh), and instead we have assigned responsibility for the relevant activities as portfolios to individual Council members, creating a cabinet-style structure. This is intended to make it easier for you to know who is responsible for what, and who to approach for information, or to get something done. These responsibilities are listed below. We still get remarkably little feedback from individual members (except during the conference itself), and we would welcome more, so please communicate your views and ideas to the relevant member of Council whenever you wish.

As you will know, we increased both the number and the amount of Travel Awards for postgraduate students last year, but these are not yet over-subscribed. This is in my view one of the most positive and worthwhile activities of the Society, and Council may well further increase the modest budget for these small but helpful grants if demand increases. These are dealt with by Duncan Purdie who handles the Education portfolio, and rules and regulations can be found on our website.

This year also marks an important event for the EFMS (European Federation of Marine Science & Technology Societies) of which CSMS is a founder member, as they are holding their first conference in Athens in late September. To celebrate the occasion a special European issue of *Ocean Challenge* has been produced, and will be distributed to members of all the societies affiliated to EFMS. This has meant a special effort by our editorial team, Angela Colling and John Wright, and skilful negotiations by the chair of the Editorial Board, Tim Jickells. We thank them all.

I would also like to record here our thanks to Fauzi Mantoura and his team in Plymouth for all the work they have done in organising the Centenary Conference. These biennial meetings are the high points of the activities of the Society, and their continuing success is achieved only through the efforts of the local committees who make them happen, to whom we are most grateful

Finally, I would like to thank all the members of Council for their work on behalf of the Society, and especially for their support during what became a difficult year for me personally. I hand over the Presidency to Richard Burt with every confidence that he will lead the Society enthusiastically through what promise to be interesting times ...

John Shepherd

Summer 2002

Membership

Total membership at 15 July 2002 was 374, including 254 Full members, 58 Student members, 4 Honorary members, 48 Retired members and 5 Corporate members (= 10 individuals). In January 2002, 145 members did not renew their membership (72 Full members, 72 Student members and 1 retired member), while 25 new members have joined since January 2002 (21 Students, 3 Full and 1 Retired).

Concern has been expressed by Council members at the decline in membership in recent years and discussions were held concerning the benefits of membership and methods for increasing enrolment. While membership is relatively high at some institutions (e.g. SOC), there is a need to increase enrolment at other sites where there is a large potential membership. Among the suggestions for increasing the membership were: improved awareness, particularly among younger potential members; the creation of a young scientist network; increased publicity/presence of the CSMS at the Conference and sponsored meetings; increased registration costs for non-CSMS members at the Conference and other meetings; the arranging of local meetings in regions where there are concentrations of members; and a two-year membership linked to the Conference.

Recent developments at IMarEST have focused the attention of Council on the benefits that are derived from membership of the CSMS. In addition, consideration was given to the effect that an aggressive recruitment drive by IMarEST might have on the membership of CSMS. Encouragingly, discussions have taken place between CSMS and IMarEST concerning the creation of an umbrella organisation for the promotion of marine science and for reciprocal or joint membership arrangements.

Council membership and responsibilities

Since the last Annual General Meeting, which took place on 12 September 2001 in Norwich, the Council of the Society has met three times, on 6 February 2002, 15 May 2002 and 12 September 2002. The Council members, their terms of office, and their responsibilities during 2001–2002, were as follows:

Officers

Prof. J. Shepherd	2000–2002	President
Mrs N. Lane	1997–2003	Honorary Treasurer
Ms J. Read	1999–2006	Honorary Secretary

Council Members

Dr K. Black	2000–2003	
Prof. P. H. Burkill	1999–2002	
Mr R. Burt	1999–2002	Marketing & Publicity (President Elect)
Dr S. Cornell	2000–2003	Membership/fellowship Structure
Prof. A. Elliott	2000–2003	Membership & Recruitment
Dr H. Kennedy	2001–2004	
Dr J. Priddle	2001–2004	Meetings & Specialist Groups
Mr P. Ridout	2001–2004	
Dr D. Purdie	2001–2004	Education

The following served as ex-officio or co-opted members of Council:

Mrs J. Jones	Executive Secretary & Membership & Marketing
Ms A. M. Colling	Editor, *Ocean Challenge*
Mr J. B. Wright	Associate Editor, *Ocean Challenge*
Dr J. Allen	Editor, *Challenger Wave*
Prof. T. Jickells	Chair, Editorial Board, *Ocean Challenge*

Peter Burkill and Richard Burt retire from Council at the 2002 AGM and are sincerely thanked for their enthusiasm and commitment to Council and the Society. Richard Burt continues as President.

Awards

The Society is pleased to award the Challenger Medal to Professor Mike Fasham for his contribution to advances in biological oceanography. Four new Fellows have been elected for their contribution to marine sciences; Dr Chris Hughes (POL), Dr David Marshall (Reading University), Dr Carol Robinson (PML) and Dr Toby Tyrell (SOC).

The Society made four travel awards to students in 2001/02: Paul Crozier (University of Highlands and Islands) attended the 5th Annual Meeting of the European Elasmobranch Association, Kiel, Germany, October 2001. Claire Mahaffey (Liverpool University) attended the Gordon Research Chemical Oceanography Conference, August 2001. Lucy Horton (Edinburgh University) received some support for carrying out research on the Marshall Islands. Awards of £50 were also paid to Helen Johnson and Jeff Polton.

Policy

The main policy issue of concern to the Society has been the reconstitution of the former Institute of Marine Engineers as the Institute of Marine Engineering, Science and Technology (IMarEST), which was approved by the Privy Council earlier this year. The new Institute (which is very much larger than CSMS, with premises in London and a substantial professional staff) has adopted a much wider mission, consistent with the new name, and is actively promoting its involvement in marine science. This constitutes both a potential threat and a possible opportunity for the Challenger Society. In particular, IMarEST has already established a scheme for the designation of Chartered Marine Scientist (C.Mar.Sci.) which is likely to be of interest to some CSMS members. This would provide an alternative route to professional accreditation to that (via the Science Council) which we had been considering, which is not yet operational. Together with the Society for Underwater Technology we are now exploring the possibility of some formal relationship with IMarEST, and have invited a representative to explain developments to our members during the Plymouth meeting. Any proposals which may emerge will of course require formal approval by the membership in due course.

Education

Duncan Purdie joined CSMS Council in February 2002 and has accepted portfolio responsibility for Education. He has also recently been asked to join the Society for Underwater Technology, Education and Training Committee. In addition, he is representing CSMS Council on the IACMST Informal Committee of Marine Society Education Spokesmen. This latter group is organising a two-day Schools Education day in December 2002 at the Royal Observatory Greenwich.

Ocean Challenge

Vol. 11, Nos. 1 to 3 have been published over the last year. In addition, much of the Editorial Board's effort has gone into the production of a special 48-page European issue, which has been put together in association with EFMS. This initiative has been pushed forward particularly by two members of the editorial board, Karl Hesse and Hjalmar Thiel, who have worked extremely hard throughout the year to realise this particularly ambitious issue, alongside our magnificent editors.

The special European issue (Vol. 12, No.1) is being mailed in mid-September (shortly after the most recent 'normal issue') and will be available at the EFMS 'Sustainable Mediterranean' Conference in Athens. Each EFMS member society will receive 50 copies to send to government bodies, and most of the European societies are also mailing copies to individual members. Within the UK, copies will be supplied to SAMS and SUT, as well as to IMarEST (the Institute of Marine Engineering, Science and Technology). This represents a very large increase in our print run with attendant reductions in cost per issue and with no additional costs falling on CSMS.

For Vol. 12, we have a new cover design, which should be easier to update, and which enables us to accommodate the EFMS logo.

Challenger Wave

Thank you to all those who have submitted interesting articles and reminders about forthcoming conferences and employment opportunities. The sponsorship of individual issues by RS AQUA Ltd. and IWA publishing is much appreciated by the Society, thank you. Again, *Challenger Wave* would not be possible without the support of Jenny Jones who carries out the mail and email shots and has pioneered its publication on the Web; many thanks Jenny. As John Allen reaches the end of his term as editor of the newsletter he reports that editing the newsletter has been fun and recommends the task to anyone who might be interested in succeeding him.

Meetings

The 2001 AGM of the Society took place at the University of East Anglia on 12 September 2001. The Society has also provided support for other meetings during the year, including those noted under the report on Special Interest Groups. Some other meetings were focussed specifically on postgraduates, an area where the society wishes to place further emphasis. A full list of marine sciences meetings, including those sponsored by CSMS, is published in the diary section of *Challenger Wave.*

The UK Moorings Group held its first meeting in March 2002 – see the meeting report in a forthcoming issue of *Ocean Challenge*. An international workshop and conference on 'Benthic dynamics: *in situ* surveillance of the sediment–water interface' was also held in March – see http://www.adbn.ac.uk/ecosystem/conference. Postgraduates in marine science were served by two meetings; the 10th Postgraduate Research in Marine Earth Sciences meeting – see http://www.soton.ac.uk/~pmcleod/; and the Marine Biology Postgrad Workshop.

Special Interest Groups

Special Interest Groups are long-term activities of the society which provide foci for specific aspects of marine science. The Challenger Society supports four Special Interest Groups (SIGs) at present, one of which is also a sub-group of another society. Support for the groups is mainly in the form of a two-year grant for meetings. In the years of Challenger Conferences, SIGs normally combine their meeting with the conference, reserving funding for the inter-conference year.

The four groups are:
the British Group of Altimeter Specialists (contact Trevor Guymer: thg@soc.soton.ac.uk or Graham Quartly: gdq@soc.soton.ac.uk);
the Ocean Colour Group (joint with the Remote Sensing and Photogrammetric Society) (contact Samantha Lavender: S.Lavender@plymouth.ac.uk);
the Marine Chemistry Discussion Group (contact Peter Statham: Peter.J.Statham@soc.soton.ac.uk); and the Ocean Modelling Group (contact George Nurser: g.nurser@soc.soton.ac.uk). The Marine Chemistry Discussion Group held its meeting 'Progress in Chemical Oceanography' (PICO) in Bangor in September 2001. The Ocean Modelling Group also met in September 2001, in Reading.

Proposals for other SIGs will be considered by Council. Their area of interest should fall within the scientific remit of the Challenger Society, and should represent a coherent grouping of marine science specialists.

Marketing

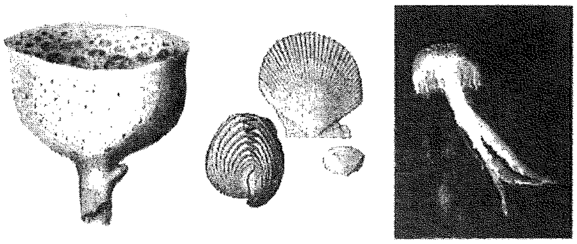
During the year, the marketing and promotion of the Society have been through the traditional routes of exhibitions, conferences (UK and Oceans 2002 in Hawaii) and publications. Over the last two years much effort has gone into providing better, more defined, products for our members. *Challenger Wave* is an excellent example of this. Not only has it been a regular source of high quality information, it has also made industry and sponsors more aware of the Society. It is important that we continue to strengthen our UK base and explore overseas opportunities. To attract overseas members we have begun appointing representatives in laboratories. This has been a slow start, which we shall build on in 2003. Marketing of the Society has usually been to increase membership. With the milestone of the centenary conference we need to promote the Society as the key influential organisation for marine science, and scientists, in the UK. The council is assessing whether the Society should form some relationship with the Institute of Marine Engineering, Science and Technology. Discussions have been held over several months but are still at an early stage. It is an interesting opportunity and more will be reported at the AGM.

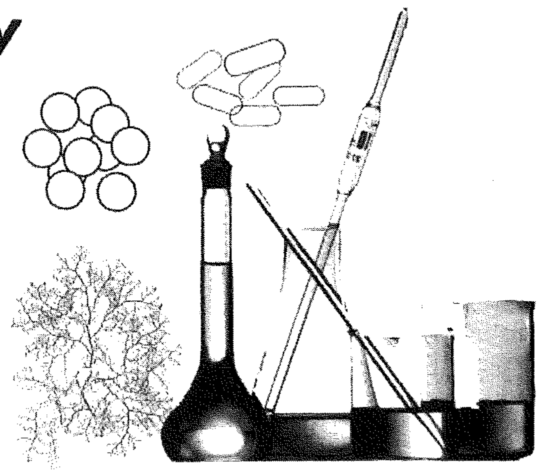
Finance

2001 saw an excess of income over expenditure of £3,210, inclusive of depreciation, compared with a budgeted loss of £572. However taking into account the losses on the investments held within the COIF Charities Fund, due to the current financial climate, an unrealised loss on investments of £5,237 must be added to this. This gives the Society an effective loss for year 2001 of £2,027. Subscription income was increased from year 2000 (£9,581) due to a rise in fees giving a total income of £14,710 against a budget of £18,550. The donation from Southampton Oceanography Centre was gratefully received, plus donations by POL and PML were reinstated at £1000 each. Regarding expenditure, savings were made by Council, in travel, subsistence and the meeting expenses. The publication of the journal plus printing, postage and stationary costs appear to have increased significantly in comparison to the 2000 figures. The explanation for this is that in 2000 the publication costs for the journal were low due to two of the 2000 issues being produced in 2001. Council took the decision that in order to be able to complete the accounts more promptly following year end, costs for the publications should be recognised in the year in which they occur, and not in the membership year to which they relate. Years 2000 and 2001 saw the transition to this new policy. *Challenger Wave* has been very well received and has generated income of £250 through sponsorship. During the year £560 was awarded to students who had applied for travel grants, plus the award of £75 was made to the Open University Oceanography student of the year.

Taking all the above into account, the Society is keeping its expenditure in line with the income, but this is helped significantly by the SOC, PML and POL donations. More membership and increased advertising should remain key issues, as these will both raise our profile and be self-perpetuating in our efforts to grow. The Society must also keep an open mind regarding IMarEST to ensure this is addressed as a potential benefit to us.

Marine Biotechnology
can it compete with terrestrial biotechnology?





Graham Shimmield

In recent decades our inclination to explore the oceans, and our freedom to do so, have been set aside in favour of rigorous process studies and hypothesis-testing. Arguably the spirit of exploration has been a casualty of modern funding structures for marine science. However, new programmes such as the Census of Marine Life (funded by the Sloan Foundation), and the work of the Office of Ocean Exploration (managed by the US National Oceanic and Atmospheric Administration, NOAA), should start to reverse this trend. Areas like marine biotechnology stand to gain enormously from the combined efforts of larger multinational exploration programmes, as long as the vision and foresight of national agencies can be focussed on the potential significant benefits to society.

The more we have explored the ocean, the more we have come to realize that the vast majority of marine organisms, primarily at the microbial scale, have yet to be isolated, identified and characterized. These organisms possess unique characteristics that allow them to cope with an enormous range of environments which, given our largely two-dimensional terrestrial life at constant atmospheric pressure, we find hard to comprehend. For example, the deep ocean environment encompasses extremes of pressure, heat (hydrothermal vents), energy (waves and tides) and light, and provides challenges to organisms dependent on episodic food supply and subject to fierce predation. Many organisms have developed highly efficient sensory organs, potent toxins to deter predation, and advanced antifouling or adhesion techniques. These biochemical and physiological adaptations represent a huge range of potential processes for development in commercially exploitable products.

Representatives of every phylum are found in the sea, with twelve phyla being exclusively marine (cf. Table 1), though there is considerable disagreement over the number of marine species, with perhaps as many as 200 000 species waiting to be described (excluding micro-organisms); the famous work of Grassle and Maciolek (see Further Reading) estimates undescribed marine species at 10 million! On land the number of species is not too well known, although the total number has been estimated at between about 1.5 and 5 million or more. The terrestrial world is dominated by insects (750 000 species) and vascular plants (250 000 species) in contrast to the 50+ species of oceanic flowering plants and 12 000 to 13 000 species of algae. John Parkes and colleagues have suggested that the total biomass of oceanic subsurface bacteria could constitute as much as 10% of the total living biomass carbon of the biosphere. Each species of organism on land, in the oceans and in the sediments and rocks of the ocean floor, represents a living reservoir of potentially useful substances.

Oceanic biodiversity, and hence the potential for the discovery of new bioproducts, is not evenly distributed amongst the major ocean basins. As in the terrestrial biosphere, oceanic diversity appears to decrease polewards, although this is the subject of current research programmes. The Indo-Pacific region has the highest diversity in shelf seas, while in the Atlantic, the Caribbean region sustains greater diversity than the equatorial African margin. Benthic organisms display greater diversity than their pelagic counterparts, the greatest diversity being found in coral reefs and in the dark, deep-sea benthic realm.

This article is adapted from a paper presented at the Greenwich Forum, 3–5 April 2002: Maritime World 2025: Future Challenges and Opportunities (published on CD-ROM).

Table 1 *Number of higher animal taxa in the three main world ecosystems*

Taxon	*Marine*	*Terrestrial*	*Freshwater*
Phyla	*31*	*14*	*16*
Classes	*85*	*28*	*35*

Most large animals in the sea are carnivores, marine autotrophs and herbivores often being microscopic in size. Characteristically, the marine food chain has five trophic levels, in contrast to the terrestrial food chain with three. This difference between basic food chains in the marine and terrestrial biospheres is of great significance for the future of marine biotechnology. In the context of mariculture, humans mainly consume marine protein that comes from the third or fourth trophic level (salmon and tuna), whereas protein from large terrestrial herbivores comes from the second trophic level. Furthermore, in the oceans, simple organisms may be part of complex food webs and have therefore developed specialised defence mechanisms.

Despite the large untapped resource of biodiversity in the oceans, and the considerable differences in trophic status and energy flow, only a few species have been studied for their biotechnological applications. From these few species several thousand chemical compounds have been isolated, but only a very small percentage of these compounds have been tested for clinically relevant bioassays.

The origins and development of marine biotechnology

Defined simply, marine biotechnology is the use of marine organisms, or their chemical and structural components, in industrial or commercial products and/or processes. A wide range of scientific disciplines can be harnessed to produce the commercial product or process, and usually involve the following fields: biochemistry, molecular biology, chemistry, botany, zoology and ecology.

The potential for natural marine products as pharmaceuticals was first realized by Bergmann in the 1950s. This work led to two marine-derived pharmaceuticals that are still in use today: Ara-C, an anti-cancer drug (used against acute myelocytic leukemia and non-Hodgkin's lymphoma); and Ara-A, an antiviral drug for treating herpes. Both were derived from natural compounds found in sponges off the coast of Florida (Table 2). Sponges are truly cosmopolitan, and can be found from the intertidal zone to the deepest abyssal depths, and from the tropics to the poles. They produce a great variety of chemical compounds, more than any other group of marine invertebrates, and have provided over 30% of the 5000+ chemical compounds derived from marine organisms to date.

Uses of compounds derived from marine organisms have of course been recorded since much earlier times, from the Tyrian purple dyes of ancient Rome and Greece (from the molluscs *Purpura* and *Murex*), to the alkali industry based on the harvesting of kelp in Scotland. The latter represents the first marine biotechnology commodity in Europe, which as a result of various trade embargoes, saw Scottish kelp rise in value from £3 per ton in the 1780s, to £10 per ton in the 1790s to over £20 per ton at the turn of the 19th century.

Terrestrial micro-organisms (primarily derived from soil) have provided the principal resource for the discovery of new drugs, and since the discovery of penicillin in the 1920s, a wide range of antibiotics, anti-cancer drugs, and immunosuppressants have been developed. However, there remains a large untapped reservoir of microbial diversity – in the oceans. In the 1950s, less than 5% of marine bacteria could be cultured, but the situation is now changing rapidly, with research programmes into marine extremophiles, e.g. hydrothermal vent microbial communities, and microbial communities living in highly polluted coastal and shelf-sea sediments.

Marine bioactive compounds are now being investigated for their potential as chemical probes. This approach allows non-drug substances to be used to investigate the basis of biochemical events. Examples include the use of potent marine neurotoxins to study nerve transmission, dinoflagellate toxins for inhibition of phosphatases (involved in cell signalling) and a unique sponge metabolite which inhibits intracellular molecular protein pathways. Most recently, Vent™ DNA polymerase has been isolated from microorganisms living around deep-sea hydrothermal vents. This is essential for a technique known as Polymerase Chain Reaction (PCR), which is used for the amplification of very small amounts of DNA or RNA, the basic process behind the gene-mapping of the Human Genome Project. PCR requires enzymes that are stable at high temperature, precisely the conditions to which the Vent™ DNA micro-organism has become adapted.

Nutraceuticals, or nutritional supplements, are a major growth area. Marine microalgae are known to produce high levels of the fatty-acids docosahexenoic acid (DHA) and arachidonic acid (ARA), both of which are found at high levels in breast milk. Because these polyunsaturated fatty acids (PUFAs) have been linked to brain grey matter development, they are regarded as an important nutritional supplement, especially for infants.

How has marine biotech developed to date?

Table 2 (*opposite*) lists a range of commercial products produced by marine biotechnology, their areas of application, and the organisms from which they are obtained. On the international stage, the USA has at least five marine biotech institutions (Marbec, Scripps, Harbour Branch, COMB, Woods Hole), and there are also centres in Australia (AIMS), Japan (Kamaishi and Shizuoka) and Germany (Greifswald). In Europe, the UK generally leads in terrestrial biotechnology but despite its island status, and relatively easy access to a huge range of shallow and deep-sea environments, it has not recognized the importance of marine biotechnology. Recent developments in Scotland, including the setting up of the European Centre for Marine Biotechnology (ECMB) (discussed later), aim to remedy this deficiency through a coordinated research and commercial incubator facility to link the scientific effort to the early phase of product identification, isolation and scale-up (further details below).

Shirley Pomponi (see Further Reading) identifies four key challenges for marine biotechnology: (1) to identify new sources of marine bio-products; (2) to develop novel screening methodologies; (3) to find sustainable sources of supply; and (4) to optimize the production and recovery of the bioproducts.

At present, the typical biological evaluation of marine products is very traditional and lacks a good understanding of marine ecology and physiology. For instance, none of the assays used in terrestrial biotech drug discovery programmes takes into account the role of marine-derived compounds as primary and secondary metabolites. There is tremendous potential for using secondary metabolites (those metabolites that have additional functions and are not simply excretory products) in treatment of human diseases; for example, toxins produced by cone shells have been used in the development of new drugs (Table 2).

Over the past few years the development of bioreactor technology has started to come of age. Bioreactors are industrial-sized fermentation flasks containing bacteria modified by the addition of genes from the organism in question, along with a culture medium plus nutrients/gases; they are usually operated at relatively high temperatures and/or pressures to allow the reactions to proceed fast. Reactors are generally of flow-through design, allowing the products of interest to be collected easily.

This area of bioprocess engineering offers huge potential to unleash the full capacity of marine biotechnology for the optimization of marine metabolite production. By manipulating culture conditions, the process engineers working with the marine biotechnologists will be able to develop the bulk production of novel marine bioproducts.

Figures for the growth of marine biotechnology are notoriously difficult to acquire and verify, because of the huge potential growth of the market, and the degree of enthusiasm shown by its proponents. In the USA, NOAA estimated that sales of all biotechnology products rose by 17% in 1998 to $13 billion, with a prediction of reaching $24 billion in 2005. However, the USA is investing only 1.2% of its total federal biotech research funds into *marine* biotechnology – $40 million compared with $519 million in Japan, where the research agency recently identified marine biotechnology as 'the greatest remaining technology and industrial frontier'.

Biotechnology as a growth industry

As an industry, biotechnology started in the early 1980s and rapidly drew on the capability of the public sector research base to sustain and develop the initial discoveries. Over the last two decades, huge strides have been made in molecular biology and biochemistry, with automated screening procedures for novel active natural products becoming the mainstay of terrestrial biotech. In addition, our ability to sequence the human genome (at a cost of over £100 million) and certain other model organisms, along with improved knowledge of pathology at the cellular and molecular level, will allow us to identify a whole range of disease-specific target molecules against which to screen potential drugs.

Although rapid discoveries can be made, the long gestation through research, pre-clinical and clinical trials (7–10 years in the pharmaceutical sector) was not initially well recognized by investors. The major pharmas are under intense pressure from their shareholders to maintain a stream of blockbuster products; so active R&D programmes must be maintained by collaboration or assimilation. As a result, new operating procedures involving mergers and takeover of assets have become the *modus operandi* of the major pharmas. External sourcing of new drug leads, out-sourcing of

Table 2 *Examples of commercially available marine bioproducts.*

Product	Application	Original source
Ara-A*	Antiviral drug	Marine sponge (*Cryptotethya crypta*)
Ara-C*	Anticancer drug	Marine sponge (*Cryptotethya crypta*)
Okadaic acid	Molecular probe: phosphatase inhibitor	Dinoflagellate
Manoalide	Molecular probe: phospholipase A2 inhibitor	Marine sponge (*Luffariella variablis*)
Vent™ DNA polymerase	PCR enzymes	Deep-sea hydrothermal vent bacterium
Formulaid™	Fatty acids in infant formula nutritional supplements	Marine microalgae
Aequorin	Bioluminescent calcium indicator	Bioluminescent jellyfish (*Aequora victoria*)
Green fluorescent protein	Reporter gene	Bioluminescent jellyfish (*Aequora victoria*)
Phycoerythrin	Conjugated antibodies used in flow cytometry	Red algae
Resilience™	Marine extract additive in skin creme	Caribbean gorgonian (*Pseudopterogorgonia elisabethae*)
Pseudoterosin	Anti-inflammatory agent	Sea whips
Kainic acid	Anthelmintic insecticide	Red alga (*Digenea simplex*)
Ziconotide	Analgesic	Cone shell (mollusc) (*Conus magus*)

*Ara-A and Ara-C are arachidonic acids.

With over 600 biotech companies, the UK is the European leader in (terrestrial) biotechnology

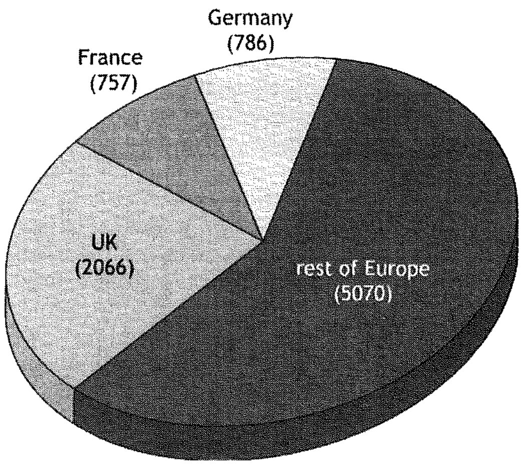


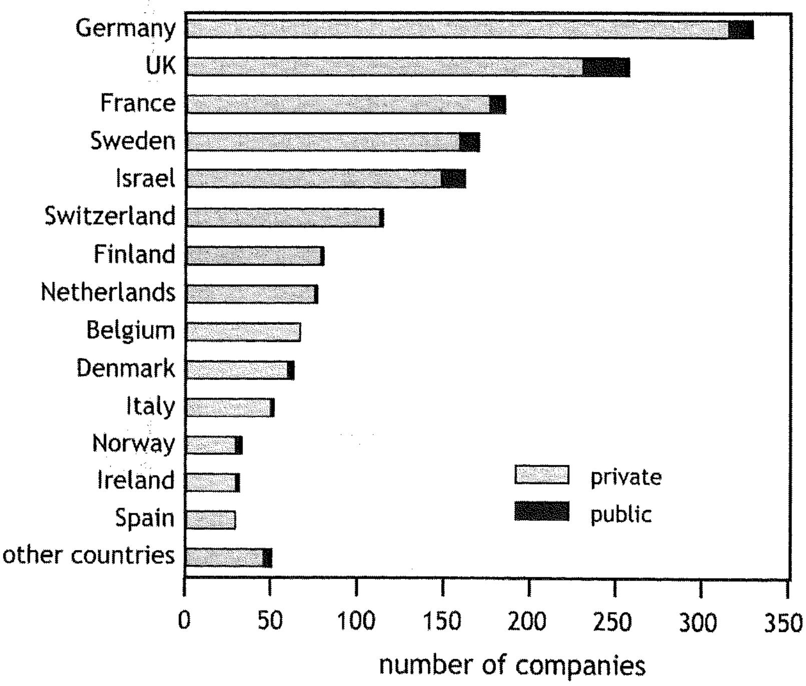
Figure 1 European revenues from (terrestrial plus marine) biotechnology by country. Values in millions of Euros. (From Ernst & Young, 2001)

technical requirements (bioinformatics) and joint venturing and licensing are now all commonplace. In the USA, more than half the drugs in clinical trials originated outside the laboratories of the large pharmaceutical companies.

The conventional (terrestrial) biotechnology field has developed quickly. The UK has over 600 companies, making it the leading biotech nation in Europe (Figure 1). However, Germany is rapidly gaining ground as a result of substantial state and federal investment in its public and private R&D base, leading to rapid expansion in the number of small and medium-sized biotechnology companies (Figure 2). Nonetheless, European biotechnology is rather small in comparison to the USA where the big pharmas have established a biotechnology industry

In Germany, biotech is benefitting from substantial state and federal investment

Figure 2 Numbers of small- to medium-sized European biotechnology companies started up in 2000–2001. (From Ernst & Young, 2001)



worth over $69 billion with associated investment from venture capitalists rising from $667 million in 1998 to $1040 million in 1999. One single US biotech company, Amgen, is only slightly smaller than all Europe's publicly quoted biotech companies put together.

Legal and moral issues

In the eyes of many members of the public, biotechnology has become synonymous with genetic modification of organisms (GMO). Other aspects of biotechnology, such as synthesis of natural products and waste remediation, are generally 'acceptable'. Even though GMO applications and field trials are under huge scrutiny from NGOs such as WWF, there remain significant grand challenges and opportunities in the marine biotechnology arena. In September 2000, Professor Yonathon Zohar (COMB, University of Maryland) presented a paper to the International Marine Biotechnology Conference in Queensland, Australia, arguing that as marine fisheries collapse, GM fish farms will be the only way to produce enough seafood protein. Already GM salmon are being produced in Canada, and genetics-based research into salmon growth rates is being carried out in Scotland (cf. *Ocean Challenge*, Vol.10, No.1, p.3). However, the rate of genetic developments in aquaculture is such that some marine scientists, including Peter Balint, have argued that the regulatory authority in marine biotechnology is poorly defined and ill-prepared. Balint is concerned that the science is still insufficiently well advanced to carry out proper risk assessments of GMO work (see Further Reading); he argues that government funding agencies must pay attention to the basic and applied research programmes in marine ecology necessary to understand the development of marine biotechnology. Each government should also set up the appropriate regulatory body as a matter of urgency, thereby allowing the full potential of marine biotechnology to be realized under appropriate ecological risk assessment and management.

The other major factor in developing marine biotechnology is the need for sustainable use of natural resources. It is vital that an industry is created that has a primary obligation to develop only those bioproducts that can be supplied or manufactured without perturbing the marine ecosystem or depleting living resources. Often, the active biomolecule occurs in very small amounts in the living organism, rendering natural harvesting impractical. However, marine aquaculture techniques and chemical synthesis methods have developed to such an extent that synthesis and production should soon become possible. The 'exploration frontier' for natural marine products is moving into deeper water, and even here it is possible to develop aquaculture techniques to a satisfactory level – for example, the deep-water sponge, *Lissodendoryx*, is being grown in New Zealand for harvesting anti-tumour compounds (halichondrins).

From the perspective of legal and intellectual property rights, marine biotechnology faces some difficult challenges. The *Convention on Biological Diversity* (*CBD*) and the 1982 *Law of the Sea (LoS) Convention* govern access to resources and organisms in the oceans and on the sea-bed. Under Article 56, in the 200-mile Exclusive Economic Zone of a maritime nation, 'the coastal State has sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living'. The *LoS* Convention enables the benefits of scientific research to flow to developing countries as long as advance permission is granted to the researcher nation (Articles 237–265). However, there is an important need to clarify the situation as far as bioprospecting within EEZs is concerned, because the *CBD* has a rather different approach, calling for conservation of biological diversity and the fair and equitable sharing of benefits from exploiting genetic resources. This convention recognizes the sovereign rights of nations to control access to their genetic resources, requiring the users of these genetic resources to share the benefits and technology with the provider of the resource. Although such terminology may have been aimed at the conservation and management of fish stocks, further restrictions on marine science in general may be imposed. There is also the vexed question of Intellectual Property Rights (IPR) within the *CBD* between the developed and the developing countries. The developed countries want strict IPR agreements on biotechnology discoveries to protect their huge investment, whereas the developing countries complain of inequitable sharing of benefits and lack of technology transfer in exchange for use of their genetic resources.

There remains, therefore, a significant legal and moral challenge to encourage fair and equitable marine biotechnology agreements around the world. Novel forms of agreements to govern bioprospecting are being negotiated in different countries, between biotech companies, governments, NGOs and the public. As some of the most promising finds may come from below the high seas (e.g. on mid-ocean ridges), the responsibility to confer benefit, whilst conserving the resources and protecting the right to conduct multidisciplinary research, at present lies squarely on scientists' shoulders.

What future for marine biotechnology in the UK?

Scandinavia is becoming a major centre for Europe's bioscience industry. This success results from the unique Scandinavian approach that has produced companies like Ericsson and Nokia. Essentially, four main prongs of strategy can be identified: strong government funding for universities and start-up companies; expansion of venture capital markets; a highly skilled work force produced by well-funded universities; and structural incentives to promote an entrepreneurial approach.

Of these, the key strategy has been the support of public research in universities, and the development of science parks. The Swedish government has provided 425 million Euros to fund medical and biotech research in universities and business enterprises. Its approach has been to assign the commercial rights of a discovery to the researcher, rather than the university. This so-called Teacher Exception Rule has produced rapid growth in the number of patent applications and has stimulated entrepreneurial activity to a high degree.

In the UK, the strategy for development of marine biotechnology is being carried forward in two areas, based on the Scandinavian model. First, there is the concept of an 'enterprise incubator', a facility providing start-up companies with the infrastructure needed for research

The new European Marine Biotechnology Centre at Oban will be closely associated with the Scottish Association for Marine Science

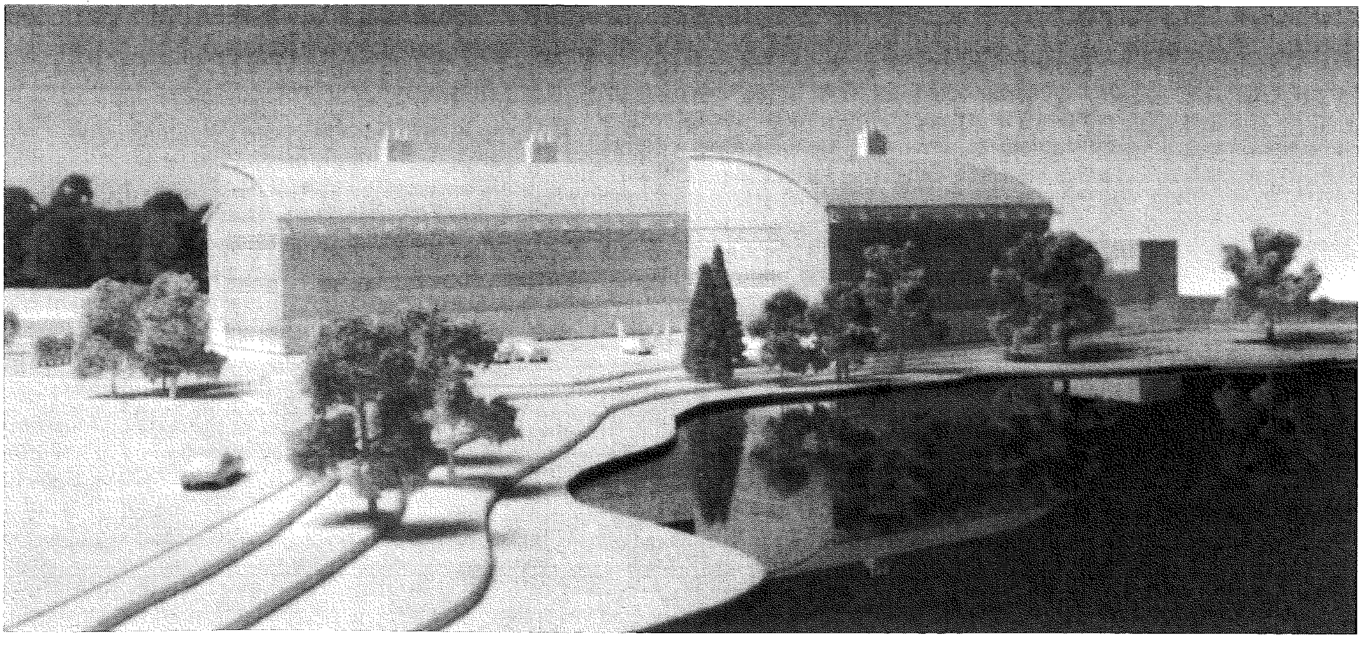


Figure 3 *A model of the new research complex being built by the Scottish Association for Marine Science on the Dunstaffnage site. The new European Centre for Marine Biotechnology will be housed in the wing at centre-right.*

and development (boats, aquaria, library, IT etc.). Creation of such a facility, in close proximity to a major marine science institution, is underway at Dunstaffnage, near Oban, Scotland. Here, the European Centre for Marine Biotechnology will provide the infrastructure to link the science base of the Scottish Association for Marine Sciences with the inward investment and regional development strategy of Highlands and Islands Enterprise. The second part of the strategy is the setting up of associated marine science and technology parks with purpose-built manufacturing facilities.

Ultimately, marine science parks will act as a magnet for growth in the marine sciences, biotechnology and applied aquaculture sectors. At the UK level, the Marine Foresight Panel has established a Task Team to evaluate and identify priorities for marine biotechnology growth and development. Such a strategy will inform the DTI, RDA and Enterprise networks. By creating a sound strategic set of objectives for marine biotech development, the UK will be well placed to take full advantage of its overall biotech lead in Europe. As an island nation, with an EEZ extending well out to the abyssal ocean depths beyond Rockall, and encompassing a range of conditions from the sub-Mediterranean climates of the Scilly Islands to the sub-Arctic conditions of NW Scotland and Shetland, the UK has huge untapped potential for the discovery of marine organisms which could provide a reservoir of natural products necessary to develop a marine biotechnology industry in a sustainable manner.

Concluding thoughts

This review has demonstrated the role and value of marine biotechnology to our society in the 21st century. The oceans remain a frontier for exploration and discovery, despite the enormous expenditure on missions to outer space. This frontier is likely to provide the raw materials (organisms, bioproducts, bioengineering techniques) for a new sustainable approach to biotechnology. Human demands for health care, nutraceutical products and bioprocess engineering, as well as marine protein, require us to address the opportunities that the sea provides in a considered but innovative, manner. We still need to establish appropriate legislative, legal and intellectual property rights to this resource, which will meet the approval of the public.

The UK has a good record in biotechnology, and a sound research base on which to develop. Despite an overall fragmentation of marine research strategy and policy in the UK (in common with several other countries, perhaps with the notable exception of Ireland), marine biotechnology offers major potential for establishing a sustainable industry. The first steps in implementing this strategy have been taken by the Marine Foresight Panel and the European Centre for Marine Biotechnology.

Acknowledgements

I would like to thank Moya Crawford for her assistance in clarifying issues surrounding the Law of the Sea Convention, and for proof reading the manuscript.

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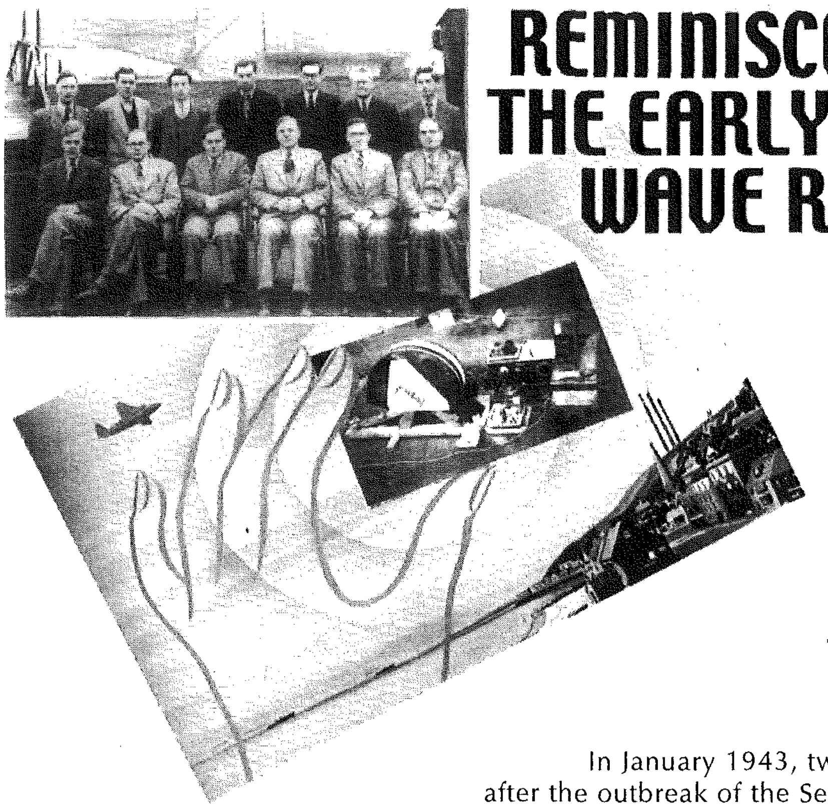
Graham Shimmield is the Director of the Scottish Association for Marine Science based at the Dunstaffnage Marine Laboratory near Oban. His research interests encompass the palaeoceanography of upwelling systems, tracing the history of ENSO variability using the geochemistry of massive corals, and more recently, the marine geochemistry and radiochemistry of the Arctic. Currently, he is Chair of a Task Team of the Foresight Marine Panel planning the future of Marine Biotechnology in the UK.

REMINISCENCES ON THE EARLY DAYS OF WAVE RESEARCH



Jack Darbyshire

In January 1943, two and a half years after the outbreak of the Second World War, I joined the Admiralty Research Laboratory, Teddington, where I was assigned to Group H under Stephen Butterworth. The 'H' stood for hydrodynamics, but in my time hardly any work was done in that subject, and most effort was directed at the magnetic detection of submarines and similar objects. However, by 1944, it had become vital to study the ocean for its own sake, particularly the action and formation of sea waves.

'W' for Waves

While in Group H, my co-worker, Norman Barber* and I were concerned with trying to detect rather small 'iron objects' which could be sent into harbours. To do this we had big wire loops on the sea bottom and the magnetic effect of the 'objects' would send a current through each loop which we could detect. Somebody had the brilliant idea that one could measure waves by this method, i.e. if you had an iron buoy moving up and down, then you could measure the height of the waves by its up and down motion. This was a relevant problem at that time, as the invasion of France was imminent. It was therefore important to be able to measure the waves in the English Channel and correlate their properties with the wind. So we got involved with the problem, and it was decided to split us from Group H to form a separate group, which was eventually called Group W – 'W' for waves.

It turned out that there were several wave recorders placed along the south coast from Dover to Penzance, and a little up the Bristol Channel, measuring variations in pressure at the sea bed, and it had been decided to attempt to correlate these wave records with the wind, which could be easily measured. This work was already in hand when we became involved. Group W consisted of Barber (who was then its head), myself and two assistants, Hubbard and Grey. There were also two Scientific Officers, Cotsworth and Alexander, from the Mine Design Department in Havant, who were concerned with servicing and looking after the wave pressure recorders along the coast. There was also Clifford Mortimer, a freshwater biologist who had been working at Ambleside, near Lake Windermere.†

Steven Butterworth, who I mentioned earlier, was a great mathematician and famous for his theory of the transformer. He had a mathematical assistant who was called Wigglesworth (a good name for a mathematician) but Wigglesworth was transferred to Scotland and Butterworth was extremely annoyed, so they gave him a chap called Fritz Ursell who had just graduated in mathematics with high honours at Trinity College, Cambridge. He was a German refugee who had come to Britain before the war and had been educated at Marlborough before going to Trinity. It so happened that his office and Butterworth's were next to ours – and so a certain amount of

* Barber had obtained an Honours degree and undertaken research in Physics at Leeds University; he had joined the Admiralty Research Laboratory some years before the Second World War.

† Mortimer eventually returned to the Lake District and did important work on internal waves in lakes (becoming an FRS at the comparatively early age of 47) before moving to the USA where he became a professor and Director of the Center for Great Lakes Studies.

'leakage' took place. Naturally, when Barber and I started on the theoretical work, we went to ask Ursell for his advice, and so he gradually became more interested in our work than the work he was supposed to be doing. After a while he got himself transferred to our group and he was, of course, a great asset.

Barber was a newly promoted Senior Scientific Officer and was not really senior enough to head a group so they found an eminent oceanographer – George Deacon, who had just been awarded an FRS, having written an important paper on the circulation of the Southern Ocean. At that time, Deacon was working at the anti-submarine establishment at Fairlie in Ayrshire. It so happened that the work he was doing was of far more use to submariners than anti-submariners. As a result, although the submariners were duly grateful, he was not very popular with the others, so he was not averse to transferring to Teddington. He did not know much about wave theory (he had been trained as a chemist) but as he had circumnavigated the Southern Ocean several times, he knew all about real waves.

Barber and I started doing theoretical work. We studied Lamb's *Hydrodynamics* and the work of Rayleigh, Stokes and others, to get some idea of how waves worked. We came across a certain controversy about which there were two schools of thought. One school studied 'Gerstner waves', which had been analyzed by a mathematician called Gaillard.* These waves were exactly trochoidal in shape and resulted in no mass transport. The other theory was due to Stokes: here the waves were irrotational and there was no exact solution, only approximations. It turned out that in this case there *was* a mass transport. An important difference between the two theories was that in Stokes' theory the ratio of height to length for a breaking wave was 1/7, whereas with Gaillard's it was $1/\pi$. As there seemed to be some evidence for mass transport, Barber and I decided to concentrate on the Stokes–Rayleigh theory.

We therefore spent some time writing a paper. Barber concentrated on the effects of the waves on beaches, how refraction caused local concentrations etc., and I studied the effect of bottom friction. Our paper was published as an Admiralty report, because wartime regulations prevented us from publishing in the open literature. Unfortunately, the Americans published a similar paper about six months later and they therefore gained the credit for the work.

Off to Cornwall

Deacon came to the conclusion that it would be good for us to experience some real sea, so he packed us off to the Cornish coast where there were still some wave recorders in action. Barber, myself, Ursell and Grey travelled to Padstow along the A30, in a V8 Landrover driven by Alexander. At Bodmin we had to interrupt our journey because Ursell was technically still an enemy alien. He had to register with the police, so we stopped outside the police station, which was the County Headquarters for Cornwall, and he went in. Some time later a policeman came out and asked us if we knew a Sergeant Clerk in Teddington, which was obviously a ploy, for if we had said 'yes', they would have thought that we were enemy aliens or something similar. In fact, the Cornish Police were the nearest I have ever seen to the Keystone Kops.

*Gaillard belonged to the US Beach Erosion Board and most of their subsequent papers were based on his work, using rules drawn from his formulae.

Anyway, we settled that and went on to Padstow, although the recorders were not actually there but at Harlyn Bay and Constantine Bay about three miles away. Ursell and I stayed at the local hotel in Padstow, and Barber and Grey went on to a hut we had at Harlyn Bay. So we started to make some progress.

Deacon was wise to send us because we had never before observed the sea from a scientific point of view, and it soon became clear that it was quite different from what we had envisaged. Barber tended to concentrate on studying the beach processes in Harlyn Bay, whereas I went to Constantine Bay and dealt with the wave records there. The wave records were thin black lines on photographic paper which was very much like lavatory paper in appearance. When I was analysing the records in Padstow, I used to do it on a big table in a public room at the hotel, and there were many rude remarks by the clientele (mainly naval personnel).

It soon became clear that there was no regularity about the waves, and that the only way to deal with them was to make a kind of histogram. The lengths of wave traces on the record could be split into different groups and the number of waves in each group counted. So you could plot a frequency distribution and for each particular group you could work out a kind of mean amplitude. This was a laborious process but it seemed the only way forward.

There were some amusing instances in Padstow. Constantine Bay was three miles away and we did not have use of the car (and we could not drive anyway) but we had one bicycle. So George Grey and I travelled there, two on a bicycle. But in Padstow we were stopped by a war reserve policeman, who also happened to be the local grocer. He asked our names and addresses. Because my address was exactly the same as the one that Fritz Ursell had already given the police, and because of my accent, the 'grocer policeman' thought *I* was the German refugee and that I had given a false name. When Ursell saw the real policeman he sorted it out.† The 'grocer policeman' must have been very slow, because I found later on that there was a gang of quarry workers and their wives in Padstow and, as they came from Trefor in North Wales, their accents were exactly like mine!

†That incident has evolved into a funnier version which, while more amusing, is sadly not true. In the apocryphal version, Ursell and Darbyshire were taken to the local police station for questioning. One of them (Ursell) was released and the one with the strong accent (Darbyshire) was kept in overnight for further questioning under suspicion of being a German spy!

After about two months we felt we had done all we could in Padstow, and we went back to Teddington to face the flying bombs and the V2 rockets once more. There was an amusing incident involving a flying bomb. Following an air raid warning, I remember Barber sitting under a table having an erudite discussion about wave theory with a mathematician called Kreisel who was based in London. I have never heard of a learned discussion in such a place before.

New premises and new colleagues

By this time we had been given new quarters in Teddington. These had previously been the shipyard and the shipyard drawing office. In the shipyard they made models of warships with steel or iron so that their magnetism could be studied. The drawing office, where thay had designed the models, became an office, and the shipyard our lab. The workshop itself was very good, with plenty of space. There was a gallery on one side where the remnant of the shipyard workers were still working. Relationships with them were pretty good and we fraternised by blowing peashooters at each other – there were plenty of tubes around and little balls of plastic for ammunition. (They had the advantage as they were above us, of course!) There were also huge doors which led onto National Physical Laboratory (NPL) grounds, and these were useful when heavy luggage and goods had to come in. There was also a very small room just off the main workshop and this became our dark room. I would spend many hours in there doing official and unofficial work. The offices were all on the roof, in a prefabricated building. There was plenty of space and on the face of it, it was ideal. However, the office was very cold in winter, and not long after we had to face probably the worst winter of the 20th century, the winter of 1946/47.

About this time we were joined by a man called Baxter who used to work at Teddington in the shipyard days, and by another engineer called Pierce who had been in the fire control department and knew Deacon. Another recruit was Collins, a really remarkable person who had been trained as an optician and was a natural genius at electronics and had all sorts of brilliant ideas. He is described in R.V. Jones' book *The Most Secret War*.

Another member who joined our group at this time was Norman Smith who had been an assistant to Cooke, the chief instrument-maker of the laboratory. A lot of Cooke's knowledge had rubbed off on Norman, so he was a very capable instrument-worker and a great asset to the group.

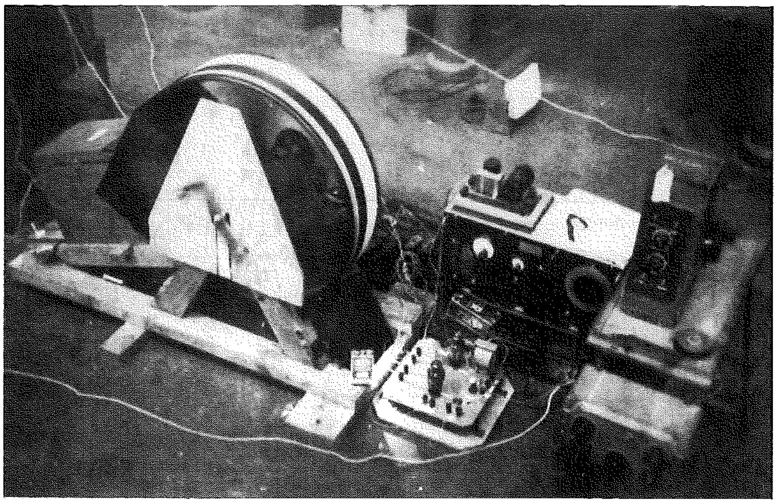
New techniques

We then decided to do something better than the histogram, although along the same lines. The original idea was to send the wave record through a lot of different filters, one filter for each period, but this was not really practicable. George Deacon had a friend in the film industry and we learned that the film 'Fantasia', which was then a recent success, had the sound part of the film as black and white wavy silhouettes along the side of the picture frames. It therefore occurred to us that we could do the same thing, only using not transmission but *reflection*. We could use the type of paper we used in Padstow, and instead of printing lines we would have a big block of light which would move about, generating a silhouette of the waves. We could then put this on a wheel and, as the wheel spun round, the variations in black and white could be detected by a photocell.

One day Pierce presented me with a contraption from the workshop. It was a big flange wheel, about 1 metre in diameter and about 0.2 m wide on a wooden stand, and with a handle at the side. I asked 'Where is the monkey?' – it turned out *I* was to be the monkey. This was the basis of it: you could put a wave record about 10 feet long on the wheel and then spin it round. A narrow strip of light was focussed on the record and the light reflected off it was viewed by a photo-cell. This signal was then passed to a narrow filter in the form of a standard vibration galvanometer tuned to 100 cycles per second. The output from this was then rectified and passed to one pen of a double pen recorder. As the wheel spun round you would obtain a complete spectrum as the speed decreased. The wave record also had a

The Admiralty Research Laboratory, Teddington

Initially, Group W worked in the large building in the centre of the photo. Later they moved to the lower building on the left. The 'Crazy Gang' group photo (p.29) was taken on the roof of this building.



The original wave analyser

black time-mark every 20 seconds and this could also be lit and analysed by a subsidiary analyser, with a second photocell and a different lamp and a filter. The details of this pioneering instrument were published in *Nature* in 1946 (see Further Reading, 1).

By this time, most of the recorders had been discontinued but there was still one at Pendeen. We had a man looking after it who worked for Western Union and he used to send us terse messages with the records. He would send them undeveloped and we would develop them in Teddington. Then, having dried them, we put them on the wheel. We started analysing on a regular basis. The records were taken every two hours, so some days we had as many as twelve to process.

The spectra came out successfully but the shape was rather surprising because we had expected a continuous line, but it was nothing of the sort, it was a series of peaks at regular intervals. We were a bit puzzled by this but Ursell explained that we had been used to Fourier analysis with deformed wave forms, whereas in this case the analyser regarded the whole record as a deformed wave and so there was a line for each sub-multiple of the length of the record. The heights of the individual peaks were also something we did not quite understand, but later on we found that the square of the height followed what is called a chi-squared (χ^2) distribution for one point with two degrees of freedom, and so by summing up for various frequency intervals one could get a more stable estimate.

We pressed on with the analyses. At first they all looked very complicated, a mass of lines, but one day the analyser record showed a narrow band at about 20 seconds period. As we analysed more of the records, this narrow band gradually decreased in period, getting shorter and shorter. At long last we realized we were on to something significant. In the storm areas there would be a mixture of waves with different periods. Longer period waves travel faster than those of shorter period, so they would arrive first and would be followed by the shorter period ones. Hence the waves were dispersive, and the period of the peak in the spectrum would get shorter over time.

This was quite an achievement, we had never seen anything like it before, and we called it 'Exhibit A'. A week or two later there came an even better example. This one lasted for over a day, and indeed it lasted so long that we were able to identify, by working back, where the waves came from. We were using 6-hourly weather charts of the Atlantic from the Naval Weather Service, and when we plotted on a time/distance graph the wind speeds pointing towards Cornwall, then worked back, we could identify the sea areas where the waves had come from. Barber found that numerically the wind speed in the storm in knots was twice the period of the wave in seconds; in other words, a 20 knot wind would cause a 10 s wave. This looked rather suggestive because the speed of the surface wind, which was estimated at two-thirds of the speed of the geostrophic wind, would in this case be the same as the wave speed.

At about the time we finished the analyser, M. J. Tucker (we called him 'Tom' Tucker) joined us. He was a proper electronics expert. He started building a new analyser based on a tuning-fork filter rather than on a vibration galvanometer. His analyser was transferred to our station in Perranporth, which I will descibe later. Our wave analyser was more or less 'a 9-day wonder', as in those times it would take a human calculator a week to analyse a 2-minute record, whereas our analyser could do a 20-minute record in 15 minutes. A lot of important people came to see it, including Sir Henry Tizzard, the Chief Government Scientist, Professor Bernal, and Sir Frederick Brundred, the Admiralty Director of Scientific Research; also Professor Sverdrup and many others. In fact, at that time, we were the only people in the country, and indeed the only people in the world as far as I am aware, who could make Fourier analyses of long records.

Around this time they set up a new Mathematics Department at the NPL next door. Indeed, in due course, the 'Ace' computer was to be designed there. When they had problems involving Fourier analysis they came to us and I usually had to deal with them. I remember helping with a problem concerning the variation in the width of wool in Yorkshire Mills, and also with lightning research involving variations in atmospheric electricity. Work was never predictable in those days.

There were other attempts at wave analysis. Collins, for instance, was doing almost the same thing but with a type of magnetic tape called a 'blatnoform'. The idea was right but it never seemed to work properly, probably because the tapes were not of the quality that they are now. Barber's idea, which is still used today (Further Reading, 5), was to get a photograph of the sea-surface, make a transparent glass slide of it, and then use it as a diffraction grating. In theory, this should give you a series of lines, the angle giving you the direction, and the length of the line the strength. We used a sodium light point source and, although the light was very poor, it did work. Now of course, with the use of lasers, this technique is quite successful.

I have mentioned the drawing on graph paper of lines from the origin that would correspond to the paths of waves for various periods from 6 to 24 seconds. We would obtain a weather chart and draw a line from Pendeen to the centre of the storm. We would then read off the wind speed at points spaced 200 miles apart along the line. In practice, most storms were in roughly the same location, to the north-west of Cornwall. On the rare occasion when there were two storms in the Atlantic at the same time, two separate lines had to be drawn from Pendeen, and two sets of wind speeds had to be estimated. Making these plots was very laborious, especially as the weather charts were produced every six hours.

Analysing waves from distant storms was a step forward since, although waves in the Channel had been predicted fairly well, they depended almost entirely on local winds. (Credit for the local predictions was mainly due to Commander Suthons of the Royal Naval Weather Service who devised the wave growth formulae.) The Americans had been successful in predicting the swell for the North African landings in 1942, using methods devised by Sverdrup and Munk. I am inclined to think that they were rather lucky because their method was based on very old visual observations. They had nothing to compare with the results that had been obtained by our group.

From our graphs we could now work out the distance over which a wind of given speed had acted on a wave of chosen period, and for how long. It was assumed throughout, however, that the waves did not interact with each other.

Post-War progress

The war ended rather sooner than expected, in August 1945. There were a lot of naval ships standing idle and somebody had the brilliant idea of measuring waves in mid-ocean and comparing them with those at the shore. At this time, methods for measuring waves from ships were not very advanced. However, it was well known that an echo sounder placed on the sea bottom did record waves at the surface – as the beam was conical it tended to miss very short waves, but it was better than nothing. So they had the idea of using a submarine with an upward-looking echo sounder, and stationing it deep beneath the surface so that it would be unaffected by wave motion. This was done using a submarine called the *Seneschal* and a destroyer called the *Tremadog Bay,* which were sent out into the Atlantic. I did not go, as Deacon thought other people were more suited for that task, but as a sop I was sent to measure the waves at Perranporth (a new site, not one of those used for studying waves at the time of the invasion). We installed a wave recorder there and we built a substantial hut, in which the analyser designed by Tucker was set up. We therefore had dark room facilities for developing the records, and of course the means to analyse them.

During the experiment with the *Seneschal* and the *Tremadog Bay* I went down to the beach at Perranporth to see what was happening. It was very strange – the sea seemed remarkably calm

The author in 1970, when he was Professor of Physical Oceanography at the Marine Science Laboratories of the University of Wales, Bangor

but not quite flat, and there was a peculiar swell. I started analysing the records. It was very convenient having everything at hand – wave recorders, the analysers and development facilities etc. – so I started processing the records every two hours, not every four, which was the norm. Soon it became clear that something peculiar was happening. There was a very narrow band of frequencies corresponding to a very long period of 24 s and there was nothing else on the records, and the period gradually shortened as time went on – this lasted for several days, with the period decreasing only very slowly. I made a rough estimate of the distance from the storm and it came to about 7000 miles. However, it also turned out that there was a strong tidal influence, a kind of Doppler effect, in which the ebb and flood of the tidal currents caused the wave period to increase or decrease – the same kind of effect as when a police siren passes the listener. I analysed all of these records and took them back to Teddington.

The ship observations were not very satisfactory since it had been a calm sea, and I did my best with the records to see if there was any trace of waves similar to those we had observed at Perranporth – but there was no sign. However, the Perranporth records proved very useful. Barber and Ursell, of course, had a look at them and, when the whole dataset were plotted out and the Doppler effect was allowed for, the storm generation region seemed to be about 10 000 miles away near Cape Horn. Nobody had ever tracked waves travelling over such a long distance before. It was rather ironic that the affair at Perranporth, which was supposed to be a sideshow, was to produce what was at the time arguably the most significant discovery in wave propagation, whereas today nobody even remembers the names of the ship and the submarine.

Deacon had wanted Barber and Ursell to write and present a paper about the work, possibly at the Royal Society. But the only discovery was that under certain conditions waves travelled with the theoretical group velocity and this was hardly enough to make a paper. So the result from Perranporth proved to be a godsend to them because, not only was it a much better example of waves travelling with the theoretical group velocity, but also we had observations of the Doppler oscillations due to the tide. In fact, this effect is not quite so simple as the police siren case. They made rather a meal of it, and Barber was to write a separate paper on that alone (Further Reading, 3). Anyway, the paper went ahead and eventually was printed in the *Philosophical Transactions* (Further Reading, 2). Barber and Ursell were kind enough to mention that I had analysed some of the records. My contribution had been to predict the amplitudes and period from the wind observations, a far more difficult task which took me about four years to complete.

In the meantime, we wanted to know what happened at shorter fetches, and at that time it was discovered that a radar signal from an aeroplane would be reflected back by waves on the sea surface – rather like sound from a bottom-mounted echo sounder, but in reverse. So the Telecommunications Research Establishment (TRE) at Malvern developed an airborne wave measuring device that used radar. Deacon and Smith went up in an aeroplane and flew over the Irish Sea taking measurements on the way across. This was to prove extremely useful.

About this time Henry Charnock joined the group. He had been a meteorological student at Imperial College and was interested in marine meteorology, particularly the marine atmospheric boundary layer. Charnock wanted to do wind measurements so we decided to go to Loch Neagh in Northern Ireland, where we had wave recorders at various points on the lake. We also had water-level recorders to measure the seiches and the long-term changes in the level of the lake.

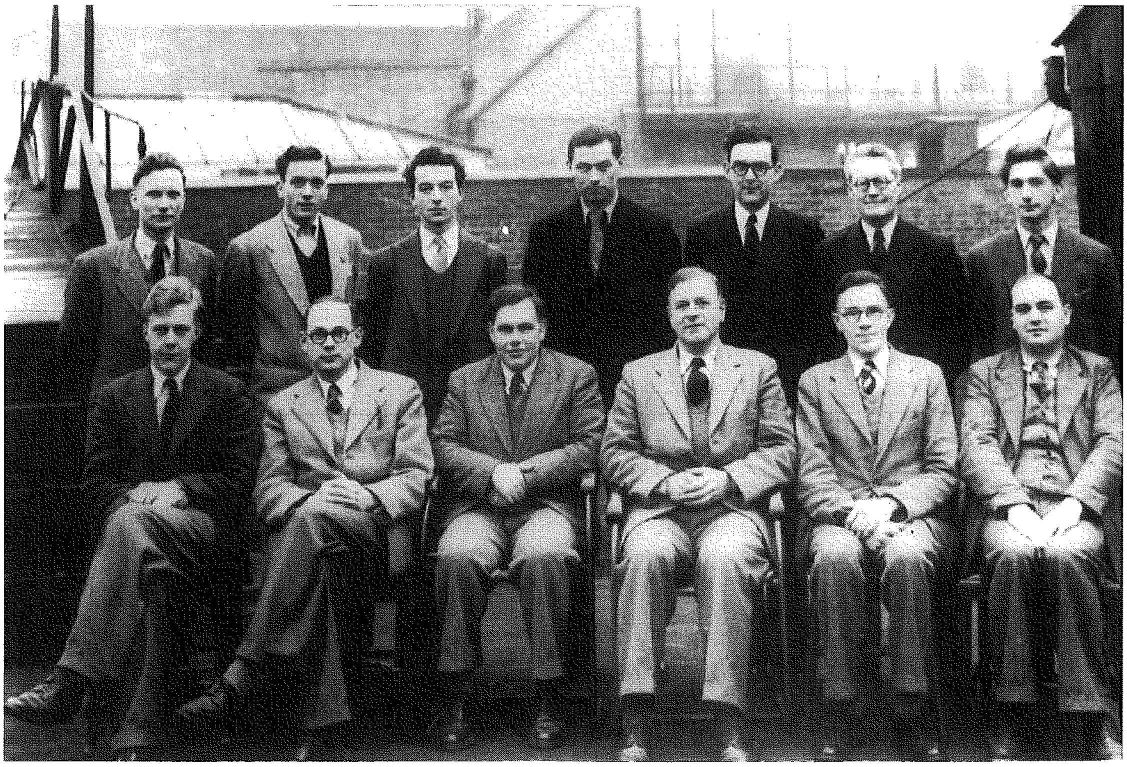
In addition there was an aeroplane – an old Lancaster – with a radar sensor to measure the waves. Norman Smith and myself flew in this across to an RAF station in Northern Ireland. I think I used a lot of my nine lives on that occasion. Every time we went into the air, something happened. The first time, a long piece of wire was dangling from the plane, apparently going back yards and yards, and nobody knew what it was. On another occasion, we got lost in fog and the ground station, which was at Nuts Corner, told us they couldn't help us any more. Another time, some of the chaps were in a boat on the lake and the pilot, who was a New Zealander, decided to have a look at them and he dived and just cleared the tops of the masts! Finally, on the way home one of the engines failed and we had to land with just one. I wasn't at all frightened – I thought it was common practice in an aeroplane – but Norman Smith, who was an experienced flier, was having kittens.

However, some useful work was done, and it turned out that although the radar measurements did not amount to much we had a lot of decent photographs, particularly of windrows etc., and of course the other results from the team on the lake were extremely useful. In time, we were able to incorporate all of these results with those from Pendeen and Perranporth and make a complete analysis of the system, from short to long fetches.

Now I must mention the subject of microseisms. These are very tiny sea bed oscillations which are supposed to be excited in stormy areas and then propagate outwards. The theory was worked out analytically by Michael Longuet-Higgins (Further Reading, 7), another Trinity College mathematician who had joined us by this time. He showed that if two sets of waves with a narrow range of similar frequencies meet, some interesting things happen. If the frequencies exactly match, a stationary wave will be produced and the pressure effect of this wave remains unattenuated down to the sea bed. More interestingly, if the frequencies don't quite match, i.e. if you have two frequencies, σ_1 and σ_2, with wave numbers k_1 and k_2, you find there is a wave with speed $(\sigma_1 + \sigma_2)/(k - k_2)$. So you have roughly twice the sea wave frequency, and since $(k_1 - k_2)$ would be small, the speed could be very large. If this speed equals that of seismic ground waves then ground oscillations with twice the sea wave frequency should be excited. This could happen: (1) when sea waves incident on a coast meet the reflected waves, (2) when waves in the open ocean from two different storms meet each other, and (3) when waves formed in different segments of the same storm meet each other.

It is well known that the arrival of heavy swell often precedes the arrival of the storm generating it by a few hours. It was thought that, given their high propagation speed, microseisms would behave similarly. Thus the detection of an increase in microseism energy at a coastline could be used as a practical basis for predicting the arrival of a storm, i.e. if a sudden onset of microseisms was detected, then a storm was coming. In those pre-satellite days this was important, because large areas of the Indian and Pacific Oceans did not have real-time meteorological coverage. According to the theory, the microseism spectra should be very much like the corresponding wave spectra – except that the microseism frequency should be twice that of the waves. There were seismographs at Kew Observatory – only a fourpenny bus ride from Teddington – which provided us with access to microseism data. The data were usually recorded graphically on a large sheet of paper, about half a metre square. The ground movement was denoted by wavy lines, one for each hour.

It was fairly easy to work with amplitudes, and Deacon wrote a paper which showed a correspondence between the amplitude of the microseisms at Kew and the wave heights at Perranporth. There really was some sort of relationship, but then the problem was to derive the spectra of the signals. This was not very easy because from the graphical lines we had to somehow obtain the black and white silhouette form we were used to. There were basically two methods. The hard way was to photostat the original record and put the resulting strip in a photographic enlarger and magnify it to a respectable size. The profile was then traced from the



Group W (the 'Crazy Gang') in 1952 *Back Row, left to right: Norman Smith, B. Lincoln, C. Williams, Ric Hubbard, Dicky Privett, L. Baxter, Leo Verra. Front Row, left to right: Jim Crease, Tom Tucker, Henry Charnock, George Deacon, Ken Bowden, Jack Darbyshire*

enlargement onto paper the same size as the photographic paper we used with waves. The easier way was to use a photo-electric curve-follower which had been designed very cleverly by Tucker and Collins – basically, it was a narrow beam of light that automatically followed the record.

One way or another, we did obtain many examples of interesting wave spectra from Perranporth and checked them against the microseisms recorded at Kew (Further Reading, 8). Not only was there was a very strong correspondence between them, but the microseism spectra preceded the waves, although not by very much, only a matter of about 6 hours. So they could not be actually related to the centre of the storm, but were instead probably due to reflections off coasts nearer to the storm area. But there was one example, in November 1945, when there was a severe gale and the microseisms provided a 24-hour warning. In that case, when we checked the meteorological data, we found that the winds had in fact veered around very quickly. This event thus provided clear evidence that an increase in microseism energy at the coast could be used to monitor wave activity at the centre of a storm.

I think I ought to mention some work done by others during this time. There was research on the relationship between waves and ship motion by Barber and Mrs Wood, and later by David Cartwright who had worked at the Department of Naval Construction at Bath. There was also a lot of work on currents, using the Faraday effect: if you have a moving conductor in a magnetic field, an EMF (electromotive force) is set up, which is due to the dynamo effect. So if a river is considered to be a moving conductor in the Earth's magnetic field, an EMF should be generated across it. Faraday knew this, and he tried to measure the EMF across the Thames but his apparatus was not sufficiently sensitive. The effect had however been detected by Post Office workers when they were working on cables laid across the English Channel. Longuet-Higgins and Barber worked on this phenomenon at various piers on the south coast where there were lots of cables near the shore, and they obtained some positive results. Also, Tucker constructed an instrument in which a magnetic field was generated *in situ*, as it were, so that by measuring the induced EMF across a pair of electrodes he could estimate the speed of the water. Later on, Ken Bowden, who was to join the group from Liverpool, trailed electrodes behind a ship and was able to measure the induced EMF and thus derive estimates of the water currents (Further Reading, 10).

The early 1950s

The years rolled on, and we eventually came to 1952. In that year my work on waves was finally published by the Royal Society, but in the *Proceedings* (Further Reading, 4) and not in the more prestigious *Transactions*. However, I was asked to read the paper before that Society – an honour not given to Barber and Ursell! Looking back on it after 50 years, I can only say that I do not think I could have done a better job, in view of the limitations of computers and numerical techniques at that time and the knowledge of oceanography generally. I set out to predict the wave spectra at Cornwall, and I succeeded. I was not to know that deep sea spectra tended to be rather different – that would only be discovered much later (cf. Further Reading, 11).

It was also in 1952 that I went on the *Discovery II*. Tucker had developed a ship-borne wave recorder which could record waves at sea (Further Reading, 9). It was a very cunning device. If you had a very long ship and short waves, then the ship was effectively stationary and a pressure recorder would give an accurate result.
On the other hand, if the waves were much longer than the ship, then an accelerometer would give the right answer. This was a combination of the two, a sort of compromise, and it worked under both conditions. It could be fitted on the hull of a ship, requiring only that there should be a hole about 1 cm in diameter on each side of the ship in the engine room area. The variation in the pressure of the sea was transmitted to an instrument in the engine room and the results were fed to a pen recorder. One of its advantages was that it did not need attending to once it had been switched on – everyone could be as sick as dogs and it would still be working. There was one slight snag: because a pressure signal attenuates with depth, there was some uncertainty about the wave height. This did not matter much with deep sea waves, but when the system was later used to measure waves in shallow water it did cause problems.

So, one of these wave recorders was fixed to *Discovery II*. She had just come back from the Antarctic and had been fitted out at Devonport and Deacon and I and some others went to join her. Eventually we sailed from Devonport and by the time we got into the Celtic Sea just south of Ireland, quite a nasty storm had brewed up. The waves were very high and the wave recorder was working and recorded heights as much as 30 feet (10 m). I found I was reasonably immune to sea sickness and I was busy going on top of the bridge, even the flying bridge, taking pictures of the waves with still and cine cameras (unfortunately many of them were lost when I moved office some years later). A lot of my colleagues could not eat a thing during the cruise and on one occasion we had mulligatawny soup – which I liked – and I got everyone's helping!

These waves were very interesting and, what is more, they agreed with my formulae, which was extremely satisfying. The ship-based wave recorder was then transferred to the weather ship, *Weather Explorer*, which used to be stationed alternately at Station 'India' about 200 miles south of Iceland, and at 'Juliet' which was about 200 miles west of Ireland.

In 1953 we moved to Wormley, near Godalming, and a new phase began – the National Institute of Oceanography was established under the directorship of George Deacon. Those of us who had been in Teddington looked back wistfully to those earlier years.

So what became of the 'Crazy Gang' in the years that followed? In 1963, I returned to North Wales where I took up the post of Professor of Oceanography at the Marine Laboratories in Menai Bridge. By then, Barber had taken up a Chair of Physics in New Zealand, and Ursell had gone to Manchester to fill the Horace Lamb Chair of Applied Mathematics. George Deacon was knighted for his services to oceanography, Tom Tucker became the Director of the NERC laboratory at Taunton, Bowden took the Chair of Oceanography at Liverpool, and Charnock became Professor in Southampton. Not a bad record, really.

Acknowledgements

I write this account as a tribute to my old colleagues, many of whom have now passed on. I wish to thank my family for putting up with me when I was dictating my memories to tape, Lynda Goold for deciphering the tape and typing the first draft, and Alan Elliott for his help in editing the text.

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Book Reviews

Coastal Processes with Engineering Applications by Robert G. Dean and Robert A. Dalrymple (2002) Cambridge University Press, 475pp. £75 (hardback, ISBN 0-521-495-35-0).

This is the latest of a number of (unconnected) books covering coastal engineering that have been published recently. As one might expect from the pedigree of the authors, *Coastal Processes with Engineering Applications* is an excellent book. Although it is intended to be used by, and is certainly useful to, a mixed readership of students, lecturers, practising engineers and researchers, it will probably find most favour with practising coastal engineers. Its wide coverage of material and its price will probably deter individual purchase, but university library purchase will provide access for students and academics, and the book will surely become part of the standard collection of volumes found in design offices and research institutes. It is not suitable for the casual reader or a newcomer to the topic, being too long and a little too intensive and detailed, either for a generalist or for someone requiring an introduction to the field. Neither is it a detailed design manual.

The book comprises fourteen chapters divided into four sections. These are: Introduction to Coastal Processes (Chapters 1 to 3); Hydrodynamics of the Coastal Zone (Chapters 4 and 5); Coastal Response (Chapters 6 to 10) and Shoreline Modification and Analysis (Chapters 11 to14). Each chapter is prefaced with an italicised anecdote that exposes some of the key concepts to be covered, and finishes with a list of references and a set of exercises. The book uses a mixture of units (metric and so-called English system), which is probably the best approach to any topic that is heavily dependent on case studies from the USA but which has an international audience.

One criticism is that no answers are provided for numerical exercises, nor guideline solutions for descriptive or design-oriented exercises. The lack of answers certainly reduces the appeal of the book to students and lecturers, but is not uncommon in books designed for a mixed readership. My personal view is that the provision of such material would be helpful to all readers and should be included in any book that includes exercises.

The first three chapters provide good scene-setting with early warnings of the complexity of the real-world problems encountered later in the book. Chapter 1 provides an overview of some coastal engineering problems, illustrated using case studies. Chapter 2 summarises the characteristics of granular sediments, and Chapter 3 introduces pertinent long-term physical processes such as sea-level rise and the development of coastal features, including beach profiles and submergent and emergent shorelines. Many of the concepts introduced in this first part of the book are inevitably returned to in later chapters.

The second part of the book covers the main processes causing water movement in the coastal zone, namely tides and waves. Neither of these chapters delves deeply into the underlying mechanics of the processes. Chapter 4 gives an overview of the equilibrium theory of tides, but omits the dynamic theory. It includes a good short section on storm surges. Chapter 5 provides an overview of water wave mechanics, referring the reader to several excellent texts for detailed treatments. Wave generation is omitted, but the main features of linear wave theory are presented, together with a summary of non-linear theories and shallow-water transformations. The important concepts of radiation stress and wave-induced currents are briefly introduced. The chapter finishes with three useful sections covering low-frequency shoreline motion (surf beat, edge waves and shear waves), near-shore circulation and swash-zone dynamics.

The third section of the book discusses coastal response with particular reference to equilibrium beach profiles and sediment transport. Chapter 6 describes field measurement techniques, including the measurement and analysis of beach profiles and studies of historic shoreline change.

I found Chapter 7, covering theoretical models for beach profile development, to be very enlightening. Analytical solutions for several approaches are presented and compared against measurements. Not being familiar with studies of coastal geomorphology, I was pleasantly surprised at the success of these solutions. The second part of this chapter considers the application of beach profile evolution models to practical problems such as predicting the response of beaches to the effect of sea-level rise. Chapter 8 gives a comprehensive coverage of sediment transport theory. The chapter provides a clear separation of the various components that make up the overall transport of sand in the coastal zone, with detailed treatments of longshore and cross-shore transport. The theme of demonstrating the veracity of theories by using observed phenomena is carried over from the previous chapter, and is extremely valuable. After some applications of littoral drift predictions developed earlier, the chapter concludes with short sections on aeolian sand transport and the properties of cohesive sediment transport. Although cohesive sediments do not feature much in the book (mainly because estuarine systems are not covered), the inclusion of this short section acts as an important reminder that some coastal deposits do yield non-granular material and that allowance needs to be made in such cases.

Chapter 9 covers several additional coastal features that are inherently related to sediment transport processes, but which are far from well understood. Most attention is focussed on crenulate bays and beach cusps. Chapter 10 is entitled 'Modelling of Beaches and Shorelines'. Although aspects of modelling also appear elsewhere (particularly Chapters 7 and 8), Chapter 10 discusses aspects of physical and mathematical modelling in some detail, with applications to beach evolution in both profile and plan form. Important issues are raised, such as scaling in physical models and the number of spatial dimensions that are both desirable and feasible in mathematical modelling.

The final part of the book begins with aspects of soft and hard engineering solutions to a number of sediment transport phenomena, considers the behaviour of tidal inlets, and finishes with an introduction to some issues of coastal zone management. Chapter 11 describes various soft engineering approaches for counteracting natural erosion, and emphasises the key options of either supplying an artificial source of new sediment and/or of reducing the wave energy available for moving sediment. Both theoretical and practical approaches are considered (using results from earlier chapters to develop design solutions) and some interesting case studies are provided. The impression is given that we understand the physical processes well and that therefore designs perform well in practice. In view of the caveats provided earlier, however, this chapter could perhaps have been improved by including an example of a design that failed.

Chapter 12 considers the intended function of the main types of hard engineering structures, with particular reference to their role in controlling sediment transport. The advantages and disadvantages of groynes and offshore breakwaters are described in detail, with illustrative practical examples and reference to research studies. Artificial headlands, sea walls, revetments and jetties are also covered, but in less detail. I found this to be an excellent overview which, although it does not cover detailed design, contains sufficient detail to be useful for conceptual design.

Chapter 13 analyses the behaviour of tidal inlets and examines their impact on coastal sediment transport. The first part of the chapter covers the tidal response of inlets. Much of this is devoted to tidal amplitude ratios, and associated phase differences, between ocean and inlet. Results from analytical solutions to simplified dynamic equations are presented and are used to illustrate the different behaviour of large and small inlets. Other issues discussed include tidal velocities, tidal prisms and the role of plan-form and cross-sectional inlet areas in inlet behaviour. The second part of the chapter is devoted to two main issues of sediment transport that are inherently related to the interaction between inlets and the coastal zone. First, the potentially transient nature of the inlet entrance channel is discussed in relation to its ability to maintain a naturally self-scouring geometry. The impact of engineering work designed to maintain inlet entrances as navigable channels is also discussed. Secondly, sand by-passing, i.e. the longshore flow of sediment around inlet entrances, is considered. Several (artificial) ways of maintaining natural sand by-passing patterns are described. As in earlier chapters, the material here is based on a pleasing mixture of theory and practical experience. The final chapter, Chapter 14, discusses several coastal zone management issues. Various management options for dealing with eroding coastlines are clearly identified in relation to the long-term shoreline change rate. The chapter exposes the difficulties in selecting the optimum strategy and suggests some solutions. Several other issues are briefly introduced, e.g. construction standards and sand rights.

In summary, the book aims to help the reader to understand the physical processes that control coastal sediment transport. It also aims to help engineers provide better solutions to coastal problems. It succeeds in these aims by exposing the difficulties of working in the coastal zone, while leaving the reader with the message that with proper application of knowledge and experience, coastal engineers should be able to provide robust and sustainable solutions to most coastal zone management problems. I recommend the book to all who have an interest in understanding the behaviour of the coastal zone and how it responds to our attempts to control it for our own benefit.

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Dynamics of Estuarine Muds by Richard Whitehouse, Richard Soulsby, William Roberts and Helen Mitchener (2000). Thomas Telford, London,210pp. £50 (hard cover, ISBN 0-7277-2864-4).

Many years ago, John Woods (then the intimidatingly tall Director of NERC), came to visit the University Marine Laboratories in Menai Bridge, North Wales. I was standing by my shiny new recirculating flume in my very dirty lab coat, and during his walkabout Woods asked me what I was doing. After a few sentences of gobblydegook, accompanied by some gentle and deliberate caresses of my new flume, I concluded that mud research 'was almost intractable'. To my horror (and John Simpson's too!) Woods leaned forwards and said – in a tone that only Woods was able to produce – '... well, then, why are you studying it?'. Err, pass!

Muddy sediments, 'tis true, remain particularly difficult to deal with, but this book, written by four experts at the internationally renowned HR Wallingford, shows the progress that has been made in the last 15 or so years. Based upon the earlier (1988) 'Mud Manual' by Andy Delo, also of HR, and complementing a more recent *Dynamics of Marine Sands* by Richard Soulsby (1997), it deals with the major processes involved in the behaviour of cohesive sediments, namely erosion, transport, deposition and consolidation. The authors say in the Preface that they have 'attempted to summarise a complex topic in a readily accessible manner', and to my mind they have done a great job. The key to their success relates, I think, to a simple and clear presentational approach, which is maintained throughout the book. Actually, although I say 'book', this is more of a manual, as worked examples are presented and the reader can purchase an accompanying CD containing the necessary software to run the calculations (£200 for academic use, £300 for commercial use).

Each chapter is divided into two, the first part presenting a summary of current 'Knowledge', which includes relevant references, important graphs and formulae; this is followed by a 'Procedures' section, in which field and laboratory procedures/protocols are described and worked practical examples are provided. This makes the book especially useful for practising engineers and hydraulic engineering consultants. For instance, in Chapter 5, the Procedures section includes a number of different methods of collecting sedimentation data, and Example 5.1 then presents the correct method for calculating the settling velocity of flocculated mud in saline waters. All good stuff. In addition, in each worked example where it is possible to use the software to do the calculations, the necessary commands are included.

The book covers a lot: sediment properties, hydrodynamics, erosion, suspended sediment, fluid mud, transport rate, deposition, consolidation, mud–sand mixtures, mathematical modelling, intertidal processes, and case studies. Some of these topics, such as mixed-sediment processes, are very new, and rarely can you find such information elsewhere. It is encouraging to see that some of the information is derived from recent HR Projects and EC-MAST projects, a rapid transfer from fieldwork to guidance indeed. My hope is that future editions will repeat this trend, and that new data and concepts arising from research will eventually become part of the manual.

An enormous amount of work has been devoted to publication of this book, and the authors are to be congratulated – as are the publishers, because the publication quality is very high. I find only a few shortcomings. The book is perhaps overly reliant on in-house HR research for examples. The section on intertidal processes could certainly have been expanded, given the number of USA-UK–EU projects in recent years, and a chapter on fieldwork methods/data could perhaps have been included. The book's general practical usefulness, however, far outweighs these quibbles. I had wondered when HR would update Delo's review. Perhaps I should send the book to John Woods!!

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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

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

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

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

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The Challenger Society Website is www.challenger-society.org.uk

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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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CONTENTS