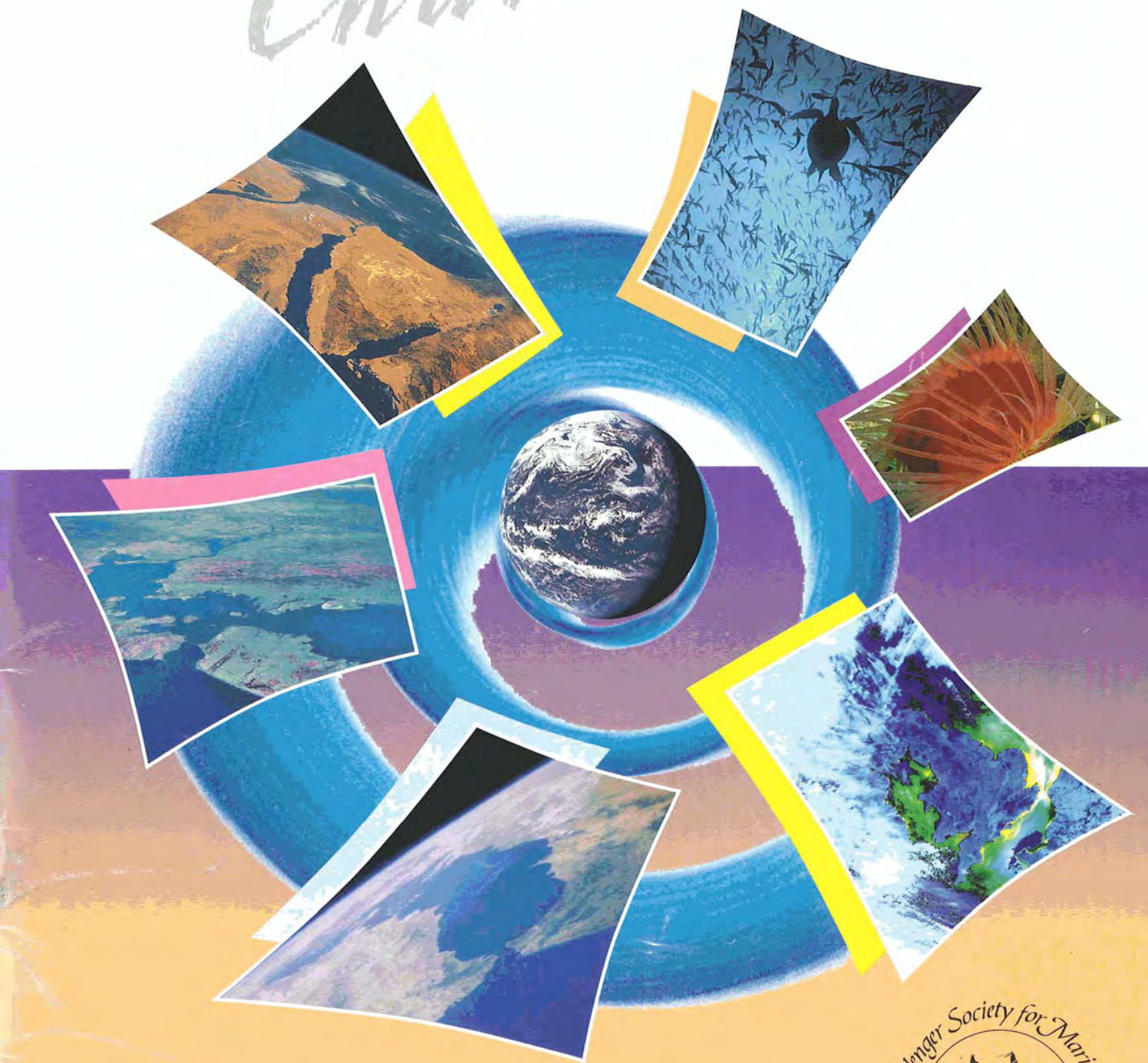
OCEAN Challenge



The Challenger Society for Marine Science

Volume 9, No. 3, 1999

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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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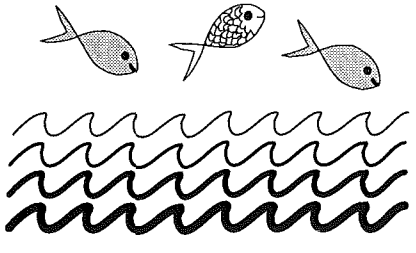
News and Views

Has Cod had its Chips?

It was bound to happen. Fish and chips, that standby of the Briton's diet, has traditionally meant cod and chips. Not any more, it seems. Thanks to overfishing, cod is becoming scarcer and more expensive, while each year farmed salmon gets more abundant and cheaper. Salmon is a much oilier fish than cod, but all the same it is confidently predicted that within five years salmon and chips will be the norm, cod and chips an expensive luxury. Although haddock is preferred to cod in some parts of the country, its stocks are similarly threatened – in fact, in November last, the Government announced that quotas for both cod and haddock in British waters were to be halved. Huss is sometimes used instead of cod, but is regarded as much inferior, and is discarded by many fishermen.

Indeed, the list of popular but endangered fish species grows apace. Recent additions include monkfish and sea bass, fish that scarcely featured on the British culinary scene only twenty years ago. Stocks of both are now at crisis levels, to the extent that farming of sea bass (but not of monkfish – yet) has become a growth industry.

But at least salmon (and sea bass) farms are not significantly threatened by seal predation, unlike open sea cod fisheries. The provincial government of Newfoundland recently claimed that seals eat tens of thousands of cod each year and are threatening attempts to revive the province's fishing industry. There is even a video that purports to show the remains of hundreds of dead cod littering the sea floor, which is used to justify their seal-culling programme. Are seals really such messy eaters that they leave bits of fish lying around? Do they really consume so many fish so fast that the scavengers can't cope with the leftovers? Or is it that the seas around Newfoundland have become so barren that there aren't any scavengers left either?



Global Warming and Ecosystem Drift

Seasonal changes and poleward migrations of animals and plants appear already to be underway in response to global warming (*Ocean Challenge*, Vol. 9, No.1, p.4). Trophic relationships within ecosystems are bound to be affected, since different species migrate at different rates. According to recent press reports, groups such as WWF are suggesting that the gradual northward shift of marine animals, including seabirds, by (eventually) hundreds of kilometres, could lead to 'devastation' of stocks of commercial fish species such as haddock, cod and plaice, in European waters.

That is probably an exaggeration. There is no reason why fish migrations of themselves should reduce fish populations. In the late 17th century, for example, at a time when the Little Ice Age was especially intense, Icelandic waters became so cold that the cod moved away. A possibly better known example occurred in the English Channel between the 1930s and 1960s and became known as the Russell cycle. In brief, slightly warmer water appeared in the western English Channel: herring left the area, to be replaced by pilchards, which were in turn replaced by mackerel when the water cooled again. There is no suggestion that either of these examples was associated with reduction of fish stocks. The fish merely moved away, so fishermen had to go elsewhere to catch them.

Irrespective of whether species migration occurs or not, however, temperature changes can affect natural populations by altering interactions between species and their competitors, their predators, or their prey. A few key interactions commonly contribute disproportionately to maintaining the composition and functioning of an ecosystem. If such interactions are sensitive to temperature, a small climatic change could generate ecological changes that might be both larger scale and more abrupt than gradual shifts in the geographic distribution of organisms.

A neat illustration of this is provided by recent research on a rocky intertidal shore in Oregon, northwestern USA (*Science*, 1999, **283**, 2095–7). Upwelling in the California Current is common along this coast from May to September, and water temperatures drop 3–5 °C during upwelling events, which generally last several days to a few weeks. When water temperatures fall during upwelling, predation by sea-stars on mussels (their principal food source) declines sharply. Experiments have shown that were sea-star predation to cease altogether here, a diverse assemblage of algae and invertebrates would become instead a virtual monoculture of mussels.

Changes in the frequency and intensity of upwelling could therefore have significant ecological effects. In recent decades upwelling patterns in the California Current have changed considerably in response to more frequent and intense ENSO events, secular changes in North Pacific current patterns, and global warming. Systematic changes in upwelling patterns would be likely to modify the intensity of sea-star predation during summer months, leading to changes in the intertidal communities. More generally then, slight temperature shifts that lead to changes in the timing and intensity of seasonal events can modify the key interactions within an ecosystem.

When all is said and done, however, commercial fish stocks are nowhere likely to be endangered by any ecological changes that might occur in response to human-induced global warming. Direct human exploitation poses a much more immediate and much larger threat (as in the case of terrestrial biodiversity). Overfishing itself is bad enough, but it is accompanied by huge accidental by-catches of non-commercial fish species, marine reptiles and mammals, as well as seabirds. Add to that the deliberate plundering of tropical shallow-water environments for corals and sea shells, to be sold as ornaments or even used as building materials, not to mention clearing mangroves for shrimp farming, and ecosystem drift becomes a minor problem.

Ecotourism, Stressed Whales and Acoustic Smog

Since whale hunting was officially banned, whale watching from small boats, and swimming with whales and dolphins, have grown apace. Scientists' concerns that too much human contact may cause undue stress to the animals have recently led several countries – including New Zealand, Canada, USA, South Africa, and probably Portugal's Azores as well – to ban the swimming component of this branch of ecotourism.

People like swimming with whales and dolphins because of the widespread perception that they are 'gentle giants' of the sea. That may be true for baleen whales, which (like the basking sharks) filter-feed on plankton. But the majority of marine cetaceans are (like most sharks) toothed carnivores. They may look as though they are smiling, but they are formidable predators, and killer whales take seals and sea lions, even other whales. What is more, recent observations show that the smile on the face of the bottlenose dolphin conceals a capacity for infanticide and a tendency to murder its smaller relative, the harbour porpoise. Both the USA and the former USSR trained dolphins for military uses during the Cold War, and it is claimed that at least the Russian ones were trained to kill 'western bloc' divers too.

Even if they knew all that, though, most people would probably still want to swim with these animals, not least because there are very few recorded instances of humans being injured by them, even accidentally. In fact, given the way humans have treated whales and dolphins over the centuries it is suprising that the animals are still so friendly. But they might become less friendly if stressed by excessive human contact.

However, not everyone agrees that the problem is serious enough to warrant a ban on swimming, and it may not always be enforced. Either way, whale-watching seems set to increase, with or without a swimming component.

That must inevitably add, at least locally, to ambient noise levels in the oceans, which are higher now than they have ever been, mainly thanks to engines of all sizes, but also because of the variety and number of acoustic devices routinely used on ships, not to mention noise from drilling rigs, seismic prospecting, and so on. Whale 'language' is learned rather than inherited, and thus varies between different groups (pods), even within the same species (*Ocean Challenge* Vol. 8, No. 2, p.27). A high level of background noise – *acoustic smog* as it has been neatly termed – could impair the learning process. There is good evidence that loud sounds can disorientate whales and dolphins, and acoustic smog is unlikely to make things better. It could help explain the growing number of whale and dolphin strandings that are reported nowadays.

BIFs and Brimstone

Banded Iron Formations (BIFs) are the principal source of the world's iron ores. These rocks are vast and extensive sedimentary sequences consisting of millimetre-scale laminations of iron oxides (mainly haematite, Fe_2O_3) and silica. The majority – and the largest – range in age from about 3.8 to 2.0 Ga, though there are a few smaller occurrences as young as late Precambrian (~ 600 Ma). The great size and extent of these deposits preclude deposition in any but a marine environment, but their formation has always been difficult to explain. The central question is this: How could vast amounts of iron oxides have been precipitated in the early Precambrian, when there is almost overwhelming geological evidence that both atmosphere and ocean were devoid of oxygen until around 2 Ga ago?

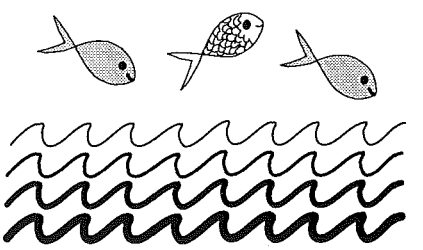
Libraries of literature have been written on the formation of BIFs, and a good proportion seem to involve some combination of oxygenic photosynthesis, upwelling and/or seasonal/annual turnover of the water column in shallow basins and embayments of the early ocean, plentifully supplied with soluble ferrous iron by weathering and/or hydrothermal activity. Oxygen liberated by photosynthesis did not escape to the atmosphere, but instead was instantly sequestered into ferric oxides and precipitated. The laminations are explained by postulating that photosynthetic production was seasonal – as it is throughout much of the present-day ocean.

A key question in this discussion must concern the first appearance of oxygenic phiotosynthesis. Recent molecular fossil (biomarker) evidence (*Nature*, **400**, 503, 554–7) suggests that micro-organisms that produce oxygen during photosynthensis (early cyanobacteria) did not evolve until around 2.7–2.5 Ga ago. To be sure, bacterial microfossils identified in stromatolites as old as 3.5 Ga bear a striking resemblance to modern cyanobacteria, but it is not known whether or not they were oxygenic photosynthesizers. Indeed, biochemical considerations and other lines of evidence indicate that *an*oxygenic photosynthesizers evolved first. These organisms can use reduced species such as hydrogen sulphide and ferrous iron as electron donors, producing ferric oxides and oxidized sulphur species.

According to this scenario, early photosynthetic oxygen production may initially have been limited by the supply of nutrients 'escaping' from the anoxygenic photosynthesizing population. Oxygen could not begin to accumulate in atmosphere and oceans until the supply of reduced species in the oceans became limiting, and oxygenic photosynthesis became widespread.

In complete contrast, another recent study uses modelling results and sulphur-isotope data to suggest that the precipitating agent for all that iron in the BIFs was *sulphide*, not oxygen (*Nature*, **396**, 414, 450–53). According to this scenario, which starts from the standpoint that aerobic deep-ocean waters did not develop until about 1.0–0.54 Ga ago, sulphide was made available by reduction of sulphate ions in the early anoxic ocean. Nowhere in this intriguing proposition, however, is there any explanation of why BIFs consist of iron oxides, not iron sulphides. Where has all the sulphur gone? More fundamentally, did sulphur occur in the Precambrian ocean as sulphate or as sulphide?

Most interesting of all perhaps, both hypotheses postulate that the deep ocean did not become oxygenated until the late Precambrian, 700–800 Ma ago. If that were so, arguments about the origin of BIFs could become less interesting than the possibility of a causal link between oxygenation and the late Precambrian 'explosion' of eukaryotic organisms, such as the Ediacaran fauna.



Gardening and Beach Erosion

No, it's not a new university course, though it may sound like one. The proliferation of TV programmes about gardening in the UK has precipitated a dramatic increase in the erosion of shingle beaches. It has become fashionable to have 'water features', in which gravels are an important component. Rather than pay a few pounds for commercially extracted and washed gravels, many people prefer to take sackfuls from suitable beaches. We mentioned recently (*Ocean Challenge,* Vol. 9, No.1, p.6) that glacially deposited boulders are being removed from Porth Nanven in Cornwall. Illicit gravel 'mining' has apparently now reached serious levels at Crackington Haven (also in Cornwall and also an SSSI).

On the other hand, Cornwall has a steep and rugged coast that is surely in much less danger of invasion by the sea than the flatter lands of eastern England. The problem there is to persuade people to let the sea in and allow it to build up new mudflats and saltmarshes naturally, instead of wasting millions of pounds constructing concrete coastal defences in fruitless attempts to protect a few hectares of barely viable farmland. Actually, East Anglia has quite a few shingle beaches too, which provide natural barriers to erosion. So perhaps it is as well that the illicit miners are focussing on Cornwall.

Stop Press *We have been reliably informed that anyone caught removing pebbles from Budleigh Salterton beach in Devon may be fined up to £5000!*

Government Policies and the Marine Environment

Within the last few months, Greenpeace (supported by other environmental groups) has obtained a High Court injunction forcing the oil industry to establish a network of marine protected areas before drilling for oil in the so-called Atlantic Frontier Zone off Scotland. According to the High Court, the EU Habitats Directive quite explicitly applies to the whole of the EEZ, that is, it applies out to 200 nautical miles from a state's baseline. Strangely, the British Government appears to have believed that the Directive extended only to the 12-mile territorial sea limit, when it originally granted the exploration licences.

Implemention of the Court's ruling will in fact only mean some delay and additional cost for the oil companies; it will not otherwise hinder their operations, and any hydrocarbons in the Atlantic Frontier region will sooner or later be extracted. In fact, the British Government is to appeal against the ruling, so there is bound to be some delay and added expense. Greenpeace and their allies brought the case because of their concern for the rich and diverse fauna that inhabit the region, including several species of marine mammals (which could be affected by the seismic testing used for oil exploration) and the ecosystems of the deep water *Lophelia* reefs (which could be affected by the drilling).

... so does one hand know what the other is doing?

It is difficult to see how any Government that has signed up to the various agreements for reducing greenhouse gas emissions can simultaneously support further large-scale fossil fuel extraction. In granting licences for oil extraction in the vicinity of the Atlantic Frontier, the British Government is doing just that. There can hardly be two more diametrically opposed policies.

An extra dimension is added to this issue by recent warnings from some eminent scientists. They suggest that continued drilling for hydrocarbons in continental slope and rise deposits may trigger the release of very large volumes of methane presently trapped in the sediments as gas hydrates. If they are right, global warming could accelerate, since molecule for molecule, methane is about twenty times more powerful as a greenhouse gas than carbon dioxide.

In this context, an additional contradiction – albeit one that only indirectly affects the marine realm – is the UK Government's imposition of an industrial energy tax that would penalise the use of energy from alternative (renewable) sources in the same way as energy from fossil fuel sources. A Royal Society report commented critically on this policy during 1999, pointing out that since only fossil fuels produce greenhouse gases, a Carbon Tax would be more appropriate. As yet there has been no widely publicized response from the Government. Nor has there been any obvious outcry from the wind and solar power industries; even the nuclear industry seems not to have complained.

Bioluminescence and the KGB – is it the money talking?

The arrest of three marine scientists at the Institute of Biology of Southern Seas in Sevastopol, who were engaged in collaborative projects on plankton dynamics and ecology with western institutions, has triggered a good deal of angry comment from colleagues in – among other places no doubt – Germany, the US and Britain. This is not surprising, for the list of cooperating institutions is impressive, including, for example, our own Royal Society and the Plymouth Marine Laboratory, Amsterdam University, the US Office of Naval Research (ONR), and the Smithsonian Institution.

The grounds for prosecution smack of Kafka-esque Cold War politics. First, bioluminescence of plankton apparently features in the research, and every schoolchild knows that bioluminescence can reveal the passage of submerged submarines. However, since the research collaboration has apparently been going on for several years, that seems a pretty feeble excuse – if the work was so strategically/militarily sensitive, why was the collaboration not stopped long ago? One answer of course, could be that Where Kafka Rules, the Wheels of Bureaucracy Grind Exceeding Slow, that the Ukrainian KGB has only now caught up with what's been happening – perhaps the involvement of the ONR was only recently recognized? But we've all seen enough Cold War spy movies to realize that's not likely.

The real reason is generally thought to be money. The scientists may have annoyed some people in high places, and then added insult to injury by obtaining sizeable hard currency grants from international projects such as the Darwin Initiative. Charges of currency fraud and smuggling would no doubt be easy enough to bring, and could be hard to disprove.

The board of the Deutsche Gesellschaft für Meeresforschung (the German equivalent of the Challenger Society) gave its support to an appeal for a proper international review of the Ukrainian scientists' case (see below), and similar sentiments have been expressed by individuals in both Britain and the US – there was even a report that the AAAS was to invite the 'Sevastopol Three' to a meeting early in the New Year.

Is this the kind of issue about which the constituent Societies of EFMS should have a collective voice? What do readers think?

News from the DGM

The latest issue of the *DGM Mitteilungen* (No. 3/99) reached us recently, with an editorial that writes of the often serendipitous relationship between science and technology, and of how curiosity-driven research can lead to socially beneficial outcomes. There is an obituary of Hans-Erich Reineck, who died in 1999 (aged 81), also a transcript of the commemorative address marking the 95th birthday of Werner Kroebel. These accompany the usual mix of features and articles on a variety of subjects. We provide below very brief summaries of some contributions.

A view of how marine research might look twenty years hence is of necessity hypothetical, touching both on new generations of remote-sensing equipment, and on future pollution problems – including a sideswipe at the idea of putting surplus anthropogenic CO_2 into the deep ocean.

A long article on integrated coastal zone management, with particular reference to the Wadden Sea, emphasizes the importance of interdisciplinary research and cooperation, not only between different scientific disciplines, but also between practitioners of the sciences and of the social sciences.

That is followed by a description of an automated technique for distinguishing different algal groups (blue–green and green algae and diatoms) using their characteristic fluorescence spectra. Then there are two short features about setting up a German centre for marine biodiversity, and about installing OSCR-type equipment on ships of opportunity to provide time-series measurements of wave and current regimes, especially in coastal waters.

'Politics' are represented in part by an analysis of progress in, and support for, marine and polar research by the Government's Ministry for Education and Research (BMBF), and by reports of DGM business (its AGM was held in October) and of the setting-up of the EFMS.

Perhaps most interesting of all, however, are a couple of features, both by women, on the need for reform in higher education and research. Among other things, they discuss the raw deal that many women scientists get relative to men, and the need for more transparency and consultation in decision-making by management. They claim that too much is decided Behind Closed Doors – sound familiar?

The last page of this issue carries the most politically significant item. It concerns the Ukrainian marine scientists arrested by the local KGB for exchanging research data and results on bioluminescence with colleagues in western Europe and the US (see also previous item). The DGM Board (Council) – which was in fact contacted directly by the Ukrainian scientists – has put its name to an appeal for their case to be reviewed internationally in an 'open and transparent' manner.

CCMS hit by decline in external funding

The NERC Centre for Coastal and Marine Sciences (which consists of the Dunstaffnage Marine Laboratory, Plymouth Marine Laboratory and Proudman Oceanographic Laboratory) has been coming to terms with severe financial difficulties. For several years budgeting has been greatly hampered by large fluctuations in external income, and the recent widely reported deficit arose mainly from a drop in income from research commissioned by other organizations, including Government departments.

Fluctuation in external income is a widespread problem amongst organizations dependent on 'mixed economies' and has affected other parts of NERC, as well as the research sector as a whole. One of the problems has been that, because the government wants to get scientific questions answered quickly, commissioned projects have tended to become smaller, with shorter time-scales, and there has been a general move away from large, long-term strategic programmes to smaller, short-term contracts – this is a common feature across the whole of the UK science base.

The NERC report into the background to the CCMS deficit identified the problem of external funding issues. It also stated that although deficits had occurred before within CCMS laboratories, the current projected shortfall in income was unsustainable.

NERC has invested £7 million as part of a recovery package, but it requires CCMS to stabilize external income at a realistic level in order to run on a balanced budget, and also to introduce improved financial controls. CCMS is having to carry out a restructuring, involving reduction in staff numbers. In all, 47 posts have been lost, including 21 compulsory redundancies. Plymouth Marine Laboratory has been hardest hit, and the proposed extension at its Plymouth Hoe site has been cancelled (although a refurbishment programme for the existing West Hoe Laboratory has been retained).

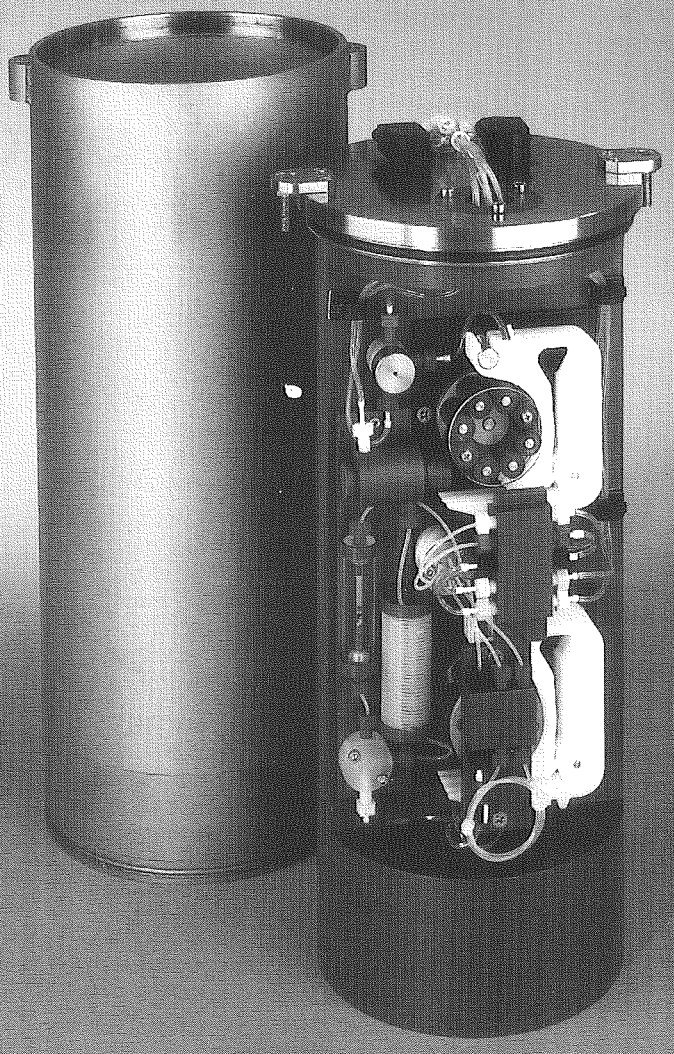
Research institutes are not alone in finding the funding situation tough. Universities and other marine sectors are suffering as well. For example, the National Marine Aquarium in Plymouth also laid off staff recently.

Marine science is not immune to the pressure and priorities of public spending by the Treasury. It competes for public funds along with Health and Education. If it is to get a larger slice of the pie, the public must perceive it as delivering science and products that are useful and important, and the Government must consider it as contributing to the national agenda, even when set against crises in the National Health Service and problems in Education. This can only happen if marine scientists themselves do a better job of explaining to both the public and Government *why* oceanography is important, and why long-term projects are essential for tackling pressing problems such as climate change, overfishing and other unsustainable practices.

CCMS Director Resigns

Professor Jacquie McGlade has resigned as Director of CCMS. Professor McGlade, who inherited financial problems when she took over the Directorship two years ago, feels that it would be appropriate for someone else to take CCMS forward in the new circumstances. The Acting Director of CCMS is Dr Graham Shimmield, Director of Dunstaffnage Marine Laboratory at Oban.

In situ flow analysis



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NOW There's a FUNNY THING...

Cleaner water – fewer fish?

It seems that the Trent is not the only river where anglers have been complaining that their catches have been drastically reduced, because the water is now so clean and clear that fish are either starving to death or being caught by bird and/or animal predators (*Ocean Challenge,* Vol. 8, No. 3, p.13). Similar stories are now circulating about the Great Ouse, the Wye, even the Thames, and some other large rivers as well.

The water in these rivers has become clearer because concentrations of suspended solids have been greatly reduced. There is no evidence at all that the water lacks nutrients. In fact, biodiversity has increased: there are now more invertebrates than there used to be, and a greater variety of aquatic vegetation.

I reckon the anglers' recollection of once-bumper catches is a hangover from the many decades when Britain's rivers were more or less badly polluted – in fact, some of the rivers have taken over 100 years to clean up. The 'Good Old Days' scenario as I see it is this: Nutrients were abundant – but not everywhere so abundant that excess algal growth deoxygenated the water – and suspended solids included a lot of organic matter. So there was plenty of food on which fishes could grow fat and multiply. But I would wager that biodiversity was not great.

I am reminded of a sewage outfall into the Douro estuary in the heart of Oporto, which I saw a couple of years ago. There was a 24-hours-a-day feeding frenzy by a large shoal of grey mullet, which moved towards and away from the river bank with the tides. This very simple food chain – detritus and detritivorous fishes – was (probably still is) a favourite spot for local fishermen.

That is an extreme example of what many of Britain's rivers must have been like before they got cleaned up.

The fish nowadays are neither starving nor being lost to other predators – unless there really is something in the anglers' claim that flocks of cormorants are migrating to inland fisheries. Is it not more likely that there are fewer fish because the ecosystem now has more trophic levels than before and is better balanced? Indeed, the rivers probably haven't been in this condition since before the Industrial Revolution – something like 250 years ago!

I bet there's another factor as well: more fishermen are chasing fewer fish – a familiar story in the marine environment too. The big difference is that, unlike Britain's rivers, the oceans are become more polluted, not less.

Hot bubbly anyone?

In *a recent Ocean Challenge* (Vol. 9, No.1, p.17), I briefly and rather flippantly mentioned the generation of light (sonoluminescence) from bubbles 'irradiated' by sound (insonified) – flippantly because I didn't really understand the process from the descriptions available. The underlying principle was evidently not easy to elucidate (*Nature,* **398**, 378–9), though it turns out to be quite simple: The 'rarefied' phase of the acoustic wave allows a small bubble to grow by more than an order of magnitude (from about 5 to 70 mm), so that it contains what is virtually a vacuum. When the 'compressive' phase of the sound wave comes along, the bubble is collapsed almost instantaneously, adiabatically compressing the small amount of gas inside and raising its temperature to 20 000–30 000 K, sufficient to create a plasma of ions, electrons and atoms. The process is repeated every acoustic cycle, and the result looks like continuous light emission, but in fact consists of about 20 000 flashes per second or more, depending on the sound frequencies used (values of 20 and 34 kHz were reported).

It may be some time before technological developments flow from these discoveries, but there is considerable interest in the possibility of achieving temperatures high enough for (hot) nuclear fusion to occur inside the bubbles. It does seem to be a more energy-saving way of researching nuclear fusion than the present methods, which involve building huge machines and expending vast amounts of fossil-fuel-generated electricity.

It's counter-intuitive and it's plausible ...

Deforestation leads to soil erosion and flooding, especially in mountainous regions. Forests are like sponges, they soak up the rain, so it doesn't immediately run off the land and fill the rivers and dump large amounts of freshwater and sediment into coastal seas. Right?

Wrong. Rainstorms tend to be local and affect only relatively small areas of large river catchments. Deforestation is not a recent phenomenon, and regions where forests were cut down decades ago or more have not become significantly more flood-prone. Research reveals no consistent relationship between deforestation and increased flooding.

It seems that deforestation by itself doesn't lead to increased run-off. The associated activities of cultivation, drainage, soil compaction and road construction do that. What's more, it's ground vegetation that does most of the job of preventing run-off. Thick scrub or even a crop of wheat will apparently suffice.

... but is it true?

I remain unconvinced. First, most deforestation is going on in tropical regions, where there are rainy seasons that do not consist only of isolated storms. There are prolonged periods of heavy rain over areas quite as large as the catchments of major rivers. Secondly, in managed forests and/or where deforestation is in progress, the ground vegetation is also removed (often by burning); added to which the soil is probably being compacted by these activities.

Anyway, what about *interception*? A quarter to a third of rainall in forested regions never reaches the ground because it is caught on leaves and either evaporated directly or absorbed and then transpired – so it returns to the atmosphere without touching the ground. When there are no trees, the role of interception is taken over by *infiltration.* Water that would otherwise be returned swiftly to the atmosphere soaks into the ground to be lost to the evaporation–precipitation part of the hydrological cycle (let alone to the oceans) for decades or more – unless the soil is compacted or covered with tarmac or concrete, and floods become more likely!

All in all, I can't help feeling that cutting down trees is not a good way to save water.

John Wright

IYO: the UK's contribution

David Pugh and Martin Angel

As you may remember from the last issue of *Ocean Challenge*, the International Year of the Ocean (IYO) was one in a long sequence of 'International Years'. *(Question: What was the 1997 International Year? For the answer, see bottom of column.)* Will IYO become just another in a series of unmemorable events? Were our efforts in any way successful in fulfilling the initial aim, which was to increase public awareness of marine and maritime issues?

IACMST was given the task of co-ordinating the UK's contribution. Initial efforts were focussed on publicizing the year and encouraging a wide range of organizations and individuals to contribute. A database of IYO-related events being organized in the UK was compiled, which helped co-ordinate the activities. A key activity was encouraging a series of regional open fora whereby the obvious (but often forgotten) message could be sent to Government that public perception of which issues are most important varies from region to region. Regional meetings can help not only to disseminate information but also to build greater consensus about how to resolve problems. Readers familiar with the activities of the Irish Sea Forum and the Solent Science Forum will be aware that this is not a novel approach, but it needs to be adopted more widely.

Events included scientific meetings, training workshops, courses, public lectures, publication of books, periodicals and posters, field excursions and recreational events. Several major events were hosted by Government Departments (DETR, FCO, DTI) and supported by Ministers. For example, DETR contributions included: Glenda Jackson launching the Port Waste Management Planning meeting in Southampton in January, at which proposals were made that should lead to a reduction in marine pollution; the address by John Prescott to the Advisory Committee on the Protection of the Seas, which introduced the concept of 'Seven Threats to the Seven Seas' (a theme reiterated by Michael Meacher when he opened Oceanology International in Brighton), and the second London Oceans Workshop, held at the end of the year.

Answer: 1997 was the Year of the Reef.

Many scientific societies (notably the Challenger Society, the Porcupine Society and the Geological Society) ran scientific meetings devoted to IYO themes. Research centres (Southampton Oceanography Centre, Centre for Coastal and Marine Sciences, Millport Marine Biological Station) and Universities (Plymouth, Liverpool, Southampton, Portsmouth, East Anglia, Bangor, Aberdeen) ran series of activities ranging from workshops to public lectures. Many Non-Governmental Organizations (NGOs) (for example, WWF, the Marine Conservation Society, Marwell Zoo and the County Naturalist Trusts) ran events including 'shark swims', beach days and a 'penguin week'. The hugely successful and popular 'Festival of the Sea' celebrated in Portsmouth over the August Bank holiday, included several contributions dedicated to IYO. The database of UK events is included on the compact disc being produced by IOC, summarizing IYO activities worldwide.

The IACMST efforts were linked with the parallel efforts of the UNESCO Forum which took on the task of publicizing the *Ocean Charter* to the general public and, particularly, to local authorities. Much of the NGO activity for IYO was focussed on events for World Ocean Day at the beginning of June, and WWF ran a campaign on sustainable fisheries which was launched in London by HRH The Duke of Edinburgh.

Two of Britain's oceanographic research vessels visited Lisbon during Expo '98. RRS *Discovery* with John Battle on board visited for a week and was in almost continuous use for receptions and as a floating trade exhibit. RRS *James Clarke Ross* called in for three days on her way south and was overrun by more than 5000 visitors. Cambridge University Press published the report of the Independent World Commission on the Oceans, *The Ocean: Your Future*, and London was chosen as one of three international centres for its launch. Marine journals published by Elsevier Science Ltd carried the IYO logo on the title page. Many marine research laboratories increased their efforts towards educational initiatives, participating in SET week, and in the annual meeting of the Association for Science Education, giving lectures on topical marine issues, and producing posters (NERC produced a poster to celebrate IYO; POL produced a poster on 'Tides and Weather' linked to a web-based teaching aid). The British Association for the Advancement of Science devoted a session to marine science and hosted one of the Buckland lectures on the theme of the rational use of the oceans.

The major effort was devoted to the series of Regional Open Fora, several of which stimulated considerable interest by local newspapers, radio and television. Their goal was to encourage discussion of local issues associated with sustainable exploitation of marine resources. Each forum was structured to provide participants with a clearer understanding of the issues and translate these to a national level. Local activists were sought to establish a committee to organize one-day meetings and to choose the issues of greatest local importance. Generally the response was both enthusiastic and effective. Most local organizers found sufficient sponsorship to support the meetings and to assemble large audiences from academia, local government and industry, and there was participation by sixth-formers in a number of the fora. Several were also attended by senior politicians. The Eastern England forum was opened by Elliot Morley, the Minister for Fisheries and the Countryside, as well as two local MPs and the local MEP. At the Welsh Coastal Forum, the Neil Kinnoch, the European Transport Commissioner, gave the after-dinner speech, Jon Owen Jones MP gave the keynote address, and the Secretary for Wales also attended. Michael Meacher gave a major address to the London Open Forum.

At many of the meetings it was emphasized that the choice of 1998 as the International Year of the Ocean had been timely. In addition to presaging the Millennium, it also fell only a few years after the United Nations Convention on the Law of the Sea (UNCLOS) came into force in November 1994. UNCLOS has been described as one of the most significant pieces of international legislation ever devised. Responses to UNCLOS are developing slowly, and IYO has helped these to emerge. IYO also came at a time when scientific evidence was showing increasingly

how the influence of humankind is affecting the open ocean as well as coastal seas. The role of the oceans in ameliorating climate change and buffering the effects of emissions of greenhouse gases to the atmosphere also came up at many of the meetings.

Some of the potential conflicts of ocean use relate to maintaining clean seas as a contribution to the quality of life, while still exploiting marine resources as a contribution to wealth generation and economic well-being. Nevertheless, some apparent conflicts may be readily resolved through open discussions and transparency in the decision-making process. For example, in one region a potential clash between fish-farming and tourism was defused when it became apparent that many tourists prefer to visit places where they can see commercial activity, provided the overall scenic beauty is not degraded.

Throughout 1998, John Prescott, the UK's Deputy Prime Minister and Secretary of State for the Environment, Transport and the Regions, alluded to the 'Seven Threats to the Seven Seas'. These Seven Threats featured repeatedly in both the national and the regional meetings. Here are some of the key questions associated with them.

[Much of this list featured in Vol. 9, No. 2, but is repeated here for completeness.]

Shipping

As world trade continues to increase, the bulk of goods and materials traded internationally will be transported by sea. In 1994–95, goods to the value of £32 000 per capita were imported and exported by the UK. In this context of continuing growth of transportation by sea:

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

Fishing

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

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

Pollution

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

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

Dumping waste at sea

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

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

Sea-bed minerals

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

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

Coastal Zone Management

There are real conflicts of interest about how our coastline is managed, and changes in coastal defence policy announced during the year stimulated even more vigorous discussions at many of the meetings. This is the main area of concern in which greater efforts at building consensus are likely to produce the best dividends.

- Local consultation and decision-making processes are often ineffective. How can they be improved?
- How can national and European directives be better reconciled with local and regional requirements?
- How can the best balance be achieved between commercial needs

(ports, outfalls, coastal defences) and environmental needs (conservation, recreation and human environment)?

- Developments exploiting renewable energy (wind, tides and waves) will produce more demands on coastal resources and facilities. How are these to be integrated into planning procedures?
- How are those directly affected by the new policies on coastal defence and managed retreat to be fairly compensated?
- Heritage and archaeological sites at present receive relatively poor safeguards. How is this to be remedied?
- How can the aesthetic, spiritual and cultural values of coastal environments be evaluated?
- Are discussion fora an effective way of improving consensus over coastal zone management policies?

Climate change

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

- What role can the UK play in developing a better understanding of likely responses of the oceans to climate change?
- How can coastal retreat be managed, and can policies be evaluated on economic grounds alone?
- Should greater efforts be made to stimulate exploitation of renewable marine energy sources (wind, tides, waves), as a major contribution towards reducing the UK's emissions of greenhouse gases.

Building on IYO

This list of UK concerns has a very close correspondence with those expressed during IYO by other countries, as identified, for example, by the Independent World Commission on the Oceans in *The Ocean; Your Future* (Cambridge University Press, 1998). The UK is making a significant contribution internationally, for example through scientific research into the role of the oceans in climate change and in seeking the means of ameliorating the potential effects of emission of greenhouse gases; also in conservation, through NGOs active in development of the concepts of marine reserves and no-take zones. We are State Parties to the UN Convention on the Law of the Sea, and participate actively in the work of the Commission on Sustainable Development, which is monitoring the progress made on the UN Convention on Environment and Development, and the Conventions on Climate Change and Biodiversity. The UK is active in some thirty international organizations with marine interests, ranging from the International Maritime Organization, which has its headquarters in London, to the International Whaling Commission, which is based in Cambridge. Both the Washington Convention on Land-based Discharges and the Oslo and Paris Commission for the Prevention of Pollution in the Maritime Area of the North East Atlantic (OSPAR) also have their headquarters in London. The work of these international organizations continues; for example, Quality Status Reports are being finalized for the five subregions of OSPAR, and are due to be published early in 2000.

Television programmes, films and well-illustrated articles often stimulate intense public interest in the coastal seas and open oceans. Nevertheless, developing public awareness of ocean issues and improving the ways in which awareness of the seas is introduced into the National Curriculum in schools, are matters for continuing concern. There are novel ways of doing this. For example, a special CD-ROM has been prepared for planning and educational work in the Dee Estuary; several of the local authorities collaborated to fund and promote this interactive programme in local schools. We learned of many other similar initiatives during IYO, throughout the UK. One useful next step will be to exchange information on what is available and perhaps to publish it centrally so that the best use is made of teaching experience and resources.

As highlighted by the Marine Foresight Panel, there is considerable potential for wealth creation from ocean resources, but if this potential is to be realized by the UK, it will need more people with the appropriate skills and knowledge.

One of the strongest messages coming through via the Regional Fora organized during IYO, was the need to sustain local dialogue on ocean issues. In some regions (west of Scotland, north-east England) the 1998 meetings were novel events, and may be continued. In other regions (Irish Sea, Solent and Wales) the mechanisms for holding such discussion meetings were already in place. One barrier to such Forum meetings becoming annual events in every region, is that there is no natural structure within which they can report, other than back to their respective departmental and sectoral interests. Should one of the Government Departments take on the role of encouraging these wider debates by calling for reports on a regular basis?

In order to resolve the challenges arising from the Seven Threats, we need to answer some general questions:

- o What new marine technologies are needed to deal with the threats?
- o What scientific programmes are most urgently needed to underpin the decision-making required?
- o How can improvements in scientific understanding and technical capability be rapidly and effectively applied to solving marine problems?
- o How can the general public be better informed, so that people's participation in debates on relevant issues can be more effective and more democratic, and so lead to greater compliance with the necessary controls and regulations?
- o How can marine topics and issues best be introduced into the National Curriculum?
- o Is present legislation so inflexible that it is inhibiting adoption of the best solutions?
- o Is DETR, which deals with environment and transport, in effect the lead Government Department on marine issues?
- o Does Britain need an Oceans Act similar to that of Canada?

Although the general theme of the International Year of the Ocean emphasized the holistic nature of marine issues, the regional meetings demonstrated very clearly the diversity of local interests and priorities. There can be no universal, or even national, strategy for meeting Mr Prescott's Seven Threats, not to mention the other concerns expressed at the fora.

Nevertheless, sharing experiences internationally, nationally and at local level must be beneficial. In a small but important way the UK regional and national meetings helped to achieve this.

David Pugh (IACMST Secretariat) and **Martin Angel** are at the Southampton Oceanography Centre.

Geophysical biology?

Strange goings-on aboard Large-Scale Facility RV *Sonne*

Peter Herring

No, the title is not a mistake, nor an oxymoron. Yet if any two disciplines within oceanography seem to be mutually exclusive they must surely be these two. Nevertheless, a very successful exercise in geophysical biology has just taken place in the Pacific, namely a joint cruise of the German research vessel *Sonne* working between Midway Island and Honolulu.

The GEOMAR/ University of Kiel research programme HULA, co-ordinated by Professor Ernst Flüh, undertook a two-leg cruise (Manila–Midway–Honolulu) aimed at studying the geology and geophysics of the volcanism both along the submerged part of the Hawaiian seamount chain and within the Musicians group of seamounts to the north of Hawaii. ('Trivial Pursuits' question: Where do Bach, Berlin and Bizet stand tall together?) The main objectives of the cruise were to examine the evidence for the hypothesis of fixed hotspots in the mantle (by collecting samples of rock along the Hawaii–Emperor chain for precise dating), and to study the elongate ridge-like submarine volcanoes within the Musicians group.

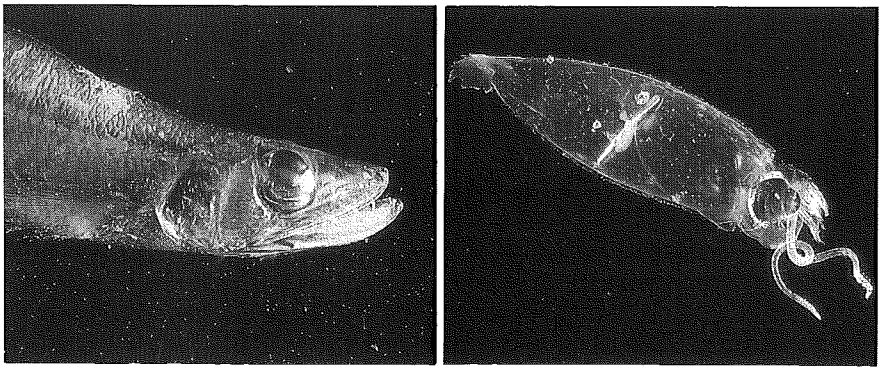
An additional biological programme formed part of the second leg of the cruise (SO 142). This programme arose out of the designation of the *Sonne* as a European Large-Scale Facility and an advertisement in *Nature* asking for scientific proposals from other European researchers that could be included in the German cruise programme. A small group of British deep-sea biologists put forward a proposal to study the optical and bioluminescent features of the deep-sea fauna of the Hawaiian area, working in association with Prof. H.-J. Wagner (University of Tübingen), whose research interests include the structure and function of the eyes of deep-sea fishes. Prof. Wagner had previously been a participant in NERC cruise programmes in the Atlantic addressing these questions, and the research group were keen to maintain the scientific momentum of this research. The proposal was accepted and incorporated into the HULA programme, forming a rare – perhaps unique – joint geophysical and biological collaboration.

The *Sonne* sailed from Midway on 30 May 1999 after the biologists had made the brief acquaintance of the chicks of thousands of Laysan Albatrosses, whose nests cover almost every piece of open grassland on this tiny island. The island was the focus of an important naval battle in World War II and is now a derelict naval base and US National Wildlife Refuge, with truly spectacular bird life. By the time we reached Honolulu on 27 June the cruise programme had involved interwoven periods of dredging, fishing with midwater trawls, and air-gun work with the ocean-bottom hydrophones, all interspersed with hydroacoustic and magnetometer surveys, and ending with two video-monitored grabs.

The biological work successfully deployed 21 deep midwater trawls fitted with the SOC closing cod-end system, designed to recover live animals in cold and dark conditions. A large variety of fish, squid and decapod crustaceans were obtained, several specimens of which were larger than the maximum size reported in the available taxonomic literature. Most specimens were in excellent condition, permitting material to be fast-frozen for later microspectrophotometry of the visual pigments and study of their regeneration after bleaching.

Catches of rare tubular-eyed species (*Stylephorus, Gigantura, Winteria* and *Opisthoproctus*) provided the opportunity to analyze the optics of these remarkable eyes and the properties of their lenses. A key to understanding the relative importance of vision in the sensory suite of deep-sea fishes is an analysis of the relative sizes of, for example, the optic and olfactory lobes of the brain and the number of nerve fibres to each region. During the cruise, many fish brains were prepared for this analysis, which involves marking the cut ends of the fresh optic nerve with fluorescent dyes. The dye then travels up the nerve fibres and can be localized later in sections of nerves and brain. The visual pigments of deep-sea fishes are located in the outer segments of the retinal photoreceptors (the rods). In shallow species these are constantly renewed, but nothing is known about how this works in deep-sea species. It will be possible to follow this process from the incubation of freshly isolated retinas in other fluorescent dyes. The dyes will show whether new rod segments are added by preferential attachment. The dyes will also reveal a great deal about the different neuronal circuitry within the retinas of different species, providing a better idea about how the eyes are used.

The eyes of most bathypelagic species, which live below the penetration of daylight, serve to detect and image only bioluminescent flashes and patterns. Studies of the sources and properties of this light therefore go hand-in-hand with those of the visual systems. This cruise was no exception. One of the exciting features of the catches was the presence of several specimens of two remarkable dragonfishes (*Pachystomias* and *Aristostomias*) which can emit both red and blue light, and have red-sensitive visual pigments. Another was the presence of several specimens of species of squid with both tubular eyes and light organs underneath them. Bright bioluminescent flashes were observed from



Left Benthalbella, *a 'pearl-eye' fish whose tubular eyes point upwards.* ***Right*** Sandalops, *a squid with tubular eyes.* © *P.J. Herring*

several other dragonfishes and from lanternfishes. Material was collected from these and other species for later study ashore.

The combination of activities and personnel on the cruise (22 scientists of seven different nationalities and from eleven different institutions) worked well. Every group achieved all its prior sampling objectives. The biologists learnt a lot about deep-sea geology and geophysics, and the geologists enjoyed their exposure to deep-sea biology. I think that our exclamations of pleasure at the exquisite appearance of some of the more bizarre or slithery specimens were viewed as an acceptable form of lunacy, but the animals were no more bizarre than the mud-spattered and goggled appearance of the young lady rock-cutter from Texas! The ship's company were expecting something larger than our usual 10–20 cm fish and never quite understood why they were asked to turn out all the lights when the catch was removed from the cod-end. I am sure they thought we had something to hide, particularly when we then rushed the catch off to the darkroom, and some hours later a number of eyeless and brainless fish carcasses were consigned to the deep.

The *Sonne* was built in 1969 as a stern trawler, was converted to a research vessel in 1977 and lengthened in 1989 to 98 m. She has first-class laboratory spaces, freezers, darkroom, cold-room and computing facilities and is operated by the company RF GmbH which also provides first-class technical support staff and both sampling and data-handling equipment. The catering is excellent and the British contingent were agreeably surprised by the regular break for tea and cake in the afternoon. The only oversight was that the tonic ran out early on, forcing a rapid transfer to gin and bitter lemon!

Most of *Sonne*'s time is spent in the Pacific on geological, geochemical or geophysical cruises. The success of this collaborative cruise further demonstrates that she is a splendid European facility, capable of most multidisciplinary sampling requirements, and that the continued provision of national vessels of this calibre is essential for the advance of global oceanography.

The biology programme on *Sonne* provided a preview of a similar but more extensive programme undertaken on *Discovery* later in the year by a similarly multinational team of university, SOC and US oceanographic institution scientists (plus BBC personnel). Perhaps we should have included a group of geophysicists in that scientific party.

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Deep Biosphere

Silke Severmann

In early September 1999, during the 144th meeting of the Society for General Microbiology (SGM) in Leeds, the Challenger Society and the Geological Society Marine Studies Group teamed up with the SGM to host a joint symposium. John Parkes, who is leading the geomicrobiology research group at the Department of Earth Sciences, Bristol University, and Rachel Mills, a marine geochemist in the School of Ocean and Earth Science at Southampton Oceanography Centre, invited colleagues from their respective fields to share the platform. Scientists from Europe, the USA and Japan responded to their call to present and discuss the latest advances in research into the deep subsurface biosphere.

Rachel Mills was not able to attend the meeting herself, as she was on maternity leave. The kick-off was thus provided by John Parkes, who presented an overview of recent findings from the Ocean Drilling Program (ODP). It has now been demonstrated that active microbial populations occur as deep as 842 m down into the sediment pile and they are believed to be present even deeper than that. The increase in pressure and temperature with sediment depth, and the progressive decrease in degradable organic carbon, require that the bacteria are well adapted to succeed under these extreme conditions. It could be said that their key survival skills are stamina, modesty and patience, as reflected in their estimated division time of 2000 years.

Subsequent presentations included examples of microbial life in environments as extreme as minute cracks in solid rocks (Terje Torsvik, University of Bergen), deep groundwater aquifers (James McKinley, Pacific Northwest National Lab., Richland, USA), oil reservoirs (Hilary Lappin-Scott, University of Exeter), the bottom of the Mariana Trench (Chiaki Kato, Japan) and ancient salt deposits (Terry McGenity, University of Reading). Karsten Pedersen from Gothenburg University, who kindly agreed at short notice to cover for Derek Lovley, introduced us to the Åsprö Hard Rock Laboratory in Sweden, which is a network of tunnels extending hundreds of metres deep into granitic rocks of the Baltic Shield. Biogeochemical processes are continuously monitored in this natural laboratory, and it has now become clear that microbes are of major importance for many of the reactions that take place.

A wide variety of microbiological techniques were mentioned throughout the presentations, from more traditional methods, such as laboratory incubations and total counts of viable cells, to some of the most recent applications such as molecular analysis and gene sequencing. However, one of the biggest challenges when studying microorganisms from extreme environments is to maintain *in situ* pressure and temperature conditions during sampling and to avoid contamination of the samples. Chiaki Kato from the Japan Marine Science and Technology Centre in Yokosuka presented the latest rather impressive technology for sampling under extreme pressure, which has been successfully employed to incubate bacteria from 11 km water depth in the Mariana Trench.

The knowledge that microbes can survive at great depth in sediments and rocks does not come as a total surprise to the geochemists. It is a well known fact that microbial metabolic activity modifies the chemical and isotopic characteristics of the environment, and geochemical analysis of minerals and pore fluids are valuable tools for establishing the presence of bacteria in modern and ancient deposits. James McKinley

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presented results from a number of studies where this type of forensic evidence was used to investigate the diversity of the microbial ecosystem along groundwater flowpaths. In close analogy to the terrestrial groundwater system, Rachael James from Imperial College London described how a deep marine aquifer could potentially represent a significant mechanism for supplying metabolites to subsurface bacterial communities.

Simon Bottrell from the Department of Earth Sciences, Leeds, gave an example of how isotopic evidence was used to elucidate the previously unexplained occurrence of non-seawater-derived SO_4^{2-} in deep sediments from ODP drill cores, thus stimulating bacterial sulphate reduction well below the zone of seawater irrigation. Adrian Boyce and colleagues from the Scottish Universities Environmental Research Centre in East Kilbride, Glasgow, have applied similar techniques to ancient metal ores from the Navan zinc and lead mine in Ireland. Adrian invited the audience to raise their glasses to the sulphate-reducing bacteria that have contributed an estimated 80% of the total amount of sulphides to this ore-deposit, which today is Europe's biggest zinc producer.

The session concluded with a presentation by Max Coleman, University of Reading, who offered his thoughts on one of the basic principles of geology – that the present is the key to the past. In a comparative study of siderite concretions from modern and ancient deposits, Coleman and his colleagues had explored whether this rule also applies to microbially produced minerals. Current evidence might suggest that this is not the case, but this situation is believed to reflect our still rather limited understanding of the processes involved, and further work is certainly required to answer the question. Their study did, however, provide one of the many fine examples of how integrated research can help us to improve our understanding of biosphere–geosphere interactions.

Great advances have been achieved in the field of geomicrobiology over the last two decades and we are now beginning to recognize the significance of microbial activities in a number of geological processes, such as weathering of rocks, mineralization and biogeochemical cycling. In addition, is has now become clear that bacteria can survive in much more extreme conditions than previously thought possible. Research into the deep biosphere has potentially far-reaching implications, as it touches on questions concerning the origins and limits of life, and the search for life on other planets. The most important outcome of the meeting was therefore to stimulate communication and further collaboration between scientists from a broad range of disciplines in this exciting new field.

Following the conference, a three-day workshop was held in the Devonshire Halls in Leeds. It was the first gathering of the European Network on Exploring the Deep Sub-Seafloor Biosphere, which is a scheme funded by the European Science Foundation. The purpose of the workshop was to identify and discuss potential targets for deep biosphere research in Europe. In three working groups, a variety of sites were considered, including mud-volcanoes and sapropels in the Mediterranean, carbonate mounds along the North-Atlantic margins, pre-existing and proposed boreholes such as the KTB deep borehole in Germany and numerous holes into oceanic crust, hydrothermal systems on the Mid-Atlantic Ridge and in the Guaymas Basin, and gas hydrate deposits and oil-reservoirs. Two more meetings of the network are planned, and the hope is that by the end of the programme in 2001 a coherent and ongoing European research framework will be in place.

For further information please contact: Professor R. John Parkes (Chairman), University of Bristol, Dept of Earth Sciences; Email: j.parkes@bristol.ac.uk

Dr Andrew J. Weightman (Secretary), Cardiff University, School of Pure and Applied Biology. Email: weightman@cardiff.ac.uk,

or check out the web page: http://www.esf.org/life/ln/Edssb/ln_edssba.htm

Silke Severmann is at the School of Ocean and Earth Sciences, Southampton Oceanography Centre.

European Society of Limnology and Oceanography

Do you believe such a body would be viable and would be of interest to aquatic scientists in Europe? If so, please have a look at the website given below for more information, and if you are interested, fill out the electronic form so we can put your name on the mailing list.

Feel free to circulate this information amongst European limnologists and oceanographers you think might also be interested.

Daniel Conley and Peter Koefoed Bjørnsen, National Environmental Research Institute, PO Box 358, DK-4000 Roskilde, Denmark; Tel. +45-4630-1200; Fax: +45-4630-1114; Email: eslo@dmu.dk
Website: http://www.eslo.org

Oceanography Course for Divers a Great Success

On 27–28 November 1999, twenty-six scuba divers attended an 'Introduction to Oceanography' course devised and organized jointly by the British Sub-Aqua Club and the Challenger Society. Students travelled to Plymouth Marine Laboratory (PML) from Cornwall, Devon, Yorkshire, London and Bristol, to hear about all aspects of oceanography. Topics covered included physical oceanography, history of oceanography, phytoplankton blooms, zooplankton, marine 'snow', fisheries and fish identification, marine mammals, life in the deep sea, satellite imagery as a tool in oceanography, environmental management, and the effects of climate change.

Presentations were given by scientists working at PML, Southampton Oceanography Centre, Plymouth University, the Marine Biological Association and the National Marine Aquarium. Participants voted the event a great success and would like to express their thanks to the presenters who communicated their science in such a professional, accessible and enthusiastic manner.

It is hoped that the course will become an annual event. Anyone interested in participating or presenting should contact Carol Robinson at Plymouth Marine Laboratory. Email: carol.robinson@pml.ac.uk

Earth System Science at the Royal Society

A very personal view (are we fiddling while Rome burns?)

John Wright

What does the concept of the Earth System mean to you? To me it means the solid Earth, the atmosphere, hydrosphere and biosphere, and the way these components interact and influence one another. Well, the Earth System Science Day, held at the Royal Society on 7 September 1999, was mostly concerned with the solid Earth parts of the system, though the topics covered were pretty varied, extending from the core to the top of the crust.

An exposition of the origins of Earth and the Solar System was followed by presentations about wave motions in the core, seismic tomography, and the 'new mantle dynamics', as well as about fluid flows in rocks and fluid-flow interactions; also about the plumbing systems of volcanoes and the behaviour of magmas before and after eruption; and about the rise and fall of mountain belts (the rheological properties of rocks in igneous and orogenic environments also featured in these latter presentations). The three final contributions dealt with fossils and biodiversity, the stability of Antarctic ice-sheets, and the mechanisms that control glacial–interglacial cycles.

Three-quarters of the talks were thus devoted chiefly to examining diverse aspects of the solid Earth, and some people present felt that the remaining components of the Earth System got pretty short shrift. On the other hand, discussion sessions interspersed with the talks enabled a diversity of views to be expressed, and there was no shortage of points to debate, since this meeting was very much about research at the frontiers of science, with plenty of new ideas and discoveries.

The presence of distinguished guests lent some credence to speculations that the meeting had been convened as a means of encouraging high-level support for Earth science research. The glossy full-colour booklet of abstracts could be seen as consistent with such speculations – but I wouldn't know and couldn't possibly comment.

In light of the largely 'non-Life' bias of the meeting, it seemed mildly ironic that it was kicked off by Aubrey Manning (presenter of the hugely successful 'Earth Story' on TV), whose background is in behavioural biology. His observation that Life got started on Earth nearly 4 Ga ago was followed by a plea that Earth and Life scientists get together to become environmental scientists and help humanity to cope with the next 100 years, which he sees as potentially the most dangerous in human history. He spoke of the need to raise public awareness and bring issues of Earth and Life into schools, noting that nowadays there is a serious lack of both geographical understanding, in the sense of knowing where places are, and of historical awareness, particularly about the 20th century ('those who ignore the past are condemned to repeat it').

A speaker-by-speaker account of the meeting would be excessively tedious, so this report is about those aspects of the day that struck me as interesting and/or controversial, not necessarily in any particular order – though I shall at least begin at the beginning.

Any planetary system developed around a star can be expected to have rocky inner planets and gaseous outer ones – but it is purely a matter of chance that one of the rocky planets in our Solar System is at the right distance from its star (the Sun) to support Life. Over twenty other stars in our galaxy are believed to have planetary systems round them, but the objects so far identified are large and in unexpectedly small orbits. Earth-like planets have not been observed, which is not really surprising since, as I understand it, about the only way of detecting other planets is by the gravitational perturbations they cause to their parent star – and only big planets can do that. A planet like Earth, which amounts only to a few p.p.m. of the mass of the Solar System (that puts us in our place!), is effectively undetectable. If our own Solar System is anything to go by, giant planets are not suitable for life – but they could have satellites that are – Jupiter's moon Europa is a good candidate – but it will probably be a decade or two before we can find out.

All sorts of permutations and combinations of planetary bodies can result from condensation of stellar nebulae and the almost infinite variety in number and style of collisions between orbiting bodies. There are billions of stars in our galaxy alone, so there must surely be at least a few other planets with surface conditions approximating to those on Earth and able to sustain Life. Once an Earth-type planet has formed, capable of retaining liquid water at the surface, it is a racing certainty that Life will appear – whether indigenous or by importation (i.e. by 'panspermia') – and that it will begin to evolve. But surely we cannot confidently say more than that? It was by no means pre-ordained that the Earth would be as it is now, 4.6 Ga down the line, if an early (prokaryotic) life-form hadn't developed photosynthesis, and started the long process of replacing CO_2 with oxygen. There are plenty of anaerobic bugs around even today – and they provide clear evidence that Life doesn't need oxygen to flourish. If Earth had retained its early CO_2-rich atmosphere it might well not now have oceans and the dynamic interior that have given us plate tectonics. But for photosynthesis, Earth could have gone the way of Venus or Mars.

Some meteorites contain micron-sized particles of refractory silicon carbide (SiC), corundum, graphite and diamond, which are thought to be pre-Solar System left-overs, possibly formed in long-dead red giants. But since they are inert and contain no radiogenic isotopes (so they cannot even be dated), there's no way of establishing their origins. So just how this stardust contributes to our understanding of planetary origin and evolution remains enigmatic.

Returning now to the present day, it seems that our familiar ideas about plate tectonics may soon look old-fashioned. According to proponents of the new concepts of mantle dynamics, there is now abundant evidence that both sinking slabs of subducted lithosphere, and ascending mantle plumes, can pass through the discontinuity (defined by a mineral phase-change) at 660 km depth in the Earth, although some material may be

deflected or even stopped by it. The growing body of physical evidence for whole-mantle convection seems to be at odds with some geochemists' picture of a compositionally distinct upper and lower mantle.

Be that as it may, we can henceforth expect geophysicists increasingly to talk of the dynamic topography of the Earth's surface, which is somewhat analogous to the dynamic topography of the sea-surface (with which *Ocean Challenge* readers will be familiar), in that surface elevation is related to underlying density contrasts, with convergence (as at subduction zones) associated with sinking of oceanic lithosphere, and divergence (as beneath spreading ridges) associated with uplift. On the continents it is generally the other way about, which is why we have mountain belts and rift valleys. However, continental lithosphere can stretch and subside even where convergence (mountain-building) is still in progress, if the upper mantle 'root' beneath the uplifted region is removed. It seems that initial isostatic rebound following root removal is in turn followed by extension and subsidence, as the rocks effectively collapse under their own weight. All this may seem to be of little interest to oceanographers, until you realize that, for example, there are basins in the north-west Mediterranean formed by just such a process during later stages of uplift of the Pyrenees.

It seems that proponents of the 'new mantle dynamics' have still to resolve the issue of whether or not the Earth's heat flow has declined more or less uniformly with time; and hence if rates of sea-floor spreading (Earth's principal heat-loss mechanism) have likewise gradually decreased with time. The alternative is that heat has been lost in 'bursts' resulting from the mantle plumes that cause major eruptions of basalt, as well as from periods of accelerated sea-floor spreading. As discussed in *Ocean Challenge*, Vol. 7, No. 3, p.6, this has a bearing on causes of past sea-level rises, since the inflation of ocean ridges associated with increased spreading rates would displace ocean water onto continents.

But I digress. The recent advances in scientific understanding of deep Earth processes would not have been possible without the sophisticated instrumentation and modelling techniques that now enable geophysicists to see thousands of kilometres beneath our feet. But data-acquisition does not necessarily depend upon expensive equipment. Information can come from unusual and unexpected sources. Thus, it was fascinating to learn of a recently discovered record of some 15 000 magnetic measurements compiled aboard ships of the East India Company, dating back to the early 1600s. This archive is providing valuable additional information about how the direction and intensity of the Earth's magnetic field has changed during recent historical times.

Despite my earlier strictures about bias, I have to admit that even in those sessions that focussed mainly on geophysical and geochemical phenomena, the influence of biological processes could not be altogether ignored. For instance, some of the CO_2 (though by no means all of it) involved in fluid–rock interactions in the crust comes from the decomposition of limestones which were formed by marine plants and animals. In addition, we now know that the deep biosphere extends a kilometre or two below the Earth's solid surface, so processes of diagenesis and re-crystallization must, in part at least, be biologically mediated. Another nugget of information that emerged during discussions was that a small contribution is made to palaeo-magnetism by biology. Apparently, short-term excursions (mini-reversals) in the Earth's magnetic field over the last 800 kyr of positive polarity can be reliably identified and correlated only because they are recorded by magnetite biogenically precipitated in sediments.

In fact, even processes much deeper within the Earth could be influenced by activity in the biosphere. Subducting slabs of oceanic crust (and lithosphere) carry a substantial load of organic materials, consisting of dead plant and animal remains and of living bacterial and viral communities. Together with water trapped and combined in crustal rocks and sediments, these organic remains influence the chemical evolution of the mantle, and probably affect its rheology too.

In this connection, hydrous minerals in mantle-derived rock samples have strongly negative δD ratios, i.e. they are depleted in deuterium (^2H or D) relative to hydrogen (^1H). One possible explanation is that the lighter hydrogen isotope comes from subducted hydrocarbons, having been preferentially fractionated into living organisms; which would be consistent with the slightly negative $\delta^{13}C$ of mantle-derived carbon (–7 per mil).

It seems, however, that the preferred explanation for negative δD ratios in mantle rocks is that there is a source of hydrogen deep within the mantle, perhaps even in the core. The idea of hydrogen in the core is neither new nor implausible. For a long time, geophysicists have known that the core is not quite dense enough to consist entirely of iron and nickel, and must therefore contain a lighter element. Possible candidates include carbon, sulphur, silicon, and hydrogen (in a highly compressed metal-like form). There has even been a suggestion that the core could contain 97% of the Earth's store of hydrogen. That may seem like a lot of hydrogen, but back-of-envelope sums suggests that it isn't. The core makes up nearly a third of the Earth's mass, i.e. nearly 2×10^{21} tonnes. Water in the hydrological cycle amounts to about 1.4×10^{18} tonnes, only a ninth of which is hydrogen. Even if *all* the world's hydrogen were in the core, it still wouldn't amount to more that 3 or 4 parts per thousand of the mass of the core.

Entertaining though such speculations may be, the reality is that there's a lot of hydrogen locked up in the water that circulates through the various reservoirs of the hydrological cycle at and near the Earth's surface – as indeed it has been doing almost from the beginning. There is a powerful case for arguing that without Life, the Earth's surface would be without liquid water (let alone a hydrological cycle) and that the plate tectonic 'engine' would long ago have seized up, since it is the lubricating effect of water that enables it to keep going.

The oceans were probably also the cradle of life, and they have been responsible for recording most of its evolution, since nearly all fossils are in marine sediments. At this meeting, fossils were dubbed 'the diarists of the Earth' which defines their role rather well. They are more than just historians (that is the role of geo-chronology and lithostratigraphy in this analogy), since it is 'fossil diaries' that reveal what life was like in the distant past. How else might we discover, for instance, that – like their contemporary counterparts – plankton may have suffered from iron-starvation in the Ordovician, some 400 million years ago? Large concentrations of fossil graptolites (the dominant zooplankton of their day) in shales overlying ash layers have been interpreted as resulting from plankton blooms following volcanic eruptions that supplied iron-rich dust to surface

waters, just as they do today (Mount Pinatubo being a recent well documented example). More subtly, by analogy with present-day plankton blooms, large fossil graptolite populations comprising a range of growth stages (from juvenile to adult) can be correlated with the ash-fall events, which would have provided large but temporary supplies of iron. Fossil populations dominated by adults are found in ordinary black shales, and could thus represent normal 'high nutrient/low chlorophyll' (HNLC) conditions, where little ash was available.

Palaeontology can also contribute to understanding of present-day biodiversity and may thus help to arrest the horrific decline of species numbers that we read and hear about almost daily (should we therefore be worried that there are fewer palaeontologists in the whole of Britain than there are librarians in London?). Over the last 20 million years or so, for example, massive corals have become the dominant component of Caribbean reef systems, proving more resistant to ecological change than branching coral colonies. Unfortunately, it is the massive corals that tend to be preferentially quarried for constructional and/or ornamental purposes, and their removal makes the whole reef ecosystem less able to resist the other environmental pressures caused by human activities. In this connection, I was reassured to learn that according to the fossil record, corals in the geological past survived temperatures significantly higher than those prevailing today, confirming suspicions (reported in *Ocean Challenge*, Vol. 9, No. 1, p.5) that the main cause of the current world-wide decline of reef corals is not rising temperatures (though that cannot be helping), but other anthropogenic influences.

Global warming may also be having less effect on Antarctic ice-sheets than is popularly supposed. The East Antarctic ice-sheet is largely grounded on the Antarctic continental landmass, and beneath part of it lies the mysterious Vostock Lake. This contains water that may be as much as a million years old – some sources say up to 30 million years old – and remains untapped because of fears of contamination. Several lines of evidence suggest that this eastern ice-sheet has been stable for something like 15 million years, as a consequence of several feedback mechanisms that maintain the cold polar climate. Such likely long-term stability is just as well for us, since if this ice-sheet were to melt, global sea-level would go up by about 60 m.

By contrast, the much smaller West Antarctic ice-sheet appears to be a good deal less stable, for its ice shelves have been shedding substantial chunks of ice into the Southern Ocean for the last couple of decades. But the ice here is much less thick and contains the equivalent of only about 6 m of sea-level rise. The West Antarctic ice-sheet appears to wax and wane as sea-level falls and rises with glacial–interglacial cycles. The reason it is shrinking now may be only because it always does so during interglacials anyway, and not primarily as a consequence of enhanced greenhouse warming. The situation may be analogous to that of the Sahara, which became desert because the North African climate became warmer and drier around 5 500 years ago, not necessarily because of overzealous agricultural practices by our forebears.

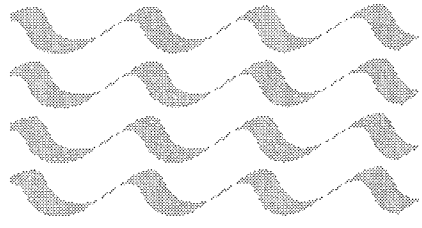
According to records preserved in ice-cores and deep-sea sediments, during the last 10 000 years (the Holocene period) the Earth has enjoyed a period of climatic stability and relative warmth unprecedented in the previous half million years, perhaps more, even allowing for oscillations like the Mediaeval Warm Period and the Little Ice Age of the 16th to 18th centuries. As most readers probably know, the quite regular (100 kyr) alternation of glacial and interglacial periods is almost certainly driven by the Milankovich orbital cycles which control the amount and distribution of solar radiation received by the Earth. The cycles are modulated by several other factors, such as concentrations of dust, aerosols and greenhouse gases in the atmosphere, as well as variations in the intensity of solar radiation itself. But there are so many different feedbacks between the various parts of the Earth system that it is not at all clear which factor(s) – if any – is/are the most important.

Short-term climatic variability seems to have been commoner during glacials than interglacials, but human interference with the Earth system has become very extensive. Our present comfortable (interglacial) climatic regime could become subject to upheavals that might make recent disturbances associated with large tropical cyclones and strong ENSO events seem quite mild.

How to sum up this meeting? The perceived imbalance of topics under discussion seems to me less important than the feeling – expressed in the subtitle to this report – that Big Science is not addressing the real problems that face the Earth system. Aubrey Manning may feel the same, for he took the floor again towards the end of the meeting and asked what could or should be done to help the world through the next critical century. Somebody voiced what must surely be a consensus view, that something should be done to stop pumping out pollution, and otherwise grossly interfering with the Earth's own biogeochemical cycles.

The meeting was concerned primarily with basic curiosity-driven (albeit large-scale) research. But 'Research is no substitute for political action ...' as a *Nature* editorial proclaimed late last year. Yes indeed. Alas, the fact of the matter is that serious political action to cure the world's ills, to alleviate the disease of human interference, would destroy the global economy. Imagine the effect of even a 10% statutory reduction in *global* fossil fuel use (i.e. not just in the rich countries), let alone the 60% that is generally reckoned would be needed now. Would not the ensuing economic disruption cause an immediate shortage of funds for any research, curiosity-driven or not?

How many who were present at this meeting read about the UN report on the dire, indeed critical, condition of the global environment, which appeared in the broadsheet newspapers and the broadcast media in mid-September? Like me, did anyone wait in vain for a government spokesperson to suggest policies for dealing with the crisis? Like me, did they hear instead Britain's Chancellor confidently forecast at least two years of 'sustainable economic growth'? Perish the thought that either politicians or scientists are 'fiddling while Rome burns', but disinterested observers from another planet might wonder if that is indeed what they are doing.



Challenger Society for Marine Science

ANNUAL REPORT 1998–99

Message from the President, Dr Harry Elderfield

This, the 96th year (1998–99) of the Challenger Society, has been my first as its President, or almost so. The President elect, Professor Ernest Naylor, very unfortunately was unable to take up the Presidency because of illness and I was elected as his replacement in time for the first meeting of Council in January this year. It is very pleasing to report that Professor Naylor has made significant progress in his recovery.

Professor Whitfield reported last year on steps towards the establishment of a European Federation of Marine Science and Technology Societies (EFMS). This is now a reality. The Act of Creation was signed at a colourful ceremony on Friday, 11 December, 1998, at the Institut Océanographique in Paris, and is now registered under the French law of 1 July, 1901. What this means for UK marine science is two things. First, it provides a mechanism and springboard for better communication between scientists in the UK and Europe, and for further development of marine sciences with a European perspective. Of course, other sorts of organisations do exist for European collaboration but EFMS is unique in representing scientists at a grass roots level. The challenge will be to set up and develop its unique identity and steps are being made in that direction. The EFMS currently represents four UK marine science organisations: the Challenger Society for Marine Science (CSMS), the Society for Underwater Technology (SUT), the Scottish Association for Marine Science (SAMS) and the Marine Biological Association of the UK (MBA); and this is a second advantage of the establishment of the EFMS. It has become clear that better links between the four UK organisations were necessary to best represent our views within the EFMS and this itself has led to the recognition that such links are mutually beneficial within the UK too.

The year has been an active one for the Society, with numerous meetings, as will be reported later. Also, we have further developed the idea of a more structured approach to operation of Council so that skills and memory can be transferred to new members. We have also revised the system of awards and honours, which we hope will, as well as recognising talent and achievement in a public manner, be of some benefit in providing small grants to students and aiding career development. The Education Committee under Dr C. Turley has been very active and will lead to a further broadening of our remit to marine scientists of the future as well as those of today.

The public face of the Challenger Society is, for many, *Ocean Challenge*. This represents a remarkable achievement by the team involved and does much to foster interest in UK marine sciences. I have picked out this aspect of the Society's activities to make an additional point. The Challenger Society is not a wealthy society; the reverse is true. We rely on your subscriptions to keep us afloat. So, please encourage all your colleagues and friends, who are professional marine scientists or the oceanographers of the future or simply interested in the sea, to join the Challenger Society. We represent you and the more who join the better we can represent you. Also, in this context, I wish to express the Society's grateful thanks for the support of NERC's two marine science laboratories: the Centre for Coastal and Marine Sciences and the Southampton Oceanography Centre. Your help has been crucial to our activities, as has been the hard work and commitment of the Council members and those who have also helped the Society in various ways such as organising meetings and advertising in the magazine; and it is much appreciated.

Marine sciences is a broad community. One can see this from the articles in *Ocean Challenge*. Professionally it includes not only biological, chemical and physical oceanographers but also engineers, geologists, geophysicists and historians. Marine science has an important rôle to play in education in general. It also has a rôle to play in recreational activities on and under the sea. We wish to hear the voice of all members of this broad community. Write and tell me what you like about the Challenger Society or what you would like to see changed. Offer to run meetings, or specialist courses, or write articles for our magazine or for newspapers. Volunteer suggestions and volunteer your time. Be active!

September 1999

Membership

Membership as at August 1999 was 559, including 345 Full members, 163 Student members, 4 Honorary members, 33 Retired members and 14 Corporate members. This is an increase in membership of about 20 compared with last year.

Since the last Annual General Meeting, which took place on 8 September 1998, the Council of the Society has met four times, on 9 September 1998, 7 January 1999, 28 April 1999 and 9 September 1999. The Council members and their responsibilities were as follows:

Dr H. Elderfield	President
Professor M. Whitfield	Immediate Past President
Mr C.P. Quartley	Honorary Treasurer
Dr C. Robinson	Honorary Secretary
Mr S. Hall	Publicity and Marketing (Chair Designate)
Mr M.J. Howarth	Chair of the Meetings Committee
Mrs N. Lane	Membership Development
Dr R. Lewis	Specialist Groups / Education
Dr G. Shimmield	Policy
Dr C. Turley	Chair of the Education Committee
Dr J. Allen	Publicity and Marketing
Mr K. Boot	Education Committee (Chair Designate)
Dr D. Curtis	Meetings Committee (Chair Designate)

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

Mrs J. Jones	Executive Secretary; membership, publicity, marketing
Ms A.M. Colling	Editor, *Ocean Challenge*
Mr J.B. Wright	Associate Editor, *Ocean Challenge*
Dr R. Mills	Chair, Editorial Board, *Ocean Challenge*
Dr N. Wells	Chair, Organising Committee UK Oceanography '98

Prof. M. Whitfield, Mr C.P. Quartley, Dr G. Shimmield and Mr J. Howarth, who retire from Council at the 1999 Annual General Meeting, are sincerely thanked for their enthusiasm and commitment to Council and the Society. Mrs N. Lane will take over as Honorary Treasurer at the 1999 AGM.

Policy

Apart from further development of a *Challenger 2000* document, the main activity this year has been EFMS. The European Federation of Marine Science and Technology Societies (EFMS) was founded at a ceremony on Friday, 11 December, 1998 at the Institut Océanographique in Paris, and is now registered under the French law of 1 July, 1901. The EFMS currently represents four UK marine science organisations: the Challenger Society for Marine Science (CSMS), the Society for Underwater Technology (SUT), the Scottish Association for Marine Science (SAMS) and the Marine Biological Association of the UK (MBA). Professor John Simpson (ex-President of the Challenger Society) represented CSMS at the signing ceremony. The EFMS will be run by a Council and Executive Committee. In order to get EFMS up and running, the meeting of the Federation made the following appointments for 1999: President: Professor Lucien Laubier (UOF, France); Vice-Presidents: Dr Ricardo Cattaneo-Vietti (AIOL, Italy) and Dr Harry Elderfield (Challenger Society); Treasurer: Professor Adolf Weber (DGM, Germany); General Secretary: Dr Jean-François Pavillon (UOF, France). In addition, the UK delegate on EFMS Council is Dr Graham Shimmield (SAMS). To better coordinate UK participation, an *ad hoc* meeting of the four UK marine science organisations currently within EFMS was held in February. This proved to be extremely useful and will be repeated annually.

Education

Dr C. Turley (Research Scientist, CCMS-PML) (Chair), Mr S. Hall (SOC School Liaison Officer and Chair of the NERC School Liaison Officer network) and Mr K. Boot (Chief Education Officer at the National Marine Aquarium) were asked to form the next Education Committee. They met with members of the Policy Group in February 1999 to discuss the future policy and strategy of the Committee and to set specific and achievable objectives in order to make best use of CSMS resources. It was felt that the Society as a whole should play an active role in the Public Understanding of Science through the compilation of a list of

marine science experts from its members. C. Turley agreed to organise a database of experts and a questionnaire has been sent out to members enlisting their co-operation. This could be provided to media science correspondents in order to resolve the problem correspondents sometimes have in finding experts. K. Boot agreed to collate available marine science education material and assess its usefulness as a resource. S. Hall continued his strong links with the SUT Education Committee and has just had his book, which was written for children, published. It's called *Exploring the Oceans*. All members of the Education Committee attended the National Forum on Education and Training in Marine Science and Technology organised by the Inter Agency Committee on Marine Science and Technology (IACMST) (Royal Society, June 1999). S. Hall gave a presentation on Marine Science and Technology for Young People. An open discussion by representatives of relevant professional societies (CSMS, SAMS, MBA, MCS, SUT, etc.) agreed to convene a meeting of the educational committees of these societies to compare strategies and resources related to MST education and training in the UK.

Ocean Challenge

This has been a good year for *Ocean Challenge*, but there is a continued need for suitable articles and news items. The mix of lively, interesting and accessible articles on all marine-related topics – including news items, controversial comment and review, and cutting edge research – is a successful formula, and the journal continues to prove its worth as a forum for debate about topical issues. Vol. 9, No. 2 has been designated a European issue, but contributions from Europe are increasing generally and will add to the variety of published material. Interest from advertisers is growing less rapidly than perhaps it should, but the wider distribution and circulation accompanying closer integration of European societies (through EFMS) should improve the 'reach' of advertisements.

Meetings

The last AGM, in September 1998, was held during UK Oceanography '98 at the University of Southampton, where 345 attendees contributed to 131 oral presentations and 104 posters. Many thanks to Dr N. Wells, members of the local and national organising committees and to the commercial sponsors who ensured this conference was such a success. The next CSMS conference will be at the University of East Anglia, 10–16 September 2000, and has been renamed UK Marine Science 2000 to reflect the broad range of marine science subjects encompassed by CSMS. During 1999, the Society has supported the organisation of the following meetings: Postgraduate Research Seminar in Marine Earth Science (joint with the Geological Society), 23–24 February 1999 (Dr J. Jones; University College, London); Ocean–Atmosphere Interactions near Coasts (joint with the Royal Meteorological Society), 21 April 1999 (Dr P. Nightingale, Plymouth Marine Laboratory); Progress in Chemical Oceanography, 9–10 September 1999 (Dr E. Achterberg; University of Plymouth); Primary Productivity of Planet Earth: Biological Determinants and Physical Constraints in Terrestrial and Aquatic Habitats, 6–11 September 1999 (Dr R. Geider, Marine Biological Association); and The Deep Subsurface Biosphere, 9–10 September 1999 (Prof. J. Parkes, Bristol University and Dr R. Mills, University of Southampton).

Publicity and marketing

The Publicity and Marketing committee combines the activities of the Membership, Marketing/PR, Web Site, Sales and *Ocean Challenge* Income teams into a single entity which reports to CSMS Council. Membership is drawn from CSMS Council with secretarial support from J. Jones and comprises S. Hall, N. Lane, D. Curtis, J. Allen, and C. Quartley. The committee met twice in early 1999 and agreed a remit that covered the following areas: ensuring membership growth; ensuring the efficient collection of subscriptions; ensuring the distribution of publicity material; maintaining the CSMS website; and ensuring that suitable stock is available for sale to members. The Committee also agreed a number of targets for the end of 1999. These were to increase membership of the Society to 650; to have at least 10 corporate members; to achieve sales of £600; to achieve an advertising income of at least £2000, to achieve an income from *Ocean Challenge* mailshot inserts of £500 and to achieve an income from library subscriptions of at least £1500. These are ambitious targets for a small society and we welcome suggestions from CSMS members as to how the Committee can meet its targets to increase membership and income.

Affiliated Groups

The BRITISH GROUP OF ALTIMETER SPECIALISTS met at the Meteorological Office, Reading on 28–29 June 1999. As usual, presentations spanned the range of applications of altimetry. The oceanographic talks included the drift in radar backscatter of *TOPEX* which became apparent after the first four years of operation; a comparison of an altimeter-based rain climatology with other sources of data; Rossby wave studies using altimetry, SST and ocean colour data; North Atlantic wave climate and teleconnections with other oceans; and new work on wind speed algorithms. Estimation of sea ice thickness from a satellite altimeter has been shown to be possible and a presentation showed the results to be more realistic than the existing climatology derived from submarine-based sensors. There were also talks on the use of WOCE bottom pressure measurements to intercalibrate *Geosat* and *TOPEX/POSEIDON* and on assimilation of altimeter data into models. The Group continues to be grateful for financial support from CSMS which allowed several students to attend the meeting. Attendance was lower than on previous occasions, perhaps due to clashes with other meetings. It was suggested that a joint meeting be held in the near future with the European Group of Altimeter Specialists.
(Contact: T.Guymer@soc.soton.ac.uk)

The OCEAN MODELLING GROUP held their annual meeting in association with UK Oceanography '98, in Southampton on 10 September 1998. It was again an opportunity for the Ocean Modelling community to meet, and for less experienced modellers, especially, to give short presentations. Most of the talks were on global and North Atlantic modelling, with a few more idealised studies, and also some biological and coupled studies. This year's meeting is being held at University College, London, on 7–8 of September.
(Contact: G.Nurser@soc.soton.ac.uk)

After initiatives started about four years ago, the meetings of the MARINE CHEMISTRY DISCUSSION GROUP (MCDG) have settled down into a stable pattern of sessions at the Challenger Oceanography meetings every second year, with Progress In Chemical Oceanography (PICO) meetings in the intervening years. After the UK Oceanography '98 meeting, which was well supported, the next MCDG meeting was PICO 3 at Plymouth University on 9–10 September 1999. This meeting was supported by the CCMS laboratory at Plymouth, BMT, AstraZeneca and Brixham Environmental Laboratory, and once again provided a forum for discussion and exchange of ideas for the established and new members of the marine chemistry community within the UK.
(Contact: Peter.J.Statham@soc.soton.ac.uk)

The first OCEAN COLOUR SPECIAL INTEREST GROUP meeting was held on 11 September 1998 at UK Oceanography '98. The meeting was attended by about 40 people, with twelve talks, several poster presentations and a discussion session during the day. The themes of the talks ranged from the subject of processing ocean colour satellite imagery to research in ocean optics (see http://www.npm.ac.uk/rsdas/csms_ocolour/annmeet1.html for further details). The associated mailbase mailing list has also been growing (currently 33 members) and provides a forum for circulating details of forthcoming events. The group is planning a second meeting in Plymouth, but the date has not yet been finalised.
(Contact: S. Lavender, sajh@unixmail.npm.ac.uk)

Finance

1998 saw an excess of expenditure over income of £4269, compared with a budget deficit of £5886. The UK Oceanography conference provided a surplus of £2157, as well as advance membership subscriptions for 1999 of £2133. Council have undertaken a well defined budgeting exercise for the current year [1999], aiming at a slight surplus, and the indications are that this will be met. This will have been achieved by control of expenditure budgets. For the future, the Society must strive to improve direct income for *Ocean Challenge*, so that it can become more self-sufficient, since it currently represents the major expenditure of the Society.

I am now coming to the end of my four-year tenure as Treasurer, and I would like to offer my sincere thanks to Jenny Jones at SOC for her able assistance as Executive Secretary during that period.

CPQ

scavenging) fluxes were estimated for the two sites in the north-east Irish Sea, and were extrapolated to the whole Irish Sea. A number of conclusions can be drawn from the study: (1) At the Liverpool site, 'dry' deposition of Al and Fe exceeded 'wet' deposition, but for the other trace metals 'wet' deposition dominated. (2) 'Wet' deposition exceeded 'dry' deposition at the IOM site for all the trace metals. (3) 'Wet' deposition exceeded 'dry' deposition by a higher factor at the IOM site than at the Liverpool site. (4) In comparison with other fluxes, it would appear that atmospheric transport is an important source of Ni, Cu and Pb entering the Irish Sea; comparative data are not available for the other trace metals covered by the study.

Ups and downs in the Irish Sea over the last 70 years *by Richard D.M. Nash, School of Biological Sciences, University of Liverpool, Port Erin Marine Laboratory, Isle of Man*

The physical and biological environment of the Irish Sea has shown many fluctuations over the life-span of the Proudman Oceanographic Laboratory. The fluctuations and variations described were taken from research work undertaken in the Irish Sea by the Port Erin Marine Laboratory (PEML), once affiliated to the Liverpool Oceanography Department.

PEML has been collecting sea-surface temperatures in Port Erin Bay since 1902. These data show numerous warming and cooling periods with a general warming trend over the period. Similar variability and trends are seen in the sea-surface temperature records from Den Helder, Holland. PEML has also been collecting data on nutrient levels in the water column on the west side of the Isle of Man (Cypris Station) since the late 1950s. These data show interannual fluctuations in nitrate and soluble reactive phosphate, with a tendency for winter levels to be increasing over time.

Animal populations have also been varying over time. For example, the lesser weever population has varied in size considerably between 1988 and the present. This is not a commercially harvested species and the change in population size appears to be related to the thermal regime, warm years tending to give larger population sizes. Juvenile plaice populations in Port Erin Bay have also fluctuated considerably, the research leading to insights into variability in fish recruitment. At the level of commercial fish stocks, there has been considerable variation in landings and stock sizes. In these stocks, both harvesting levels and natural variations in stock size have to be considered. A number of commercially exploited fish species in the Irish Sea show a general trend of decline, but with fluctuations in stock size. There are also fluctuations or variability over much shorter periods, for instance annual variation in sea temperature (which is under physical control) and annual variations in nutrients and chlorophyll-*a* fluorescence (which are under biological control). At even shorter time periods are diel variations in, for example, fish catch or fish behaviour.

Thus there have been many ups and downs over the last 70 years, in everything from temperature to fish stocks. The ups and downs will continue and provide an interesting area for research.

Morphology, sediment and bedforms in the Irish Sea *by J.W. Ceri James, British Geological Survey, Keyworth, Nottingham*

A regional survey of the Irish Sea, undertaken by BGS (including interpretation of data from an extensive seismic and sampling programme), as well as university research and Hydrographic Office surveys, have provided the basis for the publication of a series of maps of the Irish Sea, depicting the morphology, sediment and bedforms of the sea-bed.

The primary morphological feature of the bed of the Irish Sea is a central depression, with depths >100 m, which runs north through St George's Channel then west of the Isle of Man to the North Channel. This is flanked by platforms at depths of <60 m, which form the wide embayments of Cardigan Bay and the eastern Irish Sea on the Welsh and English side, with the Irish platform as a narrow coast-parallel feature to the west.

Gravelly coarse-grained sediment covers the largest area of sea-bed and is generally confined to the areas underlain by glacial sediment and swept by strong tidal currents. This includes much of St George's Channel, the North Channel and the eastern Irish Sea north of Anglesey and the Isle of Man.

There are two extensive areas of muddy sediment. One is in the central depression west of the Isle of Man and the other is east of the Isle of Man; both are associated with areas of low current velocities. Extensive sand deposits are common at the margins of the two mud belts and have also been driven by tidal currents into Liverpool Bay and the coastal margins of Cardigan Bay. Many of these areas of sand have been reworked into large-scale sand waves up to 30 m in height, and extensive fields of megaripples. Strong rectilinear tidal currents sweep the Irish platform south of Dublin and have fashioned a series of linear tidal sand ridges off the Wexford coast, which is being actively eroded and is feeding sediment offshore.

Discussion on future needs *led by Rick Boelens, EOLAS, Ireland*

The session concluded with a short discussion on the needs and opportunities for a more cohesive Irish Sea science programme. The Irish Sea could be seen as an accessible, 'prototype' shelf-sea area, embodying many complex and interesting features, and it was felt that a sound knowledge of the processes that regulate Irish Sea ecosystems would benefit science and management both locally and in other parts of the north-east Atlantic shelf. There was general agreement that the programme should focus on the development and use of integrated (physical, chemical, biological) models to improve understanding of contemporary issues such as the effects of climate change on coasts and resources, the impacts of commercial fishing on ecosystems, and the transport and fate of persistent contaminants. It was noted that recent assessments (Quality Status reports) show these issues to be of growing concern throughout the NE Atlantic region. Accordingly, managers and policy-makers will be keen to ensure they are adequately addressed by the scientific community.

Attention was drawn to a number of key deficiencies, including accurate measurements of the inflow to the Irish Sea through St George's Channel (of primary importance to modelling), high resolution bathymetry (also essential to modelling; suitable data exist but are not yet available to modellers), spatial and temporal trends in offshore primary production (greater use could be made of data from the Continuous Plankton Recorder), and changes in the structure of benthic invertebrate communities (more training and support for taxonomists). There is a general need for greater investment in the collection of long-term datasets, of importance both to modelling and trend assessment, at strategically selected sites.

Irish Sea Science

To celebrate the occasion of three anniversaries for Bidston Observatory in 1999, a Challenger Society meeting on Irish Sea Science, organized by John Huthnance and John Howarth, was held on 12 November at the Observatory. The anniversaries were: eighty years since the foundation of the Liverpool Tidal Institute in 1919, seventy years since its amalgamation with the Liverpool Observatory in 1929, and thirty years since the Natural Environment Research Council assumed responsibility in 1969. The meeting, which was well attended, was preceded on Thursday evening by the first 'Joseph Proudman Lecture' given by David Cartwright at Liverpool University. Summaries of all the talks, by the speakers themselves, follow.

The learning curve of tidal science *by David E. Cartwright, FRS*

Humanity's understanding of ocean tides has developed slowly over many centuries, from seamen's lore to the use of modern computers and technology. The main theme of the lecture was the tentative trial-and-error nature of its development. Abu Yusuf al Kindi (9th century), the 'philosopher of the Arab world', suggested by apparently logical steps, verifiable by domestic experiments, that the tides were due to a heating effect of the Moon caused by its celestial motion, a view endorsed by his better known contemporary, Albumassar. Some six centuries later, Galileo used simplified kinematics to deduce that the Sun, not the Moon, was the principal cause of tides. He used his arguments as the main basis for his defence of the Copernican (heliocentric) hypothesis against the Ptolemaic (Earth-centred) view of the Universe preferred by the Vatican. He was unsuccessful, as is well known. Descartes applied his own theory of vortices to the tides; this theory had supporters in France long after it had been demolished by Newton. But even Newton's (mainly correct) theory of tides had deficiencies, improved in important essays by Bernoulli, Euler, and especially, Laplace.

Eschewing the saga of the much debated role of tidal friction in Earth and lunar physics, the speaker then focussed on attempts to solve the problem of mapping the tides, which first became prominent in the early 19th century but only culminated at the end of the 20th. There had been interesting forerunners in the writings of the Venerable Bede and of Archdeacon Gerald of Wales, but the first to take up the matter seriously were Lubbock and Whewell of Cambridge, with the valuable assistance of the Chief Hydrographer, Beaufort. Whewell deduced the existence of a point of zero tidal amplitude in the southern North Sea (disputed by the Astronomer Royal, Airy), but he was unable to make much sense of tidal behaviour in the deep ocean. When the American hydrographer Harris developed a theory of resonant basins, he found Whewell's 'points of no tide' in all oceans; these he called 'amphidromes'. However, Harris too had to face severe and justified criticism from theoreticians.

Finally, this subject led naturally to the work of the 'Liverpool Tidal Institute', founded 90 years ago at Liverpool University. Professor Proudman wrote a penetrating series of mathematical papers on the problems of tidal mapping, and he and Doodson applied the theory to the seas round Britain, to the central Atlantic Ocean, and to theoretical hemispherical ocean basins of various depths.

Essentially they were the first to add contours of equal amplitude to those of equal phase. It is hard to criticise their work in its own terms, but it was ultimately limited by lack of computing power and of modern measurement technology. Further development had to await the last quarter of the 20th century.

Bidston Observatory and Irish Sea science *by Eric Jones, CCMS Proudman Oceanographic Laboratory (POL), Bidston Observatory*

For many years there has been a natural connection between Bidston Observatory (currently the CCMS Proudman Oceanographic Laboratory) and Irish Sea Science. Geographical proximity has meant that the Irish Sea has become a test-bed for both observational and theoretical studies carried out at Bidston. However, Bidston Observatory has its origins in the science of astronomy, and the founding of the Liverpool Observatory in 1843 to carry out astronomical observations as a navigational service to shipping. The Observatory was moved to Bidston in 1866. (See 'From Astronomy to Oceanography' by J. Eric Jones (1999) *Ocean Challenge*, Vol. 9, No.1, pp.29–35.) Astronomical work declined at the end of the 19th century but there was an increase in meteorological and seismological work which included measuring the tilt of the Observatory due to tidal loading by the Irish Sea.

The establishment of a Tidal Institute at the University of Liverpool under Proudman and Doodson in 1919 led to an immediate collaboration on work involving the analysis and prediction of tides, in which Bidston soon gained an international reputation. The amalgamation of the Observatory and the Institute in 1929 bought both theoretical and observational oceanography to Bidston. Using current meters designed by Doodson, along with other instruments, oceanographic campaigns were carried out in the Irish Sea from 1936 to 1939. After the Second World War, further measurements were performed.

With the entry to the Natural Environment Research Council in 1969 it became possible to carry out the British Irish Sea Oceanographic Project in 1971, an intensive collaborative observational experiment. Further observations were made in the Irish Sea which led, for example, to fundamental questions about offshore tides; on one occasion there was fortuitous measurement of storm surge currents. The data gathered at Bidston enabled improved estimates of Irish Sea tidal energy fluxes and dissipation to be made. Unconventional methods such as using a helicopter to gather water samples from the Irish Sea were attempted, and the first trials of the OSCR HF radar system to measure surface currents were made in Liverpool Bay.

As well as being a subject for observations, the Irish Sea has also been a test-bed for numerical models at Bidston. In 1954 a model based on manual calculations successfully computed a cotidal chart of the Irish Sea. Fifteen years later this became a computer model which was used by Norman Heaps to look at tides, surges and density currents. Further models at finer resolution and of greater complexity have successfully represented three-dimensional circulation of the Irish Sea (including surges), as well as salinity and temperature distributions. At present, Bidston is involved in many collaborative projects involving the Irish Sea, which will continue to be a proving ground for oceanographic applications and may yet have surprises in store.

Turbulence studies in the Irish Sea: a modest tribute to Ken Bowden *by John H. Simpson, School of Ocean Sciences (SOS), University of Wales, Bangor*

In the 1950s and 1960s, the Irish Sea was the setting for important pioneering studies of turbulence and the associated shear stresses in tidal flows. Ken Bowden, who was Professor of Oceanography at Liverpool (1954–82), undertook a series of measurements in Red Wharf Bay on the North coast of Anglesey from the RV *William Herdman*.

Together with colleagues (Arthur Fairbairn and Peter Hughes), he investigated the distribution of shearing stresses in a tidal current by integrating the equations of motion upwards from the bottom boundary, using a value for the bed stress found either from measurements in the near-bed logarithmic layer or from measurements of the sea-surface slope based on open sea tide-gauges.

In both cases, the acceleration terms were found from measurements of the current profile over the tidal cycle. These studies of the role of friction in the dynamics of the mean flow identified the essential balances involved, and revealed a significant lag in the time of maximum shear stress with increasing height above the bed.

At about the same time, Ken and Arthur Fairbairn used the newly available miniature electromagnetic current meter to measure all three components of the turbulent velocity fluctuations in a tidal current. They mounted two of the 10-cm diameter flow-meter heads on a tripod which was oriented relative to the flow by a vane, as it settled onto the sea-bed. These new measurements enabled Bowden to determine, directly, the Reynolds shear stresses in the flow and to investigate the spectrum of the fluctuations u' and w' and their covariance (which is essentially the stress). These results, which were followed by others from measurements in the Mersey (with Malcolm Howe), constituted a considerable achievement, and subsequently have been much quoted in the literature and used as a model for later bottom boundary layer investigations. Ken, however, was a very modest and retiring individual and, as with his many other achievements, refrained from broadcasting his success in this area. He would probably have found the present system, where we are almost obliged to strenuously promote our work, very difficult to live with.

In recent times, the Irish Sea has again featured strongly in the development of studies of turbulence in tidal flows. With the advent of free-fall probes measuring velocity on scales down to 6 mm, it has become possible to determine the profile of turbulent dissipation throughout the water column and over the tidal cycle. A group at SOS (Tom Rippeth, Ray Wilton, Mark Inall and myself) have developed an advanced version of the FLY profiler with generous assistance from Bill Crawford (IOS, Patricia Bay, Canada), the originator of the FLY system. Measurements with the FLY over the tidal cycle show characteristic variations in dissipation at the M_4 frequency with a marked phase lag, increasing with height, in the timing of maximum dissipation. This delay, which is analogous to the delay observed in the Reynolds stress by Bowden, has been observed both in the mixed regime of the central Irish Sea and under the seasonally stratified conditions which occur in summer west of the Isle of Man. Counter to initial intuitions, this feature is not primarily due to diffusion of turbulent kinetic energy (TKE) from the high production region near the bed to higher levels in the water column. Trials of turbulence Mellor–Yamada level 2 closure models, with and without the diffusion of TKE, indicate that the phase lag is equally well reproduced by both models. A constant N_z (eddy viscosity) analytical model of an oscillating boundary layer demonstrates that there is a delay in the phase of the velocity shear which increases upwards from the bed, and this results in a lag in TKE production, which means a delay in dissipation since production $\approx$ dissipation.

In Liverpool Bay, we have an area of strong horizontal density gradients maintained by freshwater input from the Mersey and other rivers. The density gradient interacts with the tidal flow in a process termed 'tidal straining' to produce a periodic variation in the stratification of the water column. Stratification which develops on the ebb flow, as higher velocities near the surface carry lighter water over heavier water below, is removed on the flood by the reverse tidal shear, so that at high water the water column may approach complete vertical mixing. The influence of these density effects on the pattern of dissipation has been revealed in a recent series of measurements with FLY which show that dissipation in near surface layers occurs predominantly towards the end of the flood when, with decreasing stability, there is a surge in TKE production which reinforces the tendency to complete vertical mixing. By contrast, on the ebb, the strain-induced stratification acts to inhibit production, and hence dissipation, in the upper half of the water column. Bowden was probably not aware of this contrast in dissipation pattern (M_4 near the bed, mainly M_2 near the surface), but careful reading of his paper with Sharaf el Din shows that he had already realized that there was a marked periodic variation in stability associated with tidal straining.

Flow through the Irish Sea *by John Howarth, CCMS POL, Bidston Observatory*

The flow through the Irish Sea has been studied for over a hundred years, with the application at one time or another of most of the technologies available for measuring currents, starting with drifters. In principle the problem is a well posed one, concerning a prototype shelf sea which has large variations in tidal currents, wind forcing and significant freshwater run-off, and which is semi-enclosed and has only two entrances – the North Channel and St George's Channel. In practice, the sea is part of a bigger system which includes the Celtic and Malin shelf seas, with large depth changes over short distances (e.g. the Beaufort Dyke in the North Channel), and shelf-edge events to the west of Ireland possibly influencing flow through the North Channel. Although much of the Irish Sea is well mixed throughout the year, the regions to east and west of the Isle of Man stratify in summer and there are fronts close to both entrances.

The mean northward direction of the flow has been shown unambiguously from tracer studies. These began with salinity measurements by Knudsen in 1907, continued by Professor Bowden, and were later based on the distribution of radionuclides, particularly caesium, discharged from Sellafield. Current meter studies started in 1935 with a year-long series of measurements at the Skulmartin light vessel, close to the Irish coast, analyzed by Proudman. In the 1950s, Bowden used the measurement of voltages induced in telephone cables by the movement of seawater to show the importance of wind forcing, especially in winter. The spatial and temporal variability of currents in the North Channel was more rigorously quantified by a 15-month deployment of an ADCP and an OSCR HF radar system in 1993–94.

A multi-year experiment measuring simultaneously the flow through the

North Channel and that through St George's Channel was proposed to test hypotheses and operational models, to quantify processes, and act as the basis of a wider study.

Seasonal circulation of the Irish and Celtic Seas: a challenge for baroclinic models *by Juan Brown[1] with contributions from Liam Fernand[1], Kevin Horsburgh[2], Ed Hill[3], John Read[1], Emma Young[1], Laura Carrillo[2,3], John Aldridge[1], Ken Medler[1], Sue Norris[1] and John Wooltorton[1]*

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[2]School of Ocean Sciences, University of Wales, Bangor.

[3]CCMS POL, Bidston Observatory.

Often, for management purposes, simplistic circulation maps of shelf seas, synthesized from the observational and modelling work of this century, are relied upon to explain contaminant dynamics and factors determining fisheries recruitment. These representations suggest an apparently weak yet coherent circulation pattern. However, such a view runs counter to a significant body of work that suggests that shelf-sea circulation is dominated by tides and short-term (wind) events.

Recently, work in the western Irish Sea has demonstrated the crucial role of seasonal stratification in isolating a dome of cold bottom water which then drives a strong and coherent baroclinic circulation. Following on from this, extensive observations were made during the summer of 1998 in the stratified Celtic Sea and St George's Channel, using a towed undulating CTD, an ADCP and satellite-tracked drifters. These demonstrated that the summer (May–October) circulation of the region is dominated by intense ($> 25\,cm\,s^{-1}$) and narrow (< 15 km) jet-like flows associated with the margins of an isolated pool of cold saline bottom water.

These results highlight the importance of considering the appropriate time-scales and processes for management of shelf seas. Ultimately, if models are to become reliable and believable management tools for biological and contaminant issues, they must accurately represent temperature, salinity and flow fields. This can only be achieved by rigorous comparison with appropriate data and inclusion of the best possible forcing in models. Achieving this will require an integrated and co-operative approach between interested agencies.

Investigating year-to-year variations by observations and modelling *by Arnold H. Taylor and Meryl C. Prestidge, CCMS Plymouth Marine Laboratory*

A three-layer phytoplankton–nutrient model has been developed on a 5 km x 5 km grid covering the Irish Sea, based on current flows from a depth-averaged model of the shelf. It has been used to model copepod egg production per female over the region by utilizing empirically derived relationships to chlorophyll concentration and temperature. The model has been driven with hourly meteorological observations at Dublin from 1966 to 1994 to simulate interannual changes over the Irish Sea during the last three decades.

There is a tendency for the mean timing of the spring bloom across the region to be related to water depth, with later blooms occurring in deeper water. However, the interannual standard deviation of the timing is related to the strength of tidal mixing so that areas with the most mixing show greater fluctuation in the timing. In stratified waters, earlier blooms tended to be more intense than later blooms at any location. This is caused by the increased impact of grazing over the course of late spring and early summer.

The relationship between bloom intensity and timing differs between years when the Gulf Stream is further north than usual and those when the Gulf Stream is further south. The model therefore partially replicates the observed relationship between the position of the Gulf Stream and plankton abundance. As the latitude of the Gulf Stream can be forecast by statistical relationships or by a deterministic model, there is now the possibility of making limited plankton forecasts up to a year ahead.

Nutrients and plankton in the cold water dome *by Chris Gibson, Brian Stewart, Phil Elliott and Bill Clarke, Department of Agriculture and Rural Development* (DARD), *Agricultural and Environmental Science Division*

DARD have made synoptic and intensive measurements in the north-west Irish Sea since 1991, and these are developing into a long-term dataset. Work has concentrated on the season-ally stratified water mass overlying the muddy sediments which support a valuable scampi fishery. Automated water samplers have been deployed since 1995 and these have captured samples of nutrients and plankton for laboratory analysis. A sustained series of nitrate analysis (often daily) is now available.

Nutrient concentrations are never static – they build up over the winter period and are depleted by the spring bloom – so monitoring of long-term trends requires intensive sampling. In most years, nitrate is depleted in surface waters but this is not always the case and there is significant interannual variability in the values of the nitrate maximum and minimum, in winter sea temperature, and in the timing of the spring bloom. Nutrient budgets are dominated by advection and the inflow of water northwards from the Celtic Sea.

It is assumed that the quality of the water in the Irish Sea, its nutrient content and some of the planktonic species, are determined by events south of St George's Channel. To understand fully how the different areas of this shelf sea interact requires a sustained integrated study encompassing water movement, water chemistry and plankton.

The 'cold water dome' (see earlier) shows significant warming and loss of nutrients over the summer. The formation of the thermocline allows a downward flux of particulate matter from the surface water, with a rapid increase in light penetration. Below the thermocline, a tidally-induced cycle of particle settlement and resuspension has been documented by a time-series of turbidity profiles.

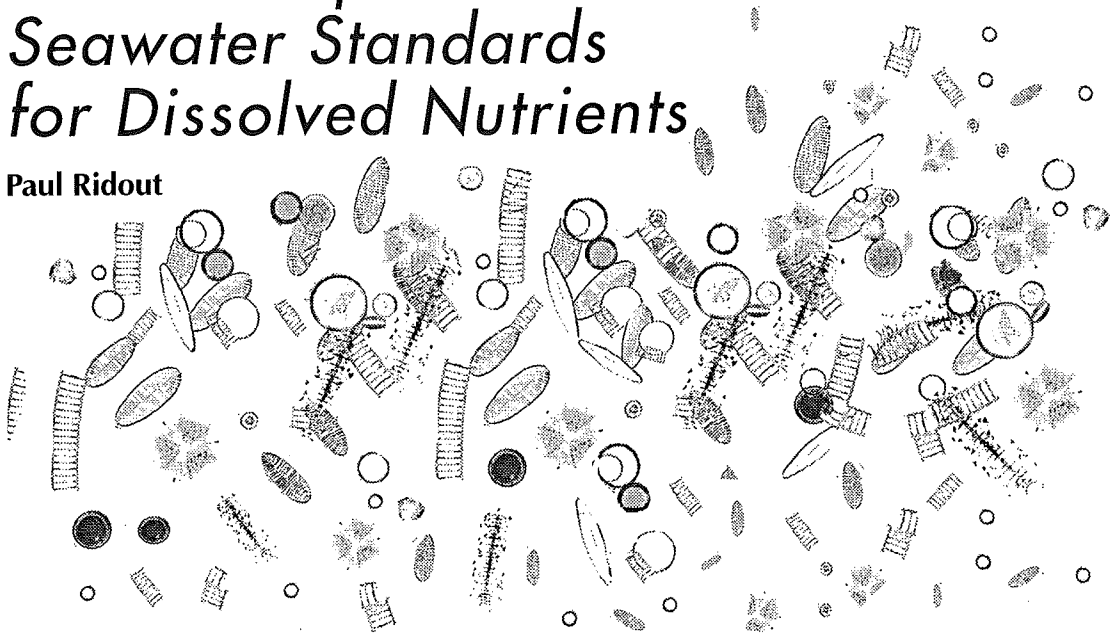
Atmospheric inputs of trace metals to the Irish Sea *by Roy Chester, Martin Preston and Sarah Keyse, Department of Earth Sciences, University of Liverpool*

During April–December 1997, a study was carried out in which aerosols and rainwater samples were collected simultaneously at an urban coastal site (Liverpool) and an open-sea site (Port Erin, Isle of Man (IOM)) with the aim of quantifying the atmospheric fluxes of trace metals, trace organics and nutrients to the north-east Irish Sea. The results are still undergoing assessment, and data were presented on the atmospheric concentrations and fluxes of the trace metals (Al, Fe, Ni, Cr, Cu and Pb).

The aerosol and rainwater samples collected at the Liverpool site had concentrations of trace metals typical of those found at other urban coastal sites in western Europe, but concentrations in the two atmospheric phases were lower at the IOM site. Both 'dry' (aerosol fall-out in the absence of an aqueous deposition phase) and 'wet' (precipitation

The Development of Seawater Standards for Dissolved Nutrients

Paul Ridout



Mass balance equations have shown that the input of the major biologically important nutrients (nitrogen, phosphorus and silicon) to the ocean plays an important role in regulating global oceanic production. Most of these nutrients are terrestrial in origin, finding their way to the oceans via riverine and atmospheric pathways. Once in the marine system, nutrients are made available to biological organisms for primary production either through nutrient-rich water being drawn up from below, or by local regeneration resulting from cell breakdown. In surface waters of the open ocean, uptake of nutrients by organisms usually results in one or more of those nutrients becoming limiting to their growth (i.e. when the nutrient is used up, production ceases). However, coastal and estuarine waters are increasingly subject to anthropogenic input stress, whereby frequent input of nutrients as run-off from agricultural land results in artificially prolonged algal growth. In either case, the need for high quality measurement of nutrients is driven by economic factors associated with climate change, depleted fisheries, eutrophication, and aquatic ecosystems being out of balance.

Nutrients are measured using a variety of wet chemistry techniques which generate a colour reaction measurable with a colorimeter or spectrophotometer. The technique involves adding a reagent (or reagents) to the seawater sample, allowing a colour to develop and then measuring the intensity of the colour against blanks and standards. Manual methods usually allow the colour to develop fully before measurement, whereas most automated methods (e.g. segmented flow analysis, flow injection analysis) provide partial colour development with time controls. Concentrations of nutrients are measured in optical cells (static or flowthrough), using a spectrophotometer tuned to defined wavelengths.

Quality assurance is an essential part of any chemical analysis. The measurement of nutrients in seawater has posed a number of difficulties, particularly in terms of matrix* interference and calibration. Ocean Scientific International (OSIL), who produce the IAPSO seawater standards for Practical Salinity, have been working for some years to develop seawater calibration standards for dissolved nutrients. This article describes that development and the current availability of reference materials and standards.

*The term 'matrix' refers to the chemical components of a sample (normally dissolved). Matrix interference results when these dissolved components of the sample affect the response of analytical instruments. If standards are made up in simple solutions, they often are not truly comparable with the samples being analyzed.

Certified reference materials

The International Council for Exploration of the Seas (ICES) has drawn attention to an urgent need for the development of certified reference seawater for dissolved nutrients. Unfortunately, this occurred almost a decade ago at the meeting of the IOC–IAEA–UNEP Group of Experts on Standards and Reference Materials (GESREM) and to date, no such material has appeared.

A certified reference material (CRM) is a material or substance, one or more properties of which are sufficiently well established and certified to be used for the calibration of an apparatus. In many laboratories, a CRM is analyzed, as a sample, to determine the accuracy of analysis as part of a quality assurance scheme. In the case of nutrients, the ideal CRM would be a natural seawater which has been analyzed for dissolved nutrients by more than one method, with confidence limits provided for the nutrients in question.

One of the main problems encountered in the production of a CRM, has been the stability of the product. Biological and chemical activity can lead to changes in nutrient concentrations over short periods of time. Various forms of chemical preservatives have been used, including organic solvents, formalin, potassium cyanide, sodium fluoride, various acids and mercuric chloride. Most fixatives/preservatives prevent growth of biological organisms, thereby stabilizing the solution. Some chemicals that lower the pH (e.g. acids) also serve to maintain some components in solution.

The use of additives is generally undesirable as it changes the matrix of the reference. In addition, mercuric chloride, the most commonly used poison, is known to degrade the efficiency of the cadmium reduction columns on some nitrate analyzers. There are also problems associated with the handling and transport of solutions containing such toxic compounds. As a result, some workers have investigated the use of heat as a means of preserving nutrient concentrations in seawater. Uncertified reference materials have been produced for dissolved nutrients in seawater by the Quasimeme Project (see Further Reading). These materials, which comprise seawaters spiked with nutrient salts, are provided as part of a laboratory performance study. The Quasimeme Project preserves mixed nutrients in seawater by autoclaving the samples.

Although reference materials are important in quality assurance, the preparation of working standards is a fundamental component of any chemical analysis. OSIL has been studying the feasibility of producing commercially available working standards for nutrients in seawater. A number of products were already available from other sources, but none offered a natural seawater matrix at salinity 35.

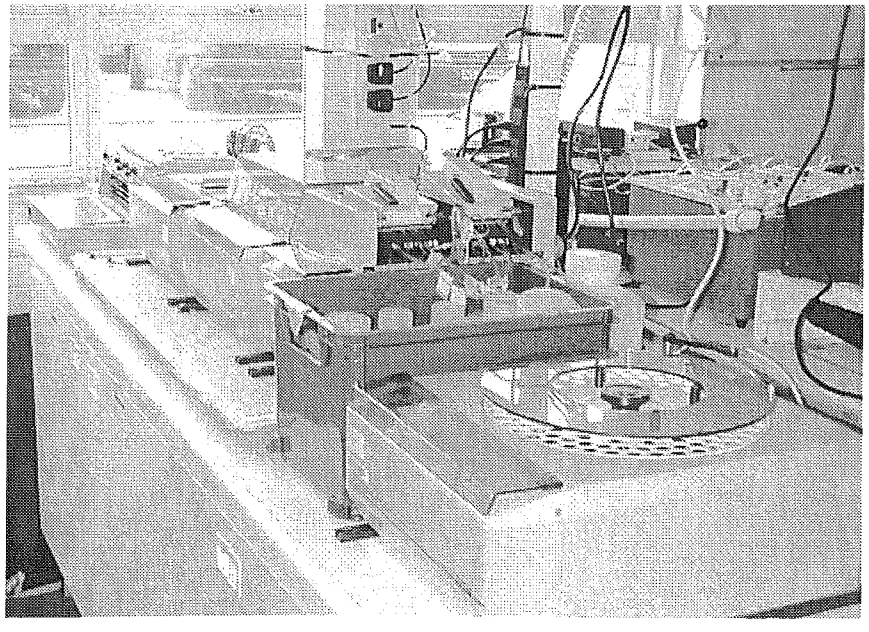
The need for nutrient standards

The need for seawater nutrient standards has intensified in recent years, with international programmes such as WOCE requiring high-quality nutrient data to be collected at sea. Most shipboard analyses are carried out using automated chemistry systems which measure nutrients colorimetrically. The kinetics of the chemistry of these techniques, and often the ultimate colour intensities, are generally affected by the presence of seawater matrix salts. Elimination of these salt effects requires that working calibration solutions be prepared in natural low nutrient seawater (LNS) rather than in demineralized water. The WOCE protocol produced by Gordon and colleagues (see Further Reading) stated a preference for the production of working standards in natural low nutrient seawater (LNS), but recognized that artificial seawater may suffice when LNS is unavailable. In continuous-flow analysis, LNS can also be used as a refractive index (RI) blank. This is to correct for a false positive absorbance signal generated by refraction effects within the flow cell when saline samples are run with a demineralized water baseline and inter-sample wash.

Low Nutrient Seawater

The first requirement of a standard for nutrients in seawater is the seawater matrix itself. It must be significantly lower in nutrients than the required standard concentration. This is particularly difficult for open ocean measurements where analyte levels can be lower than 1 µm as a result of depletion by plankton. Low Nutrient Seawater (LNS) can be prepared naturally or artificially. OSIL regularly collects relatively large quantities of seawater from the mid-Atlantic Ocean in order to operate the IAPSO Standard Seawater Service, and has investigated methods for depleting the nutrient content.

Chemical removal, using co-precipitation techniques with iron and aluminium compounds, was found to be effective in terms of nutrient depletion, but the subsequent removal of the precipitate proved difficult and costly. Biological depletion using an inoculum of plankton to create an artificial 'bloom' in the



A segmented flow analyser (SFA) used for automated analysis of nutrients in seawater at Southampton Oceanography Centre

bulk seawater was occasionally successful, but was unreliable because of the difficulty of controlling conditions for growth. As a result, OSIL has now standardized on a practice of measuring each batch of bulk seawater for dissolved nutrients and reserving the batches with very low concentrations for bottling. This LNS has the advantage of being depleted naturally which, combined with our processing/bottling regime, gives rise to a very stable product. The LNS fulfils all the needs of a seawater matrix for the preparation of standards, carrier solution and RI blank.

Standards preparation

Initial attempts to produce 'mixed' nutrient standards in LNS gave rise to problems of preservation. Although we were able to stabilize the product using mercuric chloride, this was considered undesirable by many users, for the reasons described earlier. Another problem which arose was defining the most useful working concentrations of the nutrients. It became obvious that it would be commercially uneconomical to produce the wide range of standards necessary to meet all user needs.

The problems described above led to the production of a range of marine nutrient standard kits (MNSKs). These comprise concentrates of single nutrients in deionized water, together with bottles of Low Nutrient Seawater (LNS) (see Table 1 and photograph below).

The user dilutes the concentrate with the LNS to provide working standards. This method overcomes problems with preservatives, as the concentrates of single nutrients in deionized water, and the LNS, are stable for long periods. However, once diluted, the working standards should be used immediately after preparation. The concentrate method also allows the users to define their own working concentration range, thereby overcoming the need for a wide range of products. Although confidence limits are given for nutrient levels in the concentrates and the LNS, the final working standard concentration is dependent on the dilution made by the user.

Table 1 *Marine Nutrient Standard Kits*

Code	Analyte	Matrix	Concentration (µM)
NSSPO	phosphate	deionized water	100
NSSNI	nitrite	deionized water	100
NSSNA	nitrate	deionised water	1000
NSSSI	silicate	deionized water	1000
LNS	all nutrients	ocean water (S = 35)	<1

Performance evaluation

Although our standards may be used as working calibration standards, many laboratories make up their own standards using nutrient salts, and incorporate our standards as quality assurance (QA) samples. As a result of requests by users, we now offer Performance Evaluation (PE) samples for dissolved nutrients and salinity. These PE samples are supplied, 'unknown', to analysts who include them in a normal analysis run. After analysis, the measured value for each PE sample is forwarded to our laboratory where a certificate is issued showing the true value and the analytical error.

The need for a certified reference material still exists for nutrients in seawater. However, data quality for marine nutrients can be improved by the careful selection of standards, carrier solutions and performance evaluation samples.

Further Reading

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Kirkwood, D.S. (1992) Stability of solutions of nutrient salts during storage. *Mar. Chem.*, **38**, 151–64.

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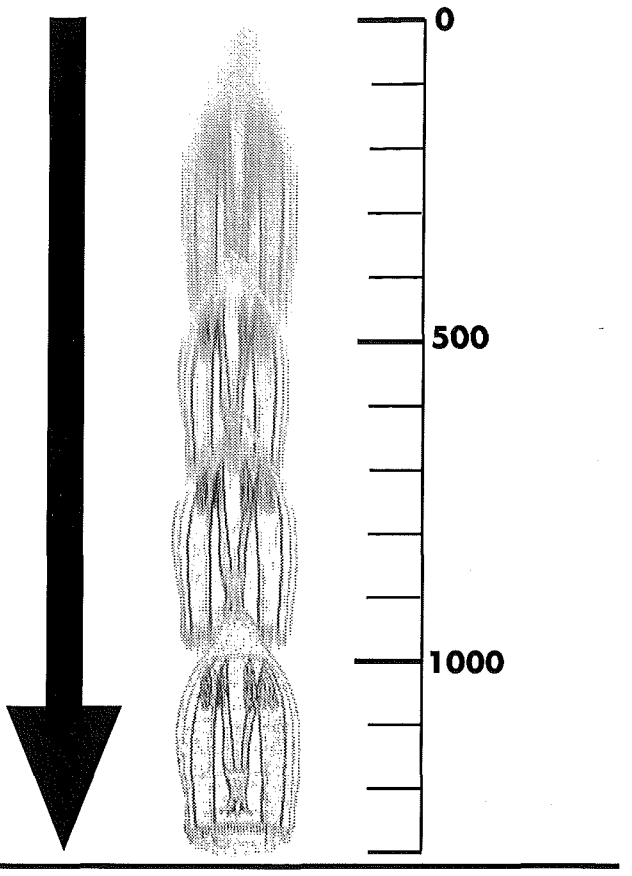
Topping, G. (Ed.) (1997) Quasimeme quality measurement for marine monitoring. Review of the EU Project 1993–1996. *Mar. Poll. Bull.*, **31**, 1–6.

Ocean Scientific Ltd (OSIL) specializes in the provision of high-quality products and services for the marine scientific community. Further information may be obtained from the OSIL website (http//: oceanscientific.com) or from Paul Ridout, Tel. +44-(0)1730-265015; Fax: +44-(0)1730-265011; Email: paul.ridout@oceanscientific.co.uk

Norwegian marine science goes deeper

Ulf Båmstedt
Marsh Youngbluth



Scientists in Norway have a new tool for basic and applied marine science. The ROV – Remotely Operated Vehicle – *Aglantha* (Figure 1, overleaf), built by Argus Remote Systems A/S, was delivered to the University of Bergen in 1998.

ROVs allow direct access to deep-water environments. Such vehicles have been used extensively in undersea regimes for nearly 25 years, principally by the oil industry. However, only in the last decade have such robotic platforms served as useful tools for scientific investigations. Integrated and increasingly computerized networks of technologies, now commonplace on ROVs, have allowed marine scientists to undertake optical, mechanical, and environmental 'interrogation' of water column and sea-floor habitats.

We hope that this article will encourage extensive use of *Aglantha* to undertake innovative *in situ* investigations, such as studies of geochemistry and research on biodiversity, community complexity, and adaptive behaviour of marine organisms. The benefits of direct observation and intervention have been discussed many times over the years, and there is agreement that 'being there', in reality or via a robotic tool, is crucial to understanding marine life.

Presently, deep-diving ROVs are only used routinely for scientific research in a few locations. The most active programmes are in the USA and Japan (see Table 1, on p.30). A new French ROV named *Victor 6000* has recently completed its initial sea trials.

The current configuration of the ROV

Aglantha is named after a jellyfish. Roughly translated from the Greek, the name means a royal, bright, shining little flower. The vehicle is a state-of-the-art craft designed for work in fjord systems as well as the open sea. The modular nature of the design facilitates repair and reconfiguration, i.e. instruments and sampling devices can easily be attached or removed. The vehicle can be deployed from any adequate ship, and all components are transportable.

A 2000 m, 20-mm diameter cord links the ROV to the research vessel. This umbilical cable has six optical fibres and six power leads, and is braided with Kevlar. Five thrusters are used to position and manoeuvre the craft. The special design of the hulls ensures that water currents generated by the thrusters are directed away from objects being studied. There are six camera bays, and more camera modules can be fitted to the front of the vehicle. Five of the cameras are black and white (B/W) and infra-red-sensitive; they can be positioned freely, for example to provide 360° viewing.

In addition to conventional underwater halogen lamps, two HID Gas Arc light sources are positioned at the front of the vehicle for close-up camera work. The

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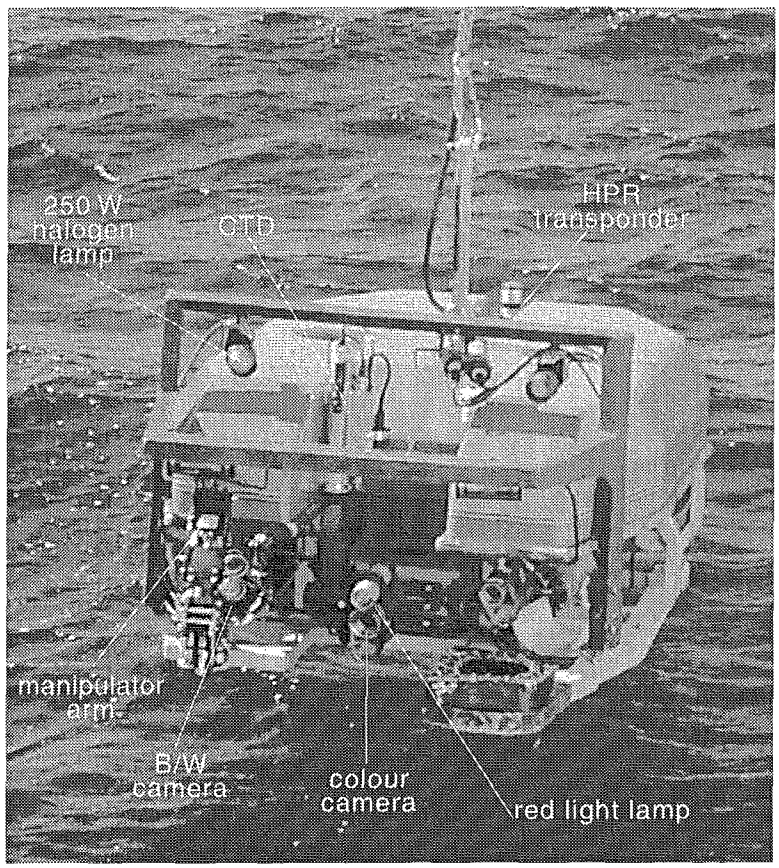


Aglantha's modular construction makes it easy to add optional instrumentation and sampling gear

Figure 1 *ROV* Aglantha *ascending from a deep dive in Lurefjorden.*

resolution of the main video system exceeds that of normal quality. The Hasselblad still-photo system has a B/W video viewfinder with direct transfer of images at 16 million pixels resolution or higher. The system is currently being completed.

A S/W video viewfinder with 410 lines resolution gives full control of the object through the lens. In all, there are 10 electronic photo-flash units, set up on a frame that provides illumination from the sides, thereby minimizing scattering disturbance from suspended particles and plankton. There will be a focus control system based on scanning laser beams that indicate the depth of field for the two nearest standard distances.

For scaling measurements, a laser system with three parallel beams is available. The distance between the first two beams is a few centimetres whereas that between beams two and three is variable. This system ensures that objects ranging in size from cm to metres can be accurately measured. Measurements are actually performed from the video tapes, by identifying the laser points and scaling the object from the known distance between beams.

A CTD sensor package provides data on depth, salinity, temperature and density. Additional sensors measure turbidity, chlorophyll and oxygen content in the water. Acoustic images of objects outside the video range of the vehicle are generated with a multifrequency scanning sonar with frequencies of 320, 675 and 935 kHz. The high frequencies make it suitable for quantification of objects down to mm size, such as zooplankton, and fine-scale distributions in three dimensions will therefore also be possible at depths where the sonar of the research vessel does not reach. A Simrad HPR 418 system is used to give true positions in three dimensions. All information from the ROV is displayed on a master monitor, logged in a computer, and overlaid on the videotape records. Thus, the visual information from the video records can easily be related to the different environmental variables measured.

Aglantha's maiden voyages and plans for future deployments

Aglantha commenced its scientific programme in April 1999, after successful completion of dock and field tests. In the period April–December 1999, the submersible was used during six major cruises on board four different research vessels. The studies focussed on the ecology of planktonic and benthic fauna in fjords to depths of 1300 m, extensive surveys of cold-water coral reefs at around 300 m depth on the Norwegian shelf, geological processes on the Mid-Atlantic Ridge south of Iceland down to 1400 m, and investigations of the shallow-water fauna around the island of Jan Mayen in the Greenland Sea. Each of the ROV-based studies has provided a wealth of exciting new discoveries, presently being worked on for publication.

Highlights from the cruises illustrate what can be learned from ROV deployments. The illustrations of fauna are all from our records with a Sony Hi8 video camera, transferred from a composite signal, frame-grabbed and digitized (and therefore do not correspond to the new digital video system in *Aglantha).*

With its long slender arms, Brisingella coronata is well adapted to life on the deep soft bottom

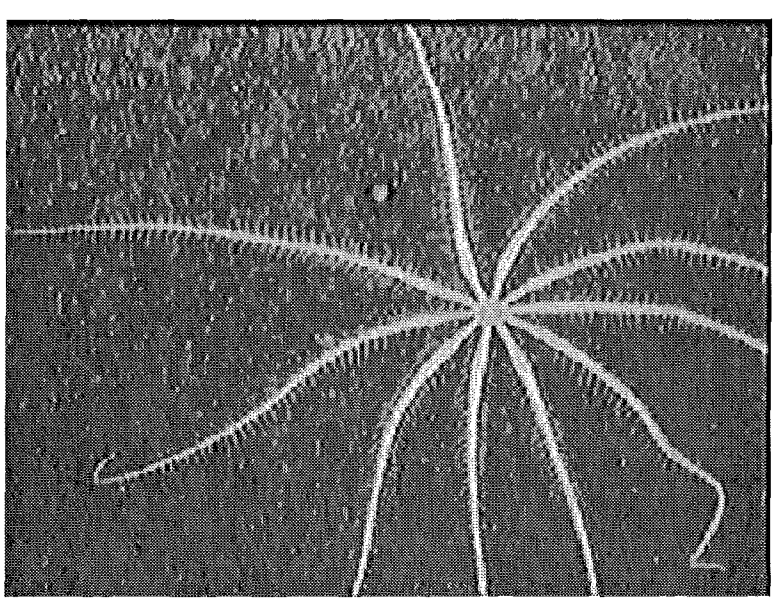


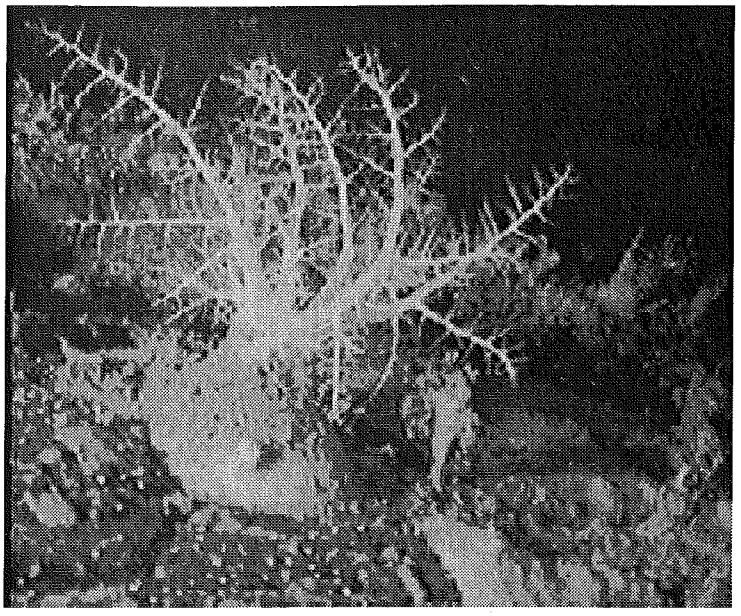
Figure 2 Brisingella coronata *from the soft bottom of Sognefjorden (~1300 m). The arms are about 20 cm long.*

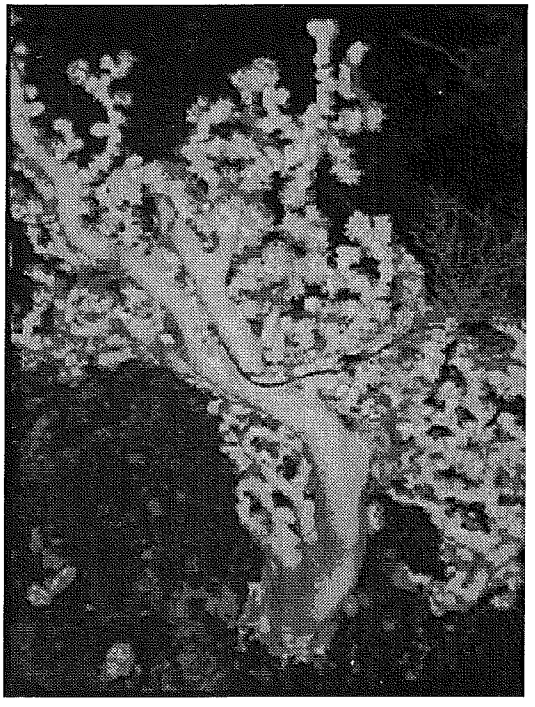
Figure 3 Psólus phantopus *on a deep rocky surface in Sognefjorden. This sea cucumber reaches ~ 15 cm in length.*

In Sognefjorden the deep soft bottom has an abundant population of the decapod crustacean *Munida tenuimana* which, together with the sea cucumber (of the Holothurioidea) *Bathyplotes natans* and the sea star (Asteroidea) *Brisingella coronata* (Figure 2, opposite), are key species of this biotope. The sea cucumber *Psólus phantopus* (Figure 3) and several kinds of sponges and sea anemones (Actinaria) numerically dominate the cliffs that rise almost continuously from 1200 m depth to the shoreline. In the water column there are high densities of undescribed species of predatory comb jellies (Ctenophora) and physonect siphonophores (colonial pelagic sea nettles), as well as previously unrecorded populations of filter-feeding oikopleurid appendicularians (small planktonic urochordates, closely related to sea squirts and salps).

Dives along steep vertical cliffs from over 600 m depth in Korsfjorden, south of Bergen, revealed an enormous richness of corals, actinarians, sponges, the large bivalve *Acesta excavata* and the sea star *Brisinga endecacnemos* (Figures 4 to 7). This site has been visited by university marine biological classes for several decades, and samples have been taken using the traditional method of dredging. The faunal richness seen from the ROV is in sharp contrast to that determined from the dredge samples. Typically, a maximum of one or two *Acesta,* fragments of corals and a few sponges are retrieved from a single dredge haul. *In situ* observations clearly illustrate that there will be a paradigm change for future students. They will be able to see, selectively sample, and eventually conduct *in situ* experiments in the epibenthos.

ROV dives in Lurefjorden confirmed that a dense population of large medusae called *Periphylla periphylla* occurs throughout the 400 m water column. Although this species has invaded a number of fjords in Norway, its importance as one of the dominant planktivores has not been recognized, primarily because this animal is gelatinous and easily damaged by collection with nets. Unobtrusive *in situ* observations of these animals with red light from the ROV provided the first unambiguous documentation of their diel migratory movements and feeding strategies. Most of these animals clearly respond to daily light fluctuations, moving upward *en masse* at night and concentrating just below the thermocline where they prey voraciously on the calanoid copepods that are numerous there





***The faunal richness of the vertical cliffs of fjords is only now becoming clear, thanks to* in situ *observations using* Aglantha**

Figure 4 *The sea tree Paragorgia arborea* on a vertical cliff in Korsfjorden (~ 500 m). This cold-water gorgonial coral may reach 2 m in height.

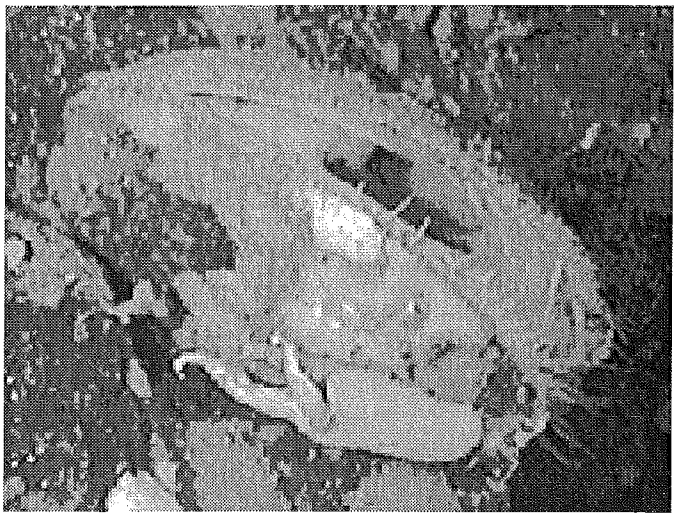


Figure 5 Acesta excavata *in Korsfjorden (depth ~ 600 m). Note the different attached sponges and the legs of the sea star* Henricia *sp. climbing on the shell. This bivalve may reach more than 20 cm in length.*

ROV-based video survey is the only method that can give a true picture of abundance and structure within deep-water communities occupying vertical cliffs

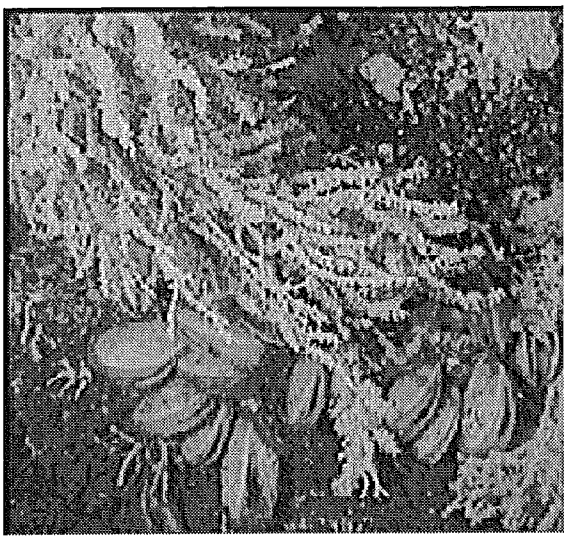
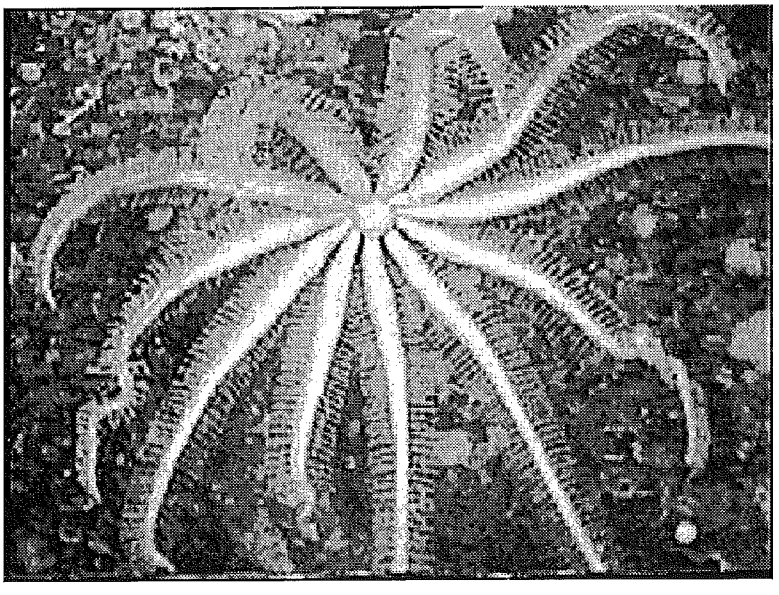


Figure 6 Acesta excavata *together with the coral* Primnoa resedaeformis *in Korsfjorden (depth ~ 400 m), the latter reaching a height of 1 m.*

Figure 7 Brisinga endecacnemos *in Korsfjorden at ~500 m. The diameter of this specimen is ~ 40 cm.*



(Figure 8, opposite). At dawn the medusae descend and distribute more widely in deeper water. Feeding at these times is less intense and involves a hitherto unsuspected dive-and-drift behaviour: the jellyfish adopts an inverted posture with its flexible tentacles positioned alongside the umbrella, swims slowly downward for ten metres or so, and then floats slowly upward for similar vertical distances, consuming copepods and chaetognaths with rapid upward sweeps of individual tentacles.

A curious observation made several times in Lurefjorden was of a trophic relationship between the large sea anemone *Bolocera tuediae*, dominating the deep soft bottom in the fjord, and *Periphylla periphylla*. When migrating down, a medusa might reach the bottom, and by chance also touch a sea anemone, which would immediately react by catching and ingesting the medusa, even if the prey were almost as large as itself (Figure 9, opposite). Although the ecological importance of this trophic connection is probably negligible, it shows the potential for detecting unsuspected ecological relationships through the use of ROVs.

Recent investigations with ROVs have indicated that extensive trawling for fish along the Norwegian shelf has caused significant damage to coral reefs. Dives conducted with *Aglantha* in May 1999 provided rigorous quantitative data on the extent of damaged reefs and the occurrence of undisturbed ones. Such information is of great importance in an ongoing effort to protect reefs from further damage by trawling. One positive step has been taken by the Norwegian government in that a law has been enacted to safeguard two extensive reefs.

To date, all of the fieldwork with *Aglantha* has been technically and scientifically successful. Videotapes archived from the ROV dives are permanent records demonstrating its ability to quantify macroscopic fauna in habitats difficult to study by conventional methods. Thus, future short- and long-term studies of marine life using this platform are certain to provide a basis for documenting the wealth and health of species in Norwegian waters for decades.

The currently scheduled scientific programme for *Aglantha* includes biological studies on the jellyfish community in Lurefjorden and deep-living appendicularians in Sognefjorden, further surveys of the deep-water coral reefs, and studies of geological and microbiological features around black smokers on the Mid-Atlantic Ridge. Grants have also been provided for ecological investigations of a spawning ground for herring, and for surveys to document the impact on the benthic community of fishing activities with bottom trawls.

Future missions

A national committee for deep-water technology has been established by the University of Bergen, with members from the universities of Trondheim and Tromsø and the Institute of Marine Research. Scientists from these institutions also have access to *Aglantha*. Furthermore, the University of Bergen, together with the Institute of Marine Research, have been appointed by the European Union as a Large Scale Facility (LSF) for marine research. ROV *Aglantha* is now included in this project and European scientists can use this advanced tool for field studies (see internet address at the end for information on how to apply). We are also including *Aglantha* in proposals to the EU, presently under the Fifth Framework of MAST, and in proposals to the Norwegian Research Council related to more national projects. A current research grant at the University of Bergen, 'Subsurface biosphere, hydrothermal activity and magmatism along the Arctic ridges', involves utilizing *Aglantha* over the next four years. *Aglantha* will also be used in the EU-supported programme, 'The impact of Appendicularia in European marine ecosystems'. This is a collaborative programme between scientists from the University of Bergen, Bathypelagica Incorporated, Centre National de la Recherche

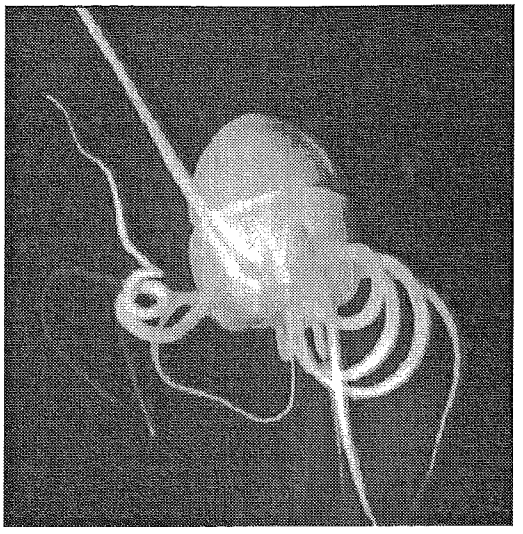
Scientifique and Plymouth Marine Laboratory. The National Science Foundation in the USA is also supporting a US–Norway cooperative project, 'The predatory role of the coronate medusa *Periphylla periphylla* in a fjord ecosystem', where *Aglantha* will be utilized. The project 'Environmental effects of trawl fisheries' has been funded from the year 2000 and will involve *Aglantha* in surveys of the fishing grounds off northern Norway. Several other national and international projects are in their planning phase, making it likely that *Aglantha* will have a busy future.

The benefits of increased use of ROVs

Science and technology are intertwined. Advancement in either field has sooner or later promoted advancement in the other. Progress in oceanography, in particular, continues to rely on an ever-increasing array of sophisticated tools, including undersea vehicles, optical and acoustic imaging devices, satellite communication networks, and long-term observatories. Technology is now available to eventually make all of these systems operable in real-time modes with interactive, two-way communication via internet nodes. Gradually, technological developments and increased availability of ROVs around the world are attracting more marine scientists and students to explore deep-water environments in ways that are not possible with conventional gear like bottles, nets and sonar. (See Table 1 overleaf for a list of internet addresses for ROV-based scientific operators.)

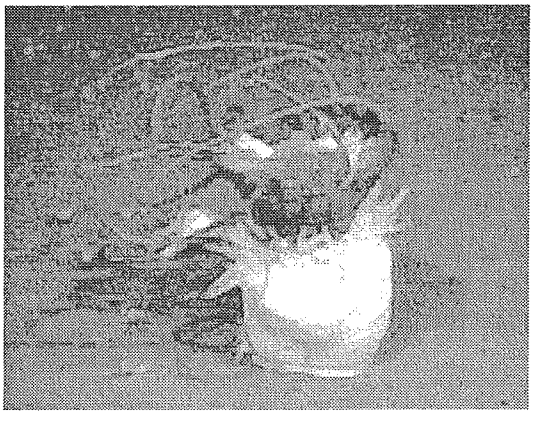
ROVs also offer splendid opportunities for educational outreach to the general public. Operating these vehicles can broaden scientific literacy as well as enhance an awareness of marine organisms and processes occurring in natural environments. Observations from ROVs can be brought directly into the classroom, in real time, with videotape or microwave technology. Such direct exposure can certainly facilitate environmental management in coastal areas. For example, there can be assessment of threats, both natural and anthropogenic, to marine life off Norway, including deep-water coral reefs and fish spawning grounds. Normally unseen disturbances, e.g. subsurface impacts of oil spills and toxic chemicals, and damage by bottom trawling, can be monitored.

Such exposure should stimulate wonder and excitement about science, and glimpses of unseen marine worlds should encourage new perspectives and promote greater interest in scientific, marine-oriented careers. The Monterey Bay Aquarium Research Institute in California is already using direct microwave links transferring '*in situ*' observations to the public and scientists. Likewise, the *Jason* ROV Project curriculum, with its interactive internet components and field research opportunities for students, has attracted a worldwide audience. We believe that this virtual approach of engaging, instructive, two-way communication will be used increasingly in the coming decades, for public information, for educational purposes, and for innovative research.



The outer surfaces of the twelve tentacles of the jellyfish* Periphylla periphylla *contain thousands of nematocysts which discharge a toxin that paralyzes prey

Figure 8 Periphylla periphylla *feeding on copepods in Lurefjorden (~ 200 m). The diameter of its bell is ~ 12 cm. As a prey animal touches a tentacle, it is paralyzed. Simultaneously, the tentacle bends and coils, and the coil is quickly inserted into the gastric cavity. The picture shows straightened, coiled and inserted tentacles.*



By bad luck, the predator (see above) itself becomes the prey

Figure 9 *Unusual benthopelagic interaction at 440 m depth in Lurefjorden. The large sea anemone* Bolocera tuediae *has just caught a* Periphylla periphylla *(here appearing dark), which will be ingested within a few hours. The diameter of the sea anemone is ~15 cm.*

The new millenium

We predict that regular voyages to deep ocean environments off Norway, and its neighbouring seas, will stimulate an exciting era in ocean exploration. The ROV will allow scientists to observe directly biological interactions, geological phenomena and physical processes in regions that have heretofore been inaccessible. Such information will permit a more complete understanding of the ocean as a dominating planetary system. We also foresee increasing accessibility of remotely located marine environments to students and the general public through increased use of ROVs and advanced communication technology. Voyages of discovery in the vast but hidden deep-water environments of our planet are just beginning.

Table 1 *Sources of information about remotely operated vehicles (ROVs).*

Organization	Internet Address
Research Programmes	
Harbor Branch Oceanographic Institution, USA	http://www.hboi.edu/
IFREMER, France	http://www.ifremer.fr/anglais/flotte/engins/index.htm
Institute of Ocean Sciences, Canada	http://www.ropos.com/index.htm
Japan Marine Science and Technology Center, Japan	http://www.jamstec.go.jp/jamstec/exp.html
Jason Project	http://www.jasonproject.org/
Monterey Bay Aquarium Research Institution, USA	http://www.mbari.org/
National Undersea Research Center, UCON, USA	http://www.nurc.uconn.edu/rov.htm
Woods Hole Oceanographic Institution, USA	http://dsogserv.whoi.edu/ships/rovs/rovs.htm
General and Technical Information	
Benthos Incorporated, USA	http://www.benthos.com/rov.htm
DiveWeb	http://diveweb.com/rovs/features/uw-wi99.01.htm
Internatioanal Submarine Engineering, LTD, Canada	http://www.ise.bc.ca/index.html
Perry Tritech Incorporated, USA	http://perrytritech.com/pti.htm
ROVnet	http://www.rov.net/
Marine Technology Society, USA	http://www.rov.org/index.html

For information about applying to use* Aglantha *within the LSF programme see: http://www.ifm.uib.no/lsf/

Ulf Båmstedt is Professor of Marine Biology at the Department of Fisheries and Marine Biology, University of Bergen.* After many years of study based on traditional sampling methods, he initiated the use of ROVs for basic research in Norway and is leading a national committee for deep-water technology there.

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Email: ulf.baamstedt@ifm.uib.no

Marsh Youngbluth is a Senior Scientist at Harbor Branch Oceanographic Institution.* Even after completing hundreds of submersible dives, he continues to be awed by the complexity of behavioural responses exhibited by planktonic fauna. Future generations of scientists who actively enter the ocean's interior are likely to learn much about biocomplexity.

*5600 US 1 North, Fort Pierce, Florida, FL 34946, USA. Email: youngbluth@hboi.edu

Specifications of ROV *Aglantha*

So as to be suitable for different tasks, *Aglantha* is built on a modular basis. Different instrumentation and sampling gear can be hooked onto the main frame and there is plenty of capacity for power and signal communication for additional instruments and gears.

Specifications as follows:

• *Length* 2.42 m • *Width* 1.43 m • *Height* 0.78 m • *Weight in air* 740 kg • *Weight in water* Slightly positive buoyancy

• *Buoyancy adjustment* ± 10 kg at 2000 m depth • *Payload* 100 kg • *Maximum depth* 2000 m • *Maximum velocity* 2 knots forwards; 1.5 backwards; 1.0 sideways/up/down • *Propulsion* Five thrusters giving 2.5 HP each • *Manipulator arm* Five function electric. Tritech EH5.

• *Power unit* Transformer giving 20 kW continuous effect. • *Lights* Two HID gas lights, 1000 W; two halogen lights, 500 W and adjustable; 7 removable batteries of red light diodes (660 nm).

• *Operating modes* Either with a winch and 2000 m umbilical cable, weighing 3 tonnes altogether, or in shallow water with a separate 600 m cable, neutral in water, handled manually.

• *Main video system* Panasonic high-resolution digital 3-chip video with full remote-control functions. The system gives a resolution of 795 (H) x 596 (V) lines. • *Additional video systems* (1) Two S/W cameras for 3D imaging; 3D glasses on control deck for true 3D effect. (2) Five S/W cameras sensitive to IR light, and removable in order to be placed where needed.

• *Photo system* Hasselblad 6 x 6 cm with high-capacity film cassette. Three optional distances, 15 cm, 100 cm and 4 m, giving magnification factors of 1 : 2, 1 : 10 and 1 : 40, respectively. A frame with photo flashes gives the necessary light and an effect of dark field. Laser beams indicate when object is in focal plane. Digital viewfinder and remote control of all functions.

• *Size measurements* Paired laser-beam system giving two points on the object with known distance between them.

• *Positioning* Simrad HPR system giving true position in three dimensions.

• *Environmental sensing* CTD giving salinity, temperature, density; also turbidity and oxygen. Capacity for optional probes such as CO_2, nutrients, light etc. • *Acoustics* Scanning sonar giving information about objects around the vehicle.

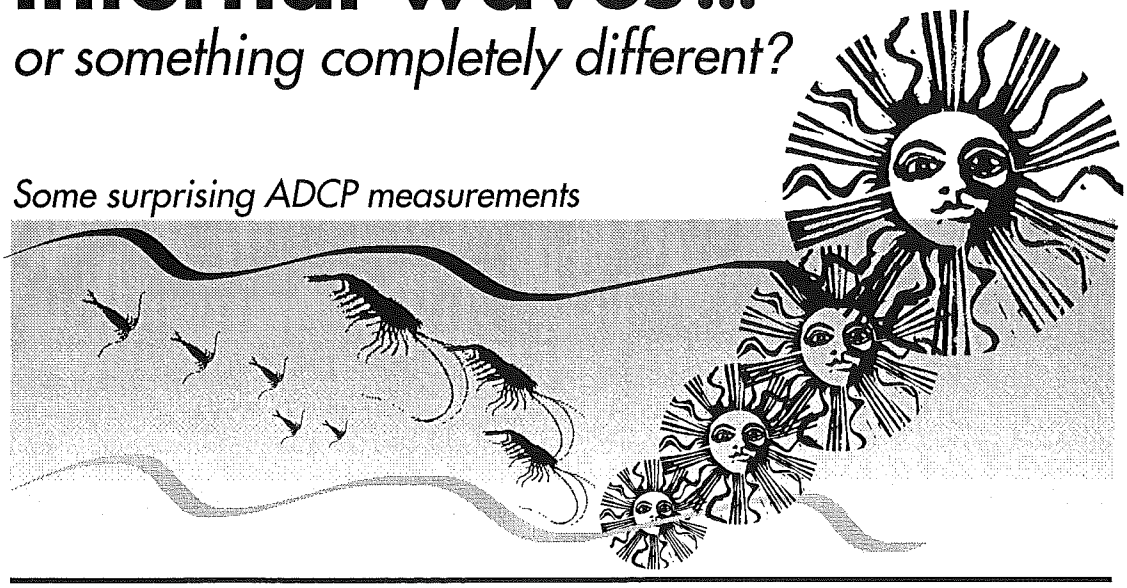
• *Special controls* Auto depth (± 0.5 m); Auto heading (±1.0°); Auto height (± 0.2 m at 0.5 to 30 m from bottom); Fluxgate compass (± 1.0 degree); Pitch/roll sensor (± 1.0 degree, range 90°); Speedometer (± 0.01 $m\,s^{-1}$).

• *Unused capacity* There are three unused fibreoptic connections available, giving almost unlimited scope for optional instrumental communication.

Internal waves...

or something completely different?

Some surprising ADCP measurements



Tom Rippeth

As part of the recent efforts to study the internal tide generated at the Hebridean shelf edge (part of the LOIS–SSES Project*), bottom-mounted Acoustic Doppler Current Profilers (ADCPs – see Box opposite) were deployed at locations on the continental shelf as well as over the slope. The resulting time-series have not only contributed to our understanding of internal tide motions in the region, they have also provided useful biological information. Here I will describe observations of both vertical velocity and backscatter intensity, made using an ADCP mounted on the sea-bed (in 140 m of water, at a location about 50 km to the west of the Island of Barra), from which useful information about the activities of zooplankton has been inferred.

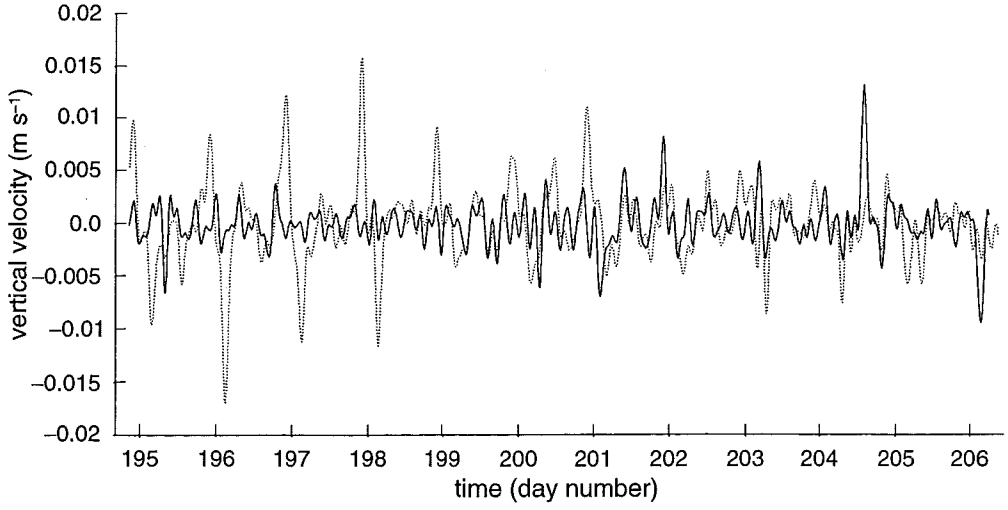
The observations

Off the Island of Barra, at the time of the measurements, the density structure of the water column was largely determined by temperature. Thermistor-chain data show that during the period of the observations, the water was thermally stratified, with vertical motions indicative of an internal tide of amplitude 10–15 m.

Through consideration of the observed vertical temperature gradient (dT/dz) and the temporal derivative of temperature at a particular depth (dT/dt), the vertical velocity associated with the internal tide has been estimated for the thermocline region (the solid line in Figure 1). This was compared with the vertical velocity measured at this depth using the ADCP (the dotted line in Figure 1). The main difference between the

Figure 1 *Vertical velocity (1) estimated from the movement of the thermocline (solid line) and (2) measured in the thermocline region (depth ~37.5 m) using the ADCP (dotted line). Positive values correspond to upward velocity (here peaking at 0.015 m s^{-1}), negative values to downward velocity (here peaking at 0.017 m s^{-1}). Days 195 to 206 were 13–24 July, 1996.*

The fact that the two plots differ shows that many 'particles' in the water column were moving independently of the water



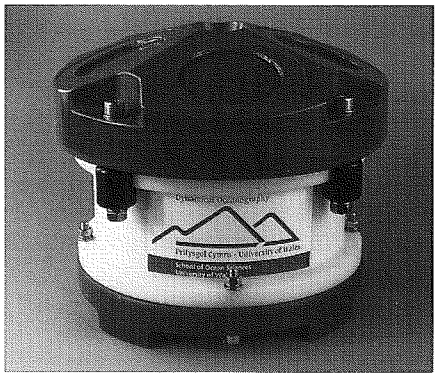
* LOIS–SSES is the Shelf-Edge Study component of the Land–Ocean Interaction Study.

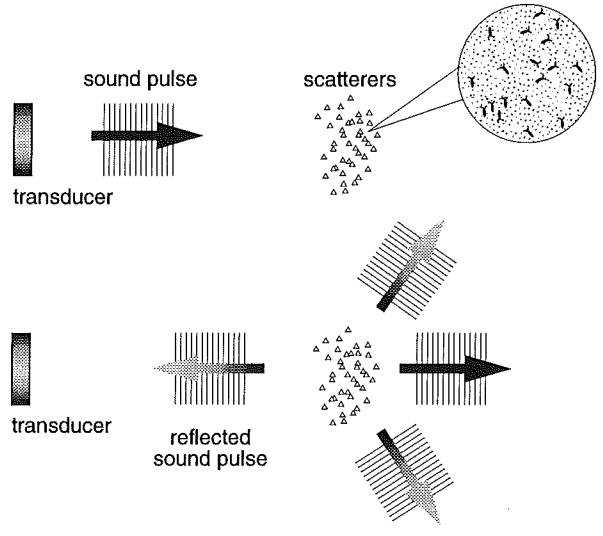
The Acoustic Doppler Current Profiler (ADCP)

The ADCP has revolutionized observational oceanography, having become a key component in many physical and biological oceanographic studies. ADCPs use the Doppler effect by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water column. The sound scatterers are the small particles (including zooplankton) found everywhere in the ocean. Common scatterers are species of euphausiids and copepods. They float in the water and it is generally assumed that on average they move at the same velocity as the water.

Sound is scattered from the particles in all directions. Most of the sound goes forward, unaffected by the scatterers. The small amount that is reflected is Doppler-shifted. The along-beam velocity of the scatterers is calculated from the Doppler shift of the echo. An ADCP normally has four beams and the horizontal and the vertical velocity components are calculated from the along-beam velocities of three of those beams.

The ADCP also provides profiles of the concentration of sound-scattering particles, through measurement of the returned signal strength.





Above *The ADCP used.* ***Right*** *A sound pulse emitted towards a patch of scatterers is scattered in all directions and the echoes are Doppler-shifted according to the direction of movement of the scatterers. If, for example, the patch is moving away from the ADCP, the reflected sound pulse will be Doppler-shifted to longer wavelengths.*

two is a large diurnal pulsing, which approaches 2 cm s^{-1} and is most evident during the first three days of the deployment. The implication of this difference is that, at this time, the acoustic scatterers were moving independently of the water particles.

This pulsing is present throughout the section of the water column sampled by the ADCP during the first half of the observation period, and is strongest in the middle of the water column (Figure 2). After day number 201 the pulsing is no longer clear. Comparison of the diurnal pulsing with sunset and sunrise times (Figure 3, overleaf) shows the pulsing to be strongly phase-locked, with the upward velocity peaking at sunset and the downward velocity peaking just before sunrise.

So what exactly are the scattering particles? It is known that many zooplankton undertake daily vertical migrations, moving up nearer the surface at dusk, and down at dawn. This behaviour may be related to efficient utilization of resources, avoidance of predation, or even attaining horizontal transport through exploiting vertical shear in the flow (see Further Reading). The diurnal signal observed in the vertical velocity strongly suggested that the acoustic scatterers were zooplankton performing such vertical migrations.

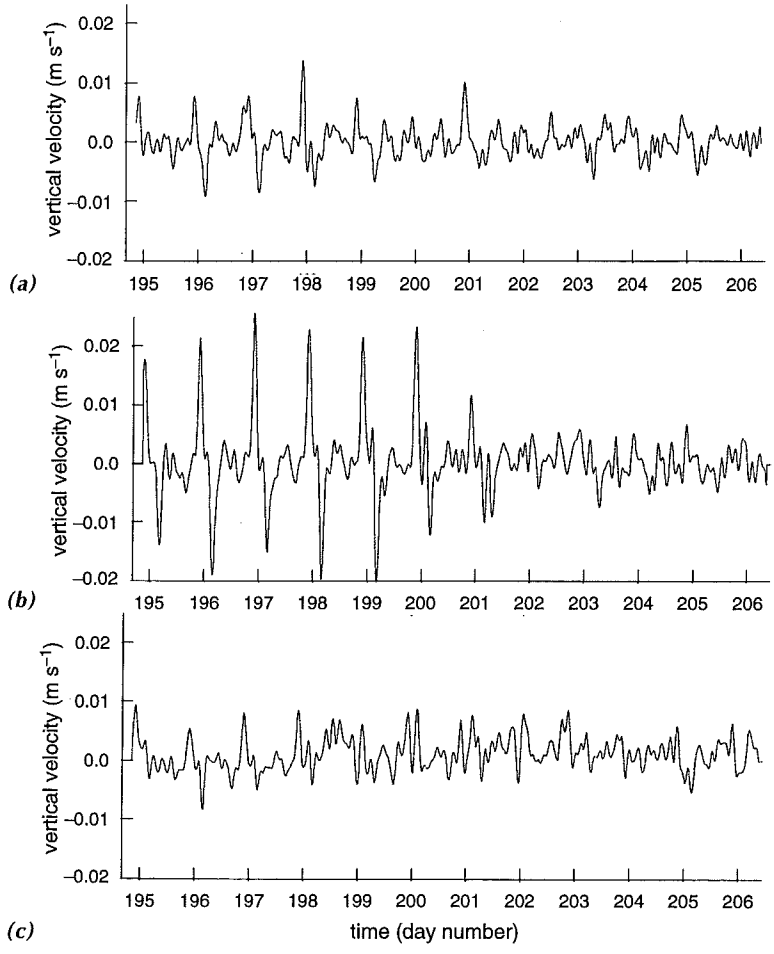
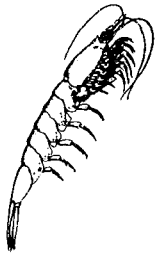


Figure 2 *Vertical velocity measured by the ADCP at depths of* ***(a)*** *27.5 m,* ***(b)*** *77.5 m and* ***(c)*** *127.5 m.*

Peak upward movement occurs at sunset, peak downward movement an hour before sunrise



***Likely candidates for migrating scatterers at the location in question are the euphausids* Meganyctiphanes norvegica**

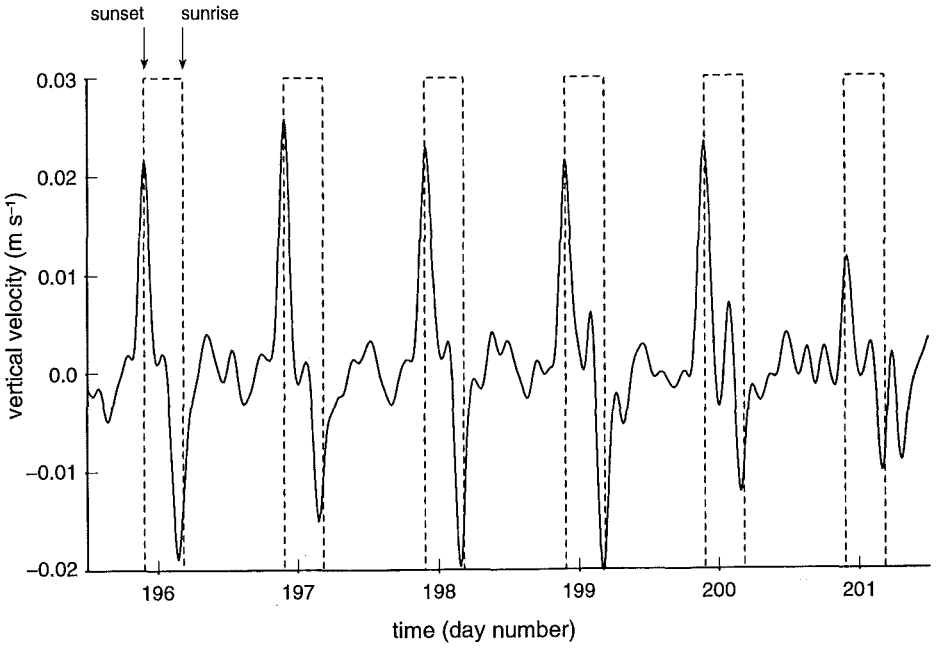


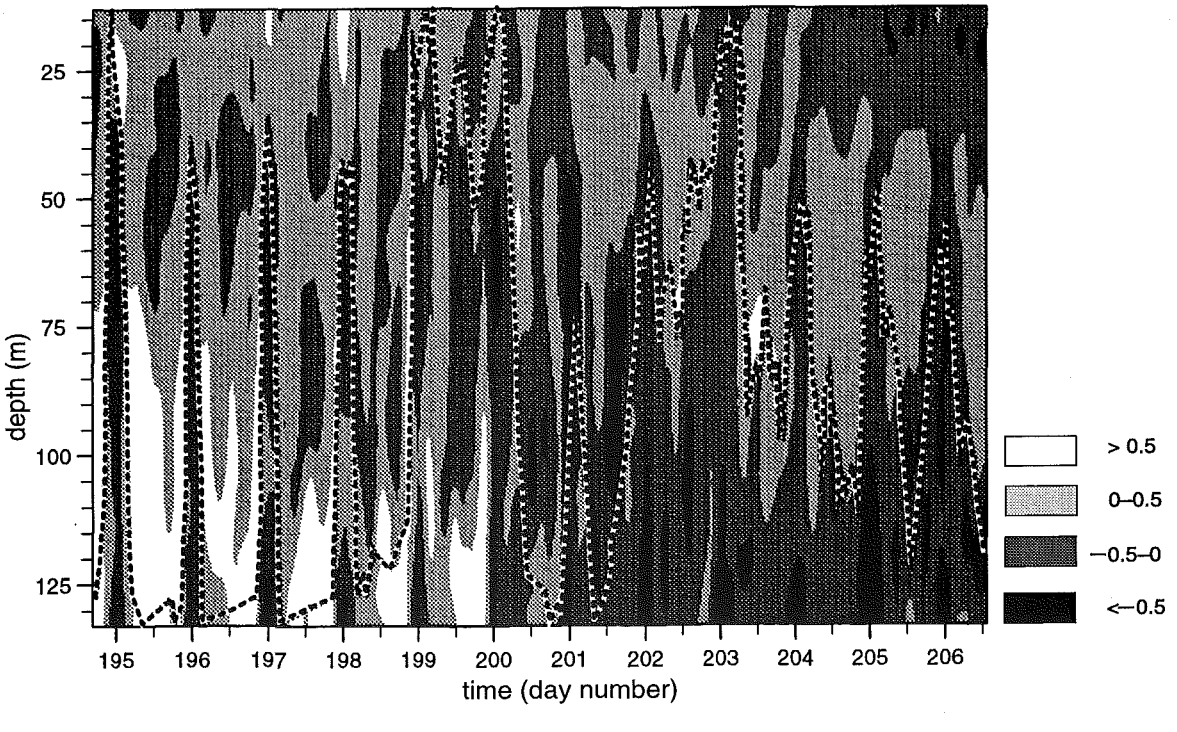
Figure 3 *Vertical velocities measured in the middle of the water column and sunset and sunrise times at this location.*

Independent evidence is available by looking at the acoustic backscatter intensity, also measured by the ADCP. At any depth, the variation in the backscatter intensity is dependent only on changes in the total scattering cross-sectional area (in other words, the number and size of the scattering particles). This quantity will therefore provide a useful qualitative indication of the changing position – i.e. vertical movement – of the zooplankton.

The backscatter intensity anomaly was calculated by removing the mean backscatter intensity profile (Figure 4). A positive anomaly indicates an above-average number of scattering zooplankton, and a negative anomaly a below-average number of scattering zooplankton. In Figure 4 we see an excess of particles near the bed during the day and a dearth at night, along with an increase in the number of particles near the surface. The consistency between the estimated vertical motion and backscatter intensity supports the hypothesis that we are observing the vertical migration of zooplankton.

Although no biological samples were taken during these observations, previous studies of the area suggest that likely migrating scatterers are large copepods and euphausiids (see

Figure 4 *The backscatter intensity anomaly (arbitrary units). The track of migrating zoplankton, estimated from the observed vertical velocity, is overlain. (The sea-bed is at a depth of ~140 m.)*



Further Reading). The high migration speeds tend to suggest that euphausiids are the most likely candidates (cf. Figure 3).

Do we learn anything about the precise timing of the migration? Figure 2 shows that the migration signal is present through much of the water column, but is strongest at mid-water depths. Figure 3 indicates that the ascending zooplankton reach the middle of the water column at sunset, while the descending zooplankton reach the middle of the water column just before sunrise. Clearly, the zooplankton must have begun their ascent at least an hour before sunset, and started descending more than an hour before sunrise, and this raises interesting questions as to what triggers their ascent and descent. Are they responding to changes in light level? Or perhaps they are driven by an internal clock?

We attempted to test these hypotheses during the solar eclipse on 11 August 1999, with two ADCPs looking down from RV *Challenger*, which was anchored at a site to the south of Plymouth, in the line of totality. Although we could clearly see the day–night migration signal in the observations from both instruments, the zooplankton did not appear to respond to the sudden darkness, leading the Principal Scientific Officer, Jonathan Sharples, to conclude that 'They were either asleep, not fooled, or mucking us about!' In reality, the eclipse was not an ideal light trigger, because it was so short, and probably also because the change in the light level was diminished by heavily overcast conditions.

What happened around day 201, when the vertical migration signal became very weak throughout the water column (Figures 2 and 4)? There are two possible explanations: either there was a change in scatterer population or there was a change in the behaviour of existing scatterers. On day 201 the weather changed from clear to overcast, and so the light regime changed. Previous studies (see Further Reading) have indicated that on sunny days certain species of euphausiid tend to gather in discrete bands, whilst on overcast days they are well dispersed with depth. In Figure 5, the drop in daily mean backscatter intensity after day 201, above 30 m and below 80 m, is consistent with the scatterers becoming more dispersed with depth. However, we would also expect to see an increase in scattering particles in the middle of the water column. This is not evident in Figure 5.

An alternative hypothesis is that the migrating zooplankton patch had been advected away from the ADCP. To test this, a particle-tracking model was set up in which the migrating zooplankton were advected using horizontal velocities measured by the ADCP, from the particular depth at which the zooplankton resided at any particular time. The predicted horizontal movement of the migrating zooplankton is shown in Figure 6. Prior to day 201, the zooplankton are predicted to stay within 5 km of the starting position. After day 201, the zooplankton are

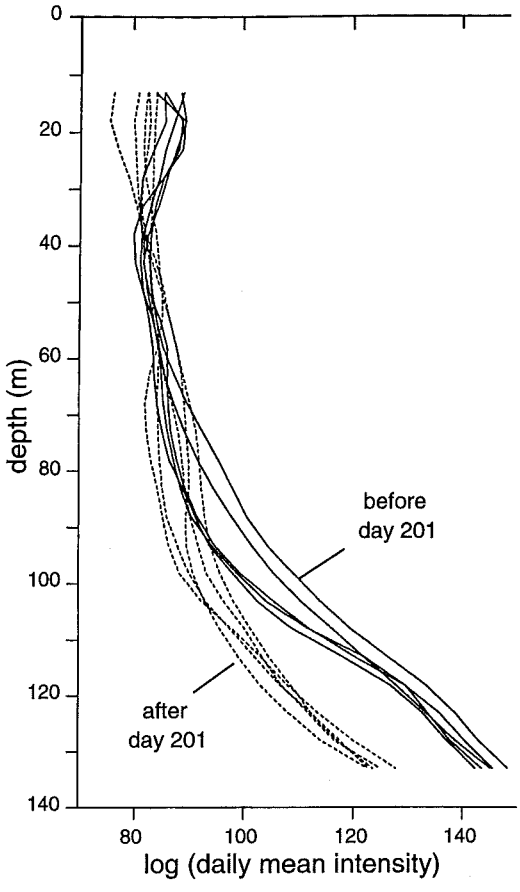


Figure 5 *Profiles of daily mean backscatter intensity (units are arbitrary). Solid line profiles are for days before day 201 and dotted profiles are for days after day 201.*

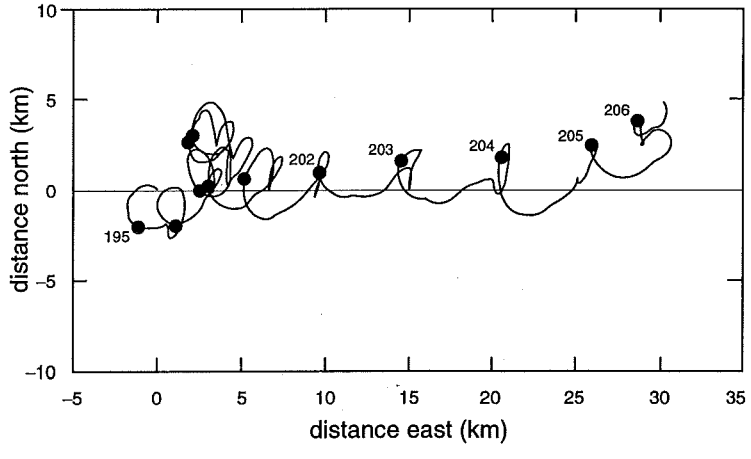


Figure 6 *An estimate of the horizontal distance moved by vertically migrating zooplankton, assuming they are advected by the observed current field. The black dot represents the predicted position of the patch of zooplankton at midnight on the day in question.*

advected east at a rate of approximately 10 km per day. This movement is due to an easterly residual flow near to the sea-bed. This result is sufficient to explain both the weakening of the diurnal migration signal in the observed vertical velocities (Figure 2) and the decrease in the daily mean backscatter intensity (Figure 5).

In summary, we have demonstrated the usefulness of ADCP measurements of acoustic backscatter intensity and vertical velocity in providing quantitative information about the timing and speed of vertical migration. The simultaneous temperature measurements were very useful for separating the migration signal from the internal wave motion. Clearly, future studies should include a focussed zooplankton sampling scheme, which would provide details of species, size and spatial distribution, along with direct measurements of the local optical irradiance.

In terms of our study of internal waves, the results presented clearly indicate the need for care in separating out the 'biological' and 'physical' signals in the vertical velocities measured using ADCPs.

Those interested in knowing more about this work are directed to our recently published paper 'Diurnal signals in vertical motions on the Hebridean Shelf ', *Limnology and Oceanography*, **43** (7), 1690–96. For more details of the internal wave work, the reader is directed to the March 1997 edition of the *LOIS Newsletter* (Special Issue number 11), and a forthcoming paper in the *Journal of Geophysical Research*, 'The impact of non-linear waves on the dissipation of internal tidal energy at a shelf break', by M.E. Inall, T.P. Rippeth and T.J. Sherwin.

Further Reading

Buchholtz, F., C. Buchholz, J. Reppin and J. Fischer (1995). Diel migration of *Meganyctiphanes norvegica* in the Kattegat. *Helgol. Meeresunters.* **49**, 849–66.

Longhurst, A.R. (1976) Vertical migration, pp.116–40, in D.H. Cushing and J.J. Walsh (eds) *The Ecology of the Seas*, Blackwell Scientific.

Oceanographic Laboratory, Edinburgh (1973). Continuous plankton records: a plankton atlas of the North Atlantic and North Sea. *Bull. Mar. Eco.* **7**, 1–174.

The data presented here were collected through the Shelf-Edge Study component of the NERC-funded Land–Ocean Interaction Study. The equipment was deployed from the RRS *Challenger* by Alan Harrison and his team from the Proudman Oceanographic Laboratory (Centre for Coastal and Marine Studies).

Tom Rippeth is a NERC Research Fellow based at the School of Ocean Sciences, University of Wales Bangor.* His main research interest lies in the study of the forcing, mechanisms and consequences of vertical mixing in shelf seas and estuaries.

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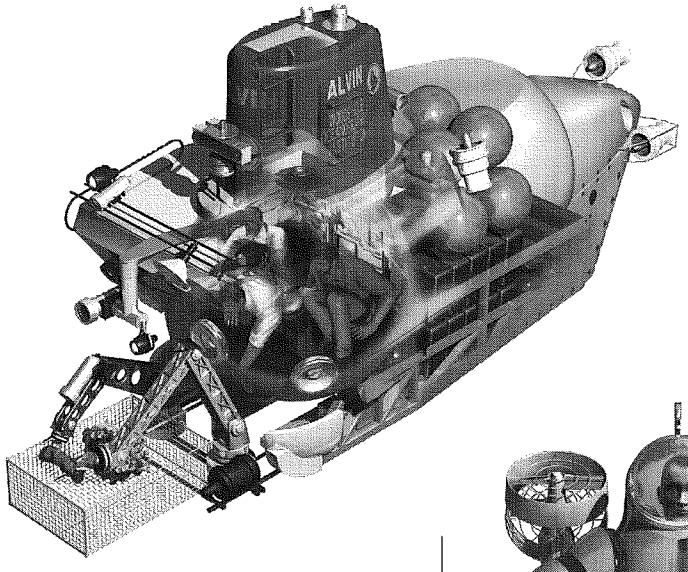
Book Reviews

How it Works: Exploring the Oceans by Stephen Hall (1999). Award Publications Ltd, 46pp., £5.99 (hardback, ISBN 1-899762-41-8).

I love this book and, more importantly, it would have been one of my cherished, well-mauled and most revisited books when I was between the ages of seven and twelve. It is absolutely full of things children love. Brilliant illustrations, informative text (but not too much) and a wonderful sense of adventure that allows children to fire their imagination about the oceans. Most important for this age group, it explains 'how things work' – anything from plate tectonics, tides and waves, to life in the oceans, including food webs, coral reefs and sea birds. There are also sections on how humanity has used the oceans (transport, mining and fishing), including the technologies used to extract the oceans' resources. The sources and effects of pollution also have a section, as does harnessing the power of the oceans.

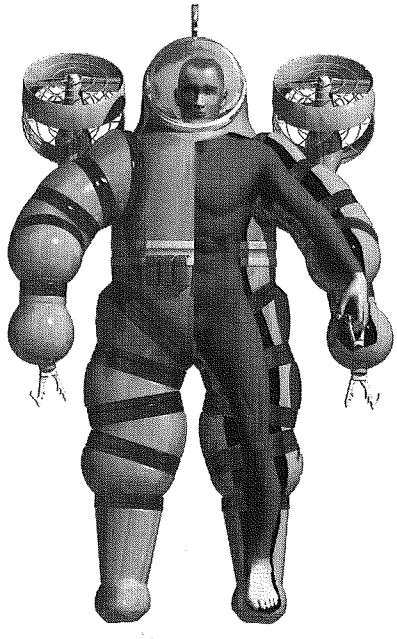
On rare occasions, the odd over-scientific word creeps in. For example, 'density' is used several times without explanation. Despite this, Stephen Hall has done an excellent job of explaining complexity in a reasonably simple way.

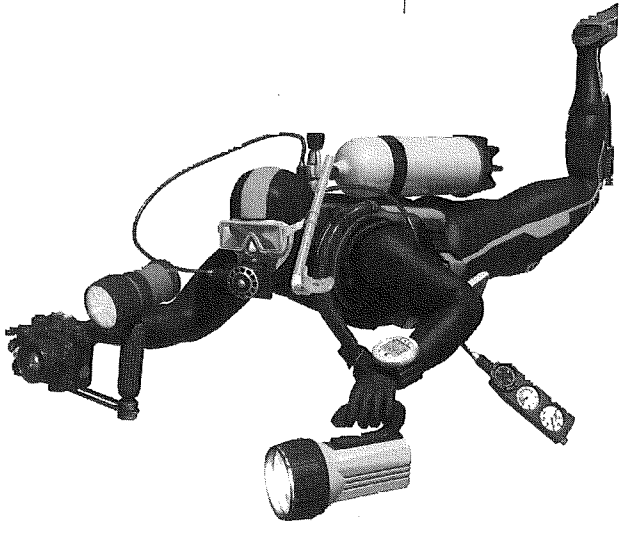
The well-labelled illustrations are truly wonderful and will absorb your children for hours. For example, there is a cross-section of a submarine,with details like where the crew sleep (next to the torpedoes!); a section through a factory



fishing ship, showing where the crew eat and where the fish are processed and stored frozen; the wonderful colours and shapes of life in a coral reef; and how the sea shapes our coastline.

Even the *Titanic* gets an illustration in 'Early Ships and Shipwrecks'. In the 'Shipwrecks' section, as with the whole book, Stephen Hall uses the topic creatively to show the technology that has been used to explore the wrecks. In the case of the *Titanic*, remotely-operated vehicles (ROVs), submersibles, side-scan sonar, camera sledges, survey ships and divers are all shown to play a role in exploring the murky wreck, draped in the rusty crusts of iron-eating bacteria.





If you want to release the imagination of your children and enable them to see and feel what the oceans are like, then this is the book for you. They will soon be in *Alvin* exploring the deep ocean, or in SCUBA gear with compass, wrist-computer, and demand valves, watching sea birds dive and taking care not to step on those spiny fish in the coral reefs. I certainly was!

So parents beware – you may get caught sneaking into the children's bedroom to do a spot of private reading! But as the book costs only £5.99, that is a small price to pay. You can order it from the publishers at The Old Riding School, Welbeck Estate, Nr Worksop, Nottinghamshire S80 3LR. Happy reading!

Carol Turley
Plymouth Marine Laboratory
Centre for Coastal and Marine Sciences

Tropical Climatology (2nd Edition) by Glenn R. McGregor and Simon Nieuwolt, John Wiley & Sons Ltd, 339pp. £18.99 (flexicover, ISBN 0-471-96611-8); £60 (hard cover, ISBN 0-471-96610-X).

What to make of a book that starts by agonizing over the definition of the tropics, that aims to provide a geographical viewpoint on the physical processes in the tropical atmosphere, and accuses meteorologists of misleading everyone by exaggerating the vertical scale on plots?

Well, despite such off-putting remarks I did enjoy reading this book. It is a healthy mix of climate statistics and descriptions of the physical processes that lead to climatic variations. I do not have access to the first edition which, according to the author, was very 'successful' in providing a 'non-technical appreciation' of the workings of the tropics. I therefore cannot comment on the changes made in this second edition. However, in a field that has undergone rapid development in recent years, updates are a necessity, as demonstrated by the fact that the majority of references post-date the first edition. Of course, rapid development also means that a book can become quickly out-of-date. The question is raised as to what will happen to the rapidly developing ENSO event of 1997. Of course, now we all know the answer.

The least successful of the chapters is one of the new ones, the 'Laws of Weather and Climate'. The attempt to use 'word equations' to discuss atmospheric dynamics has, in my view, failed. The language is very loose, often vague and difficult to follow, and in some places downright misleading. The title of the chapter is also misleading as it concentrates on the dynamical and thermodynamical equations of the atmosphere rather than on what controls its variability. The next chapter, on radiation, is much more sound and informative.

The rest of the book is broadly divided into three parts: a general description of the distributions of temperature, general circulation and precipitation (the last being strangely placed towards the end of the book, separate from the other two); a description of the physical processes leading to temporal variability of the system; and the regional variation of meteorological statistics.

The discussion of physical processes is comprehensive, with good descriptions of the Quasi-Biennial Oscillation, ENSO, monsoons, intraseasonal oscillations, cold surges and tropical cyclones. There is again an annoying habit of being picky about the classification of processes. Quite frankly, I find this can often get in the way of understanding, although fortunately in this case it is not too excessive.

The statistics presented are 'climatological' averages. You can marvel at the differences in rainfall between the windward and leeward sides of the Hawaiian Islands and at the rate of increase of the seasonal variation of temperature with latitude. A disappointing aspect is the minimal linkage between the statistical section and the chapters on physical processes. There is some discussion on the variation in conditions between different states of the monsoon and ENSO, but I would have liked a more quantitative analysis and a graphical presentation.

The penultimate chapter looks at agriculture. Did you know that wheat survives best at altitudes above 2000 m and, in terms of the need to supply water, bananas are your best bet?

The book closes with a discussion of climate change and the impact of human activities on climate. Fortunately there is only one of those wretched causal flow charts which purport to describe the connection between a long list of effects, without any statement addressing the magnitude of each.

There is a healthy scepticism about the results of coupled ocean–atmosphere GCMs. However, to some extent this is another case where the book quickly becomes out of date, as more recent work in this area has made substantial improvements in the characteristics of coupled models, and should be consulted in preference to the references quoted. Of course, the scepticism should still remain.

If you are looking for a good introduction to the general characteristics of the tropical climate, then this book may well serve your purpose. Do not expect an in-depth treatise. You will need to consult the reference list for that. You will also need to look elsewhere for a better understanding of the underlying physics of the system. The book is aimed at second- and third-year students in geography and environmental sciences, and to this end I guess it serves it purpose. However, the more 'technically' minded coming from outside the subject would also gain insight into the workings of the tropical atmosphere.

Kelvin Richards
Southampton Oceanography Centre

Gas Hydrates: Relevance to World Margin Stability and Climatic Change edited by Jean-Pierre Henriet and Juergen Mienert (1998). Geological Society, London, Special Publication 137, 338pp. £79, GSL members £39 (hard cover, ISBN 1-86239-010-X).

This timely volume covers a topic which for many years was the province of chemists and had very little exposure in the geoscience literature. In 1811, Sir Humphrey Davy conducted an experiment on the crystallization of chlorine hydrate. Laboratory studies in the 1930s were stimulated by the problems posed by hydrates (clathrates) in the natural gas industry. In the last two decades the oil and gas industry has confronted the challenges of the deeper continental shelves and slopes where buried hydrates constitute hazards for the stability of offshore structures.

This book presents 26 papers from a wide variety of scientific endeavours, and distils the progress made by the delegates at a workshop held in Ghent (September 1996) under the auspices of the European Commission's Marine Science and Technology (MAST) Programme and the European Marine and Polar Science Boards (EMaPS). The chapters reflect the interdisciplinary nature of the discussions, and progress in the field made by geophysicists and geologists, oceanographers, marine chemists and biologists, petroleum geochemists, thermodynamicists and geo-politicians.

Many readers new to the subject of gas hydrates will find the three excellent introductory chapters a concise and effective primer on this theme. The editors summarize the history of research along with current lines of investigation. Keith Kvenvolden then provides key insights into the geological occurrence, petrophysics and geochemistry of hydrates. Unfortunately, the important subject of bottom-simulating reflectors (BSRs) is given a cursory treatment and this topic, along with seismic/acoustic imaging, is nowhere dealt with satisfactorily. Dendy Sloan rounds off the first section with details on the

physical and chemical properties of hydrates from the important work at Colorado School of Mines.

The second part of the volume consists of four chapters on analysis and modelling of hydrates. These papers may bypass many geoscience readers without a strong mathematical background but are sufficiently strong that they should be reprinted in other marine modelling texts. The main body of the book contains a series of case histories on exploration strategy, reservoir evaluation and occurrences of hydrates worldwide, from the eastern margin of the United States to India, the Black Sea, the Barents Sea, the Mediterranean and Sulawesi. Finally, a section on margin stability and climatic change provides an all-too-brief finale to discussion of current research in this fascinating area.

I strongly recommend the volume to marine geoscientists working in this rapidly expanding interdisciplinary area and await with interest a follow-up text from the session on 'Gas Hydrates: Resource? Hazard? Origins?' at Geoscience '98, held at Keele University.

Tony Grindrod
Consulting Geoscientist

Estuarine Shores: Evolution, Environments and Human Alterations
edited by Karl F. Nordstrom and Charles T. Roman (1996). John Wiley & Sons,* 486pp. £95 (hard cover, ISBN 047-1-96596-0).

This book is undoubtedly an ambitious attempt to collate everything you ever wanted to know about estuary shorelines, but were afraid to ask! *Estuarine Shores* examines the spatial and temporal aspects of processes, sediments, landforms and biota, and their interactions, in the intertidal zones of estuaries and those supratidal parts that are frequently flooded. The book reminds me in some respects of an Academic Press publication I used when doing my Ph.D, namely *Estuarine Comparisons* (1982). However, this book is quite different in that it explicitly addresses the *interactions* between physical and biological processes operating along the shoreline, rather than being simply a compilation of individual estuarine problems.

The book's aim, which is to be commended, is to provide the reader with a series of interdisciplinary studies of 'linkages' between and among the environments that define the shore. 'Linkages' encompasses the way environments are connected through exchanges of sediments, nutrients and biota. This approach reflects the trend, over the last twenty years or so, towards interdisciplinarity in estuarine science. Recent community programmes in UK marine science such as LOIS (Land–Ocean Interaction Study) have highlighted the usefulness of interdisciplinary studies of estuarine environments, combining all the traditional scientific disciplines. The whole is much greater than the sum of the parts. Environments described in the book include sea-grass beds, saltmarshes, mangroves, eroding uplands, stream banks, and a wide variety of human-altered landforms and structures. The editors are to be congratulated on the sheer number and variety of estuarine sub-environments they have managed to bring together in a single publication.

Estuarine Shores addresses environmental interactions by highlighting the functional ecology of habitats, the inter-relationships between habitats, and the alteration of habitats due to shoreline change and shoreline development. There is a strong emphasis throughout the book on the nature of the interaction between these environments and people, providing the reader with interesting socio-economic and coastal zone management perspectives, as well as with the more scientific aspects.

The book includes 21 chapters (including case-studies and reviews) by specialists in estuarine research from eight countries. It is organized into three parts: shoreline evolution; environments and processes; and human alterations and management. Contributions in Part One are case-studies of the geomorphology and evolution of estuarine shores in different parts of the world. These are dominantly on short (annual–decadal) time-scales, although the paper by Woodroffe addresses the evolution of shorelines of Australian estuaries throughout the Holocene. Part Two includes contributions on mudflats, estuarine beaches, saltmarshes and seagrass beds, focussing on the physical, chemical and biological processes that affect change and on connections between adjacent environments. The final section of the book (Part Three) is an explicit treatment of human impacts on estuarine shorelines, presenting management and policy alternatives. This is a welcome inclusion for those of us who have our heads down in scientific research most of the time. Increasingly, we are required by funding bodies to place our research within policy frameworks and relate them to practical benefits for coastal communities, and these chapters provide useful and relevant information side-by-side with the science.

The inclusion of both introductory and concluding chapters, as well as chapter summaries (probably editorial policy), makes the subject matter more accessible and distils the main points of each section for the reader. In addition, the editors have gone to some lengths to present the wealth of information in the context of a springboard for the future: the start of a new programme of research, as opposed to a summary of past research. To this end, Chapter 21 ('Emerging research needs related to interactions on estuarine shores') is effectively an overview of the book, with several pages devoted to specific research issues for the future.

Estuarine Shores is more a reference book than a textbook, and will be of considerable use to coastal scientists and engineers, to those charged with responsibility for shoreline management and planning, and to environmental and conservation agencies and policy-makers. The book is in my view rather ambitious in attempting to encompass so many diverse aspects of estuarine science, but I suspect this aim makes it good value for money. Shorelines are the only thing between the sea and us, and this book is a timely reminder of what we do and do not understand about how they function, of just how sensitive they are to human intervention, and of the best practices to adopt so that we can continue to go to the beach on a sunny Sunday afternoon.

Kevin Black
Gatty Marine Laboratory
University of St Andrews

*Sales of this book have been transferred to University Microfilms International (Books on Demand), 300 North Zeeb Rd, PO Boz 1346, Ann Arbor, Michigan 48106 -1346, USA.

Forthcoming Events

Events in 2000

Oceanology International 2000 7–10 March, Brighton, UK. Exhibition and conference, with sessions on Global Marine Policy, GOOS, Sensing the Environment, Deriving Value from Data, Dynamic Coastlines, Pollution Impact, Renewable Energy, Data Visualisation. *Contact* PGI–Spearhead Ltd, Ocean House, 50 Kingston Rd, New Malden, Surrey KT3 3LZ, UK; Tel. +44-(0)20-8949-9222; Fax: +44-(0)20-8949-8186/8193; Email: oi2000@spearhead.co.uk Website: http://www.spearhead.co.uk

Marine Oceanographic Collections – their value, use and future 3 April, Natural History Museum, London. Collections are more than just assemblages of physical items, they are valuable resources for modern research. New technology is now producing a wealth of new information from existing collections, and demonstrating their continuing value as long-term physical archives. The meeting should interest marine researchers, collections specialists, curatorial staff and all who work with preserved marine material. *Contact* Guy Rothwell, Southampton Oceanography Centre. Tel./Fax: +44-(0)2380-596567/596554; Email: R.G.Rothwell@soc.soton.ac.uk *or* Gordon Paterson, Natural History Museum, London SW7 5BD; Tel./Fax: +44-(0)207-942-5678/5433; Email: gljp@nhm.ac.uk

The Estuaries and Coasts of South Wales (ECSA Local Meeting). 13–14 April, Cardiff University, with an optional field trip on 15 April. *For more information, contact*: Madeleine Havard, Continuing Education and Professional Development, Cardiff University, 38 Park Place, Cardiff CF10 3UB; Tel. +44-(0)1222-874133; Fax: +44-(0)1222-668935; Email: havard@cardiff.ac.uk

Transport and Mixing in Geophysical Flows (European Geophysical Society XXV General Assembly). 25–29 April, Nice, France. The symposium will review current understanding of transport and mixing processes, with emphasis on application of theoretical ideas to real systems, including implications for chemical and biological processes. Sessions: Biogeochemical processes and mixing in the ocean; Mixing in stratified and rotating flows; Advances in transport and anomalous diffusion; Transport and mixing of chemical species in the atmosphere. *Convenor:* Dr Bernard Legras, Laboratoire de Meteorologie Dynamique, Ecole Normale Superieure, 24 rue Lhomond, 75231 Paris Cedex 05, France. Tel. +33 (0)1-44-32-22-28; Fax: +33-(0)1-43-36-83-92; Email: legras@lmd.ens.fr

North Sea 2000 (13th International Senckenberg Conference on Burning Issues of North Sea Ecology). 8–12 May, Wilhelmshaven, Germany. Topics will include biodiversity in North Sea ecosystems, ecological barriers, gradients and modelling; structure and functioning; influx/effects of alien organisms, pelagic–benthic coupling. *Contact* Dr I. Kröncke, Seckenberg Institute; Tel./Fax: +49-4421-947532/947550; Email: kroencke@sam-terranare.fh-wilhelmshaven.de *or* Dr M. Türkay, Senckenberg Institute, Senckenberganlage 25, Germany; Tel./Fax: +49-69-7542240/746238; Email: mtuerkay@sng.uni-frankfurt.de Web: http://senckenburg.uni-frankfurt.de/fis/sngc13.htm

Oceanography and Marine Resources in the context of Global Environmental Change and Ecosystem Sustainability (Euroconference on Water and Life – Oceanography, Meteorology and Marine Resources). 25–28 May, Vigo, Spain. *For more information, see:* http://www.uvigo.es/ewl2000

The Deep Ocean Biosphere – Change and Sustainability (9th Deep Sea Biology Symposium). 25–30 June, Galway Ireland. Papers and posters on any aspect of deep-sea organisms (from macro- to micro-) and ecosystems will be welcome, including the abyssal benthos, deep waters and the deep sub-seafloor biosphere. Interdisciplinary papers are particularly encouraged. There will be the traditional programme of social events, with plenty of local food and drink. It is intended that information on the symposium will be promulgated mainly by electronic means. *To be on the Email list, email* John Patching: john.patching@nuigalway.ie

Managing Eutrophication of Estuaries and Nearshore Waters: a Challenge for the New Millenium (31st Annual Symposium of the Estuarine and Coastal Sciences Association). 3–7 July, University of the Basque Country, Bilbao. *For more information contact* ECSA 31, Emma Orive, Departamento de Biología Vegetal y Ecología, Universidad del País Vasco, Apartado 644, 48080 Bilbao, Spain. Tel: 946012570; Fax: 944648500; Email: ecsabilbao@lg.ehu.es Website: http://www.ehu.es/ecsabilbao

The Southern Ocean: Climatic Changes and the Cycle of Carbon (International JGOFS Symposium). 9–13 July, Quartz Congress Centre, Brest, France. 'Brest 2000' a huge gathering of old sailing ships will start immediately after the symposium. *Contact* Paul Treguer, UMR CNRS 6539, Institute Universitaire Européen de la Mer, Technopole Brest-Iroise, 29280 Plouzané, France; Tel./Fax: (+33-2)-98-49-86-64/45; Email: Paul Treguer@univ-brest.fr

Meteorology at the Millenium: Its Relationship to other Sciences and Technology, and to Society 10–14 July, St John's College, Cambrdge. *For more information contact* The Royal Meteorological Society, 104 Oxford Rd, Reading RG1 7LL, UK. Email: execsec@royal-met-soc.org.uk

Science and Conservation of Deep Sea Corals (1st International Symposium on Deep Sea Corals) 30 July–2 August, Dalhousie University, Halifax, Nova Scotia, Canada. The symposium will cover all aspects of deep sea, cold water coral biology, ecology, and conservation; also, climatic reconstruction using corals and technologies available to map corals. It is open to scientists, managers, ocean users and all those with an interest in deep sea corals. *For more information, contact*; Symposium Secretariat: Susan Gass, Ecology Action Centre, 1568 Argyle Street, Suite 31, Halifax, Nova Scotia, B3J 2B3; Tel. +1-902-429-2202, Fax: +1-902-422-6410; Email:coral@is.dal.ca

UK Marine Science 2000, 10–15 September, University of East Anglia, Norwich. *(See full page ad on p.31.)*

Underwater Optics (A topical meeting within Optics 2000, at the Applied Optics and Opto-Electronics Conference). 17–21 September, University of Loughborough. Website: http://www.iop.org/IOP/Confs/AOD

9th International Coral Reef Symposium, Bali, October. For more information see the website: http://www.nova.edu/ocean/9icrs.html

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Remember If you are organizing a conference or meeting on any aspect of oceanography, you can publicize it through *Ocean Challenge*. Details should be sent to the Editor (for address see inside back cover).

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

MEMBERSHIP SUBSCRIPTIONS

The subscription for 2000 costs £30 (£12.00 for students in the UK only). If you would like to join the Society or obtain further information, contact the Executive Secretary, Challenger Society for Marine Science, Room 251/20, Ocean Technology Division, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

ADVICE TO AUTHORS

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

For further information, please contact the Editor:

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