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SCOPE AND AIMS

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

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

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The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

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Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references. If at all possible, they should be well illustrated. Copy may be sent electronically.

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Message from the Editor

Welcome to another issue of *Ocean Challenge*. This is the first since the special European number, which contained articles by authors from across Europe, and was sent to selected MPs, MEPs and European decision-makers, as well as to members of other European marine science societies. This was felt to be a valuable contribution to increasing awareness of the importance of the ocean, at a time when marine science, and marine matters generally, are coming to the fore politically, both in Britain (where the Marine Bill is at last making headway) and Europe as a whole, for which a new European Maritime Policy is on the horizon.

In this issue, the first feature article is by Tim Jickells, on the topic for which he was awarded the Challenger Medal at the 2006 Marine Science conference in Oban, and – to whet your appetite for next year's event in Bangor – there are some reminiscences from Oban, and suggestions which may be of interest to the organizers of the Bangor event. Because of the European Issue, this is our first chance to publish a tribute to Sylvia Harvey, who was an invaluable asset to the Challenger Society over the course of three decades.

The other two feature articles are about the *Scylla* (the first vessel to be purposely 'converted' to a reef in northern Europe), and about HMAP – History of Marine Animal Populations. The HMAP project is part of the Census of Marine Life (CoML), and the work of EuroCoMLis also described in this issue. On the technology side, we have news of a holographic camera that may facilitate investigations of planktonic organisms, particularly fragile gelatinous animals.

Angela Colling

News and Views

The Southern Ocean CO_2 sink may be weakening – and is more complicated than we thought

The rate at which atmospheric concentrations of CO_2 are rising is currently only half what would be expected on the basis of its rate of addition through human activity. This is because of large CO_2 sinks on land and in the ocean – the largest marine sink is widely believed to be the Southern Ocean, which currently accounts for perhaps 15% of the CO_2 taken up by the ocean – though this value is vigorously disputed. At any one place, the strength of the sink or source depends on the balance between the amount of CO_2 outgassed and that taken up by the ocean, including that contributing to the 'biological pump'– carbon in organic debris (dead phytoplankton, faecal pellets etc.) which sinks down into the deep ocean, and is buried and so removed from the carbon cycle.

Stronger winds mean more outgassing

A recent paper published in *Science* (22 June 2007) by Corinne Le Quéré and colleagues warns that the efficiency of the Southern Ocean sink is declining. On the basis of observations and inverse modelling, the authors estimate that between 1981 and 2004, the strength of the sink declined by 80 Mt C yr^{-1} per decade, relative to what would have been expected given the rate of addition of anthropogenic CO_2 to the atmosphere.

The authors show that the decline in the strength of the sink reflects not a decrease in CO_2 uptake, but an increase in outgassing of CO_2, resulting from more vigorous mixing and upwelling. The increased mixing/upwelling is driven by increased wind strength, which itself seems to be anthropogenic. Observations suggest that stronger winds could result from depletion of stratospheric ozone, and models indicate that changes in sea-surface temperature gradients, brought about by global warming, are also playing a part.

The implications of this work are that as atmospheric CO_2 concentrations continue to rise, the proportion of emissions that will be taken up by the Southern Ocean (and hence the ocean as a whole) may well decrease, especially if wind strength in the Southern Ocean continues to increase (as climate models predict). Furthermore, in the long term (centuries), the level at which atmospheric CO_2 concentrations eventually stabilize could be higher than has so far been estimated.

Upwelling faster (and more interesting)

Cold deep water (carrying dissolved CO_2) sinks at high northern latitudes as a result of vigorous mixing over all/much of the water column. Hundreds of years later, it comes to the surface again in the Southern Ocean in the vicinity of the Antarctic Circumpolar Current (ACC), at what is often referred to as the Antarctic Divergence (either side of which sinking occurs). This rising water is often envisaged as being carried in mesoscale eddies along the isopycnals (density surfaces) that slope rather steeply up to the south at mid-depths in the ACC. According to this scenario, only near the surface is wind-driven turbulent mixing (across isopycnals) thought to play a part in bringing the water into contact with the atmosphere once more. However, another (longer standing) view is that the upwelling is mostly driven by turbulent mixing below the permanent thermocline, often as a result of breaking internal waves, and especially in the vicinity of marked bottom topography.

The complexity of the physical processes governing the rates at which upwelling/mixing occur, and hence the rate of outgassing of CO_2, is highlighted in a recent *Nature* paper (10 May 2007). To quantify rates of mixing/upwelling, Alberto Naveira Garabato and colleagues exploited a natural tracer, primordial helium (^{3}He) produced by hydrothermal vents on the East Pacific Rise. ^{3}He carried south in the eastern Pacific enters the ACC west of Drake Passage, downstream of which the flow interacts strongly with the topography of the Scotia Arc.

Dispersion rates of ^{3}He in this part of the ACC indicate rapid upwelling along density surfaces and intense mixing across them, both at rates an order of magnitude greater than those implicit in models of the average overturning circulation in the Southern Ocean. This suggests that wind mixing at the surface may drive not only mesoscale eddy activity but also internal waves and turbulent mixing – providing a more direct route to the surface – in regions like the Scotia Arc. To quote from the article, it seems that: '... deep-water pathways along and across density surfaces intensify and intertwine as the ACC flows over complex ocean floor topography, giving rise to a short circuit of the overturning circulation in these regions.'

Biological pump weaker ...

We could comfort ourselves by hoping that the biological pump might work harder in a world with a more CO_2-rich atmosphere. However, the biological pump may weaken in the future in response to climate change and/or ocean acidification. Furthermore, according to Andrew Yool and colleagues writing in *Nature* (21 June 2007), the efficiency of the biological pump may have been over-estimated.

For 20 years, the amount of organic debris sinking into the deep ocean has been estimated indirectly using the *f*-ratio – the ratio of 'new' primary production (that supported by nitrate (NO_3^-) brought up in nutrient-rich water upwelled from below) and total primary production ('new' plus that supported by 'recycled' ammonium (NH_4^-) produced by decomposition of plankton in surface waters). The *f*-ratio has been used extensively to extrapolate from small-scale experimental results to large-scale estimates of the strength of the oceanic biological pump.

NO_3- is released at depth through decomposition of organic material sinking from surface waters. It is also produced from NH_4^- through nitrification by certain bacteria. It has recently been shown that nitrification – thought to be insignificant in surface waters – in fact occurs throughout the water column. With this in mind, Yool and colleagues used data from around the world in a 20-year run of a global biogeochemical model. They found that throughout much of the ocean a substantial fraction of the NO_3^- taken up in primary production is not upwelled but results from near-surface nitrification. Globally, it seems that nitrification accounts for about half the nitrate used by phytoplankton.

... and rather patchy

Estimates of the strength of the global oceanic biological pump depend on the large-scale distribution of primary productivity. However, the presence of islands increases primary productivity locally (partly because they supply iron to the surface ocean); and on the smaller scale, it has long been appeciated that primary productivity is higher around icebergs, as a result of the upwelling they generate. It has now been discovered that they enhance the flux of carbon to the deep ocean in another way, by fertilizing surrounding waters.

Ice that breaks off from the Antarctic ice-shelf to form icebergs contains terrestrial material – ground rock and dissolved nutrients – that are released as the icebergs melt. The bergs thus act like 'mobile estuaries', distributing nutrients which elsewhere would be supplied by rivers. Around an iceberg, the biological pump is enhanced out to a radius of >3 km, and perhaps 40% of the area of the Weddell Sea is affected in this way.

In the vicinity of icebergs, diatoms, krill and fish flourish, attracting seabirds and penguins which take up residence on top (their guano presumably contributing to the carbon sink). Explorations using

an ROV also found animals in the underwater caves in the undersides of the icebergs. (See K.L Smith *et al.*, *Science Express* website, 21 June 2007.)

The biggest extinction ever ...

... occurred at the end of the Permian, some 251 million years ago, when over 99% of the species then living were extinguished. An article in a recent *Nature* by Nick Lane, under the somewhat scary title: 'Reading the Book of Death' (12 July 2007, p.122) tells the full story better than you could expect from these columns. In brief, he focusses on differences between 'species that died and those that survived', and he lists possible causes, ranging from absence of an ozone layer, through lack of atmospheric oxygen, to meteorites and volcanic eruptions, notably the eruptions that gave rise to the expanses of basalt known as the Siberian Traps.

In the late 1980s, Robert Berner showed that, during the Carboniferous, oxygen concentrations were some 30% greater than at present. However, there is evidence that by the end of the Permian and early Triassic, atmospheric oxygen concentrations had fallen dramatically to little more than 13%. The possibility favoured by Lane is that there was a 'dearth of atmospheric oxygen' plus a lack of dissolved oxygen in the sea. This in turn led to an excess of H_2S in the oceans, produced by reduction of sulphate ions in sediments, whereby – so the argument runs – an oxygen-poor but H_2S-rich water layer could rise toward the surface asphyxiating organisms there, even venting poisonous H_2S to the atmosphere. At present, H_2S-rich waters only occur deep in the Black Sea, but there is evidence that they were widespread in the later Permian (the so-called 'Strangelove Ocean'). As the author puts it: 'Head for the hills and there's no oxygen, stay on the shore and you risk breathing H_2S'. If there were global warming as well, the situation would be worsened, because gases are less soluble in warm water than in cold – the palaeontologist Richard Twitchet of Plymouth University believes that such a situation could have developed in the late Permian.

A clue to possible causes is a series of spikes in the carbon isotope record, as represented by abrupt increases in the ratio of lighter carbon ^{12}C to heavier ^{13}C, which are too big to be explained by changes in the total amount of biomass – and that tends to be enriched in ^{12}C anyway. A plausible explanation is bursts of methane from the deep ocean, though amounts of methane in hydrates would not be adequate to account for all the spikes. According to Jonathan Payne and colleagues at Harvard, sea-floor hydrates could account for one of the spikes, but reserves of methane could not be replenished quickly enough to account for them all.

On an entirely different track, Greg Retallack at Oregon University suggests that magma responsible for the Siberian Traps rose through coal measures, heating them and breaking down heavy hydrocarbons to methane. Although this 'thermogenic methane' is not as light as methane in hydrates, it is nonetheless light enough to explain the isotopic spikes.

Research by Peter Wagner and colleagues at the Chicago Museum of Natural History, suggests that life in the sea before the extinction was divided roughly 50:50 between simple marine systems, dominated by filter feeders such as crinoids, and more complex ecosystems in which larger numbers of species moved about and interacted. However, *after* the extinction, when life on Earth was able to regenerate, complex systems outnumbered simple ones by three to one, and that has remained much the same ever since, with 'patterns of biodiversity reflecting the extinction bottleneck that a few creatures squeezed through with fluttering gills'.

Nick Lane ends his account of the end-Permian extinction with these words: 'The genetic memory of those times is etched in our physiology – and in the living fabric of our world.'

Methane and the mystery hills

Scientists have long been puzzled by hundreds of dome-shaped submarine hills, up to 40 m high and several 100s of metres across, first discovered on the Beaufort Sea shelf, off northern Canada, in the 1940s. In many ways, the hills resemble pingos, dome-like features that are common in the Arctic, and other areas with permafrost. There are ~1400 pingos around the southern and eastern shores of the Beaufort Sea alone. Until recently, it was believed that the hills were pingos that had emerged on land but were submerged when sea-level rose after the last glacial period, 10 000 years ago.

However, a team of geologists from Monterey Aquarium Research Institute (MBARI) believe they know the hills' real origin. Methane gas, observed bubbling out of the tops of several hills is believed to originate from methane hydrates (a frozen mixture of gas and seawater) trapped 100s of metres down, below the impermeable permafrost layer. The area was flooded when sea-level rose after the last glacial period, and has since been gradually warmed by the overlying seawater (itself within a few degrees of freezing). As a result, the hydrates have decomposed, and the methane gas so released has moved laterally under the permafrost layer, collected and risen toward the surface, pushing the sediments upwards until they have been extruded out onto the sea floor, via faults or weak points in the permafrost layer.

The team's seismic investigations showed that the hills consist of a jumbled mixture of sediment and small nodules of freshwater ice, and ^{14}C dating of organic material in sediment at the crests of several hills confirmed that the sediment had been deposited before the last glacial period, and must have been pushed up from below.

Law and the Lomonosov Ridge

In a summer when Arctic sea-ice extent has fallen below the previous minimum of 2005, much has been made of Russia planting a flag on the Lomonosov Ridge at the North Pole. In fact no less than eight countries are keen to stake a claim on the sea-bed in the central Arctic Ocean. They are: Denmark, Norway, Sweden, Canada, Russia, Finland, Iceland and the United States.

Under the Law of the Sea, coastal states have rights to exploit the waters of their exclusive economic zones (EEZs), which extend 200 nautical miles (n.m.) from the coast, and they also have rights over the legal continental shelf, for the purposes of exploring and exploiting it. This legal continental shelf extends out to a distance of at least 200 n.m., regardless of whether or not the actual continental shelf is this wide. What's more, where there is a natural prolongation of the shelf beyond 200 n.n., the coastal state can claim out to a distance of 350 n.m., or 100 n.m. beyond the 2500 m isobath, depending on the nature and configuration of the continental margin. It is on this basis that Denmark (by virue of the Faroes) and (amazingly) Iceland laid claim to the Rockall Bank. Importantly, though, such claims can only be considered by the United Nations if the country concerned has signed *and* ratified the UN Convention on the Law of the Sea. Furthermore, the International Sea-Bed Authority would take part of any revenue derived from (say) oil extraction beyond the 200 n.m. limit, to be used for the benefit of countries which have no coastline.

The Lomonosov Ridge is a 'bank' of continental crust which stretches between the Siberian continental shelf and that off Canada and Greenland, and runs roughly parallel to the nearby Gakkel Ridge (a mid-ocean spreading ridge). Whether the Lomonosov Ridge can be considered an extension of the continental shelf is unclear, but the need to find out is proving to be a great incentive for multinational marine geological and geophysical research.

Difficult negotiations for the IWC and CITES – why conservation politics is the 'art of the possible'

Skirting around 'scientific whaling'

In May, the annual meeting of the International Whaling Commission in Anchorage, Alaska, was the forum for difficult negotations, particularly regarding 'scientific whaling'. The Commission adopted a resolution calling on Japan to suspend the 'lethal aspects' of its new programme in the Southern Ocean Whale Sanctuary; JARPA II has been given a special permit by the Japanese government – although the IWC noted that none of the goals of its predecessor, JARPA I, had yet been achieved. In JARPA II, the approved take of minke whales has been more than doubled, and and fin whales and humpback whales have been added to the list of targeted species.

The resolution relating to JARPA II was carried by 40 votes in favour, 2 against and 2 abstentions – but 27 countries did not participate, believing that submission of the proposal was not conducive to bridge-building within the Commission. For the same reason, Japan withdrew a proposed amendment and draft Resolution relating to its request for a whale quota to alleviate hardship suffered by four Japanese whaling communities that subsist on 'small-type coastal whaling'.

CITES follows IWC lead

In June, Japan again attempted to revive commercial whaling via a motion put forward at the 14th Convention on International Trade in Endangered Species (CITES), held in the Hague, Netherlands. Historically, CITES (which meets every three years) follows IWC advice on whale stocks, and this year the IWC passed a formal resolution intended to strengthen links between the two bodies.

The IWC maintains a global moratorium on commercial hunting, effectively banning international trade in whalemeat. The introduction of the moratorium in 1986 was supposed to be accompanied by a global IWC review of whale stocks. The review is a long way from completion, so at the CITES Convention, Japan asked for whale stocks to be re-evaluated (at Japan's expense): if such an assessment indicated that some international trade could be allowed, it would suggest that stocks were sufficiently robust to sustain some commercial hunting. Japan had some support, but not enough, and the meeting passed an amendment saying that CITES should not re-assess whale stocks while the commercial moratorium remained in place. A similar proposal on fin whales by Iceland was also defeated.

A two-thirds majority of the 171 member countries is required before a species can be included in a CITES Appendix. Appendix I consists of species for which trade is completely banned; Appendix II of species for which trade will be allowed under strict conditions; and species in Appendix III are included at the request of countries that need the cooperation of other countries to stamp out illegal exploitation. Lax enforcement and corruption mean that involvement of organized crime in animal trafficking is now at a level comparable with trafficking of drugs or people, or gun crime and money laundering. Sometimes, trade in endangered animals continues to be allowed if it is thought that a ban will result in more illicit trade and a greater threat to the population concerned.

Sawfish safer in seawater

CITES delegates agreed that six of the seven species of sawfish should be listed in Appendix I. Sawfish are a kind of large ray, and are named after their distinctive saw-like snouts or 'rostra' which are sold as curios. They are caught for their rostra and their fins. Sawfish tend to get entangled in nets and damage fishing gear, so when captured accidentally are often killed rather than released.

At Australiia's request, the freshwater sawfish was included in Appendix II, which allows international trade in live specimens to supply public aquaria.

Porbeagle and spiny dogfish are the EU's responsibility

Other elasmobranchs were not so lucky. The EU proposed that porbeagle shark and spiny dogfish (sold as huss) should be listed in Appendix II. Populations of both species have fallen dramatically in the North Atlantic – spiny dogfish have declined by 95% in the last 10 years. But the UN Food and Agriculture Organization considered that neither species met the necessary 'biological decline criteria'. There was a feeling that the problem could be better addressed by effective fisheries management by the EU itself. In the event, both motions achieved a majority in favour, but not the two-thirds majority needed.

Good news for European eels

On the other hand, the future of the European eel (*Anguilla anguilla)* looks brighter now that, from March 2009, it will be listed in Appendix II. Eels are consumed mostly in Europe and parts of East Asia, and are threatened by overexploitation and by degradation of rivers and estuaries. Since the 1970s, numbers of eels reaching European rivers after spawning in the Sargasso Sea are thought to have declined by ~90%.

Cardinalfish a 'valuable resource'

The US proposal that Banggai cardinalfish, which is collected for aquaria, should be listed under Appendix II. *Pterapogon kauderni* lives mainly in isolated populations around islands of the Banggai Archipelago, Indonesia. Between 2001 and 2004, 700 000–900 000 fish were traded annually. Mortality during collection, holding, and transport suggests that actual collection rates were almost certainly much more.

The other factors threatening the cardinalfish are those that threaten many reef fish: loss of habitat caused by destructive fishing/collecting practices (use of dynamite and cyanide); increased sedimentation as a result of land clearance and poor agricultural practices; and pollution. Unlike most other marine aquarium fish, *Pterapogon kauderni* is a paternal mouthbrooder, and rather than releasing thousands of eggs into the plankton, it produces relatively few (<90) eggs.

CITES delegates followed the advice of the IWMC (International Wildlife Management Consortium) World Conservation Trust, which felt that a ban on international trade could encourage illegal activities. It said that trade had been significantly reduced and was not threatening the survival of the species. The Indonesian government does not favour a ban, and regards the cardinalfish as a valuable resouce. In cooperation with NGOs and local communities, it is putting in place protective measures for this species, and working to ban destructive fishing measures generally. There are also experiments with captive-breeding.

Red and pink corals left unlisted

The US withdrew its proposal that the 26 species of red and pink corals (*Corallium* sp.) should be listed under Appendix II (hard corals have been listed for more than a decade). Although initially accepted, the proposal was rejected at the Plenary Session, after objections by some Mediterranean countries that had not been sufficiently consulted beforehand.

Red and pink corals are used in the making of jewellery and art. They are collected in the western Pacific and the Mediterranean, using highly destructive dredging that wipes out entire sea-bed communities. Some *Corallium* populations off the coasts of Italy, France and Spain are no longer commercially viable, while in the western Pacific they are being depleted within five years of discovery.

That so few marine species attained listed status suggests that CITES is not keen to become directly involved in management of marine resources. On the positive side, progress was made regarding rules for dealing with marine animals caught seaward of national jurisdiction, which were defined so as to be consistent with the UN Convention on the Law of the Sea.

Marine Bill on the horizon

Consultation on the Marine Bill White Paper closed on 8 June. There were nearly 300 individual responses from a wide range of interest groups and the public, and around 8000 postcards and letters in support of campaigns by non-government organizations. A summary of the responses is being published in September.

During the rest of 2007, Defra will be preparing a draft Marine Bill which will be published before introduction to Parliament (probably in early 2008) to allow time for pre-legislative scrutiny of the proposals, some of which are breaking completely new ground. Hopefully, inclusion of this extra stage will lead to a better Bill. The timing of the introduction of the final Bill to Parliament will depend on the Government's overall legislative programme and the availability of Parliamentary time.

Many people believe that integrated management of UK waters, and a more proactive approach to conservation and environmental management, are long overdue. Especially urgent is the need for fisheries to be managed using an ecosystem approach, as proposed by the White Paper.

Unfortunately, the approach to Marine Protected Areas set out in the White Paper is half-hearted – the Marine Conservation Society described it as 'apologetic', and so it is – there are phrases which suggest 'MPAs will be set up, as long as it does not cause any inconvenience'. If ecosystems and fish stocks are to be successfully protected, the balance needs to be the other way around.

At present, there is a kind of hand-waving about consultations benefitting from scientific expertise, but it is worryingly vague. It is not clear how expertise would be sought, and scientific advice is seen as just one of many possible inputs. One does not get the impression that sound scientific evidence is seen as an essential underpinning of policy decisions.

While on the subject of science, the wording of the relevant part of the White Paper strongly suggests that development of carbon capture and storage (CCS) means that we can stop worrying about greenhouse gases – despite the long time-scales needed to develop CCS techniques, and the inertia in the ocean/climate system. Climate change policies should not be built on the premise that CCS is a 'magic bullet!

Much of what is in the White Paper implies a need for greater investment in scientific research, particularly interdisciplinary coastal research and Integrated Coastal Zone Management, but there is no indication that this greater investment will be forthcoming. For example, a key part of the proposal is the setting up of a Marine Monitoring Organization MMO), which will rely on efficient sharing of data. Facilitation of data-sharing must be a good thing, but if the system is to work properly it will need to be properly funded. The Bill makes little or no mention of how MDIP (and MEDAG) – important for the functioning of the MMO – are to be funded at a level that would allow them to do the work required of them. *Eds*

After the Marias and the Josephs – how about Super Boffin?

Here is an idea that came to me in the middle of the night, after watching a TV programme about the plight of young albatrosses on the Galápagos, who are starving as a result of being filled up with plastic debris which their parents had mistaken for food.

The essence of the idea is that there should be a public competition, funded by a large company, or even a hedge fund billionaire, for which the prize would be a grant to support research into an important scientific problem. The problem chosen would need to involve topic(s) that the public could engage with. Plastic in the oceans seems a good candidate – its dangers to marine animals can be appreciated by even the most unscientific person, and there must be a variety of different ways of tackling it.

A number of responsible supermarket chains already invest in activitiies promoting sustainable management of resources – Waitrose, for example, are working with lobster fishermen (cf. p.6). Such activities are good publicity, and perhaps good value when you bear in mind that the average budget for producing a 30-second commercial in the UK is around £140 000.

The competition would be open to anyone, young or old, not just active researchers – good ideas thought up by non-scientists could be tried out with help from others with the necessary expertise. The ideal way to publicise and run the competition would be a short series of TV programmes; the first would set out the problem to be solved, the second would look at ideas that had been proposed, and then one or more would follow up development and trials of the best of the proposals.

If the programmes could involve viewer participation in some way, so much the better. One of the problems for science, and hence for science-funding, is that it is seen as separate and different from everyday culture. The more that scientific research can be shown to be an intergral part of modern life, undertaken by normal people, the better.

Even if none of the ideas put forward had any serious merit, at the very least the problems that plastic is causing for the global environment would have been further brought to public atention. But it does seem that, in theory at least, this man-made problem can be solved by man – unlike climate change (whatever the 2007 Reith Lecturer, Professor Jeffrey Sachs, might believe). *Ed*

Post Script Since writing this piece, I've read that Richard Branson has offered a prize for cost-effective technology to remove CO_2 from the atmosphere. Perhaps this is an idea whose time has come!

The smoking ban is bad for you – if you live in the sea

Since the smoking ban came into force on 1 July 2007, many more cigarette ends will have been discarded on our streets, watersides and beaches, and it is likely that a good proportion of these will find their way to the sea. Cigarette filters are designed to absorb the tar and toxic chemicals found in cigarettes; each cigarette end can contain up to 60 known cancer-causing chemicals, including arsenic, formaldehyde, chromium and lead, plus 1400 other potentially harmful chemical additives. If cigarette ends are ingested, these chemicals can enter the blood stream, leading to irritation of the gut; nicotine has been shown to be lethal to species of fish, crustaceans and other aquatic organisms. Cigarette ends have been found in the stomachs of many different marine species, including whales, dolphins, sea birds and turtles.

Cigarette ends cause harm even if they are not ingested, because the noxious chemicals leak into the surrounding seawater. A study by Kathleen Register, founder and executive director of Clean Virginia Waterways in the USA, has estimated that one cigarette end can contaminate and pollute up to eight litres of water – a worrying thought considering that worldwide some 4.5 trillion cigarette ends are discarded as litter every year – one new cigarette end for every 90 m^3 of ocean each year, with each lasting up to five years.

... and so are balloons

The Marine Conservation Society and the Plymouth-based National Marine Aquarium are calling on local authorities to ban balloon races. Balloons often end up in the sea, putting a variety of species at risk. Turtles that feed on gelatinous animals such as jellyfish easily mistake balloons and plastic bags floating at the surface for food. Dolphins, whales and many species of seabird and fish can also fall foul of balloons through entanglement or suffocation.

UK supermarkets improve their contribution to sustainable fishing

Over the last decade, more and more independent high street fishmongers have closed down, and 85% (by volume) of chilled and frozen fish is now sold through supermarkets. The policies used by supermarkets to source their fish have therefore become increasingly influential in the struggle to bring about more sustainable fishing practices.

For several years, both Greenpeace and the Marine Conservation Society (MCS) have been running campaigns to make supermarkets and consumers alike more aware of the need to consider the sustainability of exploited fish stocks. Their campaigns have included surveys of the species of fish available in supermarkets and supermarket policies for sourcing fish. Both organizations carried out UK surveys in 2005; the MCS carried out UK surveys in 2006 and 2007, while Greenpeace have been undertaking surveys in Europe and elsewhere.

Over the last few years, a number of supermarkets have removed from sale ('delisted') many kinds of fish from overexploited stocks, and the sale of fish products from sustainable sources has grown in response to demand from informed consumers. The surveys have shown that supermarkets now sell a wider range of fish, allowing consumers to broaden their tastes and so take the pressure off the most heavily exploited species. Nevertheless, 60–80% of fish sales are still of cod, haddock and tuna, warm-water and cold-water prawns.

Some supermarkets have developed 'decision trees' as part of their procurement policies. These tables or flow diagrams allow supermarkets to demonstrate how they decide which fisheries to source from, taking into account both environmental factors and economic factors (e.g. alternative species available, health of stocks, fishing methods, traceability, market significance and social impacts). In the UK, the four biggest supermarkets**,** Sainsbury's, ASDA, Tesco and Morrisons, all use decision trees, some of which were developed with the help of their main suppliers.

In March, as part of its continuing Consumer Awareness campaign, the MCS published its latest Sustainable Supermarket League Table. This ranks the main UK supermarkets on the basis of criteria such as the policies that shape their buying decisions and the sustainability of stocks from which they source their fish. The survey also addresses aspects such as details of the supermarket's environmental policy and whether it is publicly available.

The 2006 and 2007 MCS League Tables are as follows :

	2006	**2007**
1	M&S	M&S and Waitrose
2	Waitrose	
3	Sainsbury's	Tesco
4	Tesco	Sainsbury's
5	Co-op	ASDA
6	Morrisons	Morrisons
7	ASDSA	Co-op
8	Somerfield	Iceland
9	Iceland	

(Lidl did not respond to the survey in 2006 and were not contacted in 2007. Somerfield did not respond to the 2007 survey.)

At the top of the League, Waitrose and Marks and Spencer are both strongly committed to sustainability and have a reputation for only selling fish from responsibly managed fisheries. As Marks and Spencer sell only M&S branded prducts, they can apply their sustainability criteria to all fish they sell, even if it is an ingredient in a dish. Currently, they are the only retailer taking responsibility for all seafood sold in their stores.

M&S, Waitrose and Sainsbury's lead the way in terms of the policies they use to source their fish sustainably. M&S has also announced that all fish sold will be certified by the Marine Stewardship Council, MSC (or equivalent) by 2012. Since last year's survey Sainsbury's has continued to develop its policy for both wild-caught and farmed fish.

Until recently, ASDA was lagging well behind, and was the last UK supermarket to stop selling North Sea cod. However, it has now greatly improved its fish-sourcing policy, and has announced that within the next three to five years it will only stock wild-caught fresh and frozen fish from fisheries that meet the environmental standard for sustainable and well-managed fisheries laid down by the MSC.

Fish no longer sold

Fish no longer sold by some or all of the supermarkets include wild Atlantic salmon, bluefin and big-eye tuna, monkfish, orange roughy and other deep-sea fish. A number of fish identified as being from unsustainable sources have been removed from sale by various supermarkets since the 2006 MCS survey. For example, as well as North Sea cod, ASDA has discontinued sale of swordfish and European monkfish; Waitrose has delisted thornback ray; Morrisons has delisted brill, ling, European hake, grey mullet, grouper, redfish, dogfish (huss), conger eel, and megrim; Tesco has delisted wild Atlantic halibut and monkfish from overfished stocks; Co-op delisted wild Atlantic halibut and is currently working on the replacement of wild warm-water prawns with a farmed alternative.

Skates and rays, previously sold widely in UK supermarkets, have now been delisted by ASDA, the Co-op, Sainsbury's, and Somerfield. In addition, Morrisons, Tesco and Waitrose delisted all skate species except starry, spotted and cuckoo rays. MCS is working with industry, and with Waitrose specifically, to address the issue of sustainability in skate and ray fisheries. Waitrose is also funding the production and distribution of a skate and ray identification card, including information on minimum and maximum landing sizes, in order to help fishermen, anglers and producers avoid the most vulnerable/overfished species.

However, some supermarkets are still selling overexploited species such as marlin, Atlantic cod from overfished stocks such as the Eastern Baltic, plaice from the North Sea, warm-water prawns trawled in the wild, and Dover sole from the western Channel.

Fishing methods

Increasingly, supermarkets are paying attention to the way in which fish have been caught, as well as the species. For example, Waitrose does not sell fish caught by drift-netting, pair-trawling and dredging, and aims to phase out sales of fish caught by beam-trawling by the end of 2007. M&S does not sell fish caught by high-seas drift-netting, reef netting or deep-water trawling. Iceland is reducing the number of beam-trawled plaice products it sells.

M&S have phased out a lot of beam-trawled species, and between 2004 and August 2006 reduced the percentage of beam-trawled flatfish it purchases from 55% to 35% (the beam trawlers still in use are relatively small and therefore use less fuel); a further reduction to 25% beam-trawled products is planned in 2007 – only Dover sole remains, and M&S launched a project in August

2006 to look for alternative catching methods and want to move to a full ban. In December 2006, Iceland cut the amount of beam-trawled seafood it sells by 50%. Morrisons has removed all beam-trawled products from its fresh fish ranges and have only one remaining product containing beam-trawled plaice.

In the last two years there have been significant movements in supermarket attitudes to fishing methods for Atlantic cod and haddock. Both smoked and chilled (uncoated) cod and haddock fillets sold by M&S come from fish line-caught in Icelandic waters, and M&S intends to switch the remaining cod and haddock in its other ranges to 100% line-caught by 2008. Sainsbury's announced in April 2007 that they will only sell line-caught fresh cod and haddock, primarily from Iceland but also from Norway (as yet this policy doesn't cover frozen fish). Waitrose plans to have its entire range of cod and haddock caught by long-lines by the end of 2007.

Transparency and labelling

Transparency – supermarkets being open and honest about the seafood they sell – is a key issue in the development of sustainable fishing practices. This means supermarkets being willing to reveal the details of their procurement policies, and clearly telling customers what the fish on sale are, where they were caught, and how.

Seafood labelling in the UK has greatly improved in recent years, and is generally better than in other European countries. Fish Labelling Regulations 2003 (introduced to enforce EU regulations laid down in 2001) state that labelling should include the commercial (common) name of the fish and the name of the FAO catch area(s) where it was caught (e.g. North-East Atlantic for the North Sea or irish Sea). Latin species names (e.g. *Salmo salar* for Atlantic salmon) are not compulsory, but if they are used they should be used along with the common name, not instead of it.

Catch method is increasingly being supplied for fish caught by more sustainable methods, e.g. line-caught Icelandic cod or pole-and-line caught Pacific yellowfin tuna. Waitrose provides further details on the origin of its seafood on its website. Morrisons has made significant improvements to its labelling of counter fish, and in October 2006 was the first supermarket to include the Latin name on its fish counter labels.

The MCS would like to see all fish products labelled with the common and scientific name of the fish, the specific area where it was caught, the method of capture, and an indication of its sustainability, allowing the consumer to make fully informed decisions about the seafood they buy.

Farmed fish

What of farmed fish, which account for approximately a third of UK 'sustainable' fish production and have undergone a massive growth over the last 50 years? Unfortunately, although aquaculture is often seen as taking the pressure off wild fish, many kinds of aquaculture exacerbate the pressures placed on the over-exploited marine ecosystem. The primary reason for this is that – with the exception of freshwater fish and some shellfish – farmed aquatic animals are carnivorous and are fed wild fish in the form of fishmeal and fish oil. Over three tonnes of wild fish are needed to produce one tonne of salmon, for example. Industrial fishing for small fish like sandeels and anchovies for use in fishmeal has caused massive disruption to marine food webs. It has almost certainly played a part in the decline in cod, seals and seabirds in the North Sea.

Aquaculture enterprises can be a source of effluent, as well as chemicals, antibiotics and vaccines, bacteria, viruses and alien species. Finally, in developing countries many aquaculture operations have negative impacts on local people, including loss of land and access to fishing grounds, and poor employee rights.

However, some supermarkets (notably Waitrose) now have good sustainable aquaculture polices in place and are working to improve the sustainability of their farmed seafood. A number of UK supermarkets have sustainability requirements for production of UK farmed fish such as salmon, but few have such stringent requirements for fish farmed outside the UK. Supermarkets have yet to develop policies for imported farmed fish, or to seriously consider the sustainability of the food of farmed carnivorous fish, either within the UK or elsewhere.

The farmed fish or shellfish with the highest environmental standards are those certified as organic or as 'Freedom Food'. The main organic certifier is the Soil Association; the Freedom Food labelling scheme also addresses welfare, including health, feeding, handling and management, transport and slaughter. For more on farmed fish see: www.fishonline.org

In Europe

Of course, UK consumers are only part of the European market for fish, and Greenpeace have been working in France and Austria. The biggest fish trader in Europe (and the third largest grocery retailer globally) is the supermarket chain Metro. In December 2006, Metro stopped selling northern or southern bluefin tuna or bigeye tuna in their Austrian shops. The Italian retail chain COOP stopped selling bluefin tuna in April 2007.

Some of the most threatened species have been delisted by various supermarkets around Europe. For example, when the Greenpeace campaign started in Austria in May 2006, shark products were sold in six Austrian retail/wholesale chains. All of them had delisted these products by spring 2007.

The Austrian chain Hofer (a subsidiary of Aldi), now obtains the plaice sold in Austria from the only FAO sub-area in which ICES has ascertained that the population is fully reproducing and where sustainable fishing practices are in use. In Austria, the discount chain Lidl removed plaice from its product range entirely. The Swedish supermarket chain ICA stopped selling frozen Eastern Baltic cod. Another key threatened species that has been delisted around Europe is swordfish.

Various deep-sea species are also being delisted: Groupe Casino stopped selling blue ling and roundnose grenadier, and the Austrian supermarket chain MPreis no longer sells any deep-sea species.

A number of Austrian supermarkets have good labelling. For example, the chain Norma has developed a 'transparent fisheries' logo which gives the Latin species name, catch area, catch method and catch date on each of its frozen products, enabling full traceability of the product back to the ship.

Our thanks to both the MCS and Greenpeace for the information used in this article. See also www.fishonline.org.

A new kind of Atlas

Atlas of the world ocean – for a sustainable policy for the planet has been produced by Nausicaä (Centre National de la Mer, Bologne), published by Editions Autrement. The cartography of this unusual atlas is by Cécile Marin and the text is by Jean-Michel Cousteau and Philippe Vallette, General Manager of Nausicaä.

The aim of the 80-page atlas is to show how human beings are linked to the ocean, with the emphasis on the economic and social needs of human communities. These links are illustrated by around 80 maps and graphics which highlight the need for global, long-term management of the planet.

The Atlas is currently only available in French, but it will probably be translated into English next year. It costs 15€ plus postage of around 6€, and it can be obtained from Nausicaä: Tel. 0033-(0)3.21-30-99-99; info@nausicaaa.fr.

The European Census of Marine Life (EuroCoML)

Bhavani Narayanaswamy

The Census of Marine Life is a ten-year initiative involving an ever increasing global network of researchers with the overarching aim of assessing and explaining the abundance, diversity and distribution of life in the oceans – past, present and future. There are currently 14 CoML field projects attempting to answer these questions, as well as research being undertaken to look at the history of marine animal populations. Historical data combined with results from the field projects are being used by researchers trying to predict what will live in the world's oceans in the future. (For more information on CoML see *Ocean Challenge*, Vol.15, No.1, and for more on the History of Marine Animal Populations project, HMAP, see this issue, pp.26–31.)

In order to cover as wide an area as possible, CoML have implemented National and Regional Implementation Committees (NRICs). The European Census of Marine Life (EuroCoML), funded by the Stavros S. Niarchos Foundation and Argyll and Islands Enterprise, is represented by one of 13 CoML NRICs (see map below). These committees began by assessing what is known, unknown and unknowable of the marine biodiversity in 'their' areas. The aim of all NRICs is to prioritize CoML's objectives and projects and, importantly, to help build national and regional programmes that will address the environmental and societal needs of their countries. The European NRIC, chaired by Graham Shimmield (Scottish Assocation for Marine Science), covers the largest area of all NRICs, as it ranges from Greenland through to eastern Russia, and from the Arctic to the Mediterranean.

EuroCoML has four main aims:

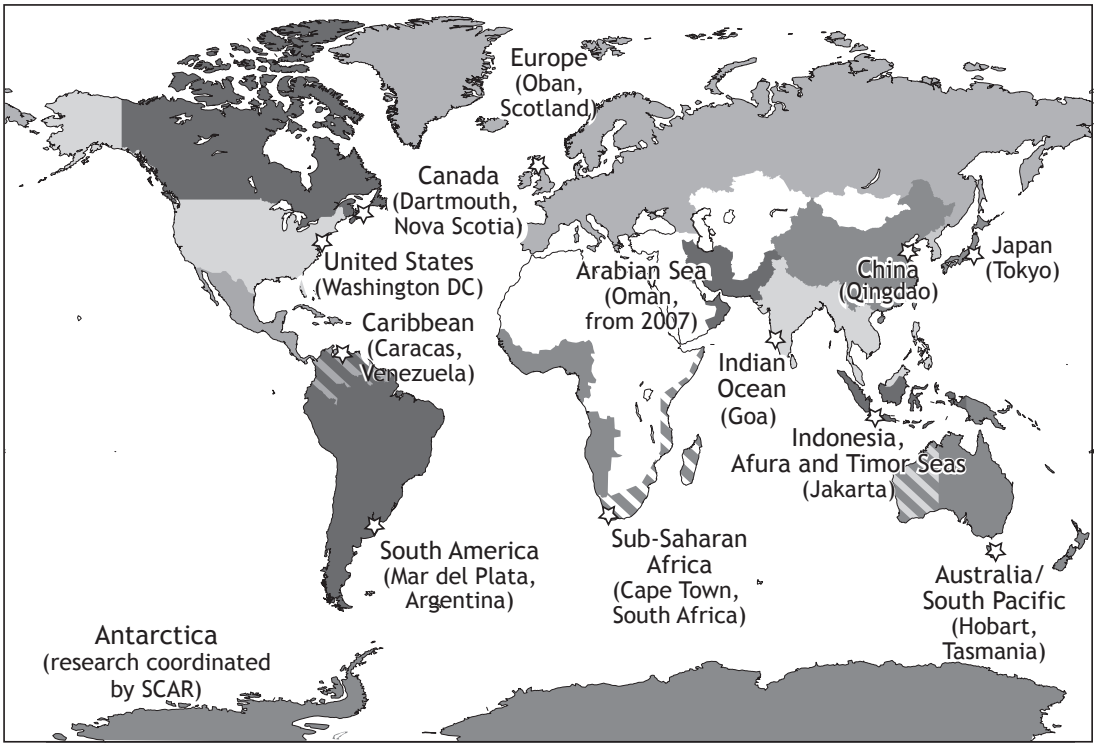
- To expand partnerships and coordination with relevant European programmes and organizations, in tandem with the general growth of the CoML.
- To increase participation in CoML projects where untapped potential remains.
- To build up marine taxonomic expertise and improve species data in European waters.
- To improve information about biodiversity and ecosystems in the context of resource management in waters where European nations hold a major influence.

To achieve these aims, EuroCoML has been raising awareness and interest within the European scientific community and national funding agencies, as well as providing advice and support for fundraising efforts. EuroCoML is also committed to helping build regional programmes addressing both environmental and societal needs in Europe by funding a number of different workshops: eight in total. EuroCoML is also actively involved in raising the awareness of the wider public using a variety of media.

The historical part of the CoML programme is extremely important for our understanding of the condition of the present marine environment. EuroCoML has supported two workshops studying past ocean life and the interaction of humans with marine animal populations. The two regions that the workshops have focussed on are the Mediterranean and the Arctic.

The main aim of the Mediterranean study (HMAP-MED) is to study fishing activity in Mediterranean ecosystems from the Roman period until the 19th century. More specifically, researchers in HMAP-MED want to: (1) investigate interactions between fishing activities, fish trade and management in subsystems of the Mediterranean Sea (e.g. the Aegean and Ionian Seas), looking at both marine animal populations and their habitats: and (2) identify species and ecosystem components that have undergone change since the Roman period.

In the Arctic, researchers want to map the relationship between the development of settlements from the 17th century to the present day, and to determine the extent of exploitation of marine life in Arctic and sub-Arctic waters. Their main aim is to understand the way that socio-economic systems respond to rapid environmental change, so that developmental and government policies can better support human populations living in Arctic regions.



The areas represented by the CoML National and Regional Implementation Committees (shaded), and the locations of the NIRCs (stars)

The areas with grey stripes indicate extended NRIC regions

The world over, the coastal region is important to both governments and the general population; it is an environment they can relate to most easily. As a result, CoML has a programme looking at the Natural Geography in Shore Areas (NaGISA). Research in this field is being expanded and is beginning to take on a more quantifiable approach. EuroCoML has funded a workshop aimed at determining the causes of change in marine coastal biodiversity by identifying key ecological processes operating at different spatial and temporal scales.

Although not specifically limited to coastal regions, research into alien invasive species in near-shore regions is increasing steadily as the impacts of these species on local fauna become more apparent. Europe's large coastline, the increase in shipping and therefore increased activity at ports, has meant that introduction of non-native species occurs relatively easily. Through a EuroCoML-funded workshop, researchers from across Europe collaborated to discuss how best to exclude, eradicate or effectively manage the risks posed by marine invasive species.

Moving offshore into the open ocean, several projects within CoML are utilizing novel technology to track animals of interest to discover their behaviour and movements in relation to the environment they inhabit. Currently, there is a lack of understanding about where marine top predators go, what they do when they get there, and, crucially, why they select particular habitats over others at certain times. In the Atlantic Ocean and Mediterranean Sea, there is a large gap in our knowledge regarding important species such as sharks, seabirds and baleen whales, despite the availability of good quality environmental data in these regions. The European project Tracking of Predators in the Atlantic (EUTOPIA), initially funded by EuroCoML, aims to describe and understand the movements and behaviour of marine vertebrates in relation to their environment. By identifying behavioural rules they aim to improve prediction of the scope and extent of species re-distributions in response to natural and human-driven environmental changes.

With sea-ice retreating and becoming thinner, and predictions that Arctic summer sea-ice may disappear by 2100, the Arctic is one area of the marine environment that requires urgent baseline studies to be undertaken. To date, many of the studies undertaken in the Arctic have focussed on processes rather than on faunal diversity. The Arctic Ocean Diversity (ArcOD) project is aiming to counteract this lack of knowledge by compiling inventories of the fauna inhabiting the sea-ice, water column and sea-floor. ArcOD is also coordinating biodiversity-related research being undertaken during the International Polar Year (IPY), and in order to increase European participation, ArcOD, in collaboration with EuroCoML, hosted an IPY biodiversity meeting. Researchers interested in Arctic biodiversity came together from a number of different institutions, allowing cross-project synergy to develop, and ensuring that duplication was reduced or eliminated where possible, and that scientific ideas and methodology were consolidated.

All the data collected from CoML projects are being stored on an international database, the Ocean Biogeographic Information System (OBIS), which is a web-based provider of global geo-referenced information on marine species. Europe, like other CoML areas, also has a system that interfaces with OBIS, EurOBIS, which is funded through the EU FP6 Network of Excellence, MarBEF. EurOBIS allows searches for biogeographic information to be understaken through multiple datasets simultaneously. This 'distributed system' will thus integrate individual datasets on marine organisms into one large consolidated database. Through collaboration with OBIS, the scientific community will have rapid free access to data on marine species distributions, and ocean environmental data.

In 2006, CoML arrived at a consensus whereby projects being undertaken at national and international levels could become affiliated either to one of the specific CoML projects or to one of the NRICs. EuroCoML is actively encouraging programmes to consider affiliation to EuroCoML itself or to one of the CoML field projects. To date, EuroCoML has agreed on affiliation with two projects: (1) Ecosystem of the Mid-Atlantic Ridge, with special emphasis on the Sub-Polar Front and Charlie Gibbs Fracture Zone (ECOMAR), coordinated by I.G. (Monty) Priede (University of Aberdeen, UK); and (2) Southern European Seas: Assessing and Modelling Ecosystem Changes (SESAME) coordinated by Evangelos Papathanassiou (Hellenic Centre for Marine Research, Greece). Further proposals are welcome and will be discussed at forthcoming EuroCoML Executive Committee meetings.

One of the most important CoML activies is engaging with the general public. EuroCoML also endeavours to promote public interest in research undertaken in Europe. Recently, the coordinators for the four European-led CoML projects* and the EuroCoML project officer (the author) formed a group known as the Deep Sea Education and Outreach group (DESEO) with the aim of presenting deep-water research in an enjoyable, exciting and accessible way. One of the major achievements has been the creation of a book called *Deeper than Light*. This book will be on sale alongside the MAR-ECO (Mid-Atlantic Ridge Ecosystem Project) travelling exhibition, also called Deeper than Light, as it is showcased in different venues around Europe (including Aberdeen in spring 2008**).** EuroCoML has also developed a website where information for a variety of users can be found. The most recent development has been the collating of material for use by teachers in schools throughout Europe.

As CoML enters into the last three years of its original plan, it has a number of legacies which it hopes will last well beyond 2010:

- To have a sustained, dynamic OBIS that will meet the requirements of the scientific community, as well as those of government, industry and educators.
- Proven technologies and approaches to surveying marine biodiversity that can be replicated by researchers globally and implemented in monitoring programmes and ocean and coastal observation systems.
- Increased public interest in the oceans and marine life, and support for ongoing research.
- Centres of excellence in marine biodiversity to build capacity in the developing world.
- Identification of a new generation of ocean biogeographers and ecologists.

The work that is being conducted under the auspices of EuroCoML and the other NRICs will help CoML in achieving its long-lasting legacies.

For further information please visit the website www.eurocoml.org or contact Bhavani Narayanaswamy, EuroCoML Project Officer, Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA.

Further reading

Perry, S.M. and D.G. Fautin (2003) Beginning with the *Challenger* (about OBIS), *Ocean Challenge,* Vol.13, No.1, 4–6.

Europe's role within the Census of Marine Life (CoML), *Ocean Challenge*, Vol.15. No.1, 8–10.

*The project co-ordinators are:
Leniack Menot (COMARGE – continental margins); Eva Ramirez/Maria Baker (ChEss – chemosynthetic environments); Brigitte Hilbig (CeDAMar – abyssal plains); Jo Hoyer/Morten Steffensen (MAR-ECO – Mid-Atlantic Ridge Ecosystem Project).

eHoloCam – a better way to record tiny and delicate marine organisms

Knowledge of the distribution and concentration of living plankton and of aggregates of decaying organic debris (marine snow) is vital to an understanding of marine food chains. It is therefore also important for estimating fluxes of carbon through the ocean, an important aspect of studies of the ocean's role in the climate system. The electronic holographic camera, eHoloCam, is a step forward in recording the three-dimensional distribution of small organisms and organic particles in the oceans; and by recording high-resolution images in three dimensions it is also useful for identification of the organisms present in a given volume of water (Figure 1).

Design features

eHoloCam has been developed jointly by the University of Aberdeen, the offshore instrumentation company CDLtd of Aberdeen, and Elforlight of Daventry (developers of compact solid state lasers). eHoloCam has been developed from the HoloMar camera which featured in the *2002 Guiness Book of Records* as the most advanced holographic underwater camera. Like other holographic cameras of the time, HoloMar recorded holograms using photographic emulsions on plates/films; it was bulky and heavy, and difficult to deploy. In particular, it could not be deployed from modern observation platforms such as remotely operated vehicles or autonomous vehicles (ROVs or AUVs), and has never been used at depths greater than 100 m.

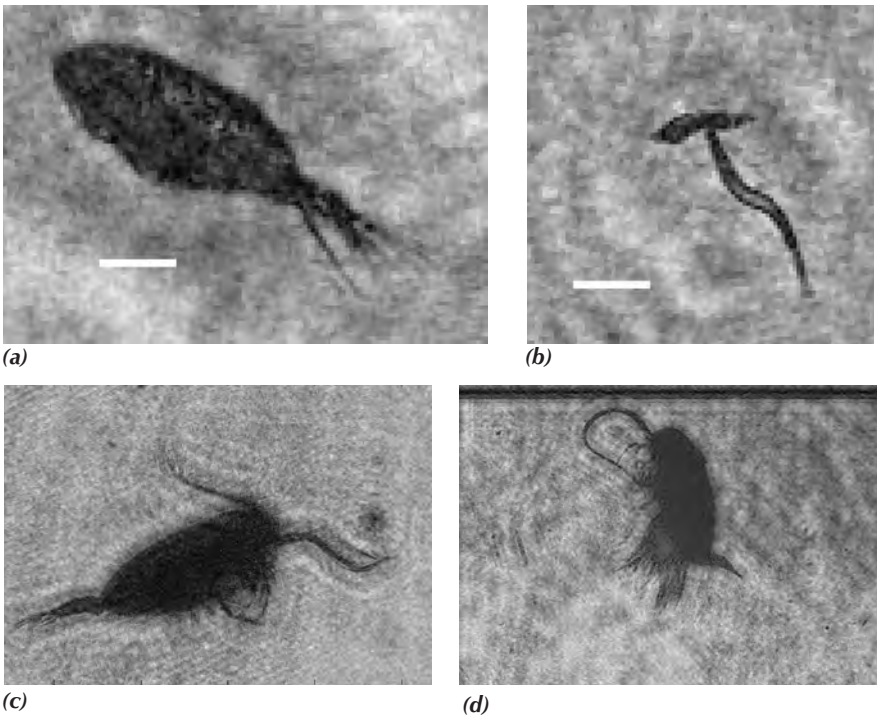
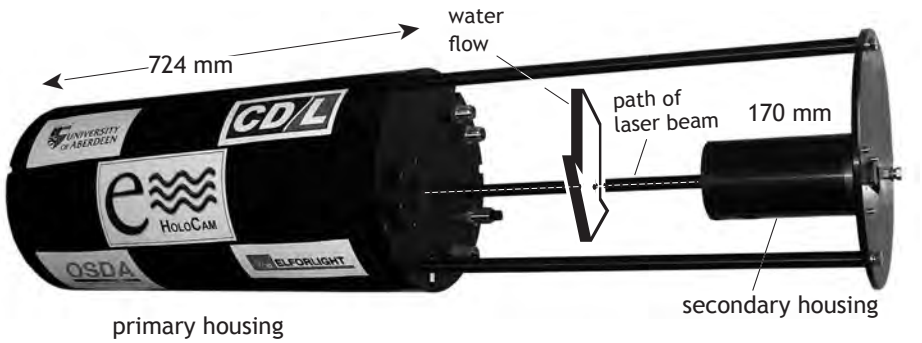


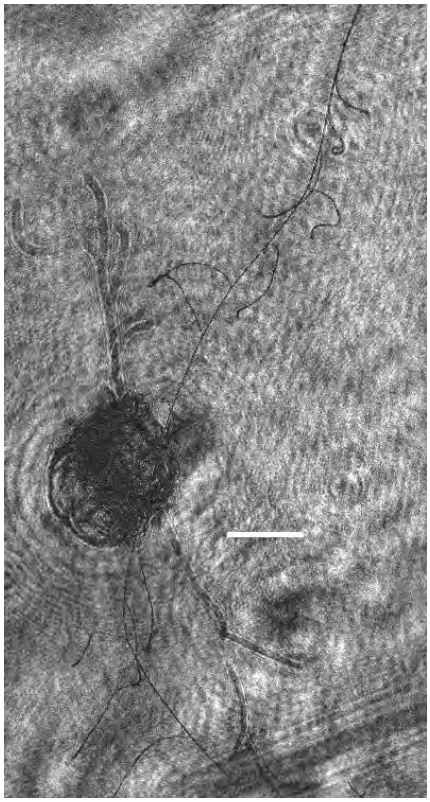
Figure 1 *Examples of holographic images obtained using eHoloCam. (The background patterns are mostly artefacts caused by laser coherence during the image reconstruction technique.)* ***(a)*** *A copepod and* ***(b)*** *a small appendicularium, recorded at a depth of 430 m in the Norwegian Sea, 82 mm from the sensor. Scale bar: 210 µm; imaging sensor resolution: 10.5 µm × 10.5 µm.* ***(c)*** *The copepod* Calanus finmarchicus, *about 2.5 mm long, recorded at a depth of 92 m in the northen North Sea; imaging sensor resolution 7 µm × 7 µm.* ***(d)*** *A large copepod, about 3 mm long, jumping beneath the water surface in a laboratory tank; imaging sensor resolution: 11 µm × 11 µm.*

eHoloCam is one-sixth of the volume and one-twentieth of the weight of the HoloMar camera. Rather than using photographic film, eHoloCam is based on digital holography, and contains an imaging sensor (similar to those found in video cameras) on which an electronic hologram is directly recorded. A fast-pulsed laser is used to freeze-frame particles moving relative to the laser beam (cf. Figure 2), and eHoloCam can record all organisms and particles within a water volume of 36.8 cm^3, at a rate of 2–25 per second. and the recorded images may subsequently be reconstructed numerically on a chosen plane.

As well as enabling the equipment to be smaller and lighter, all-digital capture of the holograms allows almost immediate viewing of the images. Computer replay of the holographic images will allow identification of the species present, and determination of their concentrations and their positions relative to one another. Marine organisms from 10s of microns (µm) to several millimetres in size 'captured' holographically can be imaged to a resolution of about 10 µm, i.e. so that features of this size can be distinguished (see Figure 3(b)).

Figure 2 *The eHoloCam instrument. The larger housing on the left contains the laser, power supply units, embedded computer hard drives, plus beam-steering and collimating optics; the secondary housing on the right contains the CMOS camera (CMOS = complementary metal oxide semiconductor). Both housings are made of aluminium and are black-anodized on the outside to reduce the risk of corrosion by seawater. They are designed to an operational pressure of 300 bar (i.e. a depth of 3 km) and have been pressure-tested to a depth of 1.8 km. Sapphire windows, 75 mm in diameter, allow the passage of the laser beam from the laser head in the primary housing, through seawater to the sensor in the secondary housing.*





(a)

(b)

Figure 3 ***(a)*** *Ctenophore (sea-gooseberry) with delicate tentacles visible; note that only some of the tentacles are in focus at the image plane. Scale bar: 1 mm.* ***(b)*** *Chain diatom (species unknown). Scale bar: 210 μm; each cell is ~20 μm .*

The sensor can be used in three modes, producing images at high resolution (recording all pixels, which results in an effective pixel spacing of 3.5 μm), medium resolution (recording two pixels and then skipping two pixels in both *x* and *y* directions, resulting in an effective pixel spacing of 7 μm, 1/4 of the data per frame), and low resolution (recording two pixels and then skipping four pixels in both *x* and *y* directions, resulting in an effective pixel spacing of 10.5 μm, 1/9 of the data per frame). Such subsampling permits higher frame counts, and so a higher 'captured volume' in a given time at the cost of fewer pixel counts per frame. The maximum repetition rate of the laser limits the maximum frame rate to 25 frames per second.

Apart from speed, convenience and freedom from wet chemical processing, eHoloCam has the distinct advantage of being able to record holographic videos. This allows not only 3D interrogation, but introduces the third dimension – time. Figure 4 shows a sequence of frames from a holographic video which showed the copepod performing bouts of feeding followed by a rapid escape reaction.

Deployment

The system has been designed to operate on the rig ARIES, a square cross-section open frame, developed by the Fisheries Research Services Marine Laboratory in Aberdeen, which is towed by RV *Scotia*. ARIES permits stable, level tows, along with a multi-depth plankton sampling net, and other instruments such as a video camera, an optical plankton counter, a fluorometer and a CTD (salinity–temperature–depth) profiler; eHoloCam is attached to the lower side of the ARIES frame, underneath the plankton net.

ARIES is towed at up to 4 knots (~2 m s^{-1}), with sampling tow depths being monitored on a deck display. During towing, water flows laterally though the support bars of eHoloCam, perpendicular to the beam path (Figure 2).

During a cruise of RV *Scotia* off the Shetland Isles, eHoloCam was successfully deployed four times, at depths down to 430 m. As well as high resolution images of a variety of zooplanktonic organisms, eHoloCam collected data on the three-dimensional distribution of the copepod *Calanus* (Figure 1(c)), which is an important food for a number of commercially important fish in waters around the British Isles, but whose geographic distribution is shifting in response to changing climatic conditions. Analysis of the *Calanus* data showed that it was irregularly distributed, with its population density varying from 92 m^{-3} to 352 m^{-3}, regardless of time and depth.

Particular uses of eHoloCam

By recording the three-dimensional distribution of zooplankton such as *Calanus*, eHoloCam should be a valuable tool in research aiming to understand the movement of fish stocks.

The camera should also be valuable for recording the many planktonic organisms – e.g. jellyfish, sea-gooseberries (Figure 3(a)) and the larvae of many species – that are completely or nearly transparent and, being very fragile, are very difficult to sample using conventional techniques. Use of eHoloCam allows non-intrusive and nondestructive analysis of such organisms in their natural environment, while preserving their relative spatial distribution in three dimensions.

Increasing our understanding of gelatinous species such as salps, jellyfish and sea-gooseberries (Figure 3(b)) is important as they are increasing in abundance, as a result of changing climatic conditions and because of removal of other animals from the marine food web as a result of overfishing. Up until recently, difficulties in observing and sampling them meant that relatively little was known about them.

Future work

Since December 2005, eHoloCam has been deployed during four cruises in the Faroes Channel and in the North Sea. Further deployments of eHoloCam are planned (but not yet confirmed) for Lake Baikal in Siberia (the world's largest freshwater lake) and Loch Ness.

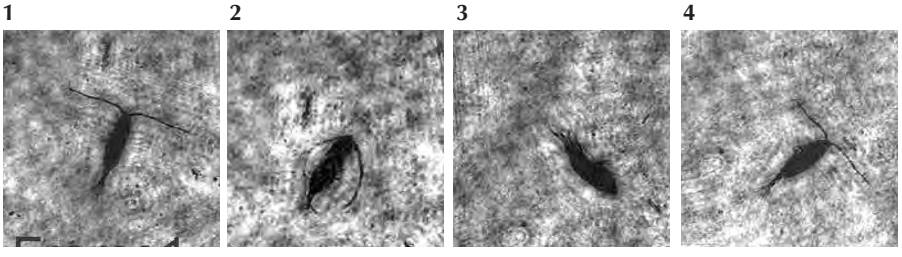
Although the system has been designed to be deployed on ARIES, it can be adapted for use on other observation platforms such as tethered landers and AUVs/ROVs.

The team at Aberdeen hope that, as the power and benefits of the technique are realized, the eHoloCam system will find widespread use amongst the marine biological community and will prove to be an invaluable tool in marine science.

Eds

For more details see: Hongyue Sun, David C. Henry, Michael Player and John Watson (2007) *In situ* underwater electronic holographic camera for studies of plankton, *IEEE Journal of Oceanic Engineering*, **32**, No.2 (April). We would like to thank the authors for their input.

Figure 4 *Sequence of frames from a video of a copepod (*Calanus *sp.) (~1 mm long) swimming in natural seawater in a laboratory tank (for details see text). The video frame rate was 25 Hz; the time interval between frames 1 and 2, and between 3 and 4 = 1/25 seconds; the 29-frame gap between frames 2 and 3 corresponds to 1.2 seconds.*



Sylvia Harvey: a tribute

Sylvia Harvey was the Secretary for the Challenger Society from the mid-1960s until 1985, and was the Executive Secretary for the reconstituted Challenger Society for Marine Science from 1987 until 1995. She died on Monday 13 November 2006. These reflections are a tribute by her many friends from the days of the National Institute of Oceanography (and later the IOS).

Sylvia Harvey (1930–2006) – a much valued and loved member of the marine science community

Although these recollections extend beyond the Challenger Society, they do provide an inkling of why 16 years after her retirement so many colleagues gathered for her funeral service, which was followed by burial in her home village churchyard of Hambledon in Surrey. For those who packed the church to its doors it was a greatly moving occasion. Afterwards, at a reception hosted by her family, reminiscences of her ebullience and interest in the lives of her colleagues made clear why she was so often a welcome and dear friend on family occasions in the lives of her colleagues.

Arthur Fisher writes that Sylvia joined the National Institute of Oceanography 40 years ago, at which time Arthur himself was Treasurer of the Challenger Society. Sylvia's role was to be secretary to Ronald Currie and to provide secretarial assistance to the whole Biology Department. Ron had recently become head of this Department, and for a number of years had been Secretary of the Challenger Society. As Ron's workload increased, he encouraged Sylvia to assume a role in organizing the annual programme of meetings held and sponsored by the Society. She enjoyed this role which brought her into contact with many marine scientists inside and outside the Institute.

Sylvia's efficiency and discretion, and her outgoing and pleasing personality, brought her very much to the fore, and when Ron Currie left the Institute to become the Director of the Scottish Marine Biological Association, Sylvia, for many, became the first point of contact for the Challenger Society. Not only did her position within the Society develop, but at a time of expansion and reorganization at the Institute, she became secretary to the Director, George Deacon, who obviously recognized her abilities. Sylvia remained his secretary until his retirement as Director. At this stage she became secretary to the Marine Physics department, remaining in that post until her retirement. Throughout this entire period Sylvia continued in her role as Secretary of the Challenger Society. She was supported in her role by many members of the Society who recognized the value of her work for the marine science community. On the transition of the Society to the Challenger Society for Marine Science in 1987, Sylvia was awarded the Society's Silver Medal, duly inscribed, as recognition for all her work to that date.

James Crease
Delaware

Challenger Society News

The 2007 AGM was held during the meeting of the Challenger Society Special Interest Groups on Biogeochemical and Biophysical Interactions in the Oceans, held in Galway, Ireland, on 4–6 September. A full report of this most enjoyable event will appear in the next issue.

At the AGM, the following people retired from Council: Duncan Purdie (Immediate Past-President), Sarah Cornell (Hon. Treasurer), Ruth Parker (Young Scientist Network, YSN), Toby Tyrrell (Communications, including the web page) and Jenny Pike (Education). The President, Peter Liss, thanked them all warmly for their work for the Society.

The new members elected to Council were Elaine McDonagh (who will take over as Hon. Treasurer), Gary Caldwell (taking on the YSN), Alexander Piotrowski and Tim O'Hare.

They join Andy Rees (Travel Awards), Gary Fones (Editor, *Challenger Wave*), Simon Holgate (Local Networking Events), Axel Miller (Publicity), Geraint Tarling (now Education), and Phil Williamson (Meetings and Special Interest Groups).

Carol Robinson (who in the past served as Hon. Secretary to the Society) is joining the Council as President Elect. She will take over from Peter Liss as President at the Bangor Marine Science Conference in 2008.

Rachael Shreeve is continuing as Hon. Secretary, and membership services will continue to be run by Jennifer Jones, the Society's tireless Executive Secretary.

The Aberdeen Declaration: A New Deal for Marine and Maritime Science

Drafted and approved at EurOcean 2007, the Aberdeen Declaration calls for urgent action by the European Commission and Member States (with stakeholders) to initiate in 2008 a comprehensive and integrated European Marine and Maritime Science, Research, Technology and Innovation Strategy. The Strategy is intended to support the proposed European Maritime Policy, adding value in the areas of economic development, environmental policy, and ocean and coastal governance, particularly in the context of the challenge of climate change. The Declaration has already been given support by EU Commissioners Borg (Maritime Affairs) and Potocnik (Research).

The Declaration also calls for the establishment of an adequately resourced and sustained process to oversee implementation/delivery of this Strategy within a holistic European Maritime Policy; also called for are the necessary funding mechanisms, specialized infrastructures, management of data/information, and capacity-building, all essential for managing activities in the oceans and seas.

The Declaration builds on the Galway Declaration which had a major influence on EU and National Funding Programmes for Marine and Maritime Research Programmes and Strategies. For the full text see: http://ec.europa.eu/maritimeaffairs/declaration_en.html. Distribution of a printed version of the Declaration, and an official report on the EurOcean Conference, are both planned for September 2007.

Is it time for Challenger meetings to go green?

Thoughts on the Marine Science conference in Oban, September 2006

Elizabeth Hawker

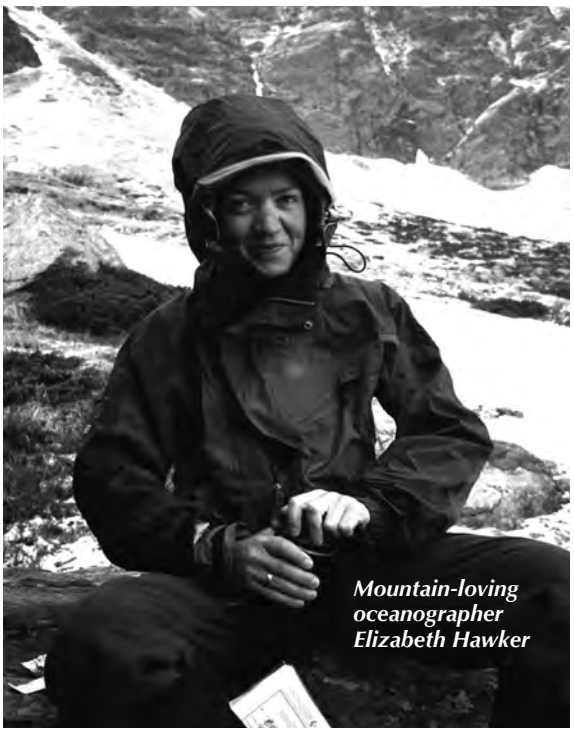
For me – a mountain-loving polar oceanographer – Oban, with the sea and the hills, was an appealing venue for a scientific conference. It didn't disappoint. The national and local organizing committees are to be congratulated on hosting an extremely well run event, with a particularly interesting and varied programme to engage us. The biennial Challenger Society conference always provides a great opportunity for the UK marine science community to gather together to share research, progress and ideas. Oban was a chance to meet with old friends from past cruises, socialise with current colleagues, and also to make new contacts, opening the door to fresh opportunities. It was great to see such a range of interesting presentations and posters, from the younger Ph.D and post-doc scientists as well as the far more established!

I was particularly impressed with the organization of the conference. There were no problems that I was aware of, and the impeccably smooth flow between talks certainly helped to set both the speakers and the audience at ease so that we were at liberty to concentrate on the actual presentations. The presentation and poster sessions were interspersed with two afternoons of workshops. These provided a welcome change of pace, with opportunity for debate and interaction. I strongly feel, however, that we should extend this idea to an afternoon with conference-wide participation tackling topics such as the state of knowledge of 'climate change' and its communication to the public.

One of the most memorable presentations was the keynote talk by Stephan Rahmstorf. He presented some new work suggesting that the IPCC has underestimated the rate of sea-level rise. The structure of observed sea-level rise has mirrored the time evolution of global mean temperatures, and if this continues during the 21st century sea-level rise will be far greater than the IPCC predictions. Food for thought indeed … .

To supplement the scientific content of the conference, our hosts arranged a number of evening entertainments allowing participants to 'network' on a more informal basis, and some to make substantial contributions to the local economy by the sampling of local brews! Of particular note was the Conference Dinner which ended with a traditional Ceilidh amid much amusement. I also really enjoyed the Marine Art Exhibition at SAMS, featuring local artists from the Oban Art Society and the Appin Art Group. This was a great idea, providing another opportunity for some conference participants to support local livelihoods.

I was also very impressed by our visit to SAMS. The new building is a wondeful facility and seems a great environment in which to work. However, I doubt I am alone in being disappointed to hear that it was not built to the very highest environmental and sustainable standards. Unlike the project to build a new Environment Centre for Wales (a partnership between the Centre for Ecology and Hydrology and the University of Wales, Bangor), with SAMS we seem to have missed an opportunity to create an environmentally sustainable building.



Mountain-loving oceanographer Elizabeth Hawker

We are the *Challenger* Society for Marine Science, and so these key meetings should always provide each of us with new challenges. During the conference it struck me that as environmental scientists, we should perhaps be challenging ourselves in a new way: we need to question our own perspectives, attitudes and behaviour by putting the environment at the centre of our agenda in ways we have so far failed to do.

The aims of the Challenger Society 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 world's oceans and an awareness of the need for their proper management; and to contribute to public debate on the development of marine science'. Admirable objectives indeed, but where is the commitment to achieving those ideals in a way that is sustainable and environmentally responsible? We should constantly be seeking to reduce our 'ecological footprint'. We need to lead by example – how can we communicate our understanding and concerns about the effects of 'climate change', if we fail to acknowledge the impact of our own everyday actions? If we don't do this, how can we expect public and commercial enterprise to undergo a change in mindset and a shift of attitude and values?

On the very small and local scale, there are a few measures that could be considered for future Challenger conferences? For example:

- Extend the 'climate change' workshop to a conference-wide debate for an afternoon.
- Promote travel to the conference by public transport, particularly to avoid flights within the UK.
- Host an evening reception with a prominent local environmental speaker, open to both conference participants and the local community to encourage interaction.
- Hire a local catering service which uses fresh, local produce and non-disposable containers etc., and reduce waste generally.
- Recommend local lodgings with a 'green' ethos.
- Host an exhibition with a marine theme, promoting work by local artists and craftspeople.

The Challenge is before us – and not only in the oceans.

Elizabeth Hawker is currently working at the British Oceanographic Data Centre as a part-time Data Scientist. In the future she hopes to combine scientific writing and more direct environmental research with the pursuit of her athletic career and mountaineering ambitions.

Atmospheric inputs to the ocean – changing sources and perspectives

Tim Jickells

Being awarded the Challenger Medal was truly one of the greatest honours of my career to date and I remain profoundly grateful to the Challenger Society and to all the colleagues I've worked with, for their support. The citation was for my work on atmospheric inputs to the oceans, and therefore recognizes in part the developing realization that the atmosphere and ocean are closely coupled within the Earth System. So when I was asked to write an article for *Ocean Challenge* about the medal award, I decided to look at the way that our view of the role of atmospheric inputs to the oceans has developed over time. This is not an authoritative or comprehensive history – that will have to await someone better qualified than me – but rather a largely personal perspective.

The atmosphere is made up primarily of gas, mostly nitrogen and oxygen but also a wide range of important trace gases, including CO_2 (trace gases are those with concentrations < 500 parts per million, often << 1 p.p.m.). There are also many short-lived gases (with life-times of a day or so) such as dimethyl sulphide (DMS) and methyl iodide which can be transformed into aerosols – liquid and solid particles suspended within the atmosphere. Aerosols play a key role in creating clouds and reflecting sunlight back to space. A large proportion of aerosols are particles produced by mechanical processes at the surface of the ocean or land, such as bubble-bursting, forming sea spray, and wind erosion producing dust particles. These mechanically produced aerosols tend to be relatively large (>1 μm). Another major type of aerosol – those formed by chemical processes from gases in the atmosphere – are relatively small (<1 μm diameter).

An aerosol's size influences its light-scattering properties and its lifetime in the atmosphere. Larger particles are removed more rapidly by both wet deposition (i.e. being washed out in rain) and dry deposition (settling on the surface of land or sea). Wet and dry deposition of aerosols are the main ways in which many nutrients and trace metal contaminants are delivered to the oceans from the atmosphere.

Darwin described deposition of atmospheric dust from soil ('impalpable dust falling all around') on the *Beagle* in 1832, and mariners surely knew of this long before. Hence the idea of atmospheric transport of material from land to the oceans was obvious from the earliest days of exploration at sea. The idea that dust formed a significant component of marine sediments is well established in the 1940s textbook by Sverdrup, Johnson and Fleming. (However, these authors also implied that rivers provide most of the material to the oceans, so the role of the atmosphere as an important source of dissolved components to the oceans was presumably not yet recognized.) The assessment of soil dust concentrations in marine sediment cores is still used very effectively today in developing histories of atmospheric transport and climate.

Darwin had sailed from a Britain where the cities suffered from serious local pollution. Strategies to remedy this had included the use of high chimney stacks that reduced local pollution problems (Figure 1, opposite). This strategy, together with improved fuel quality and additional clean-up measures on chimneys, continues to this day. The air quality in cities is now vastly better than in Victorian times, but the high stacks do allow long-range atmospheric transport, creating some large-scale pollution problems such as acid rain. While acid rain and bomb test nuclides were some of the first examples of large-scale long-range transport of atmospheric contaminants receiving widespread public attention, we now know that such transport has been going on for a very long time. High-resolution records of lead content and isotopic abundance from Swedish lake sediments, for example, indicate increases in lead during Roman times due to smelting activity, a signal that

seems almost certain to have arrived via atmospheric transport. This signal does not necessarily imply very large-scale lead smelting at that time, but rather large emissions from fairly small-scale 'dirty' operations. Levels of lead in soil/sediment fell in post-Roman times and increased again in 1000 AD before the rapid increase associated with Victorian industrialization and the later impact of lead in car fuels.

Junge's *Air Chemistry and Radioactivity,* published in 1963, is a remarkable and authoritative text reviewing the state of the art at that time. In addition to discussing gases, Junge considers aerosols extensively. A really important section of the book deals with atmospheric radioactivity, including natural and bomb test material. For us older members of the community, reading this material is a chilling reminder of the darkest days of the madness of the Cold War. It also illustrates the scale of scientific studies of bomb debris – the U2 spy planes were even used for sampling. As Junge comments of the radioactive (natural and anthropogenic) work, 'Most of our information on residence time for atmospheric constituents became available through these studies.' Bomb fallout tritium (H^3) and caesium are still used today as tracers, now of ocean processes. The Cold War era also brought home to Junge and his contemporaries the interconnectedness of the Earth System, the efficiency of atmospheric transport, and the interactions between science and public policy. He wrote 'The global distribution of fission products from atom bomb tests has been the subject of considerable public and scientific interest in recent years. Never before has it become so clear that air chemistry must consider the whole atmosphere as a unit.'

By the 1970s some of the techniques developed for bomb debris sampling were being applied to studies of contaminants. For instance, at the UK Atomic Energy Research Establishment, Harwell, Roger Cambray and colleagues were estimating atmospheric inputs of metals to the North Sea. It was also in the 1970s that large-scale systematic studies of air–sea interaction began. The classic SEAREX (Sea/Air Exchange) programme ran in the 1970s and 1980s, under the leadership of Bob Duce (then at Univeristy of Rhode Island, now Texas A&M). The original motivation for SEAREX included the recognition of the long-distance transport of trace contaminants through the atmosphere, and the programme set up sampling stations on remote Pacific islands 'to identify the sources of the materials, their transport mechanisms over the ocean and the processes affecting their fluxes across the sea–air interface.' This benchmark programme developed most of the methods used today for these kinds of studies – including the use of tall towers for sampling, with their attendant horrors for those of us scared of heights (cf. Figure 2); it also led to much of our fundamental understanding of the scale and significance of atmospheric transport.

The classic dust records developed by Joe Prospero (University of Miami) began from SEAREX and continue to this day. These now provide clear evidence of the links between dust transport and climate, although the original network

Figure 1 *Battersea power station, photographed in 1944. Atmospheric emissions in industrial England were much higher than now and, despite tall chimneys, had major impacts on the local environment.*

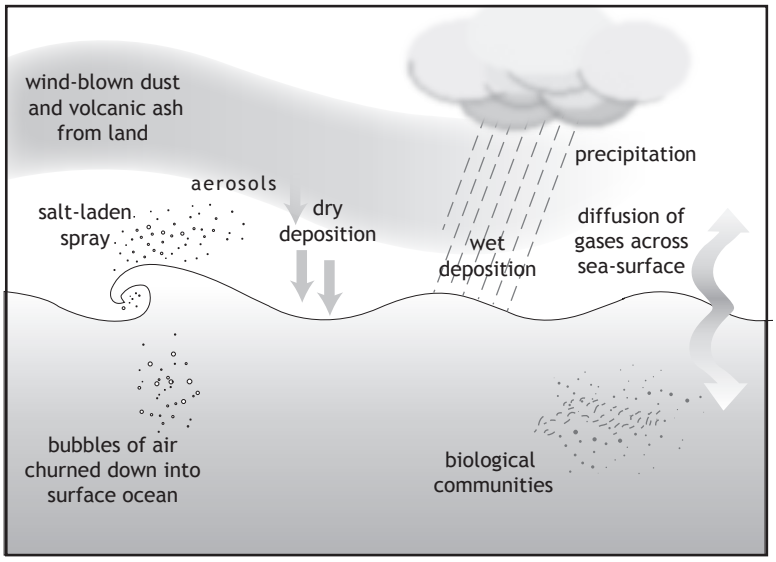
Tall chimneys somewhat ameliorate local pollution problems, but lead to acid rain elsewhere

was set up in part to measure contaminants. In the early 1980s, I was lucky enough to become involved in a related large-scale programme in the Atlantic – WATOX (Western Atlantic Ocean Experiment). Led by Jim Galloway (University of Virginia), WATOX was stimulated by concerns about long-range transport of acid rain. Much of the work focussed on contaminants, but we did also begin to consider if the nitrogen associated with acid rain (as nitrate and ammonium) might act as a fertilizer to the ocean.

Figure 2 *The 30-m high sampling tower at the Cape Verde Atmospheric Observatory. Although the site may be subject to deposition of dust from high-level air masses originating over Africa (cf. Figure 4), it also receives 'clean' air blowing off the tropical North Atlantic.*

(Photo by courtesy of James Hopkins)

Capturing aerosols using equipment located at the top of tall towers is now a key part of research into atmospheric inputs to the ocean



Air–sea exchange of gases and aerosols can occur by several different mechanisms which are influenced by processes in the atmosphere and surface ocean

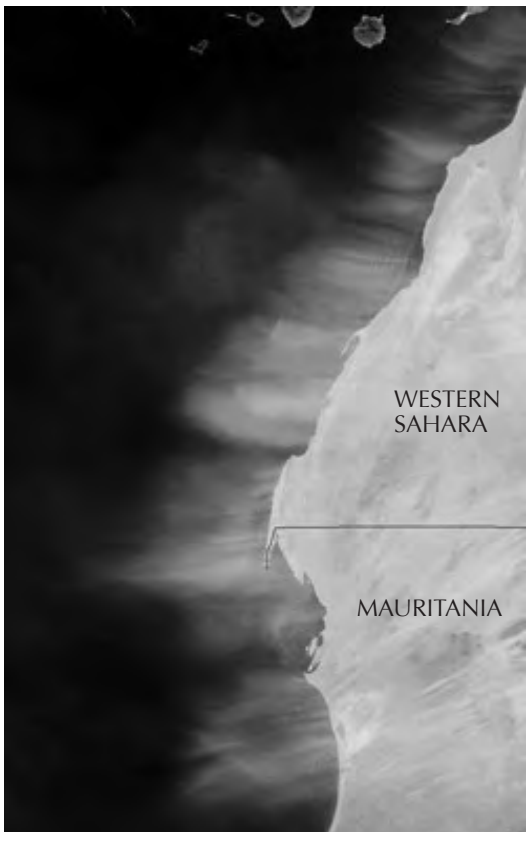
Figure 3 *Summary diagram of various kinds of air–sea exchange, whereby particles, water and gases pass across the sea-surface in both directions.*

As the significance of air–sea exchange (Figure 3) became clearer in the 1990s, NERC set up the ACSOE* programme (led by Stuart Penkett, University of East Anglia), which drew atmospheric and marine scientists into a common programme and even joint field campaigns. This highly successful programme involved studies of both atmospheric inputs to the oceans and emissions of substances from the oceans and their subsequent atmospheric transformations.

*ACSOE = Atmospheric Chemistry Studies in the Oceanic Environment.

Figure 4 *Dust storm off the Sahara, in January 2007. The islands at the top of the image are the Canary Islands; the Cape Verde Islands (cf. Figure 6) are just off the image, to the south-west. (Courtesy of NASA)*

Darwin's 'impalpable dust' is now recognized as the wind-borne Saharan dust which fertilizes the tropical North Atlantic with iron



Recognition of the acid rain problem and other large-scale air pollution issues has led to a series of strategies to reduce emissions which have, in general, been successful for a range of contaminants such as sulphur and lead. As emissions have decreased, concerns over the likely scale and effect of contamination through human activity have abated somewhat (or been eclipsed by climate change concerns). Also, we have realized the important role of biogeochemical cycling in modifying inputs to the ocean – for example the detoxifying effect of organic complexation of trace metals such as copper in the oceans. However, there has been less success at regulating nitrogen emitted as nitrous oxides (NO/NO_2) from combustion processes (transformed in the atmosphere to nitric acid), and ammonia (NH_3) from intensive agriculture. The agenda has therefore shifted from the role of the atmosphere as a source of contaminants to the ocean, to its role as a supplier of nutrients.

In the late 1980s John Martin (Moss Landing California) proposed that iron is supplied to the ocean primarily in atmospheric dust (Figure 4) and that a lack of dust supply led to iron limitation of primary production (since iron is essential for algal growth) in remote ocean regions such as the Southern Ocean. John was careful to point out that the proposal was not really new, since the physiological importance of iron for phytoplankton has been known about since the 1920s. However, John's work was informed by the new developments in sampling and analysis for trace metals, allowing the very low concentrations of iron to be measured. The new SF_6 (sulpur hexafluoride) tracer technology developed by Andy Watson (University of East Anglia) then allowed oceanographers to formally test the hypothesis of iron limitation. Martin's landmark papers thus led to a fundamental change in the way oceanographers think about atmospheric inputs to the oceans.

We now recognize a network of connections between the atmospheric supply of iron and productivity in the oceans, with feedback mechanisms via climate and dust production (Figure 5, opposite). These cycles interlink with supplies of other nutrients such as nitrogen and phosphorus which can also be delivered via the atmosphere, or in the case of nitrogen by biological fixation as well, a biochemical process which also needs an abundant iron supply.

Although rivers are also an important source of material to the oceans, much of their input can be trapped in the coastal zone, so atmospheric inputs are particularly important in the open ocean far from riverine inputs. The impact of atmospheric inputs is pervasive and long-range but probably subtle. It now seems likely that changes in iron supply were a contributing factor in glacial–interglacial climate change (increased iron supply during drier glacial periods leading to higher productivity) and that changes in atmospheric nutrient supply may be able to alter the productivity of the oceans (Figure 5). At any one location, such effects are going to be modest and difficult to distinguish from the natural 'noise' in the system, but changes in primary production of

a few percent scaled over the whole ocean add up to fixation of millions of tonnes of extra carbon.

We still do not properly understand the production, transport, transformation and deposition of material to the oceans via the atmosphere, or its subsequent processing within the oceans, so much work remains to be done. This is part of the agenda of the IGBP SOLAS* project and the UK SOLAS directed programme. Over the coming decades, global change pressures (including climate change, population growth and increased consumption of food and energy) seem certain to increase atmospheric nitrogen supply to the oceans and may alter iron supply too. We need to understand the significance and extent of atmospheric nutrient supply to the oceans as a contribution to effectively predicting and planning for the future in a changing world.

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*There will be more about SOLAS (Surface Ocean–Lower Atmosphere Study) in the next issue.

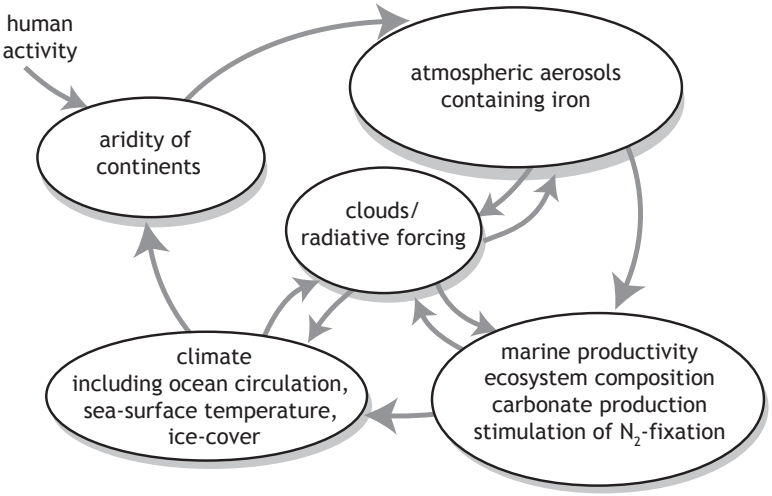

Figure 5 *Feedbacks within the Earth System whereby the atmosphere, ocean and the continents are linked by the influence of aerosols. Dust in the atmosphere affects radiation balances and provides iron to fertilize the oceans. Increased marine productivity alters the exchange of gases which affect the Earth's radiation balance either directly (e.g. CO_2, N_2O, CH_4) or indirectly (e.g. DMS and methyl iodide which form aerosols), which in turn affects climate, aridity and dust production.*

Effects of iron fertilization in the ocean feed back through the climate system

Figure 6 *Eric Achterberg (National Oceanography Centre, Southampton) inspects the aerosol collector at the international SOLAS observatory on Cape Verde, which is located in an area that is well supplied with Saharan dust (cf. Figure 4) and is thus ideal for investigating impacts of dust on the marine ecosystem. (This instrument is run by the Leibniz Institut für Troposphärenforschung, in partnership with INMG Cape Verde and UK SOLAS.)*

(Photo by courtesy of Phil Williamson)

Cape Verde is ideally located for investigating impacts of dust on the marine ecosystem

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HMS *Scylla* – a new role for a redundant ship

Deborah Snelling and Kelvin Boot

HMS *Scylla*, a former Royal Navy Leander Class Frigate, made her last journey on 27 March 2004 – a mere twenty metres down to the sea-bed where she became northern Europe's first purpose prepared conversion from ship to reef. *Scylla* was the last warship to be built in the Devonport Royal Dockyard. She was commissioned in 1970 and took part in the 'Cod Wars' of the 1970s as a fishery protection vessel, and was part of the Cayman Brac hurricane relief effort in 1980. She was eventually decommissioned and 'paid off' in 1992, and until 2003, when she was sold to the National Marine Aquarium, she was laid up in Fareham Creek in Portsmouth.

Why would the NMA want to sink a warship?

It was two local divers who first put together the concept that *Scylla* might be purchased, converted and scuttled to form an artificial reef. For such a complex plan to succeed, a properly constituted body was needed to administer the finances and manage the various parts of the project. The National Marine Aquarium (NMA) had always aspired to include 'man's interaction with the oceans' as part of its activities, and the notion that an artificial reef could become a focal point for marine research and education fitted this brief very well. The coming together of *Scylla*'s availability, the original idea, local enthusiasm for the project, the National Marine Aquarium's project management skills, and funding support from the South West of England Regional Development Agency (SWRDA) all enabled the project to develop from a dream into a very real possibility. The National Marine Aquarium was selected as the contractor to carry out the work, and the ship was purchased from the MoD for £200 000.

Preparation

From her mooring in Portsmouth, the ship was brought to Plymouth, the only port close by with the resources and expertise to carry out the preparation work. The move also ensured that preparation took place close to the ship's final resting place and allowed the National Marine Aquarium to maximize marketing and PR activities. Initial preparation was carried out under contract by Devonport Management Limited (DML), and specialist preparation and explosive cutting was undertaken by the Canadian Artificial Reef Consortium (CARC), which had carried out similar work on similar vessels elsewhere.

Once the ship was in dry dock in Plymouth, the mast and funnels were removed to allow the necessary clearance above the vessel at low tide at the chosen site. Additionally, all air-conditioning plant, diesel generators, boiler equipment and fuel-carrying pipework were removed, and all hydrocarbons (oil etc.) were cleaned from the vessel. At all stages of the work various agencies were involved in the inspection process to ensure the vessel would not pose an ecological threat once placed on the sea-bed; Defra became the key point of contact and the licensing authority for this activity.

It was obviously essential that the ship should remain structurally sound and stable throughout the entire operation of placing it on the sea-bed, not least as a requirement from the insurance assessor. The Wolfson Unit for Marine Technology and Industrial Aeronautics, Southampton, carried out computer model simulations, and an inclining experiment was undertaken prior to the ship leaving the dock. The results confirmed the stability of the vessel for transfer to the 'placement' site.

Both DML and the Devonport Naval Base operate under a Nuclear Site Licence, which presented a challenge when it came to putting explosives on *Scylla*; to comply with the relevant regulations the ship was moved to a new location prior to installation of any explosive devices. A total of 168 explosive charges were set to produce 48 holes – 24 cut-throughs below the waterline and 24

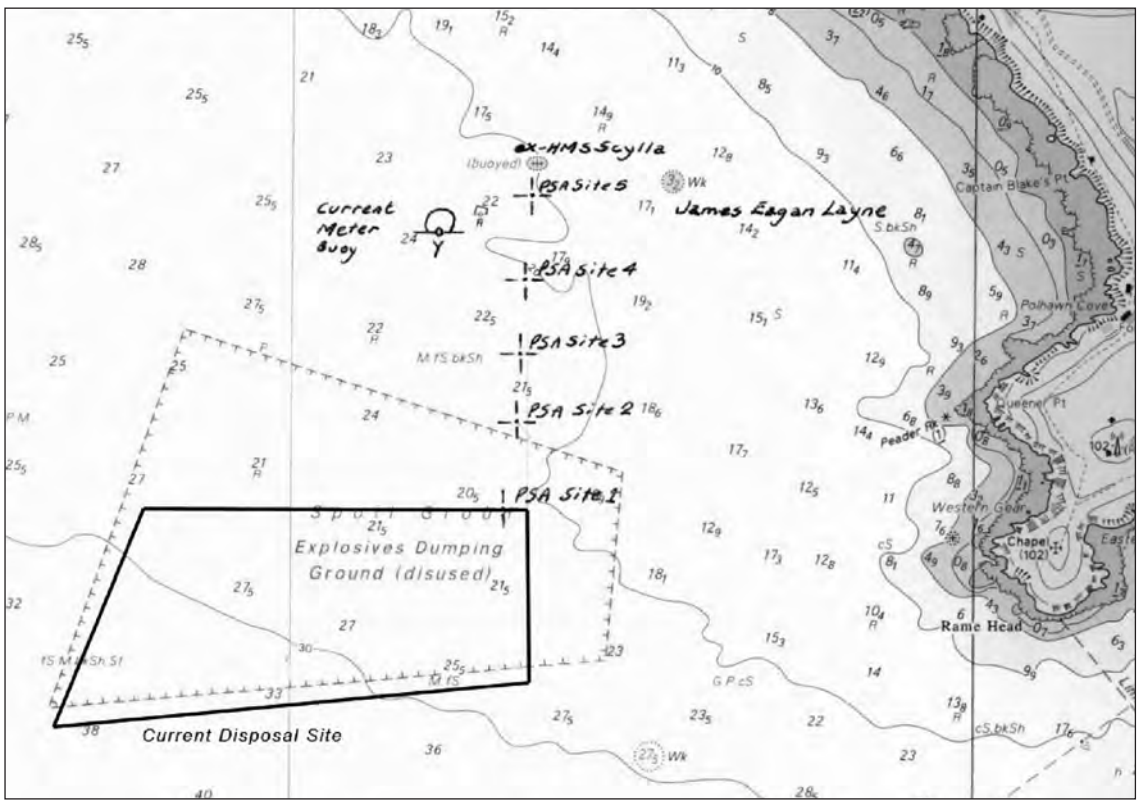
'tab cuts' above (a tab cut results in a hole where the plate is retained by intact tabs). Positioning of the eventual holes was decided on the basis of how the ship was to sink, as well as to provide the best access and exit points for future divers – the CARC and National Marine Aquarium dive team were consulted about this, along with local divers, a Health and Safety Executive diving specialist, police and rescue services. CARC fitted explosive charges with the assistance and advice of the Royal Navy Southern Diving Unit (SDU). Detonators were fitted once the ship had left the port on the day of placement.

Placement day: 27 March 2004

The final decision to go ahead with the placement rested with a team representing the agencies that had been involved from the start. The team met at 5.30 a.m. in the office of the Royal Navy's Queen's Harbour Master (QHM). QHM had the final say over whether the vessel could transit through the Dockyard Port of Plymouth; the Maritime and Coastguard Agency were to make the ultimate decision about whether the placement could go ahead – the only factor that was likely to prevent the project being completed on the chosen day was the weather. During the last few weeks of the project the UK Meterological Office had been supplying increasingly detailed weather predictions for the location and the day of placement. The decision was made to proceed and *Scylla* began her final voyage at 7.30 a.m. on Saturday 27 March 2004. At 15.32 hrs the charges were blown and *Scylla* came to rest in the location, more or less upright as planned.

Figure 1 *Placement day.* ***Upper*** *Scylla is towed out from Plymouth into Whitsand Bay off Cornwall.* ***Lower*** *Detonation of the charges at 15.32 hours, photographed from outside the 1-mile exclusion zone. Some of the holes cut for divers can be clearly seen.*

Figure 2 *Map of Whitsand Bay, showing the sites of* Scylla *and the* James Eagan Layne *(near the top of the map), as well as the position of the current meter and sediment sampling sites (crosses). The boxed area is the Rame Head disposal site.*



Scylla*'s final resting place was chosen to be close to the wreck of the* James Eagan Layne

The Maritime and Coastguard Agency coordinated and marshalled the day – a ring of private craft of all shapes and sizes marked the site around the 1-mile exclusion zone. On shore, an estimated 15 000 people gathered to watch. In the order of 125 media representatives broadcast to an estimated live audience of 60 million people around the world. The final tally of world viewers has now been estimated at 100 million people.

Benefits

The underlying reason for placing *Scylla* on the sea-bed was to create a dive-site in Whitsand Bay, Cornwall (Figure 2), to replace the deteriorating *James Eagan Layne*, which has lain on the sea-bed since 1945. The financial justification for the purchase, preparation and placement costs of £1.4 million was the prediction that *Scylla* would generate a similar amount back into the local economy each year. The National Marine Aquarium's interest was the possibility that *Scylla* could become a sea-bed 'observatory' where colonization and other factors could be monitored over a period of years.

All aspects of the plan are progressing well. *Scylla* has attracted a huge number of divers to the area (10 000 dives in her first season) and the 'payback' in terms of contributions to the local ecomony was easily achieved within the first year; she continues to generate income for local dive boat operators, equipment suppliers and the hospitality industry. Divers agree that she is becoming well colonized and amongst the premier dive sites around the UK.

As an observatory she has been equally successful, with a number of agencies using *Scylla* as a platform for gathering data. *Scylla* has acted as a catalyst amongst the diving and scientific communities in Plymouth; working together, they have amassed a wealth of ecological data.

The monitoring programme

One condition of the licence issued to the National Marine Aquarium by the Secretary of State for Environment, Food and Rural Affairs was the implementation of a 10-year monitoring programme. One of the aims of this programme is to study the colonization of 'Scylla Reef', including the effects of any residual tributyl-tin, TBT.* The other part of the monitoring programme involves examination of changes in sedimentary processes as a result of the vessel's placement in Whitsand Bay.

In the first instance, a site survey needed to be conducted prior to the placement of *Scylla*, to establish baseline data. This included the collection of sediment samples from five specified sites between the Rame Head disposal site and the proposed placement site for *Scylla* (cf. Figure 2), together with the collection of biota samples from the *James Eagan Layne*, which were analyzed for TBT. The *James Eagan Layne*, an American Liberty Ship torpedoed during World War II, lies approximately 600 m south-east of *Scylla* in Whitsand Bay, and was to be used as the reference vessel with which colonization of marine organisms and accumulation of TBT in biota samples on *Scylla* would be compared. The Rame Head disposal site lies approximately 3 km to the west of Rame Head, within Whitsand Bay (see Figure 2), and was first used approximately 100 years ago for the disposal of old munitions. During the last 30 years it has received 6 million tonnes (wet weight) of dredge material, mostly originating from the ports, harbours, berths and navigation channels situated in and alongside the River Tamar and Plymouth Sound. The disposal site is a possible source of silt for areas further north in Whitsand Bay.

Because of the varied requirements of the monitoring schedule a number of different organizations were involved in data collection, either to contribute their particular expertise or simply to provide additional information. Data were collected by the National Marine Aquarium, the Marine Life Information Network (*MarLIN*), the National Oceanography Centre, Southampton (NOCS), Plymouth Marine Laboratory (PML), the Royal Navy Maritime Warfare School, Hydrographic and Meteorological Training Group (HMS *Drake*, Plymouth), Seasearch and the University of Plymouth. Data were processed and/or interpreted by the National Marine Aquarium, *MarLIN*, PML, the Royal Navy, Unicomarine Limited, and CEFAS, as appropriate.

*TBT-based antifouling paint was first used on ship hulls in the 1960s to reduce drag caused by fouling organisms such as barnacles. However, less than a decade later concerns were raised about the environmental impacts on non-target organisms, such as marine gastropod molluscs. In 1999, the International Maritime Organisation (IMO) banned the application of all TBT paints from 1 January 2003, with a total phase-out by 1 January 2008.

The sites of the quadrats were chosen to cover locations with different aspects, both with and without TBT paint

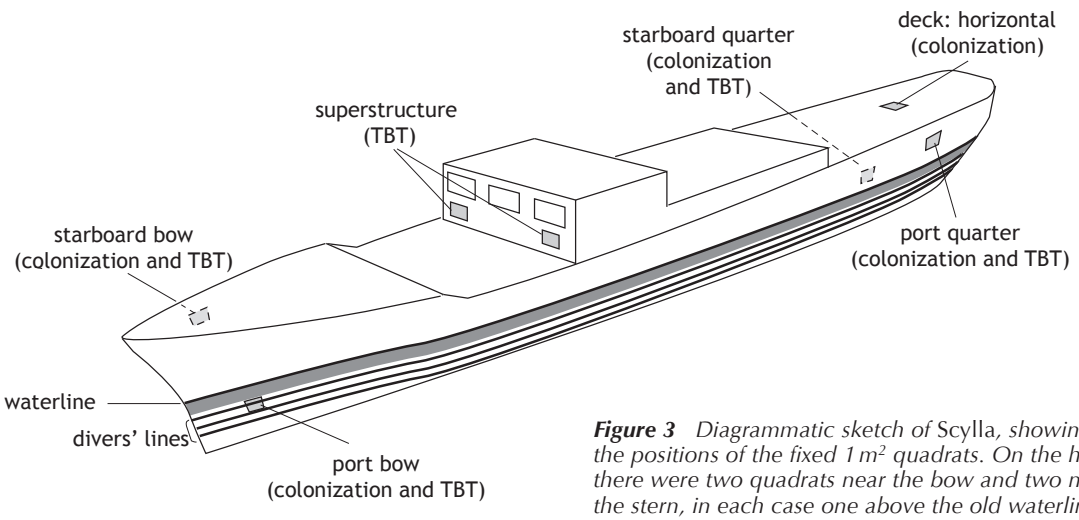


Figure 3 *Diagrammatic sketch of* Scylla*, showing the positions of the fixed 1 m² quadrats. On the hull, there were two quadrats near the bow and two near the stern, in each case one above the old waterline and one below. (Divers' lines are orientation lines added for the benefit of divers.) (Not to scale)*

Monitoring schedule

The overall colonization process, and the effects of TBT migrating from paint on the hull into the area surrounding the vessel, are being monitored using photographic evidence of pre-determined locations on the vessel, shown schematically in Figure 3; these are fixed quadrats, 1 metre square, each marked by four bolts. The aim is to highlight any differences in species succession occurring between *Scylla*'s hull and her superstructure, and to establish whether colonization of these areas is progressing towards that of the reference vessel, the *James Eagan Layne*.

Furthermore, biota samples have been collected and analyzed to assess whether there has been any accumulation of TBT in the organisms found in the vicinity of the hull. TBT is lipophilic in nature and bioaccumulates in organisms because of its solubility in fat. Marine organisms acquire metals by a variety of routes, including direct uptake of metal from solution in the surrounding seawater across the entire body surface and/or across the gills, by ingesting food, and through uptake of water, or by a combination of all these routes. For many organisms it is not always clear which route is the most important, and there are numerous studies which illustrate that the route of metal uptake influences both the distribution of metal in animal tissues and the toxicity of the metal. The biota samples from *Scylla* and the *James Eagan Layne* included mobile species (e.g. starfish), sedentary species (e.g. sea-anenomes) and sessile species (e.g. dead man's fingers), with a range of uptake routes and a variety of different feeding mechanisms.

There is also monitoring of sedimentary changes in the area around *Scylla*. In order to provide an overall picture of the effects of placing *Scylla* in Whitsand Bay, three types of data were collected: particle-size analyses of sediment samples collected by grab at the locations labelled 'PSA site 1' etc. in Figure 2; current meter measurements; and acoustic images of the sea-bed immediately around *Scylla* Reef. Five months' worth of current meter data, together with two sets of sediment samples analyzed for particle size, provided valuable information on sediment transportation in the area. In the longer term, on-going annual collection of acoustic images will provide a time-series showing the build-up and/or removal of sediment around *Scylla*.

Results

Colonization

The initial colonization of an artificial reef can be rather variable. For a given site, the various abiotic and biotic factors affecting incoming species, and interactions between these factors, make colonization and subsequent succession unique to that site. Furthermore, the structure of the reef itself, its composition (the extent to which it is constructed from a material suitable for colonization) and its level of complexity as a habitat (e.g. whether it has sufficient holes and crevices for cryptic species, i.e. those that live hidden out of sight), will also affect settlement patterns and subsequent changes in the epibiotic community.

That said, colonization of *Scylla* does appear to fall broadly in line with other temperate artificial reefs studied. Within days of *Scylla* being placed on the sea-bed, mobile species such as spiny spider crab (*Maja squinado)*, ballan wrasse (*Labrus bergylta)*, and small gadoids (i.e. fish of the cod family) such as bib and poor cod (*Trisopterus luscus* and *Trisopterus minutus)* were noted around *Scylla*, all most probably using the wreck for shelter, and as a potential source of food. The first organisms to colonize the surface of *Scylla* were typical fouling organisms, such as hydroids (e.g. *Obelia dichotoma*), barnacles (e.g. *Balanus crenatus*), and keel worms (*Pomatoceros triqueter*), all of which appeared within the first month. Brown algae (e.g. *Saccorhiza polyschides*), bryozoans (e.g. *Electra pilosa*) and more hydroids (*Tubularia* sp.) appeared within three months, swiftly followed by species of red algae (e.g. *Polysiphonia elongata*) and green algae (*Ulva lactuca*), solitary sea squirts (e.g. *Ciona intestinalis*) and sea-anemones (*Sagartia troglodytes decorata*), which had all colonized by July 2004.

As seaweeds and encrusting organisms form food for other animals, further mobile species were also found on and around the Reef within the first six months, including various crustaceans, echinoderms (e.g. sea-urchins and starfish), molluscs (e.g. bivalves and nudibranchs or sea-slugs) and fish. During this time there were some notable events: a number of nudibranch species and their eggs were recorded in July; a mass settlement of juvenile Queen scallops, *Aequipecten opercularis,* was observed in August, and high numbers of the green sea-urchin *Psammechinus miliaris* were noted in September 2004. Common starfish, *Asterias rubens,* were first noticed on the sea-bed around *Scylla* in August but were found in abundance all over the vessel a couple of months later, quite possibly predating on mussels (*Mytilus edulis*), which were themselves initially observed in large numbers during August.

Early colonizing species, and subsequent succession events, may be influenced by the coincidence of reef deployment and spawning activities of fouling species and, for this reason, a good understanding of a species' life history, biology and ecological preferences will help to elucidate the pattern of colonization on the Reef. For instance, the barnacle *Balanus crenatus* was one of the first species noted as settling on *Scylla*, in April 2004. As their larvae are released between February and September, with peaks of abundance in April and late summer, the first peak in larval release and subsequent settlement in April, would have coincided with the sinking of *Scylla*. Barnacles grow quickly and, as *B. crenatus* usually grow at a rate of 4.4 mm per month, they were visible within a month of settlement.

Grazing of reefs by both vertebrate and invertebrate predators (e.g. fish and echinoderms) can greatly reduce the biomass of the fouling community, and by mid-winter 2004/5 there was a noticeable decrease in algae, barnacles, and keel worms following grazing by urchins and starfish. This reduction in biomass also coincided with the natural seasonal decline of species such as algae.

***Nearly two years after placement, colonization of* Scylla *had begun to resemble that of the long-wrecked* James Eagan Layne**

***Figure 4* (a)** *Video image of the bow of the* James Eagan Layne *in April 2005.* **(b)** *The starboard side of* Scylla*, photographed on 28 January 2006. Note the abundance of plumose sea-anemones (*Metridium senile*) in both cases. (Photo (b) by courtesy of Keith Hiscock)*

The following 18 months saw colonization of the Reef by numerous additional mobile species and species that live attached to hard surfaces, together with seasonal additions/variations in flora and fauna and successional changes. The most recent scheduled survey (March–April 2006) demonstrated continuing changes in species diversity over time. For example, images of the starboard bow quadrat, taken three months after placement, indicated a high percentage of keel worms (*Pomatoceros triqueter*). By March 2005 the quadrat looked much barer, almost certainly following grazing by species such as *Psammechinus miliaris,* the green sea-urchin. By April 2006, the same quadrat appeared to be dominated by the plumose sea-anemone *Metridium senile,* rather than by keel worms, probably due to the previously mentioned grazing, coupled with the fact that *P. triqueter* usually live approximately 1.5 years, so there may also have been some natural die-off by this time. *M. senile* usually spawn in August and September. These fast-growing, aggressive colonizers were first noticed in August 2004, immediately after their usual spawning period. By April 2006 some of them had reached over 15 cm in length.

The difference in colonization above and below the original waterline is very striking

Figure 5 *Differences in colonization between areas with and without an antifouling paint covering, on 23 April 2005.*

(Photo by courtesy of Keith Hiscock)

In September 2006 additional, unscheduled sampling was conducted in an effort to identify some of the smaller macrofauna on the Reef. From the samples collected, approximately 80 'new' species were identified, including the nationally rare sea slug, *Trapania maculata* (Figure 6, opposite). At this time, the additional species brought the recorded number of species found on or around *Scylla* to over 220.

It therefore appears that a combination of seasonal inputs of larval epifauna and flora, together with the successional development of the epibiotic community, has led to *Scylla* beginning to resemble the local natural 'reef' community (see Jensen *et al*. in Further Reading). *Scylla* was scuttled in an area of flat sand, with the nearest 'reef' being the wreck of the *James Eagan Layne*, which is covered in typical, easily recognized wreck species such as 'dead man's fingers' (*Alcyonium digitatum,* a cnidarian) and *M. senile*. The increasing similarity between *Scylla* and the *James Eagan Layne* is particularly noticeable if images of *Scylla* taken in January 2006 are compared with images of the *James Eagan Layne* taken in April 2005 (Figure 4, above).

As well as biotic processes, physical and chemical processes are influencing colonization on the Reef. As soon as the monitoring programme commenced, it became clear that there were distinct differences in rates of colonization between the different quadrat locations on the Reef, with the most important factors appearing to be the aspect of the surface, and whether or not the area in question was coated with anti-fouling paint (Figure 5). In general, greater colonization was noted on the starboard side of *Scylla* and areas not covered with antifouling paint, e.g. those parts of the hull above the vessel's 'waterline'.

The starboard quadrats showed more evidence of colonization in the earlier months particularly. Analysis of the current meter data indicated that current flow was mostly parallel to the coast, with tidal currents running north-west to south-east (and vice versa) (cf. Figure 7(a), overleaf) and the strongest flow on the flood tide. As *Scylla* was scuttled with her bow pointing south-west, into the prevailing weather, currents from the north-west would be perpendicular to the vessel, flowing into and around the starboard side of *Scylla*. This would present a greater opportunity for organisms to settle on the starboard side than on the port side. However, it was also noted that colonization on the one horizontally placed quadrat was minimal. A study of five vessels sunk as artificial reefs, undertaken by Wendt and colleagues (see Further Reading), found that biomass, percentage cover, and number of sessile organisms were greater on vertical surfaces than horizontal surfaces.

These results suggest that differences in colonization between surface orientations may have been due to heavier predation and/or increased sedimentation on horizontal surfaces or, alternatively, that negative phototactic behaviour (i.e. preference for lower light levels) of settling larvae may have led to a preference for colonizing vertical surfaces, which are usually more shaded than horizontal surfaces. Other studies have suggested that any colonization on horizontal surfaces is likely to be by organisms with erect growth forms or a tolerance of higher sediment loads. It is also possible that the activity of divers may influence the colonization of horizontal surfaces – divers' fins may be more likely to come into contact with horizontal surfaces than vertical ones, possibly damaging any settling organisms.

TBT accumulation

Biota samples from both *Scylla* and the *James Eagan Layne* (including some collected from the *James Eagan Layne* as part of the baseline survey) contained elevated levels of TBT (i.e. above 2 $\mu g\,kg^{-1}$ wet weight of biota sample or 20 $\mu g\,kg^{-1}$ for molluscs). On each vessel, the species that usually exhibited higher levels of TBT were active filter feeders such as the solitary sea-squirt, *Ciona intestinalis,* and dead man's fingers, *Alcyonium digitatum*. 'Active' (as opposed to 'passive') suspension feeders filter their food from the water column by actively pumping in seawater, or sweeping appendages through it – by increasing their contact time with the surrounding water they increase their chance of

Figure 6 *The sea-slug* Trapania maculata*, which is rare in British waters. It is translucent with vivid orange markings, and may grow to nearly 2 cm long.* T. maculata *arrived on* Scylla *some time before September 2006.*

Table 1 *Time-line showing how many new species were observed for the first time on* Scylla *during each observational period. For more information about the groups of organisms mentioned see below.*

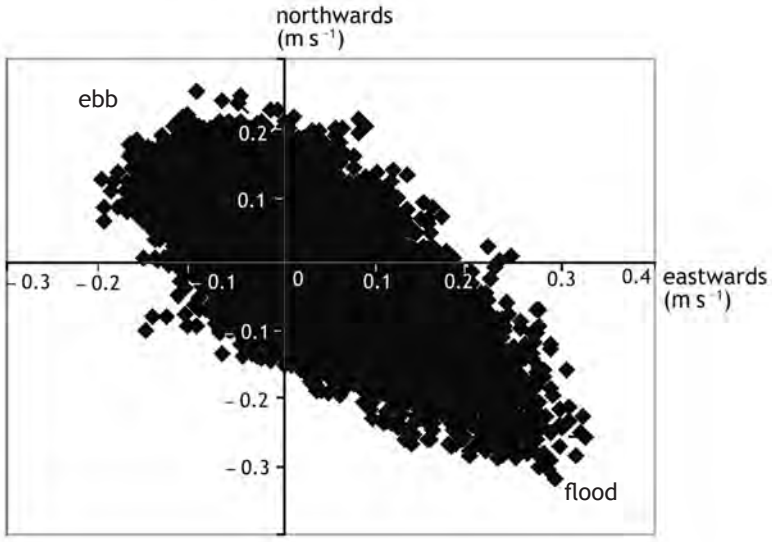
Date		Numbers of species observed for the first time
2004	March	1 crustacean, 3 fish
	April	1 annelid worm, 2 crustaceans, 1 cnidarian
	May	1 cnidarian, 1 echinoderm
	June	1 brown alga, 1 bryozoan, 2 cnidarians, 1 echinoderm, 1 mollusc, 4 fish
	July	1 green alga, 1 brown alga, 2 red algae, 1 annelid worm, 2 tunicates, 1 cnidarian, 5 molluscs, 1 fish
	August	2 red algae, 3 crustaceans, 1 tunicate, 3 cnidarians, 2 echinoderms, 2 molluscs, 6 fish
	September	1 tunicate, 2 echinoderms
	November	1 brown alga, 1 crustacean, 2 tunicates, 2 cnidarians, 1 echinoderm, 4 fish
2005	January	1 fish
	February	1 sponge
	April	1 sponge
	June	1 cnidarian
	July	2 annelid worms, 1 bryozoan, 1 crustacean, 2 tunicates, 2 cnidarians, 1 echinoderm, 1 sponge, 2 fish
2006	January	1 mollusc
	March	1 bryozoan
	August	2 brown alga, 7 red algae, 3 annelid worms, 8 crustaceans, 9 bryozoans, 4 tunicates, 6 cnidarians, 1 echinoderm, 1 sponge, 3 fish
	September	1 protist, 27 annelid worms, 2 sea spiders, 22 crustaceans, 5 bryozoans, 2 cnidarians, 3 echinoderms, 30 molluscs, 1 nematode worm, 1 nemertine worm, 1 platyhelminthe

Notes

- Annelid worms are segmented worms. Bryozoans are also known as 'moss animals'. Cnidarians include sea-anemones and hydroids. Crustaceans include crabs, shrimps and barnacles. Echinoderms include starfish and sea-urchins. Molluscs include bivalves such as mussels, marine snails and sea-slugs. Nematode worms are threadworms; nemertine worms are ribbon worms; platyhelminthes are flatworms. Protists are single-celled organisms. Tunicates are sea-squirts.
- It is not always possible to verify all species sightings, particularly those noted by volunteer recreational divers who may not have sufficient taxonomic knowledge to correctly identify many of the less conspicuous species, such as sponges, bryozoans and hydroids. In view of this, any reports of species sighted but not substantiated by photographic evidence, may not be definitive. Data were collated from information received between March 2004 and September 2006, from the following sources: Keith Hiscock (*MarLIN*); National Marine Aquarium; Amy Bugg, Seasearch Co-ordinator, Plymouth; Sally Sharrock, Seasearch Co-ordinator, Devon; Seasearch volunteers; Unicomarine Ltd, Plymouth.

taking in food particles contained therein. However, this increased contact with the water column and suspended particulate matter could also render them more susceptible to contamination from TBT in their surroundings. Establishing how toxic the TBT would be for any particular organism can be complex, as it depends on a number of factors including the amount and duration of exposure, uptake mechanisms, genetic variation, age, size, metabolism and excretion rate.

Although the presence of antifouling paint on *Scylla* is the likely source of TBT found in biota samples collected from the Reef, the origin of TBT found in pre-placement samples from the *James Eagan Layne*, a vessel that could not have been painted with antifouling paint, has not been determined. However, *Scylla* was last painted with antifouling paint in 1992, and it is anticipated that any TBT residue will continue to diminish over time, eventually allowing the rest of the vessel to become colonized.



(a)

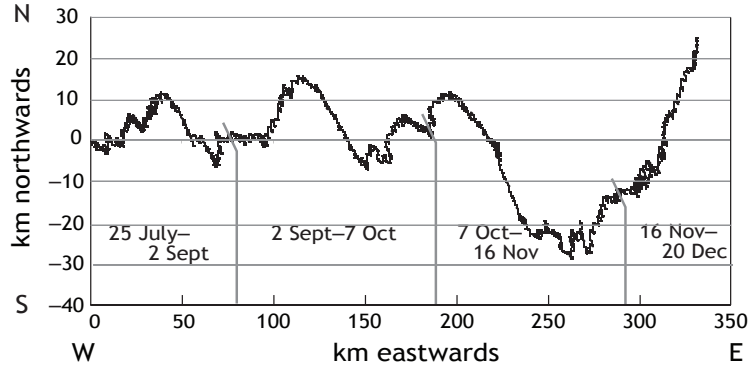
Currents in the vicinity of Scylla are NW/SE tidal motions typically superimposed on an easterly flow

Figure 7 *Current velocity data collected 400 m to the south-west of* Scylla, *5 m above the sea-bed (see Figure 2 for site of current meter).*

(a) *Tidal ellipse for 25 July – 2 September 2005, showing the predominantly north-west–south-east current velocities, with strongest flows on the flood, towards the south-east.*

(b) *Progressive vector diagram for 25 July – 20 Dec. 2005, showing the cumulative effect of current flow on a hypothetical particle initially at the location of the curent meter. The net flow direction was eastward, and the average eastward flow velocity was 0.02 m s^{-1}. The marked south-eastward flow during the third deployment of the current meter is discussed*

(b)



Monitoring sedimentary changes in the area around *Scylla*

Particle-size analyses of sediment samples, collected at sites along a line running from the Rame Head disposal site to *Scylla* (Figure 2), were broadly consistent with existing geological maps (BGS Geological Map Sheet UTM020SSQ, Lands End, Scale 1 : 250 000). The two sampling sites closest to the disposal site, located to the south-east of Whitsand Bay, were composed mainly of slightly muddy, sandy gravel, and the remaining three sites contained mostly muddy, gravelly sand, but with increasing percentages of silt/clay nearer to *Scylla*. A small number of paint remnants were also found in the sediment samples collected from the three sites closest to the Rame Head disposal area.

Five months of consecutive current meter data, collected from July to December 2005, indicated that (as mentioned earlier) tidal current flow 5 m above the sea-bed was mainly parallel to the coast, running north-west to south-east (and vice versa), with the strongest flow on the flood tide (Figure 7(a)). Average tidal current speeds were low, around 0.1 m s^{-1}, and even the maximum speeds measured, just over 0.4 m s^{-1}, are still considered fairly low. Progressive vector diagrams (e.g. Figure 7(b)) showed an average eastwards current velocity of approximately 0.02 m s^{-1}. Current speed and direction appeared to have been affected in a relatively minor way by the seasonal onset of strong winds up to gale force during the third deployment of the current meter (7 October – 16 November). It seems that a prolonged period of strong winds from the south/south-west caused more surface water to be driven into Whitsand Bay than normal, resulting in a return flow to the south-east at depth (cf. Figure 7(b)).

The current meter data provided an explanation for the results from the most recent acoustic images, which indicate asymmetrically distributed areas of scour around *Scylla* (Figure 8). As stated, current meter data indicate that tidal currents in the Whitsand Bay area are strongest on the flood, i.e. when the tides are running from the north-west to the south-east. As *Scylla* is positioned with her bow pointing to the south-west she receives any tidal currents beam on, from the north-west on the flood tide and from the south-east on the ebb; the greater scouring on the port bow could result from turbulence and eddies in the lee of *Scylla* on the flood, and that on the starboard side from turbulence and eddies in the lee of *Scylla* on the ebb. The most visible scour pits, around the port forward and bow, are approximately 12–15 m in length and in places reach depths of as much as 0.5 m.

Although no further current meter data or particle-size analyses of sediment are required, images to show sediment movement around the hull are to be recorded annually for at least another eight years.

Summary of findings on colonization to date

As mentioned, colonization of the Reef depended on the aspect of the surfaces concerned and whether or not the areas in question had been coated in anti-fouling paint. In general, greater colonization was noted on the starboard side of the vessel, above the original waterline; even

after two years, very little or no colonization was observed on areas painted with anti-fouling paint. TBT was found in biota samples from both *Scylla* and the *James Eagan Layne*, with the greatest levels being found in active suspension feeders.

Despite the presence of TBT, colonization continues and evolves on the Reef. To date, over 220 species have been recorded on and around *Scylla*, and the vessel is beginning to resemble the reference vessel, the *James Eagan Layne*. However, as colonization of *Scylla* by marine biota is still in its early stages, caution should be exercised when trying to characterize the habitat ('biotope') of this developing 'reef'. Marine communities exhibit seasonal changes over the course of a year, such as changes in algal assemblages and mass settlements of juvenile animals (e.g. mussels and barnacles), as well as longer term changes in community composition as a consequence of interaction between the organisms and their environment. All these physical and biotic processes need to be borne in mind when interpreting the results of a monitoring exercise.

Furthermore, unless this or any similar community is studied for a sufficient length of time, any true long-term successional development will be difficult to distinguish from seasonal and other short-term variations in the community structure. Most studies on artificial reefs have concentrated on the early stages of colonization of benthic communities, and only a few have examined the long-term development of artificial reef communities beyond the initial successional phases. In view of this, the original foresight shown in the placement of the *Scylla*, and the subsequent planned monitoring programme, which is scheduled to run for another eight years, should provide an almost unique insight into the development of a new biological community for this type of artificial reef.

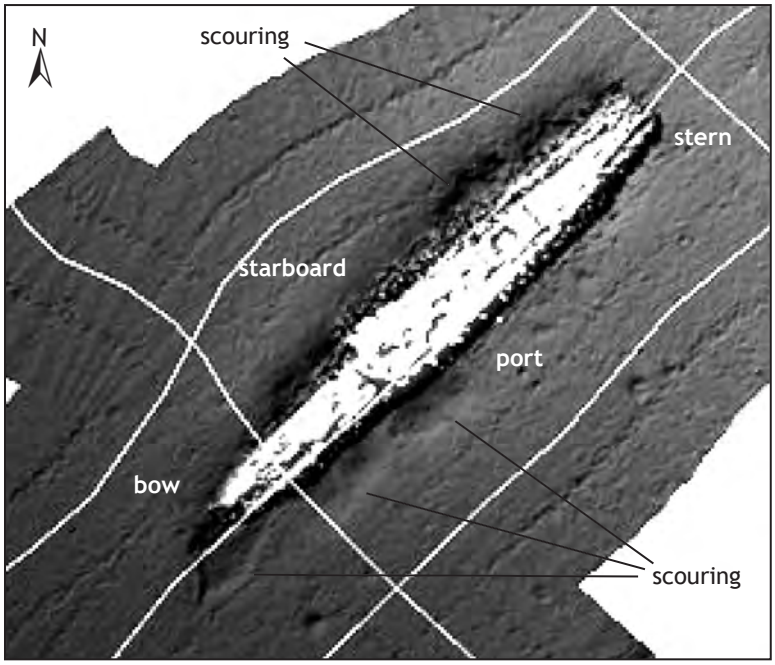


Figure 8 *Image of* Scylla *and the surrounding sea-bed produced by multi-beam sonar (shown as if illuminated from above right), indicating the main areas of scour. Also visible are ripples and small rocky outcrops.*

By courtesy of the Royal Navy Maritime Warfare School, Hydrographic and Meteorological Training Group, HMS Drake*, Plymouth*

Further reading

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The MARLIN website is: www.marlin.ac.uk

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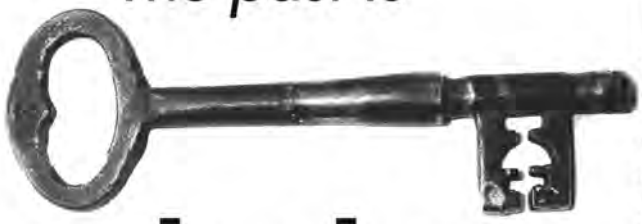
Real-time environmental information for ferry passengers and 'free' data for researchers

The new AquaLine FerryBox is a robust environmental monitoring system for ships of opportunity such as ferries and cargo vessels. Data are logged onboard and then transmitted to shore by GSM phone links and satellite systems. Screens displaying sea-surface data in real time, together with explanatory information, are situated throughout the ship, and the same displays also provide passengers with a map of their position *en route*. The AquaLine FerryBox, made by Chelsea Instruments, evolved from a three-year EU-funded project, which produced data that should prove useful for assessing long-term trends in coastal and ecological models on water transport and environmental parameters. The system was fitted to P&O's *Pride of Bilbao*, operating between Portsmouth and Bilbao, and continues to provide data to the National Oceanographic Centre, Southampton. The latest version of the system is currently being fitted to the Northlink Ferries vessel, the *Hascosay*, which operates between Aberdeen and Lerwick, Shetlands. Data collected from this route will feed into the aquatic environment programme of the Fisheries Research Services in Aberdeen.

The past is the key to the future



How marine historians are providing the long view of marine ecosystems

Kira Paulli Pravato

Biologists can trace changes in marine animal populations back for no more than 100 years or so – their knowledge as to how marine ecosystems functioned in distant decades and past centuries is extremely limited. To understand long-term changes in marine populations we need to peer even further back into the past to piece together a more complete picture of the way things were. A close look at historical records relating to the harvesting of marine animals reveals that they are filled with information of interest to biologists – information they can use to understand how marine populations arrived at their present state, and so improve the way we manage the oceans, now and in the future. These records just need a little translating, and that's where marine historians are beginning to play an important role.

History of Marine Animal Populations

Seven years ago, a group of marine historians from across the world joined forces to develop the History of Marine Animal Populations (HMAP), an interdisciplinary research programme exploiting information contained within historical and environmental archives. The HMAP project, involving more than 100 researchers, is encouraging collaboration between ecologists, marine biologists, historians, archaeologists and oceanographers. This innovative strategy has led to the emergence of the disciplines of marine environmental history and historical marine ecology.

Scientific and historical methodologies developed by the HMAP team are improving knowledge and understanding of humanity's interaction with the marine environment since Byzantine times. The history of marine animal populations has long been one of the great unknowns, but these advances are expanding the realm of the known and the knowable.

'We now know that the distribution and abundance of marine animal populations change dramatically over time. Changes are attributed to climatic and human forces, and while few marine species have gone extinct, there is concern that entire marine ecosystems have been depleted beyond recovery. An understanding of historical patterns of resource exploitation is the key to identifying what has actually been lost in the habitat and is an essential part of developing and implementing recovery plans for depleted marine ecosystems and ecosystem attributes.'

Poul Holm, Chair of HMAP

HMAP is a part of the Census of Marine Life (CoML), a ten-year initiative running from 2000 to 2010, which is led by an International Scientific Steering Committee. CoML's goal is '… to assess and explain the diversity, distribution and abundance of marine life in the oceans – past, present, and future'. Aside from HMAP, CoML consists of 12 field projects and a project entitled the Future of Marine Animal Populations (FMAP). In the final years of CoML, HMAP and FMAP will work closely together for the benefit of future marine animal populations and ecosystems.

By gathering, collating and disseminating historical data, HMAP is demonstrating how ecosystems have changed over time. By analyzing data relating to marine populations before and after the impact of humans on the ocean became significant, HMAP has made available a welter of information on long-term changes in stock abundance, the historic ecological impact of large-scale human harvesting, and the role of marine resource utilization in the development of human societies. Such evidence, in turn, has broadened and deepened knowledge of the contemporary condition of the marine environment and provided the time-series and ecological insight required to assess future sustainability of marine animal populations. At the same time, the analysis sheds light on the reasons why life in the oceans appears as it does today. In essence, the message of HMAP is that the past is an accessible and exciting domain that is of great relevance to the marine environment – and therefore the well-being of the human population of the contemporary world.

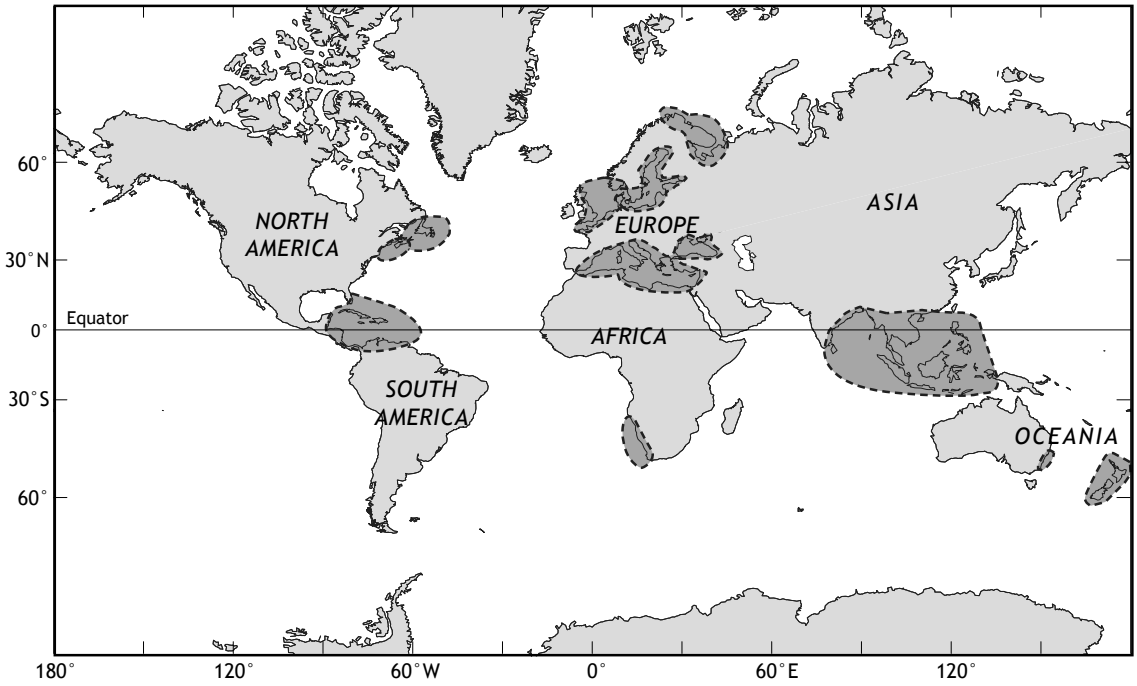


Figure 1 *The geographical distribution of the 16 HMAP case-studies. A complete list of HMAP projects (case-studies plus four other projects which focus on particular topics) is shown down the right-hand side; for more information, see the HMAP website, www.hmapcoml.org.*

HMAP case-studies

White Sea and Barents Sea
Baltic Sea
Wadden Sea
North Sea
Gulf of Maine cod
North-west Atlantic
Mediterranean Sea and Black Sea
Caribbean
South-west African Shelf
South-East Asia
South-East Australian Shelf
New Zealand

plus

History of nearshore biodiversity
Fish bones
World whaling
Mega-molluscs

How is it done?

How is it possible to tell how the marine environment looked way back in the distant past? One of the methods is to analyze various documents where catch sizes were recorded. For example, Jeremy Jackson and Loren McClenachan work with antique tax ledgers, and find themselves handling crisp paper from the time of Columbus, their nostrils filling with the scent of old leather. These historians are gathering information concerning the influence humans have had on Caribbean reefs over the course of more than 400 years. They have analyzed changes to the reef and have established well-defined ecological profiles from the past four centuries.

Another project located in northern Europe involves studying kitchen middens. Under the leadership of James Barrett, the Fish Bone Project is investigating long-term trends in the development of intensive sea fishing and fish-trading in north-west Europe, from 800 AD up to the end of the Middle Ages. Archeological samples extracted from the fish-processing sites are analyzed and examined in order to discover the kinds of fish that were caught in this region, and the quantities of fish that were processed. Thus catch sizes can be estimated and a more accurate ecological profile can be constructed.

Shifting baselines

An important term in HMAP's work is 'shifting baselines'. When we consider the state of the marine environment today we have no other option than to compare marine populations with what we know about the environment in the past. But what if that comparison is based on incomplete information or misinterpreted data? For example, today, the Pacific north-west's Columbia River contains twice as many salmon as it did in the 1930s. This may seem like good news, but in the 1930s the salmon population was only about 10% of what it had been in the 1800s.

All over the world, historical analysis has shown that past ecosystems assumed to be in their 'pristine' states were, in fact, not so. This was the case for the south-east Australian shelf where the baseline had been defined on the basis of what was known about the ocean in 1950, by which time the waters were already depleted by the fishing industry. Neil Klaer's research into the first commercial fishery on the south-east Australian shelf revealed the extent to which human harvesting has been impacting upon stocks since 1917. Furthermore, the archives contain evidence that major shifts in the compositions and sizes of fish stocks had already occurred before the Second World War. The largest and most easily caught fish species had been taken out of the ecosystem first, allowing other species to take their position in the food web. Today, Australians are better able to strive for a healthy and sustainable marine environment, equipped with knowledge of what the shelf waters have been able to produce in the past and therefore might be able to produce in the future.

Long-term changes

Another important issue to address is *why* animal populations and ecosystems change. Do changes in the size of marine harvests indicate changes in fishing activity, or changes in marine populations brought about by environmental change? HMAP historian Bo Poulsen has conducted a research programme on herring in northern Europe. Since Viking times, herring have been a staple part of the diet of northern Europeans, but historical analysis shows that the abundance of North Sea herring has fluctuated dramatically over past centuries. This fluctuating abundance of herring has led to speculation that there is a link between their populations and changing sea temperatures in the region.

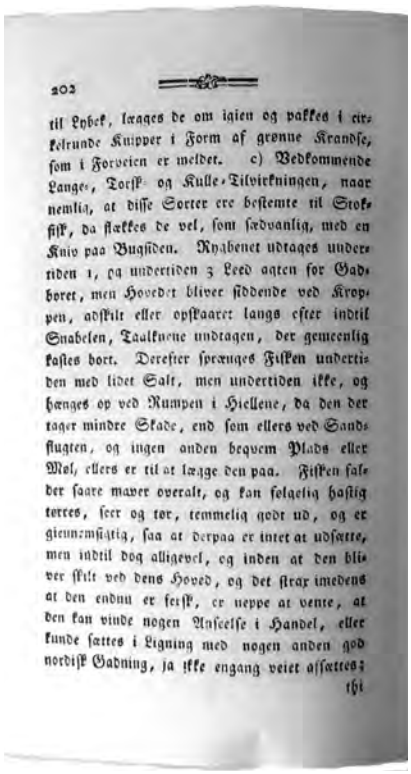
From an eighteenth century text on socio-economy to ....

On the northern shore of Denmark two women are hanging out fresh cod, plaice and haddock to dry in the warmth of the July sun – a sight not often seen these days. The two women are the HMAP historians Maibritt Bager and Anne Dorthe Holm, and they are undertaking an experiment to enhance our knowledge about fish preservation methods used between 1600 and 1900. Historically, the preservation of fish was of vital importance to the fishermen in this area, as well as the surrounding community.

Fish rot very easily, but a well preserved fish was a valuable piece of merchandise, enabling fishermen to distribute their goods all over Denmark and northern Germany. But a close neighbour of Denmark, Norway, had a much greater production of dried fish. Was that because the quality of dried fish from Denmark wasn't high enough?

Printed sources surviving from that time, such as tax ledgers (see below), maps, atlases, and recipes in cookbooks, tell us that dried fish were requested as supplies, but none of the sources mention the quality of the dried fish.

Sometimes, archives do not provide all the data needed, and the historian has to use creative techniques to gain the information required. The purpose of the fish-drying experiment is two-fold: first, it provides information about the quality of dried fish produced in Denmark, allowing a better understanding of the early fishing industry and the fishing trade. Secondly, it provides a key conversion factor enabling us to compare 16th century fish catches, listed in customs and tax records in terms of dry weight, with fish catches of today, which are recorded in terms of wet weight.



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til Lybek, lægges de om igien og pakkes i cirkelrunde Knipper i Form af grønne Kranse, som i Forveien er meldet. c) Vedkommende Langes-, Torsk- og Kulle-Tilvirkningen, naar nemlig, at disse Sorter ere bestemte til Stokfisk, da slækkes de vel, som sædvanlig, med en Kniv paa Bugsiden. Nyabenet udtages undertiden 1, og undertiden 3 Leed agten for Gadboret, men Hovedet bliver siddende ved Kroppen, adskilt eller opskaaret langs efter indtil Snabelen, Taalknene undtagen, der gemeenlig kastes bort. Derefter spræenges Fisken undertiden med lidet Salt, men undertiden ikke, og hænges op ved Rumpen i Hiellene, da den der tager mindre Skade, end som ellers ved Sandsiugten, og ingen anden bequem Plads eller Møl, ellers er til at lægge den paa. Fisken salder saare mayer overalt, og kan følgelig hastig terres, seer og tør, temmelig godt ud, og er gienemsigtig, saa at derpaa er intet at udsætte, men indtil dog alligevel, og inden at den bliver skilt ved dens Hoved, og det strax imedens at den endnu er ferisk, er neppe at vente, at den kan vinde nogen Anseelse i Handel, eller kunde sættes i Ligning med nogen anden god nordisk Gadning, ja ikke engang veiet assættes: thi

Above *Olaus Olavius' description of the procedure for drying cod, haddock, plaice, and other important species (published in 1787).*

Below *An account ledger from the county of Hammershus, Denmark, early 1700s. The document gives full details of taxes paid by cod fishermen from every fishing village in the district. The taxes were paid in dried cod, and the numbers of cod demanded provides an insight into the abundance of cod in the coastal waters around Bornholm on the Baltic.*

Translation of left-hand page

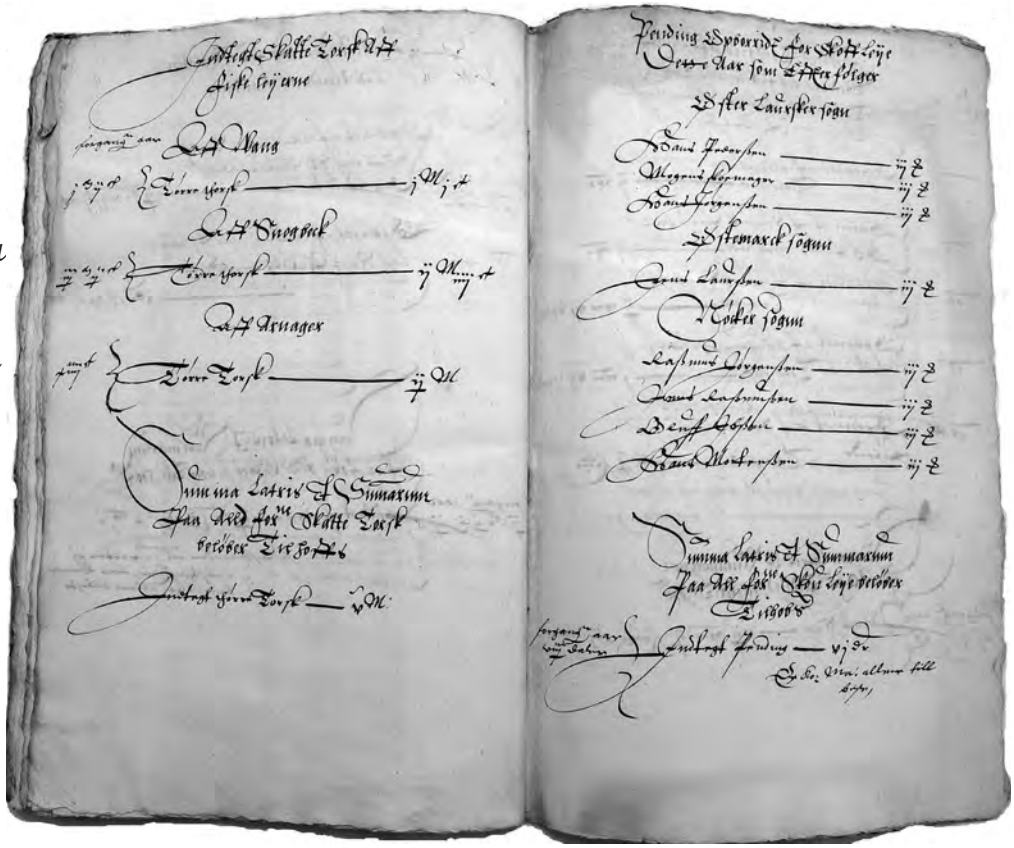
Revenue tax received from fishing villages

From Vang
Dried cod
—— 1 thousand 1 hundred

From Snogbeck
Dried cod
—— 2 thousand 4 hundred

From Arnager
Dried cod — 1½ thousand

This page's total of cod paid as tax — 5 thousand



... a greater understanding of fisheries, then and now

By employing the same drying techniques that were used in the late 18th century, Maibritt Bager and Anne Dorthe Holm will gain a better understanding of the process and learn exactly how the drying process works under the weather conditions in that particular region of Denmark.

The experiment

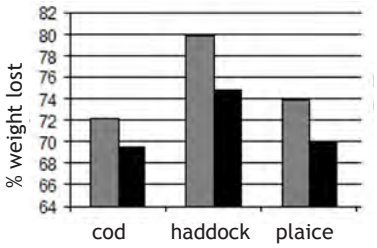
The technique they have chosen to use was described by Olaus Olavius, a customs official from Skagen, Denmark, who wrote a book on socio-economic conditions in Skagen, which was published in 1787. Other sources make it reasonable to assume that the same method was being used as early as the 16th century.

The researchers are using 18 cod, 20 haddock and 20 plaice. The fish have been gutted and cleaned thoroughly so that blowflies aren't tempted to lay eggs. The fish are then divided into two groups, and laid in brine for two days. The first group are dried using the drying technique from 1787, and the second group are dried using a technique from 2005. The difference between the techniques lies mainly in the amount of salt used in the respective brines, with the 2005 method using more salt than the older recipe. For the fish being dried using the 2005 method, Pyrethin, an insecticide used by most modern fish producers, is also added during the first 10 days of the drying process.

Both groups of fish are hung out to dry on a 'hjeld' or drying rack (see photo below) set up in a location used by fishermen of that period. Fish are approximately 80% water, and during the first 7–11 days all the fish in both groups reduce in weight by 50%. At the end of the process, the fish have reduced in weight by 70–80%, depending on the species. The process is finished when the fish stop losing weight. At that time, the fish is so dry that it sounds like a board when banged on the ground, just as described in the historical sources.

Conclusion

Maibritt Bager and Anne Dorthe Holm's experiment demonstrates that fish dried using the 1787 procedure provide the best results, with only a minimum of water remaining in the fish. This proves that the preservation technique used over two hundred years ago in northern Denmark was extremely efficient, and that the quality of the fish was very good. It seems that it was possible to produce as good a quality of dried fish in Denmark as in Norway. But geographically, the seasonal climate window for drying fish in Denmark is much narrower than that in Norway, which is the most likely reason for the Danes not producing as many dried fish as their more northerly competitors.



Comparisons of the differences in weight loss for cod, haddock and plaice, using the recipe from 1787 (grey) and one from 2005 (black).

On the basis of the experiment, Maibritt Bager calculated a wet weight/dry weight conversion factor for fish caught and dried in this particular area of Denmark using the old preservation techniques. She has been applying this information in research on changing abundances of cod and haddock in the North Sea (another HMAP project), comparing the size of today's catches of some important species in the Danish North Sea fishery with those of the 16th and 17th century. Such work will help advance understanding of changes in the size of exploited fish populations over time.

In the experiment, cod, haddock and plaice were dried on a 'hjeld', a rack used by fishermen in Denmark between about 1500 and 1950

Sources

Olaus Olavius' book was entitled Beskrivelse over Skagens Købstad og Sogn, København, 1787.

The tax ledger is reproduced by courtesy of the Danish National Archive, Copenhagen (Hammershus county accounts 1602 and? 1607).

The photograph and graph on this page are by courtesy of Maibritt Bager.

Today, the North Sea is as far south as herring will go, and there is evidence that if temperatures in the area continue to rise, herring will disappear from the waters of the North Sea altogether. They feed primarily on copepods, which prefer cooler waters, and if the copepods move north, the herring are likely to follow.

Only when we know what caused past changes in the oceans will we be able to understand what will influence the oceans in the future. With such knowledge as a guideline, we will be better equipped to work toward sustainable and bountiful marine ecosystems.

In the 16th century, herring were much more abundant in the seas off northern Europe than they are today

Figure 2 *This woodcut from 1555 shows a sea brimming over with herring. In fact, although historical records describe an abundance of herring in the seas around northern Europe, they were not in the quantities that the woodcut suggests.*

Courtesy of University of Southern Denmark.

HMAP's expertise has already been put to good use. Catch data for humpback whales collected and pieced together by Tim Smith and his HMAP colleagues, were used in 2004 by the Scientific Committee of the International Whaling Commission to determine the recovery status of this species in the North Atlantic. Similarly, the locations of historic whaling grounds for right whales have been used to predict where in the North Atlantic the few survivors of this critically endangered species may be found. Logbook records of 18th and 19th century whaling provide our only insight into past distributions and abundances of these two species, as well as those of sperm whales, gray whales and bowhead whales. Careful analysis of those records in the context of current information is providing insights into past whale populations not otherwise available.

HMAP and FMAP

As mentioned earlier, to ensure that the work of HMAP will make an impact in the future, there is a strong link with FMAP, the Future of Marine Populations. The aim is to develop a global perspective of the changes in exploited marine animal populations and the status of ecosystem exploitation over centuries and decades. Establishing historical baselines for ecosystem shifts has stimulated a policy debate in many regions. As fishery managers work to address the effects of overfishing and develop strategies for building up stocks in areas such as the Baltic, North Sea and western North Atlantic, population targets are under intense discussion. Recent estimates of stock productivity suggest very limited possibilities for stock recovery, and more information about historical baselines can broaden perspectives. While HMAP and other research programmes throughout the world have documented many long-term declines in abundance, there are many instances where populations have increased and ecosystems have improved, even in recent decades of the 20th century. The intention is that collaboration between HMAP and FMAP will make a significant contribution by identifying what facilitates recovery of populations and species that have declined, and of ecosystems that have been altered or degraded.

Use of historical records to model biomass

For centuries, fishermen have sailed from Beverly, Massachusetts, and other ports, and brought back cod from the Scotian Shelf (the area of continental shelf to the east of Nova Scotia). Athough the fishing effort* has increased tremendously, today's catch from that area (now within the Canadian Exclusive Economic Zone) is not nearly as much as that taken by fishermen in 1852. Under the leadership of Andrew A. Rosenberg, HMAP researchers are working on the Gulf of Maine Cod Project (GMCP) at the University of New Hampshire. The group have used records from New England fishing vessels, along with population modelling, to establish a biomass estimate of cod stocks on the Scotian Shelf in the mid-19th-century. From geographically specific daily catch records in old logbooks (numbers of fish caught and their weight) they have drawn a picture of an ocean that was full of cod.

The researchers studied logs from the 1639 vessels fishing in that area. Not all the boats spent all their time in that region, so the vessels were divided into three categories.

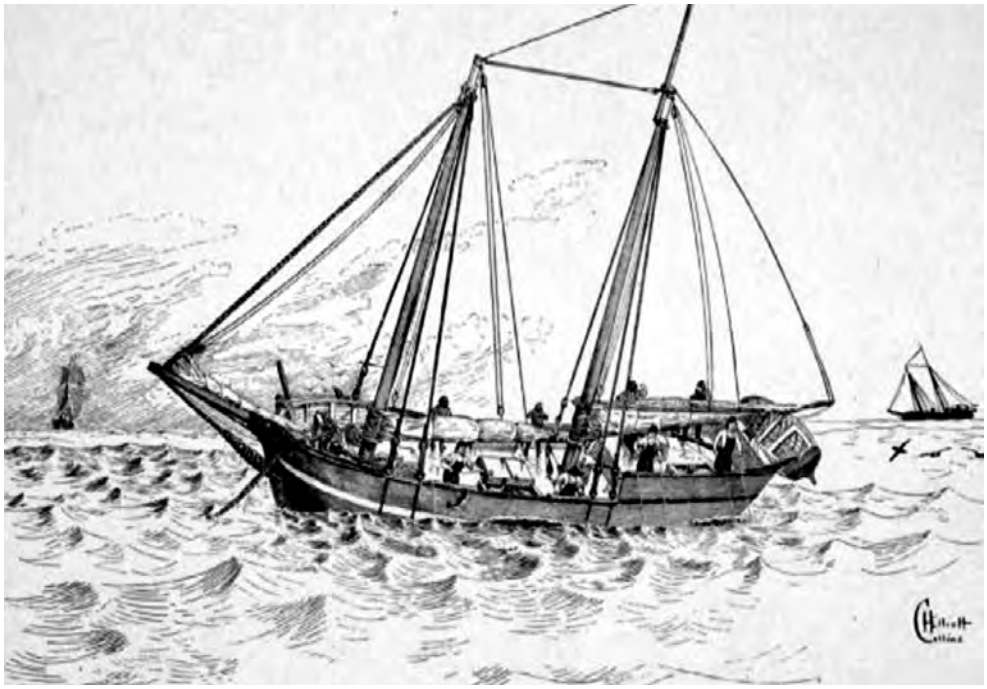
1. 236 Beverly vessels fishing solely on the Scotian Shelf.

2. 90 Beverly vessels fishing part of the season on the Scotian Shelf. Here it was assumed that even if the boats spent 60% of their time on the Scotian Shelf, only 25% of the catch came from that area.

3. 1313 vessels from other ports. The logbooks did not say exactly where the fish were caught, so conservative assumptions were made on the basis of the results of 1 and 2.

A handliner typically fished with two hooks over the schooner's rail (Figure 3). In 1852, seven or eight handliners, fishing with two hooks apiece were, on a good day, able to catch about 100 cod each. In the logbooks, the cod were given only in terms of dried weight, so a way had to be found to convert weight of dried cod to numbers of live cod. To calculate a conversion factor, the researchers used information on the numbers of fish caught each day, taken from the logs of those vessels that spent the entire season on the Scotian

*'Fishing effort' is a measure of the resources devoted to fishing. It may be expressed in various ways, e.g. days at sea, number/size of vessels, gear used, and engine power.



In the mid-19th century schooners on the Scotian Shelf fished for cod with handlines

Courtesy of NOAA National Marine Fisheries Service

Figure 3 *This illustration from the 1880s shows fishermen lining the rail, each deploying two baited hooks in essentially the same manner as Europeans fishing off Newfoundland in the 1500s.*

The HMAP analysis shows that in 1852 the biomass of cod on the Scotian Shelf was many times greater than at present

Shelf. Using this information, plus the records of the weight of dried cod sold to the merchant at the end of the season, the team were able to make a weight-to-number conversion.

To produce statistically solid comparisons, the HMAP team looked at the time-frame between 1852 and 1859. Based on the available data, it was possible to calculate the catch per day per man, and use it as an index of abundance in a dynamic population model. There were some surprising results. First, it was estimated that in 1852 there were altogether 1.26 million tonnes of adult cod on the eastern and western Scotian Shelf. According to a recent estimate by the Canadian Department of Fishery and Oceans (DFO), the *total* population of cod in this area now is less than 50 000 tonnes, in other words only 4% of the biomass of adult cod in 1852. According to biomass estimates from 2002, the weight of adult cod in the area is about 3000 tonnes, which means that 16 schooners from the 1850s could contain all the adult cod found on the Scotian Shelf today.

Secondly, during the short period between 1852 and 1859, the catch-per-day-per-man declined by 50%. That indicates that human activity was having a tremendous influence on fish stocks, even before the fishery became industrialized. In the original article presenting this research, 'The history of oceans resources: modeling cod biomass using historical records', the HMAP team concludes that: 'an important point, frequently neglected, is that human activities are clearly part of the marine ecosystem today and have been throughout history.'

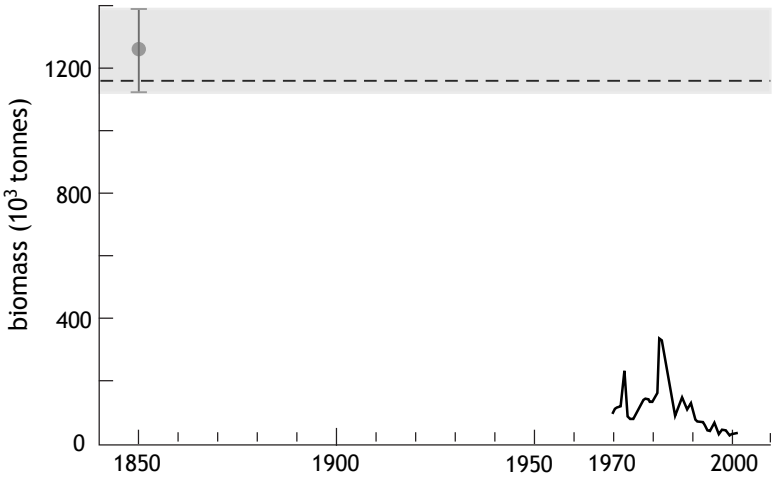


Figure 4 *The weight of cod on the Scotian Shelf in 1852 (grey, with error range shown as pale grey band) along with that at the end of the 20th century (black). The black dashed line is the estimated carrying capacity for the Scotian Shelf ecosystem at that time.*

Further reading

Rosenberg, A.A., W.J. Bolster, K.E. Alexander, W.B. Leavenworth, A.B. Cooper and M.G. McKenzie (2005) The history of ocean resources: modeling cod biomass using historical records. *Frontiers in Ecology and the Environment,* 3 (2), 84–90.

Barrett, J. H., A.M. Locker and C.M. Roberts (2004) The origin of intensive marine fishing in medieval Europe: The English evidence. *Proceedings of the Royal Society* **B 271**, 2417–21.

Smith, T.D., K. Barthelmess and R.R. Reeves (2006) Using historical records to relocate a long-forgotten summer feeding ground of North Atlantic right whales. *Marine Mammal Science,* **22** (3), 723–34.

Jackson, J.B.C. and 17 others (2001) Historical overfishing and the recent collapse of coastal ecosystems. *Science*, **293**, 629–38.

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Book review

The Silent Landscape: Discovering the world of the oceans in the wake of HMS Challenger's epic 1872 mission to explore the sea bed by Richard Corfield (2005) John Murray, 285pp. £7.99 (paperback, ISBN 0-7195-6531-6).

The circumnavigation of HMS *Challenger* from 1872 to 1876 is well known to most readers of *Ocean Challenge* and needs little in the way of introduction. During the 69 890 nautical mile voyage under the scientific direction of Charles Wyville Thomson, some 360 official oceanographic stations were occupied and the results in physics, chemistry, geology and, above all, biology filled 50 volumes of official expedition reports completed in 1895 under the direction of John Murray. These results provided a solid foundation on which to build almost everything in oceanography that has been achieved subsequently and the *Challenger* Expedition is therefore widely recognized as marking a crucial stage in the development of marine science.

Apart from the scientific reports, the expedition has been the subject of half-a-dozen more or less popular accounts by participants and has also been dealt with reasonably extensively in numerous articles during the last 130 years. But, somewhat surprisingly, it has been the main subject of only two 'independent' full-length book treatments, *The Voyage of the Challenger* by Eric Linklater, published by John Murray in 1972 to mark the centenary, and this more recent one by Richard Corfield, also from John Murray.

After the hardback version of *The Silent Landscape* appeared in 2003, the Dalhousie-based Eric Mills, who has forgotten more about oceanographic history than I have ever known, wrote a review of Richard Corfield's book that was published in the *Limnology and Oceanography Bulletin* in March 2004. Like me, Eric liked the basic idea of the book, '... a vivid depiction of what the ship and its men experienced, based mainly on published accounts by junior officers such as Lord George Campbell and Herbert Swire, the engineer W.J.J. Spry, the zoologist Henry Moseley, and most interesting of all, the below-decks record kept by the assistant steward Joseph Matkin …'. Alongside this contemporary treatment Eric was also rather taken by Richard Corfield's digressions at various points in the narrative to provide an updated version of the *Challenger* findings into such fascinating areas as sea-floor geology and plate tectonics, coral biology, the Bermuda triangle, and ocean circulation and global warming. So am I; with these digressions the author neatly bridges the gap between the *Challenger* Expedition and present-day problems.

But there is a down-side too. Eric's main gripe was that pervading this mass of very well-written stuff were rather too many factual errors. These included: the over-emphasis on the search for deep-sea living fossils to prove or disprove Darwinism, rather than W.B. Carpenter's row with James Croll about deep ocean circulation, as a driving force behind the *Challenger* expedition; Richard Corfield's amazing attribution of the leadership of the *Meteor* Expedition of 1925–27 to Fritz Haber, and directorship of the Woods Hole Oceanographic Institution to K.O. Emery, both wrong; and the suggestion that James Cook discovered Antarctica! So all in all Eric thought that a great opportunity to place the *Challenger* achievements into a modern context had been missed for the sake of a ha'pennyworth of editorial tar, so to speak.

You would have thought, wouldn't you, that with modern electronic publishing techniques being what they are, it would have been possible to correct some of these howlers between March 2004 and the appearance of the paperback version about a year later? Well, whether it was possible or not, it wasn't done, and I have to point out a few more dreadful errors that particularly irk me, especially as Richard Corfield cites references in his rather limited biography that, if he had read them, would have enabled him to avoid them.

For example, the *Challenger* personnel famously used rope for soundings and not piano wire (p.36); the *Challenger* not only did not discover the Carlsberg Ridge (p.60), but she didn't sail remotely near it! Similarly, not only did Wolfgang Schott not sail on *Meteor* (p.140), but if he had he certainly wouldn't have used a Kullenberg corer (p.141) which wasn't invented until the 1940s! And so close to the bicentenary of the battle of Trafalgar, how on Earth did the statement that Nelson lost his eye in Tenerife (p.50) survive? Surely, after all the publicity during 2005, any schoolchild will know that the great man lost his right arm in Tenerife and damaged his eye at Calvi in Corsica!

Of course, in the overall scheme of things these errors might be considered relatively unimportant against the background of a well-written and pacey account of the expedition, including some well-chosen quotes from contemporary sources. Unfortunately, even here the book irritates me, though this time not, I am sure, the fault of the author. Despite being published by John Murray, still thank heaven a London-based firm, the book is clearly directed particularly at the American market. But what smart-arsed editor decided to 'correct' all the '-our' endings in the quotations so that 'harbour', 'honour' and 'colour' become 'harbor', 'honor' and 'color', and so on? You simply don't do this even in a popular publication; quotes should be reproduced exactly, warts and all! This cavalier attitude to our language admittedly irks me as an anglophile anorak. But more importantly, it suggests to me that an editor who can condone this is not likely to be too bothered by the presence of a few inaccuracies in the rest of the book.

Nor, of course, is such an editor likely to realize that an Earth scientist author is understandably biassed towards geology and the physical sciences in his choice of modern topics to review against the background of the *Challenger* results. But since the Expedition became *de facto* primarily a biological one and almost 19 000 of the 30 000 or so pages of the scientific reports were devoted to the biological collections, modern biological oceanography is grossly underplayed in Richard Corfield's treatment. Perhaps a decently qualified referee at an early stage would have noticed this.

Despite these criticisms the book contains some excellent stuff and is well worth reading. Unfortunately, as Eric Mills concluded: 'Oceanography's icon, the voyage of HMS *Challenger,* and its significance to present-day oceanography, deserve better.' Attaboy Eric! How about writing it?

Tony Rice
formerly Southampton Oceanography Centre