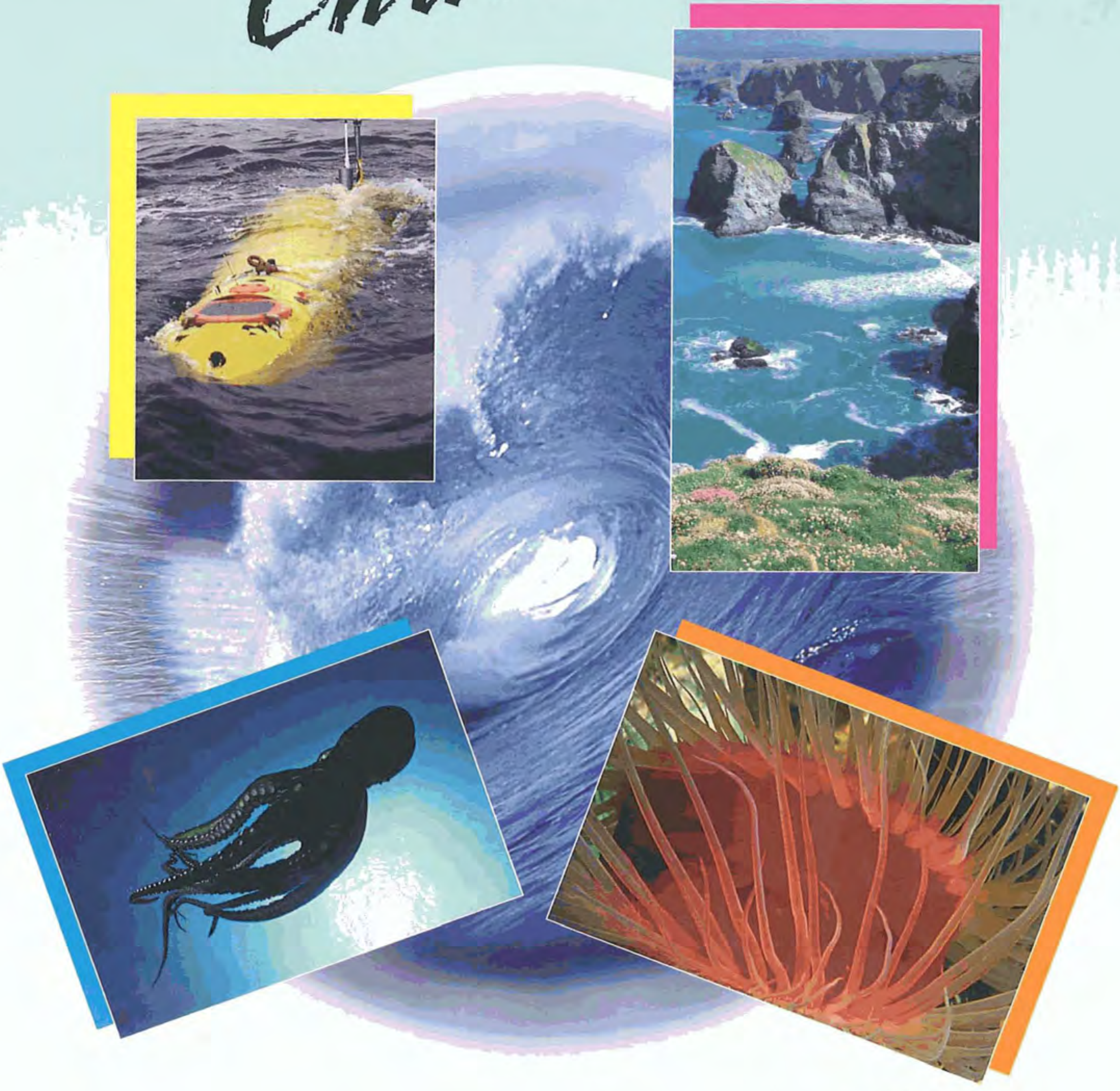
OCEAN Challenge



Volume 12, No. 3

The Challenger Society for Marine Science

Volume 12, No. 3, 2002
(published 2003)

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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

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INSTITUTIONAL SUBSCRIPTIONS

Ocean Challenge is published three times a year. The subscription (including postage by surface mail) is £80.00 ($US 152) per year for libraries and other institutions. New subscriptions, renewals and information about changes of address should be sent to Parjon Information Services, PO Box 144, Haywards Heath, West Sussex, RH16 2YX, UK.

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Cover printed by Albanian Press, St Albans.
Text printed by Halstan & Co. Ltd, Amersham.

ISSN 0959-0161

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The cover was designed by Ann Aldred Associates.

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

Message from the Editor

Dear Reader

This issue of *Ocean Challenge* has two very different features articles. In 'A Plankton Guide to Ocean Currents ...', Graham Quartly and Meric Srokosz show how the global resource of SeaWIFS images can be used to reveal the detail of current patterns around South Africa and Madagascar. By contrast, in 'Tidal Response in Sea Lochs: a case of waves versus jets', Finlo Cottier and Mark Inall describe how research into tidal mixing in sea lochs not only has important implications for the economics of the Scottish west coast, but also helps us to understand the global thermohaline circulation.

We also have the latest news on the UK's new ROV, *Isis*, an overview of the important GOOS programme, and a piece about how the shark's bad image can be turned to advantage. And, as you will see, the topic of ocean sequestration of CO_2 continues to stimulate debate! If you have views on this, or any other topic aired in these pages, please write to us and share them with other readers.

Ang.

News & Views

Iceland to save cod by culling whales

Despite the existing moratorium on whaling, set up in 1986, Iceland will join Norway and Japan to go whaling again, specifically for Fin, Sei and Minke whales. According to press reports in May, Iceland's justification for the move is to protect the fishing industry, because – they say – the whales are depleting fish stocks, especially cod. Conservation groups have condemned the proposals, claiming that the chief reason for resumption of whaling is not research into the whales' eating habits, i.e. (among other things) to count the numbers of fish in their stomachs, but to sell the meat. Minke whales are relatively abundant, Fin and Sei whales are not; moreover, harpooned whales die slowly and painfully.

Is this merely the story of Andre the seal writ large (see p.6)? Anglers wanted to shoot the seal because he was eating 'their' sea trout and salmon. Iceland wants to slaughter whales because the whales (allegedly) eat 'their' cod and other fish. In the last couple of years, the Norwegians have taken to culling whales too, because of competition with fishermen (cf. *Ocean Challenge*, Vol. 9, No. 2, p.7). Fishermen see seals and whales as pests, but from the point of view of the marine environment the the real pests are the fishermen themselves, not seals or whales (cf. *Ocean Challenge*, Vol. 11, No. 2, p.4). It is commercial overfishing by humans that has caused the global depletion of fish stocks, not predation by seals and whales, large though that predation undoubtedly is. If we humans want to achieve a sustainable relationship with the natural world, we must realise that killing off wild predators because they compete with us for food, must inevitably disrupt – if not destroy – both marine and terrestrial ecosystems.

Iceland's intention to go whaling will not contribute to global sustainability, but the next item suggests at least an initial move in that direction (see below).

Iceland and the hydrogen economy

In what may be the first stage in a global 'greening' of energy use, a 'hydrogen filling station' was opened in Reykjavik last April. The hydrogen will initially be used to refill the fuel cells powering some of the city's bus fleet. Despite its reliance on geothermal steam and water for both electricity and municipal central heating, Iceland is alleged to have the world's highest *per capita* greenhouse gas emisions, because the population is relatively affluent and Icelanders use cars a lot. However, it is expected that within a few years (perhaps) fuel cells will be used for powering small devices such as laptops and CD/DVD players.

'Burning' hydrogen in fuel cells may be all right for road and rail transport, but it's less easy to power aeroplanes that way. Using hydrogen as a transportable fuel in aircraft would require the gas to be in liquid form, possibly under pressure, and that's not easy, because hydrogen has a boiling point of 20 K (–253 °C), and it's highly flammable, hence the well-known concerns about safety in this context.

Be that as it may, in Iceland the (much) longer term aim is to convert all the nation's buses and cars to electric vehicles driven by fuel cells. Newspaper reports about these developments have mentioned nine other European cities, including London, where it is planned that road transport will be based upon fuel cells. They also mention plans to export Iceland's surplus geothermally generated electricity via cables to Britain and other parts of Europe, a project that would require enormous investment, not to mention vast annual expenditure on maintenance. We venture to suggest it is unlikely to happen – it might be cheaper to build a new nuclear power station.

At all events, the eventual intention in Iceland is to convert the country's fishing fleet to fuel-cell electricity. One might be forgiven for wondering whether, by the time that happens, there will be any fish (or whales) left for them to catch.

Jellyfish – a new danger for salmon farms ...

The Scottish salmon-farming industry is already beleaguered by accusations from both environmental and animal welfare groups about alleged bad practices, involving pollution by excreta, excess fish food (containing dyestuffs to ensure 'attractive' flesh colour on fishmongers' slabs), pesticides and growth hormones, plus high stocking densities leading to stress and disease. And when fish escape from storm-damaged or poorly maintained cages, they can interbreed with wild stocks and pass diseases onto them – except for the 'giant' salmon genetically engineered not only to grow six times faster than normal, but also to be sterile (cf. *Ocean Challenge*, Vol. 10, No. 1, p.5). International competition from cheap imports is apparently forcing down prices, so that salmon are being sold for less than the costs of production.

As if all that were not enough, jellyfish swarms now pose another threat to the industry, for they appear suddenly and without warning and can have disastrous effects on the caged fish. Larger species may clog the cage walls and prevent water flowing through, so that the fish suffocate, while smaller species can have the same effect by drifting into the cages and clogging up the gills of the salmon. Other small species have stinging tentacles that are normally used to catch prey, but when these get among the fish the stings cause so much irritation that the fish damage themselves in frantic efforts to escape.

As Ferdinando Boero recorded in the EFMS issue of *Ocean Challenge* (Vol. 12, No. 1, pp.24–7), there is need for a great deal more research into these gelatinous zooplankton, not least to understand their abrupt appearances in gigantic swarms that can decimate populations of fish and zooplankton, if not by consuming them directly, then by grazing on the primary producers.

The biggest problem is sampling, for the animals range in size from centimetres to metres, and because they are gelatinous, they are destroyed by nets. Fortunately, advances in the technology of both diving and submersibles have enabled scientists to study jellyfish in more detail than was previously possible. Not before time either, since we humans are manifestly destined to rely increasingly on aquaculture and mariculture if protein from fish is to continue to form an important proportion of our diet.

... but the bad press doesn't stop

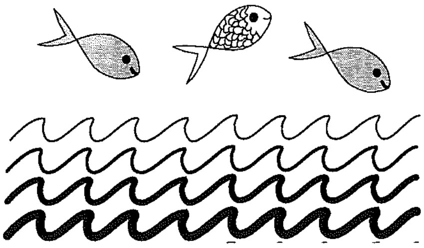
An article in the May issue of *The Observer's* Food Monthly mounted a scathing attack on the fish farming industry as a whole. The tally of farmed fish has grown quite large in recent years: salmon, trout, cod, halibut, sea bass and sea bream, tilapia, tuna, turbot, shrimps and prawns, and even whales – that's the latest wheeze being pioneered in Japan, where whale meat is a popular dietary item. As indicated above, a bad press is nothing new in fish farming, whether it's freshwater aquaculture, or sea-based mariculture.

At the front of the *Observer* article is this trenchant summary: 'Dyed, de-sexed, and a threat to the planet: the fish on your plate is more likely than ever to be farmed. Still think cod, sea bass and tuna are wild?'

Market forces to the rescue?

Fish farmers in Shetland have devised a novel way to keep large fish within nets while allowing smaller immature fish to escape and grow. The net is simply a grid made of nylon rope fitted with tubes of hard plastic that rotate round the ropes. Large fish cannot get through the grid, small fish easily slip through, while medium-sized fish can wriggle backwards out of the grid, because of the rotating tubes. The rotating tubes minimise damage and stress, which result when fish are size-graded by hand and which will lower their market value when they are sold. As indicated in the previous item, fish farming in general has a poor environmental image already, so any development that improves the condition of the fish is to be welcomed, even if the reason for it is principally commercial.

If nets of this kind could become more widely available, many fewer juveniles of wild stocks would be caught and subsequently discarded (because they are undersized and cannot be marketed). However, cost considerations alone, never mind the bureaucracy of the CFP (or whatever succeeds it), will combine to ensure that the introduction of 'juvenile-friendly nets' into general use will take years. In the meantime, immature wild fish will continue to be killed in large numbers, and there can be no foreseeable end to overfishing. Within five years, possibly less, signs reading 'fresh fish' will mean 'fresh farmed fish'.

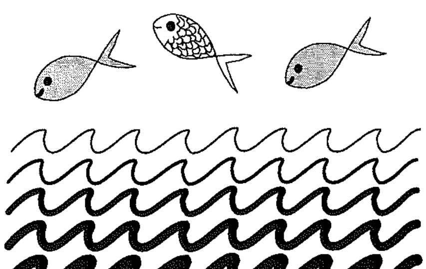


Dolphin-friendly sea-bass – update

In recent years both politicians and the fishing industry have endlessly discussed and debated the need for nets that allow not only juvenile fish but also dolphins, turtles and other 'by-catch animals' to escape, the one to grow to maturity and breed (and contribute to future catches), the other simply to stay alive. Discussion and debate continues, but little is done, in spite of repeated media attention in newspapers, as well as on radio and TV, with graphic pictures and gruesome accounts of suffering sea mammals. Perhaps, at last, there is some hope, at least for dolphins,

Trials of new 'separator grids' that allow fish into the net but push dolphins out through 'doors' in the top, have resulted in many fewer dolphins being drowned (cf. *Ocean Challenge*, Vol. 12, No. 2, p.3). If such separator grids could be combined with nets of the kind described in the previous item, there might be a future for both dolphins and juvenile fish.

Elliott Morley, Britain's fisheries minister, is reported to be in favour of these developments, but it will take many years to achieve the necessary changes in fishing gear, cost alone being a major factor. In any case, the British government's attitude to environmental matters is not noticeably proactive, and help for marine conservation is likely to be a long time coming.



Ministerial dithering over reefs

Press reports in April accused Margaret Becket, the Environment Secretary at that time, of reneging on promises she made two years ago to protect the cold-water reefs off north-west Scotland known as the Darwin Mounds, from destruction by (mainly) French and Irish trawlers. The reports stated also that Franz Fischler, the EC fisheries commissioner, was in favour of protecting the reefs, but went on to suggest that the hydrocarbon industries also have interests in the area, which is part of the Atlantic Frontier, where drilling for oil and gas has been going on for the last two years.

The oil industry has *still* not set up any marine protected areas, as directed by a High Court injunction (*Ocean Challenge*, Vol.10, No.1, p.4, also Vol. 9, No. 3, p.4), presumably with the approval of British Government Ministers. So why are the reefs still being smashed by trawling gear? Broadsheet newspaper reports in late June described 'Ministerial concern' about these ecosystems and attributed the lack of action to restrictive clauses in the Common Fisheries Policy. Without changes in the CFP, Britain's deep water coral communities are likely to be doomed.

... and the dithering continues

Britain's new Environment Minister Elliot Morley (who is also Fisheries Minister) was all set to ban fishing near the Darwin Mounds during the summer months, when trawling is generally most intense. Morley let it be known that emergency powers would be used to close the area to fishing vessels in a matter of weeks. However, the relevant letter sent from DEFRA to the EC contained no formal proposal to close the area, which would force the commission to reply. It merely 'suggested' that emergency powers be adopted, making it likely that the issue will become lost in Euro bureaucratic tangles.

Conservation groups are reported to be outraged. They evidently feel that nobody in the EU gives a damn about the Darwin Mounds, and that fishing will be allowed to continue – and presumably hydrocarbon exploration too. Perhaps Elliot Morley would like to tell *Ocean Challenge* readers why the marine environment is of so little concern to his government?

Ministerial dithering over Sellafield ....

In April there were press reports accusing John Prescott, the Deputy Prime Minister, of reneging on promises made *five* years ago, at a ministerial meeting in Sintra, Portugal (when he was in charge of environmental matters). Apparently, he agreed to ensure that discharges of radioactive wastes from Sellafield would be greatly reduced; and he subsequently signed an OSPAR agreement to that effect, in the hope that Britain would shed its image as 'the dirty man of Europe'. However, discharges are allegedly higher now than they were in 1998, partly on account of the need to re-process spent fuel from the first-generation Magnox stations, which BNFL plans to close by 2010. Prescott himself has not been doing well lately: around five years ago he promised to reduce traffic on Britain's roads, and there are now more cars around than ever. That may not be entirely his fault, which is more than can be said for his failure to reduce radioactive discharges from Sellafield.

However, when Margaret Beckett was made Environment Secretary in June, she did what John Prescott failed to do. She instructed BFNL to cease discharging radioactive wastes from Sellafield for nine months from July, in accordance with the long-standing demands from both Ireland and Norway.

... and Norway complains yet again

The Norwegians are reported still to be concerned about levels of technetium-99 in their fish and shellfish, especially in their so-called 'Arctic quality' lobsters which can no longer command the high prices they used to. The report in question says that discharges of technetium-99 have actually increased over the last year or so. In a recent issue of *Ocean Challenge* (Vol.11, No.2, p.3) we recorded Sellafield's claim to have reduced discharges a thousand-fold in the last 25 years, which sounds very good – but we repeat the question posed then: what were discharge levels before 25 years ago?

Cod Wars are different now

It's no longer about who's catching whose cod, and sending in the gunboats to settle matters when disputes flare into open hostility. Nowadays it's about how many fishing boats this or that country must scrap or decommission – a distinction without a difference – and about compensating fishing communities for loss of livelihood. Compensation is not a popular word in government circles, especially in the UK, because money spent to support erstwhile fishing communities is *ipso facto* not offset by revenue from fish catches – because decommissioned (scrapped) fishing boats catch no fish and bring in no taxable revenue.

Sure enough, in June this year, Whitehall made no response to a petition from three women (wives of Scottish fishermen) pleading for help from Government to support their husbands who cannot fish because of the cod ban (*Ocean Challenge*, Vol. 12, No.2, p.4). Large-scale decomissioning of boats is accompanied by massive hardship, consequent upon the loss of tens of thousands of jobs in fishing related industries.

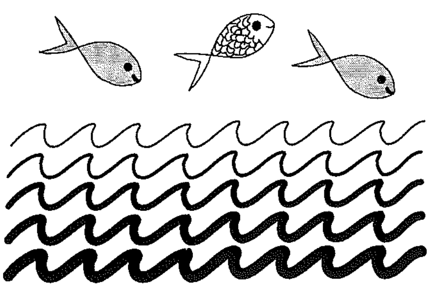
At the same time, industrial fishing is allowed to continue unabated, to provide the fish meal used to feed both terrestrial and aquatic (fish farm) livestock. This practice takes large quantities of young cod, thus destroying the very stocks that the cod ban is intended to protect. Worse, it seems that according to provisions of the EU's Common Fisheries Policity, Spanish fishermen now have unrestricted access to the so-called Irish Box, including the Irish Sea and the Bristol Channel, a development that (it is claimed) will wipe out Ireland's fish stocks, thereby virtually eliminating coastal communities. Spanish boats apparently also have access to North Sea waters off Scotland, hitherto the main fishing ground of the Scottish fleet. If the Scots are not allowed to fish those waters because of the cod ban, what loophole in the CFP permits Spanish boats to do so?

Meantime, Britain's Government Ministers – including the Fisheries Minister, Elliott Morley – continue to ignore pleas for help from Scotland's fishing community, but make little or no effort to lobby for reform of the bureaucratic Common Fisheries Policy. How long will it be before fish farms provide humanity's only source of fish-based protein (cf. p.3)?

Baltic blues

Humans have now come to realize that the oceans are part of the global environment, with its own eco-systems, not a dumping ground for everything from old cars to nuclear waste. No such attitudes prevailed when the War ended over 50 years ago. Hundreds of thousands of tonnes of chemical weapons, apparently captured from German forces, were dumped by British and American ships in various parts of the Baltic. Mustard gas laced with arsenic was (still is) a major component in these munitions, but there are high explosives too. Tales of fishermen (notably but not exclusively from Denmark and Norway) catching shells in nets have resulted in fishing vessels being equipped with first-aid kits especially designed to deal with mustard gas burns and with Sarin-like nerve gases, and some parts of the Baltic have become no-go areas for fishing. It seems that the British stand accused of non-cooperation and of suppressing documents that relate to the weapons-dumping. The Kaliningrad Institute of Oceanography, near the south-east Baltic coast, leads research into these now largely forgotten dumps and recently warned that seawater corrosion of casings will bring new hazards.

And now there's a another threat for Baltic waters: Russia's President Vladimir Putin was recently warned about the dangers posed by old single-hulled tankers carrying oil across the Baltic – but no action has so far been taken. EU countries are especially concerned about the risk of collision or storm damage, with the *Prestige* disaster off north-western Spain uppermost in the minds of many (*Ocean Challenge*, Vol.12, No. 2, p.3). There is little prospect of improvement, partly because EU rules requiring use of double-hulled tankers cannot be enforced till 2010, and partly because Russia may well be too poor to build – or perhaps even to lease – such vessels.



Pier review

Brighton's West Pier has had a rough time in recent months. Winter storms last year caused collapse of the seaward end, and fires in March and May – blamed on arsonists – gutted much of what was left. Built in 1866, the pier's popularity peaked in the 1920s but later declined because of rapid social changes after the second world war, and it has been closed to the public for nearly three decades. But there are plans to renovate the pier, and the recent setbacks have if anything reinforced local determination to proceed with the renovations. However, a *Guardian* article in May noted that much of what was valued of the original pier has now gone, and went on to cite criticism of the restoration scheme as both expensive and controversial.

All told, something like 70 piers were built for many of the country's seaside resorts between 1860 and 1900, a time when the Royal Navy's control of the seven seas allowed Britain to dominate the globe. Their original purpose was to provide landing jetties in deep water offshore, in places where there was no sheltered harbour – indeed, by the end of the 19th century something like 200 paddle steamers served the country's piers. However, as the years passed, the piers became pleasure palaces, featuring theatres, concert halls, winter gardens and bandstands, as well as amusement arcades with their almost obligatory slot machines, and providing an ideal promenade where folk who fancied themselves as fashionable gentry could see and be seen. Brighton's West Pier in particular excelled in flamboyant architecture, with domes and minarets and lots of ornamental cast iron.

The *Guardian* article described how the paper's Arts+Books department had asked a group called Foreign Office Architects to provide an innovative architectural design for a new West Pier at Brighton. The article rhapsodised about how Foreign Office have proposed a wave-like design that has more in common with natural landscapes than with the pre-existing rather gaudy superstructure, perched on a forest of iron columns. Were the design to prove acceptable and, more important, were a new West Pier ever to be built for Brighton, then there might be some hope for renovation of other seaside piers in Britain. It seems more likely, though, that there will be piecemeal restoration of the various structures that already exist, rather than application of innovative design concepts.

PICO Continues to Flourish

More than 10 years ago, a group of UK marine chemists decided that it would be a good idea to create a forum to meet and present new results in the years in between the biannual Challenger conferences. With generous support from the Challenger Society we began the PICO (Progress in Chemical Oceanography) series of meetings. The intention has always been to provide a relatively informal atmosphere, and particularly to encourage young students to present their work. The idea clearly had some merit because this series of meetings is still going strong. PICO 5 took place at the School of Environmental Sciences, UEA, on 16–17 July with sponsorship from the Challenger Society and the School of Environmental Sciences.

Almost forty people from a wide range of institutions attended the meeting. They were treated to oral and poster presentations of a very high standard from both students and established members of the community. The research presented covered all aspects of marine chemistry from the deep ocean to estuarine systems and from equatorial to polar waters. The visitors also had a chance to look around the chemistry laboratories in the School, which have recently been refurbished as part of the NERC JIF award for the Laboratory for Global Marine and Atmospheric Chemistry (LGMAC). The organization of the whole event was undertaken by Rosie Cullington at UEA, to whom we all offer our grateful thanks.

Tim Jickells
School of Environmental Sciences, UEA

No more cockles ...

Cockle beds around Britain are to be closed down by order of the Food Standards Agency (which is headed by Sir John Krebs). Apparently, the FSA transferred its shellfish testing contract to the CEFAS lab in Weymouth, which uses a testing procedure devised by a Japanese scientist who has acknowledged that it is unreliable and suggests that it be abandoned. The test used by the CEFAS lab involves adding solvent to large amounts of shellfish extract (equivalent to several hundred kg of cockle flesh), and injecting the solution into mice. Apart from the dubious ethics of using animals to test for toxins which might harm humans, it is also alleged that the CEFAS lab uses no controls to monitor the reliability of these tests. Independent analyses by other laboratories have apparently turned up no trace of the alleged toxins in the cockles, and when representatives of Britain's cockle industry notified John Krebs of their concerns, he appeared to understand the points they made. But nothing happened to remedy the situation and the programme of cockle-bed closures continued to be implemented. The Radio 4 programme 'You and Your's' featured this same story on 22 July, when a spokesperson for the FSA refuted cocklers' claims that the CEFAS tests are unreliable, but gave the impression that the FSA is simply covering its back. It seems that nothing will be done and cockle beds will continue to be closed. It's bad news for an industry that employs thousands of people, is worth £20 millions annually, and exports most of its product. Meanwhile the cockles continue to grow, and the beds are getting overcrowded.

... or mussels

It seems that the FSA has much to answer for. At the end of June it was reported that the agency now proposes to prohibit domestic sales of dredged mussels, because results of allegedly unreliable CEFAS tests show the water in which the mussels grow to be polluted. Laboratories in Holland and France are reported to have tested the same water, without finding any evidence of pollution. In consequence, Dutch and French operators have taken to buying up British mussels at low cost, reclassifying and exporting them back to Britain, labelled as being of Dutch or French origin, and selling them at substantial profit in supermarkets. So the FSA has apparently closed down another industry that employs thousands of people and is worth many £millions. Perhaps the FSA will now turn its analytical spotlight onto the mussel *farming* industry – unless all of this fuss about toxic cockles and polluted mussels is merely a cunning plan to support shellfish farmers by eliminating competition from 'natural' sources.

News Nuggets

Crisis for large predatory fish

An article in the 15 May issue of *Nature* (pp.280–82) achieved much press and media publicity because of its sombre message that in all the major oceans there have been reductions of 90% or more in stocks of tuna, marlin, swordfish, sharks and rays in the last two to three decades. Over the same period the size of mature fish has also decreased: they are now only about half the size of those caught in the 1950s.

Toothfish drama in Southern Ocean

Customs vessels from Britain, Australia and South Africa were recently in hot pursuit of the *Viarsa*, a Uruguayan-registered fishing boat alleged to have £millions worth of endangered Patagonian toothfish illegally caught off Australia. After three weeks, the *Viarsa* was caught, and the Australians aim to remove (and sell?) the fish, prosecute the crew and scuttle the boat. Countries in the Southern Hemisphere are angry that those in the north have over-exploited their own waters and now go south to look for more fish; the *Viarsa's* Uruguayan owners are alleged to have Spanish connections. Catching her won't make a lot of difference though, there are about 70 pirate boats fishing illegally round Antarctica.

'Mussel dating'

Because illegal 'pearling' and diminished water quality have driven freshwater (pearl-secreting) mussels in England and Wales to near-extinction, conservationists plan to collect solitary males and 'seed' them among groups of females, to encourage procreation. Apparently the mussels live for 80–100 years, and breed successfully in Scotland and Ireland, but not elsewhere in the British Isles.

Alien in the North Sea

A short item in *The Independent* in February reported that a specimen of the world's longest teleost (bony fish) was caught in the North Sea off Cleveland. According to the news item, sightings of oarfish could have given rise to legends about sea serpents, although the animal normally inhabits deep waters of the eastern Atlantic and Mediterranean and is rare in shallow coastal waters. Its presence in the North Sea is difficult to explain but is thought unlikely to result from global warming.

The seal in Loch Lomond

A grey seal found his way into Loch Lomond last April and attracted some modest publicity, because he consumed sea trout and salmon that would otherwise have been caught by anglers. Their frustrations led to threats to shoot the animal, nicknamed Andre. Initial attempts to net the seal and remove him to a colony on the Fife coast were entertaining but initially unsuccessful. What happened next?

What, another bridge?

The Woolwich Ferry offers a free daily service for car commuters across the Thames, and costs around £5 million a year to run. There are plans to replace it with a six-lane road bridge costing £400 millions or more – a sum that would keep the ferry going for at least 80 years! – and the ferry vessels would be subsumed into a commuter service along the Thames. The bridge would need to be 50 m high to allow clearance for shipping, but no more than 70 m high to avoid obstructing the approach to London's City airport.

Analysing really, really old seawater

Droplets of fluid trapped in crystals of Archaean quartz and emerald are to be analysed using a new laser technique that should reveal what seawater was like when (microbial) Life on Earth began. Using lasers is better than crushing crystals to release the fluid, though a question remains: the crystals must be in ancient sedimentary rocks where quartz is common enough – but aren't emeralds precipitated from hydrothermal fluids in granitic environments? How can their fluid inclusions carry information about ancient seawater?

Sharks: turning the tide

Kelvin Boot

Not so long ago the *Weekly World News,* an American 'supermarket tabloid' devoted most of its front page to a fearsome photograph of a Great White shark accompanied by the headline:

Castro's evil plot to terrorize our beaches! CUBA LAUNCHES SHARK ATTACK ON U.S.!

The 'depraved dictator', Fidel Castro, had allegedly hatched a plot to threaten US national security through super-intelligent killing machines – sharks – bred by marine biologists at an isolated island laboratory.

The article continued:

'Ichthyologists, geneticists and other scientists and animal behavioural experts working at the secluded laboratory bred several generations of various shark species before developing the dreadful killer species that now patrols America's coastlines.'

This story not only reinforces the popular notion that scientists manipulate nature to create monsters and/or develop weapons of mass destruction, it also feeds the belief that sharks are malevolent, calculating killers, bent on wreaking vengeance on the human race. The story is patently suspect – especially when taken in context with the other lead story about a three-breasted woman and a three-armed man who between them produced a three-legged baby – but an awful lot of people would want to believe that that it is true.

Even now, it is difficult to find a shark story in the media that does not pander to the belief that all sharks are at best dangerous and at worst 'man-eaters' . The mythology, of course, makes for very good headlines and sells newspapers. A more recent 'serious' article reported the capture off Cornwall, of a 'baby killer shark', allegedly a Mako shark, a species which has been implicated in injurious encounters with humans. The journalist had in fact been informed that the shark was a Porbeagle, but chose to run with the 'better' (but totally inaccurate) story. Shark stories are often embellished to 'give them teeth', but 'improvements' can also be gained by omitting relevant information. The report of a Mediterranean Great White repeatedly attacking a small boat was covered by all news media and seemed to provide evidence for the vindictive nature of sharks, yet neglected to mention that the shark was on the end of a fishing line at the time, and was understandably a bit fed up.

Fascination with fear

Fascination with the 'blood and guts' element of shark encounters has resulted in a self-perpetuating myth: the media generate gory stories in response to the blood lust of their audience, which in turn is fed by the stories and so on. Even credible 'blue chip' TV programmes find it hard to talk about sharks without including the obligatory section on shark attacks, often illustrated in true Hollywood style. Articles or TV programmes about bees or coconuts never revel in the lethal potential of these 'man-killers', both of which kill more people a year than sharks do.

We are still at the point where nobody wants a shark story unless it has a high gore content – breaking the chain is not easy. Those of us concerned with raising awareness of, and concern for, the oceans and the life they contain, and who hope to change attitudes and perceptions, face a real challenge – especially when the best-known ambassador from the depths is a creature that apparently means us harm.

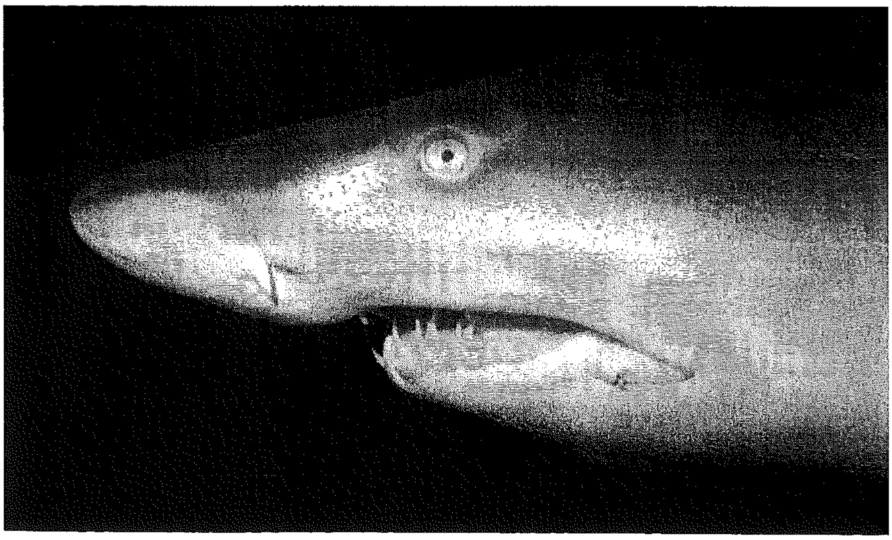
Yet it is the macabre fascination that provides the most powerful tools of engagement. Asked to sketch their favourite fish, most children visiting the National Aquarium will draw a shark with large sharp teeth at the front end. Almost everyone has seen or heard of the film 'Jaws'. Sharks are used in advertising to convey the idea of menace, and they leap out of the sea to 'snap up' holiday bargains. They are used to depict the human occupations we love to hate – taking the place of tax inspectors, traffic wardens and accountants in cartoons. It is no surprise, then, that the over-riding impression of sharks is of a calculating predator bent on ridding the seas of humans ... and this is exactly what fascinates people.

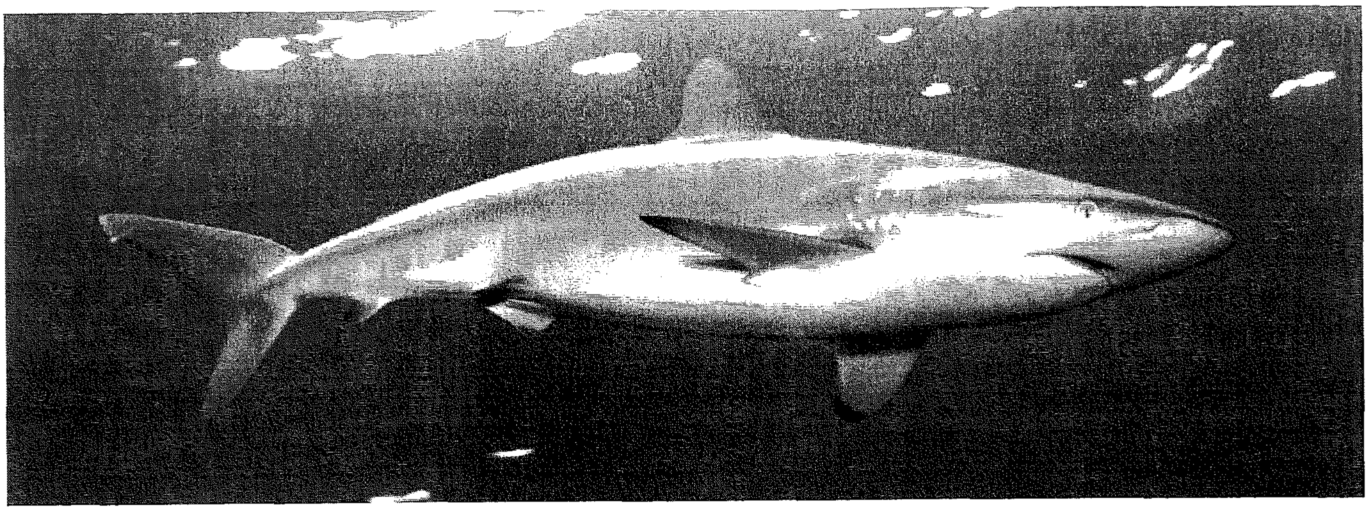
So if we cannot beat these propagandists, let's join them. By focussing on the existing misconceptions, we have an opporunity to set the record straight.

Turning the tide

The 'Jaws' connection is an important tool for engagement. Sharks do not have to be 'sold' to aquarium visitors – there is already a very strong familiarity, albeit based on a fallacy. In the UK, the National Curriculum majors in a few subjects of which numeracy (mathematics) and literacy (language) are key elements. Sharks provide ideal vehicles to address the needs of schools whilst providing us with the vehicle for dispelling myths. A group of children (or adults) can be encouraged to see sharks as perfect swimming machines, or as flying creatures – the underwater equivalent of birds of prey or even aeroplanes. Measurements of the 'engine' – the tail movements – can be matched to different species and different

A Sand Tiger shark





A shark is a superb machine

lifestyles. Gill slit movements can be related to the shark's activity. Different fin shapes, body outlines and tail designs are largely hydrodynamically determined, so sharks may be thought of as technological products.

Language relating to sharks is varied and colourful. Asked to participate in a word association exercise, a group of visitors to an aquarium can generate a shark vocabulary in a very short time. At the first mention of the word 'shark' they will respond with 'bite, fear, blood, teeth, man-eater, jaws, killer, cold-blooded', etc. This provides the educator with the perfect opportunity to put the record straight. Simply asking what visitors know about sharks is an excellent way of bringing out the truth because, surprisingly, many children and adults do know much of the truth already – it simply needs raising to the surface. In a group there will often be someone who is more knowledgeable or concerned than the others, and he or she will become a champion of the cause. It is never long before the vocabulary changes to include the words 'sleek, misunderstood, elegant, endangered, beautiful, amazing', and so on.

Aquariums provide an intimacy with living sharks that very few people will experience in the wild, but even dead sharks hold a fascination for people. The trophy shark on the quayside is a decreasingly common sight as attitudes gradually change – perversely but predictably the people who hunt sharks are the very people who are starting to champion their cause. But sharks still come ashore, and when they do they still generate a huge amount of interest. Watching people around a dead shark can teach us much. They are fascinated and want a closer look, they see the animal in the flesh as an incredible creature – it is they, not the shark, who become hooked. Any 'expert' close by is bombarded with questions about what it is, where it came from, what age, sex, species it is. If a female, has she left her babies out at sea, and will they die without her? The over-riding emotion is not the revulsion and disdain you might expect but rather, concern and respect. The reason for this contradiction is the proximity of the real thing. Most people never see a shark so close, even a dead one, but when they do, they see it for what it is, not what they have been told it is.

Sharks suffer by the million

The end-product of all our work in the aquarium has to be a greater understanding of sharks, which will in turn lead to more sensible and sustainable management and conservation. Most of our visitors have little understanding of the actual frequency of shark attacks, the relative risk of shark attack, or the figures for global mortalities. They certainly have little appreciation of the number of sharks killed by humans, whether by accident or design, for malicious pleasure or economic need.

The scale of the slaughter is staggering: 100 million shark deaths every year. This equates to over one quarter of a million sharks each day – about three sharks each second. Such shocking numbers are perfect for making the point. Timing a talk and translating it into shark deaths, or having a death counter totting up the total is both immediate and very powerful. The message is clear – sharks have far more to fear from us than we do from them.

Attitudes are changing

Not so many years ago the idea of a conservation organization specifically for sharks would have been met with derision. After all, the prevailing attitude was that 'the only good shark is a dead shark'. Now we have the Shark Trust in the UK, the European Elasmobranch Association, and many other societies established throughout the world (see below for websites). The real strength of these organizations is that they have been born of necessity rather than sentiment. They have grown from scientific concerns rather than from a fluffy feel-good factor. They can only go from strength to strength as more people are converted to the cause.

There is a growing understanding of sharks and their importance in their environment, and there is a growing awareness of the threats that sharks face worldwide. There is also a growing appetite for information about sharks and there is a great opportunity to accelerate the changes in attitude that are taking us from killing to conservation. Aquariums should be at the vanguard of this turning tide. They have a huge part to play in replacing shark fiction with shark fact. Sharks are ambassadors for the seas and their inhabitants, so we all have a duty to be less hostile to them, treat them well and help our visitors understand the truth rather than the fiction.

Kelvin Boot is Head of Education and Information at the National Aquarium, Plymouth.*

Sharks feature prominently in the Aquarium's excellent website: http://www.national-aquarium.co.uk; and the Aquarium is the home of the Shark Trust: http://www.sharktrust.org/

*The Rope Walk, Coxside, Plymouth, PL4 OLF.

Global Observations for Climate

Colin Summerhayes

Climate affects us all. Regardless of whether or not there is global warming, with more and more people having to live on the surface of our finite planet we would be wise to understand climate better and, if possible, forecast its behaviour. Climate change occurs on many time-scales from the seasonal, through the interannual to the decadal, and includes short- and long-term fluctuations as well as progressive change.

In order to track these changes and make those forecasts, the international scientific community is engaged with governments in instrumenting the surface of the planet, especially the ocean, the least well known bit. That brings us to the Global Ocean Observing System (GOOS), and its twin, the Global Climate Observing System (GCOS). The climate part of GOOS *is* the ocean part of GCOS. GOOS and GCOS are helping to provide the mechanisms we need if we are to get where we want to be. For a good picture of where we are generally, readers might find it useful to consult the second Adequacy Report on the Climate Observing System, produced by GCOS (with the aid of GOOS) for the UN Framework Convention on Climate Change (see http://www.wmo.ch/web/gcos/gcoshome.html).

In summary, GOOS is:

- A sustained, coordinated international system for gathering data about the oceans and seas of the Earth
- A system for processing the data to enable the generation of beneficial products and services
- The research and development upon which such products and services depend for their improvement.

GOOS is sometimes referred to as 'operational oceanography' (i.e. providing a day-to-day service) at the global scale. In fact, it involves systematic and sustained observations, most of which have dual purposes in meeting the needs of both the research and operational communities. Indeed, many of the observing elements of GOOS are funded by research budgets, which evidently makes GOOS a quasi-operational animal at best. Given the clear need to involve researchers in designing and improving the elements of GOOS, and the need for GOOS data to answer many research questions, it would appear counterproductive to describe GOOS as purely 'operational'. That being said, the message for funders is that GOOS will not work without the long term commitments that the operational community is more accustomed to.

Already, a great many countries are actively involved in GOOS through GOOS Regional Alliances in different areas, including Europe, the USA, the Mediterranean, the Black Sea, the Caribbean, the Indian Ocean, the Pacific Islands, the south-east Pacific, south-east and north-east Asia, and Africa.

We need systematic and sustained observations of the ocean to:

- Understand global change
- Forecast weather and predict climate
- Protect life and property on the coast and at sea
- Forecast future ocean states for a variety of uses and users.

Focussing on climate, we know that that El Niño affects agriculture in many places, especially in the tropics. For example, El Niño events have been associated with drought years and low maize yields as far away from the Pacific as Zimbabwe. With improved ocean information we can forecast the droughts more accurately, and farmers can adapt their planting strategies to mitigate undesirable effects.

We know that El Niño affects health in many places, especially in the tropics. For example, El Niño events are associated with more rain and hence more malaria in places like Colombia. Because we can forecast the rains, health workers can allocate their limited resources more effectively.

Climate fluctuations like El Niño events also affect fisheries. One such event is the Pacific Decadal Oscillation. One effect of the sudden warming in the Pacific in the 1970s was a massive change in the fishery in the Gulf of Alaska – and lots more salmon.

In the Indian Ocean, the Indian Ocean Decadal Oscillation affects rainfall. Warm waters off Kenya bring rains; corresponding cold waters off Australia bring droughts. The system switches every decade or so, bringing cold water and drought to Kenya and warm water and rain to Australia.

An improved observing system will help to make forecasts of these various climatic events more accurate. The observing system comprises measuring devices (satellites, planes, ships, buoys, floats, underwater devices, coastal stations), which send their data through communication networks to data centres. There the data are processed by numerical models to produce useful information (e.g. maps or forecasts), for the benefit of a broad range of customers including those working in forestry, agriculture, energy supply, water supply, fisheries, urban and coastal development, and tourism.

Let's look first at *in situ* measuring systems in the ocean. The El Niño Observing System collects observations of the atmosphere, the sea-surface and the upper ocean to help forecast short-term climate changes associated with El Niño and La Niña. It consists of moored buoys, coastal sea-level stations, surface drifting buoys, and expendable bathythermographs deployed along the routes taken by volunteer observing ships, as well as satellites measuring the temperature and topography of the sea-surface.

The long-term goal is a comprehensive operational system for observing the global oceans. It will have a full suite of tropical moored buoys extending into the Indian and Atlantic Oceans, plus a more dense network of drifting buoys and ships making measurements, plus subsurface Argo floats (of which more later) and a suite of some 30 stations at which continuous measurements will be made over long periods of time to detect global change.

To facilitate the making and processing of these measurements from the ocean, and their conversion into useful products for governments, we need an institutional mechanism. This was created in 2001 and named the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology. This body is generally referred to as JCOMM. It:

- provides intergovernmental coordination, regulation and management of operational marine meteorology and oceanography;
- is the equivalent for the oceans of the existing body for operational meteorology;
- provides integrated operational ocean observing system and data management;
- provides new products and services, and close interaction with the users to ensure that the products are what they want;
- involves all maritime countries; and
- is an implementation mechanism for global GOOS.

An important contribution to JCOMM is the data collected by commercial vessels. 6000 Voluntary Observing Ships (VOS) are observing meteorology and surface oceanography throughout the year. 120 similar ships (Ships of Opportunity or SOOP) are using disposable bathythermographs to measure subsurface temperature and salinity; some are beginning to measure also the partial pressure of CO_2 in the upper ocean.

There are some 1400 surface drifting floats observing meteorology and surface oceanography; some 100s of fixed ocean buoys measuring meteorological and oceanographic properties; and around 300 sea-level stations managed for JCOMM through the GLOSS programme. A substantial number of satellites measure a wide variety of oceanic and marine meteorological properties, and sea ice is monitored both by satellite and 'in the field'. The various buoys and ships of opportunity are monitored from a JCOMM operations centre (JCOMMOPS) in Toulouse. Maps of the distribution of each element of the observing system at any time are available from JCOMMOPS via the internet (http://www.jcommops.org/).

Because the lines along which ships collect subsurface data on temperature and salinity are confined to trade routes, we have very limited ability to observe beneath the ocean's surface. Inevitably, there are large data gaps in the southern parts of the oceans, which must be filled to improve forecasts. To fill these gaps and improve our effectiveness, we are developing a programme for a fully global network of subsurface observations, and an associated global project that will allow us to integrate space-based and ocean data and assimilate them into numerical models to improve our forecasts of weather and climate and ocean conditions.

The Argo project is seeding the ocean with 3000 profiling floats between 2003 and 2005. The floats will drift for ten days at a time at 2000 m depth, then rise to the surface measuring temperature and salinity. Using an antenna on top, they will relay the data back to base via satellite. We already have around 800 Argo floats deployed, and commitments for the full 3000. (See *Ocean Challenge*, Vol. 12, No. 2.)

The Argo data will be fed into the *Global Ocean Data Assimilation Experiment* (GODAE), whose objective is a practical demonstration of real-time, global ocean data assimilation for operational oceanography. GODAE will apply state-of-the-art ocean models and assimilation methods to produce short-range open-ocean forecasts, along with boundary conditions for coastal forecasts and initial conditions for climate forecast models. It will also provide global ocean analyses and re-analyses to improve our understanding of the oceans, of our assessments of the predictability of ocean systems, and of the design and effectiveness of the global ocean observing system.

Outputs from the GODAE models are freely accessible on the internet, for example from the French MERCATOR model (http://www.mercator.com.fr/en/), where forecasts are available, for one week ahead, of sea-surface temperature, sea surface height (which tells us about the currents), and salinity.

We now have a clear view of what the *in situ* observing system should look like over the next 10 years if it is to provide the most useful and accurate forecasts of weather and climate. In 2003 the system is around 45% complete, so we are about half-way there (see diagram below).

The ten-year plan for* in situ *observations *(Courtesy of NOAA)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Tide gauges	40	40	45	45	55	80	86	86	86	86	86	Operational GPS/DORIS stations
Surface drifting bouys	807	671	779	810	1050	1100	1150	1200	1250	1250	1250	Number of buoys
Tropical moored bouys	77	77	79	79	83	87	90	94	99	99	99	Number of moorings
Ships of opportunity	23	24	26	26	29	32	36	41	41	41	41	High resolution and frequently repeated lines occupied
Argo floats	20	31	544	1000	2000	3000	3000	3000	3000	3000	3000	Number of floats
Reference stations	1	2	6	7	10	14	16	29	29	29	29	Number of flux moorings
Coastal moorings	0	0	0	0	15	40	80	120	150	150	150	Moorings with climate sensors
Ocean carbon network	14	16	18	20	24	32	36	38	40	40	40	Number of flux sites/lines One inventory per 10 years
Dedicated ship time	250	250	250	250	430	670	700	760	820	820	820	Days at sea (NOAA contribution)
System evaluation	0	1	1	1	3	4	6	7	9	10	10	Product evaluation and feedback loops implemented
Total system	30	34	40	44	48	77	88	94	99	100	100	System % complete

The other part of the ocean data for GOOS comes from outer space via remote sensing instruments on satellites. These enable us to observe the ocean's surface both globally and synoptically for the first time. By 2010, we should have continuity in being able to use remote sensing from satellites to measure currents, fresh water, ice surface temperature, ocean imagery, littoral sediment transport, net heat flux, net short-wave radiance, ocean colour/chlorophyll, ocean wave characteristics, salinity, sea-ice age and edge motion, sea-surface height/ topography, sea-surface temperature, sea-surface winds, surface wind stress, suspended matter, and turbidity. Of course, these observations all stop more or less at the ocean's surface, reminding us of the need for ocean data from *in situ* programmes to make products useful to decision makers and managers.

In conjunction with *in situ* measurements, altimetry and scatterometry will be used to map surface currents, and altimetric data will also be used for wave forecasting. Scatterometers, like NASA's QuikSCAT, can also be used to measure ocean surface winds. Synthetic Aperture Radar also provides useful information on such phenomena as coastal winds and sea ice, especially useful to fishermen and navigators. Another biological application is mapping of chlorophyll from ocean colour data. Knowing the temperature and salinity as well as the chlorophyll we can pinpoint areas that may be susceptible to the formation of harmful algal blooms.

A useful guide to the ocean observations needed for understanding and forecasting climate change is *Observing the Oceans in the 21st Century* by Chet Koblinsky and Neville Smith (published in 2001and obtainable from the GODAE Office at the Australian Bureau of Meteorology).

The ocean observations carried out for climate purposes through GOOS are designed by the Ocean Observations Panel on Climate (OOPC), and form an integral part of the Global Climate Observing System (GCOS). JCOMM is the implementing mechanism, the actual implementation being carried out by the individual nations participating in the programme. All of these observations are being made as part of an overarching strategy, the Integrated Global Observing Strategy (IGOS), which is basically a partnership between the space agencies, the UN agencies, and international research organizations like the World Climate Research Program (WCRP), the International Geosphere–Biosphere Program (IGBP), and the International Council for Science (ICSU).

In summary: we are establishing a system; it integrates space and ocean observations; it is nearly half-way to completion; it relies on free exchange of key data; and it supports sustainable development. We urge you to contribute and to benefit.

Colin Summerhayes is Director of the GOOS Project Office, Intergovernmental Oceanographic Commission, UNESCO, Paris, France.

NERC funds two new Science Programmes: UK SOLAS and QUEST

UK SOLAS: Surface Ocean–Lower Atmosphere System

In April, NERC Council agreed to fund the 5-year, £11M UK SOLAS thematic programme, as the UK contribution to the International SOLAS programme. NERC's Science & Innovation Strategy Board (SISB) made the award on the understanding that the programme will work closely with the evolving NERC QUEST programme (see below).

The full UK SOLAS proposal can be downloaded from the NERC website: http://www.nerc.ac.uk/funding/thematics/solas but, in summary: 'The UK SOLAS project aims to advance our understanding of the mutual interactions between the atmosphere and the oceans, focussing on chemical exchanges which affect both ocean productivity and atmospheric composition and climate'. UK SOLAS aims to assemble interdisciplinary teams of atmospheric and marine scientists to work together within a single programme to tackle the following priority questions:

- What are the physical processes governing air–sea reactive trace gas and aerosol exchange, in addition to wind speed? What is the production rate for sea spray aerosol and what is the impact of sea spray on processes in the atmospheric boundary layer?
- What biological and photochemical processes are involved in the ocean surface in the production and release of volatile compounds and how are these processes affected by inputs of iron and nitrogen? On release from the ocean, what transformations and transport occur in the atmosphere and how do they affect radiative properties, acidity, oxidizing capacity and stratospheric ozone.
- What are the important physical and chemical processes leading to the formation and evolution of atmospheric aerosols and their impact on cloud formation?
- How can this knowledge be integrated to the global scale that is relevant to climate? How can the improved process understanding be integrated into climate and other models?

NERC are in the process of establishing a UK SOLAS Steering Committee, a Science Co-ordinator and the International Project Office. Funding rounds are expected to take place in the latter part of 2003/early part of 2004.

QUEST – Quantifying the Earth System

To address future priorities, as identified in the document *Science for a Sustainable Future* (http://www.nerc.ac.uk/publications/strategicplan/), NERC has recognized that a co-ordinated 'Earth system' approach is required, and has initiated the Quantifying the Earth System (QUEST) programme. This programme has an initial core budget of £13M over 5 years. Its principal characteristics will include: strongly integrated modelling–observational–experimental approaches; an emphasis on quantification and predictability; strong partnerships with other programmes/organizations (including those involved with policy development) and an interface with the human dimension. Although QUEST is committed to an integrated carbon–climate programme as an initial focus, it will not be restricted to this science area. For more information, please see the NERC website: http://www.nerc.ac.uk/funding/thematics/quest/

A QUEST Town Meeting has been held and NERC's SISB has broadly endorsed its conclusions. NERC is also in the process of making a senior appointment for the strategic leadership of QUEST.

NOW There's a YNNUF ...ƎNIHT

Offshore cities – a vision of the future

It was bound to happen. The pressures of population on both town and countryside have caused developers (in Europe at least) to view colonisation of the seas as an 'obvious' solution to chronic overcrowding and soaring house prices. To coin a phrase, they cannot be serious ...

The vision is of 'affordable floating homes', with concrete (*sic*) tanks attached to the underside of each property, allowing it to be moored in estuaries and docklands ... oh yes, and 'calm offshore locations'. That last bit has to be a joke, because storms can strike anywhere, and when that happens there are no 'calm offshore locations'. One enthusiast for the scheme suggested that 'there is a romanticism attached to the water, and the idea of creating floating communities is very appealing, a natural extension from the popularity of narrowboats'.

Could the *Freedom Ship* project be a better option? Estimated to cost getting on for £10 *billions,* it would be a floating 25-storey city nearly a mile long and capable of accommodating up to 80 000 permanent residents. It's called *Freedom Ship* because it offers 'freedom from living on land'. The imagination boggles at the scale of this notion, but that is all that it's likely to remain, if only because nobody will be able to afford to build it, never mind acquire any of the luxury apartments that require prospective residents to be multi-millionaires, paying big bucks for the privilege of living 'away from *terra firma*'.

Cunard's new cruise liner *Queen Mary 2,* built in France (St Nazaire) for a mere £500-odd millions and launched earlier this year, will eventually accommodate 2600 passengers, who will need to pay a great deal less to 'get away from it all' than anyone buying an apartment on *Freedom Ship* and committing themselves to live permanently at sea. However, the instability in Iraq will not only scare off passengers from the *Queen Mary 2,* it will also discourage potential buyers of accommodation on *Freedom Ship.* As for the idea of offshore 'cities', that's also likely to be stymied by the economic downturn consequent upon the Iraq conflict. Anyway, the concept itself is about as crazy as the futuristic hallucinations of those loonies in the 1960s (and probably in earlier decades too) who envisaged establishing communities of humans on the sea-bed – albeit only on continental shelves, not on abyssal plains!! Whatever the answer to over-population may ultimately be, it doesn't lie in the sea ...

Q: When is an island not an island?

A: When the EU changes the definition

According to new criteria devised by EC statisticians, an island cannot have fewer than 50 permanent residents, cannot be attached to the mainland by a rigid structure (like a bridge), cannot be less than a kilometre from the mainland, and cannot contain the capital of an EU state. How peculiar.

On the one hand, Lundy Island in the Bristol Channel (population 18) can no longer be classified as such, while on the other, the bridges that link Anglesey to mainland Wales, and Skye to mainland Scotland, exclude them from island status too. These interesting 'facts' appeared in newspapers early this year, generating a good deal of journalistic spleen. Few people noticed though, except for a few MPs, one of whom suggested that since the EU tends to give financial priorities to island communities, they might be trying to cut back on possible future expenditure in readiness for the huge enlargement programme due in the next year or so.

At all events, except for the size of its population, Britain no longer qualifies as an island according to the new definition, especially as the Channel Tunnel is definitely a 'rigid structure'. But Britain remains an EU state, and it does have a capital. What have I missed?

Well, what a surprise, fish can feel pain

For years if not centuries, anglers have claimed that a fish struggling against the hook at the end of a fishing line doesn't experience pain. Recently they have cited American research which purports to show that 'fish do not have specific regions of the brain than enable them to feel pain or fear', and that anyone (like me) who supposes otherwise must be indulging in 'anthropomorphic speculation'. Only now, in the early years of the 21st century, do we finally see accounts of research indicating that fish possess nerve receptors near their mouths which 'respond to tissue-damaging stimuli' and which, when injected with pain-inducing substances (like bee venom), cause the fish to behave rather like we so-called higher vertebrates do when stung. And if fish don't feel fear, what makes them try to escape from predators, including anglers? I reckon that anglers' rationalisations are on a par with those of those hunting folk who claim that foxes enjoy being chased by hounds.

Oh dear, what if martian ice is dry ice?

Beagle-2 is now well on its way to Mars. Five years in the making, this brainchild of Colin Pillinger of our own Open University will confirm whether or not Mars has water and will look for signs of life there – albeit primitive bacterial life and quite possibly fossil bacterial life at that.

But the big question is whether Mars really does have water, for if not, then the prospects for past or present life are bleak indeed. Conventional wisdom has it that many landforms on Mars were carved by running water. But there's an alternative view, which arises from the fact that the martian atmosphere is dominated by CO_2 and doesn't contain a whole lot of water vapour. Added to which, the ice caps are both seasonally ephemeral and rather thin.

Both these facts, plus an alternative interpretation of the putatively water-eroded landforms, have led to an 'outrageous' hypothesis that there's lots of CO_2 inside Mars, that it has erupted at the surface from time to time, giving rise to CO_2-fluidised masses of boulders and sand-sized debris, analogous to pyroclastic (hot ash) flows and other dry debris flows on Earth, and that it is these flows that carved out the martian landforms.

This alternative hypothesis first came to my attention towards the end of 2000 (cf. *Ocean Challenge,* Vol.10, No.2), and it reappeared in a *Nature* article in October 2001 (**413**, 664–66), accompanied by several strenuous counter-arguments from the 'martian water' community. I've seen no more articles about CO_2 versus water on the martian surface – which is not to say there haven't been any. All the same, I do wonder just a little. The hype over *Beagle-2* has tended to overshadow NASA's proposal to send a couple of landers to Mars (at a combined cost of several hundred million dollars, as against a few tens of millions for *Beagle-2*); but with all this effort to find both water and signs of life on Mars, could it have been deemed politically expedient not to provide the outrageous CO_2-hypothesis with the oxygen of publicity? Absence of water on Mars would be jolly inconvenient for the authors – not to mention the publishers – of a new book (from the Geological Society) entitled *Volcano–Ice Interaction on Earth and Mars*.

John Wright

HIMOM Hierarchical Monitoring Methods for Tidal Flats

There is a seemingly endless list of acronyms for European-funded projects, and one of the most recent is HIMOM (Contract No: EVK3-CT-2001-00052). HIMOM stands for HIerarchical MOnitoring Methods and aims to develop a toolbox of techniques to monitor changes in estuarine mudflat ecosystems.

The estuaries and coastal seas around Europe are of great commercial and ecological value, and have been exploited for centuries for transport, waste disposal, power generation, leisure amenities and fisheries, as well as being one of the most productive natural ecosystems on Earth. The major producers in estuaries are the micro- and macroalgae which form the basis of food webs that support vast numbers of invertebrates as well as fish and wading birds. 50% of the world's population now live within 60 km of the coast, and to assess the potential impact of such demographic pressure it is essential to first understand the dynamics and functioning of the ecosystem before assessing the impact of any change.

HIMOM will create a Europe-wide assessment of the biological and physical dynamics within a range of estuaries by means of remote sensing as well as 'ground truthing'. The project provides a platform from which to test and develop methodologies, and the work will culminate in the production of a 'toolbox' of monitoring methods as well as the introduction of new instruments and techniques.

The concept behind the HIMOM methodology is that it will form a hierarchy of techniques, and end-users can enter HIMOM at any one of five levels (see below) based upon both experience and finance. Furthermore the socio-economic implications of changing management practices will be assessed so that cost benefit analyses can be conducted. At the end of the project, the findings (well as the HIMOM toolbox itself) will be presented to a a group of potential end-users, including environmental protection agencies, shellfish farmers, tourists, drilling companies and those involved in the fishing industry, as well as educational institutes.

The following institutions are working on the HIMOM project: Brockman Consultancy (Germany), University of St Andrews (UK), GKSS Forschungszentrum Institute of Hydrophysics (Germany), Netherlands Institute of Ecology (Netherlands), Environmental Research Institute, University College Cork (Ireland), University of Groningen (Netherlands), Instituto de Oceanografia, Universidade de Lisboa (Portugal) and the National Institute for Coastal and Marine Management RIKZ (Netherlands).

Level Five
Remote sensing supported by ground-based radiometric measurements and basic optical measurements
+ Secondary ground suite

Level Four
Ground-based radiometric measurements and basic optical measurements
+ Secondary ground suite

Level Three
Basic optical measurements (e.g. PAM Fluorescence)
+ Secondary ground suite

Level Two
Secondary ground measurements
Extended protocal suite
Pigments/bioassay/ID/system diversity

Level One
Entry level: Primary ground measurement following basic protocol suite and requiring limited laboratory insfrastructure
Basic pigments/bioassay/simple ID

The HIMOM Hierarchy

Further information and publicity materials are available from: M. Consalvey (mc6@st-andrews.ac.uk) or from http://www.brockmann-consult.de/himom

CO_2 sequestration experiment revisited

The EFMS Issue* of *Ocean Challenge* contains an account of a carefully planned experiment to release some 5 tonnes of CO_2 at various depths in the water column off Norway. The following issue reported that environmental groups had managed to block the experiment, on the grounds that if it were successful it would facilitate the continued use of fossil fuels. It is likely that Greenpeace was the main instigator of this action, and the principal reason for their objections was that putting CO_2 into the sea could adversely affect marine ecosystem and food-web relationships. As one commentator put it, Greenpeace could have *'shot themselves in the foot'*, because of course the experimental results might have confirmed their fears, thereby demonstrating that marine sequestration is *not* a good way of lowering CO_2 additions to the atmosphere.

However, legal aspects of marine CO_2 sequestration must also be considered, and for European waters the relevant legal code is set out in the *1992 OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic*. The 'OSPAR' part of the name reflects the fact that this convention arose out of the *Oslo Convention* relating to dumping from ships and aircraft, and the *Paris Convention* relating to marine pollution from land-based sources, both of which came into force in the 1970s. The 'Contracting Parties' to the OSPAR Commission (OSPARCOM) are 15 European states and the European Commission itself.

Last year, prompted by the planned Norwegian CO_2-sequestration experiment, the OSPAR Commission asked a body of experts known as the Group of Jurists and Linguists to explore the issue of marine 'placement of CO_2' in the context of OSPAR legislation. The Group made a preliminary report in June this year.

The *OSPAR Convention* has five Annexes, of which the first three refer explicitly to 'the prevention and elimination of pollution', from land-based sources (Annex I), by dumping or incineration (Annex II), and from offshore sources (Annex III). As a starting point, therefore, it is pertinent to ask: 'Does CO_2 cause pollution?' The obvious answer to this might appear to be 'yes', particularly given OSPARCOM's wide definition of pollution.† But what of the fact that CO_2 comprises 0.3% of the atmosphere, that the oceans already contain something like 40 000 tonnes of the stuff (which is emitted to the atmosphere in regions of upwelling and/or warming of the surface ocean), that volcanoes emit CO_2 continuously, and there is continual leakage from underwater volcanoes? The best example of this last is the Loihi Seamount near Hawaii, which annually delivers around 100 000 tonnes to the surrounding sea.

The Group of Jurists and Linguists concluded that under Annex I of the Convention, it would be possible for CO_2 to be piped directly from a point source on land to the oceans, providing that the activity is strictly subject to authorisation/regulation by the competent authority (this would include implementation of OSPARCOM rulings).

The Norwegian plan involved the release into the sea of CO_2 from a container suspended from a ship. This experiment therefore falls under the terms of Annex II. However, 'dumping' is defined as 'deliberate disposal of wastes or other matter from vessels or offshore installations' and as the experiment would have involved 'placement of matter for a purpose *other than mere disposal*', it would not have been considered to be dumping.

On the other hand, if the experiment had proved that ocean sequestration was a viable option, under the terms of Annex II it could not be implemented in the same fashion as in the experiment, i.e. the CO_2 could not be tranported in a vessel, because dumping of waste from a vessel is prohibited. Similarly, Annex III prohibits dumping from offshore installations (e.g. converted oil rigs). Currently, disposal at sea of water and CO_2 that occur in all oil and gas fields is subject to strict authorisation and regulation.

This preliminary assessment of the applicability of OSPAR legislation to marine sequestration of CO_2 suggests that proposals to collect and pump the CO_2 from Europe's power stations into the sea are possible under the *OSPAR Convention*. It also suggests that experiments like the Norwegian proposal are legal. Problems might arise if large-scale sequestration in ocean waters or under the sea-bed were undertaken from vessels or offshore installations.

The Group of Jurists and Linguists were of necessity only concerned with interpretation of the *OSPAR Convention*, and could not make any recommendations on any other aspect (ethical, practical, scientific) of 'CO_2 placement' in the oceans. The Group were at pains to make it clear that they were not making any judgements about whether the activities under discussion were compatible with other pollution-related obligations of the Contracting Parties. Furthermore, they had only been asked to consider the implications of Annexes I to III, as the wide definition of 'pollution' made it likely that these could be applicable. Nevertheless, Annex V, concerned with protection and conservation of ecosystems and biological diversity, could also be argued to be relevant.

The report of the Group of Jurists and Linguists ended by stating that there needed to be more 'consideration' both of the legal position and 'the possible physical impacts of the placement of CO_2 in the marine environment'. In fact, quite a bit of work is being done on the latter, but it is not well known.

In Norway, the cancellation of the sequestration experiment was covered by radio and TV reports, and the scientific and political communities were well aware of it, but no serious political debate ensued. In Britain, the topic of underground or under-sea disposal of anthropogenic CO_2 seems to have received little or no publicity in the media. There has been a lot of research into marine sequestration of CO_2 (e.g. *Science*, **234** (1999), pp.943–5) but where are the newspaper and magazine articles and editorials, the radio and TV documentaries? Could it be that scientists have not done enough to raise awareness of the issues, and make the science comprehensible and meaningful to public and politicians alike?

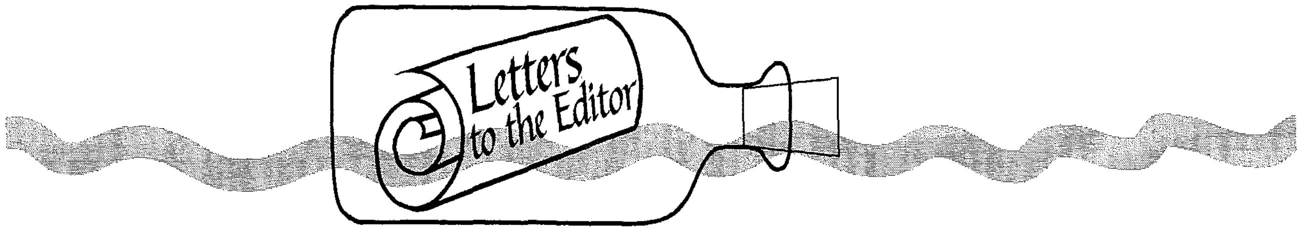
Eds

*The *Ocean Challenge* articles referred to here are: 'Ocean sequestration of CO_2' by Helge Drange *et al.*, Vol. 12, No.1, pp.33–39; and 'CO_2 sequestration experiment blocked' by Lars Golmen, Vol. 12, No.2, pp.5–6.

†The introduction by man, directly or indirectly, of substances or energy into the maritime area which results, or is likely to result, in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea.

The OSPAR website is: http://www.ospar.org/

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



Stakeholders submerged?

Marine scientists should find the article 'CO_2 sequestration experiment blocked' by Lars Golmen (*Ocean Challenge,* Vol. 12, No. 2, p.5) extremely alarming. Two NGOs (non-governmental organizations) had apparently protested against the planned and licensed experimental release into Norwegian waters of just 5 tonnes of pure CO_2, claiming that if it went ahead it might 'pave the way for future implementation of CO_2 ocean sequestration on a large scale, which may facilitate the continued use of fossil fuels.' Sadly, the Norwegian Ministry of Environment gave in to the pressure and stopped the experiment.

Eight years ago, Greenpeace stopped Shell from sinking the *Brent Spar* in the deep Atlantic since when (as predicted) no-one has dared mention the words 'disposal' and 'deep-sea' in the same sentence. As a result of this latest development, are we to understand that no-one will be able to carry out an experiment in the ocean without the express permission of the NGOs, whose members generally know little or nothing about the environments they are so concerned to protect? Along with their pride in having saved the oceans from the pin-prick effects of a 5-tonne CO_2 injection, are these NGO members equally proud of having stimulated a decision possibly prejudicial to the interests of human society as a whole? For it is not too far-fetched to suggest that the cancellation of this experiment may have catastrophic consequences far beyond those of wasting valuable research funds and the time and efforts of the international group of scientists who had planned it carefully and responsibly.

We humans, including politicians, scientists and NGOs, have manoeuvred ourselves into a terribly difficult situation. Our increasing world population (about which none of the NGOs are protesting), and our similarly increasing demand for energy, mean that despite all attempts to minimise the environmental effects, the terrestrial environment and the overlying atmosphere are already severely affected by man's activities and will come under increasing pressure in the future. The other 70% of the planet's surface, the oceans, are less polluted, but are by no means pristine. The very survival of our species in the long term may depend ultimately on whether we learn to use and manage the seas rather better than we have treated the land. But we must not pretend that they are somehow disconnected from the rest of our world and therefore should be totally protected (even if this were possible), for there can be no rational or even ethical argument to do so.

Amongst our existing and continuing problems is that of preventing the build-up of CO_2 in the atmosphere. Hundreds of dedicated and inventive scientists around the world are actively investigating a whole plethora of possible solutions, including sequestration (see *Greenhouse Issues,* in the Further Reading). One of the many possibilities is long-term storage in the deep ocean. The marine scientific community in university, government and, yes, commercial laboratories, collectively knows a great deal more about the seas than all the NGOs put together. But it is humble enough to acknowledge that it cannot with confidence predict the effects of a number of potential anthropogenic impacts on the marine environment, including the sequestration of CO_2, by extrapolation from the results of small-scale tests typical of conventional research. Instead, moderate to large-scale tests would be essential and, in some cases, even these could have effects that would make them unacceptable by any standards (see Thiel *et al.* in the Further Reading). But this is not the case for CO_2 sequestration, and the proposed experiment could have provided answers to important scientific questions with absolutely no risk of any significant long-term damage to the seas. And now it is cancelled, with the loss to society not only of money, but also of a much more valuable commodity, knowledge!

As individual members of the public we are all, to use a modern jargon term, 'stakeholders' in the natural environment. But depending upon our affiliations and our expertise, we have specific duties and responsibilities. Environmental NGOs have an important role to play in drawing the attention of the public, politicians and industry to threats to the natural world. Governments have a duty to take these views, and others, into account, to formulate policies based on the best available information, including the ethical and economic arguments, and to put them before the public. Scientists have a responsibility to provide the most accurate answers to difficult questions in their particular fields of expertise, sometimes undertaking environmental experiments to do so. Whether these involve genetically manipulated crops, disease control or CO_2 experiments in the sea, scientists must be prepared to defend their proposals against informed opposition, and expect sometimes to lose the argument. But they should also protest loudly and publicly against ill-informed decisions like the cancellation of this experiment.

For just as scientists *per se* are not qualified to adjudicate between the ethical or economic arguments, NGOs have no right to dictate what science should, or should not, be undertaken. Furthermore, governments who allow them to do so are abdicating their responsibilities in favour of those who can simply shout loudest. The scientific community should point this out to them. Indeed, although few of us could match Galileo's scientific acumen, we can all adhere to his principles of seeking after the truth in the face of ignorant, albeit powerful, opposition.

Tony Rice and Hjalmar Thiel
(ex-SOC and ex-Hamburg)

Further Reading

Greenhouse Issues is the newsletter of the IEA Greenhouse Gas R&D Programme and can be obtained, free of charge, by emailing louise@ieagreen.demon.co.uk

Thiel, H. *et al.* (1998) *Environmental risk from large-scale ecological research in the deep sea: a desk study.* Marine Science and Technology Contract No. MAS2-CT94-0086 (ISBN 92-828-3517-0) European Commission, Brussels, 210pp.

The maiden voyage of UK ROV *Isis*

Chris German, Paul Tyler and Gwyn Griffiths

In December 1997, one of us (Chris G.) attended an annual meeting of the Deep Submergence Science community in San Francisco, where the first item of business was a letter from Tony Blair, then recently elected Prime Minister, to President Bill Clinton. The letter praised the team running the US ROV (remotely operated vehicle) *Jason* for their help in conducting UK government investigations into the wreck of the *Derbyshire*, lying on the floor of the north-west Pacific Ocean. Chris returned to the UK convinced that if there was ever going to be a good time to propose acquisition of a deep-diving ROV for the UK marine science community, that time had now arrived. He set to work early the next year joining the project jointly led by Paul T. and Gwyn G. (both also at SOC) which was ultimately successful through the JIF (Joint Infractruture Fund) scheme (see *Ocean Challenge*, Vol.11, No.3, p.11).

Some five years later, and after learning far more than we ever thought we would need to know about the subtleties of fibre-optic cables or the relative merits of different launch and recovery systems (Paul and Chris were very pleased to have Gwyn around to 'translate' many of the engineering issues) – our new 6500 m-rated ROV *Isis* finally set sail on its maiden voyage.

Isis is a close copy of *Jason II* launched last year, and was also built at the Woods Hole Oceanographic Institution in the USA. To give our vehicle a thorough testing on this first engineering and delivery trials cruise, we took along not only our own five-person UK ROV team* but also a selection of key individuals from the USA, led by Andy Bowen, the WHOI ROV team leader. Further, so that we were working from a ship where the personnel were already familiar with the ROV tasks we planned to undertake, we operated from the WHOI ship RV *Atlantis* under the command of Captain Gary Chiljean.

The area we had chosen to visit, on the basis of Paul Tyler's local knowledge, was an area termed the 'Tongue of the Ocean' near the Bahamas (Figures 1 and 3). You might wonder why we chose this area rather than any other for such a trials cruise. First, we wanted to test the ROV at close to full ocean depth but at minimum cost to the taxpayer (i.e. using as little ship-time as possible). Second, the trials needed to take place as soon as possible after delivery of the finished vehicle (spring 2003) so that *Isis* could then be shipped to its new home in the UK. Unlike the north-west Atlantic off New England at that time of year, the Bahamas area offered good operating weather, close to the USA, but also in deep water *and* sheltered by islands from all directions.

An elegant solution, therefore, was to transfer all the *Isis* ROV components from the late-February snow-bound dockside at WHOI to Jacksonville, Florida, where the RV *Atlantis* was just finishing a period of re-fit. After a few days of activity we were ready to sail. The full *Isis* system, including shipboard control and workshop vans, winch and launch systems, takes up the equivalent of nine 20-ft containers. The full suite of the *Isis* system is much greater than the *Atlantis* requires to operate her sister (or rather brother) ROV, *Jason II*, but the beauty of the *Isis* system is that, in future, it can be mobilised to be used from any sufficiently large ship of opportunity, anywhere in the world.

Eventually, on Thursday 6 March, all was set and RV *Atlantis*, sailed with the noon high-tide (Figure 2). Next morning, approximately mid-way to the Bahamas, we hove to, and at about 10 a.m. local time commenced a test-dip to approximately 100 m depth, just to check all systems were functioning properly (Dive 001 on Figure 1). After about an hour, with everything working well, we could resist temptation no longer and decided to continue all the way to the bottom. 30 minutes later, *Isis* made her first 'land-fall' at the bottom of the Atlantic in a respectable water depth of 814 m. After a busy 45 minutes trialling thrusters, cameras and manipulators over a smooth, sandy sea bed, it was time to return to the surface, and by 1 p.m. everything was back on board. It was time to head full-speed to the Bahamas – *Isis* Dive 001 had been successfully completed!

Early on 7 March we were approaching the Tongue of the Ocean, but before conducting any further *Isis* dives it was important to generate a detailed bathymetric map so that we would know where we were going. This was done using the shipboard swath bathymetry system and by 2 p.m. we were ready to get *Isis* back in the water. Figure 4 shows *Isis* being launched on Dive 002 off the Bahamas. Over the next three days,

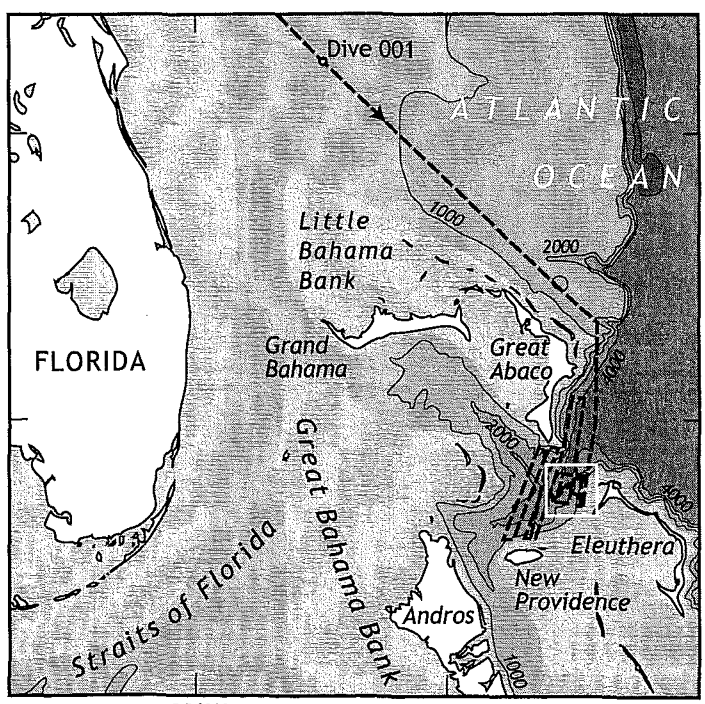


Figure 1 *The position of Isis dive areas. The dashed line is the* Atlantis *cruise track, and the white box indicates the location of Dives 002 to 004 off the Bahamas (see Figure 3).*

*The *Isis* ROV team at SOC is: Pete Mason (Project Manager), Dave Edge (Deputy Project Manager), Dave Turner, Mike Bisset and Andy Cartney.

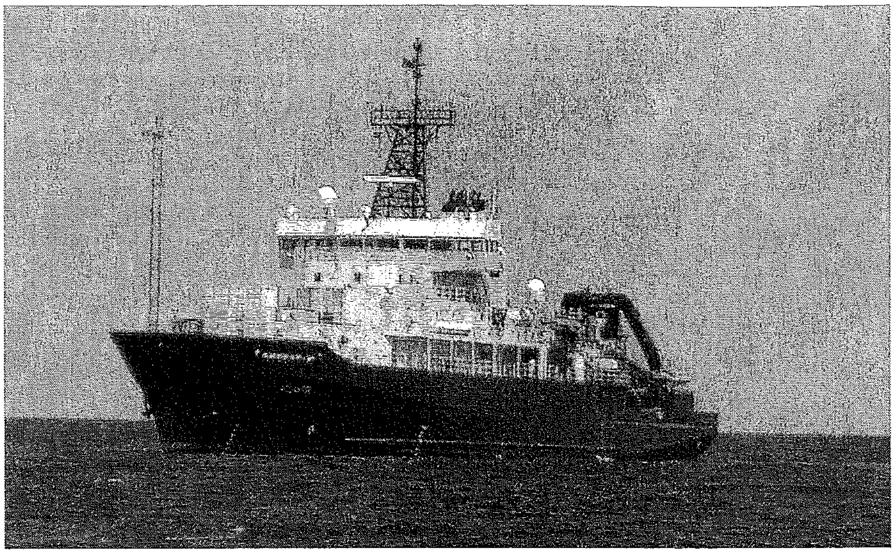


Figure 2 *The RV* Atlantis *at sea off the Bahamas in March, 2003. The darker areas at the stern are all part of the* Isis *ROV system.*

Isis was deployed to maximum depths of 1930 m, 4330 m and 1037 m respectively (Figure 3), for dives of duration 9.5 hours, 10 hours and 7 hours. Regrettably, during the last of these dives (Dive 004) a problem developed with the ship's bow thrusters compromising its ability to hold station and thus precluding any further ROV dive operations. After frantic negotiations between those of us on the ship and key parties ashore – NSF and WHOI in the USA, NERC and SOC in the UK – agreement was quickly reached to bring the cruise to an abrupt end and, on 12 March, Chris German and Paul Tyler disembarked at Nassau, along with the remainder of the scientific party that we had taken to sea with us – quite content with what we had been achieved for starters!

For Pete Mason and the rest of the ROV team, however, the time for relaxation had *not* yet arrived. They were to remain aboard the *Atlantis* for its transit to Grand Bahama where, following essential ship repairs, they were joined by Gwyn Griffiths on an expedition to put *Isis* to immediate good use – helping WHOI colleague Mike McCartney recover six deep-sea moorings, crucial to his two-year physical oceanography investigation. The acoustic releases built into their design had failed, so these moorings were 'stuck' at the bottom of the Atlantic, at depths of 4900–5500 m. The *Isis* team's mission therefore, was to effect their release by attaching specially designed cutters to each of the remaining moorings, and so recover both the equipment and the stored data. That mission worked very much as planned, and all six sets of moorings were recovered safely.

In early May, *Isis* arrived back in the UK where she is now installed in the new Deep Submergence Vehicles hangar alongside her autonomous counterpart, *Autosub*. *Isis* will be ready to start full scientific operations in spring 2004, immediately following completion of the three-year commissioning grant award from JIF (2001–2004). As for any other ship-time application, the next deadline for a bid for a NERC grant to use the ROV is 1 December 2003. We look forward to seeing *Isis* back at the bottom of the ocean, where she ultimately belongs, at the earliest opportunity!

Enquiries concerning the use of the ROV should be directed to Pete Mason, Email: pjm@soc.soton.ac.uk

cont. overleaf

Figure 3 The location of Dives 002 to 004 *in the 'Tongue of the Ocean' off the Bahamas (cf. Figure 1).*

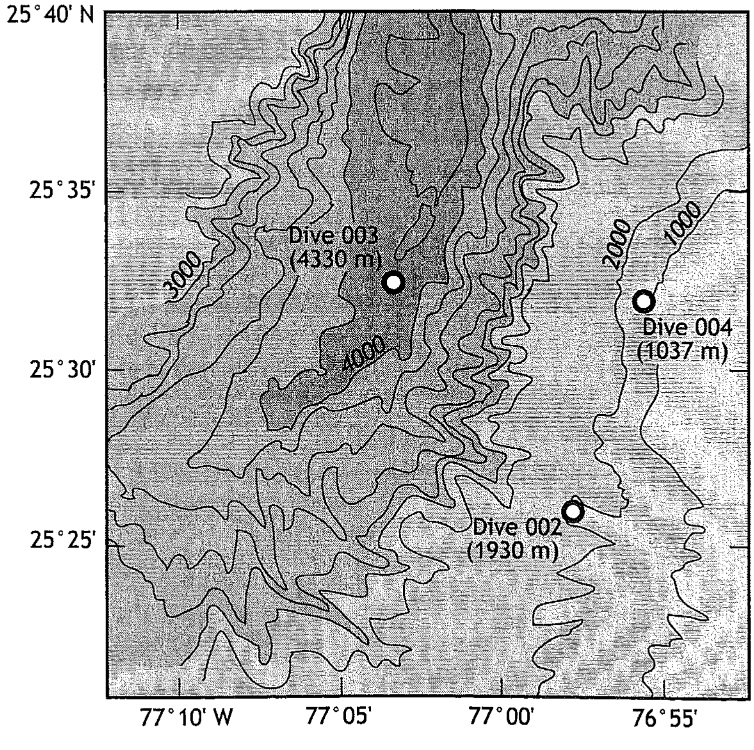
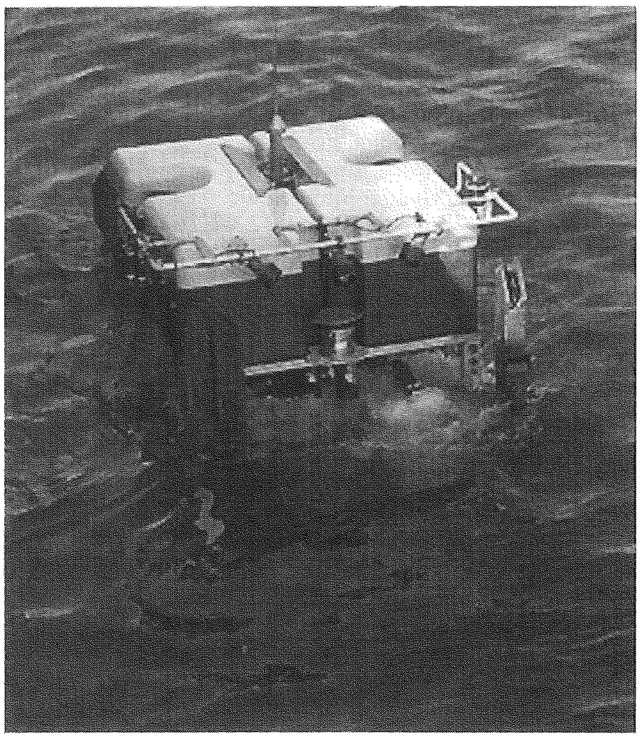


Figure 4 *The UK ROV* Isis *entering the surface ocean off the Bahamas at the start of Dive 002, 8 March 2003. Three dives were conducted in this area before ship problems brought a premature end to the cruise.*



Specification of the Isis ROV

Following the spirit of the JIF scheme, the general specification of the *Isis* ROV was based on that of an existing design – the *Jason II*. All of the items listed in Box 1, except the tether management system (TMS), derive directly from *Jason II*. The decision to use a TMS rather than the more straightforward streamlined weight used on *Jason* was intended to provide additional flexibility in operating the ROV close to the sea bed, and to simplify launch and recovery operations: with the ROV latched into the TMS, only one package needs to be handled at these critical times. In the offshore industry, using a TMS in workclass ROVs is now common practice, but it is still relatively new to deep submergence science vehicles. This is partly because of the additional dynamic load problems caused by using a TMS.

The ROV is well provided with equipment for control, observation, manipulation and sampling. The key systems are listed in Box 2. Full use is made of the 2 Gbits s^{-1} bandwidth of the optical fibre cable for the transmission of video and still images, sonar data and control telemetry. The camera suite includes high resolution video and still formats which provide the definition needed for quantitative scientific analysis as well as the quality material needed by broadcasters. A notable inclusion is the Pixelfly monochrome camera. Its imaging sensor provides an 11-bit dynamic range needed to observe detail within shadows. A separate fibre is available for use with a High Definition TV camera. Although such a camera will not be fitted as standard, the vehicle systems are designed with HDTV in mind.

The choice of manipulators was difficult. While some vehicles carry an agile (though complex) 7-function arm and a more robust, simpler 5-function arm, we chose to equip the vehicle with two identical 7-function spatially coherent master–slave manipulators, in which the actual manipulator arms are linked to miniature versions which are operated by someone at the surface. This provides the dexterity needed for sampling operations in complex environments such as hydrothermal vent fields.

Beneath the ROV itself, a tool sled can be fitted. The basic tool sled that comes with the vehicle comprises a front motorised tray for storing tools and for transporting samples. This tray is supplemented by smaller motorised trays on the port and starboard sides.

Box 1: General specification of the *Isis* ROV

Parameter	*Specification*
Length	*2.7 m*
Width	*1.5 m*
Height	*2.0 m*
Overall weight	ROV: 3000 kg in air TMS: 1000 kg in air
Science payload	On ROV: ~ 70 kg in front tray 22 kg in each of two motorised side-trays On TMS: Two cameras, lights and altimeter
Maximum working depth	6500 m (with safety factor of 1.5)
Vertical, lateral and forward thrust	Not less than 2000 N bollard pull, provided by six 3.7 kW thrusters
Speed, forward and lateral, at 6500 m	Not less than 0.75 m s^{-1}
Power	5 kW

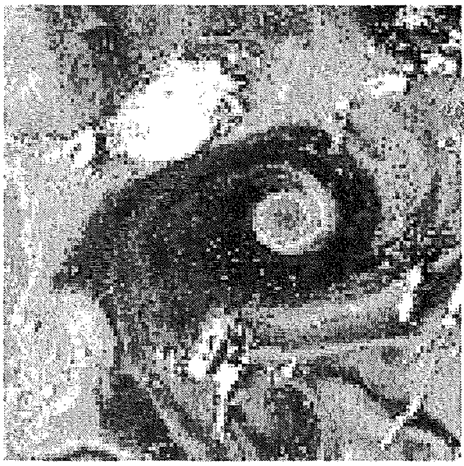
Box 2: Installed systems on *Isis*

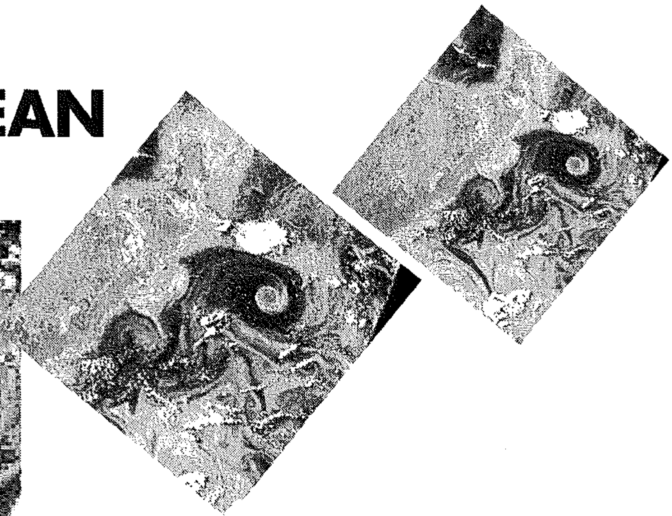
Cameras	High resolution colour (3-chip broadcast quality, 800 lines) Digital still (3.34 Megapixel) Low light (Monochrome ICCD) Wide dynamic range (Monochrome Pixelfly, 11-bit dynamic range, 1 Megapixel) General (miniature colour and b/w cameras for science and navigation) Pan and tilt unit (pan of ± 165°; tilt of ± 75°)
Lights	HMI (three circuits, 1200 W total) Incandescent (five at 250 W each) Strobe (dual 600 J units) Scale (two-beam red laser)
Manipulators	Two Kraft TeleRobotics 7-function, spatially coherent units
Attitude and heading	Octans fibre-optic gyrocompass and Crossbow three-component magnetometer
Pressure	Paroscientific Digiquartz gauge
Sonars	Doppler Velocity Log (RD Instruments 1200 kHz navigator; > 30 m range; error < 0.22% distance travelled) Forward-look sonar (Kongsberg Simrad SM2000 series; 200 kHz, 400 m range) Profiling sonar (Kongsberg Simrad MS900 series; 675 kHz, 100 m range)

With no active buoyancy control, the ROV needs to be deployed with disposable ballast if the task includes retrieving samples from the sea bed. More complex tool sleds will be constructed in the future for other tasks. There are also opportunities to develop new tools, and to source tools already developed elsewhere, e.g. samplers that can keep the contents at the pressure at which they were collected during ascent.

At the very outset *Isis* was envisaged as a fully transportable, self-contained system, complete with its own cable, winch and launch and recovery system. As delivered, the storage drum holds 10 000 m of 0.68-inch diameter cable, with three power conductors and three optical fibres. A traction winch provides the motive power and an integral 'A' frame provides the means to deploy the vehicle over the side (or stern) of the ship. The penalty for this versatility is that the system is extremely bulky and weighs about 90 tonnes.

A PLANKTON GUIDE TO OCEAN PHYSICS





Colouring in the currents round South Africa and Madagascar

Graham D. Quartly and Meric A. Srokosz

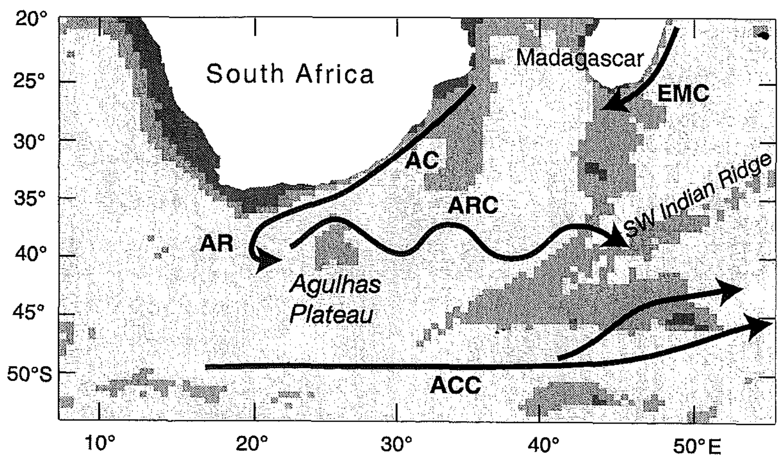
The ocean colour sensor SeaWiFS,* launched in August 1997, has been a great boon to those researching large-scale oceanic biological productivity. The sensor can detect variations in the colour of the water due to the presence of chlorophyll in phytoplankton, which essentially changes the water colour from blue to green. SeaWiFS has provided measurements of chlorophyll concentration over nearly all the world's oceans, and because of their association with fronts, eddies and regions of upwelling, these records of phytoplankton abundance reveal much about physical processes occurring within the ocean.

The long data record from SeaWiFS has engendered a number of studies of physical ocean processes. Here, we will describe a number of examples taken from the Agulhas Current system around South Africa (Figure 1). Typically, the waters in this region show an annual cycle in the quantity of phytoplankton, with highest values around July and August (Figure 2, overleaf). This so-called 'spring bloom' is triggered by the increase in light levels and the enhanced stratification due to surface warming and the abeyance of storms. A secondary bloom occurs in the Madagascar Basin to the east of Madagascar. This is due to the seasonal deepening of the mixed layer coupled with strong eddy activity mixing up nutrients into the surface layer. Here, we are not concerned with the absolute values of chlorophyll concentration, but in the ability of chlorophyll to act as a tracer of water motion.

Clearly, we are dealing with a non-conservative quantity: growth, mortality, and grazing by zooplankton all affect the abundance of phytoplankton present. Additionally, any processes that raise or lower the depth of the biota will affect the value in the surface layer that the satellite 'sees'. The sensor can only detect phytoplankton near the sea-surface. However, it is often valid to assume that the near-surface chlorophyll concentration is homogeneous within a given water body (for example, a current or an eddy), and so changes in chlorophyll concentration can be used to delineate the boundaries of features and enable their temporal evolution to be studied.

Figure 1 *The main oceanographic features in the Agulhas Current system. Light shading indicates waters deeper than 3000 m; dark shading indicates those shallower than 1000 m. The poleward-flowing Agulhas Current (AC) 'retroflects' (turns back) to the south of South Africa forming the Agulhas Retroflection (AR), and the resulting eastward-flowing Agulhas Return Current (ARC) has north–south meanders, partially forced by topography, such as the Agulhas Plateau at 26°E. The Antarctic Circumpolar Current (ACC) is much further south in this region. The East Madagascar Current (EMC) flows poleward along the coast of Madagascar and then, guided by the bathymetry, flows round the southern tip of that island.*

Bottom topography plays an important role in guiding ocean currents around South Africa and Madagascar



*SeaWIFS = Sea-viewing Wide Field of View Sensor.

In July and August, high plankton productivity occurs throughout the mid-latitudes, especially where fed by upwelling

Observing upwelling

Most of the waters in the Indian Ocean are oligotrophic, that is, low in nutrients, and so phytoplankton growth is limited by nutrient supply. The major exceptions to this are in regions where subsurface nutrient-rich waters are being upwelled into the euphotic zone. The most pronounced examples in our area of interest are the Benguela Upwelling, the Delagoa Bight, and regions to the south-east and south of Madagascar, which all stand out as areas of high biological productivity (Figure 2). These features continue to be noticeable in the ocean colour images even when the annual cycle of phytoplankton concentration is at its maximum.

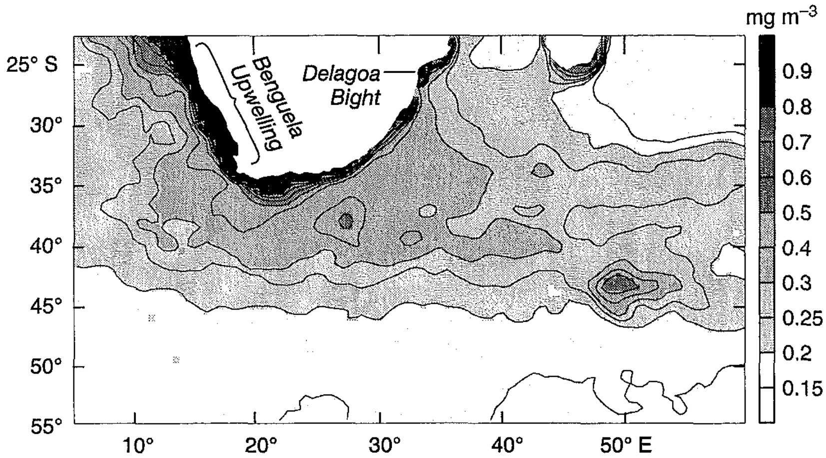
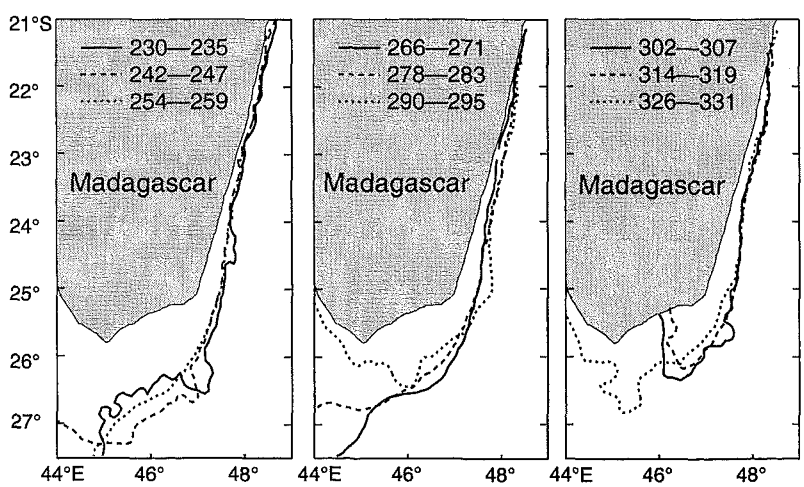


Figure 2 *Mean chlorophyll concentration for August (averaged over 1998 to 2001), showing high productivity in the Benguela Upwelling region and the Agulhas Current system, with much lower chlorophyll concentrations* [than] *in the regions to the south or in the central Indian Ocean (top right). As well as high productivity to the south of Madagascar, there is increased chlorophyll concentration year-round to the north of Crozet Plateau, near 50°E, 44°S.*

Ocean colour images show that the extent of upwelling to the south of Madagascar is very variable, whereas that to the east of the island is more constant

Figure 3 *Boundary of the upwelling region in late 1998 for a series of six-day composites. Numbers correspond to Julian Day (230 = 18 Aug. etc.) and the contour represents 0.2 mg m^{-3}. North of 25.5°S the boundary between upwelled waters and the East Madagascar Current (EMC on Figure 1) remains fixed, but south of that latitude, the boundary changes much more rapidly (especially between days 266 and 290) in response to shifts in the path of the EMC.*



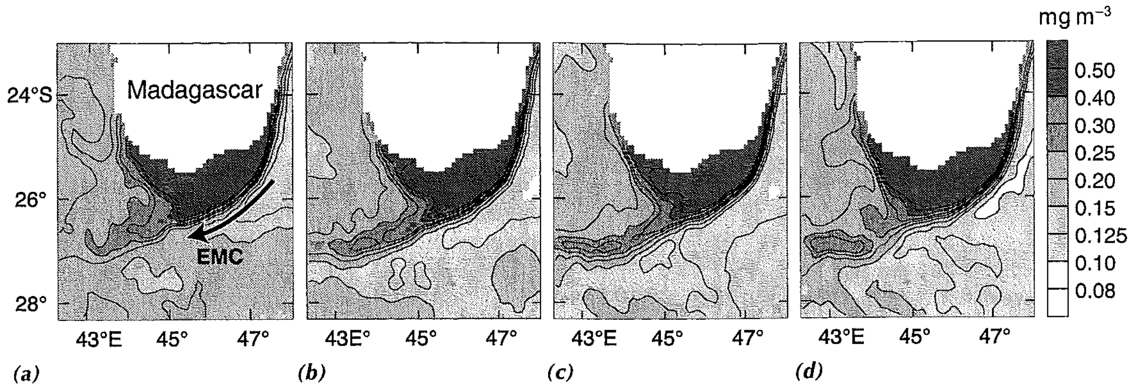
The dynamics of the various upwelling regions are very different. Persistent upwelling had already been noted in the Delagoa Bight, despite the frequent easterly onshore winds; this implied that it was the alongshore current rather than the winds that was the motive force for the upwelling. The predominant winds over Madagascar are also from the east, and upwelling along the east coast of Madagascar can be explained in terms of the poleward flow of the East Madagascar Current (EMC) together with the broadening of the shelf to the south of Madagascar.

As the waters of the East Madagascar Current are low in nutrients and thus in chlorophyll, we may characterise the edge of this upwelling region by the contour corresponding to a chlorophyll concentration of 0.2 mg m^{-3}. Little short-term variability (days to weeks) is observed in the boundary of the upwelling to the east of Madagascar (Figure 3), except during January–February (not shown). Neither is there much long-term variability, nor any clear seasonal signal. As the upwelling is predominantly current-induced, this in turn suggests that there is little seasonality or shorter term variability in the flow of the EMC, in agreement with the limited *in situ* observations which have been made of the current.

South of Madagascar the behaviour of the current is very different: here, the EMC is much less constrained and often lies much further offshore, and the winds, varying from south-easterly to north-easterly, make a variable contribution to the upwelling. The productive upwelled shelf waters may at times be entrained and advected westwards by the EMC, which is itself low in chlorophyll (Figure 4). The picture is further complicated by the presence of eddies in this area (see below).

Imaging fronts

Fronts may also be marked by locally high levels of phytoplankton, when the mixing between two adjacent water masses provides the optimal ingredients for growth (nutrients, light, warmth, remnant plankton, and enhanced mixing and upwelling) that neither water mass contains alone. A particular example is the region just to the south of the Agulhas Return Current (Figure 5), where there are three major fronts – the so-called Agulhas Return Front, the Subtropical Front and the SubAntarctic Front – in close proximity. The latter front is associated with the eastward-flowing Antarctic Circumpolar Current, which lies to the south of the Agulhas Return Current (Figure 1). In this frontal zone the phytoplankton distribution is extremely inhomogeneous, with many small patches of enhanced productivity, some transitory, others longer lasting. The surface waters to the south are all richer in nutrients than the more northern waters, but the increased primary productivity lies mainly along the Subtropical Front. This is because the interaction of colder nutrient-rich waters with warmer, more stratified ones provides the right conditions (enhanced



The East Madagascar Current draws out 'blobs' of more productive water

Figure 4 *Successive six-day composites from late 2000 for the region to the south of Madagascar, showing rapid evolution in patterns of chlorophyll concentration. The EMC, distinguished by water with low chlorophyll concentrations (and marked by an arrow in (a)), draws the productive upwelled waters south-westwards away from Madagscar. In successive pictures, this strand is seen to separate forming a 'blob' of high chlorophyll concentration water.*

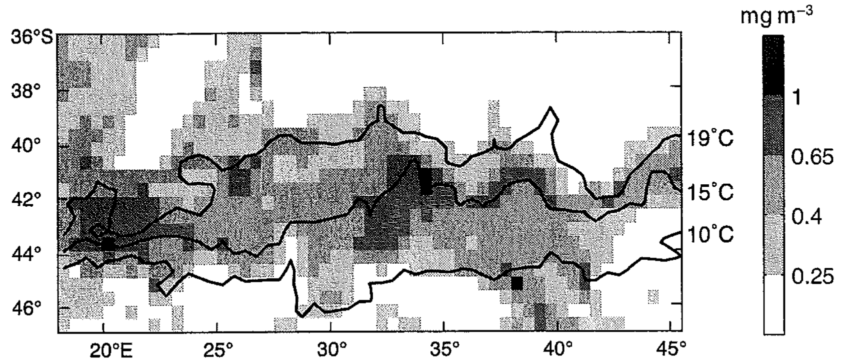


Figure 5 *Chlorophyll concentrations for February 1999. The isotherms are from ATSR (Along-Track Scanning Radiometer, a space-borne infrared sensor for sea-surface temperature). At this time of year, the 19°C, 15°C and 10°C isotherms typically correspond to the positions of the Agulhas Return Front (marking the position of the Agulhas Return Current), Subtropical Front and the SubAntarctic Front. The highest chlorophyll concentrations lie along the Subtropical Front, especially where the strength of the front (inferred from the SST gradient) is greatest.*

The Subtropical Front (between the Agulhas Return Front and the SubAntarctic Front) is highlighted in SeaWIFs images by its high primary productivity

nutrient and light levels) for phytoplankton growth. This region of enhanced growth is bounded to the north by the Agulhas Return Front, which enables the front to be detected in ocean colour imagery. Monitoring changes in this front using SeaWiFS gives results that agree very well with satellite observations of changes in sea surface temperature (SST), again demonstrating the close link between physical and biological processes.

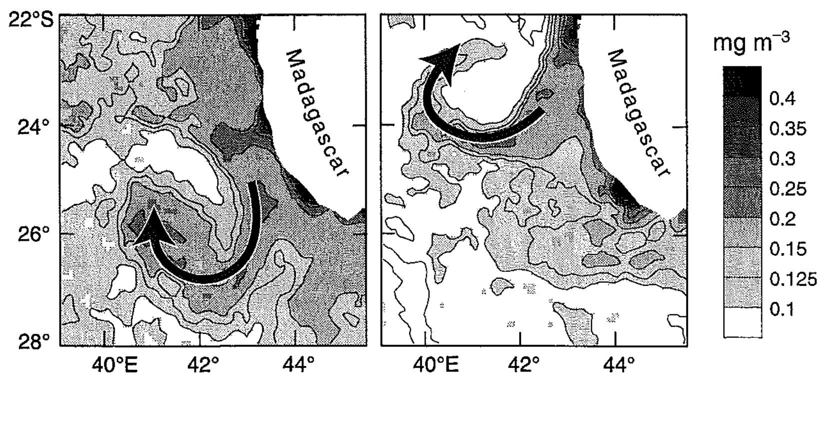
Revealing eddies

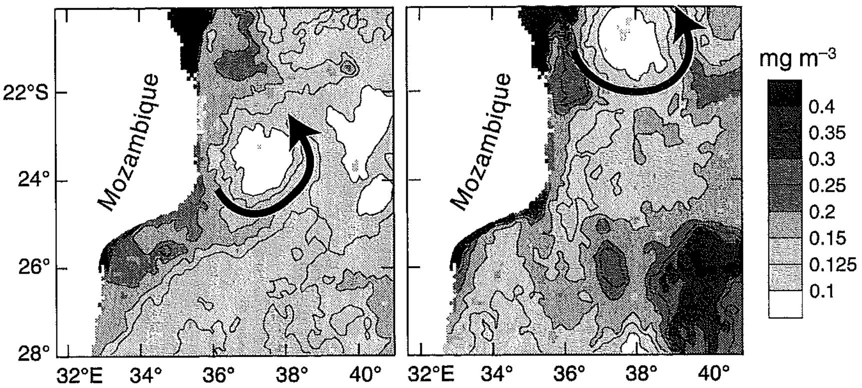
The flow field associated with eddies can affect the amount of plankton growth because the dynamics associated with the eddies can bring nutrients from deeper in the water column into the euphotic zone. However, in the Agulhas region, eddies are more commonly revealed by wrapping themselves in a 'Cloak of Visibility', as they entrain chlorophyll-rich surface waters from upwelling regions (see Figure 6). From single images it is not always clear what the eddies' sense of rotation might be, but by looking at a sequence of images (or better still, an animation of such a sequence) it is easy to deduce whether their sense of rotation is cyclonic or anticyclonic. From the chlorophyll patterns these particular eddies appear to be cyclonic.

It is not apparent whether the cyclonic eddies in Figure 6 form in the lee of Madagascar or have been generated elsewhere, and only become apparent when they entrain more productive waters. This acquired 'green mantle' provides a means of tracing the movement of the eddies. In an animation of the SeaWiFs data for this region, a number of such features can be discerned moving westwards or west-south-westwards towards the African coast and the Agulhas Current. This interpretation is consistent with the progression of anomalies in sea-surface height seen from space in radar altimeter data, thus confirming the more indirect observation of their dynamics using the chlorophyll patterns. The advantage of chlorophyll distributions over altimeter data is that (in cloud-free conditions) they provide much higher resolution (1 km) observations of the features.

Two cyclonic eddies off south-western Madagascar are revealed by the 'Cloak of Visibility' provided by high-chlorophyll coastal waters

Figure 6 *Cyclonic (clockwise) eddies to the south-west of Madagascar revealed by enhanced chlorophyll-rich waters. The high chlorophyll concentration waters had originated from coastal upwelling of nutrients, and were subsequently entrained around the eddies.*





Two examples of anticyclonic eddies sweeping polewards along the coast of Mozambique

Figure 7 *High-productivity waters off the coast of Mozambique are dragged into mid-channel by southward-moving anticyclonic eddies; however the cores of these two eddies continue to be marked by low chlorophyll concentrations.*

A different situation is found on the western edge of the Mozambique Channel, where there is a train of poleward-heading anticyclonic eddies (see Figure 7). These reveal themselves by a scarcity of phytoplankton, for although phytoplankton-rich waters are swept from the coast into the centre of the channel, they do not penetrate into the cores of the eddies. Examination of a sequence of composite images reveals about five of these southward-moving anticyclonic features per year, in agreement with observations from current meter moorings in the channel.

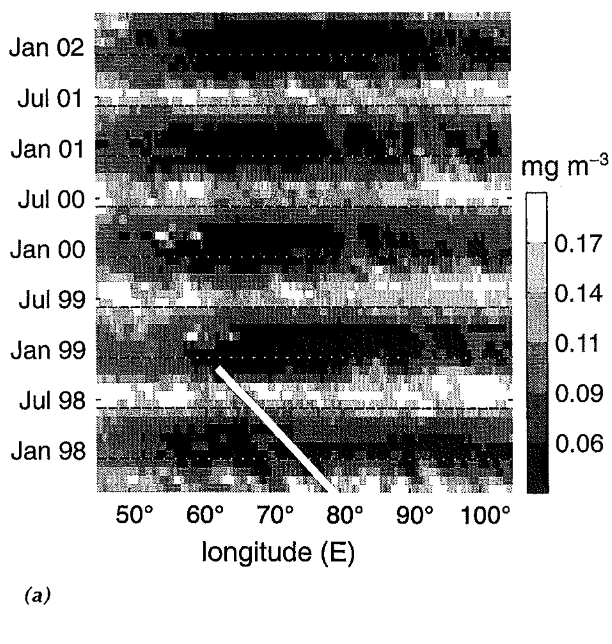
Such techniques for tracking eddies have been used elsewhere; for example, rings (eddies) shed by the North Brazil Current have been tracked by high-chlorophyll waters entrained from the Amazonian outflow region

Colouring waves

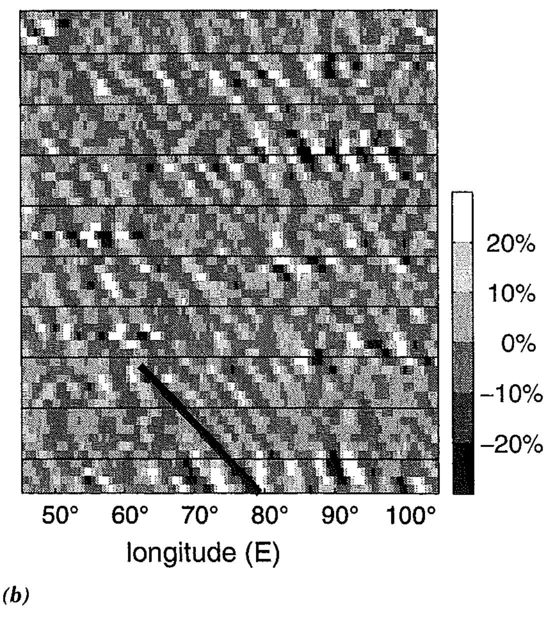
Rossby waves are important for linking events in the east and west of an ocean basin, as they are propagating disturbances their motion may also have weaker north–south components). As they propagate, the Rossby waves displace water to the north and south due to the geostrophic currents associated with the wave motion. Given their near-zonal propagation, the evolution of Rossby waves can be revealed by Hovmöller diagrams (longitude–time plots) at a given latitude. A portrayal of the absolute chlorophyll values (Figure 8(a)) mainly shows the strong annual cycle in chlorophyll concentration, with the westward-propagating Rossby waves only occasionally apparent. A filter can be applied to produce chlorophyll anomalies (values relative to local spatial mean); a Hovmöller diagram of these anomalies (Figure 8(b)) reveals the Rossby waves much more clearly. In many locations the Rossby wave phytoplankton signal is consistent with north–south displacements across a meridional gradient; that is, the chlorophyll concentration changes with latitude but is uniform in the east–west direction and this pattern is distorted by the wave motion and so detected by SeaWiFS. However, in the centre of the South Indian Ocean gyre, Rossby waves are revealed by ocean colour in a region where there is no obvious latitudinal variation of chlorophyll concentration. Candidate explanations for a visible signatures involve either significant raising of the deep chlorophyll maximum, or real phytoplankton growth due to upwelling of nutrient-rich water induced by the Rossby wave. A quantitative explanation of these moving waves of colour is a topic of current research.

Figure 8 *Hovmöller diagrams showing chlorophyll signature of Rossby waves at 32°S in the Indian Ocean: note that time progresses* ***up*** *the diagrams.*
(a) *Absolute values of chlorophyll concentration.*
(b) *Results after filtering to give anomalies with respect to a local spatial mean (expressed as fractional change in chlorophyll concentration). An example Rossby wave trajectory has been marked on both plots to indicate the size and speed of the propagating features (many others can be seen). Propagation speed is ~10° in a year, corresponding to ~3 km day^{-1}.*

Filtered SeaWiFS data reveal the passage of Rossby waves through their effect on chlorophyll concentration



(a)



(b)

End of the rainbow

The examples described in this article demonstrate that a satellite sensor designed for one purpose – ocean colour measurements of biological processes – can reveal much about physical processes. The technique exploits the intimate relationship between ocean biology and physics to enhance our understanding of both. Through the ages, writers have referred to the sea in poetic terms, with Homer's 'wine dark sea' in the Odyssey being one of the most evocative descriptions. SeaWiFS might not have shown the sea to be 'wine dark', but through its spectrum of colour measurements, it has illuminated some aspects of the endlessly fascinating oceans.

Acknowledgements

We are very grateful to Orbimage for the development of such a high quality instrument, to NASA Goddard Space Flight Centre for the efficient distribution of data, and to Rutherford Appleton Laboratory for the precise SST data.

Further Reading (with annotations)

The Agulhas Current system

de Ruijter, W.P.M., H. Ridderinkhof, J.R.E. Lutjeharms, M.W. Schouten, and C. Veth (2002) Observations of the flow in the Mozambique Channel. *Geophysical Research Letters*, **29 (10)**, 140: 1–4. DOI 10.10292001GL013714.
Paper shows the flow in the Mozambique Channel not to be a continuous southward current, but a series of anticyclonic eddies heading poleward.

Holliday, N.P. and J.F. Read (1998) Surface oceanic fronts between Africa and Antarctica. *Deep-Sea Research* I, **45**, 217–38.
More details of the structure of the Agulhas Return Front, the Subtropical Front and the Sub-Antarctic Front.

Lutjeharms, J. R. E. and E. Machu (2000) An upwelling cell inshore of the East Madagascar Current. *Deep-Sea Research*, **47**, 2405–11.
The references herein for more on how upwelling is induced by the passage of a boundary current from a narrower to a wider shelf region.

Read, J. F., M. I. Lucas, S. E. Holley, and R. T. Pollard (2000) Phytoplankton, nutrients and hydrography in the frontal zone between the southwest Indian subtropical gyre and the Southern Ocean. *Deep-Sea Research*, **47**, 2341–68.
Paper gives information about the nutrients in the region of the Agulhas Return Current, and the consequent increased chlorophyll levels along the interface of different water masses.

Ridderinkhof, H. and W. P. M. de Ruijter (2002) Moored current observations in the Mozambique Channel. *Deep Sea Research II*, **50**, 1933–55.
Discusses *in situ* observations of anticyclonic eddies in the channel.

Ocean physics studies using ocean colour data

Cipollini, P., D. Cromwell, P. G. Challenor, and S. Raffaglio (2001) Rossby waves detected in global ocean colour data. *Geophysical Research Letters*, **28**, 323–6.
One of the first papers detailing observations of Rossby waves using SeaWiFS.

Fratantoni, D. M. and D. A. Glickson (2002) North Brazil Current ring generation and evolution observed with SeaWiFS. *Journal of Physical Oceanography*, **32**, 1058–74.
Description of the use of SeaWiFS data to study physical processes associated with rings (eddies) in another part of the ocean.

McGillicuddy, D. J., A. R. Robinson, D. A. Siegel, H. W. Jannasch, R. Johnson, T. D. Dickey, J. McNeil, A. F. Michaels, and A. H. Knap (1998) Influence of mesoscale eddies on new production in the Sargasso Sea. *Nature*, **394**, 263–6.
This paper discusses how eddies can impact the nutrient supply to the euphotic zone and so change the productivity of surface waters.

Quartly G.D., P. Cipollini, D. Cromwell and P.G. Challenor (2003) Rossby waves: Synergy in action, *Phil. Trans. Roy. Soc.* **361**, 57–63.
Discusses the mechanisms whereby Rossby waves might be seen in ocean colour data, and th ephase relationship found between the height and colour signatures of Rossby waves in the southern Indian Ocean.

Quartly G.D. and M.A. Srokosz (2003) Satellite observations of the Agulhas Current System, *Phil. Trans. Roy. Soc. A* **361**, 51–6.
Shows the links between satellite observation of SST and ocean colour for the Agulhas Return Current, and interannual variation in position of the meanders.

Uz, B. M., J. A. Yoder, and V. Osychny (2001) Pumping of nutrients to ocean surface waters by the action of propagating planetary waves. *Nature*, **409**, 597–600.
Another paper showing that Rossby waves are visible in ocean colour data.

Weeks, S. J. and F. A. Shillington (1996) Phytoplankton pigment distribution and frontal structure in the subtropical convergence region south of Africa. *Deep-Sea Research* I, **43**, 739–8.
Study of CZCS-derived phytoplankton distribution in the region of the Agulhas Return Current in relation to SST fronts, and of the strong interannual variations in phytoplankton abundance.

Graham Quartly has research interests in observing Rossby waves, measuring rainfall at sea with both satellite and *in situ* sensors, and in all aspects of the Agulhas Current system.

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Meric Srokosz has research interests in the interaction of physical and biological processes in the upper ocean and the Agulhas Current system. He is the Science Co-ordinator of the NERC Rapid Climate Change thematic programme.

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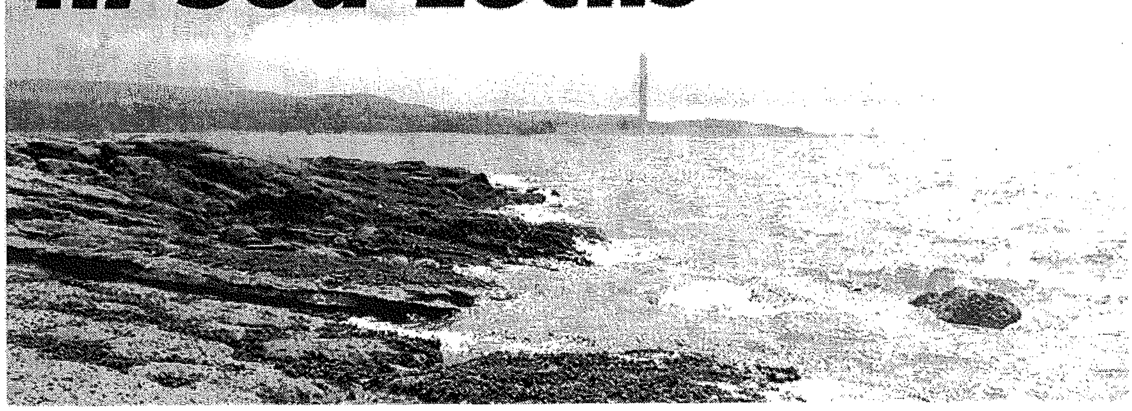
Tidal Response in Sea Lochs

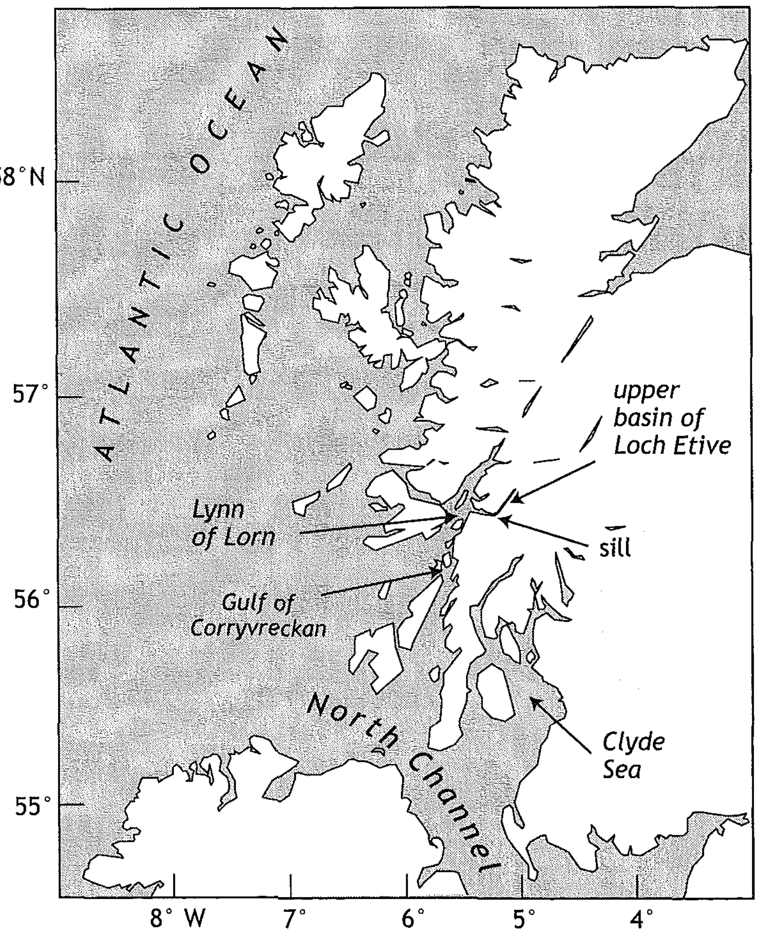


A case of waves versus jets

Finlo Cottier and Mark Inall

The Clyde Sea and Loch Etive represent two extremes in the spectrum of sea-loch morphology

Sea lochs epitomise the wild and rugged landscape of the west coast of Scotland. These distinctive fjord-like systems are not simply beautiful reaches of water, they are the link between land and ocean and play significant economic and ecological roles. According to annual statistics, salmon farming in west coast lochs is a £150M industry, producing well over 100 000 tonnes of fish and generating 10 000 tonnes of waste. Consequently, sea lochs are receiving increasing scientific, environmental and political attention, as people try to understand how they function, and the pressures upon them.



At Dunstaffnage, just north of Oban, the Laboratory of the Scottish Association for Marine Science (SAMS) is ideally placed to unravel the processes that drive sea lochs. Indeed, 'Fjordic Systems' is one of the principal themes in SAMS's Northern Seas Programme (NSP), a five-year, NERC-funded science plan. The setting up of the NSP has coincided with the re-emergence of the Marine Physics Group at SAMS. Working with external partners, the group is addressing some of the questions surrounding the transfer of tidal energy through sea lochs. This is just one element of an observational programme aimed at understanding hydrographic phenomena from the coastal margin, across the shelf and into the deep ocean.

Sea lochs and fjords are the archetypal manifestations of a glacially over-deepened landscape. Scotland has been shaped over the last 2 million years by successive ice sheets pushing west towards the north-east Atlantic. When the ice sheet from the last glacial period retreated some 10 000 years ago, it exposed the highly indented coastline we see today.

Topographically, sea lochs exhibit characteristic features, having one or more deep, semi-enclosed basins separated by relatively shallow sills, with the most seaward sill restricting

Figure 1 *Map of western Scotland, showing the location of two contrasting sea lochs, the Clyde Sea and Loch Etive.*

exchange between coastal waters and the loch. Most receive high levels of land run-off which results in the formation of a fresh surface layer that caps the underlying denser basin water. This combination of shallow sills and enhanced stratification leads to isolation of the deep water from the generally well-mixed coastal water.

The diverse physiography of sea lochs results in a range of responses to natural forcing. The principal sources of mechanical energy capable of stirring the waters in a sea loch are the tides and the wind, and key processes include advection across the sill(s), and vertical mixing within the deep basin(s). A host of mechanisms have been identified that may contribute to enhanced exchange and mixing within sea lochs, and it is these mechanisms and their relative magnitudes that are being investigated at SAMS.

The dominating force in coastal oceanography of the Scottish west coast is the semi-diurnal, barotropic* tide. Twice a day, the tidal wave surges along the coast and through the sounds and channels, representing a massive throughput of energy. Surface currents regularly exceed six knots ($\sim 3\,\mathrm{m\,s^{-1}}$) in this region, with arguably the most dramatic manifestation of tidal power being the great whirlpool in the Gulf of Corryvreckan. Propagation of tidal energy into sea lochs is key to how they function, and many of the processes occurring in them, particularly those related to mixing of waters within the loch.

How does a stratified sea loch respond to tidal forcing? The answer depends on three principal factors: the power of the tide, the dimensions of the sill, and the degree of stratification in the basin. A stable column of water has a degree of elasticity: if displaced vertically it will tend to oscillate. Sea lochs generally have a sharp pycnocline which will support internal oscillations, which then propagate through the loch as internal gravity waves. The dimensions of the waves, their wavelength and speed, are determined in part by the degree of stratification. To initiate and sustain these oscillations requires an energy source (the barotropic tide), and the efficiency by which energy is transferred from the tide to the wave is related to the relative depths of the pycnocline and the sill.

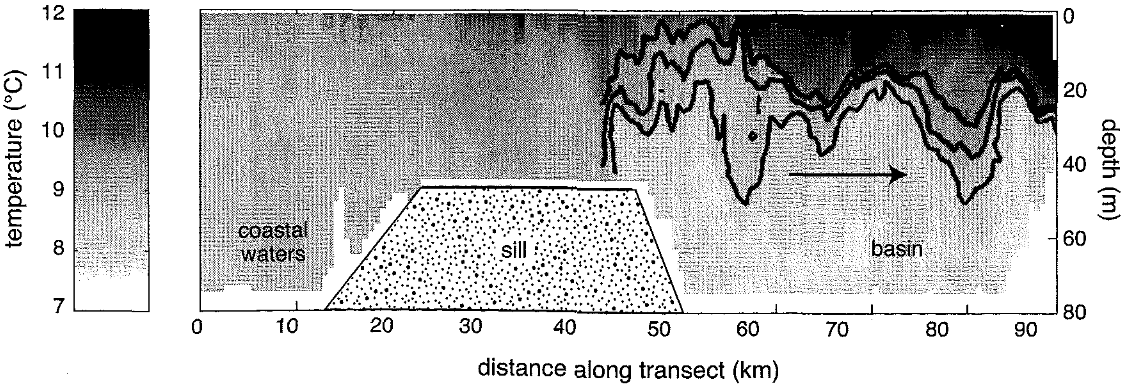
But this is just one possible scenario. If the barotropic tide is weak then internal wave formation at the sill is replaced by simple advection of coastal water into the loch. At the other extreme, highly energetic tides overwhelm the tendency for internal wave formation, creating instead an intense jet of water at the sill. Put simply, sea lochs will respond to barotropic tidal forcing with the formation of either an internal wave or a jet.

This classification of sea lochs or fjords into those showing wave-like or jet-like behaviour is not new. During a survey of Norwegian fjords, Anders Stigebrandt (see Further Reading), formulated the idea that they could be classified according to whether a wave or a jet developed at the sill. The distinction between the two classes lies in the ratio of the current speed over the sill to the propagation speed of any wave that may form; this ratio is also known as the Froude Number, *Fr* (values typically between 0 and 2). Physically, the requirement for internal-wave generation is that the maximum cross-sill tidal current is less than the speed of the internal wave it induces, i.e. that the Froude Number is less than one. In cases where the Froude Number is greater than one, a jet will form preferentially.

Over the last few years, in collaboration with the School of Ocean Sciences, University of Wales Bangor, we have been investigating the physics of these wave and jet systems by making observations in two rather different sea lochs. The first of these, the Clyde Sea (Figure 1 and heading photo), does not at first sight fit the description of a sea loch, but the outer part forms a single, wide basin, separated from the North Channel of the Irish Sea by an extensive sill area with complex topography. By contrast, Loch Etive, branching off the Lynn of Lorn, is a very narrow, multi-basin loch with small, shallow sills and classic fjord bathymetry. The Clyde Sea and Loch Etive are, in effect, the extremes of a spectrum of possible fjordic morphology.

* We refer to the tidal wave as the 'barotropic tide' as it affects the whole water column uniformly, in contrast to tidally generated internal waves which may be set up on a particular density interface; these are often described as 'baroclinic tides', because here isobars and isopycnals are not parallel, resulting in depth-varying currents.

Figure 2 *Tidally generated temperature oscillations in the Clyde Sea observed from a* SeaSoar *survey. Three isotherms (8.5, 9.0 and 9.5 °C) are picked out with black lines. (For discussion, see overleaf.)*



The waters of the Clyde Sea support tidally generated internal waves for most of the year

Figure 3 *The SAMS research vessel* Calanus *working in the beautiful upper basin of Loch Etive. (Photo courtesy of Highland Image)*

Froude Numbers for the Clyde Sea sill are typically about 0.4, predisposing it to the generation of internal waves. Indeed, observations from both moored arrays and ship surveys throughout the region have identified a clear signature for an internal tide – internal waves of tidal frequency. Perhaps the clearest picture of the internal tide can be seen in data obtained from *SeaSoar*, an undulating CTD unit (Figure 2, p.25).

A sharp front at the sill separates the internal oscillations of the thermocline inside the basin from the well-mixed water in the North Channel of the Irish Sea. The internal wave field that is established propagates throughout the basin into the upper reaches of the Clyde Sea. Because these waters are almost continually stratified, the internal wave energy remains fairly constant throughout the year (see Further Reading).

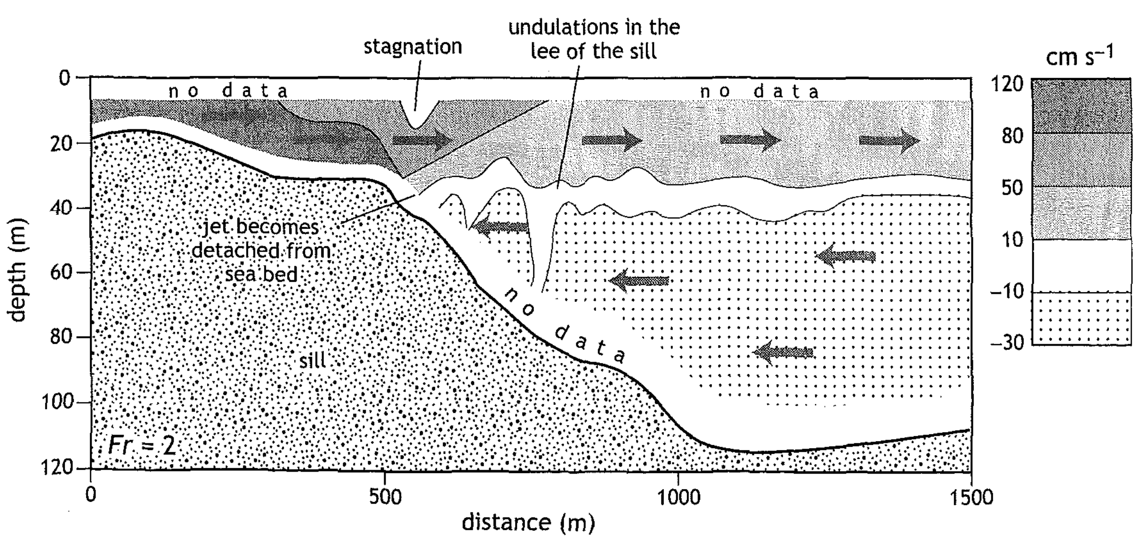
The fate of tidal energy transformed into internal waves at the sill is either via viscous dissipation to heat, or to increased potential energy of the water column, i.e. mixing up of deep, dense water into less dense overlying water. Roughly four-fifths of the energy is transferred to heat via the viscosity of water, but causes a negligible increase in temperature – consider trying to warm a bath by stirring it! The remaining fifth is available to vertically mix the water column. Rates of energy dissipation and mixing in the Clyde Sea have been estimated from the difference in baroclinic energy flux at sites close to and remote from the sill (see Further Reading). These measurements indicated that a significant proportion of the mixing occurs near the sill and at the sloping boundaries of the basin.

Closer to Oban, field observations in the upper basin of Loch Etive (Figure 1) using SAMS's two research vessels, *Calanus* (Figure 3) and *Seol Mara*, have provided data on the formation of a tidal jet and the subsequent propagation of energy into the basin. At spring tides, current flow over the sill approaches twice the speed of likely wave propagation (~ 1.5 m s^{-1}). As shown in Figure 4, the result is that a pulse of water is injected into the upper basin during each flood tide. At its maximum flow, the jet extends 2 km beyond the sill, becoming detached from the sea bed at a depth of 40 m. Below this, there is a weak return flow from the basin towards the sill.

Jet conditions in the upper basin are not sustainable throughout the entire flood tide. Variation in current speed during the flood restricts the presence of the jet to short periods at peak flow. At other times during the flood, the response becomes similar to that of a 'wave-type fjord', with propagating oscillations ob-

Figure 4 *A cartoon of a tidal jet crossing the sill and penetrating the upper basin of Loch Etive, based on data from a vessel-mounted ADCP. Note the turbulence at the interface with the deeper return flow. (Velocities from left to right are shown as positive in the key.)*

During peak flood tide, water from the lower basin enters Loch Etive as a surface jet



served along the length of the loch. Inevitably, this bimodal behaviour must hold for all 'jet fjords': as current speeds decrease after peak flood tides, the system becomes subcritical and reverts to a wave response.

Associated with the jet are a number of processes that enhance mixing within the loch. On the flood and the ebb, flow over the sill draws water from the upstream basin, from depths of over 25 m, which is twice the depth of the sill. This has the effect of squeezing the isopycnals together and so reducing the energy required for vertical mixing. Further, in the lee of the sill, there are undulations at the interface of the jet and the underlying water (Figure 4). As the current changes, these undulations become unstable and break like oversteepened surface waves, causing intense, local mixing. However, these processes are restricted to regions close to the sill, a small proportion of the total loch volume. Overall, Loch Etive experiences relatively low rates of mixing, resulting in stagnation of the deep water for periods of months or even years.

Wave and jet responses to tidal forcing both produce conditions that enhance vertical mixing in sea lochs. In general, wave mixing is less intense but propagates over a greater area, whilst jets seem to generate more efficient, localised mixing. Through vertical mixing, the deep water gradually becomes less dense, preconditioning the system to convective overturning or renewal by the intrusion of denser coastal water that displaces the stagnant deep water.

So where does this understanding of mixing ultimately take us? At the local level, we can use our knowledge of water renewal in these often poorly oxygenated systems for economic/strategic purposes, environmental management (e.g. effluent discharge) or for interpreting sediment, geochemical or biological distributions and cycles within sea lochs. On a regional scale, we can estimate the exchange and modification of water in the lochs and adjacent coastal waters, part of the much bigger oceanographic framework that links the oceans, via shelf waters, to the coast. Finally, at the oceanic scale, vertical mixing driven by the very same processes seen in fjords, may well exert a controlling influence on the Meridional Overturning Circulation. Our understanding of these global processes is sparse, but there are analogous processes occurring in sea lochs and fjords. We can use sea lochs as a laboratory for oceanic processes.

Further Reading

Cottier, F.R., Inall M.E. and Griffiths, C. (2002) Seasonal variations in internal wave energy in a Scottish sea loch. *Ocean Dynamics* (accepted).

Inall, M.E. and Rippeth, T.P. (2002) Dissipation of tidal energy and associated mixing in a wide fjord. *Env Fluid Mechs* **2**, 219–40.

Inall, M.E., Cottier F.R, Griffiths, C, and Rippeth T.P. (2002) Sill dynamics and energy transformation in a jet fjord. *Ocean Dynamics* (accepted).

Munk W. and Wunsch C. (1998) Abyssal recipes II: energetics of tidal and wind mixing. *Deep-Sea Research* **45**, 1977–2010.

Stigebrandt, A. (1999) Resistance to barotropic tidal flow in straits by baroclinic wave drag. *J. Phys Oceanogr.* **29**, 191–97.

Stigebrandt, A. and Aure, J. (1989) Vertical mixing in basin waters of fjords. *J. Phys Oceanogr.* **19**, 917–26.

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Mark Inall is Head of the Marine Physics Group at SAMS. His interests encompass many of the exchange and mixing processes that occur in stratified flows.

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The photo used in the article heading is by courtesy of Linda Robb (SAMS).

Nearing completion ...

The new SAMS offices and laboratories, and the new European Centre for Marine Biotechnology

28 October 2003 will be a busy day as the transfer from the Dunstaffnage Marine Laboratory gets underway. For more information on research activities and on the latest developments within the SAMS Group, see www.sams.ac.uk

Book Reviews

A cautionary tale

Killer Algae: The True Tale of a Biological Invasion by Alexandre Meinesz (translated by Daniel Simberloff) (1999). University of Chicago Press, 360pp. £10 ($16) (flexicover, ISBN 0-226-51923-6) and £16 ($25) (hardcover, ISBN 0-226-51922-8).

This the story of how a rampantly invasive clone of the alga *Caulerpa taxifolia* was accidentally introduced into the Mediterranean, and then found its way to the seas off California and Japan. It is a tale of careful scientific investigation, the results of which were ruthlessly suppressed by influential authorities who saw the findings not only as a attack on their professionalism, but also as likely to compromise a lucrative financial investment.

This male clone of *Caulerpa* first appeared in the tropical aquarium in Stuttgart. It flourished and its brilliant green colour superbly offset the tropical fishes, so it was quickly passed round public aquaria. Within two years of its arrival at the Oceanographic Museum of Monaco, a small patch was seen to be growing on the sea bed below one of the windows of the Museum. Six years later it was found five kilometres along the coast. It was growing just as vigorously as it had in the aquarium and was out-competing and excluding the *Posidonia* seagrass, along with a rich and diverse fauna and flora – an ecological disaster in the making.

In these days when biodiversity matters, one would have thought that alarm bells would have rung, and immediate action would have been taken against the invader. Unfortunately for our author (Meinesz), his conclusion that the original introduction had occurred from the Museum caused considerable upset amongst the oceanographic panjandrums, which earned him the antagonism of some of the most powerful people in the French oceanographic establishment. There followed an extraordinary succession of stalling tactics and manipulation of funding procedures. His publications were blocked, his laboratory was taken over, his research was downgraded, and he lost funding. A public campaign of denigration occurred. The book reads like a science thriller, and even if it is only one side of the story, it will send shivers down your spine to see just how successful authority can be at blocking bad news.

Meanwhile, the alga continued to spread, not only by sexual reproduction but asexually, as fragments broken off by storms were carried by currents along the coast and took root where they were deposited. The dominant agent of dispersal was (and is) almost certainly humanity, as the alga is picked up and dropped by the anchors of recreational boats. Almost every new locality at which it is found is an anchorage. In the Mediterranean, it has now spread to waters off Spain, Italy, Croatia and Tunisia; fish catches are tumbling and richly diverse areas of sea bed are being swamped by monocultures of *Caulerpa*.

How then did *Caulerpa* make its gigantic leaps from the Mediterranean to Japan, Australia and California? The circumstantial evidence points to a lucrative business set up to supply tropical aquaria. These aquaria were established using material supplied under a patent accorded to Professor Jaubert at the Oceanographic Museum. At Enoshima, Japan a rampant clone of *Caulerpa* appeared offshore soon after the aquarium had been established. It had the unique genetic fingerprint of the Mediterranean strain – could there be any doubt as to its origin? Prince Khaled of Saudi Arabia arranged for his two luxury yachts to be fitted with tropical aquaria supplied from the same source. He had these yachts re-painted in San Diego, and in 2000 the rampant Mediterranean strain of *Caulerpa* was found there, dispersed over several hectares. A vast effort is now being made to exterminate it.

This is an excellent tale of scientific investigation, but is also a cautionary tale about the dirty tricks that may result when self-interested authorities find scientific results unpalatable. It should be compulsory reading for oceanographers ... and those running aquaria.

Martin Angel
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When the going gets tough ...

Life at the Limits: Organisms in Extreme Environments by David A. Wharton (2002). Cambridge University Press, 307pp. £18.95 (hardback ISBN 0-521-78212-0).

People have always been fascinated by organisms living in tough places. Oryx in the baking desert, foxes in the polar wastes, microbes in hot springs, plants on mountain tops, and fish in the depths of the ocean, are all making a living in environments we humans would find impossible to survive without the benefits of technology. Because of this, we tend to regard these environments as extreme. And in a literal sense they are, in that they are habitats with characteristics at one end of the spectrum of variability found on Earth; they represent the hottest, driest, coldest, most saline or highest pressure environments on the planet.

When we think of extreme environments, there is the implicit assumption that these are tough places to make a living. We humans would certainly find it difficult to survive away from a moderately warm and reasonably humid climate, but are these environments really difficult for those organisms that have adapted over evolutionary time to live there? Perhaps it is more stressful to scratch a living at the edge of a viable range than to live in the centre of a range to which an organism is adapted?

This question of what precisely constitutes an extreme environment has long perplexed ecologists, and it provides the starting point for David Wharton's book on life at the limits. His approach to answering the question is to conceive of a multi-dimensional space defined by all the environmental variables that characterise a habitat (temperature, humidity, light, pressure and so on), and populate this space with data for various habitats. The resulting cloud of points represents most habitats on Earth. Any points falling outside the cloud – e.g. points representing the high temperatures and pressures experienced by hyperthermophilic microbes living in deep-sea hydrothermal vents – represent an extreme environment. This approach, whilst useful pictorially (albeit limited to representation in only three dimensions), is simply a definition of an extreme environment as being at or near the edge of the normal range, as neatly encapsulated in the title of the book.

The interesting ecological and evolutionary question is whether these environments are perceived as tough or stressful by the organisms that live there. Wharton examines a series of extreme environments, and discusses how microbes, plants and animals have evolved to cope with them. There are chapters on living at low humidity in deserts, at high temperatures, at low temperatures, and then, in less detail, on a variety of other environmental stresses, including high pressure, extreme pH, high osmotic strength, lack of oxygen and elevated UV. These chapters mix descriptions of the environmental variables with descriptions of the adaptations exhibited by organisms living there.

In using this approach, Wharton emphasises the important distinction between resistance adaptations and capacity adaptations. Resistance adaptations are those that allow an organism to survive intermittent periods of extreme cold, drought or other environmental challenge; they include the production of stress proteins, antifreezes or cryoprotectant (chemicals used to protect cells against low-temperature damage), as well as the more extreme response of depressing metabolism to undetectable levels (cryptobiosis). Striking examples of the latter include two groups of macroscopic organisms living in soil, an Antarctic nematode that can freeze solid (most organisms that tolerate freezing only do so in the extracellular fluids) and certain tardigrades which can dry out completely and survive for years before rehydrating and returning to life. Resistance adaptations are therefore a temporary measure to allow an organism to survive an environmental challenge, for during cryptobiosis the organism cannot grow, move or reproduce. To complete its life-cycle the organism must be able to pursue all normal physiological processes under the circumstances of the extreme environment, and this requires what physiologists have traditionally called capacity adaptations. In some ways we know less about these than we do about the more spectacular examples of resistance adaptations, though in a physiological or evolutionary context they are perhaps more interesting.

The structure of the book is clear. Following the analysis of how we might define an extreme environment, the core of the book deals in turn with a variety of extreme environments. This central section opens with an overview chapter, and closes with a pair of summary and synthesis chapters, one looking at what light is thrown by these studies on the possibilities for extraterrestrial life, and a second on general principles, including a return to the question of what constitutes an extreme environment. The initial overview chapter was the one I found the least satisfactory, in that it simply covered ground that would be dealt with more thoroughly in subsequent chapters. As such it fell between a simple introduction laying out the basic themes, and a detailed analysis. The final synthesis chapter was also a little disappointing in that the coverage of some important complex ideas (such as the relationship between diversity and environment) was in places simplistic and misleading, though it does close with an interesting discussion of the evolutionary history of extreme environments and their inhabitants. For marine ecologists the main interest will be in Chapter 1 (introduction), Chapter 5 (low temperature) and Chapter 6 (which covers high pressure in the deep sea).

The book is written for a non-specialist readership, and as someone who has spent his entire working life in one extreme environment I am perhaps not best able to judge its success here. Coverage is thorough and the scholarship impressive, especially in the way the earlier literature is covered. It is good for students to be reminded that there was intelligent life before the start of electronic bibliographic databases! I thought I knew the low-temperature literature fairly well, but I found several new and unexpected gems in reading the accounts of early research. Although the lack of citation in the text undoubtedly makes it easier to read, I found the suggested further reading (grouped by chapter in an appendix) disappointing. Several times I searched in vain for the source of an interesting observation, and I feel an opportunity has been lost to provide a valuable combination of up-to-date specialist literature with important general references. This would undoubtedly have increased the value of the book by directing it to a wider audience.

Style is an intensely personal matter and whilst David Wharton's writing is refreshingly free of the prolix waffle of many technical papers, I found the clipped sentences somewhat trying to read, and the choice of illustrative example occasionally banal. There were a small number of scientific slips but these were generally minor, and overall this book represents a terrific attempt at pulling together common themes from the many ways organisms have adapted to live in tough places. David Wharton has a strong, wide-ranging grasp of the biological issues involved and puts over his arguments with conviction and clarity. This is currently the best book available on the subject and it makes a compelling case for the scientific importance, as well as the intrinsic intellectual interest, of how life has established itself anywhere there is liquid water. It has gone straight onto the reading list for my teaching.

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Going down?

The Biology of the Deep Ocean by Peter Herring (2002). Oxford University Press, 314pp. £59.94 (hardback, ISBN 0-19-854956-3) and £24.95 (flexicover, ISBN 0-19-854955-5).

In the opening pages, the author tells us that seas and oceans cover 71% of Earth's surface and that 76% of the open ocean is more than 3 km deep. He reveals that this vast three-dimensional habitat forms, by volume, a staggering 99.5% of the available living space for life on our planet. With incredible statistics like these, Peter Herring's *Biology of the Deep Ocean* starts as it means to go on, providing a wealth of fascinating physical and biological facts and figures relating to the deep ocean ecosystem and its inhabitants.

The book begins with a neat overview of the aquatic realm, describing the remarkable properties of water and some of the challenges that marine animals face as a result of having to live in it. Aspects of the physics and chemistry of oceans are, thankfully (for this particular biologist!), dealt with swiftly and concisely, before we move on to a review of the various ways and means of monitoring and sampling the oceans.

continued

There then follows a rather lengthy discussion on the subjects of photosynthesis and primary producers. The author assures us at the start of the chapter that this knowledge is an essential prerequisite for a fuller understanding of the ecology of deep-sea communities. This is, of course, absolutely correct, but I must confess that I did find myself skipping ahead impatiently through the sections on measurements, bacteria and viruses, keen to get away from the surface and into deeper waters.

The next chapter is far more engaging, with a look at the deepest habitat of all – the very bottom of the ocean. The majority of animals that live on the sea floor, thousands of metres down, are obliged to eke out an existence on recycled remains falling from surface waters. With survival at these depths being largely dependent on a diet of 'faecal pellets, marine snow and crustacean moults', this chapter's descriptions of the somewhat unusual lifestyles of such benthic creatures make an intriguing read.

A little frustratingly for the deep-sea enthusiast, we are then taken back to the surface again, this time for a look at distribution patterns. However, the reason for this diversion soon becomes clear, as we learn much about the three-dimensional nature of the oceans and the movements of water, nutrients and animals across great distances, both horizontal and vertical. That somewhere in the region of 10^9 tonnes of animals migrate vertically through the water column at dawn and dusk each day is a sobering thought – and one which puts the daily rush-hour traffic in Bristol into perspective.

The next few chapters are devoted to the amazingly varied and ingenious designs evolved by deep-sea inhabitants to cope with living in such an extreme environment. There are fish with dislocating jaws and expandable stomachs, fish with advanced 'motion-detection' systems, fish with bizarre tubular eyes, and fish with elaborately-shaped, glowing lures. It's an absolutely fascinating read and is extremely comprehensive, with a wealth of detail throughout.

With a final chapter on deep-sea biodiversity and a useful appendix outlining and describing the marine phyla, this book provides a very thorough overview, not just of life in the deep ocean, but of marine ecosystems as a whole. For me, the only disappointment relates to the illustrations dotted throughout the text; some are excellent, others less so. A couple of graphs and diagrams are printed with labels in almost illegibly tiny type and several of the figures seem to have been miniaturised purely in order to squeeze them onto the bottom of a page. To my mind, this is a shame, as the excellent text could, and should, have been complemented by equally excellent graphics.

The book claims to be aimed at 'marine scientists, student and professional' and in my opinion, it pretty much hits the mark. I would imagine that marine science students, in particular, will find its breadth and depth of information invaluable. The *Biology of the Deep Ocean* has certainly become an essential addition to my bookshelf and Professor Herring will no doubt find himself quoted in many a BBC television programme in future!

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Spreading the word

Issues in Oceanography by Daniel C. Abel, Robert L. McConnell, and Eric Koepfler (2001). Prentice Hall Inc. 40pp. £9.99 (flexicover, ISBN 0-13-018603-1).

This slender book, little more than a pamphlet, is an introduction to the main topics of concern to all marine scientists who care about the state of the oceans. As the authors state in their preface, each chapter consists of a brief introduction, the remainder of the analysis being on the Companion Web Site, access to which is detailed on the inside front cover. It is a low-cost production, and while the cover is quite colourful, all the illustrations in the book are black and white only.

Topics include coastal population growth, overfishing, bycatch (focussing on turtles and dolphins), endangered sharks, whales and coral reefs, ballast water and exotic species, global warming, sea-level rise, estuaries, coastal dynamics, toxic chemicals, not necessarily in that order. The whole approach is 'green' and praiseworthy on that count alone, though some overlap of topics couldn't be avoided, since human impacts are now global in scale. The book doesn't mention the recent discovery of toxic concentrations of arsenic being tapped in wells in Bangladesh (chapter on coastal population growth), but that probably features on the website (available to subscribers only).

The authors seem to have a misconception similar to the one in Thurman and Burton (see next review), in that they reckon the formation of calcium carbonate 'locks up' CO_2 from the atmosphere. It doesn't. Precipitation of calcium carbonate is 'CO_2-neutral', removal of CO_2 from the atmosphere requires weathering of silicate rocks, followed (or accompanied) by carbonate precipitation.

On the other hand, though, the book has some interesting information that was new to me. For example, I didn't know that the old name for orange roughy was 'slimehead', a name that was changed because it didn't work well for marketing purposes – perhaps this is the same reason that the Patagonian toothfish was renamed Chilean sea-bass. Isn't it amazing what a bit of marketing hype can do? Both these species are now heavily overfished.

Introductory Oceanography (9th Edition) by Harold V. Thurman and Elizabeth A. Burton (2001). Prentice Hall Inc. 554pp. £31.99 (hard cover ISBN 0-13-857061-2).

This latest edition is not a whole lot different from the previous one, the eighth, which was by Thurman on his own. Having a co-author for this latest version of a book that's been going since the mid-1970s has probably galvanised both authors to change the format a bit. Chapter titles differ slightly from those in the eighth edition, but remain recognizable and are in much the same sequence as before, though there has been some re-arrangement of topics and subheadings. A couple of new chapters have appeared, one of which, The Chemistry of Seawater (Chapter 7), touches on the topics of pH, acidity and (that dreaded concept) alkalinity, also the carbonic acid system, and includes some diagrams and profiles not seen in previous editions.

There are a few glitches, such as the figure illustrating the CCD (Fig. 5.17), which perpetuates the idea that carbonate dissolves *en route* to, rather than at, the sea-bed – unless I have been labouring under a misconception for the last 30 years. The authors appear neither to have recognized that seawater contains negligible amounts of carbonic acid

(H_2CO_3), nor that precipitation of calcium carbonate in surface waters involves the release of CO_2 to the atmosphere.

As usual with these updates that originate in the US, there are supporting slide sets, a CD, a website, Instructors' Manual, and test files, in short all the paraphernalia of assessment that accompany these introductory texts. There are questions and exercises at the end of each chapter, but – as with all previous editions – no answers are provided, presumably because the questions require students to regurgitate what they've read (e.g. 'Explain why the polar nature of the water molecule makes it an effective solvent for ionic compunds', or: 'Describe the factors that control the amount of gas that dissolves in water.').

A striking feature of this latest edition is that exactly the same 'Issues in Oceanography' as those reviewed above are scattered between chapters throughout this book, albeit not in the same order as in the other book, and somewhat abbreviated (though readers are then directed to the same website), and the illustrations are in colour rather than in black and white.

All in all, then, I shouldn't quibble with this book, the illustrations are lovely (even if they are mostly US-based) and the text is on the whole clear and informative, fine for the first-year students at whom it is aimed. Indeed, if the people who take our own third-level oceanography course absorbed the level of understanding that's in this book, they'd get first class passes every time ...

John Wright
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Momentum and modelling ...

Wind Stress over the Ocean edited by Ian S.F. Jones and Yoshaiki Toba (2001). Cambridge University Press, 307pp. £50 (hard cover, ISBN 0-521-66243-5).

This book is edited by two of the leading researchers in the field of momentum transfer between the atmosphere and ocean – an area of research of fundamental importance to the understanding of the interaction between our two fluid envelopes (atmosphere and ocean), on time-scales from seconds to years.

This is a subject with a history that goes back to the late 19th century with the work of Nansen on the voyages of the *Fram*, and the mathematical analysis of Ekman in the early 20th century. However, the book gives a modern view of the subject, based on the research efforts in the last 50 years, with a good number of the cited papers from the last decade. We are told of the many working groups, under the auspices of the Scientific Committee on Ocean Research (SCOR) which brings together the world's leading experts on air–sea interaction, and there can be no doubt of the credentials of the scientists who have contributed to this work.

The editors have produced a well constructed book, in that it commences with a an overview of the subject, which we are told, may be accessible to a broad range of readers. I would have defined the range of readers less broadly, limiting it to postgraduate researchers and professional scientists, because it is clear that some prior conceptual understanding of the subject is needed. This introductory overview is followed by Part 1, which is concerned with the basic dynamics related to the wind stress over the ocean. Part 2 deals with uncertainties in parameterizing ocean drag, and describes many issues that have been recognized as crucial for the understanding of the physics.

I enjoyed reading the overview as it gives a good conceptual outline of the subject, illustrated by a few but very clear figures, and without overburdening the reader with too much mathematics. The other excellent feature of the overview is that it gives an outline of the fluid mechanics and doesn't assume too much prior knowledge. In a similar way, it covers the basics of ocean waves, including power spectra and discussion of real ocean waves. It also considers the wind flow within the atmospheric boundary layer and the relationship of the wind to the wind stress acting at the surface.

However, it was here that I found my first disappointment, because there was no discussion of the wind drift current, and its variation through the upper ocean boundary layer; this was in contrast to a substantial discussion on ocean waves. Perhaps the authors felt that the science was not as well developed in this area, but it is disappointing not to have some discussion of this topic.

Part 1 is to my mind the meat of the book, containing over 150 pages of good material. It commences with a short historical account of how wind stress (or drag) has been measured from the 1950s to the present day, with brief accounts of all the major field experiments. It is a no-nonsense approach, which gives the essentials without exploring the difficulties of measurement, which have bedevilled the subject for the last 50 years.

This is followed by sections on the atmospheric and ocean boundary layer, ocean wave spectra, measurement of surface stress, and mechanisms for the exchange of momentum between ocean and atmosphere. Each of these sections is prefaced by an extremely helpful introduction. For the most part, explanations start at the beginning, reminding us, for example of the Ekman equations, and then making good progress to the present. As well as the dynamics there is some discussion on processes such as vertical convection, double diffusion of heat and salt, and the effects of rain on the surface layer. Perhaps surprisingly, the processes within the surface skin (top 1 mm) were not discussed in any detail and only mentioned in terms of their effect on ocean waves. I wondered whether this was one of those subjects that fell through the cracks between the authors' areas of expertise, and therefore was not addressed.

The more contentious material is to be found in Part 2, in particular, discussion of the relationships between wind drag (stress) and waves. Here there is a very nice succinct section on the influence of swell on the wind drag, which is insightful but has a light touch. By contrast, the section on the dependence of wave age on drag is comprehensive and thorough, but perhaps lacks insight into the processes.

In conclusion, this is a very useful book, which is aimed at the professional scientist and postgraduate researcher. Many authors have contributed to the book, and as a consequence there is inevitably some unevenness in style. However the editors have worked hard to produce a well structured and readable account of the subject, which opens up this material to a much wider audience. For this alone much credit should be given.

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Inverse Modelling of the Ocean and Atmosphere by Andrew F. Bennett (2002). Cambridge University Press, 234pp. £50 ($80) (hardback, ISBN 0-521-81373-5).

A topic of growing importance in modelling nowadays is data assimilation, because of the increasing complexity of models and the increasing availability of large datasets. Although Andrew Bennett's book is not specifically about data assimilation it will be of great interest to workers in that field, as well as to modellers in general.

The book addresses aspects of the methodology in a rigorous way and gives a good presentation of the philosophy and techniques of inverse modelling. The benefits of inverse (as opposed to conventional 'forward' modelling) are discussed in the preface. These include being able to produce 'analysed' (by some optimal interpolation) fields of currents, winds etc., corrections of forcing, boundary and initial conditions for models, improvement of empirical coefficients in models, and testing of the models themselves.

The author has worked in this field for many years, and the book has been developed from material for lecture courses for summer schools and is thus well-tested. The result is a very useful postgraduate textbook or reference book for modellers working in the fields of oceanography and/or meteorology. It is perhaps rather specialized but is written is such a way as to provide good physical insight into the mathematical formulations, which will be useful for all modellers. The text does not attempt an exhaustive coverage of every method used in data assimilation but concentrates more on links between methods. For example, the author explains the relationship between various least-squares algorithms such as optimal interpolation, Kalman filtering, fixed-interval smoothing and 'representers'.

The preface sets out clearly the focus and limitations of the book, describes the previous knowledge required, and indicates where material for presentation as a lecture course can be found on an ftp site. The author takes a theoretical and philosophical stance rather than emphasizing purely practical forecasting problems, but implementation of the methods is by no means neglected. A holistic approach to models and data is much appreciated – too often these are treated in isolation. It has to be recognized that boundary and initial conditions are essential components of models and observations, and observations and models both contain errors of various sorts.

Bennett's previous book on inverse methods, published in 1992, focussed on physical oceanography. This is by no means simply a new edition of that monograph but introduces new ideas and has a completely new layout, with different emphasis and a different starting point. However, there is a similarity in the theory presented, and in the inclusion of challenging exercises for the reader.

One of this book's excellent new features is a short description of the contents of each chapter before the main material, providing much useful philosophical insight. There are also some well-illustrated case studies, including ones involving ocean tides, tropical cyclone-track prediction and ENSO prediction using a coupled ocean–atmosphere model. A useful data assimilation 'checklist' is given in the Preamble.

The book starts with an introduction to variational assimilation, working through the development using a so-called 'toy' linear ocean model as an example. Concepts are introduced in a straightforward, logical, progressive way, taking every opportunity to draw wider lessons from the examples used. Intuitive first choices such as for the weights used in the cost function are shown to lead to ill-posed problems, thus leading naturally to more sophisticated choices. The solution centres on use of the Green's function to derive the Euler–Lagrange equations and thus find a solution using adjoint 'representer' functions. The second chapter concentrates on interpretation of the latter in terms of geometric and statistical properties, and their relation to the perhaps more familiar optimal interpolation method, for example.

In Chapters 3 and 4 implementation of the solution is discussed, and there is consideration of methods of accelerating the solution, and mention of the use of parallel computers. The problems of non-linear dynamics with the necessity for iterative solutions are highlighted, and the derivation of the Kalman filter is introduced. In Chapter 5, real applications in the ocean and atmosphere are discussed. The book is rounded off by a discussion of the specific problems of regional (spatially limited) ocean models where the problem is characteristically 'ill-posed' because the boundary conditions may be over-specified. The content is idiosyncratic rather than exhaustive, and the section headings are provocative and informal, with use of notes to highlight key points. Useful appendices include computational exercises and expansion of equations.

There are some errors in the text (proof-reading rather than fundamental flaws). I noticed that some references to work on ocean tides do not appear in the text (at least not necessarily on the pages mentioned) and there may be similar errors in other areas, and some errors appear in equations. The ftp site mentioned above also provides errata (some mistakes in equations that I had spotted plus more that I hadn't – perhaps some have still slipped through the net). The presentation style is rather patchy, probably due to the fact that the book evolved from lecture notes, but overall this is a very stimulating and educational read. I enjoyed it and recommend it to anyone who would like to get a glimpse of some unifying themes behind modelling methodology.

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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:

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

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A monthly newsletter (*The Challenger Wave*) which carries topical marine science news, and information about jobs, conferences, meetings, courses and seminars.

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

MEMBERSHIP SUBSCRIPTIONS

The subscription for 2003 costs £40 (£20.00 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, Southampton Oceanography Centre, Waterfront Campus, Empress Dock, Southampton SO14 3ZH, UK; Fax: +44(0)23-80-596149; Email: jxj@soc.soton.ac.uk

ADVICE TO AUTHORS

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

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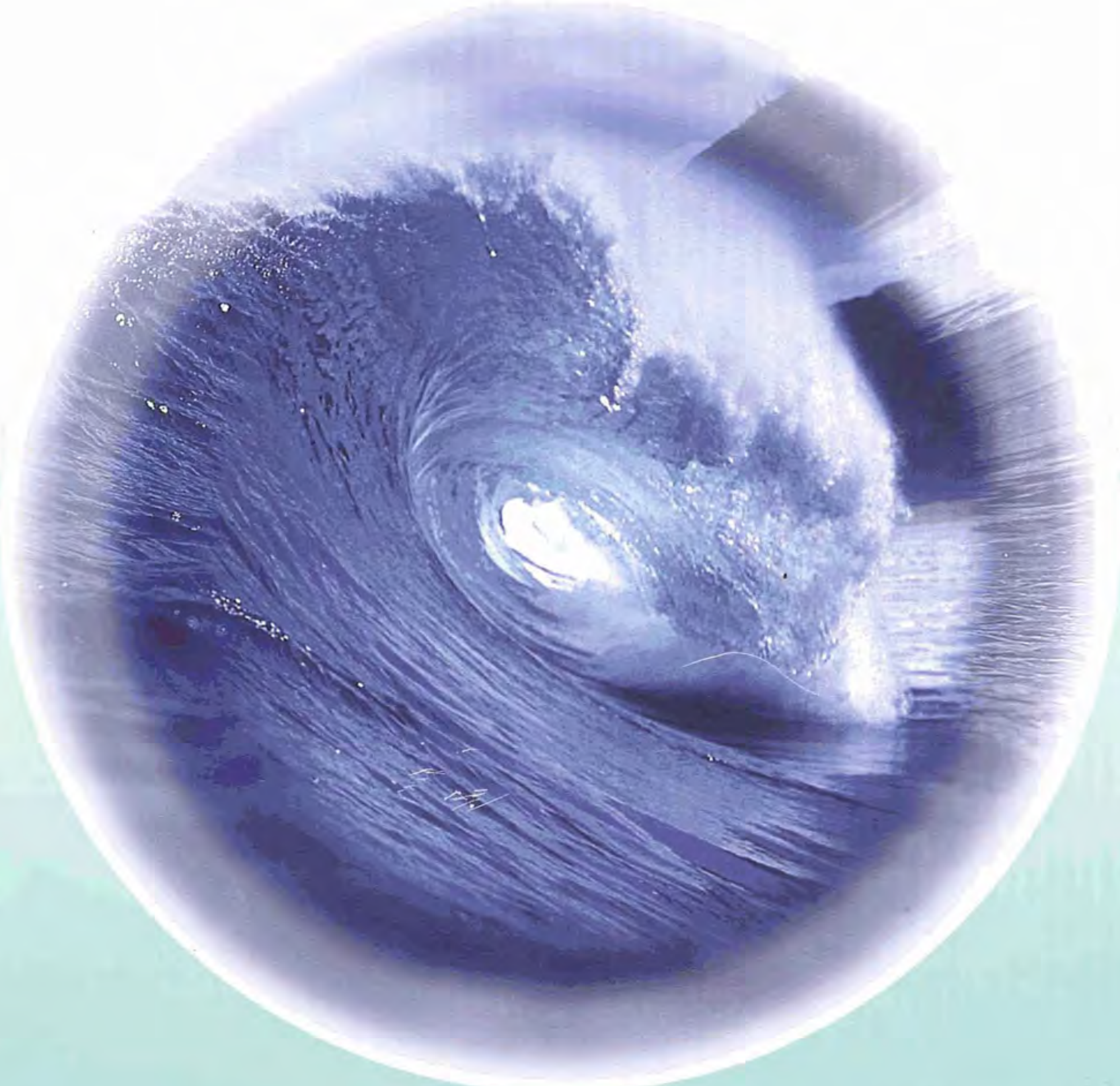
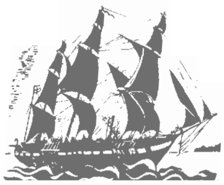
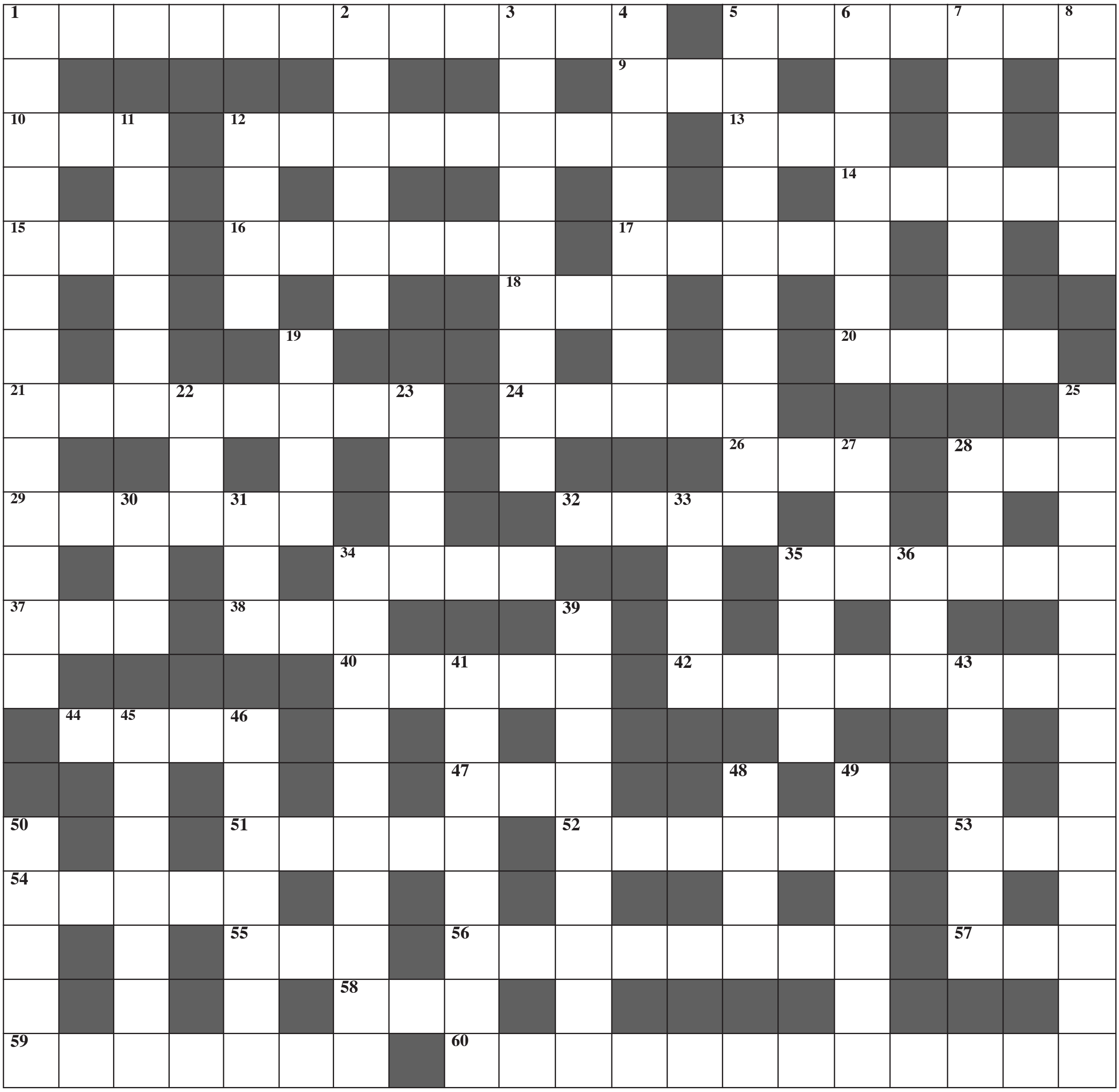


The Maritime Crossword Challenge



We hope you will enjoy our maritime crossword. Some of the clues are semi-cryptic, and all have a flavour of the ocean and/or marine science; a good many relate to stories that have appeared in *Ocean Challenge*. The first correct solution to be received by the Editor (address on inside back cover) will earn the sender a copy of *A Century of Discovery: Antarctic Exploration and the Southern Ocean* (more details opposite).



ACROSS

1. Subject of a famous print by Hokusai (not a tsunami) (3, 5, 4)
5. Melancholic friend of Darwin (and the new name for 5 Down) (7)
9. Stands for a new Scottish seat of learning (3)
10. The cause of depressing weather (3)
12. Festival time of year, when the Earth is approaching its closest to the Sun (8)
13. Purse-seine and gill are types of —— (3)
14. Describes a situation where water has flooded in, perhaps over East Anglian tidal flats (5)

15 and 50 Down. Where she might spy sea shells (3-5)

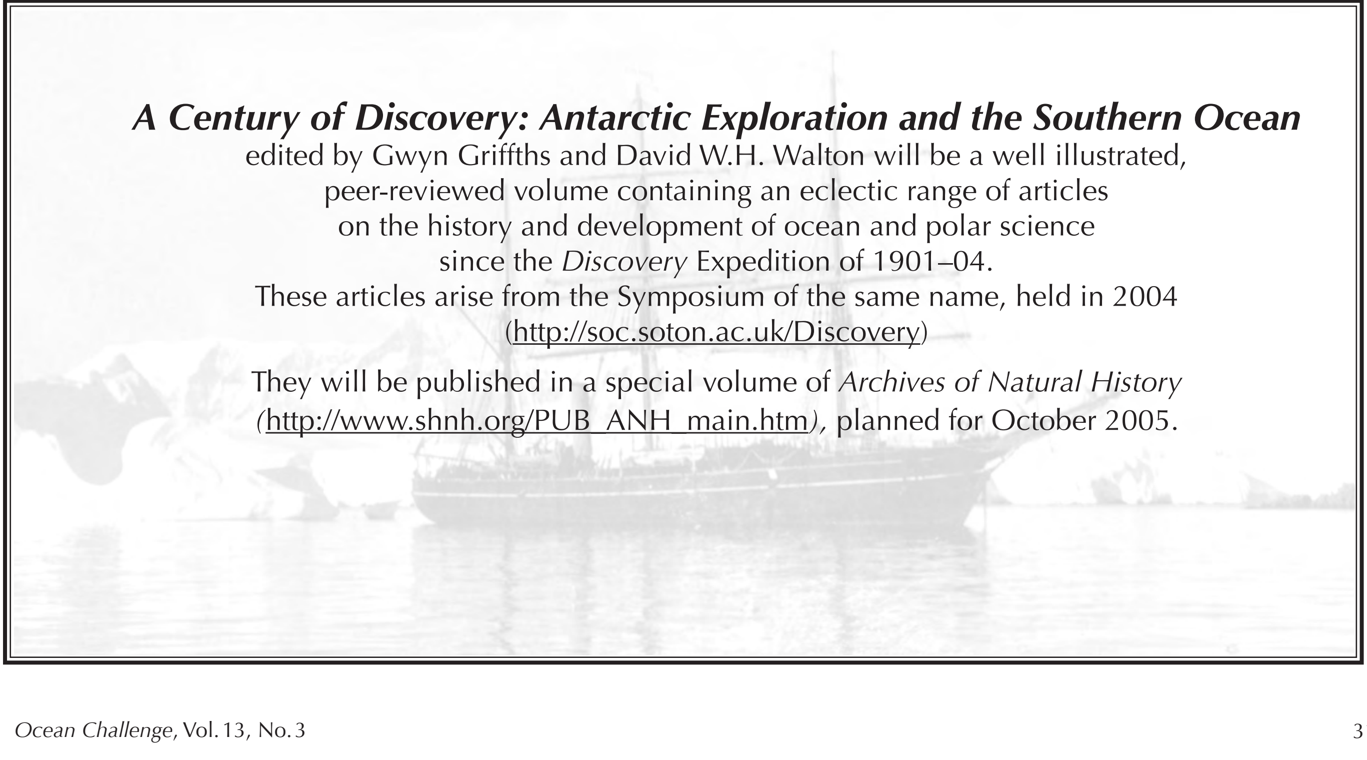
16. Missile named after a flying fish (6)
17. City off which sailing events were held at the Seoul Olympics (5)
18. Used in taramasalata (3)

20. A horseshoe —— is a very ancient animal. (4)
21. He fought with a warrior goddess over the Olympic city (8)
24. Used by the navy, fishermen, whales and dolphins (5)
26. Type of current often found where wave crests are at an angle to the beach (3)
28. Phytoplankton buried in sea-floor sediments eventually become this (3)
29. Until recently, most current meters were of this type (6)
32. Compass flower (4)
34. There are about 27 000 tonnes of this in seawater (4)
35. Found in association with buckets (6)
37. Every ship should have one (with multiple lives, not multiple tails) (3)
38 and 44, plus 41 Down. Part of the cryosphere that shares a name with a research vessel (3, 4, 3-5)
40. Prefix often used in marine science, meaning 'low' (5)
42. Jason sailed here in search of the Golden Fleece (5, 3)
44. See 38 Across.
47. Satellites (I and II) launched between 1991 and 1995 (3)
51. Part of an airborne droplet important for climate – or perhaps some bubbly chocolate bars (5)
52. Previously known as the Ellice Islands (6)
53. The — fish is the longest bony fish in the sea (3)
54. Long lines have thousands of these (5)
55. Successor to the Deep Sea Drilling Project (DSDP) (3)
56. A good sailor's tale should do this (7)
57. Type of waves found downstream of islands (3)
58. Wish you had a computer this good?? (3)
59. Land in Antarctica (and a Burgess anti-hero) (7)
60. The British one is fast declining (7, 5)

Please send your entries in to arrive by the end of March. The solution will appear in forthcoming issues of Challenger Wave *and* Ocean Challenge.

DOWN

1. For the last 30 years this has been sponsored by the makers of Cutty Sark whisky (4, 5, 4)
2. To 'swallow the —' is to retire from seafaring (6)
3. Bird of beauty and ill omen (9)
4. The —— Research Era might be just beginning (8)
5. An area of sea that's the end of the land no longer (10)
6. Sister ship of the *Britannic* (7)
7. *Porphyra*, used in laver bread and sushi, is a – — (3, 4)
8. Light sailing vessel built and rigged for racing (5)
11. They sing in the sound channel (6)
12. A Red Sea —— is full of brine (also archaic for 'ocean') (4)
19. Manifestation of vorticity (4)
22. It operates *Ariane* and 47 Across (3)
23. His searching Dad took a ride in the East Australian Current (4)
25. Water carried in this may subsequently pass though the Bering Straits (6, 7)
27. Young of 35 Down (3)
28. Type of spice for which the trademark is a sailing vessel (but now with a new image) (3)
30. A small one (3)
31. Food for 37 Across (3)
33. Sailor's mop (4)
34. Situation caused by the Earth turning (10)
35. Harbour, crabeater and hooded are types of —— (4)
36. Vessel for livestock, made of gopher wood and 300 cubits long (3)
39. The lot of a little cabin boy (3, 6)
41. See 38 Across
43. Fish learn to do this together (6)
45. Management-speak for being part of the crew (7)
46. One of the first undulating underwater vehicles – sounds like child's play! (3-4)
48. Mermaids' pillows might be made of this, tho' it's a bit hard! (4)
49. After 'Sailing by', the —— – Kintyre often comes between Colwyn Bay and Cape Wrath (4, 2)
50. See 15 Across (5)



Book Review

Revolutions in the Earth: James Hutton and the True Age of the World *by* Stephen Baxter (2003). Weidenfeld and Nicolson, 245pp. £16.99 (hard cover, (ISBN 0-297-82957-0).

It's always the same … as soon as one person writes a book on an interesting subject, another one appears. So you stand there in the bookshop for half-an-hour wondering which of the two might be the better. Deborah Cadbury, for example, wrote a marvellous book called *The Dinosaur Hunters* (the story of Mary Anning, Gideon Mantell and Richard Owen)* and about the same time Brook Hartzog released a similar book. And so it is again. Both Stephen Baxter and Jack Repcheck have written the James Hutton story (Repcheck's is the *The Man Who Found Time: James Hutton and the Discovery of the Earth's Antiquity*). I bought the one by Baxter, an ex-Cambridge mathematician but now an author, interestingly, of mainly science(-based) fiction.

Rocks, time, eternity; these, together with intellectual pursuit, farming and the Scottish Enlightenment, are the themes of the book. This is the little-known story of James Hutton, a man who laid the lowermost foundation stones of geological science as we know it today, and who established a framework within which other scientists of the day could develop their ideas about geology and natural history. So often overlooked by us in favour of Charles Lyell (who was born the same year that Hutton died, 1726), Hutton was a self-taught farmer, a man with a medical training, and an enthusiastic geologist. Living as he did at the beginning of the Enlightenment in Edinburgh, close to a time when there was brand new Newtonian physics, but only rudimentary chemistry, biology or indeed geology, Hutton occupies a period when there was authentic thought and discussion about the nature of the real world. Remember, too, that Hutton was born only 70 years after Bishop Usher had asserted that the world was just 6000 years old, and this notion still pervaded society's view of Earth history. Hutton lived alongside many now famous Scottish scientists; indeed many of them were his friends – Erasmus Darwin, James Watt, Joseph Black and Adam Smith. Between them, these brilliant men would make spectacular contributions not only to geology, but also agriculture (another of Hutton's passions), philosophy, steam engines and military tactics.

**The Dinosaur Hunters: A True Story of Scientific Rivalry and the Discovery of the Prehistoric World* by Deborah Cadbury, published by HarperCollins.

Baxter attempts to provide an insight into Hutton the man, as well as to show his personal mental journey as his geological ideas developed, and it is for this reason that I bought the book. Hutton trained originally as a medic, eventually completing his education in Paris. It seems that at this time he began to attend lectures and take an interest in the embryonic science of geology. By the time he returned to Edinburgh, Hutton had lost interest in medicine and begun dabbling in chemistry, eventually becoming a partner in a business making sal ammoniac, a salt used for dyeing. Then, catastrophe struck; Hutton had to leave Edinburgh due to severe personal circumstances – an illegitimate child it would seem. He moved to Slighhouses in Berwickshire, a small farmstead where he worked the land for some 20 years. It is here, while ploughing the harsh soils and realizing that soils are produced by the weathering of rocks, that he began to formulate his geological ideas. A bachelor, he read extensively and also took the opportunity to tour parts of the country, often with his learned friends. Hutton returned to Edinburgh life in 1767, abuzz with his new theories of the Earth. Yet it was to be 18 years before he presented his theories to the Royal Society of Edinburgh (of which he was a founding member) and another nine before he put pen to paper and published his two-volume masterpiece *Theory of the Earth with Proofs and Illustrations*, and thrillingly declared of the Earth that 'we find no vestige of a beginning, no prospect of an end'.

Baxter describes the response of Hutton's contemporaries: as one might well imagine, as well as support he received a plethora of abuse; some contemporaries seem to have gone to extraordinary lengths to try to destroy Hutton. Hutton was not (for his day) a modern scientist, nor a professional academic, which is why his ideas may be seen as all more the remarkable. Rocks, time, eternity – Hutton had most certainly hit upon a new way to view geological history, a new view of Earth processes and a new and contentious view of geological time.

Baxter's description of Hutton gives me the feeling that Hutton was mid-way up the first division whilst those around him played for Manchester United. Although many were his friends, and although he was fired by a deep enthusiasm, Hutton never really made it to the top. Like Gideon Mantell, he was up against the establishment, but unlike Mantell he had a good and life-long friend in John Playfair. But eventually it is Playfair, in his own biography of Hutton, who puts his finger on it in 1803: '[Hutton's papers] do not afford so much information as might be wished'. For all his efforts, it seems that Hutton's weakness was that he was bloomin' awful at writing (although we must remember that geology was a new science, so vocabulary was a problem). But perhaps that is a useful way in which to view Hutton: an intelligent man, and one with a practical knowledge of the Earth, an itinerant thinker, someone who came up with some profound ideas and made an outcrop near Edinburgh famous (Siccar Point – well worth a visit), but one who was never able to successfully organize and communicate his ideas.

For these reasons alone, Hutton's impact, important as it is, has long since been obscured by the fog of time. But that, perhaps, that is why Baxter's book is such a joy to read

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