OCEAN Challenge

The Challenger Society for Marine Science

Volume 10, No. 2, 2000

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The Magazine of the Challenger Society for Marine Science

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

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News and Views

Where Life Began

There is general agreement that Life on Earth originated in the oceans, because all the necessary ingredients were there: water, nutrients and trace elements, along with plenty of organic molecules from the numerous meteorites (including carbonaceous varieties) that were whizzing about the Solar System in the couple of hundred million years after its formation – plus which the atmosphere at this time was rich in CO_2. The energy for complex organic synthesis came either from the Sun or from the Earth's interior via hydrothermal vents, depending on who's telling the story.

An alternative hypothesis, that Life began in the Earth's atmosphere, dates back to the 1960s. Early proponents of the idea identified clay minerals, formed by weathering and lifted into the atmosphere by storms and meteorite impacts, as a possible substrate for the necessary chemical reactions. The idea didn't catch on, but a new version is more promising, because it involves exchange between ocean and atmosphere (*New Scientist*, 15 July, pp.4–5), specifically the formation of marine aerosols, which must by definition also contain all the necessary ingredients. including the organic molecules which come from oily films on the ocean surface. Nowadays the oils are produced by plankton, but on the early Earth they would have been supplied by the carbonaceous meteorites. Once they were in the atmosphere, evaporation concentrated the various ingredients in the aerosols (just as it does now), and sunlight provided the energy for chemical reactions to form organic polymers such as proteins. Recycling of aerosols between atmosphere and ocean would increase the variety and complexity of ingredients (especially the oily surfactants), and hence of the complexity of products. A novel twist in this hypothesis is the suggestion that those oily films round the aerosol droplets were the progenitors of the cellular membranes with which all biologists are familiar. Size becomes important here: aerosols >0.1–5 μm across don't survive for long in the atmosphere, because they get rained out – and most bacteria on Earth are within that size range. There is a small snag to this neat correlation, though: the CO_2-rich atmosphere of our early Earth was a lot denser than it is now, so aerosol droplets could well have been rather bigger.

But a good story should not be spoilt by inconvenient facts, especially as the proponents of this hypothesis extend their story to Mars. The reduced gravity there would result in aerosols from a 'martian ocean' being much smaller than those on Earth – comparable in size to the putative 'fossil bacteria' found in martian meteorites. Neat, eh?

These speculations are great fun and highly entertaining, but we should not forget the possibility that Life did not begin on Earth at all. Evidence of extraterrestrial life – both in the Solar System and beyond – continues to accumulate, and nobody can be certain that primitive life-forms did not reach the early Earth from elsewhere in the Universe, carried hither on meteorites or comets. The theory of *panspermia* is more than 100 years old, and nobody has yet disproved it.

When Life Nearly Ended

Or did it? Was 'the biggest mass extinction in history' (*sic*) really the one that happened at the end of the Permian, 250 million years ago? It was certainly a big one, a crisis in the history of life on Earth – but how do we know it was the greatest such crisis? To be sure, 90 per cent of all marine species were extinguished, along with many land plants and animals – the proportion of terrestrial species that became extinct is harder to assess because remains of terrestrial organisms tend to be rare in the fossil record. The extinction event has most recently been rather precisely dated to 251.4 million years, and blamed on a massive meteorite impact. That is partly because a huge drop in $\delta^{13}C$ values of carbonate coincides with high concentrations of microspherules of possible meteoritic origin in contemporaneous sediments, but chiefly because a high proportion of the extinctions all occurred together at this time (*Science*, 21 July, p.432–6). The decrease in $\delta^{13}C$, from about +2 to −1, is a strong indication that vast amounts of 'light' carbon had suddenly become available in the atmosphere, i.e. that photosynthesis had almost stopped and there was very little drawdown of the ^{12}C isotope into organic matter.

In fact, as the authors of the work cited above themselves acknowledge, there were multiple extinctions in the few million years leading up to the end of the Permian, and there was also a conspicuous downward 'blip' in the $\delta^{13}C$ record during this interval. In addition, the end of the Permian was also when the vast sheets of lava now known as the Siberian Traps were erupted. Large emissions of sulphur dioxide and CO_2 could have accompanied these eruptions, resulting in volcanic winter followed by a period of global warming – a thesis that is re-examined below. Pyroclastic eruptions producing volcanic ash could account for the microspherules, which have not been conclusively identified as meteoritic in origin.

Moving rapidly forward in geological time, the demise of the dinosaurs at the end of the Cretaceous was only the most dramatic part of another mass extinction that has also been attributed to a gigantic impact event. What is more, the crater has been identified with some confidence, in the Gulf of Mexico. It is perhaps not so well known that huge volcanic eruptions also occured at the end of the Cretaceous, when another huge pile of lava flows, known as the Deccan Traps (in India), were erupted. It would be far-fetched indeed to suggest that volcanic mega-eruptions on Earth coincided with orbital perturbations in the asteroid or comet belts, and brought large objects crashing down upon us. It is less fantastic to suggest that the energy from major impact events could penetrate deep enough into the Earth's mantle to induce large-scale partial melting and volcanism. Two swallows do not make a summer, however, and it is more likely to have been only a matter of chance that two major extinctions occurred around the time of the two large impacts and two episodes of massive volcanism.

Indeed, this coincidence remains a matter of debate among palaeontologists and biologists, who are by no means agreed about the principal causes of the mass extinctions of the end-Permian and end-Cretaceous. There is some evidence from the Deccan Traps that the interval between successive flows may well have been on the order of decades. That is what back-of-envelope sums indicate, if the several hundred lava flows making up the Traps were all erupted within a time span of, say,

half a million years (which the geochronology suggests to be an absolute minimum). It is also consistent with good fossil evidence that the time interval between most of the eruptions was sufficient for flora and fauna to recolonize the land surface. There is no reason to suppose that the pattern of eruption of the Siberian traps was significantly different. In sum, given rates of atmospheric mixing and reaction, it is difficult to ascribe major climate change to volcanic eruptions. Pinning the blame on a meteorite is not only more exciting, it has the additional merit of being consistent with abrupt climatic repercussions on a global scale.

The controversy will run and run. The crater formed by the putative end-Permian meteorite has not (yet) been found, and there is still the question of what caused the significant number of extinctions in the period just before the end came. There is also the still-unresolved and still widely disputed Raup and Sepkoski correlation between the c. 30 million-year periodicity of significant extinctions in the fossil record on the one hand, and of impact events on the other, first published in 1984 and considerably refined since. However, it must be said that the extinctions these authors identify are not on the scale of those that afflicted the Earth 250 and 65 million years ago.

But to return to the question posed at the start of this piece: 250 million years is as the blinking of an eye in the vastness of geological time. It does seem somewhat presumptuous to suggest that 'the biggest mass extinction of all time' occurred so relatively recently. Is it not more likely that Life on Earth was all but extinguished more than once in its long history, but that we don't know about it because before the Cambrian 'explosion' most organisms were unicellular and left hardly any fossils?

Ozone Holes

The Montreal Protocol of 1987 banned the manufacture and use of CFCs, until then widely used in (among other things) refrigerators and aerosol cans. Ozone-friendly substitutes were quite quickly developed in the richer western countries, but poor nations found it difficult to afford the necessary new technology, and many of them still use CFCs. There have even been rumours of a black market export trade in CFCs, from Europe to the Far East – especially China.

Increased penetration of ultraviolet radiation through the Antarctic ozone hole is adversely affecting marine life in the Southern Ocean – and there could be similar ecological impacts in the Arctic too, though they are likely to be masked by the effects of rising temperature and thinning ice cover.

It is more than three years since scientists began documenting increased mortality of phytoplankton, as well as of fish and krill larvae, in the Southern Ocean, and attributing it to excess ultraviolet radiation. Not only do the larvae have less food, fewer of them are surviving to breed. These trends seem set to continue, as it could be several decades before ozone-destroying chemicals stop getting into the stratosphere. Phasing out CFCs was a great idea – it's a pity that the stratospheric response time is so long.

A New Greenhouse Gas

The gas in question – trifluoromethyl pentafluoride – was discovered by scientists at the Unversity of East Anglia, while they were investigating other greenhouse gases. Trifluoromethyl pentafluoride seems to have been present in the upper atmosphere for only the last 40 years or so, which points to it being a by-product of human activity, perhaps generated by high voltage equipment. Molecule for molecule, it is 18000 times more effective than CO_2 at trapping infrared radiation and, furthermore, is probably very long-lived (or it would not be accumulating in the stratosphere). At present, the gas is not thought to be a cause of concern as it is present in only very low concentrations.

The Solar Weather Machine

Press reports of a massive solar flare in early August were accompanied by dire warnings of disrupted satellite communications, possibly even power cuts, when the 'gas ball' reached Earth a few days later. In the event, no such effects were reported, but there is no information on the extent to which the world's weather might have been affected – and more to the point, how it might be affected in the future. Such occurrences provide the sort of data that enable Piers Corbyn and his associates at Weather Action (Corbyn's company) to command hefty fees for long-range weather forecasts that are based on analysis of solar activity, a topic touched on more than once in these columns. The basis of the method, that the Sun is the major influence on Earth's weather and climate, can hardly be disputed, nor can there be much argument with the proposition that variations in solar activity cause fluctuations in atmospheric temperature. Beyond that, however, the approach of Weather Action departs somewhat from the consensus view of how our climate system works.

One of the more fascinating aspects of Corbyn's approach is his rejection of anthropogenic CO_2 emissions as a cause of global warming. He classes CO_2 as a secondary greenhouse gas because – the story goes – its atmospheric concentration is mainly controlled by temperature. However, the only example Corbyn cites is the temperature-dependent solubility of CO_2 in the oceans, an argument that some scientists consider unsound (cf. *Ocean Challenge*, Vol.10, No.1, p.2). Methane is also classed as a secondary greenhouse gas, but Corbyn does not explain why. The primary greenhouse gases are considered to be water vapour and ozone, whose atmospheric concentrations are strongly influenced by solar particle, magnetic, ultraviolet and X-ray fluxes. Parts of this story are not new (nor are they disputed), for they include the relationship between cosmic ray flux, cloud cover, and temperature, also the well-known fact that the amount of energy we receive from the Sun varies over time (cf. *Ocean Challenge, op. cit.*). A logical extensions of this thesis is that El Niño (and presumably other climatic oscillations as well) are triggered by fluctuations in solar activity, which also determine the strength and direction of high altitude jet streams (see 'El Niño: an agent of history', p.16).

Apart from these tantalizing glimpses, however, little is to be gleaned about 'solar forecasting', either from numerous articles that have been written about Corbyn, or from his own articles and conference presentations. Here is a 'taster' from one of his works: 'Many extremes of weather have been correctly predicted by the Solar Weather Technique of long range forecasting, which depends on the prediction of solar effects. These extremes can therefore be reasonably attributed to changes in solar activity. Temperature deviations from normal can be 2 °C over a season. A random addition of such (in principle predictable) deviations over 25 years (100 seasons) could easily be (using 'random walk' addition and binomial statistics) $2/\sqrt{100} = 0.2$. Therefore, a 0.4 °C change could reasonably be attributed from time to time to solar changes over 50 years. This is comparable to supposed recent man-made CO_2 effects.'

That passage is no more elegantly or clearly written than the rest of his article, which seems intended to obfuscate rather than to communicate – but that should surprise nobody, since full disclosure of his method would wreck Corbyn's business. Nonetheless, it is possible to infer at

least the basic approach that is used in the Solar Weather Technique. Shorn of details, it goes something like this: Some aspects of solar activity can be predicted months in advance. If you correlate records of past solar activity and terrestrial weather, you can link weather states to levels of solar activity. So if you can predict solar activity, you can predict the weather. It may seem simple in principle, it cannot be easy in practice.

Corbyn is neither the first nor the only person to think along these lines. For example, atmospheric scientists in Denmark are reported to have independently confirmed that there is a correlation between solar activity and Earth's climate, and that it can explain around 80% of mean global temperature change over the last four hundred years – but only up to the mid- to late twentieth century. After 1980 (or 1950, depending on who's talking), a distinct non-solar signal can be detected in the global warming curve. The consensus view is that this comes from the enhanced greenhouse effect. The 'solar-generated weather' is not thereby eliminated, however, which may help to explain why it is hard to refute Weather Action's claims that their predictions are reliable. The company's website (www.weatheraction.com) lists plenty of examples of outcomes that have matched forecasts.

On 26 September, 1998, for instance, they predicted hurricanes in the SW Atlantic/Caribbean area for the periods 6–9 and 20–23 October. Hurricane Liza started as a storm on 5 October, becoming a hurricane on 9 October. Hurricane Mitch formed on 22 October, and was the fourth strongest Caribbean storm of the 20th century, behind Gilbert (1988), Allen (1980) and the Labour Day hurricane of 1935 – in the days before hurricanes got names. To be sure, these storms were predicted only 1–4 weeks in advance, but Weather Action claim they could have been made months ahead. In the same year in Britain, they successfully predicted the two severe storms (winds up to Force 10) of 22–24 October and 24–26 December – but they do not tell us how long before the events those predictions were made. Plenty more examples can be found on the website. It is an impressive record – can it really be based on faulty science?

Sodom and Gomorrah – The Dead Sea Connection

According to the Old Testament, these ancient cities, which once lay close to the shores of the Dead Sea, were destroyed by fire and brimstone as divine punishment for the ungodly and decadent carryings-on of their citizens. The fire and brimstone are consistent with the presence nearby of hydrocarbons (including asphalt seeps), with which sulphur (brimstone) is commonly associated – and there has also been recent volcanism in the region.

However, the biblical accounts do not mention that the cities were flooded. Enthusiastic scholars have nonetheless used satellite imagery to idenfity what they believe to be man-made structures on the floor of the Dead Sea, about 60 m down near its northern end. A Channel 4 programme earlier this year, plus several press reports, documented a follow-up submersible expedition to these structures, which unsurprisingly yielded decidedly inconclusive results. The region is known to be still tectonically (as well as volcanically) active, and there is well documented evidence of faulting and landslides in the last 5000 years, which must surely include the time when these cities stood. But displacements on the faults total no more than a few metres, nothing like enough to drop anything down to the floor of the Dead Sea. It all seems to have been a large expenditure of money to little purpose, especially when other scholars have placed Sodom and Gomorrah at the southern (rather than at the northern) end of the Dead Sea – plus which, nobody is certain that they did truly exist.

Birth and Decline of the Dead Sea

The Dead Sea began its life as an isolated arm of the sea in the Pliocene, and its hypersalinity (the dissolved salt content reaches as much as 235 $g\,l^{-1}$) is a consequence of continued evaporation since that time. As most people know, it lies in a deep depression, and its water surface lay about 390 m below global sea-level until the 1930s. Since that time, and especially from the 1970s onwards, the Dead Sea surface has fallen to about 410 m below global sea-level, the result partly of potash extraction from the lake, but chiefly because of water abstraction from rivers flowing into it, especially the Jordan. In short, as global sea-level rises, the Dead Sea level continues to fall.

The Dead Sea: The Lake and its Setting, edited by T.M. Niemi, Z. Ben-Avraham and J.R. Gat, is reviewed on p.35 of this issue.

Messinian Legacy in the Mediterranean

Five-and-a-half million years ago the Mediterranean dried out completely and thick evaporites were deposited, not only in the marginal basins but in the deeper ones too. The Messinian salinity crisis, as it has come to be known, was probably triggered by a combination of tectonic closure near Gibraltar, plus a fall in global sea-level. The thickness of evaporites (more than 1 km in places), is such that there must have been repeated incursions of the sea into the Mediterranean between 5.96 and 5.33 Ma ago (the accurately dated start and finish of the dessication event, *Nature*, 1999, **400**, 613–14). The end of the salinity crisis was if anything more abrupt than its commencement. A rise in sea-level resulted in massive flooding, probably through the Straits of Gibraltar ('the Gibraltar waterfall') that permanently ended the evaporation episode, and the evaporites are overlain by normal marine sediments.

Since then there have been some tectonic movements, one consequence of which has been formation of salt domes. But that is not all. A few years ago, a brine pool 7.5 km^2 in area and averaging nearly 30 m deep was discovered in a basin in the eastern Mediterranean (*Nature*, 1997, **387**, 31–2). This is not a brine pool like those in the Red Sea axial deeps, for it is not enriched in ^3He and therefore probably not associated with hydrothermal activity (although it does appear to lie within an accretionary complex formed by convergence between the African plate and the Aegean arc). The composition of the brine is particularly interesting and unusual. It is a concentrated solution of nearly pure $MgCl_2$ (5 $mol\,kg^{-1}$). The team that discovered the brine pool estimated, from the calculated rate of diffusion of $MgCl_2$ into the underlying sediments, that the brine pool formed only 2000 years ago. They further conclude that it formed from resolution of bischoffite ($MgCl_2.6H_2O$), which itself provides clear evidence that the Messinian brines evaporated to near dryness, since bischoffite is the most soluble of all evaporite salts. For much of the Messinian, the Mediterranean must have looked rather like the Dead Sea region does today, but on a truly enormous scale.

Solved at Last: the Mystery of the Chandler Wobble

For more than a century, scientists have been trying to discover the cause of the tiny oscillation of the Earth's axis of rotation known as the Chandler wobble. The oscillation, which is a free oscillation, i.e. one resulting from natural resonance, has a period of about 14 months. It has been calculated that its natural decay time would be only 68 years, so the fact that the wobble persists means that it must be being continually excited. Since it was first observed by S.C. Chandler in 1891, many possible excitation mechanisms for the wobble have been proposed and evaluated, including atmospheric processes, fluctuations in continental water storage, core–mantle interactions and earthquakes. Until recently, very little progess was made in identifying the cause of the wobble.

Over the last few years, researchers have been using coupled climate models to show that the wobble *could* be caused by some combination of atmospheric and oceanic processes. However, the excitation of the Chandler wobble is a broad-band process and successful investigation involves computing the excitation power occurring within the Chandler band. This can only be done by using sufficiently realistic atmosphere–ocean circulation models. A successful attempt to identify the likely cause of the wobble using data for 1985 is described in *Geophysical Research Letters*, **27**, N.15, 2329–1332. Apparently, for the year in question, the single most important excitation mechanism for the wobble was fluctuations in ocean-bottom pressure, with a smaller contribution from fluctuations in the inverse barometer effect from the atmosphere. There were smaller contributions from winds and currents, but these acted out-of-phase with the pressure effects, and so reduced the total excitation.

Ice Sheets and Sea-level

Ice in/on the Arctic Ocean is thinning more and more as the years pass – but as it is floating ice, there's no effect on sea-level. But what about Greenland? If that ice-cap melted, sea-level would rise by about 7 m. Melting would take a long time, of course, and mercifully the ice-cap seems to be holding its own so far: there is some loss of ice from the margins but it is balanced by some gains at the centre (*Science*, 21 July, pp.404–5, 426–30). So far so good then, but there's no room for complacency. If marginal losses begin to exceed central gains, then a lot of low-lying coastal regions will find themselves at increased risk of permanent submergence.

The Lean Genome of the Pufferfish

At first sight, it does not seem very likely that the genome of the pufferfish would shed any light on the gene code of humans – after all, the two diverged from a common ancester about 400 million years ago. However, the pufferfish genome provides a useful key to the vertebrate gene code because although it is only one-eighth the size of the human genome, it has the same repertoire of genes. Furthermore, it seems that certain regions of the genome retain their original function when in more advanced vertebrates. Researchers from Singapore, Bristol and Berkeley demonstrated this by inserting a pair of adjacent genes from the pufferfish into rats. The genes produce the hormones oxytocin and vasopresin, which in pufferfish regulate the salt and water balance, and smooth muscle contraction. Once in the rats, the genes expressed themselves in the same way as the rats' own genes. This suggests that if we know what a

gene does in the simpler organism, it should help us work out what a corresponding gene might do in humans.

A Fatal Remedy?

Attempts to prevent another infestation of the West Nile virus that proved fatal to several New Yorkers last year seem to have had unfortunate side-effects. Lobster fisheries off the coats of New York were all but extinguished last summer, and the culprit is strongly suspected to be the pyrethroid-based insecticide used to kill the mosquitoes that spread the virus. Although spraying is officially confined to land areas, the combined effects of wind and rain ensure that it gets into coastal waters one way or another.

The pyrethroid compounds aren't actually chitin-inhibitors like calicide (*Ocean Challenge*, Vol.10, No.1, p.19), but they can apparently weaken the lobsters' immune systems and make them susceptible to parasitic or other diseases. All the same, the investigating scientists aren't certain (*New Scientist*, 12 August, p.11) – after all, the fact that an event follows a potential cause doesn't necessarily mean the two are related.

New Evidence for Water on Mars ... perhaps

There's been some hullaballoo lately over possible confirmation that there may really be lots of water on Mars, albeit mostly groundwater. New high-resolution images of the martian surface reveal small erosional and depositional features consistent with seepage and run-off from small ephemeral aquifers. Nearly all of these newly identified features occur along walls of impact craters and small valleys that face towards the pole, mostly in Mars' southern hemisphere (*Science*, **288**, 2230–35). Claims that much of the martian surface has been sculpted by flowing water are not new. So why the excitement? The principal reason is the small size and fresh appearance of these landforms, suggesting that the water responsible for them has but recently emerged from its subsurface reservoirs

The proposed scenario involves percolation of groundwater towards the surface, where it would normally evaporate. But on poleward-facing crater and valley walls it is possible, even likely, that the water freezes just below the surface, forming a barrier. When the barrier is breached, possibly because pressure gradually builds behind it as more and more groundwater migrates towards the surface, a slurry of sediment, ice and liquid pours down the slope, carving out gullies and depositing alluvial fans. The size of the features that are formed suggests water volumes of a few thousand cubic metres – not vast amounts, but quite enough to drown in.

If the interpretations are valid, then there could well be liquid water near the surface on Mars right now, not just in the distant past. Leaving aside the human life-support implications for Manned Missions to Mars (water for drinking – perhaps even washing – and for fuel cells), the presence of liquid water makes indigenous life on Mars a whole lot more likely. A few years ago, claims that traces of bacterial life had been found in a martian meteorite were met by counter-claims either that the 'bacteria' were produced by inorganic processes, or that there had been contamination from terrestrrial sources. The controversy naturally fuelled further research, and unsurprisingly it turned out that martian meteorites contain evidence of terrestrial contamination as well as unique signatures of biogenic activity which are not from earthly contaminants. Indigenous (i.e. martian) biogenic signatures include the following:

1. Magnetite crystals, probably precipitated by bacteria, within carbonates that are of martian origin and indicate formation temperatures of not more than 50 °C.

2. Reduced carbon components which contain no ^{14}C signatures and are therefore unlikely to be terrestrial (cosmic rays produce ^{14}C from atmospheric ^{14}N, and there is not a lot of nitrogen in the martian atmosphere – plus which Mars is further from the Sun than Earth is).

3. Biofilms formed of polysaccharides from colonies of bacteria that appear not to be terrestrial.

4. Unique morphological structures matching those seen in fossilized bacteria on Earth and apparently developed within clays of martian origin.

An intriguingly radical alternative hypothesis was given air time at around the same time (late July/ early August). This purported to explain the erosional and depositional features on the martian surface as resulting from CO_2-fluidized debris flows (cf. *Eos*, 81, p.302). The idea is that explosive degassing from the planetary interior produces large volumes of dust and debris, transported in the manner of terrestrial pyroclastic (hot ash) flows (or of dry air-lubricated sediment flows – which would probably be CO_2-lubricated on Mars), travelling long distances and carving out valleys, canyons and gullies, then depositing debris fans where they end their run.

Such a process could well account for at least some of the larger erosional and depositional landforms on Mars, but inspection of these new images shows that the features described are on a scale of tens of metres. Not only is it hard to see how explosive degassing could occur on such a small scale, but an absence of water would make it much more likely that any Life on Mars became extinct eons ago. A definite absence of martian water could hardly fail to be a setback for the space programme, especially as there is still no indication of whether or not there is water on the Moon. Never mind, there is always Europa, where a fluctuating magnetic field recently recorded by the *Galileo* satellite has been interpreted to indicate a thick (up to 60 km) layer of salty 'sea' beneath the jovian satellite's icy carapace (*New Scientist*, 2 Sept. p.25; *Ocean Challenge*, Vol.10, No.1, p.5).

While on the subject of salty seas, discovery of water-soluble salts in cracks in a billion-year old martian meteorite has been interpreted as evidence that there was once an ocean on Mars. The salts appear to be similar to those in seawater, for they are dominated by sodium, magnesium, calcium, chloride and sulphate (*New Scientist*, 1 July, p.19). Could it be that water in the putative martian aquifers is saline rather than fresh? If so, it would be no more than a minor setback for the colonists – desalination is scarcely new technology. Perhaps the most interesting aspect of this discovery, however, is the implication that not only the volcanism but also the ancient (Precambrian) weathering processes on Mars must have been very similar to those with which we are familiar here on Earth.

Space *v.* Marine Research?

If the hype surrounding 'water on Mars' (not to mention 'water on the Moon') gets more frenetic, there is a real possibility that NASA might be able to divert funds from Earth-related science projects. That could be detrimental to marine research programmes, though it would affect US scientists more that European ones (except perhaps for multinational projects).

However, NASA could be thwarted in its endeavours (not to mention its funding) if the European Space Agency (ESA) takes a lead in the 'race to the stars' ... oh all right then, to the planets. This possibility is very much on the cards, especially as NASA recently lost two spacecraft as a consequence of what have been described as glaringly stupid errors; meanwhile ESA's *Beagle* lander still seems to be on schedule to reach Mars in 2003.

Scotland's first BSc. in Marine Science

Axel Miller

In mid-September, as delegates gathered at the University of East Anglia for the UK Marine Science conference, the first cohort of undergraduates was being welcomed onto the BSc. in Marine Science at the University of the Highlands and Islands project (UHI).

The development of UHI is a major event for education in Scotland, because at last, after 300 years of discussion and planning, the highlands and islands of Scotland are witnessing the development of their own university. Of necessity, UHI is a project that embodies partnership, and it has been created from thirteen colleges and institutions, drawn together through the Executive Office at Inverness. The network spreads from Argyll College in the south, to Lews Castle College on Skye in the west, up to the North Atlantic Fisheries College on Shetland, and over to Perth College in the east.

The Scottish Association for Marine Science (SAMS), based at Dunstaffnage Marine Laboratory at Oban, is one of the UHI's thirteen academic partners and recently gained accreditation from the Open University Validation Service to offer the UHI BSc. Marine Science degree – the first of its kind in Scotland. Four new-blood lecturers appointed at SAMS are responsible for delivering the main subject-centred components of the course: physical, chemical, biological and geological oceanography. After a strong science grounding in years one and two, students in their third and fourth years will be offered a range of more specialist modules, including Aquaculture, Petroleum Geology, Marine Biotechnology, Microbial Ecology and Global Biogeochemical Cycling. Dunstaffnage Marine Laboratory, ideally situated on the Firth of Lorne, offers excellent facilities for degree-level projects and honours dissertations.

Students will be able to study for the BSc. in Marine Science either full time or part time. For the first few years of running the course, attendance will be required at Oban. In the long term, the plan is for the course to be available on a distance-learning basis via learning centres all over the Highlands and Islands region.

For more information about the UHI and the Marine Science Degree, please contact:

Axel Miller or Mark Inall
(Email: marine.science@dml.ac.uk)
The University of the Highlands and Islands Project, Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban PA34 4AD.

Students aboard the SAMS vessel* Calanus *learn about sedimentation rates in the Firth of Lorne, helped along by the enthusiasm of Marine Geology Lecturer Dr John Howe.

The Challenger Society and UK Marine Science

The Challenger Society's biennial conference was held at the University of East Anglia. It was a splendid conference, brilliantly organized, equally brilliantly executed. Tim Jickells and his crew were justly applauded for their efforts. The next issue will carry more about the event, including comment and review, as well as telling those who couldn't make it (and reminding the rest) of the names of the prize-winners.

The Challenger Society AGM was held at the conference, and formed a focus for the general anxiety about the future of marine science in Britain. As many readers will be aware, at the end of June, NERC Council decided that the three CCMS laboratories (Dunstaffnage Marine Laboratory, Plymouth Marine Laboratory and Proudman Oceanographic Laboratory) should return to being free-standing entities. NERC will continue to support the Southampton Oceanography Centre (SOC), which is run jointly with the University of Southampton. Those at the AGM gave the new President, John Shepherd, a mandate to write to the Chief Executive of NERC, expressing extreme concern and enquiring whether recent events are part of a longer term plan to reduce funding for marine science in Britain. Furthermore, now that SOC is *de facto* the only NERC-supported UK marine science facility, what does the future hold for DML, POL and PML? And what mechanisms will be put in place to prevent the three former CCMS institutes from becoming isolated from NERC's decision-making processes, and to allow their scientific interests to be represented?

See page 36 for a Letter to the Editor on this topic.

Plankton to the rescue

Martin Angel

Readers of *The Sunday Telegraph* on 23 July may have seen the full-page feature about Dr Michael Markels, a 74 year-old chemical engineer turned 'environmental entrepreneur' who claims to be able 'to solve global warming at a stroke – with plankton'. Markels conducted an experiment in the Gulf of Mexico, adding 3.3 tons of iron pellets to three plots each measuring 23 square miles, and found that levels of plankton rose between five and seven times. Markels believes that if he did the same along the Atlantic coast of North America he could increase the area's phytoplankton population 1000-fold. Interestingly, the Gulf Stream is included in the 20% of the global ocean classified as HNLC (High Nutrient, Low Chlorophyll) areas. The main HNLC regions are in the sub-Arctic North Pacific, the eastern tropical Pacific and parts of the Southern Ocean, where, it is now more or less agreed, iron-limitation prevents the complete utilization of available nutrients by primary production.

Calculations suggest that if phytoplankton could be enabled to use all the available nutrients, atmospheric carbon dioxide levels would be reduced substantially. Indeed, it is postulated that during glacial times, winds were generally stronger, so more iron-rich dust was blown out over the oceans, with the result that the extent of iron-limitation was much less, and carbon dioxide concentrations were correspondingly lower.

Markels continues '2% of the oceans contain 60% of its plant life, [so] if we can make the other 98% as fertile we will not only increase the amount of catchable fish by a factor of several hundred, we will also dramatically cut down the amount of carbon dioxide in the atmosphere. Phytoplankton absorb carbon dioxide, and *most of them end up at the bottom of the deep ocean about 15,000 feet below the surface, along with the carbon dioxide they contain.*' [my italics] Clearly, everything achieved during JGOFS and BOFS was wrong! Markels claims: '1.5 million tonnes of iron-based fertilizer spread over a patch 550 by 1850 km would produce enough CO_2-eating (*sic*) plankton to lock up a year's worth of CO_2 emissions from the United States.' That would be about 25% of the total global emissions of around 6 Gt of equivalent carbon. Maybe, while they are at it, the 'CO_2-eating plankton' could be persuaded to spread themselves a little more widely and also account for the 150–160 million tonnes of carbon that we in the UK emit each year. Our fishermen would then no longer have TAC quotas imposed upon them, there would be a glut of cod and other commercial fish, and the population of the world could go on expanding indefinitely.

The accuracy of the report in *The Sunday Telegraph* is called into question when one reads that 'Sallie Chisholm, a professor at MIT is very sceptical of Markel's approach'. The sceptical MIT professor is Penny (*not* Sallie) Chisholm. Nevertheless, her scepticism will be shared by many other marine scientists.

The concept of fertilizing the ocean as a way of drawing down atmospheric CO_2 has been around for some time. John Martin, originator of the iron-limitation theory, put it forward as a rather tongue-in-cheek way of winning the first tranche of funding for the initial IRONEX experiment. Jorge Sarmiento and John Orr subsequently worked out how much iron it would take (and how much it would cost) to fertilize the areas of the Southern Ocean that are iron-limited. Their answer was that you have to be really desperate even to think about it – but maybe we are getting that way. The difficulty is that one application is not enough. Once started, the fertilization has to go on at monthly intervals. Dispensing the iron quickly enough over a wide enough area could not be achieved by surface vessels; it would require about 200 plane flights a week – each pumping out yet further tonnages of CO_2.

Markels seems to have a rather distorted picture of the biological pump. Export production, that is, the amount of phytoplankton biomass sinking through the thermocline, is generally about 11%. If fertilization stimulates the growth of diatoms, that's fine. The various iron fertilization experiments (IRONEX) did reduce pCO_2 in the upper ocean. The difficulty is that they were all short-term experiments, and if they were scaled up there is no guarantee that things would not go wrong. In the longer term, would picoplankton production increase? Production by picoplankton feeds into the microbial food-web and contributes very little to export production (i.e. the sedimentation of organic material into deep water), and so the desired increase in the amount of carbon being sequestered in deep water would not occur. Similarly, if coccolithophores bloomed, they would vent more carbon dioxide back to the atmosphere than they removed, because they secrete calcium carbonate liths. For every mole of calcium carbonate formed, a mole of CO_2 is released, lowering the pH of the water and increasing the pCO_2, so that carbon dioxide is returned to the atmosphere rather than exported into deep water.

If toxic or nuisance blooms were stimulated on a large scale there would be major environmental problems. In any case, could we guarantee being awash with fish? What we know about the flows of organic matter through food webs is far too sketchy even to hazard a guess – that is why GLOBEC and the UK's Marine Productivity programme are attempting to quantify how primary production is transferred via the zooplankton into higher trophic levels.

However, we must be clear about our objectives. Fertilizing the ocean in order to grow more fish is not necessarily compatible with the goal of reducing atmospheric carbon dioxide. Increasing fluxes of organic matter to the deep ocean will mean removing more from surface waters, where it is available to the fish populations there. It will also result in depletion of midwater oxygen concentrations, particularly in the Pacific and Indian Oceans (there are already substantial oxygen-deficient zones in the eastern tropical Pacific, and seasonally in the Arabian Sea). How would it affect the depth of the lysocline, the depth at which calcium carbonate begins to dissolve? One thing we are rapidly becoming aware of is the interconnectivity of the global

ecosystem – engineer a solution in one place and new problems emerge elsewhere! Remember the Greek myth about the multiheaded Hydra? When one of its heads was cut off, a new one sprouted from the stump.

But why all the fuss, anyway? It was sparked off by a statement by Frank Lay, the United States negotiator at the UN Climate Change Conference, that the US cannot meet its pledge to cut emissions of carbon dioxide. Now that IS worrying – the *initial* reductions in emissions are relatively easy to achieve, as Britain has already demonstrated. If the USA is unable (or is it unwilling?) to reduce its emissions, then other countries will not even go as far as trying. The International Panel on Climate Change has already advised that pegging emissions back to 1990 levels will be insufficient to prevent climate change. In 1997, Wally Broecker warned of the possibility that if the climate flips into a new regime, flopping it back again may be beyond us. There are signs that climate change is already upon us, that it has not been a figment dreamed up by environmental scientists greedily trying to raise more research money. The USA seems to be more interested in 'macho' space programmes than in properly funding programmes to sort out boring old Earth! The money spent on a single shuttle flight would fund five years of the present US ocean research programme (see 'New Evidence for Water on Mars ... perhaps', p.8).

Think about it – sooner or later during this century, world population, which doubled from the end of the Second World War to now, is set to redouble to 12 billion. According to L.T. Evans (see Further Reading) it is only feasible that all these new mouths can be fed if the following criteria are met:

- We continue to meet the energy requirements for agricultural production (15–17% of all our energy use goes into growing crops!). To double the food supply means doubling the agricultural energy demand (and that is before we distribute the food).
- We increase the use of fertilizers – but already nitrogen overload is a global problem: 60% of nitrogen deposited on land is anthropogenic.
- We take more land into agricultural production – goodbye biodiversity!
- We use other means of improving agricultural productivity – but our society rejects molecular engineering of plants as unethical, partly on the grounds that it endangers biodiversity.
- We find novel means to control insect pests.
- We all become vegetarians – in which case the grain presently fed to livestock will feed 800 million people (that's 13% of the present global population).

Just to mark time with carbon dioxide emission we have to reduce the emission per capita by 50%. In the so-called developed world the reductions will have to be even greater. So where is the lead from the great US of A? Can we rely on the new President to start taking the action needed? If Governments worldwide will not do it, can we rely on the new globalized industries?

There is a glimmer of hope. Alternative power sources are being developed (though admittedly not fast enough), and fuel cells may allow us to continue to have the freedom to sit in traffic jams (maybe the demonstrations of the future will be about the cost of hydrogen!) Some research is being carried out into ways of sequestering vast quantities of carbon dioxide, but there seem to be few options available. Statoil are pioneering the re-injection of a million tonnes of carbon dioxide stripped from natural gas supplies into the Utsira Sandstones beneath the North Sea. Growing more trees and protecting forests helps – but not much, and how do we feed everyone? Putting CO_2 into the deep ocean is feasible, but very costly and Greenpeace will not be pleased (cf. *Ocean Challenge*, Vol. 9, No. 2, p.10). Putting it into deep rock strata seems to be the best option, but not every country has a convenient Utsira sandstone to hand – and you still have to collect the stuff from power stations first, which is a non-trivial task, both logistically and financially. The real difficulty is that these are all short- to medium-term 'end-of-pipe' solutions. The only effective long-term strategy is to reduce emissions, and that means major changes to lifestyles and to the aspirations of our children and grandchildren. Meanwhile the inability of governments to reduce our reliance on the internal combustion engines is highlighted by the fuel blockade fiasco in early September.

There is a more detailed review of the options for carbon dioxide sequestration, including brief summaries of the iron-enrichment experiments on the Web (British Government Panel on Sustainable Development, 1999): http://www.open.gov.uk/panel-sd/position/co2/main.htm

Further Reading

Broecker, W.S. (1997) Thermohaline circulation, the Achilles heel of our climate system: will man-made CO_2 upset the current balance? *Science* **278,** 1582–88.

Evans, L.T. (1998) *Feeding the ten billion: Plants and population growth.* Cambridge, Cambridge University Press.

Hanson, R.B., Ducklow. H.W., and Field, J.G. (Eds) (2000) *The Changing Ocean Carbon Cycle: A Midterm Synthesis of the Joint Global Ocean Flux Study, Cambridge University Press.*

Sarmiento, J.L. and Orr, J.C. (1991) Three dimensional simulations of the impact of the Southern Ocean nutrient depletion on atmospheric CO_2 and ocean chemistry. *Limnology and Oceanography* **36,** 1928–50.

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A review of *The Changing Ocean Carbon Cycle,* edited by R.B. Hanson, H.W. Ducklow and J.G. Field, will appear in the next issue of *Ocean Challenge.*

Russia's Marine Reserve

Russia has 93 terrestrial nature reserves and one marine reserve. The Far Eastern Federal Marine Reserve occupies a significant proportion of the Bay of Peter the Great, which is part of the Sea of Japan (see map). The Reserve was founded on 24 March, 1978, on the initiative of the Institute of Marine Biology (RAS).

The landscape of the adjacent region of Primorye Krai is one of taiga and subtropical forests, marshes and steppe. There are rivers, lakes and brackish wetlands, as well as steep cliffs and quiet sandy bays. The area has been inhabited for six thousand years, and there are thirty-five Neolithic sites on the mainland and the islands.

Location of the Far Eastern Federal Marine Reserve. The numbers correspond to the different excursion routes (see text).

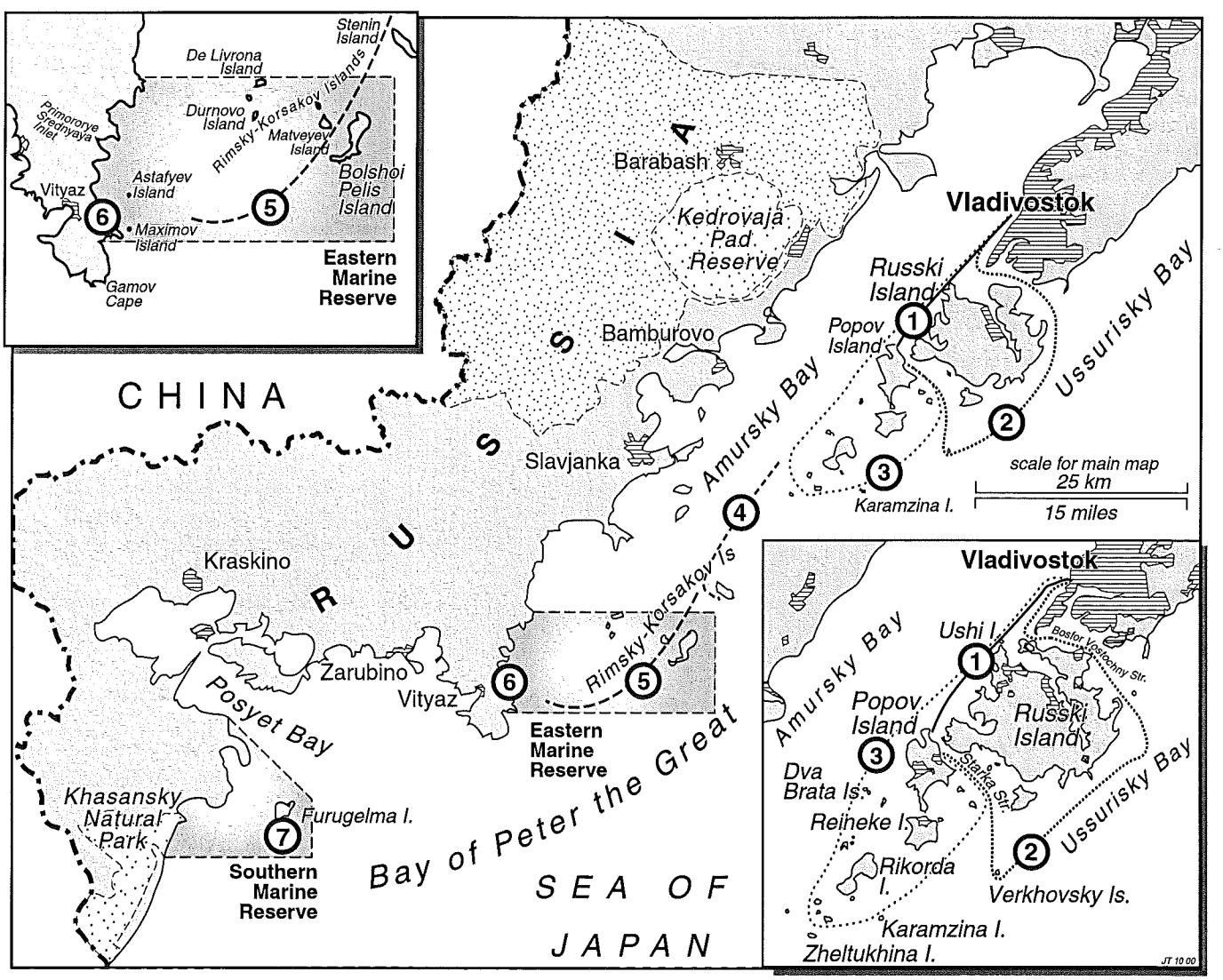
Geography and climate

The Reserve occupies more than 64 000 ha, about 10% of the total area of the Bay of Peter the Great, and includes eleven islands of varying sizes, as well as many smaller islets. It is in several parts: the islands in the north-east, to the south-west of Vladivostok; the Eastern Marine Reserve, which is a zone of strict protection, and includes Bolshoi Pelis and a number of smaller islands; and finally the Southern Marine Reserve, which is a scientific experimental zone and includes Furugelma and Vera Islands, Cape Falshivyi Islet, and Kalevala, Sivuchya, Oemzovaya Inlets. The western part of this region is used as a rearing area for juveniles of Japanese scallop for recruitment to natural populations.

The climate here is monsoonal. In winter, conditions are windy with little snow. The average air temperature in January is –11 °C, and winter water temperatures may be as low as –1.8 °C. The summer is warm, often with storms, rain or mist. The average air temperature in August is 21 °C, and water temperatures may reach 26 °C in sheltered bays.

Plants and animals of the Reserve

Because cold and warm currents meet in the Bay, Arctic, subtropical and even tropical species are found living here together. There are more than 200 species of algae and more than 2 000 species of invertebrates, including about 200 species of molluscs, 250 species of marine worms and 20 species of echinoderms.



The Reserve is home to a number of species that have almost disappeared in other parts of the Bay of Peter the Great, as a result of destructive over-harvesting. Sea-urchins (*Strongylocentrotus nudus and S. intermedius*), scallops (*Mizuhopecten yessoensis* and *Swiftopecten swifti*), the Japanese sea cucumber (*Stichopus japonicus*) – the 'ginseng of the sea' – are all targets of poachers. Giant octopus (*Octopus dofleini*), cuttlefish and Kamchatka king crab (*Paralithodes camtschatica*) frequently come to spawn; star-fish (*Distolasterrias nipon* and *Asterias amurensis*) and large banks of mussels (*Crenomytilus grayanus*) can also be found.

The larga seal, which had almost been killed off in the waters of southern Primorye, has returned to the islands as a permanent resident, and during the summer, up to 80% of the southern Primorye seal population gathers in Reserve waters. Sea lions, dolphins and killer whales have also returned.

More than 270 species of fish have been recorded in the Bay of Peter the Great, and all may be found in Reserve waters, as there are no natural boundaries between these and the sea. Tropical species are recorded here more often than elsewhere in the Bay, and Japanese sandfish, stone flounder, swordfish, tuna and tiger shark have been caught.

Vertebrates of the islands

The islands are inhabited by mice, bats, non-poisonous snakes, toads and lizards. More than 360 species of birds have been recorded on the islands and 80 of them nest in the protected zone of the Reserve. There is no comparable diversity anywhere else in Russia.

Several hundred thousand migrating birds use the wetlands where they raise their young in spring, and there are enormous colonies of black-tailed gulls and Japanese cormorants. A number of bird species found here are included in the Russian Red Book of rare species and are of international significance: the Japanese crane, yellow-billed heron, Japanese snipe, black vulture, white-tailed eagle, golden eagle, gyrfalcon and peregrine falcon, to name just a few.

In the protected mainland coastal zone of the Reserve are dappled deer (Japanese sika), foxes, and wood leopard. In winter, it is possible to see the black vulture *Aegypius monachus*, the white-tailed eagle (*Haliaeetus albicilla albicilla*) and Sterrer's sea-eagle (*H. pelagicus*). During recent winters, the Amur tiger, (*Panthera tigris altaica*) and far eastern leopard (*Panthera pardus orientalis)* have been regularly seen in the vicinity of Lion Cape.

How to explore the Reserve

Excursion routes have been chosen so as to show the beauty of the region. All start and finish at Vladivostok, and travel is by means of the Reserve's vessel. The maximum size of a group is six people. Currently, the price of excursions is $30 per hour per group, with an additional charge of $10 per hour for an English interpreter. The group may be supported by a professional diver, and tourists may also dive themselves. Marine animals can be collected and displayed in an aquarium. Tourists may fish outside the limits of the Reserve (fishing rods are supplied), and any fish caught may be prepared in the vessel's galley (although any rare fish species caught must be preserved for the Reserve Museum).

Several of the tours concentrate on the Northern 'excursion and tourist zone'. The first (1 on the map) involves a visit to Popov Island, where there is an ecological trail, the Reserve Museum, an Ecocenter, and the 'Cape Likander' Botanic Gardens. Others (2 and 3) also involve visits to Karamzina Island and the Verchovsky Islands, with their large colonies of seabirds.

Excursion 4 goes to the Eastern Marine Reserve. Excursion 5 begins the same way and then visits the Rimsky-Korsakov Islands, Astafyev, Vhodnyye, and the mainland coast (including Lion Cape and an archeological monument at Spasenye Inlet), coming ashore at the picturesque bay of Primorye Srednyaya Inlet. The night is spent in a summer cottage.

Excursion 6 is a visit to Spasenye Inlet and involves car travel from Vladivostok to Spasenye Bight – a four-hour trip through a forested landscape.

Excursion 7 is a trip to Furugelma Island, which lasts at least 60 hours. This island has the world's largest colonies of black-tailed gull and Japanese cormorant, and the rare Chinese egret nests here.

Problems facing the Reserve

Poachers

In the last few years, the Reserve has been hit by severe budget cuts. Resulting weaknesses in the protection programme have been exploited by poachers who have had a severe impact on Reserve biota.

Pollution

The future construction of a port at the mouth of the Tumangan River, where the frontiers of Russia, China and North Korea meet (a project known as 'Tumangan–TREDA'), is a threat to the inhabitants of the Marine Reserve, as any pollution would be transported into the Reserve via currents.

How to help the Marine Reserve

The Marine Reserve needs help from people who care about the natural environment and its future, and who understand that such areas protect genepools of marine organisms. To encourage fund-raising for the Reserve, a non-governmental and non-profit-making fund (the Fund for the Development and Protection of the Marine Reserve), has been established.

For more information about how you can help the Reserve, please contact:

Fund for the Development and Protection of the Marine Reserve,
Far Eastern Federal Marine Reserve,
Institute of Marine Biology,
17 Palchevsky Street,
690041 Vladivostok
Russia.

For information about visiting the Reserve, please contact Dr P. Kolmakov or Dr A.N. Tyurin at the Reserve address given above.

This information about the Reserve has been abstracted from a booklet *The Marine Reserve: Twenty Years* (in Russian and English).

Fuel and fish: a question of priorities

As you read these words, Britain could be in the grip of another fuel crisis, perhaps more severe than the one in September. But how many people recall that it all began in France? An early September blockade of French ports by fishermen protesting about the price of marine diesel provided an interesting if oblique commentary on the state of the oceans and gave a novel twist to the relationship between supply and demand. Blockades apart, diesel is not yet in short supply. The world is still awash with petroleum. It just isn't being sucked out of the ground fast enough, so the price has gone up a bit.

The same cannot be said of fish. The well-worn comforting phrase 'never mind, plenty more fish in the sea' began to ring hollow several years ago. Fish are being sucked out of the sea faster than ever before, but supply is not meeting demand, so the price is inexorably rising.

Three long features on the global fisheries crisis in *The Guardian* last August, Jacquie McGlade's Radio 4 series ('The Ocean Planet') in September, and countless other articles and statements and documentaries all tell the same story, a story that has been told and re-told for the last ten years at least. The oceans are running out of fish and the marine ecosystem is becoming progressively more unbalanced by the accelerating depopulation of key species.

For years, everyone connected with the industry has acknowledged that commercial fishing is not a sustainable activity. John Gummer's worthy pronouncement, that the Fisheries Stewardship Council should identify sustainable fisheries, is nonsense – there *are* no such fisheries anywhere. The quota system in its various guises (including Individual Transferable Quotas) is grotesquely wasteful and has been repeatedly shown to be open to all manner of corrupt and illegal practices.

But the millions of words spoken and written on this subject (some of them in these columns!), and the countless sets of scientific data testifying to global depletion of fish stocks, have had virtually no effect. Nor have the complaints of fishing communities in Britain and elsewhere that the fisherman (and -woman) is becoming an endangered species too. Bigger boats with more sophisticated gear catch more fish than ever before, not only in deeper waters (where biomass is smaller and yields must inevitably be less), but – most perniciously – also in the shelf (and even coastal) waters of developing states that cannot afford the naval vessels needed to patrol their EEZs and protect their own artisanal fisheries, which would at least approximate to something like sustainability. So-called pirate ships, flying flags of convenience and defying international regulations, fish with impunity in parts of the ocean legally set aside for countries whose governments have signed agreements to conserve stocks.

Added to all this is the continued destruction of dolphins, turtles and other marine animals in drift nets, which seem to be used on as large a scale as ever, despite international efforts and legislation to curtail their use. The loss of seabirds like albatross, which are drowned after taking the bait of long-line fisheries, continues unabated.

Nor is aquaculture the answer. To suggest that farmed GM salmon (the giants described in *Ocean Challenge* Vol.10, No.1, p.5) could help to feed a hungry world, as suggested by the boss of the company producing these fish, is no less grotesque than the quota system for catching wild fish. The eutrophication and pollution by the pesticides (some, allegedly, illegal) that are associated with fish farming are only one of the problems that beset this industry (cf. *Ocean Challenge,* Vol.10, No.1, p.19). Another is the use of fish meal as feed, not only on fish farms but also for pigs, cattle and poultry. The fish meal comes from the cheaper kinds of wild fish (herring, mackerel, sardines, sand-eels); but just because some fish are cheaper than others, it doesn't mean their stocks are less likely to be overfished. Conversion efficiencies being what they are, at least three units of wild fish are needed to produce one unit of farmed fish. Each year, something like 30 million tonnes of wild fish go into fish meal for these various end-uses. The next step – already suggested in some quarters – is to harvest marine plankton to feed farmed fish. Could anyone be daft enough to take such a proposal seriously? A recent suggestion to use surplus soya beans as food for farmed fish would at first sight seem to make more sense, but may have other drawbacks.

The seas will continue to be plundered, because too many vested and often conflicting interests are involved. Nor does there appear to be any let-up in the levels of marine pollution, which cannot be said to be beneficial to the conservation (let alone health and growth) of fish stocks. Progessive migration of the petroleum industry offshore is one factor, but oil companies are not the only culprits. There is no shortage of reports about pollution by heavy metals and other toxins, including endocrine disruptors, which may not be immediately fatal, but can play havoc with the reproductive systems of many marine animals.

Three-quarters of humanity's protein requirements will come from the seas in twenty years' time, according to Jacquie McGlade. This seems to be an unrealistic, not to say unsustainable, proposition, especially if plankton are going to be used 'down on the farm'.

These few words, added to the millions already written and spoken on the subject, will make no difference to anything. Fish stocks will continue to decline, and the fishing industry must eventually decline with them. Professor David Symes spoke eloquently about the 'Ecosystem Approach to Fisheries Management' when he gave the Buckland Lecture at UK Marine Science 2000, which we hope to bring you in a later issue. It's by far the most sensible approach, not least because it is holistic, that is, it doesn't treat each fish species as a discrete entity existing independently of all other life-forms in the oceans. I fear, however, that this approach may take too long, because (as David Symes says) it will require massive and permanent reductions in fishing capacity and fleet sizes, a policy which neither bureaucrats nor fishermen will readily accept, let alone implement. There is a real danger that when (or indeed, if) sound management policies are eventually agreed, there may be no fisheries left to manage. Set against that, public furores about a few pence off (or on) a litre of petrol are surely less important – aren't they?

John Wright

Qeshm – Gateway to the Persian Gulf

Thomas Höpner and Hossein Ebrahimpour

The burst of marine research in the Persian Gulf, that followed the tragedy of the oil catastrophe caused by the 1991 Gulf War, has passed. This is not because of declining interest by scientists – it is chiefly because of the restrictive entry and cooperation policies common to all Gulf states. The scientific importance of the Gulf, in the geological and biological aspects of the Pleistocene–Holocene transition, for example, is amply demonstrated by the research carried out during the 1970s, perhaps best documented by B.H. Purser's 1976 book, *The Persian Gulf*. Subsequent reports have dealt mainly with petroleum, and their results are not so readily available. Partly as a consequence of this, Iran's Gulf coast, one of the longest in the world, remains largely unknown to the international scientific community.

The gateway to this region is Qeshm, an Iranian island in the Strait of Hormuz, about 120 km long and 30 km across. It is a Free Trade Zone, which foreigners have for years been able to enter without a visa. Qeshm is an ancient settlement area, which today has some 75 000 inhabitants, about 30 000 of whom live in the lively trading centre of Qeshm itself, while the rest occupy 16 outlying villages and live mostly by fishing and shipbuilding. Good roads allow easy access to areas of scientific interest.

Qeshm has proved to be an 'Eldorado' for marine biologists, marine geologists and palaeontologists – the fantastic erosional features in the 400 m high mountains display marine sediments with an overwhelming richness of marine fossils. There is even a salt dome, 6 km in diameter, with the salt itself exposed to the elements. While a great deal is known about Qeshm at the national (Iranian) level, its natural history is not widely covered in the international literature.

Qeshm's uniquely 'ecostrategic' location makes it possible to study transport and exchange processes for both water and organisms, between the Gulf and the Indian Ocean. With a tidal range of up to 4 m, there are wide intertidal zones of rock, and of sand and mud ('waddens'), accommodating a breathtaking variety of organisms, as well as the largest area of mangroves within the Gulf (400 km^2). Ornithologists have excellent opportunities to observe birds on their migration routes from the Caspian and south-west Asia.

For two years, the administration of the Qeshm Free Trade area has supported a Persian Gulf Biotechnology Centre, under the supervision of a microbiologist and a biochemist from the Azzahara University of Tehran. The Centre can help visiting scientists to find accommodation as well as vehicles and boats, provide logistic support for field work and sample-processing, and can even arrange the use of laboratory space. This help and support is necessary, since there is minimal knowledge of foreign languages on the island, and for practical reasons, connecting flights from Tehran or Dubai by the regional airline (Qeshm Air) cannot yet be booked from outside Iran.

The Centre is working hard to foster and promote international scientific cooperation in the hope of developing and expanding its own work profile. At present, there is a major project in growing and screening algae for agar production, and land plants for antibiotics. However, visiting scientists are able to pursue their own interests, and the Centre staff can help with long-term (time-series) measurement and sampling programmes.

To find out more, contact Thomas Hoepner (thomas.hoepner@icbm.de). He has been there!

Thomas Höpner is at the University of Oldenburg, and **Hossein Ebrahimpour** is at Tehran University

New Database of Law of the Sea boundaries

The Global Maritime Boundaries Database (GMBD) is a complete database describing national claims to the oceans and sea-bed. The database, designed by Veridian–MRJ Technology Solutions, is unique in that it provides GIS data on boundaries (approved or otherwise) for all coastal states.

Information provided includes:

- Territorial seas, contiguous zones, economic zones, military zones, development zones, fishing zones, and other information.
- Unilateral claims, multilateral agreements, median lines, disputed claims, overlapping claims, and hypothetical claims.
- 'Hot-linked' MRJ Notes including the *Maritime Claims Reference Manual* and *World Factbook*.
- Detailed attribution for each maritime claim and zone (including arcs and polygons).
- A GIS data-viewer for display, manipulation, and querying of the spatial data.
- A complete ArcView project file of the database for integration with existing ArcView applications.

The database costs US$3000 per set, including at least one semi-annual update. For more information, contact Veridian-MRJ Technology Solutions by email at MaritimeBoundaries@mrj.com or visit the website at http://www.MaritimeBoundaries.com

NOW There's a FUNNY THING...

Bucking the sea-level trend

Imagine my surprise. 'Falling sea-level upsets theory of global warming'. So ran the headline in *The Sunday Telegraph*, an organ not normally given to wild exaggeration. It seems that scientists of the Tuvalu Meteorological Service were claiming that 'sea-level had fallen by nearly 2.5 inches [~6 cm] since the early 1990s', having previously been rising at up to 1.5 inches [over 3 cm] a year (*sic*).

The Tuvalu Island Group (once part of the Gilbert and Ellice Islands in Britain's colonial past) lies just south of the Equator and not far from the International Date Line. The Tuvalu Met. Service scientists were reported as claiming that similar sea-level falls were recorded at Nauru, the Solomon Islands and Papua New Guinea, all of which are also in the western equatorial Pacific. They attributed the sea-level falls to 'unusual weather conditions' caused by the 1997–98 ENSO event (which was particularly strong).

The most intriguing aspect of the story is that tide-gauges in this region seem to have been recording a fall in sea-level over the past five years. Moreover, 'island residents who once worried about their houses being flooded are now complaining that the lower tides are disrupting their fishing expeditions and making it difficult to moor their boards and to navigate through low-lying reefs'. Some people are never satisfied.

But it does seem premature to suggest, as the Tuvalu Met. Service scientists have apparently done, that the island communities 'will be safe for another 100 years', particularly as they are quoted as attributing their local sea-level fall to the transitory effects of an El Niño event. Given the alleged previously recorded annual rise of over 3 cm, which is vastly more than the global average (~2 mm), they should perhaps have been expecting a reversal to occur sometime soon. In any case (as trenchantly pointed out by Patrick Nunn, an expert in these matters who works on nearby Fiji), it is surely unwise to extrapolate from short-term trends. After all, satellite altimetry measurements have demonstrated that sea-level in any particular part of the ocean can rise or fall over periods of a few years, precisely because of climatic oscillations such as El Niño.

Sadly, it seems that the inhabitants of these low-lying island groups must begin to prepare themselves for evacuation, because their homes will be under the waves within decades. Unless of course, the seabed is inflating beneath them. Over the last 250 million years, this part of the Pacific has seen the eruption of huge volumes of submarine lavas that have formed features such as the Ontong–Java Plateau. Resurgence of such activity would warm the oceanic crust beneath the western equatorial Pacific, making it expand and rise. That would certainly make sea-level fall! On the other hand, we might expect incipient submarine volcanism to be accompanied by some seismic activity, however slight, and none seems to have been reported. The question is, though, how much would the effusion of submarine lavas warm the surrounding ocean, and would it be accompanied by surface volcanism? Perhaps one of our readers knows enough about these submarine plateaux to answer such questions – which might seem hypothetical to us, but could be of some interest to the people of these western Pacific islands, who might wish to know whether they will have to leave their homes to escape from waves or from erupting volcanoes (or even both).

El Niño: an agent of history

This suggestion featured in an item on the radio that caught my ear the other day. The author of a new book was being interviewed about his claim that all manner of climate-related disasters that have changed the course of history can be attributed to the influence of El Niño on the global climate. They include, for example, the excessively cold and wet weather that caused the Irish potato famine of 1845–46; the sinking of the *Titanic* in 1912, which occurred because there was an unusually large number of icebergs in the North Atlantic that winter; and the bitter winter and heavy snowfalls which halted and reversed the German Army's invasion of Russia in 1941–42.

A sceptical critic, interviewed at the same time, pointed out that the North Atlantic had lots of icebergs between 1900 and 1920 (i.e. there was no particular 'glut' in 1912), and that an El Niño occurred in 1939–41, not 1941–42. Moreover, one of the strongest El Niños on record, 1997–98, was not accompanied by a particularly severe winter, and cold winters also occured in non-El Niño years before 1941–42. The book in question is somewhat grandiloquently entitled *El Nino: the Weather Phenomenon That Changed the World* (Hodder & Stoughton, £17.99), but it seems perverse to blame El Niño for climate-related disasters that don't happen round the Pacific. Wouldn't it be more sensible to relate events in Europe to fluctuations in the NAO rather than to El Niño?

The start of the new millenium has provided no shortage of climate-related difficulties for humanity, but pinning them all on El Niño would surely be difficult. The floods in Mozambique did subside, but monsoon rains then submerged large tracts of northern India (Uttar Pradesh). Meanthile the drought in Ethiopia has spread to Kenya and shows no sign of easing – rather the reverse, if anything, to the extent that water and hydro-electricity are reportedly being rationed in Nairobi. Last summer in Europe featured droughts and forest fires in the south-east, rain and floods in the north (rain stopped play at Wimbledon and Lords, and nearly forced the closure of Chernobyl's nuclear power plant). The western half of the US seems to have been on fire for months ('the worst fires for 50 years'), even though the Pacific north-west experienced one of its rainiest winters on record in 1999. Some of these diverse calamities might indeed be consequences of ENSO events, and/or of one of its counterparts in the Atlantic or Indian Oceans. Alternatively, they could result from vagaries in behaviour of the jet stream. While the Pacific north-west was being rained on, for example, Alaska and Siberia were experiencing temperatures around –55 °C, and it has been

suggested that this could have been because zonal flow in the polar jet stream prevented cold air from flowing south. But is it too parochial to seek Earth-bound explanations for climate-related disasters? Perhaps the causes are extra-terrestrial, perhaps the answer lies in the Sun: could solar activity trigger El Niño events and influence atmospheric jet streams? (See 'The Solar Weather Machine', p.4.) Storms and floods and droughts may become more frequent in the future, not because global warming is CO_2-driven, but because it is solar-powered. Oil companies and governments *will* be pleased.

Quirks of Nature

Where's the body? The positive side of the macabre tale of a man's head found inside a 6-foot cod caught off Australia is that there are still big cod to be found. The head was identified as belonging to a fisherman lost from a trawler, but a sinister twist to the story is that cods' jaws are not equipped to bite off people's heads – dead or alive. I shall not dwell on the implications of this aspect of the tale, I record merely that the place where this cod ended up was called the 'Fine Kettle of Fish'.

Too much sugar A green slime coated great stretches of Italy's Adriatic coast in early summer, upsetting both tourists and fishermen. Called mucus by some, mucilage by others, it was found to consist largely of sugars secreted by small algae and bacteria. The unusually warm winter of 1999–2000 (average temperature some 5 °C higher than usual) is one possible cause, another may be that reduced outflow from the Po River has 'altered the chemical balance of coastal waters' – though it seems just as likely that, reduced flow or not, the Po discharges more nutrients into the Adriatic than it used to. The green slime had much the same effect when it last appeared, in 1989, and there seems to be little that can be done to counter it, since it is difficult to control either winter temperatures or the Po's discharge. The Adriatic is a shelf sea, mostly less than 200 m deep, and tides are not a feature of the Mediterranean, so wind is the best means of dispersal. The *'bora'* is a strong (up to 100 knots) cold north-easterly katabatic wind that originates in the Russian highlands and blows across the Adriatic coast of former Yugoslavia. The wind might drive tourists away as effectively as the mucus it disperses, but it cannot be all that common, or it would be mentioned in the tourist brochures – wouldn't it?

Aquariums can kill

Big effects can follow from small causes. You wouldn't think that emptying a domestic aquarium down the drain would lead to an algal infestation that kills seaweeds, coral and shellfish over large areas of sea-bed. But according to the story, that's just what happened. The alga in question is a dark-green species (*Caulerpa taxifolia*), which 'makes a luxurious green bed for display tanks', in which it is usually confined. Some was accidentally discharged from Monaco's Oceanographic Institute in the 1980s, and devastated about 40 km² of sea-bed off Spain, France, Monaco and Italy. There was also an outbreak in Australia, and now it has appeared in California, where it has been imaginatively called 'killer algae', though it doesn't affect humans. However, you can't believe all you read in the papers. The report states that the algae kill other marine organisms by consuming oxygen (when they die, maybe, but surely not while they are alive?), also that they may have mutated under the influence of ultraviolet light used in some aquariums (to simulate sunlight). It is also claimed that they can survive in colder water (colder than what is not specified) and can spread faster than other types of algae. And the cure seems to be worse than the disease: spread tarpaulin over the affected sea-bed and inject a powerful herbicide beneath it. Unpleasant though that sounds, it does at least imply that the infestation is not yet widespread.

Surf rage – no kidding

It really happens. Good surfing beaches from Britain to the US to Australia are now getting so crowded that collisions and near misses result in fights between surfers competing for rides on the biggest waves. Visitors and beginners are intimidated by graffiti and damage to their cars and surf boards. It is not always clear whether injuries sustained by the surfers are deliberately inflicted or result from accidental collisions. But them, who's to say that collisions are always accidental?

The stories go round and around

I've been getting flashes of *deja vu*. First there was an account of the experiments made off New Zealand, during World War II, to try and create artificial tsunamis by detonating high explosives offshore. It appeared in *Ocean Challenge* about five years ago (Vol. 5, No. 2, p.19), and resurfaced in *The Daily Telegraph* in October last year. It's a bit of a so-what story, mind, because natural tsunamis are generated by earthquakes (or submarine slides or meteorite impacts), and so to provide a comparable amount of energy you need an atomic bomb. Ordinary high explosives are nowhere near powerful enough. In the event, the World War II experiments served only to make some people rather wet and/or deaf or both.

Then there was William Hutchinson, whose pioneering work on tidal observation and measurements in Liverpool were recounted by Philip Woodworth in *Ocean Challenge* a couple of years back (Vol. 8, No. 3, pp.47–51). Hutchinson received an accolade in *The Observer* in January last, in the context of a short feature about accelerating sea-level rise round Britain. Remember, folks, you read it here first!

Having deplored in these columns – again several years ago – the impending end of coracle fishing as a traditional way of life (*Ocean Challenge*, Vol. 6, No. 3, p.13), it was with some surprise that last April I saw an item in *The Sunday Telegraph* describing the imminent demise of coracle fishing. Admittedly, there are now coracles on only three Welsh rivers, when once they could be seen on rivers throughout Britain (coracle fishing goes back some 2000 years), but the reason for the demise has not changed. It is the enforcement of regulations to preserve salmon stocks, on the grounds that the 'netsmen', as they are known, catch too many fish. *Plus ça change.*

John Wright

News from the DGM

DGM Mitteilungen Nos. 1/00 (May) and 2/00 (July) have reached us. In her editorial to the May issue, Susan Beddig (the Editor) mentions – among other things – that the DGM has some 500 members and that their combined efforts have contributed to the production of 75 issues of the *Mitteilungen* over the last twenty years or so – an impressive record. As Susan says, the usual mixture of diverse topics is covered in this, the first issue of the millenium

It opens with the Qeshm (Persian Gulf) item that Thomas Höpner has also kindly provided for us (see p.15). An interestingly and introspectively critical article poses the question of why Germany is no longer a member of EuroGOOS – which some might see as contrasting somewhat with British attitudes to participation in continental European programmes and projects ('We won't join unless you give us jolly good reasons why we should ...'). History is represented by an account of how a wealthy businessman, one H.A. Meyer, financed the construction of Kiel's first research vessel (the cutter *Marie*), and supported investigations into the shallow-water fauna of the Bight of Kiel (*Kielerbucht*) during the second half of the nineteenth century. Kiel was also the location of a lecture by Margaret Deacon in February, when she presented new insights into the subject of her well-known book, *Scientists and the Sea*, which first appeared in 1971. Several pages are devoted to transcripts of addresses and tributes on the occasion of the retirement in March of Gotthilf Hempel as Director of the Centre for Tropical Marine Ecology at Bremen, and there is in effect a preprint summary of a paper in *Marine Science Reports*, that reviews hydrographic and chemical assessments of Baltic Sea waters carried out during 1999.

Among several other shorter items is a brief description of the content and objectives of Expo 2000 (in Kiel, from June to October), as well as two that are written in English: one of these summarises an environmental workshop on the Baltic Sea region (Hamburg, February); the other is a meeting report of the SOLAS (Surface Ocean Lower Atmosphere Study) Open Science Conference (Damp, near Kiel, also February). The back end of this issue mainly concerns DGM administration and finances, and also lists several new links to the DGM home page (which is at http://www.rrz.uni-hamburg.de/DGM). In addition there is what appears to be a new short section headed 'DGM Global', and in this issue it carries an invitation to DGM members working abroad to submit articles and features relating to their activities. There is some evidence in the second issue that this appeal may have borne fruit (see below).

The second issue (2/00) is as diverse as the first, and it also features a fair proportion of material written in English – imagine the effect on *Ocean Challenge* readers if, say, a fifth of its content were in German (or French). Following the editorial, the magazine kicks off with an announcement of the next annual DGM get-together (held at Bremen on 6 October), with the (loosely translated) theme of 'where the river meets the sea', and a couple of useful marine science and technology websites are also advertised. The first long article concerns the need to consider the requirements of the marine research community when planning the location of offshore wind farms. This article has an abstract written in English, and it is followed by another complete article in English, about the impacts of accelerated sea-level rise around Europe's shores (could it be coincidence that one of the authors has an English name and is based at Middlesex University?). There is an overview of the series of discussions on legal aspects of maritime and environmental issues with especial reference to the Baltic, which have been held at Rostock (just south of Warnemünde), since 1993.

The behaviour of the thermohaline circulation during interglacial–glacial transitions, simulated using a coupled ocean–ice–atmosphere model, is briefly described (for further details see http://elib/suub.uni-bremen.de/FramesElib.htm). Birgit Obermüller, presently based at Plymouth Marine Laboratory, has provided an account of how mesozooplankton communities in the Arctic cope with the transition from winter to spring. She has written it in German, possibly in response to the invitation in the DGM Global section of No. 1/00 (see above). Could she perhaps be prevailed upon to produce an article (in English!) for *Ocean Challenge* readers? Most physical oceanographers may well be aware of the existence of a public domain General Ocean Turbulence Model (available on http://www.gotm.net), but they may not know much about its development which, as outlined here, seems to have begun in 1992 and to have involved modellers from (among other places, no doubt) Germany, the US, Italy and Denmark. Interested persons are invited to participate in further refining and developing the model.

The DGM Global section in this issue gives notice of an on-line introductory physical oceanography course (with examples and exercises that include some material from the Indian Ocean), which is based in Adelaide, Australia. It is at http://www.es.flinders.edu.au/-matom, which is actually the website of the physical oceanographer and long-standing DGM member Matthias Tomczak, author (with J. Stuart Godfrey) of the well-known standard text *Regional Oceanography: An Introduction.*

The rest of this issue contains: a book review (*The Sources and Consequences of Climate Change and Climate Variability in Historical Times* by Eduard Brückner, published by Kluwer); a discussion of the *1999 Quality Status Report on the Wadden Sea*; a brief description of dumped munitions as fisheries 'by-catches' (both by Thomas Höpner); and a speculation about how marine research might develop in the next decade (by Walter Lenz). There is also a letter (in English) giving notice that a draft of the International Science Plan for SOLAS (see under 1/00 above) is available on the web (http://www.fin.uni-kiel.de/ch/solas/main.html). The last page of this issue describes the terms and conditions of the Annette Bartlett Prize for Marine Research, which is awarded annually to young scientists (under 30) and will be presented at Kiel in March 2001.

Eds.

Challenger Society for Marine Science

ANNUAL REPORT 1999–00

Message from the President, Professor Harry Elderfield

This, the 97th year (1999–2000) of the Challenger Society, has taken us into a new millennium and moves us inexorably closer to our own centenary. Much of the focus of the Council during the year has been on change and looking to this future. What do we as a community want the Challenger Society to be? The Challenger Society is one of several UK societies and organisations. Our role is to represent anyone with an interest in the marine environment. Traditionally our main constituency is graduate scientists some of whom move to employment at universities and Government laboratories. We are not a professional society in the strict sense in that we do not have a scientific journal; we wish to attract a wider membership. But we do recognise professional achievements through our awards system (see below) and encourage professional activities through our meetings. Our magazine, *Ocean Challenge*, plays an important role in the broader, more popularist, aspects of marine science.

However, we attract few members compared with who is out there and many members leave after one or two years. The reasonable question that potential members may ask is: 'What's in it for me?' If we did start with a clean sheet what would we do? This is my question to all readers of *Ocean Challenge*, whether or not you are a member of the Challenger Society. What do you want from the Challenger Society? We shall be asking you this question in more focussed ways through these pages in a future edition but please write to me with any suggestions. Among the ideas currently being discussed are the production of a regular Newsletter,* running Master Classes, and local (evening?) meetings at centres such as Southampton.

Some new initiatives are already in place. One has been the organisation of an Introduction to Oceanography course for divers, which took place in Plymouth. This proved extremely popular and will be repeated. Another has been the initiation of the awards and prizes scheme. This has several purposes. One is to provide small travel awards of about £100 each to graduate students who are members of the Challenger Society. Only two students applied this year (both from the same institute; evidently they possess good research skills) and we welcome many more applicants. Another is to acknowledge the contributions of individuals to ocean sciences. We recognised Angela Colling, the long-serving editor of *Ocean Challenge* as an Honorary Member of the Society, Chris German and Karen Heywood as the first Fellows of the Society, and Peter Liss as the first recipient of the Challenger Medal. Their awards will be presented at the Marine Sciences 2000 Meeting at the University of East Anglia.

This leads me on to this our biennial meeting. We view this as one of the major highlights and accomplishments of the Society and we are very grateful to Tim Jickells and his team at UEA for their hard work in planning and running this meeting this year. The meeting will include a Challenger Lecture from Peter Liss – this year's medallist. We also plan to sponsor a Challenger Lecture in the odd-numbered years, either as part of an important scientific meeting or perhaps as a public lecture.

*This Annual Report was compiled for the AGM, held during Marine Science 2000 at the University of East Anglia, in September. A Newsletter is now in production.

On a broader front, the European Federation of Marine Science and Technology Societies (EFMS) is up and running. Its next President will be Graham Shimmield, Director of the Scottish Association for Marine Science (SAMS), and we look forward to a dynamic period of his leadership of EFMS. As I mentioned in last year's report, a big advantage for the Challenger Society in the establishment of EFMS has been the closer co-operation with the three other UK marine science organisations it additionally represents (the Society for Underwater Technology (SUT), the Marine Biological Association of the UK (MBA), and SAMS). There are some issues in UK marine sciences that affect all our organisations and it is best to tackle them jointly. This is now what we are doing.

I wish to express the Society's grateful thanks for the support of NERC's two marine science laboratories: the Centre for Coastal and Marine Sciences and the Southampton Oceanography Centre. Your help has been crucial to our activities, as has been the hard work and commitment of the Council members and those who have also helped the Society in various ways such as organising meetings and advertising in the magazine; and is much appreciated.

I will close by saying how much I have enjoyed my short period as President of the Challenger Society. I took up the role more in apprehension than anticipation but found it to be a most rewarding experience. Working with the Council has been pleasurable and stimulating. Apart from thanking Council members collectively for their active and vociferous participation, and commitment to the Society, I especially thank Carol Robinson, the Honorary Secretary of the Society, who has made my job the easier through her hard work and efficiency.

Membership

Total membership as at 31 August 2000 is 409, including 291 Full members, 66 Student members, 4 Honorary members, 38 retired members and 5 Corporate members (= 10 individuals). 103 Student members, 72 Full members and one company did not renew their membership this year.

Council membership and responsibilities

Since the last Annual General Meeting, which took place on 9 September 1999 in Plymouth, the Council of the Society has met three times, on 18 January 2000, 19 April 2000 and 13 September 2000. The Council members, their terms of office and their responsibilities were as follows:

Officers		
Professor H. Elderfield	1998–2001	President & Chair of the Policy Committee
Mrs N. Lane	1997–2003	Honorary Treasurer
Dr C. Robinson	1996–2001	Honorary Secretary
Council Members		
Dr J. Allen	1998–2001	Meetings & Specialist Groups Committee
Mr K. Boot	1998–2001	Education Committee (Chair Designate)
Professor P.H. Burkill	1999–2002	Policy Committee
Mr R. Burt	1999–2002	Membership & Marketing Committee (Chair Designate)
Dr D. Curtis	1998–2001	Chair of the Meetings & Specialist Groups Committee
Mr S. Hall	1997–2000	Chair of the Membership & Marketing Committee
Dr R. Lewis	1997–2000	Education Committee
Ms J. Read	1999–2005	Meetings & Specialist Groups Committee (Hon. Sec Designate)
Dr C. Turley	1997–2000	Chair of the Education Committee

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

Professor J. Shepherd	President of Council Designate (2000–2002)
Mrs J. Jones	Executive Secretary & Membership & Marketing Committee
Ms A.M. Colling	Editor, *Ocean Challenge*
Mr J.B. Wright	Associate Editor, *Ocean Challenge*
Dr R. Mills	Chair, Editorial Board, *Ocean Challenge*

Steve Hall, Roy Lewis and Carol Turley, who retire from Council at the 2000 Annual General Meeting, are sincerely thanked for their enthusiasm and commitment to Council and the Society. Especial thanks to Harry Elderfield who retires as President, but who continues on Council through 2000-2001. John Shepherd will become President at the 2000 Annual General Meeting.

Policy

The main activity of the Policy Committee has been a broad review of the status of the Society and its future. We decided that, rather than publishing a *Challenger 2000* document at this stage, it was first necessary to consider a number of key aspects of the Society: (i) the relationship with other marine science organisations; (ii) meetings; (iii) our membership; (iv) communications and publications; (v) education policy, (vi) financial standing. Significant progress has been made and we are in the process of consulting the membership about these main issues.

Education

Carol Turley (Chair) and Steve Hall finish their terms in office and hand over to Kelvin Boot (Chair) and Carol Robinson who will form the next Education Committee. In this last year Carol Turley organised a questionnaire that went out to all Challenger Society members, enlisting their co-operation in forming a database of experts from our members. This has been provided to media science correspondents in order to resolve the problems they sometimes have in finding appropriate experts. It is hoped that this will play an active role in the Public Understanding of Marine Science and Technology. Many thanks to all members who participated in this venture.

Ocean Challenge

Ocean Challenge continues to include a wide range of articles and features reflecting UK and European marine science. Issues 9(3) and 10(1) have been published since the last AGM and 10(2) is nearly ready to go to the printer. However, there is a shortage of news items for 10(3), and the Editorial Board is keen to increase the rate of submission of news items from you – the members. In order to meet financial constraints in the future, we propose to reduce the page length of *Ocean Challenge* to 36 pages, increase advertising revenue and investigate savings by using bulk postage. With a view to improving internet access to *Ocean Challenge* and the Society in general, the domain name www.challenger-society.org.uk has been registered. We would like to thank Bill Prior Jones, Keith Harrison and Keith Dyer for their valuable contributions to the work of the Editorial Board through the years. We are pleased to welcome new members, Kevin Black, Jon Copley, Barbara Knowles, Sue Greig and Mark Maslin, and look forward to working with them.

Meetings

Since the last AGM in September 1999, the Society has supported, and agreed to support, the organisation of meetings on a wide variety of subjects, reflecting the range of interests involved in the marine sciences and of the members of the Society. The AGM was held at the University of Plymouth during 'Progress in Chemical Oceanography (PICO)' (E. Achterberg, University of Plymouth). The Society supported this meeting as well as the following meetings: Primary Productivity of Planet Earth: Biological Determinants and Physical Constraints in Terrestrial and Aquatic Habitats, 6–11 September 1999 (R. Geider, Marine Biological Association); The Deep Subsurface Biosphere, 9–10 September 1999 (J. Parkes, Bristol University and R. Mills, University of Southampton); and Irish Sea Science, 12 November 1999 (J. Huthnance and J. Howarth, Proudman Oceanographic Laboratory).

The Society has agreed to support the following forthcoming meetings: Underwater Optics, a one-day Topical Meeting within Optics 2000; jointly with the SUT, 17–21 September 2000, University of Loughborough (M. Wall; J. Watson, University of Aberdeen; D. Pilgrim, University of Plymouth and J. Walker, University of Nottingham); New Directions in Marine Science 2000: An Interdisciplinary Forum for Research Students, jointly with SAMS and the University of the Highlands and Islands Project, 25–27 October 2000, Dunstaffnage Marine Laboratory (P. Crozier, DML); Palaeoceanography and Climate Change, jointly with the Geological Society, 25–26 April 2001, Burlington House (H. Elderfield, University of Cambridge; J. Jones, Chair of Geological Society Marine Studies Group; P. Wilson, Southampton University).

Special Interests Groups

The second meeting of the OCEAN COLOUR SPECIAL INTEREST GROUP will be associated with the Ocean Optics and Ocean Colour session at UK Marine Science 2000. Samantha Lavender moved from Plymouth Marine Laboratory to the University of Plymouth in June 2000 and so the WWW page moved to http://www.ims.plymouth.ac.uk/geomatics/csms_ocolour/ . The increasing interest in ocean

colour continued in 1999 with the launch of several marine remote sensing missions, which included NASA's Moderate Resolution Imaging Spectrometer (MODIS). The Ocean Colour Special Interest Group has been kept informed of developments through the mailing list and regularly updated WWW page. The mailing list currently contains 40 members from both the UK and Europe, but this is only a small proportion of the actual membership of the group.

After initiatives started about five years ago, the meetings of the MARINE CHEMISTRY DISCUSSION GROUP (MCDG) have settled down into a stable pattern of sessions at the UK Marine Science meetings every second year, with Progress in Chemical Oceanography (PICO) meetings in the intervening years. The last MCDG meeting was a PICO meeting at the University of Plymouth (9–10 September 1999). This meeting was supported by the CCMS Laboratory at Plymouth, BMT, AstraZeneca and Brixham Environmental Laboratory, and once again provided the forum for discussion and exchange of ideas for the established and new members of the marine chemistry community in the UK. The location of the next PICO meeting will be discussed at UK Marine Science 2000. (Contact: Peter.J.Statham@soc.soton.ac.uk)

The CEAN MODELLING GROUP held a two half-day meeting September 7/8 1999 at University College, London. It was lively and well attended, with 29 talks given. Subjects ranged from modelling estuarine flow to the large scale: the equatorial Pacific, the Antarctic Circumpolar Current, ice modelling, the effect of eddies, climate change and thermohaline circulation. A similar meeting is being held this year in Norwich as part as UK Marine Sciences 2000. (Contact: George.Nurser@soc.soton.ac.uk)

Membership and Marketing

The Membership and Marketing Committee (Steve Hall (Chair), Nichola Lane, Richard Burt and Jenny Jones) arranged to 'meet' electronically to keep costs to a minimum – however they found that this didn't provide the discipline needed to get things done quickly. Richard Burt is the Chair Designate and will take over from Steve Hall at the September 2000 AGM. The Committee identified a number of themes that have now been widely discussed by Council members, as we seek to broaden the appeal of the Challenger Society, and increase membership and income. The main themes included: 1) the efficient collection of subscriptions and encouragement of corporate membership; 2) maintaining and improving our presence on the Internet; and 3) ensuring that a stock of materials is available for sale by members. We still need to encourage more members to renew their membership by standing order. Two-year memberships renewable at the UK Marine Science conference are now in place. A CSMS Year Planner is another suggestion to raise awareness of the Society. However, the big questions have remained – how to get people to join CSMS in the first place – are we offering enough to attract and retain new members? Do they join because they wish to receive *Ocean Challenge*, or to feel part of the marine scientific community, or for some other reason? A membership questionnaire was issued and 107 responses received – the information will help the Society decide which direction to go in the future.

Finance

1999 saw an excess of expenditure over income of £572, compared with a budgeted profit of £100, the major cause of this being a lack of income amounting to £1,263. Taking depreciation into account the deficit is £2,111. On the more positive side, although income was down, subscription revenue was increased, with a total income of £12,506 against a budget of £10,500, partly due to a small increase in the annual subscription. The donations from Southampton Oceanography Centre and the Centre for Coastal and Marine Studies were gratefully received, but the income from investments, meeting donations and adverts/inserts in *Ocean Challenge* was significantly down. In addition there was no conference in 1999 to generate income.

Regarding expenditure, half the lost income was made up by the costs associated with *Ocean Challenge* being significantly under budget – the team must be congratulated for this as I know they have worked hard to be as economical as possible. The main cost, which is noticeably out of line with the budget is the fee charged by the auditors. I have investigated this and am satisfied that their invoice is completely justified, and our budget figure is in error.

For the future, including the present year, it is unlikely the donation previously made by CCMS will be received, reducing our income by £3000. Year 2000 is a conference year, and therefore funds may receive a boost from this. However, in order that the call on our reserves is reduced, methods for ensuring our expenditure matches our income must be explored. Completion of the questionnaire regarding what the members want from the Society in future will provide us with valuable input to help us to budget accordingly.

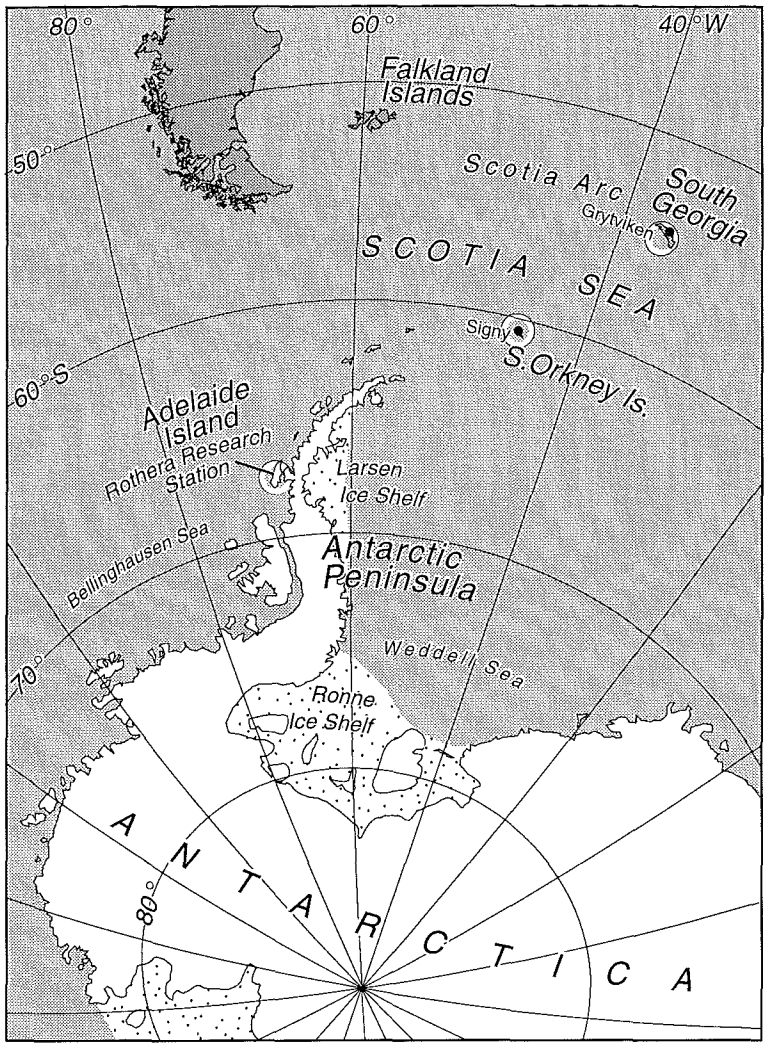
cold water HOT SCIENCE

Simon Brockington

The potential for diving to assist in biological investigations was appreciated as early as 1844 when Henri Milne-Edwards stated that the 'portable' diving helmet could be used satisfactorily by a relatively inexperienced operator 'to pursue marine animals into their most hidden retreats'. From this time on, scientific diving has been carried out all over the world, and it is not surprising that when the first marine biologists to over-winter in Antarctica needed to sample and survey the sea-floor they turned to diving, despite the low temperatures. Diving technology, and understanding of human physiological responses to working in cold water under hyperbaric conditions, have both improved dramatically in recent years, and as a result, the use of diving to support marine science has made a considerable contribution to our understanding of this most understudied of regions.

The Antarctic demonstrates many extreme physical and climatic properties. The continent itself is vast, remote and desolate, and from a biological point of view a desert devoid of any major terrestrial ecosystem. However, whilst the absence of liquid water has largely impeded development of biological communities upon the land, the same restraints do not apply to the marine realm. Indeed, the large populations of seabirds and mammals found around the coastal margins of Antarctica are a visual testimony to one of the least acknowledged properties of this part of the world – the high productivity of the Southern Ocean.

The benthic environment of the Southern Ocean also teems with life, and the first rudimentary biological observations were made during exploratory expeditions in the 1920s, led by the American and British sealers Nathaniel Palmer and James Weddell. Scientific and biological investigation within the Antarctic region commenced with two major enterprises, the *Challenger* Expedition (1872–76), and the *Discovery* Investigations (1925–39) which were to produce a massive, and (for the time) comprehensive collection of specimens and data. The period following the Second World War saw many nations for the first time setting up permanently manned bases around the Antarctic, many of which were located on the Antarctic Peninsula and the islands of the Scotia Sea (Figure 1, overleaf).



Adelaide Island, Signy and South Georgia have been the principal BAS diving locations

Figure 1 *Map of the Antarctic Peninsula region showing principal British Antarctic Survey diving locations (circled). Signy Island operated a long-term marine research programme between 1962 and 1995, which has since transferred to the Rothera Reseach Station at Adelaide Island. Diving has also been conducted at South Georgia.*

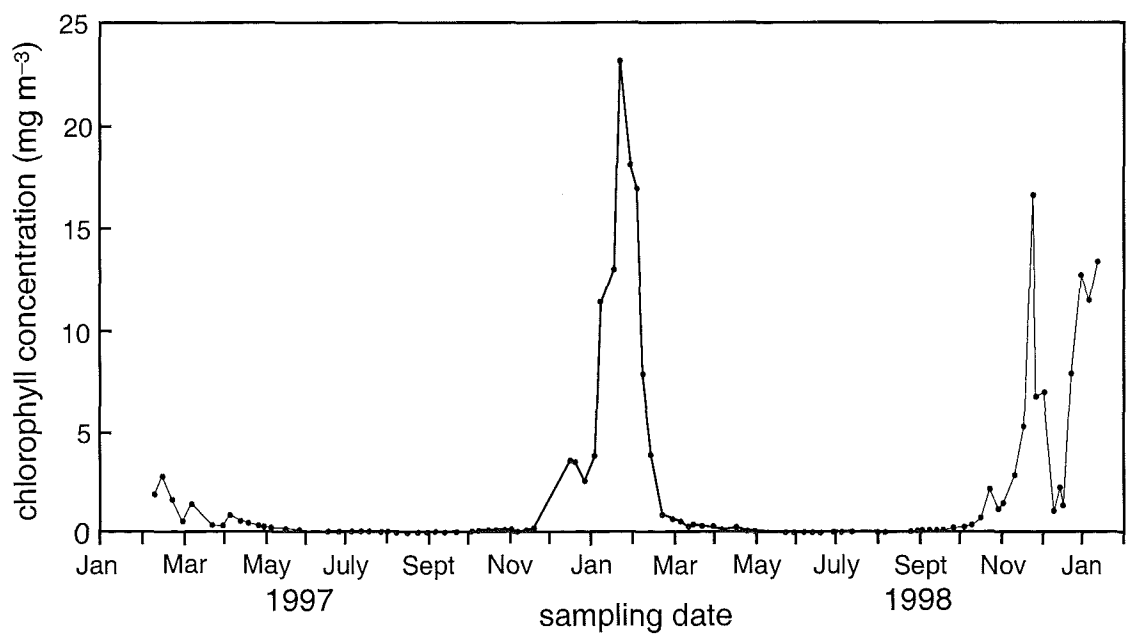
The biologists who visited these early bases found a unique opportunity to study benthic marine life at one extreme of the naturally occurring continuum of seawater temperatures. Surface seawater temperatures have a global range from freezing point (–1.9 °C) to ~37 °C in the tropics, and study at the lower end of this range helps us to answer questions concerning evolutionary adaptation to this most fundamental of physical factors. Furthermore, seasonal temperature fluctuations are minimal – typically less than 3 °C at northern Peninsula locations, becoming almost zero at the highest latitude sites, making Antarctic waters one of the most thermally constant environments yet investigated. Antarctica has been described as a natural laboratory, where the low and constant temperatures contrast markedly with strong seasonal fluctuations in levels of primary production and hence availability of food for the marine benthic faunal community (Figure 2). The diverse and abundant benthic ecosystem encountered at nearshore locations therefore shows ecological and physiological responses not only to extreme low temperature, but also to marked seasonal fluctuations in energy supply.

Without doubt, one of the biggest problems hindering successful marine research is difficulty in getting access to the environment. This is especially true of marine benthic studies at nearshore locations in Antarctica, where semi-permanent ice-cover, cold water and seasonal darkness all combine to make conditions arduous for the researcher. From a purely anthropocentric

Figure 2 *Seawater chlorophyll standing stock recorded at Rothera Research Station during 1997 and 1998. Strong peaks during the height of the austral summer (early January) contrast strongly with prolonged periods of low values for much of the rest of the year.*

(Data supplied by Andrew Clarke and Alice Chapman)

The sharp changes in phytoplankton standing stock contrast with the constancy of the very low water temperatures



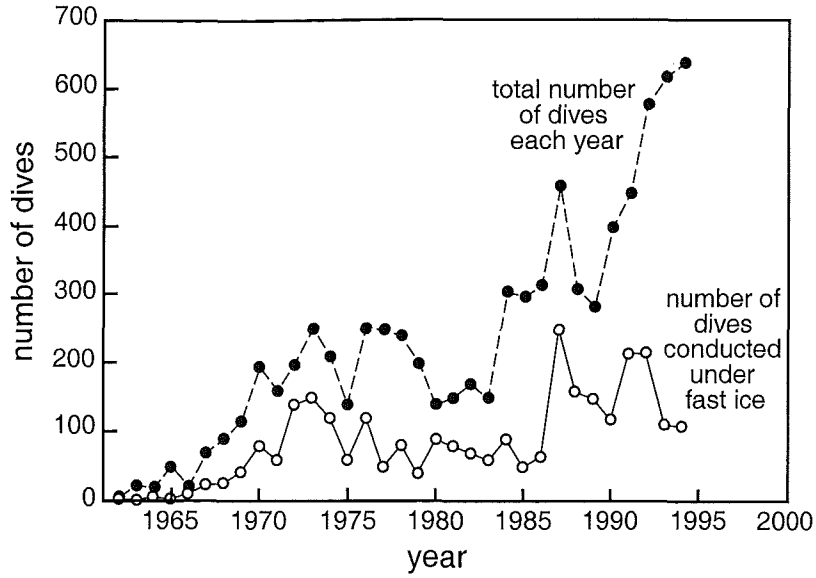


Figure 3 *Dives conducted at Signy Island between 1962 and 1995. This programme was carried out by a long succession of field diving officers, marine biologists and assistant marine biologists, many of whom spent a two-year term continuously living and working in Antarctica.*
(Data supplied by Andrew Clarke and Martin White)

Since the 1960s, the increasing quality of technical and logistical support in Antarctica has allowed an increase in the pace of scientific research, and hence in the frequency of diving

(though not biological) standpoint, polar conditions are harsh, and it therefore often comes as a surprise that over the last four decades the British Antarctic Survey (BAS) has chosen SCUBA to support the vast majority of nearshore marine sampling programmes. Despite the extremely low water temperatures, diving has proved to be a reliable and flexible tool, allowing both marine benthic surveying and collecting of samples throughout the year.

The first scientific dive by the British Antarctic Survey was undertaken at Signy Island Research Station on 14 December 1962, and diving continued at this location until the closure of the Station as an overwintering facility in 1994 (Figure 3). A total of 7946 dives were carried out at Signy alone (in this context, a 'dive' means a buddy pair entering the water), with diving also being carried out at Grytviken, South Georgia between 1972 and 1982.

There have also been individual investigations using diving supported by research vessels, with one of the most recent such studies having taken place from RRS *James Clark Ross* in 1992. This investigation was able to examine fluxes of major elements between the sea-ice microbial community and the seawater in the Bellingshausen Sea, and involved divers collecting samples from immediately beneath the sea-ice in water depths of more than 600 m.

In 1997, a new marine biological research facility was opened at Rothera Research Station (67° 34′ S, 68° 07′ W) to allow the continuation of marine science within Antarctica over the winter. During 1997 and 1998, over 500 dives per year were achieved at Rothera – an impressive record, especially considering that overwintering dive teams typically consist of between four and six personnel.

The diving year

Without any significant terrestrial vegetation to indicate the passing months, the Antarctic year becomes divided into just two seasons – summer and winter – demarcated by the respective arrival and departure of the first and last ships of summer. For the eight-month winter period (March until October) Rothera Research Station is completely isolated, and is populated by approximately 20 people, including the dive team. Summer provides a strong contrast, when the number of personnel based at the Station may rise to over 100, and frenetic activity overtakes all aspects of station life. The summer period sees diving taking place either directly from the shore or from rigid-hulled inflatable boats. At this time of year, the divers may find themselves immersed in a dense planktonic soup, as the intense solar radiation and long day-length combine with nutrient-rich waters to produce a high standing stock of diatoms.

Winter conditions are very different, and the often complete cover of fast ice (i.e. ice attached to the coast) allows snowmobiles and sledges to replace boats as transport to dive sites. For the marine research teams working in the Antarctic, the annual fast-ice formation provides one of the most spectacular opportunities of the year. The ice entirely prevents wind action on the water surface, so wind-induced mixing ceases. Suspended particles settle out of the water column, leaving some of the clearest water in the world – a record Secchi disk depth of 79 m was recorded from the German Research Ship *Polarstern* during cruise ANT V/1-3 in the mid 1980s. However, despite the clear water, the fast-ice cover restricts ambient light reaching the water column which in turn not only reduces phytoplankton and macroalgal growth, but also limits underwater visibility.

Towards the end of the austral winter, levels of incident solar radiation increase sufficiently to illuminate the underwater environment, and the divers may enjoy some truly breathtaking underwater scenery in the still water under the ice. Seals often surround the dive team, keeping company with the surface party tending the divers' lifeline, and arousing envy in those working beneath the ice – no human can match the sleek grace with which these animals glide through the water.

Although cutting holes in metre-thick sea-ice with chainsaws and ice-augers is not the simplest of tasks in the low winter temperatures, it is during this time that the advantages surrounding the use of SCUBA as a sampling method come to the fore. Many

marine survey techniques require the use of a wire, either for support or for data-transmission. The thick ice-cover prohibits the use of trawls, nets and grabs, but SCUBA allows scientists to remove only the material directly required for study, so minimizing the impact to the sea-floor in this region of heightened environmental sensitivity (Figure 4).

Diving safety

The diving undertaken by the British Antarctic Survey is governed by legal requirements set down by the Health and Safety Executive, and compliance with these regulations is the responsibility of the UK-based Institute Diving Officer. A Field Diving Officer is also employed and based in the Antarctic, with responsibilities that include management of the diving facility and equipment maintenance. A full-time boatman provides further support to the team and often takes an active role in the diving, with the remainder of the dive team being made up of marine biologists from various disciplines working on specific projects, and assistant marine biologists charged with maintenance of longer term environmental monitoring programmes and biological studies. The Bonner Laboratory for biological investigation at Rothera Station supports a comprehensive diving facility, including a recompression chamber, designed on the basis of experience and of lessons learned during operation of the Signy diving programme.

SCUBA equipment tends to be chosen from the sports market for reasons of cost, reliability and ease of servicing – this last feature being of great importance during the winter isolation of the Research Station. The extreme water temperature does however present some problems, and although close-fitting wetsuits were used successfully at Signy up until the mid-1980s, these have now been superceded by 8-mm neoprene drysuits. A study of divers' thermal status was carried out during the 1993 winter at Signy Island. For the 84 dives monitored at Signy, the mean drop in core temperature was 0.2 °C, which is well within the normal range of body temperatures (36.9 ± 0.5 °C), although this cooling was greater for those wearing dry suits, and was also accentuated by repetitive diving, a longer period of immersion, and a greater extent of manual activity during dives; it was also affected by individual physiology. For reasons of thermal comfort, and because of decompression restrictions, dive-times rarely extend beyond 35 minutes, although core temperature decline may continue for a period after leaving the water because of the peripheral vasodilation (i.e. expansion of surface blood vessels/capillaries) which takes place after exposure to cold. On one occasion, a diver's core temperature fell to 36.3°C, 19 minutes after returning to the Research Station. In this extreme example, however, the diver had been wearing an ill-fitting wetsuit. Such temperature drops do not approach the critical level of 35 °C, regarded as the minimum safe level for carrying out demanding and potentially dangerous tasks.

Cold affects not only human physiology, but also the performance of the equipment. SCUBA equipment stores compressed air at pressures of up to 232 bar, and this pressure is reduced and supplied to the diver via a demand valve (DV), which acts to reduce cylinder pressure to an intermediate value (this reduction is achieved by the first-stage

Figure 4 *A diver working in clear water under sea-ice collecting specimens of the sea-urchin* Sterechinus neumayeri.

Under sea-ice, the visibility for collecting specimens is excellent

valve). This intermediate pressure is then subsequently reduced to ambient pressure (which changes with depth) by the second-stage regulator. As compressed gas is allowed to expand it cools adiabatically, and in an aquatic environment already at −1.9 °C this additional cooling effect can cause severe ice build-up. The second-stage valve is held in the diver's mouth and is therefore exposed not only to minor ingress of seawater but also to water vapour in exhaled breath, and consequently may show a tendency to freeze, especially during the winter months. Fortunately, the normal situation is for the valve to freeze partially open as ice builds up on the valve seat, thus allowing the diver to breathe. However, this leads to unwanted escape of air, further adiabatic cooling and eventually substantial loss of gas, resulting in termination of the dive. Although such a continuous loss of air can be unsettling for the diver, these occurrences are not particularly serious as all divers carry a spare air supply.

Benthic life around Antarctica

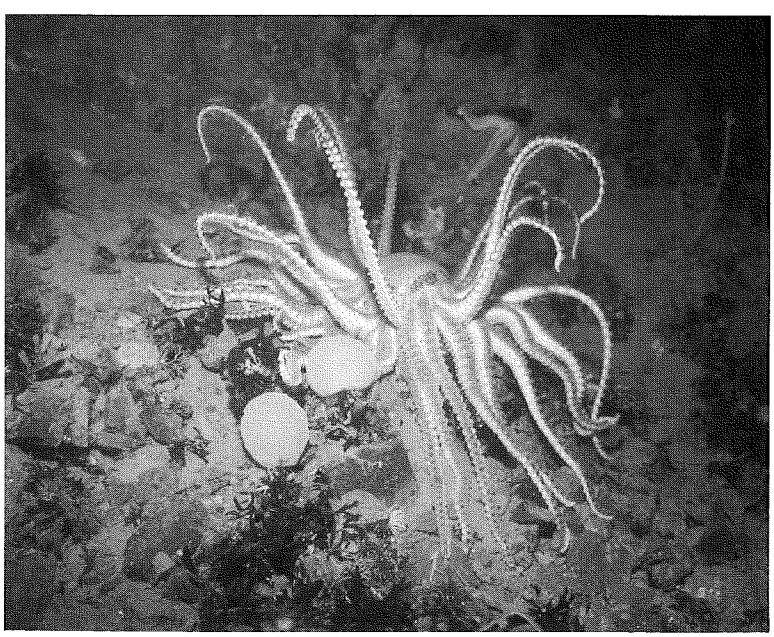
The earliest expeditions to Antarctica documented the wealth of benthic life to be found at nearshore sites in the Southern Ocean, and the first SCUBA-based surveys tended to concentrate on the characterization of these communities. Biomass levels were found to be high, and diversity was found to be comparable with many temperate regions of the globe. It was also realized that many of the species recorded in the waters around Antarctica occurred only in this region, and are therefore termed endemic (see Figure 5). However, one of the first things to strike any marine ecologist visiting Antarctica is the paucity of species inhabiting the littoral regions. Space in the intertidal zone is hotly contested in many regions, and elsewhere in the world is characterized by a vast array of communities, varying from mangroves and reefs in the tropics to heavily zonated rocky shores and kelp forests in more temperate regions. The polar regions, however, provide a strong contrast, with the littoral zones resembling in many ways nothing more than drowned land. This is due to disturbance by ice – effects range from gouging and abrasion by bergs and floes during the summer months, to complete clearance of the littoral region by plucking of the fast-ice 'foot' which develops as a result of tidal action in winter. At the highest-latitude sites, areas of the benthos may be removed by ice actually forming on the sea-floor. This so-called 'anchor ice' results from water being supercooled at the surface, sinking and forming ice crystals which encase the benthos.

The intensity of such disturbance shows a marked decrease with depth, and although gouges at depths of 200 m caused by massive tabular bergs have been recorded from areas of the continental shelf, many nearshore communities below ~30 m show only infrequent perturbation (cf. Figure 6). Physical disturbance has been shown to enhance diversity in other ecosystems worldwide, and this has been formulated into the 'intermediate disturbance hypothesis', according to which diversity is reduced both at very high and very low levels of disturbance. Recent SCUBA-based investigations have shown that an iceberg impact on soft sediments at Signy Island removed 99.5% of all macrofauna and >92% of meiofauna. The method of faunal return to the site after disturbance ceased was species-dependant, via locomotion, advection during storms and larval recolonization, and the three processes worked on different time-scales, from days to years. Levels of benthic colonization and community development after disturbance have been shown to be an order of magnitude slower than in temperate or tropical zones.

Whereas community development in the littoral zone may be moulded primarily by ice, it is clear also that the benthic taxa show strong reactions to the changing levels of primary production during the annual cycle. Phytoplankton biomass increases by more than 1000 times in summer, and although many species from temperate ecosystems show a reduction in activity in winter, this may be considerably more marked in the polar regions. Some species, for example the common sea-urchin *Sterechinus neumayeri* (Figure 4), have been shown to undergo an eight-month starvation period during the austral winter, whereas feeding /non-feeding periodicities amongst suspension feeders vary from those with distinct seasonality to species which feed continuously throughout the year. Growth has been found *not* to be tied to

Figure 5 *The sunstar* Labidiaster annulatus, *one of many endemic species to be found in Antarctica. This asteriod is an active predator which ensnares small crustaceans and larval fish on its raised tentacles. The specimen of* Labidiaster annulatus *shown here is about 1 m in diameter.*

Many species living in the waters around Antarctica are unique to the Southern Ocean

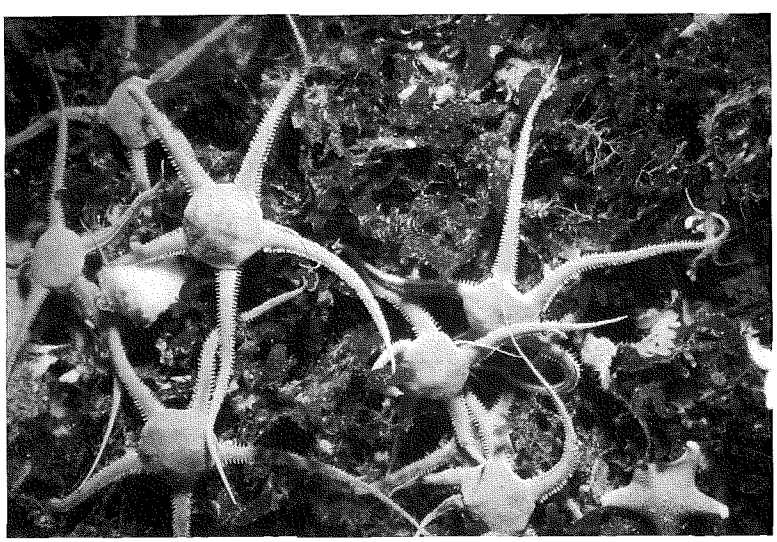


feeding periods in brachiopods and infaunal bivalves, though the limpet *Nacella concinna* does exhibit seasonal growth in phase with food supply cycles. Such data have served to intensify the debate about the importance of seasonally changing levels of food and relatively constant annual temperature in the control of invertebrate life-history characteristics

Whilst detailed SCUBA-based benthic surveys have provided data for the research mentioned above, the use of diving has also provided a means of obtaining undamaged specimens for physiological experimentation throughout the polar year. Very early studies on animals collected by these mothods suggested that polar marine ectotherms (i.e. cold-blooded animals) had relatively high metabolic rates – a concept referred to as 'metabolic cold adaptation' or MCA. The intuitive explanation for this apparent phenomenon was that a raised energy demand would be necessary to offset the inevitable temperature-induced torpor in polar and other cold environments. These early studies, however, turned out to be erroneous, and a considerable body of more recent data shows that low-temperature ectotherms are characterized by low metabolic rates. In fact, it now seems that the majority of Antarctic invertebrates are able to survive the long winter periods in the absence of food precisely because the cold water permits low metabolic rates. Furthermore, the high percentage of endemic species in Antarctica suggests that low temperatures do not provide an insurmountable barrier either to life or to evolution.

In areas sheltered from the effects of ice-scour, benthic biomass and diversity in Antarctica can be very high

Figure 6 *An assemblage of the brittlestar* Ophionotus victoria *and the red macroalga* Kallymenia *at Rothera Point, Antarctica. The central discs of the brittlestars are ~2–3 cm across.*



Conclusions

Frequency of diving within the Antarctic, and also the pace of scientific research which stems from it, have both shown strong growth since the 1960s. From the diving standpoint, evidence has shown that reasonably long immersions are possible without severe deep body cooling, and as diving becomes more popular as a recreational activity in the Northern Hemisphere, so technological improvement in the quality of equipment available should help to improve reliability under polar conditions. Novel approaches to thermal comfort are being further developed, including argon-based drysuit inflation systems and electrically heated undersuits. Along with the increased availability of improved SCUBA gear, there has been a rise in the quality of research facilities present in Antarctica. Modern buildings at the Rothera Station include thermally stable, purpose-built laboratories, allowing the continuation of marine science on a year-round basis. Much of the current understanding of polar ectotherm physiology stems from investigations conducted solely during summer months. Facilities such as the Bonner Laboratory are important not only for the continuation of routine science, but also for the investigation of animal and ecosystem responses to both environmental and seasonal changes.

Further Reading

'Antarctic Zoobenthos' by W.E. Arntz, T. Brey and V.A. Gallardo, in *Oceanography and Marine Biology: an Annual Review 1994*, **32**, pp.241–304.

Stars Beneath the Sea – the extraordinary lives of the pioneers of diving by Trevor Norton, Century Press.

Training scientific divers – Italian style by Carlo Nike Bianchi and Carla Morri, *Ocean Challenge*, Vol.10, No. 1, 25–29.

Simon Brockington is a marine biologist working for the British Antarctic Survey, and has spent a total of five years living and diving in Antarctica, conducting marine research. He is currently working up a Ph.D on Antarctic benthic seasonality at the BAS headquarters in Cambridge.*

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This article is dedicated to the memory of Martin White. Martin was the Institute Diving Officer for many years until his untimely death in 1999, and played a crucial part in the development of the BAS diving programme. He was also a key leader in the development of the current approved Code of Practice for scientific diving. His professionalism and expertise will be sorely missed.

Living probes into the marine environment

apex predators as oceanographic platforms

Sascha K. Hooker, Ian L. Boyd, Mark A. Brandon, Elizabeth J. Hawker

The primary obstacles to the collection of oceanographic data are the limitations of sampling in time and in three-dimensional space. Ship-board surveys are well designed for detailed sampling at depth, but are constrained in horizontal space and limited in time by high costs. Satellite monitoring can produce time-series of data over large horizontal spatial scales, but has only limited ability to obtain data concerning parameters at depth, and can also be constrained by the necessity for calibration and 'ground-truthing' of data. In contrast, fixed platforms can provide high-resolution data over long time periods, but only within limited three-dimensional space. So what is the answer?

The optimal data-gatherer

If we were to design the optimal oceanographic data-gatherer to overcome the obstacles of conventional sampling in space and time, we might come up with an autonomous instrument that could cruise the oceans assimilating information about its surroundings. This hypothetical instrument could examine the whole ocean surface and descend to depths of over 1000 m. It would have an operational time-span from a few days to over 50 years (depending on how we chose to use it), minimal running costs, and would return (with data) to a predictable location at a predictable time. When confronted by the scientific challenge of marine systems, most biological and physical oceanographers would find good use for such an instrument. But it would be unbelievably complicated, and would go far beyond the potential of even projects such as *Autosub,** which is limited by energy requirements and the complexity of programming needed to enable it to avoid obstacles.

In many ways, this instrument sounds like one of those unworldly theoretical concepts dreamt up by mathematicians or science fiction writers. However, the reality of this vision is much closer than one might think. Why should our instrument not be a living organism within the marine environment? Attaching oceanographic sensors to living apex predators would relinquish the user's control over fine-scale selection of samples, but could provide potentially limitless data; and if predators were chosen strategically, it could give detailed information for selected regions of interest (Table 1, overleaf).

**Autosub* is an unmanned autonomous underwater vehicle for gathering data.

Marine organisms and the environment

Like all organisms, marine animals are, to a degree, products of their environment, partly through genetic adaptation, partly through behavioural responses to variability in the immediate surroundings. Thus by recording observed variation in features of animal behaviour, development and life-histories, we can infer information on environmental variability. For example, at the most basic level, species composition of coastal ecosystems can be used to predict the range of environmental conditions in the area. Secondly, local abundance and growth of certain species can be used to infer additional features of the environment, such as the degree of wave action or exposure to storm damage. Lastly, variations in growth rate or number of offspring may reflect interannual variability in environmental conditions. Of course, it is almost always more satisfactory to carry out direct observations of the environment, but there are circumstances where observation of the underlying physical and biological systems can be difficult and/or prohibitively expensive. In the open ocean we have often relied on the use of inferential data, and it is here that the use of top predators as the vehicle for our instruments would come into its own.

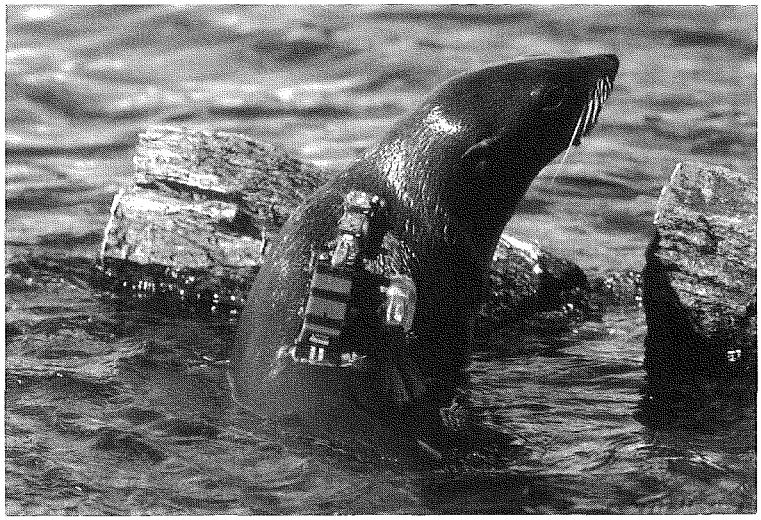


Figure 1 *Various species of marine fauna are tracked using data-logging and radio transmitting systems (VHF or satellite).* ***Upper*** *Antarctic fur seal with data-logger, VHF and satellite transmitters.* ***Lower*** *Swimming Antarctic fur seal, with satellite transmitter antenna showing above the water surface.*
Ian Boyd and other researchers at the British Antarctic Survey have been deploying time–depth recorders and satellite positioning tags on Antarctic fur seals to investigate their foraging ecology around Bird Island, South Georgia.
(Photographs by A.R. Martin.)

(Continued opposite)

Table 1 *Costs and benefits of different oceanographic sampling protocols.*

Sampling method	Costs	Benefits
Ship-board monitoring	Expensive Limited in time and space	High-resolution data
Satellite monitoring	Expensive Weather-dependent Little depth penetration	Large horizontal scale Potentially long time-series
Fixed platform	Minimal 3D spatial resolution	Cheap Potentially long time-series
Autosub	Expensive Requires mother-ship	High-resolution data Large horizontal scale Potentially long time-series
Living platform	No fine-scale spatial control	Cheap High-resolution data Large horizontal scale Potentially long time-series

At the simplest level, marine predators are often the most easily observed element of the marine ecosystem. Species vary in tractability, and those that are constrained by the need to return to land – seabirds and seals – are generally the most accessible to researchers. They therefore present highly visible and accessible platforms for carrying oceanographic data-loggers. Admittedly, using animals solves only the vehicle part of the design problems for our oceanographic data-gatherer. The data-loggers still need to be designed, programmed, deployed and perhaps retrieved, and the data downloaded. However, this approach removes many of the complications involved in attempting to design instruments for independent deployment.

Different marine mammal and bird species cover almost all areas of the globe and show a wide range of variation in depth penetration. Species such as elephant seals regularly dive to depths of over 500 m, and at times to depths of over 1000 m, and are known to travel 2 500 km on a 70-day foraging trip. Individual animals carrying appropriate instrumentation thus have the potential to provide information broadly equivalent to that of an undulating oceanographic recorder, but over many thousands of kilometres, and for periods of more than six months at a time. Although we cannot control where these animals go, research suggests that they often travel to, and disperse along, oceanographic features of interest, such as the South Polar Frontal Zone. Researchers could thus essentially 'pick and mix' species, populations, and even individuals, to obtain data about areas and depths of interest. For example, Table 2 (overleaf) shows some of the basic parameters relating to the horizontal and vertical scope of marine predators that have previously been used for instrument-attachment in the area of South Georgia.

However, oceanic predators can offer us far more than just vehicles to carry instruments. Their sensory capabilities, used to hunt for prey in the most efficient way possible, are far beyond those of any instruments we might design to be carried by them. The distribution and abundance of predators will inevitably be influenced by the distribution and abundance of prey. In the oceanic environ-

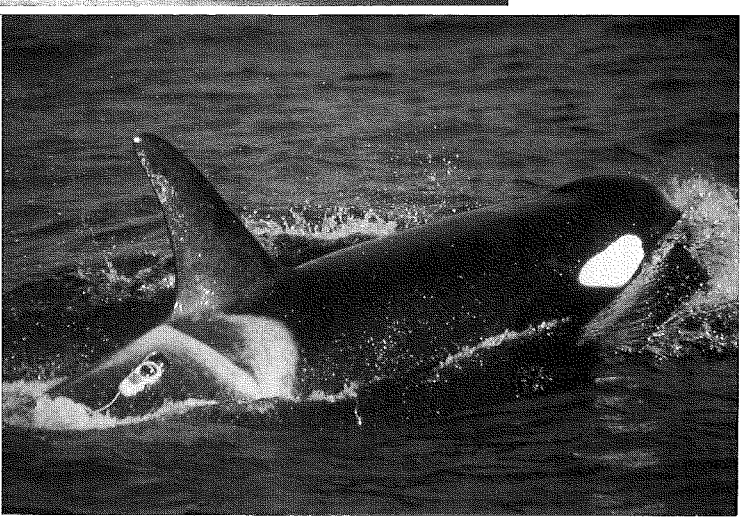
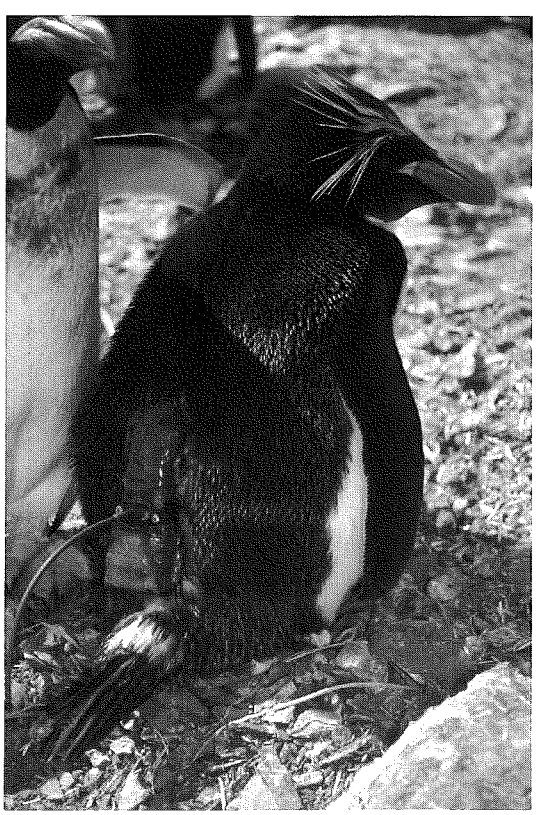


Figure 1 (cont.) ***Above*** *Dall's porpoise with radio-transmitter attached to the dorsal fin. Brad Hanson of the National Marine Mammal Laboratory, USA, is investigating the movements of Dall's porpoises in the waters around the San Juan Islands, Washington.* ***Right*** *Killer whale with time–depth recorder and radio-transmitter attached by suction cup. The subsurface behaviour of killer whales around the San Juan Islands is being investigated by Robin Baird of Dalhousie University, Canada.* ***Below*** *Macaroni penguin with satellite transmitter. Kate Barlow of the British Antarctic Survey is using satellite transmitters, taped to the feathers of macaroni penguins, to reveal the foraging locations of these predators around Bird Island, South Georgia.*

(Photos by R.W. Baird, S.K. Hooker and K.E. Barlow)



ment these prey will, in turn, be influenced by the distribution and abundance of their food, together with ocean currents and other physical variables. This interdependence continues through the food chain until we are left with the physical factors determining levels of primary production. Thus the deployment of oceanographic recorders on predators can ensure the collection of data in regions of particular interest, while data collected during travel to and from these sites can provide background information.

Seabirds and seals experience the marine environment across a wide range of spatial and temporal scales (Table 2, overleaf). At the small scale (e.g. tens of metres, and minutes) the details of their behaviour have the potential to provide an indication of the distribution of prey (for example, krill, fish or squid species). They may also reveal small-scale variability in the structure of the water mass, as the predators themselves may target certain physical characteristics within the water column in order to locate prey (cf. Figure 2, overleaf). Similar variability may be reflected at progressively larger scales, through the number of offspring produced or the time taken for individual seabirds or seals to return to feed their young with a parcel of energy of a particular size. When viewed over a number of years, changes in such parameters can provide insights into interannual oceanic variability and, since different species forage across different spatial scales, this information can be viewed

The size of the study animal and the required duration of data-gathering (which is in turn related to the frequency of sampling and the memory limitations of the data-logger) both influence the method of sensor-attachment

in terms of regional, shelf-zone or ocean basin variability, depending on the species and/or time-scale chosen.

Instrument development

Technological advances over the past decade have enabled us to obtain detailed data from animals at sea. The attachment of VHF and satellite radio transmitters to marine mammals and birds can provide us with details of their surface locations a number of times a day (Figure 1). Similar technology is used to track marine fish using acoustic transmitters. Attached tags record behavioural and environmental data, which can either be stored within the unit for later recovery, or be transmitted to a satellite. To date, most effort aimed at improving these instruments has been focussed on the technical difficulties involved in miniaturizing transmitters, battery packs and data-loggers into packages weighing as little as 25 g for deployment on flying seabirds. The need for such miniaturization arises from concerns that the attachment of instruments to the study animals may adversely affect their behaviour and welfare. In general, it has been found that terrestrial animals are largely unaffected by attached instruments weighing less than 5% of the body weight of the study animal. Among marine species, the size and shape of the instrument package is also an important consideration because of the need to minimize hydrodynamic drag. In general, the impact of increasing drag does not appear to be overly detrimental to the study animals for tags of the sizes and attachment durations currently used.

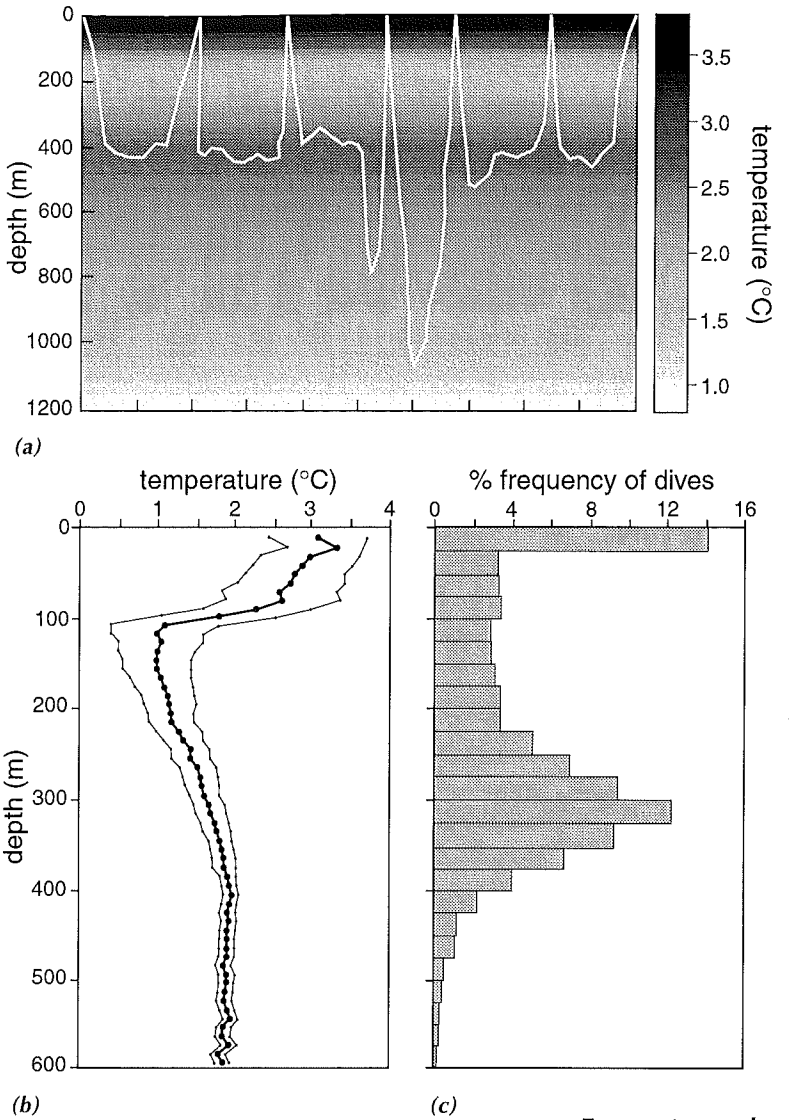
However, problems in reducing both the size and the weight of the oceanographic sensors currently in use may present the greatest obstacle to their inclusion into packages for deployment on marine animals. Since oceanographic equipment is generally deployed from large research vessels, until now there has not been nearly so much pressure for miniaturization of sensors or equipment.

The data-logging tags which have been developed to date are now beginning to help us answer important biological questions about foraging patterns in seabirds and seals. The tags used on marine animals were originally designed to record the depth of the study animal at predefined time intervals. Gradually these tags have been developed to include several other biological and environmental sensors. Many tags now also incorporate measurement of temperature and light level. The light sensor included in the tag has primarily been used to locate the position of

Table 2 *Approximate horizontal and vertical spatial scales of journeys made by marine predators during the breeding season at South Georgia. Trip-length is included to illustrate the potential time-scales for potential data-logging, and body mass to show the variation in the size of data-logger required, given that the logger should weigh less than 5% of the body mass.*

Species	Approximate horizontal range	Approximate modal dive-depth	Trip length	Body mass
Antarctic fur seal, *Arctocephalus gazella*	100s of km	50 m (max. 150 m)	4–5 days	40 kg (female) 200 kg (male)
Southern elephant seal, *Mirounga leonina*	1000s of km	400–500 m (max. 1500 m)	3–9 months	600 kg (female) 4000 kg (male)
Macaroni penguin, *Eudyptes chrysolophus*	20–40 km	20–35 m (max. 115 m)	18 hr	4.5 kg
Gentoo penguin, *Pygoscelis papua*	10 km	80 m (max. 150 m)	12 hr	6 kg
Chinstrap penguin, *Pygoscelis antarctica*	10s of km	50 m (max. 120 m)	1.5–2 days	4 kg
King penguin *Aptenodytes patagonicus*	100s of km	150–200 m (max. 300 m)	10–20 days	12–14 kg
Grey-headed albatross, *Diomedea chrysostoma*	1000s of km	3 m (max. 6 m)	1–6 days	3.7 kg
Black-browed albatross, *Diomedea melanophris*	1000s of km	2.5 m (max. 4.5 m)	1–6 days	3.7 kg
Wandering albatross, *Diomedea exulans*	1000s of km	0.3 m (max. 1 m)	1–15 days	8.7 kg
White-chinned petrels, *Procellaria aequinoctialis*	1000 km	2 m (max. 12 m)	2–6 days	1.4 kg
Blue-eyed shag, *Phalacrocorax atriceps*	10 km	80–90 m (max. 115 m)	12 hr	2.5–3 kg

Figure 2 *(a) Illustration of the diving behaviour of a southern elephant seal in relation to depth and measured water temperature, over the course of 2 hr 30 min (the tick marks are at 15 min intervals). (b) Mean sea temperature (points to either side show the standard deviation) measured in relation to depth. (c) Percent frequency of depths (over 552 dives in total) showing the predominance of time spent at the thermal discontinuity between the cold mid-water and deeper warmer water.*
(Redrawn from Boyd and Arnbom, 1991)



Temperature and depth data collected by means of a southern elephant seal highlight the temperature discontinuity between the cold mid-water and deeper warmer water

the tagged animal using the times of sunrise and sunset. Biological sensors including speed, heart rate, stomach temperature, and the measurement of ambient and internal sound (using an external or contact hydrophone, respectively) have in the past been incorporated into this basic design. Recent developments in camera-attachment also allow a truly bird's-eye view into the marine ecosystem. As far as additional oceanographic parameters are concerned, it may also be possible to extract information on light attenuation at depth from the light sensor, but this has yet to be fully explored. The potential for incorporation of several other sensors, such as conductivity (salinity) and fluorimetry (chlorophyll), is enormous, and simply awaits the necessary reduction in size of these sensors.

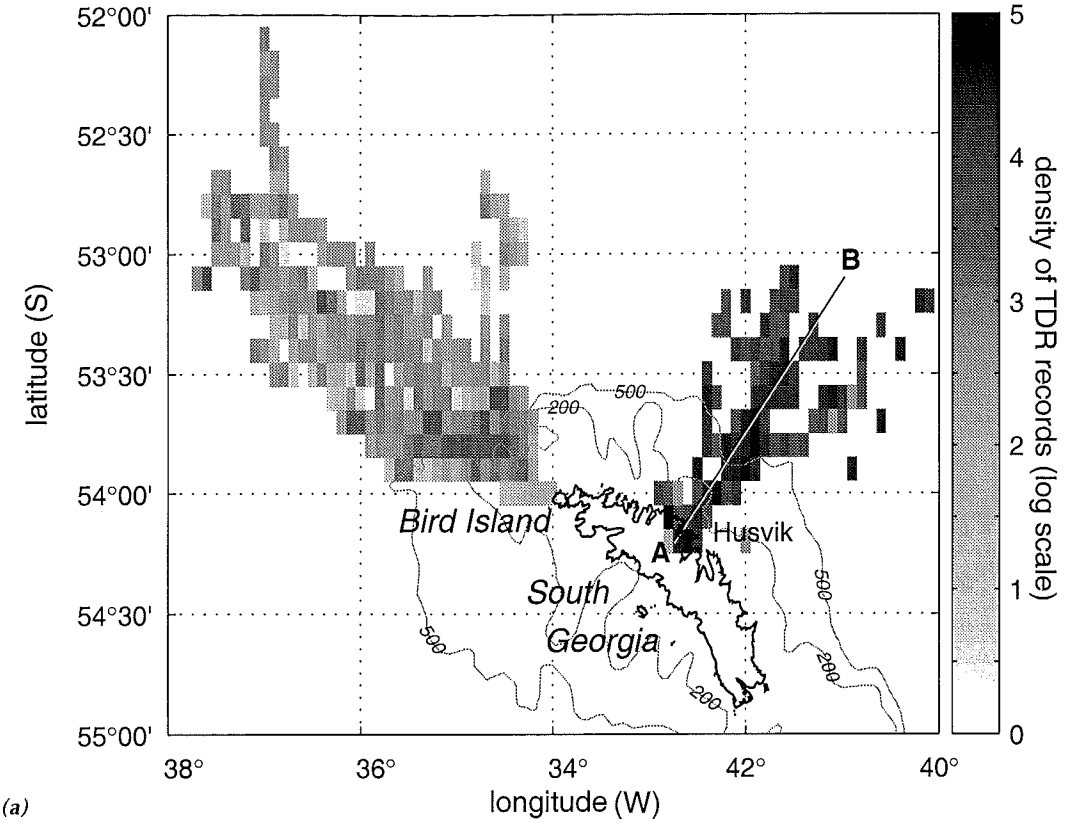
Data-collection and transmission

In the long run, the use of many different species will allow the investigation of oceanographic features at different scales of measurement, defined by the behaviour of the carrier. However, further obstacles in tag-attachment and data-retrieval may restrict our initial attempts to the more accessible near-shore species. Even then, for reliable tag-recovery, researchers need to be certain where and when the tag may be recovered. Thus, tags are primarily deployed on animals that show reasonable site-fidelity.

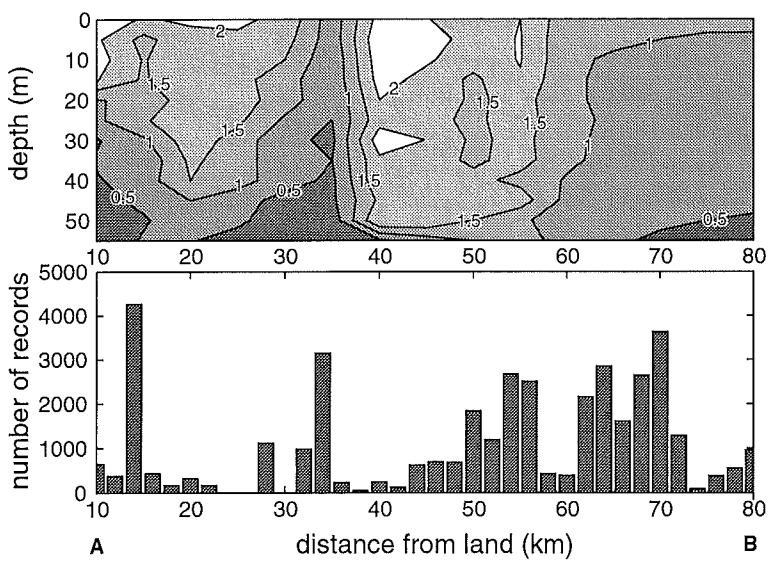
Currently, tags used on marine mammals tend either to store data onboard for downloading at a later date, or to transmit data remotely via satellite. However, both of these methods have their limitations. Onboard data-logging is restricted by the memory capacity of the tag, so that over extended time-scales there will be a trade-off between frequency and duration of sampling. However, one of the benefits of data-logging tags is that for short-duration deployments (days), data can be collected at high resolution. These tags need to be recovered in order to retrieve the data, but this also means that they can be re-used relatively easily.

Transmission of data via satellite requires the passage of a satellite overhead, and there are limited numbers of satellite passes daily. For a successful transmission, the satellite transmitter (and thus the animal platform) need to be at the water surface during the period that the satellite is well above the horizon, and the uplink must not be corrupted by wave action or environmental conditions. Furthermore, only a limited amount of data can be sent at each uplink. For the transmission of conductivity, temperature and depth measurements from a dive to 500 m, careful consideration of the optimal transmission strategy will be needed to reduce and compress the dataset for transmission. Satellite transmission of data allows much greater temporal (and thus often spatial) coverage. Its other advantage is that the tag does not have to be recovered in order to obtain the data. However, if tags are *not* recovered, then the costs of this method rapidly exceed those of the data-logging tags.

Of course, the choice of methodology is largely dependent on the study animal and simplicity of tag-attachment. For example, lactating Antarctic fur seals spend 4–5 days foraging at sea (cf. Figure 3(a)), between trips ashore to nurse their pup. Thus a data-logging tag may be deployed prior to this foraging trip and recovered a few days later. In contrast, southern elephant seals spend periods of months at sea, and would thus require a satellite transmitting tag.



(a)



(b)

Animals from the breeding sites at Husvik and Bird Island appear to forage in very different locations

Figure 3 *(a) Plot showing the density of time–depth recorder (TDR) temperature records (log scale) in fur seal foraging areas, from tags deployed at Husvik and Bird Island, South Georgia, during 1998. A–B is the transect line from the Husvik site for which temperature records were examined.* ***(b) Upper*** *Contour plot of temperature data along the transect.* ***Lower*** *Frequency distribution of diving activity along the transect, demonstrating that more time was spent in areas of temperature discontinuities.*

(Redrawn from Boyd et al., *in press)*

Wide-scale oceanic sampling must await improvements in our ability to deploy these tags on cetaceans (whales, dolphins and porpoises). Attachment of tags to pinnipeds (seals, sealions and walruses) or marine birds is usually quite straightforward, since animals can be captured at haul-out or breeding sites, and tags can be glued to the fur or feathers (Figure 1). Attachment of tags to cetaceans is more problematic. Although tags attached by suction-cups (Figure 1) may be deployed from a short distance (5–10 m) onto a variety of cetaceans (usually by pole or crossbow), they only remain attached for periods of hours and so would still require extensive ship support for deployment and recovery of tags. In order to achieve long-term attachment of tags to cetaceans, researchers can either use tags which will penetrate the blubber layer of larger cetaceans, or capture small cetaceans and surgically attach data-loggers to the dorsal fin area (since the blubber layer of small cetaceans is not thick enough for remote deployment of penetrating tags).

Feasibility analysis

Preliminary analysis of the feasibility of using seals to collect oceanographic data has been conducted by researchers at the British Antarctic Survey. Measurement of depth and temperature during diving of a southern elephant seal showed the presence of a distinct temperature discontinuity, with most of the foraging taking place in the transition region between the cold mid-water and deeper warmer water (Figure 2). Deployment of temperature sensors on Antarctic fur seals has allowed collection of data over a wide

area (Figure 3). There is a broad correspondence between sea-surface temperature measurements from instrumented seals and data collected from ship-board oceanographic surveys. However, these deployments have highlighted the need for a rapid sensor response, and further modifications of the tags to isolate the temperature sensor from the main body of the tag (and its inherent thermal lag) have gone a long way toward improving this.

Similarly, other researchers have used wandering albatrosses to collect sea-surface temperatures over very large areas, and have then used the measurements to validate satellite remote-sensing data. On a smaller scale, sensors attached to penguins have provided detailed information on water temperature within a 200 km^2 bay area and these data have been used to provide an indication of the environmental preferences of prey species. The temperature–depth profiles collected from foraging elephant seals have been used to infer the geographic position of their foraging areas. Similarly, sea-surface temperature records collected from Sub-Antarctic fur seals at Amsterdam Island have been used to estimate their foraging range in relation to the Subtropical Front.

Much of the focus on the data collected from marine predators has been on the analysis of behaviour, and it is only relatively recently that foraging information has been supplemented by oceanographic data. Over the next few years, we plan to incorporate additional oceanographic sensors into the data-loggers deployed on Antarctic fur seals at Bird Island, South Georgia. Our objectives are two-fold: to investigate spatial and temporal oceanographic variation in the South Georgia region, and to investigate how fur seal foraging distributions are affected by this oceanographic structure. These studies will be carried out in parallel with traditional ship-based oceanographic surveys of the region to provide a system of validation for our observations from marine mammals.

Long-term oceanographic variation

The collection of oceanographic information concurrent with predator foraging, and the continued monitoring of the population biology of these predators, should allow more detailed insight into the driving forces that link the physical and biological variability found in the Southern Ocean. The implications of this oceanographic variation can also be examined in light of the resulting life-history consequences for higher predators. Researchers at the British Antarctic Survey have found that the survival and growth of Antarctic fur seal pups at South Georgia show occasional sharp declines (every 4–6 years). These are a direct result of transient reductions in the availability of their main prey, Antarctic krill. Detailed dietary and behavioural studies have suggested that at these times of decline there were fewer krill swarms available, and as a result the fur seals had to travel further to find food. Using these kinds of data over a period of almost two decades, together with data from shipboard sampling during different feeding conditions, we can now begin to understand the physical processes in the Scotia Sea that result in the changing food abundance for fur seals. This is an example of marine variability that would be difficult to detect and monitor over decadal time-scales using simply intermittent shipboard observations or satellites – i.e. without the simple and inexpensive monitoring of predators, which integrate complex physical variability.

The oceanography community has not yet developed a serious interest in using top food chain predators as probes into marine systems. Oceanographers often have to wait for years to obtain enough ship time to test their hypotheses, because of the expense of running modern research vessels. Although the quality of data obtained from marine predators is unlikely to be as good as that obtained from traditional oceanographic methods, this method benefits from the potential to provide synoptic information beyond the reach of satellites, which will augment the value of available ship time. The strategy and analytical techniques used to incorporate these data into oceanographic models will require modification, but the additional information that can be gathered can only be complementary to these models. At the British Antarctic Survey we are taking up the challenge of linking oceanographic and predator research in the arena of the Scotia Sea, particularly around South Georgia. This project is set within a wider international effort to manage the exploitation of the Southern Ocean ecosystem, using these top marine predators as a monitoring tool. Nobody pretends that all the problems of using top predators to monitor and interpret variability in marine systems have been solved. Indeed, a great challenge lies ahead of us, to calibrate the variability in the signals from these top predators in terms of other variability within the marine system. This challenge will occupy us well into the 21st century.

Suggested Further Reading

Boyd, I.L., and T. Arnbom (1991) Diving behaviour in relation to water temperature in the southern elephant seal (*Mirounga leonina*): foraging implications. *Polar Biology*, **11**, 259–66.

Boyd, I.L., E.J. Hawker, M.A. Brandon, and I.J. Staniland (In press) Measurement of ocean temperatures using instruments carried by Antarctic fur seals. *Journal of Marine Systems.*

Campagna, C., A.L. Rivas, and M.R. Marin (2000) Temperature and depth profiles recorded during dives of elephant seals reflect distinct ocean environments. *Journal of Marine Systems*, **24**, 299–312.

Hindell, M.A., H.R. Burton, and D.J. Slip (1991) Foraging areas of southern elephant seals, *Mirounga leonina*, as inferred from water temperature data. *Australian Journal of Marine and Freshwater Research*, **42**, 115–28.

Hooker, S.K., and R.W. Baird (In press) Diving and ranging behaviour of odontocetes: a methodological review and critique. *Mammal Review.*

Georges, J-Y., F. Bonadonna, and C. Guinet (2000) Foraging habitat and diving activity of lactating Subantarctic fur seals in relation to sea-surface temperatures at Amsterdam Island. *Marine Ecology Progress Series*, **196**, 291–304.

McCafferty, D.J., I.L. Boyd, T.R. Walker, and R.I.Taylor (1999) Can marine mammals be used to monitor oceanographic conditions? *Marine Biology*, **134**, 387–95.

McConnell, B.J., C. Chambers, and M.A. Fedak (1992) Foraging ecology of southern elephant seals in relation to bathymetry and productivity of the Southern Ocean. *Antarctic Science*, **4**, 393–98.

Wilson, R.P., B.M. Culik, R. Bannasch, and J. Lage (1994) Monitoring Antarctic environmental variables using penguins. *Marine Ecology Progress Series*, **106**, 199–202.

Weimerskirch, H., R.P. Wilson, C. Guinet, and M. Koudil (1995) Use of seabirds to monitor sea-surface temperatures and to validate satellite remote-sensing measurements in the Southern Ocean. *Marine Ecology Progress Series*, **126**, 299–303.

Below *Grey seal with satellite tag, Sable Island, Canada. Don Bowen of the Bedford Institute of Oceanography, Canada, is investigating the foraging behaviour of grey seals in the North Atlantic.*
(Photograph by R.W. Baird)

For more information on this research, see the British Antarctic Survey website:
http://www.antarctica.ac.uk/Science/Programmes/independent/mibmmo/

Sascha Hooker is a post-doctoral researcher at the British Antarctic Survey,* and is currently investigating the interaction between marine mammals and oceanography in the region around South Georgia. (Email: skh@bas.ac.uk)

Ian Boyd is the head of the marine ecosystem management programme at the British Antarctic Survey.* He has developed a research programme on Southern Ocean top food chain predators, with primary research interests focussing on the behaviour and ecology of foraging in marine predators and the effects of environmental variability on their populations.

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Elizabeth Hawker** is a physical oceanographer, and is currently pursuing her Ph.D research at the Southampton Oceanographic Centre.

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Mark Brandon has studied the oceanography of the region around South Georgia over the past few years, and is currently lecturing at the Open University.†

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Book Reviews

Continental Drift: Colliding Continents, Converging Cultures by Constantin Roman (2000). Institute of Physics Publishing (Bristol and Philadelphia), 244pp. £26/$40 (hard cover, ISBN 0-7503-0686-6).

There are a few geophysicists who are personal advisors to heads of state, and Constantin Roman is one of them – to Emil Constantinescu of Romania – working from his home amidst the rustic splendours of Sussex, where he has an arboretum. *Continental Drift* is Roman's account of how he arrived in Britain from Romania in the late '60s, strived and prospered. It has little to do with geology or geophysics, but with personality and personalities at rarefied elevations.

Roman hails from a not underprivileged milieu, though one that fell on hard times, following the defeat of the Nazi occupiers of Romania in 1945, and the seizure of power by the Romanian Communist Party in 1947. This last event saw Roman's family stripped of their houses and businesses. Scions of the erstwhile bourgeoisie, like himself, lost their advantages relative to workers, peasants and especially members of the Party. Though the book dwells on the malign influence of the Romanian state apparatus, Roman was never jailed by the *Securitate*. Indeed he lived a seemingly charmed life in Bucharest at the beginning of Nicolae Ceaușescu's increasingly obscene hegemony, befriending tourists from the west, and corresponding widely. He managed to study to Master's level. Something moved him to seek the freer atmosphere of the west, and his growing skills as a 'networker' served him well. Not surprisingly, *Continental Drift* separates its index into 'People' and 'Places, Events and Science'.

On the strength of his MA dissertation at Bucharest University (about the palaeomagnetic properties of Romanian copper deposits), and his strategic distribution of reprints of articles based on it, Roman found himself invited to a 1968 NATO conference on palaeomagnetism at the University of Newcastle upon Tyne. What followed is, as they say, a long story, but one gratifyingly condensed in Roman's 185-page account of 21 years of voluntary exile. The focus is in fact on how he honed his skills up to the point at which he obtained a Ph.D in geophysics in 1974. Roman became the last Cambridge Ph.D student of Sir Edward Bullard and 'Dan' McKenzie's first.

Roman's research on seismicity in central Asia helped break tectonicians' preoccupation with the paradigm of rigid plates. However, *Continental Drift* suggests that his life as a research student was equally a fulcrum for social leverage of the most astonishing variety and ingenuity. One instructive tale is how Roman discovered that Peter Molnar of MIT had done similar work independently, and was on the point of publishing in *Nature*. Miffed by his supervisors' failure to keep abreast of developments in a distinctly international topic, and terrified that his thesis might fall at the last hurdle, Roman charmed his work into *New Scientist* within two weeks, thereby beating the hapless Molnar into second place. Curiously, this had little, if any, effect on Molnar's subsequent rise to academic pre-eminence in the field of continental tectonics, but became something of a feather in the cap of the exile from dull and stifling Romania.

I am at a loss to understand why Roman wrote this partial biography, when most Jewish, Hungarian or Czech scientists, who fled real mortal peril, simply got on with their lives and their research. Ambition drove him into self-exile from what at the time was a seedy Romanian version of Stalinism, yet to reach its nadir of the '80s. He met generosity, a degree of bumbling, and a raft of forbearance that formed the quintessence of British academic life in the '60s and '70s. While writing (in 1999) he would not have been unaware of how refugees fleeing the economic collapse of Eastern Europe met New Labour's anti-immigration policies and Britain's other social face, that of the racist yahoo. Among those fleeing westwards could possibly have been Roma ('gypsies') who, in the '60s, sensibly refused to exchange pots and pans for his father's redundant dinner jacket – a garment posted to Roman for obligatory black-tie events in college. That he could not spare a word of sympathy for his fellow refugees in this panegyric of his own 'escape', is perhaps a good reason for not buying this self-publicising little book.

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Biogeochemistry of Intertidal Sediments edited by Tim D. Jickells and Joy E. Rae (1997) Cambridge University Press (Cambridge Environmental Chemistry Series, No.9) 193pp. £35/$65 (hard cover, ISBN 0-521-48306-9).

This book arose from a conference held at Reading University and sponsored by the Challenger Society and Mineralogical Society. Its aim was to bring together geochemists, sedimentologists, microbiologists and estuarine scientists from a wide range of backgrounds, to consider the common biogeochemical principles that operate in intertidal areas. The result is a very useful contribution to the research area with both young and more established scientists contributing overviews and case studies. Anyone embarking on a research programme in such an environment could do a lot worse than look in this volume for guidance and initial reading lists (although these are a little dated now, because your reviewer has taken so long finishing this review).

Following an overview by the editors, Tim Jickells and Joy Rae, there is another chapter by Joy Rae on trace metals in the estuarine system. Having first dealt with the principles of establishing historical pollution trends, this concentrates on the Severn Estuary as a case study. Then follows a modelling chapter which confirms that both theoretical and practical measurements are needed to explain complex processes such as adsorption and desorption in salt marshes and estuaries. Karen Carpenter's contribution on the methodology of flux measurements is a very useful example of the 'how to actually do it' information that is often lacking in scientific papers. However, whether anyone would try after the limitations have been explained so thoroughly is open to question!

The next three chapters include nutrient cycling, the cycling of carbon and sulphur, and all aspects of microbial activity and diagenesis, based around East Anglian case-studies. Again there is an overview to help the novice, and some practical information concerning the specific area used to demonstrate the principles. The laboratories at the University of East Anglia must have been a vibrant and humming place if all the work described was being undertaken at roughly the same time, as I believe it was. Certainly the authors' enthusiasm for the subject comes across well. Why *do* people so enjoy getting wet and muddy one day and spending hour upon hour undertaking chemical analysis the next?

The final two chapters revert to the traditional approach to pollution by investigating the state of the Irish Sea with regard to radionuclides and the sorption of some insecticides onto estuarine particles. Again, overviews and specific examples – a very useful approach.

Overall, this is a consistently interesting volume. The meeting was good (I was there!) and the book reflects the interest generated. Intertidal areas are so diverse, and the inputs so variable that there is never likely to be a definitive overarching explanation for everything we see. These individual case studies show how to approach the problem in your local area before the sea-level rises too far, or the barrage, marina, port or heritage coastal park are built. Because as sure as the sea is saltier than rivers, more and more development means that the natural intertidal areas of this country are under threat and we need to understand how they work as a system before any more of them are allowed to lose their natural context. This book will help stimulate such studies.

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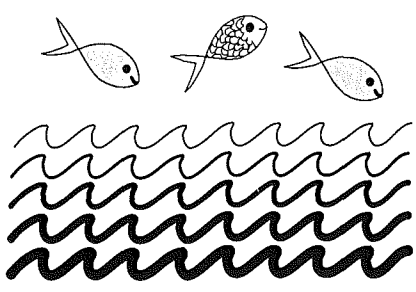

Coastal Defence and Earth Science Conservation edited by Janet Hooke (1998). Geological Society, 270pp. £59/$89, Special price for Geological Society members, £29/$48 (hard cover, ISBN 1-897799-96-9).

This book has been written in response to the tremendous changes in attitude, policy and practice in relation to coastal defences over the last ten years. It addresses the conflict between conservation pressures on the one hand and the need for coastal defence on the other, and has contributions from both engineers and conservationists, most of whom are practitioners within the field. It will be of interest to engineers and planners involved in coastal and shoreline management, and conservationists in both national and local agencies.

The need for coastal defence has long been accepted, and until recently has generally taken priority over conservation interests. Coastal defence is necessary to protect valuable economic assets such as buildings and other infrastructure, as well as to ensure safety and stability of cliffs and coastlines. Conservation pressures arise because of the scientific need to have sites and opportunities to study rocks and coastal landforms in order to understand the Earth better and manage resources effectively, as well because of the educational need to have sites available for teaching, in order to promote the caring stewardship of the Earth and to satisfy the public and popular desire for greater efforts in nature and wildlife conservation.

The book is divided into five parts: Frameworks for conservation and defence; Methods and techniques of defence and conservation; Strategies and decision-making; Resources and evaluation; Case studies of Pool and Christchurch Bays, southern England. Each part contains at least two contributions from different authors. In this respect, the book has a slightly disjointed feel, because there is very little interconnecting text to bring the different parts together. However, the individual contributions present a range of interesting topics, dealing with both technical and strategic issues in a variety of situations and locations. The nature of British geology dictates that many of the sites examined are those along southern and eastern coasts, but there are a couple of interesting contributions that focus on Scottish sites.

The format of the text is pleasing to the eye, and each contribution contains a useful summary and a comprehensive set of references, many of which may be of interest in their own right. There is inevitably a certain amount of technical jargon and quite a few acronyms, which can sometimes be rather distracting to the reader. Illustrations are almost all black-and-white line drawings or black-and-white photographs. Unfortunately, the photographs are sometimes not as crisp and clear as they might be, and give the book a slightly dated appearance. This is shame, because it detracts from the spectacular nature of some of the sites in question.

To work well as an integrated text, the book could benefit from improvements (e.g. each chapter being put into the broader context), but as a reference guide for practitioners, it would be a very helpful addition to any library shelf.

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The Dead Sea: The Lake and its Setting (1999) edited by Tina M. Niemi, Zvi Ben-Avraham and Joel R. Gat. Oxford University Press, 286pp. £62.50 (hard cover, ISBN 0-19-508703-8).

The Dead Sea is an extraordinary and unique body of water; it lies more than 400 m below sea-level at the lowest continental elevation, and its waters are the most saline ever encountered in a large lake. This multidisciplinary book pulls together more than 25 years of detailed monitoring and research on the Dead Sea, and it can make fascinating reading. For example, I discovered that radiometric age data can be linked to biblical quotes and even records contained in the Dead Sea scrolls, and that despite its high salinity, viable organisms are continuously present in the Dead Sea, and algal and bacterial life is readily restored when surface waters are diluted by rainfall.

The book is divided into three parts. The first part describes the tectonic and geological history of the Dead Sea. This is the strongest part, which is not surprising given that two of the editors are geophysicists. The chapters discussing the history and formation of the Dead Sea basin, and its geophysical framework, are excellent. Tectonically, the Dead Sea is one of the most important examples of a pull-apart basin, and the authors of these chapters are leaders in the field. The second part focusses on the physical, chemical, and biological aspects of the water body. The physical section really brings home the hydrographically challenging nature of the Dead Sea. For example, salinity is so high that it makes measurements of both density and evaporation rate extremely difficult (due to the formation of salt crystals on the one hand, and influences on vapour pressure and latent heat of evaporation on the other).

However, I found that the discussion of chemical processes occurring in the Dead Sea was rather disappointing, and narrowly focussed. There is just one short chapter concerning the events of February 1979, when for the first time, an overturn of the water column (which usually comprises an upper water and a lower, fossil, water mass) was observed. This led to far-reaching geochemical changes within the lake, yet these are poorly documented. Two chapters redeem this chemical section; both deal with halite deposition and are excellently written. Mineral salts from the Dead Sea are a big industry today, and understanding the factors controlling their precipitation is of key interest to those countries that border the Dead Sea. Reading the chapter dealing with microbiological processes in the water body, I was intrigued to learn that although many organisms have developed the capability to tolerate NaCl, and their adaptive mechanisms are well known, those in the Dead Sea also have to contend with high levels of divalent cations (Mg^{2+}, Ca^{2+}, for example); their mechanisms for coping with these chemical species are not well understood. This is clearly a fascinating area of research that is frequently neglected in oceanography texts, so it is good to see it included here.

The final section of the book is titled 'Quaternary history of the lake and its environment', but this is rather misleading as only one chapter deals with the Pleistocene, the remainder dealing only with the Holocene. Sadly, there is just one chapter concerned with studies of Lake Lisan, an important water mass which was the precursor to the Dead Sea, existing for ~45 000 years, until 15 000 years ago. Lake Lisan has been the focus of many studies by eminent Israeli scientists, so it seems a pity that this work is not covered in greater detail. There is an interesting chapter which looks at the archaeology of the region; I learnt, for example, that Neolithic wooden figurines have been found to be coated in bitumen derived from the Dead Sea.

As the book developed from a conference on the Dead Sea in Tel Aviv in 1992, it is perhaps not surprising that most of the work describes only the Israeli portion of the lake and its shores. It will be interesting to see how the Jordanian side of the story develops, should the political climate improve. I would certainly encourage a second volume on the Dead Sea in a few years' time. Although I am not sure I agree with the editors' contention that the book is accessible to the general reader, this is an extremely useful and fascinating summary of an important body of water. The high cost may discourage individual purchasers, but this is an important reference work for any library.

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Atlas of the Indian Ocean

A recently published oceanographic reference work, not widely known about in Europe, is the *Indian Ocean Atlas*. The Atlas was published in Calcutta in 1998 by the governmental National Atlas and Thematic Mapping Organization, and was edited by its Director, Dr Prithvish Nag.

The Indian Ocean, the only major ocean that is landlocked to the north but open to one of the polar regions, has been explored by traders since time immemorial. However, vast changes have taken place there since the International Indian Ocean Expeditions in the early '60s. The Indian Ocean has become important in world politics because of its strategic position and wealth of marine resources, particularly petroleum and polymetallic nodules. According to the publishers, the preparation of the *Indian Ocean Atlas* was an attempt to highlight this changed status, as well as the scope of commercial activities, against the background of its physical and cultural environment.

The *Indian Ocean Atlas* has three broad themes:
(1) Physiographic characteristics of the ocean and its sea-bed;
(2) Socio-historical aspects;
(3) Economy, trade and natural resources of physical and economic importance.

The publishers particularly stress the effort that has gone into making the nineteen large (57cm x 42 cm) maps clear and informative as possible.

The chapter topics are as follows:
1. The Indian Ocean and littoral countries; 2. Geology; 3. Physical aspects; 4. Sea-surface temperature; 5. Surface salinity; 6. Rainfall and cloud cover; 7. Pressure and wind; 8. Surface currents; 9. Tides; 10. Coastal features; 11. Mangroves and associated flora; 12. Marine resources; 13. Ports and trade; 14. Culture and civilisation; 15. Historical routes; 16. Tourism; 17. Population; 18. Towns and cities; 19. Economic activities.

List Price: $53.30
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The Centre for Coastal and Marine Science

I write this letter from several viewpoints. Firstly, as an individual with a long-standing involvement with CCMS and the laboratories that it linked. Secondly, as chairman of the Marine Foresight Task Force on managing marine resources and the marine environment.

I have been involved with CCMS and its component laboratories for over twenty years. At a formal level I have served on the NERC Marine Science and Technology Board and a number of other NERC marine-related committees and working groups, including the now disbanded CCMS Advisory Council. The insights I have gained from this involvement give me considerable cause for concern about the future of UK strategic marine science, given the decision to disband CCMS.

There is little doubt that the areas of most promising research in marine science are increasingly multidisciplinary. Certainly the scientific understanding needed to address the most pressing global and local marine environmental issues can only be achieved through a multidisciplinary approach. In common with many areas of science, the days where an individual marine scientist could expect to pursue a cloistered, isolated career, studying just one tiny subdiscipline, are rapidly passing. Most significant progress is achieved through effective cross-disciplinary teamwork, especially in areas of strategic importance.

I, and many others associated with CCMS, were therefore delighted to see the progress made towards bringing the previously rather isolated activities of the CCMS constituent laboratories together within coherent multidisciplinary programmes addressing real strategic needs. Within the CCMS Advisory Council, where we were privy to reviewing the financial basis of CCMS, there was corresponding appreciation that long-standing financial problems within CCMS were being effectively confronted and resolved.

It is a credit to the previous Chief Executive of the NERC and the NERC Council that they recognized the potential of what was being achieved within CCMS and supported funding for restructuring to achieve the new multidisciplinary vision that was beginning to emerge. By the end of 1999 a substantial restructuring of CCMS to achieve its new objectives was largely in place.

So what has gone wrong? Explanations of a complete about-turn by NERC are notably absent, as is any clearly defined basis for the future of the ex-CCMS laboratories. Equally absent is an explanation of why very substantial tax funds were expended with the specific objective of better integrating the CCMS laboratories, only to then disband them just as the objective was being realized.

If national and international strategic needs and obligations are to be properly satisfied, the UK needs an integrated capability in marine environmental science. The Foresight process has strongly endorsed this need for better integration.

Perhaps the action taken by NERC forms part of a wider plan for more effective integration. However, since no wider context has been provided for the decision to disband CCMS, it is very difficult to see how fragmentation of a research facility specifically geared to integrated multidisciplinary research, will contribute to meeting UK strategic needs or to addressing the concerns raised through the Marine Foresight process.

Ralph Rayner

24 October 2000

Forthcoming Events

Events in 2001

The Oceanography Society Biennial Scientific Meeting 2–5 April, Miami Beach Convention Center, Florida. The themes are: Air–sea interactions; The water column; The sea-floor. The meeting will be held in conjunction with the **Oceanology International Americas 2001 Conference and Exhibition** with its wealth of exhibits related to ocean science and technology. There is no registration fee for either event. *Contact* The Oceanography Society, 5912 LeMay Road, Rockville, MD 20851-2326, USA; Email: info@tos.org

Palaeoceanography and Climate Change (Challenger Society /Geol. Society meeting). 25–26 April, Burlington House, London. *Contact* Harry Elderfield, University of Cambridge; Email: he101@esc.cam.ac.uk

OCEANS III Millennium (Ist International Congress on Marine Science and Technology). 24-27 April, Pontevedra, Spain. Website: www.fomar.org

Detecting Environmental Change 16–20 July, London. Website: http://www.nmw.ac.uk/change2001/

Symposium on the Occasion of the 70th Anniversary of the Continuous Plankton Recorder Survey of the North Atlantic 7 August, Royal College of Physicians, Edinburgh. To be held in conjunction with the **2nd ICES Decadal Symposium** 8–10 Aug. *Website:* www.npm.ac.uk/sahfos/cprsymposium.htm *Prior to 31 Jan, contact* Prof. J.B.L Matthews, SMBA (Email: jama@dml.ac.uk); after that date, booking will be handled by: Institut für Meereskunde, University of Hamburg, Troplowitzstrasse 7, D-22529 Hamburg, Germany. Website: http://www.ices.dk/symposia/decadal2.

7th International Conference on Paleoceanography 16–21 Sept, Sapporo, Japan. Website: http://www.iijnet.or.jp/JTB-CS/icp7/

2001: An Ocean Odyssey (Joint Assemblies of IAPSO and IABO). (21–28 October, Sheraton Hotel, Mar del Plata, Argentina. *Contact* 2001 Secretariat, Instituto Argentino de Oceanografia; Fax: 54-291-486-1527; Email: iado@criba.edu.ar

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

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

MEMBERSHIP SUBSCRIPTIONS

The subscription for 2000 costs £40 (£20.00 for students in the UK only). If you would like to join the Society or obtain further information, contact the Executive Secretary, Challenger Society for Marine Science, Room 251/20, Southampton Oceanography Centre, Waterfront Campus, Empress Dock, Southampton SO14 3ZH, UK.

Fax: +44-(0)23-80-596149; Email: jxj@soc.soton.ac.uk

ADVICE TO AUTHORS

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

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