OCEAN
Challenge

The Challenger Society for Marine Science

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OCEAN *Challenge*

The Magazine of the Challenger Society for Marine Science

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

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News & Views

Sea-Level and Civilization – Atlantis Revisited?

Is Graham Hancock onto something? His TV series on Channel 4, 'Flooded Kingdoms of the Ice Age', was both enlightening and instructive, not least because his central thesis is so simple and plausible. Humans were around long before the onset of the last glaciation, yet according to conventional history and archaeology, they didn't start building cities and monuments until five-and-a-half millennia ago. Now along comes Hancock with claims to have discovered the ruins of huge and much older man-made structures submerged on continental shelves in several parts of the world.

Most significantly, these discoveries are near some of the oldest cities and monuments built on land, in places like Malta, north-west India, Taiwan and Japan. It is hard to see how natural processes can have formed the rectilinear features recorded by Hancock's underwater camera crew, including steep-sided trenches and walls apparently built of close-fitting shaped or carved blocks of stone. Numerous artefacts collected from the underwater sites include a well-worn tablet with markings which suggest that written language could be a good deal older than the 5500 years or so claimed by archaeologists working on land.

Sea-level rise seems to have occurred in three main phases, at ~14 000, ~11 500, and ~7000 years ago. The ~14 000 and ~11 500 events correlate with the most recent Heinrich event and with the Younger Dryas, respectively, and there is some independent evidence that meltwater discharge from Northern Hemisphere ice sheets did accelerate at those times. The ~ 7000 year 'event' seems to be less well documented, but it could be related to filling of the Black Sea (which began life as a large freshwater lake), at about that time (cf. *Ocean Challenge*, Vol. 11, No. 1, p.4).

Something like 30 million km^2 of continental shelf are estimated to have been flooded when sea-level rose after the Last Glacial Maximum. That's an area larger than North America, and there can be little reason to doubt that people inhabited the extensive coastal plains bordering ocean basins that were a good deal less extensive than they are now. The question is, were those people all agriculturalists, as conventional history and archaeology would have us believe, or did some communities build cities that are now submerged?

The maximum rate of sea-level rise could at times have been as much as 10 cm per year, a hundred times faster than it is at present, which is a phenomenal rate that must have been very frightening for the inhabitants of those coastal plains, whether in fields or towns. However, just how these bursts of accelerated sea-level rise occurred remains unresolved. A glaciologist in one of the programmes described 'glacier waves' of meltwater pouring off ice sheets into the oceans and propagating as a giant wave, perhaps 'a thousand miles long and a thousand feet high' (a sort of avalanche/tsunami hybrid) that swept round the world, inundating coastal plains as it went. A more likely scenario is the so-called 'binge-purge' process: a sudden slippage of ice sheets over a lubricating layer of meltwater (produced by geothermal heating under the ice), released 'armadas' of icebergs that drifted south and melted, shedding the sandy debris recorded in the sediments as Heinrich events.

If humans really were establishing centres of civilization around ten thousand years ago, as Hancock proposes, the Atlantis legend might not be so legendary after all. Thus, 11 000 years ago (when sea-level was still more than 100 metres lower than now), there was an archipelago of islands about 100 km west of Gibraltar. According to research published last year in France (see also *New Scientist*, 22 September 2001), this is the latest site of the lost city of Atlantis, one that has the additional merit of matching the location identified by Plato. When sea-level rose again, the islands were submerged to form a shoal east of the Gorringe Bank that features on maps of the ocean floor in this area. There must have been several islands off Iberia and North Africa at the time of the Last Glacial Maximum, and they could well have provided convenient way stations for 'prehistoric' people crossing between Europe and North Africa. Did some of them settle and build cities, establishing the civilization of legend? Plato wrote about Atlantis many millennia after it (allegedly) disappeared, however, and he ascribed the loss of the city to volcanism, which is not the same as rising sea-levels, pulsed or not. All in all, though, the dawn of civilization could be a good five millennia earlier than most historians would have us believe.

Giant Wind Farms: Britain's Answer to Global Warming

In the spring of 2001 there were reports that large offshore wind farms were to be developed in coastal waters round much of Britain. Some 1500 MW would be generated from wind power by 2010. About 500 giant turbines – each producing up to 3 MW – would be planted on the sea-bed, in groups of 30 at a time, perhaps as much as 10 km from the coast – far enough offshore for the wind farms to be neither an eyesore nor a hazard to migrating seabirds; but possibly near enough to coasts not to interfere with the majority of fishing vessels.

Came the end of 2001, and these schemes seemed paltry by comparison with the £600 million wind farm scheme proposed for the Outer Hebrides, possibly for Orkney and Shetland too. Tidal and wave energy installations are also planned, and the aim is to be generating 20% of the UK's electricity from renewable sources by 2020. Ambitious indeed, not least because the electricity is to be 'cabled' some hundreds of kilometres under the sea to centres of industry and population where needs will be greatest – £600 million probably won't be enough.

Following the 'dash for gas' in the 1990s, about 40% of UK electricity comes from burning gas, the rest from nuclear, oil and – perhaps surprisingly – from coal (10–20%, depending on demand). As North Sea gas begins to run out in the next couple of decades, it will be necessary to import gas. Security of supply could become a problem, since most gas (and oil) reserves are in countries that are not models of political stability (though 20 years is a long time in politics). But perhaps the most intriguing aspect of this 'renewables' scheme is that by

2020, Britan's nuclear power stations will be long past their decommissioning dates – and by sheer coincidence, the present nuclear contribution to UK electricity generation is about 20%.

The Danes have gone a long way with wind farms (*Ocean Challenge*, Vol. 11, No.1, p.11) – can Britain follow? The trouble with wind is that it is so much more 'dilute' as an energy source than fossil or nuclear fuels. The same is true of waves and currents – and in any case the relevant technology is still in its infancy. Anti-nuclear opinion is so strong in many parts of Europe that construction of more nuclear power stations can be ruled out, for the present at least. So oil and gas seem likely to provide the bulk of British (and EU) energy requirements for the foreseeable future, despite potential insecurity of supply.

Meanwhile, across the Irish Sea ...

Last year the Irish Government made strenuous legal efforts to have nuclear re-processing at Sellafield shut down, on the grounds that discharges from the plant increase levels of radioactivity in Irish Sea waters. A BNFL spokesman responded, stating that these levels had in fact decreased a thousand-fold in the last 25 years, and went on to claim that even people living near Sellafield and eating lots of seafood would get about the same radiation dose as passengers on a long-haul flight to Japan. Sellafield is still in business, and is planning to open (or has already opened) a new MOX plant (mixed uranium and plutonium oxide) for nuclear reactor fuel). A thousand-fold decrease in radiation levels sounds very good – but what were the levels like before that, 25 years ago?

Stop Press

The Norwegians have now got into the same act, exploring legal means of stopping radioactive waste discharges from Sellafield. In March, they claimed to have detected radioactivity in some of their seaweed, fish and shellfish. Traces of the radioisotope technetium-99 led them to point the finger at discharges from Sellafield, carried north from the Irish Sea and then eastwards to Scandinavia. The Norwegians are no more impressed by claims of big reductions in radioactivity since the mid-1970s than the Irish.

Alaskan Oil Back on the Agenda

Last year, there was a furore over US plans to open up the Alaskan oil fields to further exploration. Environmentalists were pitted against both local Inuit communities and powerful trade unions, who apparently cared more about jobs than ecosystems. It was all part of the Bush administration's refusal to take global warming seriously and ratify international agreements to reduce greenhouse gas emissions – meagre though the proposed reductions were. There was a nasty twist to this tale: a diligent cartographer published a map showing the coincidence of caribou calving areas and proposed drill sites. He was sacked. Could this mean that the big oil companies don't want potentially adverse environmental publicity?

The picture's very different now. The US and other western nations depend hugely on continued availability of oil and gas, and as most of the world's reserves are in the Middle East, security of supply became a major issue after September 11. Alaskan oil is in US territory, which should be secure enough; and opening up new hydrocarbon fields also means extra jobs. So we can look forward to learning about progressive degradation of Arctic ecosystems. The decrease in air traffic over the last few months may have led to a small decline in greenhouse gas emissions, but it's unlikely to last. The recession is all but over, so motor cars and aeroplanes will be pumping out more CO_2 than ever.

Subsidy versus Debt: An African Case-study

Multi-million pound deals are being struck with governments of countries along the sea-board of West Africa, to enable EU vessels to fish their waters, which are among the richest in the world. While European governments can afford to subsidise their fishing fleets, developing countries are indebted to the World Bank, IMF and other financial institutions, and they need the money to pay off their debts. They are too poor to police their waters and check that quotas aren't being exceeded. Catches are inevitably declining year by year, since vessels from all over Europe (including Russia) are there. The trade is profitable for the fishing fleets (if not for the governments subsidising them), and the motto seems to be: pay the money and take the fish – while stocks last.

When is a fishing boat not a fishing boat?

When it's registered in Ireland as a cargo ship, but fitted with all the most advanced fishing gear and sent away to fish off West Africa, specifically in Mauritanian waters, where the EU and its taxpayers (including *Ocean Challenge* readers) have just bought 5 years' worth of fishing rights for £300 million. The scheme has a machiavellian brilliance that is breathtaking in its simplicity and subtlety. The EU alleges that Ireland's fishing fleet is already far too large, but has allowed it to add the 14 000-tonne *Atlantic Dawn* to its complement, on the condition that the ship never (ever) fishes in EU waters. She was built in Norway (not an EU member) whose ship-building industry is allegedly both struggling and subsidised.

Fishing to extinction?

Some years ago, a News & Views item in *Ocean Challenge* (Vol. 6, No.1, pp. 12–13) discussed the proposition that it might make more economic sense to fish a stock to extinction than to spend money on conservation measures. It's worth repeating some of that item here: 'Depensation' is what happens when a natural population is so depleted by predation that survivors cannot reproduce efficiently. Extinction follows. Even if predation ceases, the ratio of recruits to total population decreases as population declines, and the population cannot recover. The N&V item continued: 'There is a real prospect that some fish stocks may be harvested to extinction if the economics of the free market are left to dominate ... a somewhat chilling analysis of this issue by Robert M. May [then Chief Scientific Adviser to HM Government] in *Nature* (4 Nov. 1994, 42–43) ... does not rule out the possibility that a political decision could be (perhaps even has been?) made to permit 'fishing to extinction' of selected stocks in some areas, in order to maximise the economic returns ... it may already have happened to the Newfoundland cod'.

A poignant commentary on the parlous state of marine fisheries was provided by a news feature last year about a record 20-stone (>100 kg) halibut, more than 2 m long and perhaps 35 years old, caught off Rockall. Fish of that size are now so scarce that this one even made an editorial paragraph in *The Guardian*!

Cull the Seals, Save the Cod

Britain's seal population is now estimated to be around 100 000, most of them in Scottish waters, where fishermen claim they consume 15 000 tonnes of cod a year. It's a plausible claim: 15 000 tonnes a year works out to about half a kilogramme a day per seal.

But why is the cod to be saved? It is to keep fish and chip shops in business, of course (or anyway, the ones that are left). The fishermen consider the seals to be pests, but from the seals' point of view the real pests are the fishermen. It is not predation by seals, but commercial overfishing by humans that has caused cod stocks in the North Sea to fall so low that draconian quota cuts (around 50%), imposed at the end of 2000, were followed by a 12-week total ban on cod fishing from mid-February 2001, over some 40 000 square miles of North Sea (mainly off Holland, Denmark and Norway and north of the Shetlands). The aim was to protect the cod spawning grounds, but no mention was made of the possibility that these 'endangered' cod might be caught along with other fish and (being 'terminally' quota-limited, i.e. banned) would end up being dumped – dead of course – back into the sea.

At the same time, however, it was reported that there would be no restriction on 'industrial' fishing for sand eels and other small fish, which are used for animal feed, ferilizers etc. Since industrial fishing uses small-mesh nets, these would inevitably catch young cod, thus negating the objective of the fishing ban. The ban lasted until mid-April 2001. What happened next? Even in the months preceding the events of September 11 there was no information. It seems unlikely that a mere three months could be long enough for cod stocks to recover, given that Newfoundland cod stocks haven't yet recovered, nearly a decade after fishing ceased there in the early 1990s.

It is at least possible that the slight rise in mean temperature of North Sea waters recorded in recent years could inhibit recruitment and recovery (e.g. *Nature*, **404**, 142). Perhaps analogous abiotic factors have prevented recovery of the Newfoundland stocks, as suggested by Richard Lampitt in a recent review (*Ocean Challenge*, Vol. 10, No. 3, p.31).

Corals and the Greenhouse

'Corals will be wiped out in 30 years' 'Coral reefs face total destruction' 'Coral grief'. The headlines are stark, even apocalyptic. Perhaps they are right. Coral bleaching (loss of colour through expulsion of their symbiotic algae, the zooxanthellae), perhaps the most commonly identified cause of death, is attributed to the increased water temperatures that result from global warming. Since most coral reefs are in low latitudes, most of them are along the coasts of developing countries, and the regional bleaching effect is commonly compounded by local damage resulting from any combination of: excessive sedimentation associated with construction projects (new hotels, factories, ports); eutrophication from sewage and/or fertiliser run-off; poisoning by toxic wastes; and fishing with explosives. It is not likely that destruction of reefs can be averted by environmental legislation in the countries concerned. Many them are poor, and it is often possible to find corrupt officials who can be bribed to turn a blind eye to environmental malpractice.

A praiseworthy proposal was made at the February meeting of the AAAS in Boston, to identify ten 'key' coral reef communities as biodiversity 'hot spots' to be protected and conserved. This may turn out to be an exercise in futility, because there is no credible way of policing a ban on destructive activities in these vulnerable environments.

But none of that will matter if global warming really is the prime cause of death in corals. The reefs would be doomed to extinction in a matter of decades anyway, irrespective of whether or not the local inhabitants continue to destroy them.

How corals can survive bleaching

Amid an apparent consensus that global warming is the main threat to coral reefs (although some corals may be more susceptible to bleaching than others, e.g. *Nature*, **404**, 142–43), there is evidence that bleaching in reef corals may be a survival mechanism rather than a harbinger of doom (*Nature*, **411**, 785–86).

Some species of reef coral can shed 'suboptimal' algae and acquire new algal 'partners' better suited to changed environmental conditions. The algal symbionts may thus have a role as adaptive agents, and bleaching may not always be wholly detrimental to reef survival. That would go some way to explaining the apparent paradox that reef corals are both environmentally sensitive and geologically long-lived, even though species living today are generally not the same as those represented in the fossil record.

Coping with extra CO_2

Corals may be able to survive bleaching but will they survive the increasing quantities of anthropogenic CO_2 entering the atmosphere? There is well-documented evidence that calcification rates of corals and other shelly organisms (especially calcareous phytoplankton) decrease with rising atmospheric CO_2 concentrations (e.g. *Ocean Challenge*, Vol. 11, No.1, pp.13, 20). Since calcification releases CO_2 to the atmosphere, reduced calcification rates would lead to a kind of negative feedback, as more anthropogenic CO_2 would tend to remain in solution in the surface ocean, and less would be returned to the atmosphere by calcification. However, years if not decades must surely elapse before any measureable changes in calcification rates can be observed, let alone any effect on pCO_2 in surface waters.

Reduced calcification may put less carbon dioxide back into the atmosphere, but won't actually remove any. Only photosynthetic production of organic matter can do that. But there may be a limit to how much extra CO_2 can be taken up by terrestrial plants (e.g. *Nature*, **408**, 656–57). If the same proves to be true of marine phytoplankton, then the proportion of anthropogenic CO_2 removed from atmosphere to ocean will become progressively less as we burn ever-increasing quantities of fossil fuel.

El Niño and corals

El Niño events can contribute to coral bleaching when they introduce extra-warm water to some parts of the ocean. But coral bleaching has been with us only for the last couple of decades, and the reefs contain long records of ENSO events. These can be unravelled by analysis of oxygen isotope measurements of samples from drill cores taken from reefs in the central Pacific, supported in one case by a time-series of sea-surface temperature measurements dating from the 1950s (*Nature*, **407**, pp.956–57, 989–93).

It turns out that the roughly four-year ENSO cycle which has characterized recent decades only began in about the mid-1950s, though its first well-publicised manifestation was the strong 1976–77 event which all but destroyed Peru's anchoveta fishery.

Equally intriguing is the conclusion that during the second half of the 19th century, the western Pacific region was significantly drier and cooler than it is now, and that El Niño events occurred on an approximately decadal time-scale. Then in the first half of the last century, El Niños seem to have become more frequent, occurring at intervals of between about 3 and 7 years, but were also relatively weak – and so presumably came to be regarded as a more or less local phenomenon (in any case, synoptic ocean-wide surveys were impossible in those days). The relative warmth and freshness of present-day western Pacific waters is a fairly new phenomenon, dating from about the mid-1970s, when global warming began to attract scientific and public attention – and when the first strong El Niño of recent decades hit the coast of Peru.

A serendipitous discovery – worms can build reefs too

At about 25 m depth a few kilometres off the Dorset coast there is a reef-like accumulation of mounds formed of the casts of 'arenaceous' worms that build their protective tubes out of sand and shell fragments (co-called Ross worms, *Sabellaria spinulosa*). The 'Great Dorset Worm Reef' could be several thousand years old, and supports a thriving and diverse ecosystem that includes anemones, sponges, hydroids and bryozoans, as well as starfish, crabs, molluscs and fish. The serendipitous aspect of this bit of news is that the reef was found quite unexpectedly, by marine biologists mapping the distribution of pink coral, which also occurs off Dorset. Global warming may be less critical for these 'reef worms' than it is for reef corals.

For more information contact Ken Collins at Southampton Oceanography Centre or look on the web at: www.soc.soton.ac.uk/PR/NEWS/htm

The End of the *Kursk*

The awful events of September did not interfere much with the sombre mission to raise the wreck of the submarine *Kursk*, which sank in the Barents Sea in 2000 with loss of 113 lives. She was finally raised in October 2001, but the sad task of laying the crew to rest was not completed until March this year. The *Kursk* was raised without the crucial bow section which is widely held to contain the evidence of what caused the explosions that occurred when the vessel sank. Those explosions were monitored in Britain and form part of the evidence in a long and complicated explanation of what sank the submarine, which was well documented in a BBC 'Horizon' Special and a feature article in *The Observer* last August. It centres round the possibility that accidental leakage of highly reactive hydrogen peroxide from a torpedo motor led to release of oxygen and an explosive reaction involving oxygen, steam, hydrogen peroxide and metal components. In the ensuing fire, warheads in other torpedos became overheated and themselves exploded, blowing open the bow of the *Kursk*, so that she sank. It will never be possible to prove whether any of this happened, and the alternative possibility, that the submarine sank because of collision with an American vessel is, of course, consistently denied by the Americans. It is in any case not supported by any strong evidence, and a collision makes it more difficult to account for the two well-documented explosions – a small one followed by a big one – that appeared on the seismic record.

DON'T FORGET!

Marine Science 2002 is in Plymouth on September, 2002.

See full page advert on p.18.

The First Scientific Conference of the European Federation of Marine Science will be held in Athens 27–29 September 2002 on the topic Oceanographic Aspects for a Sustainable Mediterranean

For more information, see p.36

Has the Snowball Stopped Rolling?

Until quite recently there seemed to be no end to the 'Snowball Earth' controversy, partly because the various hypotheses/theories proposed to account for the late Precambrian glaciations are impossible to verify – nobody was there at the time. In brief, the original argument centred round the difficulty of explaining an association of glacial deposits and carbonate sediments at what were low latitudes. Perhaps as many as four times between about 800 and 600 million years ago, a combination of low CO_2 concentrations, sunlight levels lower than now, plus a 'runaway' albedo effect enabled ice sheets to reach the Equator, and the Earth was completely frozen over for several million years. During such periods there could be no photosynthesis to remove atmospheric CO_2, which continued to be produced by volcanoes poking through the ice sheets. Eventually, the story goes, the CO_2 'greenhouse blanket' became thick enough for global temperature to rise and melt the ice. Massive rainfall in the ensuing melt-down washed out much of the excess CO_2, which caused extensive weathering of newly exposed rocks and produced the carbonate sediments.

A principal objection to this hypothesis is that the 'big freezes' would extinguish all life on Earth, which conflicts rather obviously with fossil evidence for the Cambrian explosion of multicellular animal life-forms that occurred quite soon afterwards. Such diversity is unlikely to arise on a lifeless planet.

A compromise model recently came to the rescue of Snowball Earth (*Nature*, **405**, 403–44, 425–40), a model that posits ice sheets which didn't quite cover the whole Earth and left open water at low latitudes – a refugium for life. At a stroke this elminates global extinctions but allows for greenhouse melting of the ice, also the extensive weathering and carbonate deposition.

Snowballers will presumably be content with this outcome, but there may be dissent from those who favour variations in obliquity as an explanation of the late Precambrian glaciations at low latitudes (cf. *Ocean Challenge*, Vol. 10, No. 1, p.6).

Fulfilled promise – the new *Prince Madog* !

Garry Reid, Dei Huws and Mike Kaiser

A long wait doesn't always ensure that you get exactly what you want, but in some cases months and years of effort and expectation can pay off. The School of Ocean Sciences (SOS) at University of Wales Bangor (UWB) has waited over 10 years for a replacement for its ageing research vessel, the *Prince Madog,* and last summer saw delivery not just of a purpose-built vessel but of new shoreside support facilities and a Joint Venture Company to run the vessel. Over a decade's worth of searching for an appropriate funding package let us into the world of Public Private Partnerships, and with the significant help of a £2.8 million grant from the government's Joint Infrastructure Fund (JIF) we cemented a promising 20-year partnership with Vosper Thornycroft UK Ltd (VT).

With the award of the JIF grant, £1.4 million from VT and a £400 000 contribution from UWB, the project moved into a two-year tendering, planning and building phase at the end of which, with great celebration, the ship had its official naming ceremony at Menai Bridge in July 200. Lady Isobel Laing and Carwyn Jones, the Welsh Assembly Minister for Agriculture and Fisheries shared the ceremonial tasks, which included the dedication of the Isobel and Kirby Laing Laboratory, in effect the vessel's dry lab. With all the congratulations and backslapping behind us, we moved immediately on to the real business of science (the first cruise was mobilising whilst preparations for champagne bottle breaking and drinking were still underway). With spare bottles of bubbly still in the wet lab's huge 'science' fridge, the vessel sailed out of the Menai Strait to undertake its first cruise, a collaborative project between SOS, CEFAS and CCW.

Geophysical research work forming part of a collaborative project between SOS and Schlumberger Cambridge Research brought the SOS usage of the old *Prince Madog* to an end and provided early customers for the new vessel. The offshore field experiments of this project are an integral part of the research, which is looking at ways to improve the modelling of seismic (shear wave) velocities in near sea-floor sediments. The tests involve the use of a sled towed above the sea floor, behind which are dragged a string of very sensitive seismic receivers. Careful

deployment, operation and retrieval of the equipment is vital if a good quality dataset is to be acquired, and the SOS team, led by Dr Dei Huws, were within a matter of weeks carrying out the same operations on the two very different vessels – and what a contrast!

On the new vessel, deployment and retrieval proved much easier, not only compared with the old vessel but also in comparison with many other research vessels from which SOS geophysicists have worked in the past. The new vessel had the double benefit of a seemingly vast expanse of space on the aft deck and in the working labs, together with the expertise of the old vessel's crew who make up the core of new vessel's crew. The crew of the *Madog* are very aware of, and sympathetic to, the need for such care, and have always been resourceful in solving problems that may occur on the aft deck. 'We were also pleasantly surprised at the ability of the ship to steer a good course at low speed, typically less than two knots, in quite windy conditions and in unfavourable tidal streams' said Dr Huws. 'Overall, the new vessel is a huge improvement on her previous incarnation. Living and working conditions for the scientists are bordering on the luxurious, with plenty of cabin space, good food, ample working deck space and, to top it all, somewhere pleasant and comfortable to relax and socialise after you've finished the day's work'.

The ergonomic layout of the deck and laboratories paid similar dividends for Dr Mike Kaiser of SOS who undertook a series of cruises this summer, including surveys of fish communities on the Welsh offshore sand banks, managing to sample rapidly eight sites between Anglesey and the Gower Peninsula. 'I guess it's because I was one of the many SOS research staff who had an input into the design specification' said Dr Kaiser, 'but the state-of-the-art navigation systems onboard and the wet lab and aft deck arrangements mean that the vessel is ideal for undertaking extensive fisheries orientated surveys.' Dr Kaiser's research team also used the new *Prince Madog* to study essential fish habitat for cod, whiting and haddock in the northern Irish Sea. This programme used the new vessel's QTC sea-bed discrimination system to identify subtle differences in the sea-bed habitat which can be so vital for different fish types.

Many of today's leading marine scientists received their training at Menai Bridge as undergraduates or postgraduates and the role of the *Prince Madog* as a 'floating teaching laboratory' remains critical to its mission. One of the earliest cruises took Dr Colin Jago and groups of Geological Oceanography undergraduates out on a series of transects across the Irish Sea. The objectives of the teaching cruise were two-fold: to give undergraduates a realistic experience of working on an oceanographic research vessel and to carry out a scientific study of particular aspects of shelf sea processes. Both objectives required the to ship work round the clock for a week. In 2001, the sea conditions were unusually fair for the end of September and the work – requiring deployments of CTD, corers, and geophysical equipment – was accomplished without any difficulties. The new ship gains over the old one in many respects: better facilities, greater flexibility, more comfort. 'We really appreciated the space in the wet laboratory which provided plenty of room for several simultaneous activities' said Dr Jago. 'The dry laboratory with its extensive computing facilities is also light years away from the cramped conditions of the old ship. It was easy to demonstrate real time CTD data to the students, invaluable when comparing water column structures in the mixed and stratified regions of the Irish Sea. The catering and cabin facilities are also a huge improvement, a bit like comparing a 3-star hotel with a youth hostel.'

As for the old vessel, a stroke of the pen and liberal amounts of tippex across reams of official documentation transformed the old ship to the new. Sadly, we never achieved the classic photo opportunity of the new *Prince Madog* alongside the old, but anyone who knows the two vessels will not need a photographic reminder of the contrast between the two. Fond as we all were of the old *Prince Madog*, we are happiest with memories of the old and realities of the new: a state-of- the-art vessel to take SOS, VT and the wider UK marine science community into the future. The Prince is dead – long live the Prince!

Garry Reid, **Dei Huws** and **Mike Kaiser** are all at the School of Ocean Sciences, University of Wales, Menai Bridge.

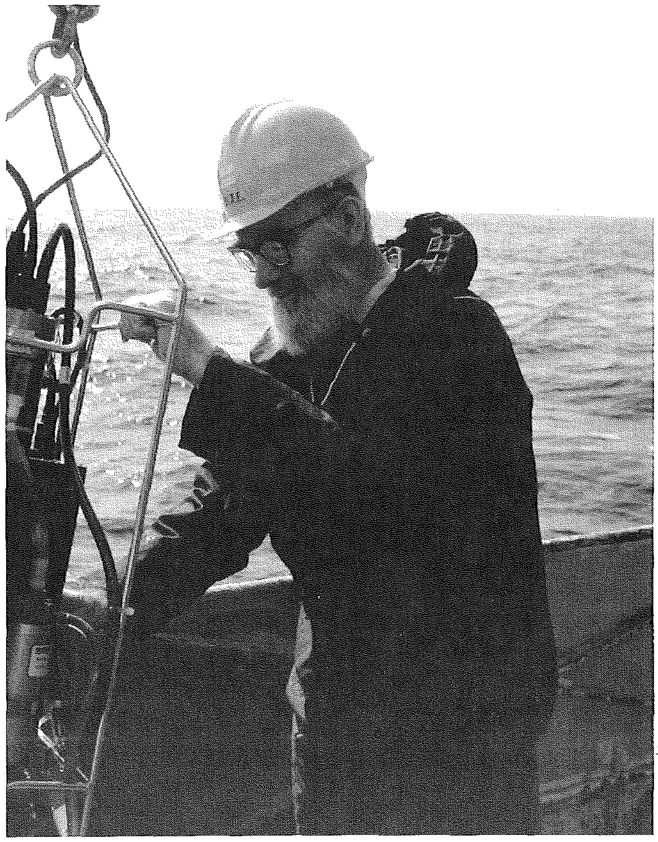
Website: http:/www.sos.bangor.ac.uk/madog/

David Ellett – the gentle Professor

David was born and brought up in Norfolk, completing his formal education at Great Yarmouth Grammar School in 1952 with A-levels in physics and geography. It is an enormous testament to the man's intelligence, dedication and scientific insight that despite these slender qualifications he rose to become a physical oceanographer of considerable international standing, whose meticulous work and deep insight commanded the highest respect amongst his peers. In some ways, he achieved a higher form of recognition than most: the automatic adoption of his name by the oceanographic community for the major hydrographic section that runs from Scotland to Rockall and beyond – the 'Ellett Line'.

David's final CTD cast from RRS* Challenger *in 1994

Photo: Martyn Harvey, SAMS



David James Ellett, born Great Yarmouth, Norfolk, 22 July 1934; died Oban, Argyll, 5 October 2001

David joined the UK Met. Office in October 1952, but transferred to MAFF's Fisheries Laboratory in Lowestoft in January 1954 because he had 'always wanted to do something connected with the sea'. His first job, working with Arthur Lee, foreshadowed the type of painstaking task that was typical of the rest of his working life – drawing up and checking the provisional mean monthly surface temperature and salinity charts for the North Atlantic from all available sources. Over the next decade or so, he absorbed and mastered the science (and art) of hydrography by participation in wide-ranging cruises to the Barents Sea, North Sea, Irish Sea, Atlantic, and further afield to the equatorial Indian Ocean. These cruises included, notably, the International Council for the Exploration of the Seas (ICES) Faroe–Iceland Overflow Experiment of 1958, marking the beginning of a long interest in these dense northern overflows which remain highly topical to this day. Spells as an oceanographic observer on both Irish and UK Weather Ships during this period marked the beginnings of his long interest and involvement with Ocean Weather Ships and their data.

The 1950s and 1960s saw the emergence of ocean variability as a major research theme, following Arthur Lee's pioneering work on the 'Warming in the North', when such a protracted wave of warmth passed though the Atlantic subpolar gyre as to influence the global mean temperature curve. David brought his key qualities of meticulous observation and interpretation to this crucial area of study and, with Arthur Lee, published in the mid-1960s important, lucid and pioneering new works on the role of the various overflows in the formation of the Atlantic's deep water masses. These seminal works are still in use today.

The Rockall Trough, the deep channel that lies immediately to the west of the Scottish shelf, was to be David's main working area and interest to the end of his career. Right up until his official retirement in 1994, he thoroughly explored these waters, deploying the first long-term current meter moorings in the Trough in 1975, planning then participating in the JASIN Air–Sea Interaction Experiment in 1978, recovering the first unequivocal evidence of a Slope Current west of Scotland in 1979, and making the first direct measurements of overflow crossing the Wyville–Thomson Ridge in 1987–88. Many campaigns led to more than 80 publications and working visits to sister institutions in Germany, Japan and the USA. Nor did this work stop at retirement. As a SAMS Honorary Fellow, David continued his patient elucidation of the long-term trends that awaited discovery in the data from his many cruises, until intractable ill health made further study impossible.

David's collaboration with Dunstaffnage began when he sailed with the then Scottish Marine Biological Association aboard RRS *Challenger* for the second ICES Overflow Survey in 1973. This led to his secondment in 1975, and ultimately to his transfer to Oban. Here, with Roy Bowers, he quickly built up a respected Marine Physics Group that combined intellectual acumen with formidable success in winning lucrative contracts from the likes of MAFF and the Department of Energy. His attentive mentoring of younger members of staff, coupled with his quiet manner and donnish appearance, earned him the affectionate nickname of 'Professor'. But there was steel behind the gentle exterior, and he was swift, sure and deadly in his many actions to deal with unfairness and intransigence in officialdom.

Despite the honours bestowed on him both by ICES and the Society for Underwater Technology, one suspects that David would have derived greatest satisfaction from being designated a Data Quality Evaluator for the World Ocean Circulation Experiment (WOCE), from the adoption, both as a name and as a landmark concept, of the 'Ellett Line' by the community, and from the use of its time-series to record the arrival-time of particular vintages of Labrador Sea Water, thus establishing for the first time their trans-ocean spreading rates. As he would happily confess he was first and foremost a 'water mass man'.

David married Sally in Beccles, Suffolk in 1963, and they had one son, Tom, in 1969. Fittingly, his wish to have his ashes scattered near Rockall was fulfilled on 4 November 2001, when the ship's company of RRS *Discovery* gathered on the after deck for a ceremony led by two of David's oldest colleagues, Captain Robin Plumley and Dr Raymond Pollard. To the sound of a long blast on the ship's whistle, David, that gentlest of gentlemen, set forth on his longest voyage, across the Ellett Line.

Dave Meldrum and **Colin Griffiths**, SAMS, Oban

Bob Dickson, CEFAS, Lowestoft.

Are MPAs on the High Seas practicable?

As outlined in the article by Hjalmar Thiel and Tony Koslow in a previous issue of *Ocean Challenge* (1999, Vol. 9, No. 2, pp.14–15), marine protected areas (MPAs) have so far all been established in either territorial seas (within 12 n.m. of the coast) or EEZs (within 200 n.m. of the coast). The scientific requirements and legal aspects of establishing MPAs in high seas areas – i.e. outside the limits of jurisdiction of any individual state, were explored at a workshop held on Germany's Isle of Viln in the Baltic, late February/early March last year.*

Participants at the workshop were mostly experts on international law, nature conservation and marine ecology, and the aim was to produce a document that would be forwarded to the UN to stimulate discussion on conservation in high seas areas at the forthcoming Informal Consultative Process on Oceans and the Law of the Sea for 2002 (UNICPOLOS 2002) – these workshops are annual events.

The interpretation of international laws is still a matter for discussion and debate, but many delegates considered that high seas MPAs could be established under UNCLOS, in certain circumstances. However, a central problem with setting up high seas MPAs is that such areas could be interpreted as infringing the UNCLOS concept of 'freedom of the high seas'. Up to a point, this is a valid objection, as within an MPA there could be no fishing, sea-bed mining (for polymetallic nodules or metal ores in stockworks below hydrothermal vent systems), or waste disposal. The question arises, therefore, whether it is lawful for a group of countries to declare a high seas MPA which would be binding on other states. Indeed, it seemed to be agreed that the rules governing access to a particular high seas MPA might be legally binding only on those states setting it up in the first place.

The workshop identified seven examples of environments, ecosystems and animal groups in the high seas which they considered worthy of consideration for the establishment of MPAs. They are listed below in no particular order:

1. Ecosystems of seamounts;
2. Cold-water coral communities;
3. Hydrothermal vents and their ecosystems
4. Deep-sea fish
5. Seabirds
6. Crustaceans
7. Unique scientific reference areas (analogous to SSIs on land)

Items 1–3 were discussed in the earlier *Ocean Challenge* article. Items 4 to 6 present considerable problems from the point of view of setting up areas for their protection. Almost by definition, marine animals regularly cross artifically drawn boundaries – including legal ones! In such cases, the delineation of MPAs should perhaps focus on breeding/spawning/nursery areas for juveniles.

In the case of seabirds, albatrosses and petrels are particularly threatened by interactions with long-line fisheries, but as they are so wide-ranging it is unlikely that individual MPAs could do much to protect them; and the problem over protection of deep-sea fishes may solve itself, when fishing yields get too low for them to be economically viable. The problems of protecting whales, however, are perhaps the most intractable of all.

The importance of item 7 (i.e. areas that have been investigated in detail and provided both spatial and temporal reference material and data) should be self-evident to all. We lack long time-series and observations of high seas areas, partly because our scientific predecessors could not have anticipated the variability we now know to characterise the deep-sea environment, nor the impacts of human activities on that environment. It is essential that we now think ahead, and establish a compilation of basic reference data that our successors can use. Long-term measurements and reference material will be of utmost importance for further research into climate change and its effects on global ecosystems.

A good example of a potential high seas MPA is the European Deep-Sea Transect, which extends south-westwards across the Porcupine Abyssal Plain from the Porcupine Sea Bight, and lies outside the EEZ of any European state. Enormous technical, scientific and financial investment has gone into research in this region, by Britain, Germany, and other EU countries, to gather basic environmental and ecological information. It encompasses the Porcupine Abyssal Plain Station, 48°N, 16°W, where UK and European (MAST-funded) have concentrated much of their activity in recent years, and the BIOTRANS/BOI-C-FLUX study site at 47°N, 20°W where long-term ecological investigations have been taking place since 1984, and which became the central JGOFS station in 1989. Any major disturbance of this long-term research area would lead to massive and irretrievable loss of scientific reference material.

Eds

*Its proceedings, *Managing Risks to Biodiversity and the Environment on the High Seas, Including Tools such as Marine Protected Areas – Scientific and Legal Aspects* (eds. Hjalmar Thiel and J. Anthony Koslow), are published by the Bundesamt für Naturschutz (BfN), and may be ordered from the International Academy for Nature Conservation, Isle of Vilm, 18581 Putbus, Germany; Email: bfn.ina.vilm@t-online.de; Download: www.bfn.de/09/090203.htm for the World Ocean Circulation Experiment (WOCE), from the adoption, both as a name and as a landmark concept, of the 'Ellett Line' by the community, and from the use of its time-series to record the arrival-time of particular vintages of Labrador Sea Water, thus establishing for the first time their trans-ocean spreading rates. As he would happily confess he was first and foremost a 'water mass man'.

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Making the Most of Marine Data

David Pugh

> *"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."*
>
> Lord Kelvin, 1883

Measurements at sea are the basis of marine science. Vast quantities of data have accumulated over the past 100 years, and the rate of accumulation is accelerating rapidly. It is no longer fashionable to think about central national databases which hold all the information collected. Instead, networks are being set up to help scientists and other users locate and access what is available from a wide range of sources. The Government's Inter-Agency Committee on Marine Science and Technology (IACMST) supports the UK Marine Environmental Data Co-ordination Centre at the British Oceanographic Data Centre (BODC). Scientists are encouraged to use the Centre to find the data they need for their research.

Working with other people's data is never easy. It can be hard to find, difficult to access, and of uncertain quality. No doubt about it – we should all go out and make our own measurements.

But, before you do go and collect your own data, think hard about it. Scientific careers are too short to be spent collecting all the data we need (ask any Ph.D student); special skills are required; and none of us will live long enough to collect the data needed for studies on long-term change. Remember also that whereas measurements at sea are expensive, once other people have used data for their own science, they are often willing to make it available to other scientists for nothing.

The NERC Marine Information and Advisory Service once used a slogan: 'we supply data of high quality; without delay; and at low cost: choose any two.' One had to be sacrificed, but which one? But even before making this choice, the first step is to know who has the marine data you might need.

Who collects marine data?

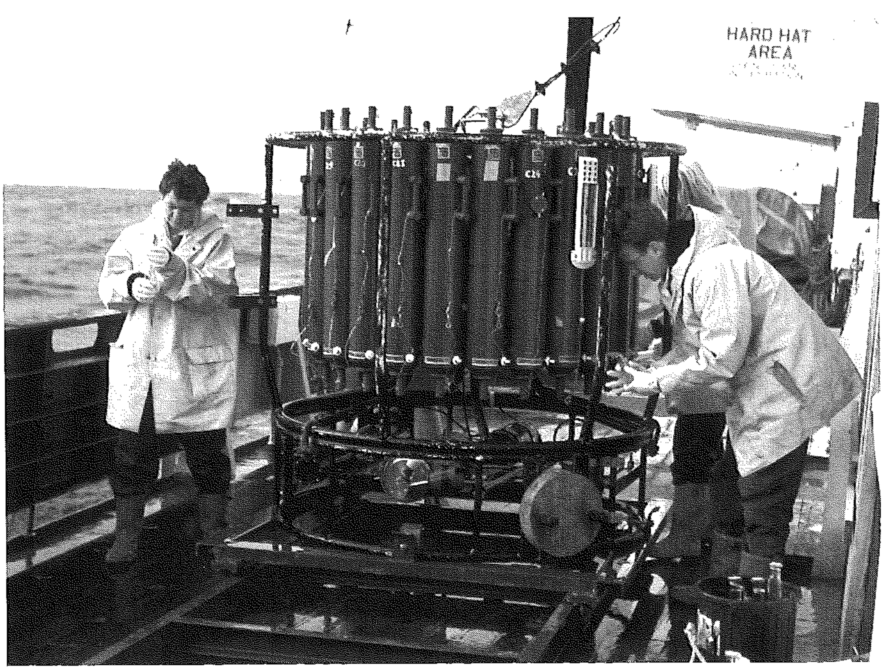
The Government (that is you, me and all the other taxpayers) funds most of the marine measurements made around the British Isles. The main source of data is information collected by Government Departments and Agencies, although some is funded indirectly through research grants to universities. The Ministry of Defence collects data for military operations, and the Meteorological Office accumulates data for both military and non-military forecasting. The Environment Agency monitors coastal water quality. Similarly, the Scottish Office and DEFRA (formerly MAFF) laboratories in Aberdeen and Lowestoft collect data on coastal water quality and movements, as well as information on fish stocks and catches.

Most scientific data-collection is funded through the Research Councils, mainly by NERC. NERC scientists in laboratories in Plymouth, Southampton, Birkenhead and Oban collect, process and eventually archive data with the BODC at the Proudman Oceanographic Laboratory, Birkenhead. University scientists funded by NERC grants are also expected to archive their data with the BODC. University scientists collect data for a wide range of experiments, but few have either the incentive or the resources to store and maintain data in the long term.

In economic terms, the value of data is only realized when it is used, so it is difficult to say how much marine data is worth. However, we can make a rough estimate of the cost of collecting some of the data already held by BODC. Taking just current meter data as an example, BODC holds around 10 000 station months of data. Even at a very conservative £5k per month, this represents a national asset of more than £50 million. Similar rough estimates could be made for temperature, salinity and sea-level data. The cost of collecting the data held by BODC alone is probably well in excess of £100 million. Of course, these estimated costs hide a more complicated truth. For example, if we are trying to understand the long-term changes of the marine environment, then the potential value of older data increases rapidly as time passes.

Some of the data collected by scientists at sea is in the form of geological or biological specimens. Like digital data, these are widely distributed. The Natural History Museum curates biological specimens from as far back as the nineteenth century *Challenger* Expedition and earlier. Cores are held at the British Ocean Sediment Core Repository (BOSCOR) funded

Figure 1 *Marine data takes many forms. This multi-sampler CTD measures temperature and conductivity (for salinity) and collects water samples at known depths.*



"... but by measure
and number
and weight,
thou didst order all things."
From *The Apocrypha, Wisdom of Solomon*

by NERC at the Southampton Oceanography Centre. A special one-day workshop was held at the National History Museum in April 2000, under the auspices of IACMST, to take an overview of the challenges and opportunities of managing and using marine specimen data (see *Ocean Challenge*, Vol.10, No.3). The conclusions have been published as an IACMST Information Document, which makes a strong case for the importance of maintaining and enhancing sample collections.

In July 2000, IACMST held an Open Forum on the value and uses of marine data. These uses include fisheries management, monitoring of water quality, port operations, planning coastal defences against flooding, as well as a wide range of local and global research programmes. Although the initial funding for collecting the data has been justified against the immediate or first application, participants at the workshop emphasized that original data can and should be made available for further applications. Several commercial organizations are now increasingly active players in the data-collection and management game. With proper safeguards, they too may be willing to make their data available for subsequent use. Compared with the initial costs, all of these subsequent uses of data are virtually free, and so represent tremendous additional value for the original public investment. A full report of the IACMST Data Open Forum is available through the website: http://www.marine.gov.uk

It is clear that the taxpayer will get the best value for money spent on marine observations if they are used as many times as possible, scientifically as well as in other applications. The difficulties of encouraging this wider and freer availability are well known, but they can be overcome.

***Stop Press** From the end of May, the Director of BODC will be Dr Juan Brown, currently at CEFAS. Another new member of staff, not shown here, is Rob Lowry.

Figure 2 *Ben, Polly and Lesley pictured outside Bidston Observatory with Meirion Jones, Director of the British Oceanographic Data Centre which hosts the IACMST data co-ordination work.*

Who's Who in UK Marine Data Co-ordination?

Lesley Rickards

Studied Environmental Sciences at East Anglia and then completed a Ph.D in Geophysical Fluid Dynamics at Newcastle. Lesley has been Chair of the ICES Working Group on Marine Data-Management. She is the nominated UK Marine Data Co-ordinator.

Mike Cowling

Professor of Marine Technology at the University of Glasgow, Mike is an Independent Member of IACMST and Chairman of the Marine Environmental Data Action Group of data suppliers and users, which facilitates the work of Lesley and her colleagues.

Meirion Jones*

Director of the British Oceanographic Data Centre at the NERC Proudman Oceanographic Laboratory, Merseyside. Meirion is well known nationally and internationally as a leader in the science of management of ocean data and its applications.

Polly Hadziabdic

Polly has been with BODC for more than 10 years. She has a background in biological oceanography and experience in all aspects of data-management.

Ben Moate

The newest member of the team, Ben joined in October 2000 after post-graduate studies in Bangor. He has special responsibilities for information system development.

A national programme

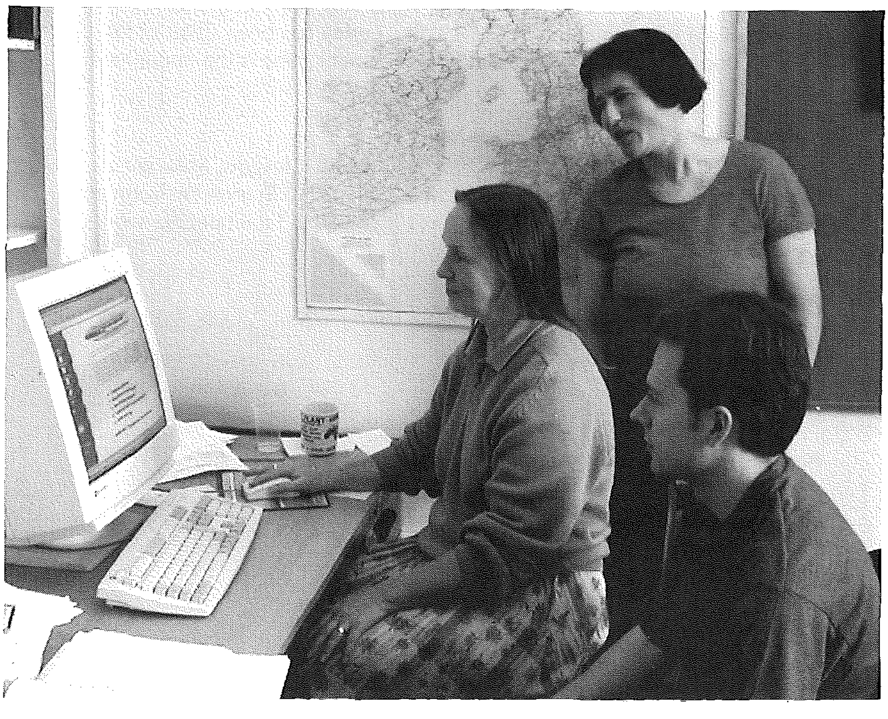
In 1996, a small IACMST group chaired by Professor Ernest Naylor recommended that the UK should have a National Marine Environmental Data Co-ordinator, assisted by a group of representatives of the various data-holders and users. IACMST accepted an offer from the BODC at the Proudman Oceanographic Laboratory for Dr Lesley Rickards to serve as the National Data Co-ordinator. After a successful test period, the arrangement has been set on a more permanent basis. Lesley is supported by Polly Hadziabdic and Ben Moate. Both Lesley and Polly have long experience of working with marine scientists and data, nationally and internationally. Ben has recently come from the School of Ocean Sciences in Bangor.

The data project is a partnership among a number of Government Departments and Agencies. It is being co-funded by NERC, DEFRA, the Fisheries Research Services (an Agency of the Scottish Executive), the Environment Agency, the Hydrographic Office, the Meteorological Office, and the Defence Evaluation and Research Agency. The project operates in the form of a distributed network among the Marine Environmental Data Managers in the various Agencies, with Lesley and her colleagues providing the focus. The co-ordination includes developing and maintaining inventories of data; developing data management guidelines and mechanisms for exchange; and raising the visibility of marine environmental data activities. The network aims to improve co-ordination and access to the multitude of datasets collected both offshore and in the coastal zone.

Lesley and her colleagues advise people looking for data about where it can be found. BODC itself holds only a small fraction of what is available. This wide distribution results from the great diversity of data types and organizations making and using marine observations. This is a natural and proper arrangement. Better information on what data is collected and by whom, together with easier access, are the most effective ways of maximizing its use. The Data Co-ordinator is guided and assisted by an Action Group of Government and commercial data managers and users. Commercial partners include the UKOOA and the Marine Information Council. The views of non-commercial users are represented by the Marine Conservation Society. The Action Group meets at least twice a year under the independent chairmanship of Professor Mike Cowling, Glasgow University. Between meetings, the Co-ordinator, participating Departments and Professor Cowling work together on agreed plans.

You can access the Marine Environmental Data Co-ordinator through the website (http://www.oceannet.org/), or from the IACMST home pages.

Figure 3 *Lesley, Polly and Ben examine new sources of data on the Internet. It is thirsty work!*



The international dimension

The British Oceanographic Data Centre has a very high international reputation, both for its lead in the technology of data-management and exchange, and for providing a data focus for major international programmes. The excellence of BODC is largely due to the leadership provided by Dr Meirion Jones, its Director. Through international agreements and collaboration in programmes funded by the European Union, Lesley Rickards, as Data Co-ordinator, also has access to marine data held by other centres worldwide. Global programmes such as studies of climate change, need global datasets. British data is exchanged as part of the international network, for the benefit of scientists world wide. In turn, British scientists are encouraged to use the Data Co-ordinator network to get data from other countries for their own work, whether or not they are part of formal international programmes. Lesley has also worked on an inventory of European marine data (the European Directory of Marine Environmental Data – EDMED) which can be searched through the SEA-SEARCH web portal. There are international agreements to encourage the exchange of data, either free or at marginal cost.

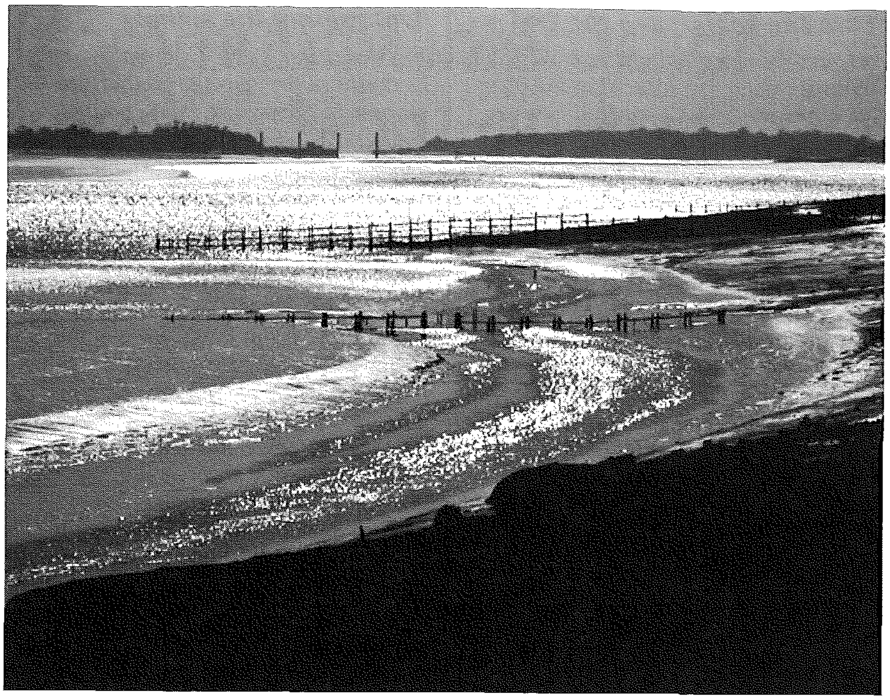
Should data be free to users?

In theory, yes, although in practice there may be constraints. Of course, there is no such thing as free data. The real question to ask is: who pays? As we have seen, in general, marine data-collection has already been paid for and justified as part of its primary purpose. Usually, data-gatherers are happy for their data to be used subsequently and distributed for little or no charge. The good news is that for scientific research and education, all Government Departments and Agencies are prepared to make data available free, without any attempt to recover the costs of the original measurements. Some will expect to

Lewis was looking decidedly impatient. "Sir! Could we please get ... a few simple facts established?"

From

Inspector Morse: Death is Now My Neighbour, *by permission of Colin Dexter*



be paid for the direct costs of preparing and sending the data but in many cases, for small requests, there may be no charge whatsoever.

For commercial applications the situation can be more complicated. During the 1980s many governments, including the UK, took the view that all data (including marine data) collected at public expense was a saleable asset. Any money recovered from these sales could be set against the cost of continuing the measurement programmes. Other governments, notably the United States, considered that the best public interest lay in maximizing the use of data by making it available for all applications, including commercial work, at marginal costs. Until recently several UK Government Agencies, such as the Met. Office, were required to recover some data-collection costs from commercial users. NERC policy has been to charge non-scientific users 'what the market will bear', without any viable means of identifying or assessing that larger market, which in any case does not exist in a true commercially competitive sense.

The UK Treasury has recently worked with various Government Departments to change the data-charging policy. In future, data collected and subject to Crown Copyright will be available much more easily. The Government wants commercial organizations to access Government information more easily and at a fair price. The reason for this very significant change is to allow them to

Figure 4 *The coastal zone is an area of intense natural and human activity. BODC have been working with Glasgow University to prepare a directory of coastal datasets that will soon be accessible on the web.*

re-package and re-use data to develop innovative products and services, and hence to boost the UK Knowledge Economy.

This fundamental change of Government policy at present excludes Trading Funds such as the Met Office and the Hydrographic Office. The Research Councils, which have their own copyright, are also excluded, but they usually seek to follow central Government policy. The details of the new arrangements will take some time to work through, and there are still many uncertainties, including what exactly is meant by basic information and data, as opposed to value-added products.

Internationally, the Intergovernmental Oceanographic Commission is considering whether it should approve a new policy for marine data exchange, particularly in relation to the Global Ocean Observing System (GOOS) and other IOC Programmes. There are still difficulties inhibiting the free exchange of data for commercial applications, which will not be solved easily. However, among data managers there is a growing conviction that through wide use of the Internet, rapid, easy, and perhaps free data will inevitably become standard procedure. For scientific use these conditions are already agreed.

"Indeed, I think that as we go on piling measurements upon measurements, and making one instrument after another more and more perfect to extend our knowledge of material things, the sea will always continue to escape us."

Hillaire Belloc,
Cruise of the Nona

Conclusion

Scientists and governments are agreed that the best overall value from the considerable cost of collecting marine data is gained by making it freely available for subsequent users. Lesley Rickards and her colleagues provide a focus for UK marine scientists to access data both in British waters and worldwide. If you want them to help you, then visit the OceanNET website, or contact them directly. Remember also that sharing data is a two-way process. If you have something to offer, please talk to Lesley to see how your data can be more widely used.

The three basic requirements remain: we all want data of high quality, free, and immediately. Usually only two of these can be satisfied, but soon we hope to be able to offer all three!

David Pugh is Secretary of the Government's Inter-Agency Committee on Marine Science and Technology.

Website: http://www.marine.gov.uk

The SEA-SEARCH website is: http://www.sea-search.net/

"A scientific attack on the limits of predictability of the ocean can only be mounted after we have gathered sufficient data."

Professor John Woods,
IOC Brunn Memorial Lecture,
1999

NOW There's a FUNNY THING...

Coal is not a marine resource

Twice recently I have been informed via the printed word that some of the CO_2 incorporated into living material at the sea surface and then sinking to the sea-bed ends up in deposits of coal and oil. Oil yes, coal no: coal is formed from the remains of land plants, albeit mostly in swampy deltaic environments. The first time I read this it was in a *Guardian* feature on Antarctic seas, written by a marine scientist at BAS, and I can only conclude that the mistake originated in the editorial office, not with the author.

The second time I read about coal in the deep sea was in the glossy coffee-table book that accompanies the stunningly beautiful 'Blue Planet' TV series, and this time there is less excuse. The photos are every bit as lovely as those in the programmes (except they don't move). But I must give it as my opinion that the accompanying text should be accompanied by a scientific health warning, for alas, it is full of errors and misstatements. Do not be surprised if bedazzled readers of this book tell you, for example, that there is no oxygen in the deep sea, that the seas are always calmer during neap tides, that surface seawater at the poles is the saltiest in the ocean, that all estuaries have narrow mouths, that seaweeds are 'creatures', or that the Tropics are at 30°. I suspect also that a whiff of the '4-degree fallacy' (i.e. that seawater reaches maximum density at 4°C) may permeate the book.

It isn't really funny at all, but rather sad, that such a beautiful book should have been spoilt because the words (and some of the diagrams) weren't properly scrutinised prior to publication, by persons knowledgable about the marine environment. Now it's probably too late, because by their very nature TV series are ephemeral, and the shelf life of the book is not likely to be more than a couple of years.

Scare the seals, save the cod

Well, it's more humane than culling them (see page 4). Attaching inflatable sharks to trawl nets could deter seals from getting in amongst the catch, though it won't prevent them decimating any shoals they find for themselves. Sooner rather than later, however, the seals will get used to the inflatables, and may even come to recognise them as a sign of food, rather as birds come and perch on scarecrows in fields. An earlier experiment with recordings of killer whales was initially successful, but ended up by attracting seals to the nets rather than scaring them off.

A more sophisticated device being pioneered by fish-farmers in Louisiana, to deter pelicans and other fish-eating birds, is a robot alligator, which can be controlled or programmed to move towards the birds and scare them off. Whether this can be extended to the development of robotic sharks to deter seals in the open sea is more problematic, not to say a great deal more costly, in both money and time – such devices could require electronics of the kind so far only found in *Autosub* and could take years and £millions to perfect. By then, though, there may not be many fish left, either for the seals or for us.

Squaring the circle?

Last year some newspapers reported on a puzzling allegation that 'mending the ozone hole' would all but cut off uv radiation and drastically slow the photolytic dissociation of atmospheric water vapour. The outcome would be a shortage of hydroxyl (OH^-) radicals which 'cleanse the atmosphere by eliminating harmful gases'. There is a curious paradox here: presumably before the advent of ozone-destroying CFCs in about the 1950s, i.e. before the hole in the ozone layer even began to form, there were plenty of hydroxyl radicals to cleanse the atmosphere. Furthermore, we are repeatedly informed these days that, on the one hand, air and water quality has greatly improved in recent decades, and, on the other, the bigger the ozone hole, the greater the danger to biodiversity and the more likely humans are to contract skin cancer. So how come closing the ozone hole may be more dangerous than leaving it open? Was the Montreal Protocol on CFCs to no purpose? Or is atmospheric pollution in fact more pervasive – but less visible – than we've been led to believe?

Untangling the signals

Not long ago I saw an entertaining account of an inspiration that came to Robert Matthews of the *Sunday Telegraph*, while in his bath. In brief: Global warming will cause the oceanic water column to expand, which should make the Earth ever so slightly more elliptical because 'the centrifugal force of the Earth's rotation is greatest at the Equator'. In other words, the Earth will get a bit fatter at the Equator than at the poles, and as it does so, conservation of angular momentum requires its rate of rotation to decrease – again, ever so slightly – and Matthews suggests this might be a way to monitor the progress of global warming. However, it is doubtful whether even the most sensitive instruments could reliably detect what must be nanosecond (if not picosecond) changes over a year. There's another snag too: careful analysis of a palaeoclimate record from the eastern Mediterranean has led to the conclusion that there has been 'an average acceleration of the Earth's rotation overt the past 3 million years'. I do not pretend to understand the science behind this conclusion (*Nature*, **409**, 1029–33), but if the Earth really has been rotating faster in (geologically) recent times, it will surely be much more difficult to detect any slow-down attributable to global warming.

All shook up

Believers in the Loch Ness monster may have been disturbed by the recent proposition, reported in a couple of broadsheets, that 'splashes and commotion of the water' in Loch Ness are not caused by a large living fossil, but by earthquakes. Loch Ness lies on the line of the Great Glen Fault, and it was proposed at the Earth Systems Processes meeting in Edinburgh last June, that the water is shaken up by tremors resulting from small movements on the fault.

Seismologists familiar with the region claim there's no evidence that the Great Glen Fault is still active; even if it were, is it likely that tremors would be centred on Loch Ness? And then there are all those photographs and eye-witness accounts depicting and describing a large animal, which has eluded all attempts at capture.

All the same, what *does* causes the splashing and commotion? One day, somebody will find out, and another bit of magic will be lost. Pity.

John Wright

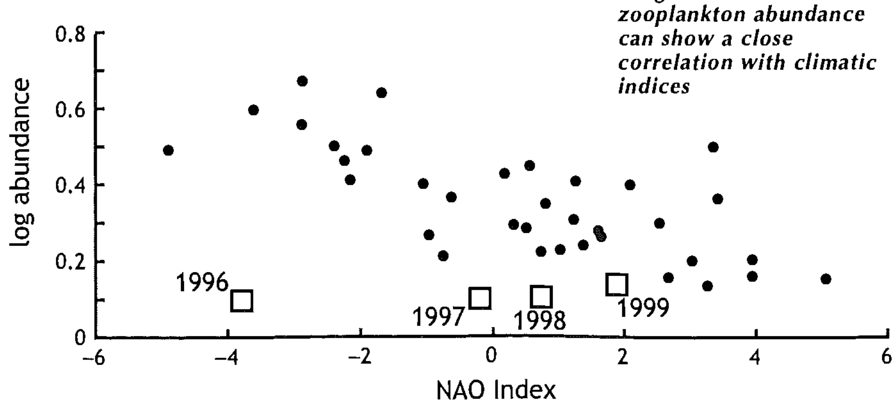
Community interactions – amongst zooplankton, and amongst researchers

Phil Williamson

Fish can swim much faster than ocean currents. Phytoplankton and bacterioplankton are able to reproduce very rapidly when conditions are favourable. But most zooplankton can do neither, and are planktonic for all their life-cycles. How then do they maintain their populations, with much the same basin-scale distribution patterns from year to year?

The answer seems to be 'with difficulty', since large interannual changes in zooplankton abundance and species composition have been found to occur wherever long-term data have been collected by, for example, the Continuous Plankton Recorder (CPR) survey in the North Atlantic, and other biological monitoring programmes off California and in the Southern Ocean. It is hardly surprising that correlations have been sought – and found (Figure 1, below) – between such population variability and climatic factors, such as the North Atlantic Oscillation, a basin-scale atmospheric alteration of the pressure field between the Azores high pressure cell and the Icelandic low. But very little is known about the causal mechanisms involved: whether the linkage between physical processes and zooplankton abundance is mostly mediated directly (via transport to suitable/unsuitable locations) or indirectly, for example by nutrients and light (affecting the quantity and quality of their food, hence growth and breeding) or by effects on predators and pathogens (affecting survival).

Figure 1 *The annual abundance of the copepod* Calanus finmarchicus *in North Atlantic CPR samples plotted against the North Atlantic Oscillation Index, 1962–1999. Recent data points indicate that a regime shift may have occurred in 1995/96.*
(Data from SAHFOS)



Long-term records of zooplankton abundance can show a close correlation with climatic indices

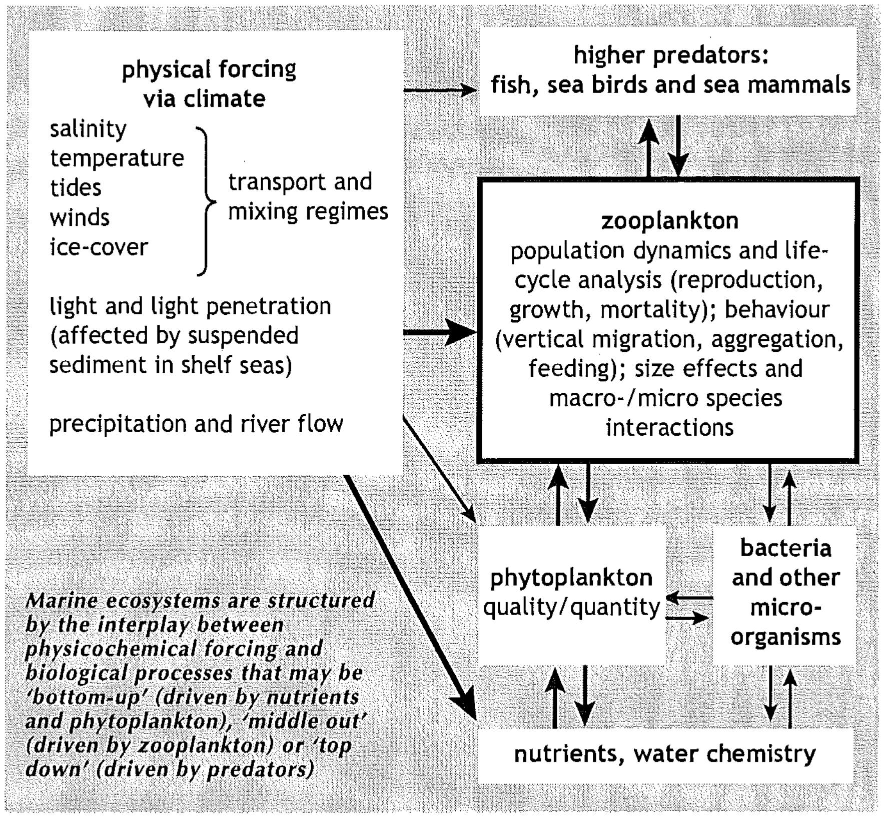


Figure 2 *Direct and indirect linkages between physical processes, zooplankton and other components of pelagic ecosystems.*

Almost certainly all these factors are involved to some degree (Figure 2, above), with the combination of interactions (and sensitivity of component relationships) varying with species, season and geography. Nevertheless, it should be possible to develop numerical models of the key processes, to give some predictability of zooplankton population responses to environmental change. This is more than just an academic challenge. The third IPCC assessment report concludes that human-driven global warming is probably already underway, and that major climatic changes can be expected over the next century. Climate and ocean circulation patterns are very closely linked, hence climate change will have profound consequences for zooplankton. Increased global temperatures *could* result in regional increases in zooplankton abundance, but overall that seems unlikely: stronger stratification in tropical oceans generally results in lower production by phytoplankton and zooplankton, and at higher trophic levels.

Whilst we do not feed on zooplankton, most fish do. The global fish harvest (of around 90 million tonnes per year) is already in a precarious state, with most stocks considered to be overexploited. Fishery management policies are at present primarily based on single-stock assessments of adult biomass and fishing mortality; however, such analyses do now include application

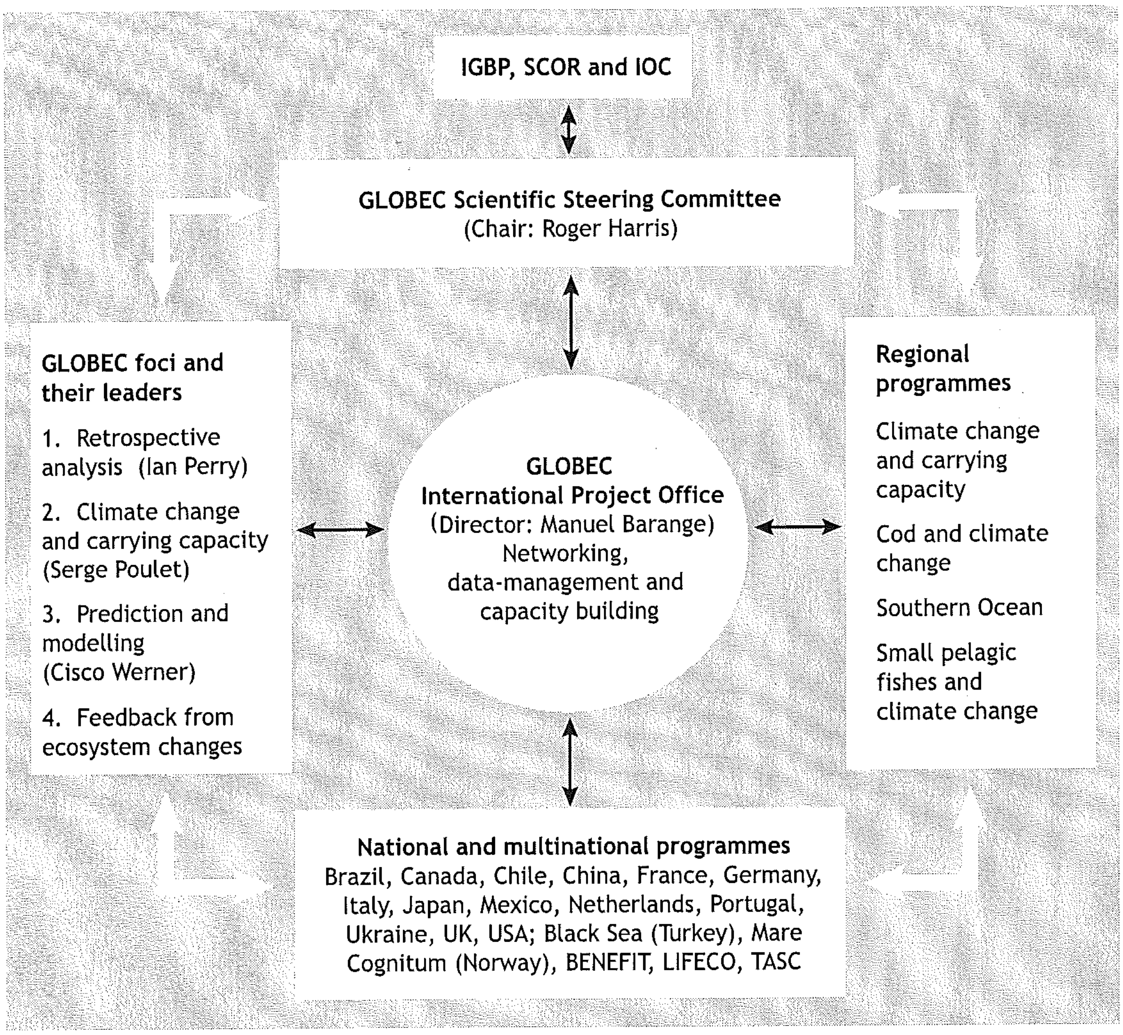


Figure 3 *Structure of the Global Ocean Ecosystem Dynamics (GLOBEC) project. The International Project Office (IPO) is hosted at Plymouth Marine Laboratory.*

GLOBEC activities can also be considered as a function of processes that are 'bottom up' (researchers in national programmes), 'middle out' (IPO-led initiatives and Working Groups) and 'top down' (Steering Committee and sponsoring organizations) – with global change providing the overall forcing

of the precautionary principle – and it would be possible to include consideration of wider ecosystem behaviour, if that were known.

The Global Ocean Ecosystem Dynamics project (GLOBEC) provides the international framework to achieve scientific progress in this area, with the overall aim of 'advancing our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing, so that a capability can be developed to forecast the responses of the marine ecosystem to global change'.

Originally developed by SCOR (the Scientific Committee on Oceanic Research) and the IOC (the Intergovernmental Oceanographic Commission), GLOBEC became a core project of IGBP (International Geosphere–Biosphere Programme) in 1995. It is now co-sponsored by those three bodies, with regional programmes under the auspices of ICES (International Council for the Exploration of the Sea) and PICES (North Pacific Marine Science Organization). Such a range of organizations with interests in GLOBEC does not, unfortunately, produce an equivalent multiplicity of funding sources for research. Instead, most scientific effort is financially supported on a national basis – whilst the international project office serves as the communications hub for GLOBEC activities (Figure 3), catalysing the advancement of knowledge through publications, coordination and planning meetings, and data-exchange.

There are now around twenty national GLOBEC programmes, some of which are very well-established (e.g. US GLOBEC, with two components, concentrating on Georges Bank and the north-east Pacific). The main UK contribution is the NERC Marine Productivity thematic programme, which helps support the GLOBEC International Project Office as well as bringing together the national research efforts of university groups, fishery research bodies and NERC laboratories, to address the following questions:

- How are basin-scale distributions of populations of different species of zooplankton maintained?
- How do zooplankton species respond to large-scale changes in ocean circulation, driven by atmospheric changes?
- What are the impacts of basin-scale physical changes on secondary production in shelf seas?

NERC funding for Marine Productivity has been provided in two tranches. During Phase 1 (£1.5m; 2000–02), fifteen projects, mostly involving shelf-sea work, received support. Thus the factors structuring community composition in the relatively well-described Irish Sea are being studied using laboratory experiments, model inter-comparisons, fishery-based field surveys and remote-sensing analyses – with new insights already obtained regarding the role of microzooplankton in energy flows, and the effects of food quality (N-poor versus N-rich) on copepod growth rates. In addition, analysis of flowmeter data from instrumented CPR deployments (since 1995) has made it possible to convert historical zooplankton abundance data (since

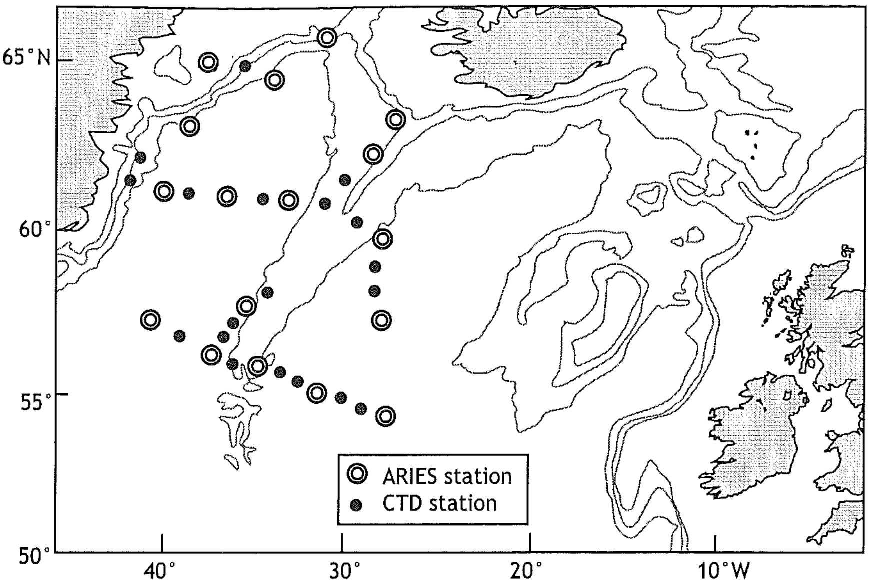


Figure 4 *Sampling stations for the first Marine Productivity research cruise, 1 Nov.–18 Dec. 2001. ARIES = Auto-sampling and Recording Instrumented Environmental Sampling System for 'depth-discriminated' zooplankton collection. Winter conditions are thought to have a crucial influence on the year-to-year variability of zooplankton populations. Large-scale, full-depth surveys repeated over a full annual cycle are needed to investigate such effects.*

1948) into numbers per cubic metre, confirming the validity of systematic trends and climatic correlations. For the North Sea, it has been found that resident species and Atlantic species show different long-term trends, and that annual variability in advection (i.e. zooplankton populations being redistributed by currents) is more important than stratification effects (e.g. when the seasonal thermocline becomes established) in determining the observed fluctuations of the copepod *Calanus finmarchicus.*

Phase 2 of the Marine Productivity programme (£4.6m, 2001–05) is directed at the open North Atlantic, with eleven projects – and four research cruises – investigating the relationship between oceanic circulation and the structure of the pelagic food web. Effort is focussed on the life-cycle dynamics and demography of key zooplankton species. These include *C. finmarchicus,* since it is the favoured food for many commercially important fish, and it occurs in high numbers over large areas (depth-integrated densities of 60 000 per m^2, making up 70–80% of zooplankton biomass in the northern North Atlantic). During spring and summer, when phytoplankton food is plentiful, the growth and reproduction of *C. finmarchicus* is relatively rapid; however, a different survival strategy is needed for other times of year, and the pre-adult stage (fifth copepodite) spends around six months in diapause (i.e. a resting state), over-wintering at depths of 1–3 km.

Two EU-supported projects (ICOS and TASC) have begun the study of factors affecting the distribution and abundance of *C. finmarchicus* in the waters between Scotland, Norway and Iceland. The Marine Productivity programme is extending this coverage to the Irminger Sea, to the south-east of Greenland (Figure 4). It will also investigate other important components of the ecosystem, including the euphausiids *Meganyctiphanes norvegica* and *Thysanoessa longicaudata* (predators on *Calanus*), and *Oithona* species (potential prey for *Calanus* adults, and/or predators on their eggs). High-resolution measurements and modelling of water body movements will be used, in addition to molecular techniques for taxonomic analyses of *Calanus* larval stages, biochemical and isotopic studies for elucidating feeding pathways, and genetic studies for testing whether physical regimes can isolate (or unify) populations.

Similar studies on key zooplankton species in an environmental context are being planned by Canada and the US for the Labrador Sea, linking to their existing national GLOBEC programmes. This basin-wide approach for the North Atlantic as a whole offers the exciting possibility that a predictive understanding of marine ecosystem behaviour can be gained over the crucial range of ecological scales, covering not only species' life cycles and interactions, but also the physical factors operating at the regional (and global) level.

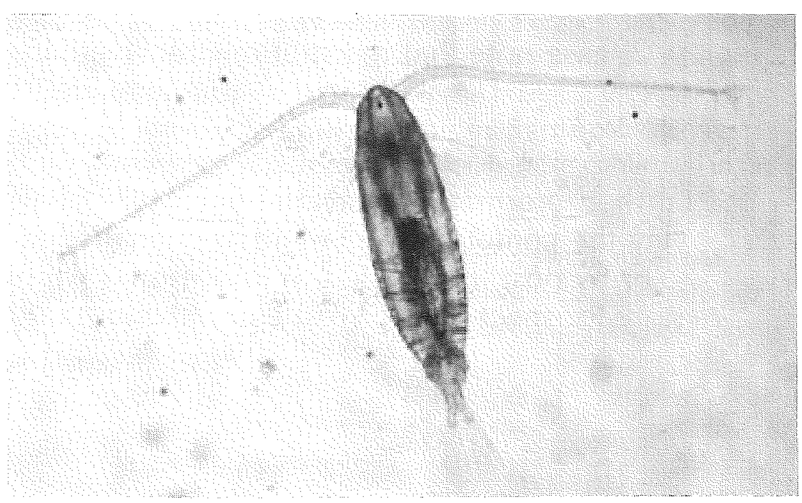
Further Reading

Information on GLOBEC is available from www.globec.org Its Science and Implementation Plans are published as *IGBP Report 40* (1997) and *IGBP Report 47* (1999) respectively. Special issues of *Fisheries Oceanography* (1998, Vol. 7, No. 3/4 and 1999, Vol. 8, Suppl. 1) contain relevant science papers.

Information on the NERC Marine Productivity thematic programme is available from www.nerc.ac.uk/funding/thematics/marprod

Phillip Williamson is the Science Coordinator for the NERC Marine Productivity thematic programme and Secretary of the UK GLOBEC Committee. He is based at the School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ; Email p.williamson@uea.ac.uk

Figure 5 *The copepod* Calanus finmarchicus. *(Photo: R.W. Campbell, Bedford Institute)*



Challenger Society for Marine Science

ANNUAL REPORT 2000–2001

Message from the President, Professor John Shepherd

This, in case you've lost count, is the 98th year (2000–2001) of the Challenger Society, which means that we have a centenary coming up. Council has been discussing how to celebrate the event, and has decided to designate the next Challenger Conference (to be held in Plymouth), as our Centenary Conference. There will be special events there, and other events during 2003 itself, including of course one of the new Challenger Lectures. The 2001 lecture was given by Professor Edouard Bard, at the very successful Geology Society meeting on Palaeoceanography and Climate Change held in London in April, which we co-sponsored. If you have any good ideas for Centenary events, especially those which look forward as much (or more) than they look back in time, please tell a Council member so that we can consider them.

Following the surveys and reflections initiated by Harry Elderfield when he was President, and discussed at last year's AGM, we have in the past year been making some of the changes that our members favoured. The most noticeable of these is our new (and mostly electronic) newsletter, *Challenger Wave*. Thanks to the excellent work of its founding editor, John Allen, this has proved to be a great success. I hope that you also feel that this keeps you much more closely involved with the Society's affairs than before, and I would like to encourage you to use it to let us know **your** views on matters of concern. We still get remarkably little feedback from our members, and would welcome more, since we shall otherwise have to continue to assume that silence implies consent ... You have been warned ! Another important change has been the increase in the number and amount of Travel Awards for post-graduate students (see the May 2001 edition of *Challenger Wave* for details). We have also made the application procedure simpler and more timely (we hope). And in response to several enquiries – yes, you do have to be a member to qualify for one of these awards!

Our membership is holding up well, but it is still not growing as I would wish. We know that there are lots of people out there who could, should, and probably would become members if they ever got around to it. The only effective way to reach them and persuade them is by **personal contacts** ... So, once again I urge you to run off a spare copy of *Challenger Wave,* and brandish it as you ask around until you find a non-member to recruit. Go for it ! Council is of course still considering several other new initiatives aimed at improving the benefits of membership (also publicised in the May 2001 edition of *Challenger Wave*) and would welcome your views.

Finally, I would like to thank the retiring members of Council for their sterling work on behalf of the Society. Especially I would like to thank Carol Robinson for her excellent work (and unfailing good humour) as Hon. Secretary. She has been a constant source of help, information and advice to me and to my predecessors, and we are very grateful.

John Shepherd

Summer 2001

Membership and Marketing

Total membership as at 13 August 2001 is 484, including 315 Full members, 108 student members, 5 Honorary members, 44 retired members and 6 Corporate members (= 12 individuals). At the Challenger Conference in September 2000 we gained 89 new members (41 full and 48 students). Membership taken out at the conference runs through to December 2001. In January, 65 members did not renew their membership (32 full, 2 retired and 31 students). Since January 2001 we have gained 51 new members (24 full, 24 students and 2 retired; two of the full members were Corporate).

The marketing of the Society has traditionally been to create awareness amongst the UK marine science community and attract new members. During the year the Council critically discussed the tangible benefits of being a member and the products on offer. With a rise in subscription fees at the beginning of the year it became very important to define the marketable product and the benefit to members. The biennial marine science conference remains a cornerstone for the Society and *Ocean Challenge* a key publication. However, it was agreed that a more regular method of communication was needed with members. The solution was the introduction of the monthly *Challenger Wave* and thanks must go to John Allen whose efforts have made it a success in its first year. In order to increase revenue we have appointed a dedicated agent to proactively seek advertising for *Ocean Challenge*. This is seen as a long-term activity that will take a period of time to attract new advertisers. In order to attract more membership from overseas we shall be appointing local representatives in national laboratories. The first is in the Bedford Institute of Oceanography, Canada. Others will follow. We continue to promote the Society at key marine science conferences both at home and overseas. This year included AGU Ocean Sciences (Providence) and OI Americas (Miami). Next year will include Oceans 2002 (Hawaii) and OI2002 (London). Participation is based upon cohabiting on existing exhibit stands and making use of registered attendees. The price of stand space generally precludes a booth of our own. Next year, the aim will be to widen the scope of the marketing, giving greater name recognition within the marine science community, and to attract a greater number of overseas members.

Council membership and responsibilities

Since the last Annual General Meeting which took place on 14 September 2000 in Norwich, the Council of the Society has met three times, on 16 January 2001, 24 April 2001 and 12 September 2001. The Council members, their terms of office and their responsibilities during 2000–2001 were as follows:

Officers

Prof. J. Shepherd	2000–2002	President
Mrs. N. Lane	1997–2003	Honorary Treasurer
Dr. C. Robinson	1996–2001	Honorary Secretary

Council Members

Dr. J. Allen	1998–2001	Editor *Challenger Wave*
Mr. K. Boot	1998–2001	Chair Education Committee
Prof. P.H. Burkill	1999–2002	Policy Committee
Mr. R. Burt	1999–2002	Chair Membership & Marketing Committee
Dr. D. Curtis	1998–2001	Chair of the Meetings & Specialist Groups Committee
Ms. J. Read	1999–2005	Meetings & Specialist Groups Committee (Hon. Sec. Designate)
Dr. K. Black	2000–2003	
Dr. S. Cornell	2000–2003	
Prof. A. Elliott	2000–2003	

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

Prof. H. Elderfield	Immediate Past President
Mrs. J. Jones	Executive Secretary and Membership & Marketing Committee
Ms. A. M. Colling	Editor, *Ocean Challenge*
Mr. J. B. Wright	Associate Editor, *Ocean Challenge*
Prof. T. Jickells	Chair, Editorial Board, *Ocean Challenge*

John Allen, Kelvin Boot and Debbie Curtis, who retire from Council at the 2001 Annual General Meeting, are sincerely thanked for their enthusiasm and commitment to Council and the Society. John Allen has kindly volunteered to remain as editor of *Challenger Wave* and an ex-officio member of Council for a further year.

Policy

Earlier this year the Institute of Marine Engineers formally resolved to change its name to the Institute of Marine Engineering, Science and Technology, and to broaden its declared mission accordingly. These changes are awaiting approval from the Privy Council, but could clearly have repercussions (not necessarily all of them negative) for the Society, and of course also for the other marine societies, especially the Society for Underwater Technology. Council has debated the ramifications of these changes, especially the possibility of easier access to an existing professional accreditation process, and has been consulting with the SUT, MBA and SAMS about them. John Shepherd and Richard Burt met with representatives of the IMarE in June, and we await their ideas as to what sort of relationship might evolve between us. We will keep you informed, and seek your views when the situation has become clearer.

Ocean Challenge

Ocean Challenge has enjoyed another busy and successful year. Two issues (Vol. 10, Nos.2 and 3) have appeared since the last AGM, and a third (Vol.11, No.1) is being mailed in mid-September. The reduction in size and other minor changes to the format to reduce printing costs planned last year have been put into effect and have not resulted in any unfavourable comments, so far as we know. A modest saving has been achieved and we continue to work to minimise costs. The supply of articles for *Ocean Challenge* is relatively healthy, a fact which we hope reflects the community recognising and valuing the special niche *Ocean* Challenge tries to occupy, providing articles of a general interest to the people interested in marine science. There is still a need for more short articles and news material and we encourage all members to help provide these. We are continuing our initiative to increase advertising revenue, but this is a long-term process and progress to date is limited. We are also working with Council to develop links with EFMS (though again this is a long-term process). To this end, Karl Hesse has joined the Editorial Board, providing a second European member to join the very hard working Hjalmar Thiel. The membership of the editorial board has otherwise changed little this year, though Barbara Knowles retired from the board when her new job moved her out of the marine area. Rachel Mills finished her term as Chair and the Editorial Board would wish to record here their thanks for all her hard work. We are very pleased to welcome Tim Jickells as the new Chair of the Editorial Board.

Challenger Wave

Editing the first year of Challenger Wave has been fun, and JA hopes that you, the readers, have felt it to be worthwhile. Many thanks to those of you who have submitted interesting articles and reminders about forthcoming conferences and employment opportunities. The sponsorship of individual issues by Chelsea Instruments Ltd. and IWA Publishing is much appreciated by the Society, thank you. However, we're still not getting enough reports from sea (SALTS section). We are all excited to know what is going on and how much fun you're having at sea so don't just leave it to your over-worked PSO – drop the editor an email and spill the beans! Remember that we have a lot of members who don't go to sea or haven't been for some time, let's try to keep them in touch with the sharp end of the job. Finally, *Challenger Wave* would not be possible without the support of Jenny Jones who carries out the mail and email shots and has pioneered its publication on the Web; many thanks, Jenny.

Meetings

The last AGM, in September 2000, was held during **UK Marine Science 2000** at the University of East Anglia, where oral and poster presentations on a wide variety of subjects, reflecting the range of interests involved in marine science, were made to 252 conference attendees. Many thanks to Prof. Tim Jickells and Karen Sturges, to members of the local and national organising committees, and to the commercial sponsors who ensured that this conference was such a success. The next **Challenger Conference for Marine Science 2002**, will be held in Plymouth from 8 to 13 September 2002.

During the year, the Society has supported, and agreed to support, the organisation of the following meetings: Underwater Optics (a one-day **Topical Meeting** within **Optics 2000**; joint with the Society for Underwater Technology) 17–21 September 2000 (M. Wall, John Watson, Derek Pilgrim and John Walker; University of Loughborough); **New Directions in Marine Science 2000: An Interdisciplinary Forum for Research Students** (joint with the Scottish Association for Marine Science and the University of the Highlands and Islands Project) 25–27 October 2000 (P. Crozier; Dunstaffnage Marine Laboratory); **Postgraduate Research in Marine Earth Science**, 20–21 March 2001 (A. Bralee; University of Durham); **Palaeoceanography and Climate Change** (joint with the Geological Society) 25–26 April 2001 (H. Elderfield, J. Jones, P. Wilson; Burlington House, London); **Progress in Chemical Oceanography**, 4–5 September 2001 (H. Kennedy; University of Wales – Bangor); **Benthic Dynamics: In situ surveillance of the sediment-water interface**, 25–29 March 2002 (M. Solan; University of Aberdeen).

Special Interest Groups

The second meeting of the OCEAN COLOUR SPECIAL INTEREST GROUP was held as an ocean colour special session at *UK Marine Science 2000*, and abstracts have been submitted to the first annual meeting of the Remote Sensing and Photogrammetric Society (RSPSoc). There is also an Institute of Physics (Optical Group) meeting on 9 October in London entitled Underwater Optics 6. The mailing list has moved, along with the National Academic Mailing List Service, to JISCmail and currently has 45 subscribed users. There is also a Geomatics mailing list, with over 50 subscribers, that covers broader issues e.g. coastal zone management, hydrography, geodesy, GIS, GPS and remote sensing. Ocean colour has continued to expand with the near-future launch of ESA's *ENVISAT*. It will carry an ocean colour sensor (MERIS) as well as several other remote sensing technologies e.g. sea surface temperature (AATSR) and SAR (ASAR). Contact: Samantha Lavender (S.Lavender@plymouth.ac.uk).

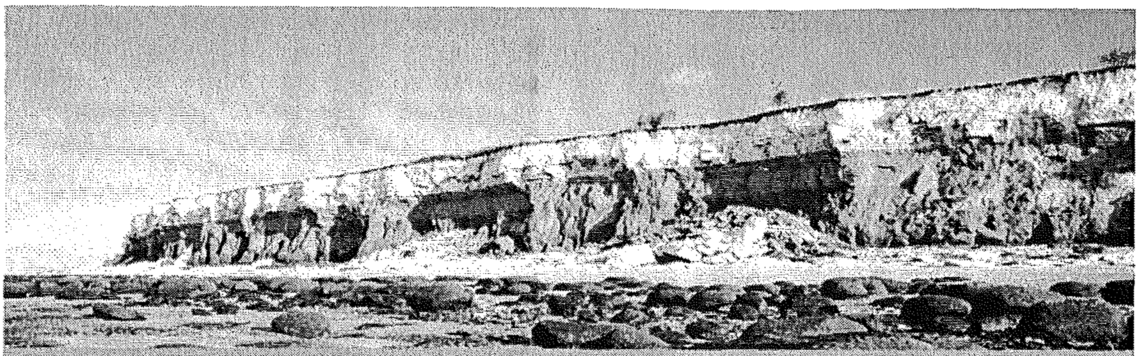
This year the annual meeting of the MARINE CHEMISTRY DISCUSSION GROUP (MCDG) will continue the alternating pattern of sessions at the Challenger Conference for Marine Science, followed by a 'Progress in Chemical Oceanography (PICO)' meeting. This year's PICO meeting is being held at the University of Wales, Bangor on the 4 and 5 September 2001, and is being organised by Dr Hilary Kennedy and colleagues. The School of Ocean Sciences and the Challenger Society are supporting this meeting. This gathering remains an important forum for discussion and exchange of ideas for the established and new members of the marine chemistry community in the UK. Ideas for themes and invited speakers for the next Challenger Conference for Marine Science: 2002 in Plymouth will be discussed at the 'PICO' meeting. (Contact: Peter.J.Statham@soc.soton.ac.uk).

The OCEAN MODELLING GROUP (OMG) meeting continues to be an important focus for the UK ocean modelling community. The meeting in 2000 was held as two half day sessions on the 12 and 13 of September in Norwich as part of the UK Marine Sciences meeting. Seventeen talks were given on a wide range of subjects, including ice models, palaeoceanography, advection schemes and the modelling of equatorial flows. The 2001 meeting is being held on 6–7 September, at Reading. (Contact: G.Nurser@soc.soton.ac.uk)

The BRITISH GROUP OF ALTIMETER SPECIALISTS (BGAS) held a one and a half day meeting this summer at Herstmonceux Castle. This beautiful venue is the site of the NERC Space Geodesy Facility, and attendees were given a nighttime tour of operations, which included tracking of the GFO satellite. This summer was an auspicious time for the meeting, marking 10 years of combined *ERS-1*, *ERS-2* altimetry, but also the dawn of new missions (*ENVISAT*, *Jason-1*) scheduled for launch late in 2001. The meeting reflected this, having presentations based on the extensive datasets of wave height, sea surface height, orbit tracking and land reflections already available, with a half-day devoted to forthcoming missions and advanced concepts yet to be tested in space. Some financial support for the meeting was provided by NERC and the Challenger Society. (Contact: Trevor Guymer on thg@soc.soton.ac.uk)

Finance

2000 saw an excess of income over expenditure of £29, compared with a budgeted profit of £100. Taking depreciation into account there is a deficit of £1,921, the major cause of which being a lack of income amounting to £4,417, balanced by a reduction in costs. Income was down due to reduced subscriptions, with a total income of £9,277 against a budget of £10,500, plus significant reductions in investment interest due to the financial market and the loss of the donation from CCMS. The donation from Southampton Oceanography Centre was gratefully received, plus the Conference generated income of approximately £2,000, and library subscriptions were increased by £233. Regarding expenditure, savings were made by Council, in the publication of the journal and in administrative costs. However, expenditure increased to fund more meetings and to provide the first of the Challenger Society medals with its associated setting-up costs. The figure shown in the accounts for the production of the journal is actually reduced in that it does not include the invoice for the production of the third issue of the year. This has been done on purpose so that the accounts can be completed in future years in a more timely manner following year end. The effect on the year 2000 accounts is that the bottom line figure would have been a loss of £4273. Regarding the donation from CCMS which was included in the budget but did not come to fruition, a problem arose when these accounts came to be made up. The two donations are actually payments in arrears and therefore when the payments are received they are substantiating the accounts for the previous year. Non-payment of the £3000 in year 2000 means that the accounts for 1999 have been overstated by that amount, and therefore the year 2000 accounts have been used to compensate for this. Consequently the year 2000 costs are £3000 higher than expected. Taking all the above into account, the Society is keeping its expenditure in line with the income, but this is helped significantly by the SOC donation. More membership and increased advertising should remain key issues, as these will both raise our profile and be self perpetuating in our efforts to grow.



East Anglia's Crumbling Coastline

Are Offshore Breakwaters the Answer?

Frank Thomalla

During the storm surge of the 31 January and 1 February 1953 more than 300 people in eastern England lost their lives. At Sea Palling in Norfolk, the surge breached the sand dunes and resulted in the death of seven people. Similar events of catastrophic tidal flooding have been recorded since medieval times and numerous coastal villages have been lost to the sea. Storm surges have played an important role in the evolution of the East Anglian coastline throughout the historical period, and large-scale morphological changes can be caused by a single storm. In north Norfolk, for example, over a three-year period more than 50 per cent of the net cliff erosion was observed to have occurred during a single storm surge.

In the near future, a predicted increase in storm frequency and the height of storm surge levels as a result of climate change is expected to exacerbate coastal erosion and to decrease the effectiveness of flood defences in East Anglia. This problem is compounded by a predicted increase in average sea-level around the UK coast. Estimates by the Intergovernmental Panel for Climate Change, for global sea-level rise by the 2050s, range between 12 cm and 67 cm. A third factor contributing to the increased vulnerability of coastal environments in East Anglia is large-scale long-term vertical land movements. The coastline of East Anglia is predicted to subside by as much as 9 cm by the 2050s as a result of continued isostatic adjustments following the end of the last glaciation 11 000 years ago. The combined effects of local sea-level changes caused by vertical land movements, and the global rise caused by climate change, could result in a relative sea-level rise of up to 76 cm within the next 50 years.

Strategic planning of the future management of the East Anglian coastline is set against this background. There is considerable scientific uncertainty regarding climate change, and our understanding of how changes in the global climate might affect the UK is even more limited. In recent years it has become apparent that traditional sea-defences have a high rate of failure because of our lack of understanding of the relevant physical processes, both locally and regionally. Because sea-defence structures interfere with natural processes, many have adversely affected the shoreline to either side of the stretches they were designed to protect. There are numerous examples in the UK and world-wide where the construction of coastal engineering works has had a detrimental effect on the wave climate and/or the transport of sediment along the shoreline, leading to increased erosion of the foreshore, or increased flooding, or both.

Low beach levels at Sea Palling in the early 1990s have been linked to protection of the cliffs around Cromer in north Norfolk. These Holocene cliffs are poorly consolidated and easily eroded, thereby providing the sand supply for the beaches and dunes that protect adjacent low-lying land. It has been estimated that the protection of 70 per cent of these cliffs

Recent beach erosion exposed underlying peat deposits at Sea Palling

Figure 1 The beach at Sea Palling during the construction of the offshore breakwaters or 'reefs'. Note the erosion of the peat along the shoreline and the protection of the increasingly exposed sea wall with large rocks.

(Courtesy of Peter Balson, British Geological Survey)

has caused a 25–30% reduction of the natural sediment supply. In the last few decades, erosion has lowered the beach level at Sea Palling to such an extent that the underlying peat has been exposed (Figure 1) and the stability of the sea wall has been endangered, leaving the land vulnerable to attack and inundation by storm waves. Prior to construction of the offshore breakwaters which are the subject of the article, this sea wall, backed by single line of sand dunes, afforded the only protection to local villages and low-lying land, including the Norfolk Broads.

Figure 2 View of the shoreline at Happisburgh to the north of Sea Palling, looking south (cf. Figure 3).

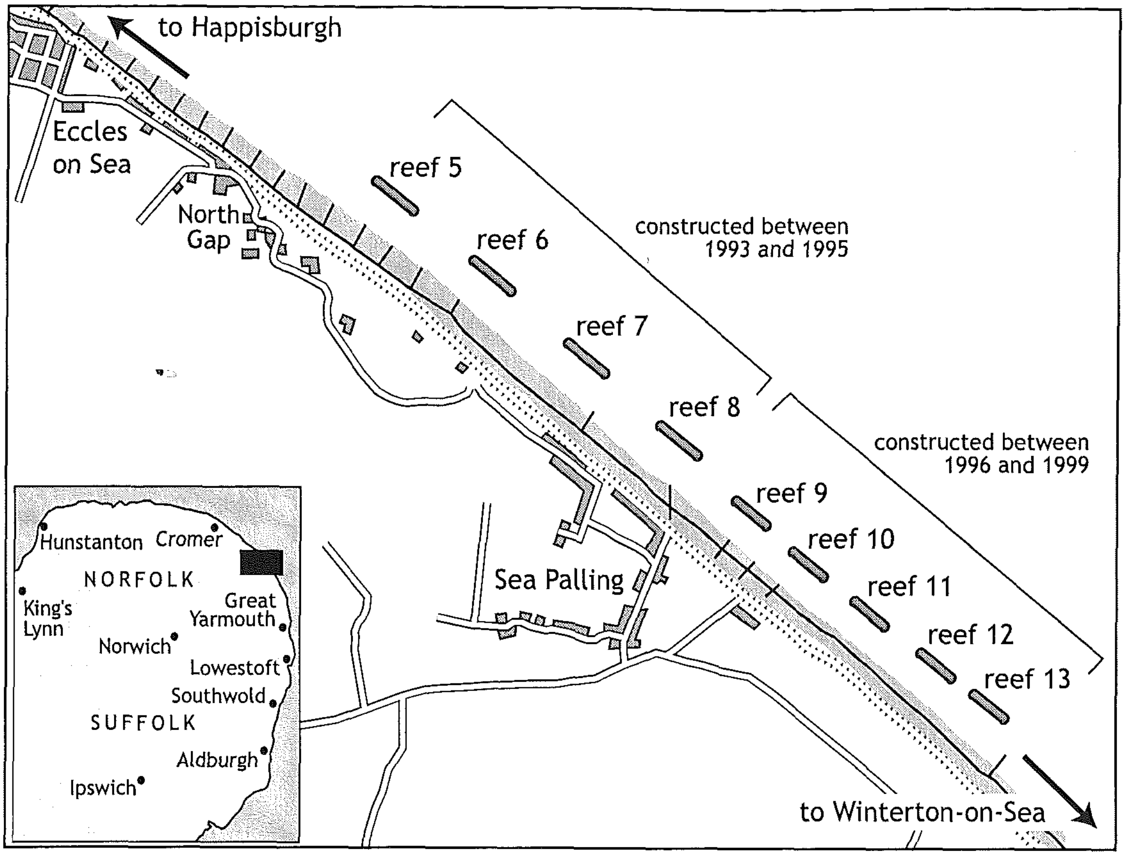
(© 1999 Frank Thomalla)

At Happisburgh, erosion has meant that the foot of the cliffs are now 10–20 m away from the revetments which were intended to protect them

The Happisburgh to Winterton Sea-Defence Scheme

Large areas of the Norfolk Broads are designated as Sites of Special Scientific Interest (SSSI), Wetlands of International Importance (Ramsar Sites), and Special Areas of Conservation (SACs), for whose protection the government is under statutory obligation. In 1990, the National Rivers Authority (NRA), now the Environment Agency, implemented a 50-year sea-defence strategy for protection of the 14 km of coastline at risk in the vicinity of Sea Palling (Figures 1 and 2). The scheme was named after the villages which represent the scheme's geographical north–south extent (Figure 3, opposite). The strategy was intended to protect several villages and 6000 hectares of low-lying land from tidal inundation, and included the construction of a series of offshore breakwaters or 'reefs' (Figures 3 and 4). In conjunction with sediment recharge, these reefs were expected to maintain the foreshore at sufficiently high levels to ensure the stability of the sea wall.

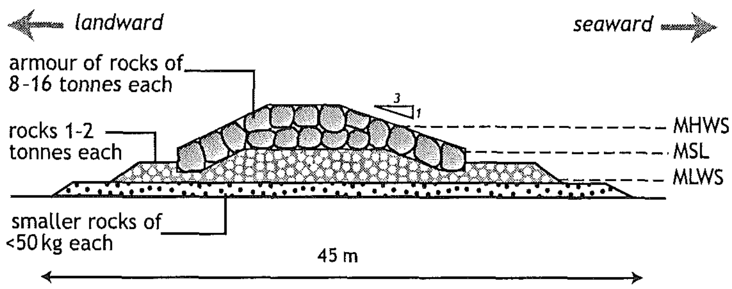
The scheme is in accordance with the long-term strategy to maintain the existing line of defence, set out by the Environment Agency. Since 1995, practices have been guided by Shoreline Management Plans to provide a more integrated approach to coastal zone management. Even though these documents are currently non-statutory and only provide guidance, they represent an important shift in thinking, in that they aim to take into consideration important natural processes such as sediment movement along the coast. Linked with this changing approach to shoreline management is a shift from hard engineering practices to so-called 'soft' engineering options. Offshore breakwaters are considered by many to be a soft engineering solution, because they protect the shoreline indirectly by influencing physical forcing. More specifically, the beach is protected through



The reefs off Sea Palling are the principle component of the Happisburgh to Winterton sea-defence scheme

Figure 3 Above *Location map showing the positions of the offshore breakwaters ('reefs') in the vicinity of Sea Palling. This article concentrates on the effects of reefs 5 to 8. (Note: Happisburgh is pronounced 'Hazeborough'.)*

Right *Cross-section showing the construction of the reefs.*



reduction of wave energy reaching the shore, as a result of structures which modify the nearshore wave and current climate. The resulting conditions enhance the sedimentation patterns that lead to a seaward progression of the shoreline and improve beach levels. At Sea Palling, the primary function of the breakwaters is to protect the coastline during extreme storm conditions.

Offshore breakwaters have been used more or less successfully to control shoreline evolution in many parts of the world, particularly in the United States, Japan and the Mediterranean. In the UK, this approach to coastal engineering is relatively new and the Happisburgh to Winterton Scheme is one of only a few such schemes in existence to date. One of the main reasons why offshore breakwaters have only recently been considered in the UK is that most of the experience gained in their design and construction is in areas where tidal ranges are very much smaller than in British coastal waters. The large tidal ranges and severe wave conditions occurring along most parts of the UK coastline tends to limit the use of offshore breakwaters, as such adverse conditions make the construction of these structures an extremely difficult (and therefore costly) option of shoreline management. Because of the lack of experience of offshore breakwaters in the UK, until recently their role has been largely limited to providing localised protection to beaches and other coastal structures.

The construction of the Sea Palling breakwaters was planned to be undertaken in a number of phases. Phase 1, from 1993 to 1995, involved construction of reefs 5 to 8, and these reefs were the focus of the research discussed in this article. Four more reefs were planned to the north of Sea Palling, but construction of these has been postponed indefinitely as initial observations indicated an accumulation of sediment in this area, due to the presence of reefs 5 to 8. Reefs 5 to 13 were constructed during Phase 2 (1996 to 1999), and their design was modified on the basis of experience gained through monitoring of the first four reefs (their impact on the beach is not considered here). For the first phase, the design parameters – e.g. breakwater length, gap length, crest height and distance from the sea wall – were based largely on empirical relationships developed in the United States.

Beach response

Changes in the morphology of the littoral zone at Sea Palling in response to construction of the Phase 1 breakwaters (reefs 5 to 8) were investigated over the period from August 1992 to January 1999. Analysis of beach-level data measured by the Environment Agency, and survey data collected by the author, showed that construction of the reefs resulted in the deposition of sediment in the sheltered areas behind the structures. This has led to the formation of bulges in the shoreline, which are termed salients (Figure 4). The obstruction in the cross-shore direction caused by the structures has resulted in the disappearance of the longshore bar. As a result, lowering of the beach has occurred behind the gaps due to the penetration of relatively high waves, which would previously have broken over the bar. In these areas the maintenance of a beach of a sufficiently high level has been problematic and has been addressed by the construction of sand-retaining structures buried in the beach, as well as by sediment recharge (Figure 5).

Following beach recharge, extensive accretion continued behind the reefs until, at low water, the beach became connected with the breakwaters, forming so-called tombolos. The scheme appears to be performing well in retaining sediment on the beach, but – as suggested by the extent of the tombolos – little or no sand is transported past the breakwaters, and this has caused significant erosion to the beaches down-drift (i.e. southward) of Sea Palling.

Significant seasonal changes in beach level were observed between April 1997 and January 1999. A continuing increase in the beach volume, particularly directly behind the reefs, suggests that equilibrium has not yet been reached.

Figure 4 ***Left*** *Aerial oblique view, looking south, of reefs 5 to13 of the Happisburgh to Winterton Sea-Defence Scheme (cf. Figure 3). Reef 5 is in the foreground. Note the salients and the tombolos connecting the reefs to the beach at low tide.*
Right *Reefs seen from the shore, each with two navigation beacons.*
(Photo (a) © The Environment Agency, 1998)

Reefs 5 to 8 have generally allowed beach sediment to be retained, but have caused erosion between the reefs

Sediment transport paths and rates

Hydrodynamic models provide a useful way of simulating the complex processes occurring in the near-shore environment and are increasingly employed by coastal engineers and oceanographers to predict the likely impact of proposed coastal structures on beach morphology and sediment transport. Such a model has been used by the author to provide spatial estimates of wave-induced circulation patterns, and likely sediment transport paths and transport rates, at Sea Palling.

The modelling work has indicated the formation of a rip current in the centre of the 'bay' between each pair of breakwaters (cf. Figure 4(a)). This is of particular interest as it is the most likely mechanism for the loss of sediment in the gap. The results also confirmed that at low water the tombolos effectively block the longshore transport. At high water, significant long-shore transport is predicted only for highly oblique waves. This is counter to the assumptions made by the consulting engineers who expected the breakwaters to render longshore variations in sediment transport insignificant.

The model predicts significant erosion for all directional sectors for a wave height of 2.0 m. Under lower energy conditions, minor redistribution of sediment prevails. Because of the high percentage of waves approaching the shoreline from the north, the influence of waves from this direction on beach evolution is considered important, particularly because the model results indicate that when there is a northerly wind no sediment is transported to the beaches south-east of the breakwaters. Southward transport of material within each 'bay' is only predicted for waves approaching the shoreline at highly oblique angles from the south-east. Wave records provided by the Meteorological Office indicate that less than 10 per cent of waves are incident from this direction. This implies that throughput of sediment through the breakwater system is very limited, and this is supported by the severe erosion observed along the beaches south-east of Sea Palling.

Figure 4 *Sediment recharge between reefs 5 and 6 at Sea Palling. The sand was dredged offshore and delivered to the beach via a pipeline. Once the material reached the shoreline it was redistributed along the beach using heavy machinery.*

(© 1996 Frank Thomalla)

Prediction versus reality

Evaluation of several empirical relationships used by consulting engineers for predicting the performance of offshore breakwaters revealed significant differences in the accuracy of the various predicted beach responses when the methods were applied to Sea Palling. The relationships generally refer to the equilibrium response of the beach and do not include the effects of a varying tidal level. Other effects, such as transmission of wave energy through the structure, or overtopping during storms, as well as the influence of longshore drift, have also been largely ignored. In addition, at least some empirical methods have been developed for systems located in areas of moderate waves. Only one of the models includes the effects of wave parameters such as the angle of wave incidence, wave period and wave height, and there are large inconsistencies in the predicted beach response. It is suspected that the inability of the methods to predict the beach response at Sea Palling correctly is most likely caused by the overriding influence of factors such as transmission of wave energy through the reefs, longshore drift and a large tidal range, which outweigh geometrical relationships in the scheme design.

Conclusions

The results of my work indicated that nearly five years after the construction of reefs 5 to 8 the beach at Sea Palling had not yet reached equilibrium. The study shows that there is a clear need for continued detailed monitoring. The investigation of the potential impact of an extreme event, such as a storm surge, is particularly important for assessing the effects of high waves from different directions, and for evaluating the overall performance of the scheme. This test is crucial since the implementation of the scheme was originally justified on the basis of its ability to prevent a severe flood event. However, as there has not been a severe storm surge since the construction of the breakwaters, their effectiveness under such conditions has to date not been tested.

Despite the uncertainties associated with the long-term performance of these structures and their impact on the coastline, the second phase of breakwater construction was completed in 1999 (Figure 3) and several more breakwaters have recently been built as part of a separate scheme at Caister-on-Sea (also in Norfolk). Following extensive hydrodynamic modelling by the consulting engineers, significant modifications were made to the design of the Phase 2 reefs at Sea Palling in order to achieve a more favourable beach response.

Investigation of the impact of offshore breakwaters on the shoreline in the UK is extremely important because most of the experience gained in their design and construction is in areas with a lower tidal range and less severe wave conditions than those found in British coastal waters. The evaluation of the engineering design criteria developed in the US has highlighted their inadequacies in locations with varying tidal levels and strong longshore transport of sediment. A new set of generic design criteria needs to be developed for breakwater schemes if these structures are to be successfully applied to coastal erosion problems in the UK.

Sediment recharge is becoming increasingly important for beach management around the UK

Acknowledgements

This article is a summary of the author's Ph.D research undertaken between 1995 and 1999 at the School of Environmental Sciences, University of East Anglia under the supervision of Professor Chris Vincent. The work was funded by a studentship provided by the University of East Anglia. The author would like to thank Steve Hayman from the Environment Agency for his guidance and advice during the early stages of the project and Ben Hamer from Sir William Halcrow & Partners for providing technical information about the Happisburgh to Winterton Sea-Defence Scheme.

Frank Thomalla* has been working as a Research Associate at the Cambridge Coastal Research Unit. He has been involved in research into physical coastal processes and coastal zone management, and has been co-ordinating a project at the Martin Centre for Architectural and Urban Studies, which investigates the vulnerability of the UK East Coast settlements to flooding by storm surges.

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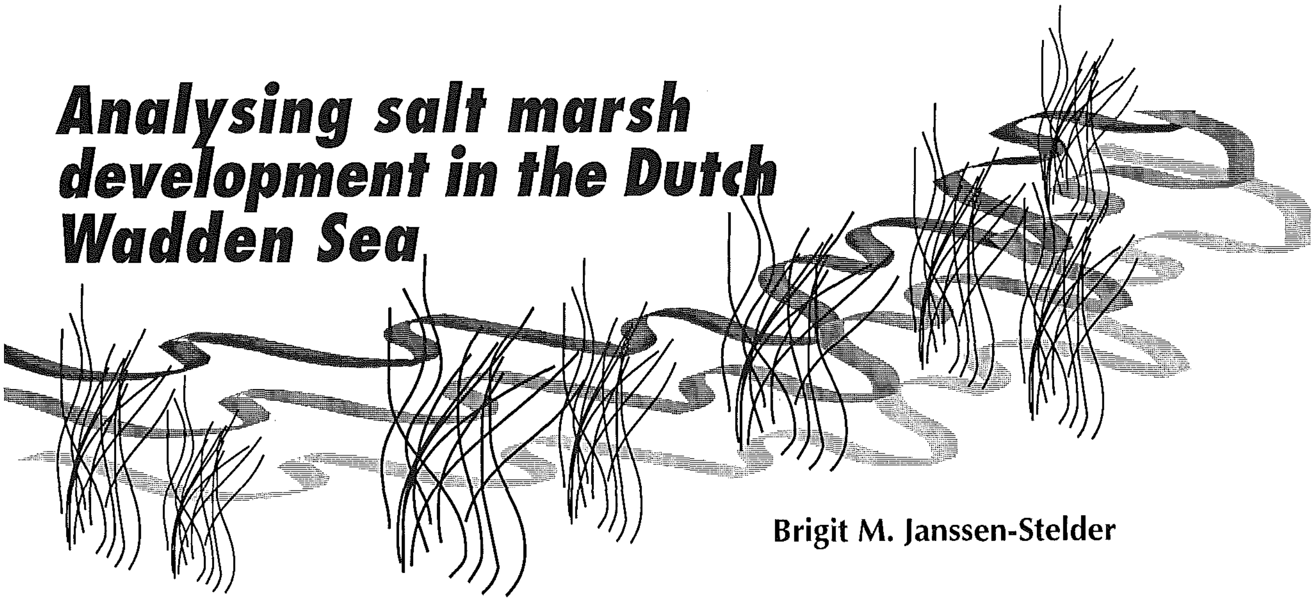
Analysing salt marsh development in the Dutch Wadden Sea



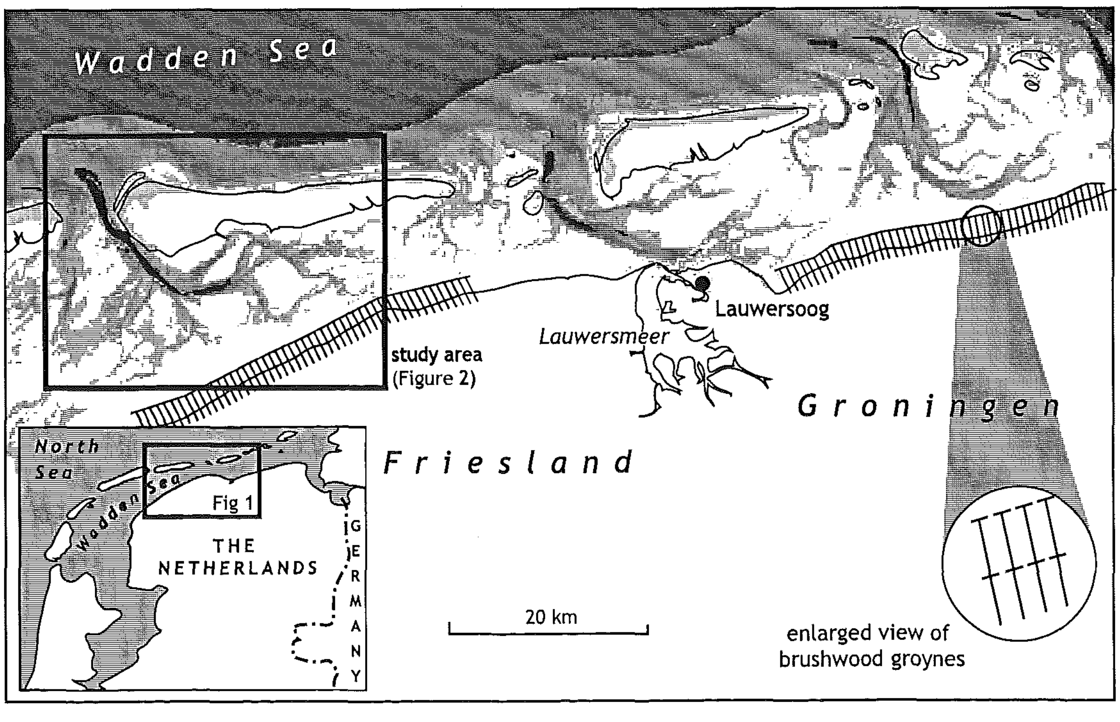
Brigit M. Janssen-Stelder

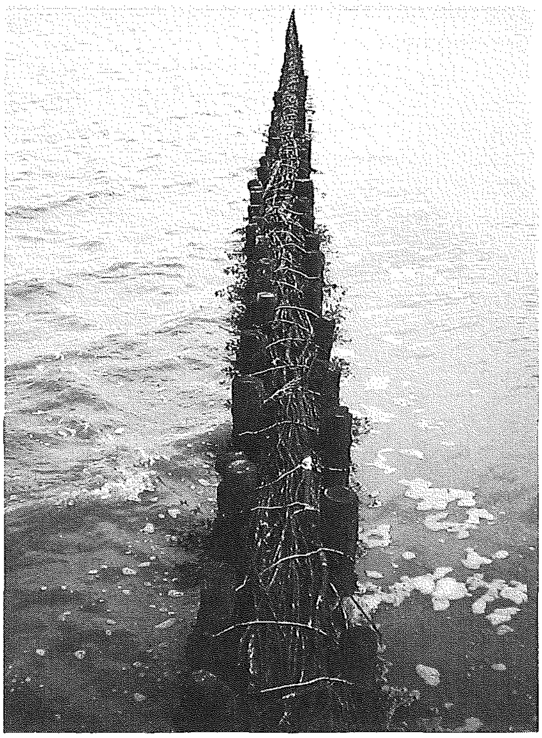
Salt marshes fringe the sheltered mainland coast of the eastern Dutch Wadden Sea (Figure 1). In the past, sedimentation was promoted in the salt marshes in order to reclaim land, but the policy of the present Dutch government is to preserve the salt marshes and mudflats as part of the natural system in the tidal basins, as nature reserves and for coastal protection. Growth of the salt marshes is slow, and occurs only under controlled conditions along the mainland coast. These conditions are produced by means of 'sedimentation fields' encouraged by the construction of brushwood groynes that reduce the incoming wave and current energy in the pioneer zone of the salt marshes, i.e. in the delicate transition zone between the upper mudflat and the vegetated salt marsh.

Management of the Wadden Sea involves contending with a number of factors that influence the entire system, including sea-level rise, changing storm climate, gas extraction and fishing. The morphological changes that are the subject of this study are probably most influenced by sea-level rise and a changing storm climate. Morphological development of the salt marshes and areas seaward of them, as a result of changing boundary conditions, cannot be predicted accurately without a proper understanding of the system. The main objective of my work has been to use field data to enhance understanding of salt marsh development along the mainland coast of the Dutch Wadden Sea, at different spatial and temporal scales.

In the Wadden Sea, brushwood groynes are being used to encourage sedimentation and growth of salt marshes along the mainland coast

Figure 1 *The eastern part of the Dutch Wadden Sea where salt marshes are being encouraged along the mainland coast by brushwood groynes Depth is represented by the grey tone; for a more detailed map of the study area, see Figure 2.*





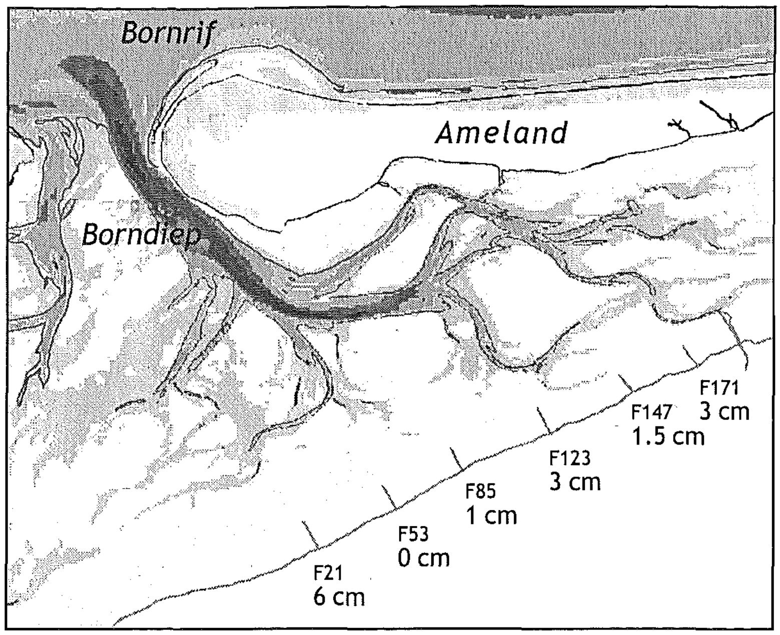


Figure 2 Map of the study area showing the relationship between sedimentation rates (given in cm per half year) and bed morphology seaward of the Friesland salt marshes. The Friesland measurement stations are numbered in terms of their position, e.g. station F21 (where the sedimentation rate is 6 cm per half year) is 21 km east of the start of the salt marshes in the western part of the mapped area.

The bathymetry is based on information in Sediment Atlas, Wadden Sea (1998). The darker the tone, the deeper the water. Most of the area between the coast and the barrier islands is intertidal and is never more than 1.5 m deep. The channel to the west of Ameland Island is more than 25 m deep. Water immediately offshore from the barrier islands is 5–10 m deep.

Sedimentation rates in the salt marsh pioneer zone are affected by the distribution of tidal channels and tidal flats

Figure 3 Upper *One of the brushwood groynes constructed from bundles of brushwood between two rows of posts.*

Lower *Knocking in PVC pipes for sedimentation measurements.*

Study area and methodology

The Wadden Sea is a micro-tidal to meso-tidal area (i.e. with tidal ranges up to 4 m) and is bounded by a number of barrier islands which are separated from the mainland by extensive tidal flats crossed by tidal channels. Part of the mainland is fringed by tidal salt marshes that are inundated only during spring tides and storm surges. These salt marshes extend along the shore of the mainland for about 55 km. They consist of two parts, a Friesland part in the west (Figure 5, overleaf) and a Groningen part in the east, which are separated by a former tidal inlet, now a lake known as a the Lauwersmeer (see Figure 1). The study area is located in the western (Friesland) part of the Dutch Wadden Sea.

Field measurements were carried out over a period of two years in the pioneer zone of the salt marshes and on the mudflats along the shore, to examine small-scale salt-marsh processes (although for logistical reasons, measurements were made in the summer half of the year only). Measuring frames and portable instruments were used to measure water depth, wave height, alongshore and cross-shore current velocity and suspended sediment concentration. Changes in elevation and the composition of the bed sediment were also measured (see Figure 3, left). For the large-scale (decadal) analysis, hydrographic maps, long-term data on salt marsh elevation and long-term meteorological data were studied in a raster-based GIS. The Rijkswaterstaat (Department of Public Works and Water Management) provided these data, which have been collected since 1965. In addition, a numerical wave model (SWAN) was used to determine wave patterns in the Wadden Sea during storms.

Erosion and sedimentation along the coasts of Friesland and Groningen

Field data were used to study the principal factors governing the development of the pioneer zone: wave height, current speed and direction, strength of the bed, bed morphology and sediment transport. Differences in sedimentation rates along the mainland coast are related to the distribution of tidal flats and tidal channels in the vicinity of the sedimentation fields (Figure 2). Tidal flats in the vicinity of the sedimentation fields – including 'tidal divides' (places where flooding tides meet, and current speed drops virtually to zero) – are sources of sediment. In these shallow intertidal areas, wave and current energy is dissipated and sediment settles. If there are no tidal channels, sediment cannot reach the sedimentation fields, resulting in low sedimentation rates in the pioneer zone.

Tidal channels oriented perpendicular to the coast, and at a distance of between 900 m and 2000 m from the pioneer zone, transport sediment efficiently towards the sedimentation fields. As a result, at locations close to tidal channels, measured sedimentation rates in the pioneer zone are generally high.

The brushwood groynes were built to interrupt wind waves and tidal currents in order to encourage sedimentation, and their height and maintenance therefore has a marked effect on whether or not sediment is deposited within the sedimentation fields (when the net supply is positive). In the summer half-year when measurements were made, low or negative sedimentation rates were measured in sedimentation fields with low or badly maintained brushwood groins. In these areas, waves maintain their heights and sediment is resuspended.

The role of storm surges in salt marsh development

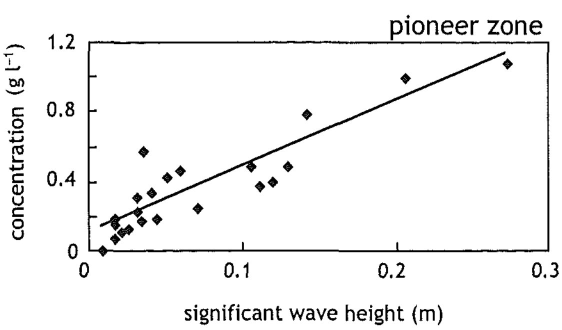
Field data from three measuring frames were used to examine the effect of storm surges on salt marsh development. Hydrodynamic conditions and sediment fluxes were measured during storm surge periods of several days at two different locations in the salt-marsh pioneer zone and at one location on the upper mudflats seaward of the pioneer zone (Figure 4).

During a complete storm surge period, and within a single tide, measured hydrodynamic characteristics were very similar at the two measuring locations in the pioneer zone. By contrast, the measuring location on the adjacent mudflats showed different hydrodynamic characteristics during a storm surge, with greater water depths, longer flooding periods and higher current velocities. In summary, storm surges have a different effect on the pioneer zone than on the adjacent mudflat.

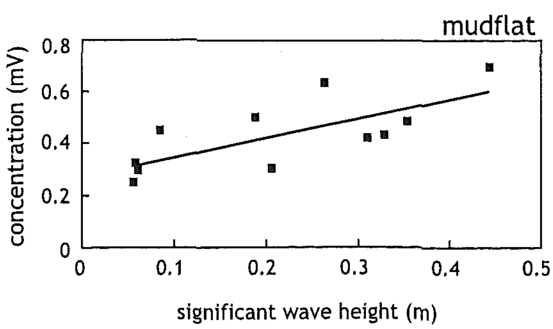
In the pioneer zone, the sediment was found to be mainly suspended *in situ* by wave action, and a linear relationship between significant wave height and suspended sediment concentration was established (Figure 4(a)). On the mudflat, advective processes influenced the net sediment transport, and although the suspended sediment concentration increased with increasing significant wave height, the linear relationship was not as clear as in the pioneer zone (Figure 4(b)).

On the mudflat, the absence of brushwood groynes meant that average current velocities were more than twice those in the pioneer zone. The measured net sediment transport was directed offshore during storm surges both in the pioneer zone and on the mudflat. During the storm surges, erosion of the mudflat in front of the salt-marsh pioneer zone was found to be greater than in the pioneer zone itself, because the mudflat was flooded for a longer period of time and to greater water depths, resulting in greater net offshore sediment transport.

Figure 4 *Relationship between significant wave height (the average height of the highest third of the waves) and the suspended sediment concentration in **(a)** the pioneer zone and **(b)** on the mudflat. (It was not possible to convert the raw mud flat data in values of suspended sediment concentration in g l^{-1}, so this is given in millivolts.)*



(a)



(b)

Salt marsh pioneer zones are subject to most erosion immediately following a stormy year, because seeds and seedlings of salt marsh plants have been washed away

Figure 5 *View from the pioneer zone (foreground) towards the established salt marsh. The sea wall can be seen in the distance.*

Salt marsh development along the mainland coast from 1965 until the mid-1990s

Data on elevation, wind and water level collected from 1965 onwards by the Rijkswaterstaat were used for the large-scale analysis. Interpolated elevation maps of the entire saltmarsh area, including the pioneer zone (Figure 5) and upper mudflats, along the coast of the Dutch Wadden Sea, show that the area has been vertically accreting since 1965. The accretion is almost linear for the Friesland part of the salt marshes (see dashed plot on Figure 6). In the Groningen salt marshes the growth is asymptotic; it has been stagnating since 1985 (full line on Figure 6).

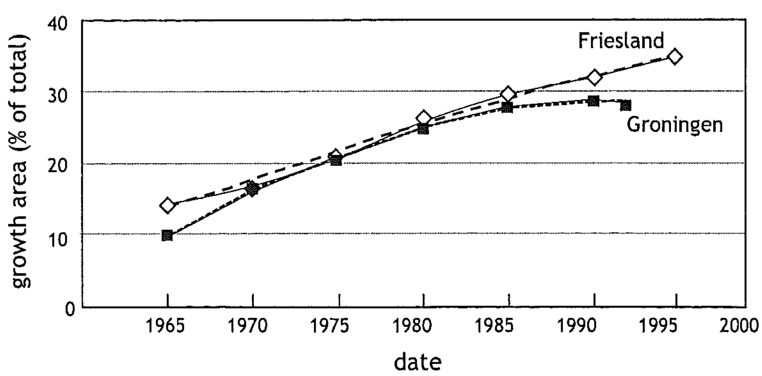
On a yearly time-scale, the effect on accretion rates of a single calendar year with many storm days combined with high water levels, was found to be similar for the Friesland and Groningen salt marshes. At the start of a 'stormy' year (i.e. one with many storm days) erosion occurs, but during the year and at the end, there is accretion. During a year with a high storm frequency much fine sediment is transported towards the shore and deposited there. Measurements have shown that (somewhat counter-intuitively) most erosion occurs in the years immediately succeeding storm years. That is because, as Houwing and others showed in 1995, during a stormy year a large number of seeds and seedlings are washed away, with the result that the pioneer zone of the salt marsh cannot extend so far in the next year. In other words, the influence of a 'storm year' extends to the following year.

The results show that, on longer time-scales (decades), the Friesland salt marshes rapidly respond to changes in wind speed and to high water levels, whereas the Groningen salt marshes react slowly to such influences. The difference in the long-term accretion balance between the coast of Friesland and Groningen may be related to the differences in embankment history: in Groningen, more extensive embankments were built than in Friesland, so the salt marshes that formed after the construction of the brushwood groynes were located at lower levels than the Friesland salt marshes.

The difference in long-term accretion balance could also be related to the different type of tidal basin and different exposures to hydrodynamic energy. Sediment budget calculations show that the Groningen salt marshes are part of a more dynamic tidal basin than the Friesland salt marshes, and that more sediment is being moved around in the Groningen tidal basin. This is because the Groningen coastal salt marsh is located behind a system of large tidal inlets, with relatively small barrier islands, and is there-

How fast a salt marsh grows depends on the history of the area and how sheltered it is

Figure 6 *Development of the Groningen and (more sheltered) Friesland salt-marsh areas between 1965 and the mid-1990s.*



fore more exposed than the Friesland coastal salt marsh, which is located almost entirely behind the large barrier island of Ameland (Figures 1 and 2). Therefore, during storms, the hydrodynamic conditions (as measured and modelled) are rougher in the Groningen salt marshes, resulting in less accretion.

Because salt-marsh development is greatly influenced by storms, modelled differences in hydrodynamic energy during storms for the entire Wadden Sea were used to explain long-term (decadal) spatial differences in accretion patterns within the Friesland and Groningen salt marsh areas. The morphology of the Wadden Sea determines the distribution of the hydrodynamic energy being supplied to the coastal salt marsh during storms, and defines the location of sediment sources for the salt marshes. Modelling results show that behind tidal inlets, and in the vicinity of large tidal channels, higher and longer waves approach the mainland salt marsh. Whether this results in high sedimentation rates depends on the presence of transporting channels and sources of sediment.

Conclusions

Changes in the boundary conditions of the Wadden Sea system are occurring slowly in response to sea-level rise and the changing wind climate, and the effects are difficult to detect. A greater understanding of how the system functions, as outlined in this article, is essential to estimate the consequences of future natural and anthropogenic changes in the boundary conditions of the Wadden Sea system.

This study has shown that development of the salt marshes along the mainland coast of the Wadden Sea cannot be treated in isolation, and hence that salt-marsh management in this region does not have to be uniform. Spatial differences in erosion and sedimentation rates occur at different time-scales and appear to be related to the geomorphology seaward of the salt marshes.

On longer time-scales, storm surges appear to be important in salt-marsh development, and the salt marshes along the mainland coast need a few years to recover from a year with many storm surges. Increasing storm surge levels result in decreasing accretion rates in the salt marshes, and on a decadal time-scale the salt marshes along the Friesland coast are adjusting more rapidly to changes in storm surge levels than are the Groningen salt marshes. As the storm climate intensifies in coming years, increased erosion in the pioneer zone of (especially) the Groningen salt marshes can be expected.

Brigit Janssen-Stelder is a Physical Geographer. She studied salt marsh development in the Dutch Wadden Sea between 1996 and 2000, for her Ph.D at Utrecht University, the Netherlands. This study was part of a national research programme, 'Modelling climate changes for the ecosystem of the Wadden Sea'. After successfully defending her Ph.D, Brigit worked at the Dutch Department of Water Management as a project leader in the field of coastal defence. Her current address is Dr. J. Röntgenlaan 15, 3723 LA Bilthoven, The Netherlands.

The Climate of UK Waters at the Millenium: Status and Trends

Edited by Graham Alcock and Lesley Rickards (IACMST)

This 48-page booklet, published last year, is a useful summary of the current state of the waters around the British Isles. To quote from its introduction, it 'describes the present (1999/2000) status and trends of weather, climate, sea temperature, salinity, sea-level, waves and plankton in UK territorial waters. ... The general aim of this report is to demonstrate the value of long-term marine measurements in aiding the effective management of the UK's marine environment; thus encouraging their commencement, their continuation or their restoration.'

Along with informative and interesting data (graphs, maps etc.) are boxes on particular topics, including: The Met. Office Marine Automatic Weather Station (MAWs) Network, 100 years of observations in the Faeroe–Shetland Channel, Monitoring in the Irish Sea, The 'Ellett Line' (from the Sound of Mull to Rockall), The UK National Tide Gauge Network, and The Continuous Plankton Recorder Survey.

The booklet may be obtained from: The IACMST Secretariat, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH.

A web version is available at www.oceannet.org/UKclimate-status, together with links to other sites containing marine data and information.

Book Reviews

Challenger – *the Book of the Conference*

Understanding the Oceans edited by Margaret Deacon, Tony Rice and Colin Summerhayes (2001). UCL Press, London and New York, £25 (ISBN 1-85728-706-1).

In September 1995 a symposium entitled 'The *Challenger* Legacy' was held as part of the celebrations associated with the opening of the Southampton Oceanography Centre. This book is the proceedings of that symposium. The changing of the title seems to have little rationale, except, I guess, to make the book more commercial.

The book's focus is primarily historical, so it has not dated too seriously during the intervening five years. It is divided into four sections, each containing four contributions written predominantly by Southampton oceanographers, but with a strong representation of some of the best writers on the history of oceanography. The first part deals with the 'Historical context'. Tony Rice starts by showing how the organizers of the *Challenger* Expedition missed many scientific opportunities by playing it very safe with technology – using rope for towing gear, rather than wire, for example.

Harold Burstyn argues persuasively that the *Challenger* Expedition was the first example of Big Science in oceanography. The right choice of leader was critical to its eventual success. Another key factor was the effort devoted to producing such a comprehensive series of reports – an achievement only made possible by what we would now describe as 'creative accounting', as the true cost of producing the reports was consistently underestimated.

Jacqueline Carpine-Lancre describes the royal researches of Prince Albert I of Monaco and King Carlos II of Portugal. Perhaps the problems of our own Royal family might be resolved if they devoted their energies to oceanography. However, the ultimate fate of King Carlos – assassination – may be a poor incentive.

I found Rosalind Marsden's account of the work of the *Discovery* Committee fascinating. So many of the problems encountered by scientists at that time foreshadow what has been happening to the Plymouth Laboratory, with inadequate funding and persistent bureaurocratic meddling.

One of the most important achievements of the *Challenger* was the wide network of soundings. The second part of the book focusses on 'Ocean basins'. Tony Laughton discusses shape as the key to understanding the geology of the oceans, showing how macro- to micromorphology of the ocean floor continues to be a rich source of hypotheses as to how the basins have evolved. It is in this chapter that the first of several examples of poor book design caused me irritation. A figure showing sea-surface gravity measurements is reproduced at such a small size that its information is almost entirely lost. Yet two pages later, at the end of the chapter, there is half a blank page. It would have cost nothing to present the gravity figure at a larger size. Authors and editors take note: many book designers are more interested in look rather than content!

Dorrick Stowe discusses how basins fill. This is a useful short review, but perhaps the first example of where the text is somewhat dated. There is no mention, for example, of Heinrich events – the extensive depositions of rock fragments and gravel dropped by outbreaks of icebergs in the North Atlantic. The next contribution is by the late Brian Funnell. He discusses palaeoceanography, and how the samples collected by the *Challenger* provided the first hints of how the imprints of climatic fluctuations are recorded in ocean sediments. As in the case of the *Challenger* Expedition, the success of the Ocean Drilling Program and its successors is based on the comprehensive series of reports that were produced. Chris German then summarizes research on hydrothermal activity at mid-ocean ridges – a nice concise summary of progress up until 1995, but one that is now in need of updating.

The third section on ocean circulation has an introduction by Henry Charnock and Margret Deacon. Henry has since died and the whole volume is dedicated to him; surely he deserves a better commemorative volume. The first chapter of this section, the one that I found the most absorbing in the whole book, is a summary of the life of Harald Ulrik Sverdrup by Robert Friedman. There is so much to admire about Sverdrup's scientific and practical skills and ethical attitudes. His responses to the prevailing scientific and political climate made him a great leader in post-war oceanography. John Gould describes how the technology of directly measuring subsurface ocean currents has led to immense strides in our scientific understanding of ocean circulation. This informative chapter is all the more valuable in that it includes a rare image of John Swallow at work.

Purists – I did note one error in the caption of the picture of a prototype Aanderaa current meter being deployed, which claims that the photo was taken during the International Indian Ocean Expedition in 1962. *Discovery* participated in the IIOE in 1963–64. If I am right that the person stretching out to steady the meter is the Australian Bruce Heman, then the picture was taken in 1964.

Trevor Guymer and colleagues discuss oceanography from space in a rather dated chapter that suffers from the absence of colour illustrations. Andrew Watson discusses transient tracers and tracer-release experiments. Amongst the earliest tracers were derelict ship's hulks whose recorded drift traced the large-scale circulation of the North Atlantic. (Somewhere in the reprint collection at Southampton is a paper on current patterns based on the cadavers of seamen washed ashore.) Neither Chernobyl nor IronEx get a mention.

The final section is rather quaintly entitled 'The ocean ecosystem'. Eric Mills first gives a fascinating account of 'Problem Children of Analytical Chemistry', a history of the development of analytical techniques in nutrient chemistry. This discusses how marine chemists gradually adapted techniques for quantifying nutrients designed for use with 'clean' laboratory solutions so that they could be used with the more difficult 'dirty' and dilute solutions represented by seawater. Dominant personalities and the need for comparability between analysts and laboratories have both inhibited the adoption of more precise techniques. Perhaps in future the factor limiting improvements to techniques will be seen to be the pedantic nature of regulations associated with 'improving' Health and Safety.

Roger Wilson and Dennis Burton discuss why the sea is salty. Discarding the trite answer, 'because it is', they give a useful brief account of the status of marine chemistry five years ago. Paul Tyler, Tony Rice and Craig Young present a short account of deep-sea (benthic) biology in the 1990s, placing a heavy emphasis on seasonality of megabenthos. They also emphasize the high species richness of the very small infaunal animals on the deep-sea floor, which they hint is comparable to that of tropical rainforests and coral reefs. I wonder if this concept, repeated in the following chapter by John Woods, will bear the test of time.

John Woods's chapter entitled 'The *Challenger* legacy: the next twenty years' is a valuable lesson. In 1975, I was involved in writing a biological chapter for the FORE report, which attempted to look ahead to oceanography in the year 2000, so I know how problematic it is to get such forecasts right. So much has changed in the last five years that Woods' chapter has already become a historical document in its own right. There have been radical changes in the UK and within the EC (EU) in the funding and support of ocean science, with a marked shift from funding basic science to wealth creation. Nationally, NERC has sold RRS *Challenger*, so that 'legacy' has gone, and the Laboratory at Plymouth is on its beam-ends, thanks to shifting priorities and lack of effective leadership and management. Internationally, the US President reneging on Kyoto has placed priority on short-term economic health over long-term environmental health, despite the clear evidence of climate regime shifts in the Pacific. In miniature, the history of the *Discovery* Committee illustrates how disruptive to scientific development such political vacillations can be. The lesson of this book is that the really valuable legacy of the *Challenger* has not been measured in national wealth, but that it acted as a catalyst to the development of scientific understanding of the oceans and of how the oceans are intimately involved in global processes, giving us the means to comes to terms with present and future changes in our environment. Oceanography must be the means to restore the willingness of Government to devote as many resources to the study and understanding of inner space as is does to *macho* activities directed at outer space, or to chasing the unsustainable goal of still further economic expansion.

Perhaps I should leave the last word to Robert Friedman: 'History is of course as much about the present, if not the future, as it is about the past. As we attempt to define a cultural heritage for ocean science, as well as to comprehend how and why its practices and structure developed as they have, we might also want to keep in mind issues that do not normally arise in our studies.'

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A Tremendous Fishy Tale

A Fish Caught In Time: The Search for the Coelacanth by Samantha Weinberg (1999). 239pp. Bath Press Ltd, £7.99 (flexicover, ISBN 1-85702-907-0); Harper Collins, £13.99 (hard cover, ISBN 1-85702-906-2).

It was Charles Darwin (1809–82) who first coined the term 'living fossil' to describe the living 'remnants of a once preponderant order' previously known only from the fossil record. In fact, he reckoned that we should find many 'living fossils' in the deep ocean where, he supposed, they were sheltered from the pronounced environmental fluctuations that drive evolutionary change. Had he been alive during the 1930s he surely would have been the most excited man on the planet to learn of the coelacanth. Prior to 1938, the coelacanth was known only from the fossil record (the Jurassic Period) and yet, off the coast of Mozambique, children were swimming in the sea with one! This book describes the extraordinary and dramatic tale of the discovery of the first coelacanth in 1938, and then of the various and often bizarre efforts to capture further specimens and learn more about this strange creature.

The first part of the book describes the life and times of J.L.B. Smith, the man who presented this creature to the world – a professional chemistry scholar but also an amateur ichthyologist. The first person to spot a coelacanth (in a trawler's net) and try to preserve it was a modest school teacher, Marjorie Courtenay-Latimer, but it was Smith who made the link to the fossil record and realized the implications.

Coelacanths were one of three possible candidates for animals that crawled out of the water to conquer the land (the others were the lungfish and rhipistidian, a squat fish with fins sprouting from stubby limb-like lobes). This could be a great opportunity to resolve the 'missing link' argument – the ancestor of man no less – a hot topic in the 1930s. It was a moment in time for Smith and it triggered an obsessive, 14-year hunt for living specimens, which culminated in a dramatic act of international piracy.

When Courtenay-Latimer wrote to J.L.B. Smith about her discovery, the existence of coelacanth fishes had been known to science for almost exactly 100 years (they were originally named by the great Swiss scientist Louis Agassiz). In a remarkable feat of mental agility, Smith had apparently taken Latimer's rough sketches of a five-foot fish and connected them with a fossil, a little over 12 inches long and 200 million years old, that had been discovered in freshwater in Greenland, which he had read about in a scientific journal. Out of respect for Courtenay-Latimer, he named this first specimen *Latimeria chalumnae*. JLB then spent many hours dissecting the fish and preparing his official monograph for the Royal Society of South Africa.

War broke out and distracted JLB, albeit temporarily, from his obsession with the coelacanth. However, he started to raise funds to explore the coral reefs and palm islands off eastern Africa, where, he was convinced, he would discover the fish's home. By now JLB was becoming an expert on Indian Ocean fishes and, with a £1000 advance on a book, he left chemistry for good to set up the new Department of Ichthyology at his university. He and his wife spent much of their time on field trips looking for the elusive fish, but fourteen years after he had described *Latimeria chalumnae*, their efforts still proved fruitless. Then their luck changed.

Whilst searching around the Comoros Islands, a remote French colonial archipelago half-way between Mozambique and Madagascar, they bumped into an Errol Flyn-esque schooner captain called Eric Hunt. Hunt was a romantic adventurer but, more to the point, like the Smiths he was an avid amateur ichthyologist. As JLB and his wife docked at Durban on Christmas Eve, they were handed a telegram from Hunt who was sailing through the Comoros islands: ' ... have five foot specimen ... injected formalin'. JLB had a big problem – on Christmas Eve he had no way of getting to the Comoros. No-one, it seemed, was going to miss the festivities for a smelly old fish! His only option would be to charter a plane. Smith was tortured by the thought that the fish might be decomposing or, God forbid, that it wouldn't be a ceolacanth after all. To make matters worse, Hunt then telegrammed that the local French authorities were claiming the fish for themselves! In desperation, JLB telephoned the South African Prime Minister, who was himself on holiday. By some divine stroke of luck, the PM had just read one of JLB's books on fishes; he decided that JLB must be totally desperate and granted him use of an airforce Dakota aircraft. (I wonder what Tony Blair would say?) After a lengthy and irritating official welcome upon landing, JLB finally got to see the object of his obsession on Hunt's boat. There before his eyes lay a coelacanth, but it was starting to putrefy so he had to act fast. Taking advantage of a breakdown in communication between the French and their scientific base in Madagascar, JLB arranged for himself and the fish to be returning to South Africa in the Dakota only three hours after landing. He returned home, exhausted, to a hero's welcome.

The dramatic cicumstances relating to the 'rescue' of *the* coelacanth (named *Malania* after the island near which it was found) was splashed across the world's press. Ichthyologists went mad, and a Hollywood producer had the idea for 'The Creature from the Black Lagoon'! JLB showed the fish to the South African Prime Minister, who was mightily impressed. It was examined by palaeontologists eager to compare it with their fossils. JLB wrote a letter to *The London Times*, and also wrote an account for *Nature*. He confirmed that there were no lungs, just a swimbladder filled with fat, but there was a primitive forerunner of a backbone (*coelcanthus* actually means 'hollow spine'), and the limb-like fins had their own internal skeleton. Meanwhile Hunt, back in Comoros, had received some 'blunt words' from the French Bureau of Scientific Research in Madagascar, and extremely vitriolic articles were appearing in the Paris newspapers. Relations rapidly declined to an all-time low when the French authorities refused Smith permission to return to the Cormoros, and then, in November 1953, refused entry to all foreign scientists.

Naturally, the French launched a concerted effort to find a third coelacanth, which they duly did. 1954 brought a bumper harvest, and because the French were more organized than Smith, with his piratical shenanigans, these fishes provided greater opportunities to examine the detailed internal structures. Ceolacanths, apparently, have features in common with both frogs and sharks, but for a long time their place in the evolutionary tree remained obscure. Even today, much of the mystery remains, and modern DNA testing show only that the lungfish is probably the sister of the first tetrapod whereas the coelacanth is likely the first cousin.

Although JLB was out of the main picture by 1956 (when he wrote *Old Fourlegs – The Story of the Coelacanth*), his interest in the ceolacanth, and other fish, never died (he published over 500 scientific papers and named 370 new species). He received many scholarly honours, becoming a Fellow of the Royal Society of South Africa. By the mid-1960s his health was deteriorating; he was terrified of having a stroke, his eyesight was especially poor and he suffered from occasional mental depression. On 8 January 1968, aged 70, he took a fatal overdose of cyanide.

The second part of the book brings this exciting story up to date. It describes the continued French efforts to find more coelacanths. Many were found and soon the Cormoran government was making a pretty penny from sales of the fish. In 1972, the Cormoros Islands gained independence from the French, and foreign expeditions were once again allowed to search for coelacanths, and so the race was on to photograph and film a live specimen.

There followed a series of expeditions by the Italians, a collaborative Franco-Anglo-American effort, and a separate French expedition that turned out to be a hoax. One American aquarium offered $40,000 for a live coelacanth. There was a multi-million dollar expedition sponsored by the Japanese giant Mitsubishi. Two Germans using several DIY mini-submarines ventured beneath the waves, and they were the first successful group to capture the fish on film. During the mid-1990s, it became clear that the fish had a wider distribution than previously thought, when specimens were recovered from nearer to Madagascar and also in the Celebes Sea off Borneo (*Ocean Challenge*, Vol. 11, No.1), sparking further excitement for coelacanth junkies.

No other single fish been the focus of such interest and for so many years. This whole book is a real gem, mostly because it is such an exciting story – indeed, it would make a great film. Samantha Weinberg has produced an entrancing account of the life and times of a most rare and precious fish – as she says: 'our own great-uncle forty million times removed'. Highly recommended.

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Explaining Atmosphere–Ocean Interactions

Air–Sea Interaction: Laws and Mechanisms by Gabriel T. Csanady (2001). Cambridge University Press, 239pp. £21.95 (flexicover, ISBN 0-521-79680-6); £60 (hard cover, ISBN 0-521-79259-2).

This book claims to give a comprehensive account of how the atmosphere and the ocean interact to control the global climate, including the physical laws governing the interaction, and the main mechanisms involved in small- and large-scale processes in both air and sea. The first and longest chapter discusses laws governing transfer across the air–sea interface of momentum, sensible and latent heat, and gas. Wind waves, and their role in air–sea transfer, are discussed in the second chapter, with the author quoting results from both laboratory and field studies. The third chapter considers the near-surface mixed layers in both atmosphere and ocean, followed in chapter four by a discussion of penetrative convection: atmospheric 'hot towers' (cumulonimbus clouds and hurricanes) and deep convection in the ocean. The last chapter, entitled The Ocean's Warm Water Sphere deals with oceanic heat transports and the ocean's overturning circulation.

I started reading the first chapter with some enthusiasm, since the author appeared to be taking a different approach from that usually used to derive the air–sea transfer formula. Rather than using dimensional arguments and 'similarity', Professor Csanady initially considers the transfers of momentum, heat and mass as irreversible thermodynamic processes in which the rate of entropy production is an important factor. However, it was not obvious to me how much this approach helped, since the author soon returned to dimensional analysis and a rather confusing statement of similarity concepts. There was also a section which shook my confidence in the author's authority. Throughout the book he tends to single out a paper, or series of papers from a particular author, to illustrate his arguments. In one chapter he makes use of various papers co-authored by myself. This should have been flattering; unfortunately he mis-interprets our results stating that they are 'as good support for Charnock's law as one could possibly get', which is the opposite of the truth. Indeed, in his enthusiasm for Charnock's law (which attempts to relate sea-surface roughness to momentum transfer), Csanady also dismisses the possibility of the drag coefficient depending on wave age. While I personally agree with that argument, it is far from being generally accepted, and in a textbook I would have expected more discussion of the alternative viewpoint. When (as in this case) a subject which one knows well is wrongly argued and incomplete, it is hard to have confidence in the information provided on other, less familiar, subjects!

In marked contrast to the first chapter, the second chapter on wind waves, begins with the historical development of wind wave research, and relies heavily on classic sources such as Phillips' 1977 book on the *Dynamics of the Upper Ocean*. While this is certainly an authoritative source, the result is that much work is quoted at third hand, and I began to wonder if any progress has been made since 1980. Nor was it obvious that the emphasis on laboratory studies of short waves was justified by their role in open ocean processes. Only in the latter sections of this chapter, which discuss the mechanisms of scalar property transfer and pathways for momentum transfer, did the author appear to be providing some original insights.

In discussing the mixed layers in the atmosphere and ocean (Chapter 3), Csanady goes to some length to emphasize the similarities between the atmosphere and the ocean (even, confusingly, referring to the atmospheric 'inversion' as the atmospheric 'thermocline'). Perhaps for this reason he initially plays down the vital role of clouds in the marine atmospheric boundary layer, and we have to wait until the end of the chapter to discover that cloud-top entrainment 'is one of the key processes in air–sea interaction'. The emphasis in this chapter, and in the following chapter on 'hot towers', is very much on processes in tropical and subtropical regions. For example, while precipitation-driven squall lines are described, there is no mention of the slantwise ascent of boundary layer air in mid-latitude depressions. Similarly, much of the discussion of ocean mixed layers is mainly relevant to light wind regions typical of the tropical convergence zones.

The last chapter, on ocean heat transport, is a good illustration of a general problem throughout the book, namely that many of the references and the facts quoted are from work which has become out-dated by more recent research, very little of which is referenced. Thus, while Bunker's surface-flux maps for the Atlantic were a major achievement at the time, more recent climatologies have the advantage of using better formulations for the transfer equations and significantly greater amounts of data. Similarly, most of the estimates of ocean heat and freshwater transport quoted by Csanady have recently been thoroughly re-evaluated using the results of the World Ocean Circulation Experiment. Indeed, I found myself wondering when the book was actually written. The opening paragraph can be dated to Hurricane Edouard (1996), but elsewhere 'recent' work refers to papers published in 1986 and 1993 (p.109, p.209), a quote from President Bush (Senior) apparently dates from 1988 (and can only confuse non-American readers!), and the most references from any given year are for a year in the early 1980s. Thus, to me, the text has the feel of a teaching course developed in the 1980s and only partially revised in the late 1990s for publication in book form.

The last chapter also highlights a further general problem. It would appear that many of the figures have been redrawn from the original papers but without any editing or simplification. In contrast, the figure captions have been considerably simplified from the original. As a result, many figures have extraneous lines and unexplained symbols, and in some cases confusing errors have been introduced. For example, Figures 3.26 to 3.31 (quoted from Bunker, 1976) have inconsistent signs for the heat fluxes and in one case (Figure 3.29) the curves are incorrectly labelled: Figures 5.4 to 5.6 show air–sea heat fluxes in W/m^2 but labelled °C. Indeed, there are various other typographic errors in the text, including an equatorial undercurrent of 110 m/s! Presumably it is also due to a printing error that the index commences at the letter 'C'. This index was generally inadequate for finding particular items, and there is no author index, or list of symbols.

The book claims to be aimed at graduate students, entry-level students and research scientists in meteorology and oceanography, and at scientists and engineers from other fields. Unfortunately, the unconventional approach, non-standard terminology, and many oversimplifications and errors make it hard for me to recommend it to students, or to others not already familiar with the subject.

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Ocean Circulation and Climate: Modelling and Observing the Global Ocean edited by Gerold Siedler, John Church and John Gould (2001). Academic Press, 715pp. £65.95. (ISBN 0-12-641351-7).

The World Ocean Circulation Experiment (WOCE), arguably the largest ocean survey ever undertaken, officially began making its observations in 1990. WOCE had two stated goals: (1) to develop models useful for predicting climate change and collect the data necessary to test them; (2) to determine the representativeness of the specific WOCE datasets for the long-term behaviour of the ocean, and find methods for determining long-term change in the ocean. Given that WOCE planning took place in the 1980s, Goal 1 seems rather far-sighted: it is only relatively recently that climate change has become quite so prominent on the global political agenda. Goal 2 is a necessary adjunct of a 'state-of-the-ocean' experiment: Was there anything odd about the measurement period, and how in future could we tell if anything odd was going on? A crude measure of the impact of WOCE on the picture we have of the ocean is the number of high-quality deep (>3000 m) hydrographic stations made during its eight-year field phase. Before WOCE, there were about 50 000 of these in total, spread over seventy years or so; WOCE added nearly 25 000 more, an increase of 50%.

This, then, is a review of 'the WOCE book', and the first comment to be made about it is that it is far too early for the book to be the definitive statement of WOCE results, which will keep flowing into the foreseeable future. Rather, it is positioned as a statement of the 'state of the art'. It has been three years in preparation, dating from the 1998 WOCE conference in Halifax, Nova Scotia, and not from the start of WOCE observations in 1990, nor from the start of WOCE planning in the preceding decades. Gerold Siedler (one the book's editors) stated in the compilation of abstracts for the Halifax conference that that meeting was timed to occur at the transition from the field phase of WOCE to the Analysis, Interpretation, Modeling and Synthesis (AIMS) phase, with the intention of addressing the following questions: Did the observations meet WOCE goals? Did our view of ocean circulation change? Did WOCE cover a transition from more qualitative to more quantitative knowledge? How do we relate models and observations? And (in short) what of the future? Although the book arose out of the

Halifax conference, its aim was ultimately to present the state of knowledge of the ocean and its role in climate change at the end of the twentieth century. This ambitious goal informs the structure of the book, and it is against this grand ambition that its success must be evaluated.

The book is divided into seven sections which address, directly or indirectly, the questions mentioned above. Each section contains from three to eight chapters, all chapters are written by separate authors, and all the authors are what one might term 'the usual suspects'. The seven sections are (1) The Ocean and Climate, which is largely background and history; (2) Observations and Models, which describes the needs of, and developments in, both ocean modelling and coupled atmosphere–ocean modelling; (3) New Ways of Observing the Ocean, which focusses on technological matters; Sections (4) (The Global Flow Field), (5) (Formation and Transport of Water Masses) and (6) (Large-Scale Ocean Transports) occupy half the book, and cover the major scientific results of WOCE to date. The final section (Insights for the Future) asks 'Where next?', and also attempts to evaluate the representativeness of WOCE in the contexts of changing climate and oceanic variability. Plainly this is no ordinary 'book of the conference'. The editors have gone to some lengths to impose coherence, one (impressive) symptom of which is the invaluable unified 80-page reference list at the end.

Space precludes detailed consideration of all the contents of such a book as this, so here are a few impressions. The book is inevitably uneven, given its multi-authorship, but it is uneven at a very high level of quality. There is the odd duff chapter, but most of the book is very good, and some of it is excellent. I particularly liked Doug Wallace's CO_2 chapter, which covers new and historical oceanic and atmospheric data, model results and implications for the future, as well as information on background, methodologies, etc. It is a model of conciseness and clarity. I also liked Carl Wunsch's chapter entitled 'Global Problems and Global Observations' (with the emphasis on problems), which, rather like a curmudgeonly uncle smoking a pipe in the dining room, points up our (physical oceanographic) limitations. But then, who better than the Chairman of the WOCE Scientific Steering Group to do so? Two of my favourite oceanographic photos are also reproduced, on facing pages in the 'float' chapter (Davis and Zenk). One shows John Swallow assembling a float on the deck of *Discovery II* in the 1950s while being watched by a ship's cat who appears more interested and less sceptical than an adjacent pair of matelots; the other shows Tom Rossby and Doug Webb being dwarfed by a 1970s SOFAR float, which demonstrates how far we've come with autonomous float technology.

WOCE 'highlights' are well described. For example, the location of high oceanic mixing rates over rough topography inferred from microstructure measurements, and complementary work by deliberate tracer release, are covered in the Toole and McDougall 'Mixing and Stirring' chapter; the impetus given by WOCE to the study of decadal-to-centennial subsurface ocean salinity and temperature changes is seen in the chapters by Clarke *et al.* and Dickson *et al.*; and the advances in our knowledge of directly-estimated ocean heat and freshwater fluxes appear in the chapters by Bryden and Imawaki, and by Wijffels.

So does this book succeed as a statement of the 'state of the art'? To answer that question, it helps to glance at the competition, from which it can be seen that there is none. Most of the old favourites (books by Gill, Pedlosky, Emery and Thompson, etc.) serve entirely different purposes. I think we are left with *The Evolution of Physical Oceanography* (Bruce Warren and Carl Wunsch, eds., 1981) whose structure and function are similar to those of the WOCE book, but which dates from when WOCE was first conceived and, while excellent, is now two decades old. The WOCE book is a worthy successor, it is beautifully produced, and, in my opinion, as near to indispensable as an oceanographic book can be. Although it's a bit heavy to say 'don't leave home without it ' . . .

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El Niño and the Southern Oscillation: Multiscale Variability and Global and Regional Impacts edited by Henry F. Diaz and Vera Markgraf (2001). Cambridge University Press, 512pp. £55 (ISBN 0-521-62138-0).

Over recent years, a number of widely dispersed climatic anomalies have been attributed to a common origin, namely the periodic warming of the sea-surface layers of the eastern and central Pacific Ocean. This recurrent feature of the tropical climate, commonly known as El Niño, or the Southern Oscillation, is a phenomenon that is now known to be of considerable social, economic and ecological importance; it is also the subject of this new volume published by Cambridge University Press and edited by the well-known climate researchers Henry Diaz and Vera Markgraf.

The book is composed of contributions by a number of leading researchers, and is divided into two sections. The first deals with the analysis of different aspects of the modern El Niño–Southern Oscillation (ENSO) record, whilst the second deals with climatic reconstructions using a variety of proxy records such as ice-cores, tree rings and lake sediments. The major theme of the volume is the relationship between the global-scale climatic patterns operating at different time-scales, and the space–time behaviour of the higher frequency ENSO system. However, the book also considers important corollary effects of ENSO such as changes in tropical cyclone frequency, worldwide hydrological effects, and impacts on public health.

The parts of the book that I found most interesting, coming from a marine science background, were those chapters that summarize recent ENSO information, particularly those that discuss recent advances that have provided a long-term historical perspective for ENSO or have led to an improved ability to forecast ENSO events months in advance. For example, Chapter 1 summarizes historical evidence to show the current complexity of ENSO, revealing significant warming signals at periods of approximately 2–2.5, 2.5–7, 11–13, 15–20, 20–30 and 60–80 years. This chapter also points the way for future research linking ENSO with other global climate signals such as the North Atlantic Oscillation, the Arctic Oscillation, the North Pacific Oscillation, and the Antarctic Circumpolar Wave.

Chapter 2 further highlights the complexity of ENSO, showing that the historical flow patterns in the upper troposphere are unlikely to provide a complete spectrum of the atmospheric sensitivity to ENSO. However, the chapter does emphasize that global circulation models forced with sea-surface temperature (SST) variations can yield a rich image of teleconnections linking the tropics with the extra-tropics during ENSO events; it also makes the point that these analyses provide the potential to predict such patterns in advance.

The next chapter that I found of particular interest was Chapter 12. This chapter reports results from a recent coupled ocean–atmosphere model in which the equatorial atmosphere is approximated as a linear feedback system whose winds are driven by SST gradients. For this model, the upper ocean is represented by a shallow-water model capped by a mixed layer of constant depth. The mean stratification of the thermocline is maintained by upwelling from the deep ocean. This model captures well the oscillatory behaviour of the current ENSO system. The model also suggests that the present oscillating Pacific climate may exist in an alternative state, that is, in a warm steady state. This alternative state is consistent with the inference from archeological data that the ENSO system did not exist during the early Holocene. The switch between climatic states occurs when the temperature contrast between the warm surface and the deep ocean reaches a critical value. The model also predicts that the degree of oscillation increases with increased temperature contrast.

Finally, Chapter 13 provides a critical long-term perspective for ENSO from the last glacial period up until recent geological time. The chapter highlights the evidence that suggests that ENSO variability may have changed during this period. Further, it stresses that the recent expression of ENSO should be viewed in the longer term context, particularly the low-frequency modes of SST variability.

Through the various contributions, the book provides a useful background to the current state of knowledge about the ENSO system. Each chapter covers a different perspective and forms a valuable introduction to the various aspects of ENSO and its importance. The intended audience for the volume is broad, covering scientists working in a range of disciplines. These include meteorology, oceanography, hydrology, geosciences, ecology, public health, emergency response management, coastal zone management and decision-making. The editors also suggest that the book is intended for use as a supplementary text and reference source for university students, both for undergraduate and graduate studies. Given this broad spectrum of intended readers, the book is likely to become a valuable addition to any science library. However, the breadth of topics covered (and the price) mean that it is unlikely to become a personal acquisition, except for those researchers working specifically on El Niño-related issues, or for university academics concerned with designing student courses in environmental studies.

The book is produced to a very high standard. It is printed in clear text on high quality paper. The figures are generally clear and, where necessary, colour is used to make sure that the author's meaning is evident. In some chapters, a few additional figures would have also benefitted from use of colour; however, these are relatively few and their meaning is sufficiently clear, given close study. The figure legends are generally self-evident, though in some cases a little more detail would have been useful to save the reader from having to refer back to the text. The index is clear and useful and gives an easy entry into the book from various differing starting points. The references are comprehensive and form a useful bibliography as the background of each chapter. Generally, the book is well edited and careful consideration has been given to achieving a standardized format for the different chapters.

Overall, I liked the book and enjoyed dipping in and out. It is not a book for cover-to-cover reading, but it is definitely a worthwhile read and full of useful and detailed information.

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Shaping coastlines

Handbook of Beach and Shoreface Morphodynamics edited by Andrew D. Short (1999). John Wiley & Sons, 379pp, £125 (hard cover, ISBN 0-471-96570-7).

Anyone who has visited the seashore and walked a beach at low tide will know the fascination held by these ubiquitous features. They change with the hour and with the season, they vary from the small, pebble-strewn pocket to the expansive sandy plain, and they provide both scientist and layperson alike with the raw material for a lifetime of study. In practical terms too, we must understand beaches as natural and sustainable sea-defences, as parts of a larger system with whose workings we meddle at our peril.

The modern scientific study of beaches is the fusion of three broad traditions: geography, physics and engineering. Geomorphologists have long described and classified shorelines on a largely qualitative basis and, using data from field surveys, aerial photographs and maps, have reported changes on time-scales of days to centuries. Typically, however, the results of their work provide more questions than answers and do not easily give predictions for specific problems. By contrast, civil engineers, charged with the practical defence of harbours, property and installations in the face of these changing shorelines, have evolved their own set of semi-empirical codes on which to predict beach behaviour. Although these are able to provide the necessary numerical data (albeit usually with an unknown margin of error) on which can be based successful designs for short-term defence, in the longer term this approach has been famously responsible for a variety of major problems. Between these extremes sit the disciplines of environmental science, that attempt to interpret the results of laboratory and field experiments using mathematics and physics. The complexity of the resulting models is often too challenging for some, and too inapplicable for others. It is thus perhaps fair to say that, at the present day, the three traditions, although now speaking to one another, have not yet mastered a common language.

The *Handbook of Beach and Shoreface Morphodynamics* brings together the study of beach systems from these different perspectives and attempts a degree of synthesis. It is a collection of 14 chapters edited by Andrew Short of the University of Sydney. The nine contributors have all worked at some time in the Coastal Studies Unit at that university and have jointly authored the various chapters as a coherent group of writers. Along with the editorial control of Professor Short (who has contributed to more than half of the chapters himself), this has created a more balanced and stylistically consistent text than is sometimes the case with edited volumes. The authors state that they write from an Australian perspective; this is largely so in the examples and illustrations they have chosen, but their theme is international and their book will appeal to students of beaches everywhere. The chapters are well supported by references to the modern literature and the consolidated list contains upwards of 1200 citations.

The contributions are organized into five parts. The first part is an overview of beach systems and gives a global perspective on the formation of beaches: the point is well made that they are geomorphic features that occur on every coastline where waves and sediments are found. Local differences, due to wave climate and sediment supply, are usually of more importance than regional variations, although the role of climatic zones in differential beach development, through differential weathering rates and the growth of coral reefs, is properly acknowledged.

The four chapters of the succeeding part consider in turn the dynamics of each of the four principal elements of the beach system: the shoreface, the surf zone, the beach face and the backshore. Together they form the solid core of the book and provide an up-to-date review and conspectus of research from field and laboratory, as well as theoretical perspectives. Some may find these chapters a little hard going, since they are necessarily built on the mathematics of wave theory and the physics of turbulent flow. One is reminded of Alphonso's alleged remark that 'If God had consulted me before embarking upon the Creation, I would have suggested something simpler'. However, collectively these chapters provide an excellent summary of the complex fluid–sediment interactions that occur across the beach system, leavened by the observations from field surveys of beach form and processes.

In the third part, entitled 'Beach types and applications' the authors consider larger distances and longer time-scales. There are three chapters: on wave-dominated beaches; on the role of tides; and on the control exerted by bedrock structure. Compared with the preceding part, these chapters are generally shorter and contain more empirical data and less theoretical analysis. This is no reflection on the authors, since research into these aspects is necessarily based less on the application of fundamental concepts and more on models built from long-term observation and spatial comparisons. I did, however, feel that some material, for example that on beach dynamics, was to an extent repetitive and I wondered if this was the best possible subdivision of the material or whether instead the more general aspects of beach behaviour might not have been better placed before the detailed consideration of their dynamics.

The remaining two parts are rather more lightweight. The first, entitled 'Beach systems and impacts' is a mixture of topics, including beach modification by exogenous factors (such as climate), beach ecology, sediment stratification and beach hazards and safety management. Notably, the last section, on safety, attempts an interesting integration of this important application with the physical processes described in the earlier chapters. Here, the Australian experience of the authors provides a context for the material, for example in the descriptions of safety practices in the beaches around Sydney. Conversely, the appropriateness of the chapter on beach ecology in a text on morphodynamics is questionable; it does not really do justice to the complexity of this subject, on which whole books have been written, and takes space that might have been devoted to other topics. Similarly, the final part (entitled 'Large scale beach behaviour') is in fact just a single chapter on the tangential subject of barrier coastlines and, as such, does not really live up to the title of what could have been a most interesting section.

One inevitably finds a few of one's own personal favourites either missing or understated. For myself, I was sorry not to have found more on the morphology and historical dynamics of longshore spits, which are prominent along the British coastlines of north Norfolk and of Morayshire in north-eastern Scotland, to name a few that have become familiar to me over many years, both as a student and as a teacher. Also, I missed any discussion of the construction and use of computer models in coastline studies, especially since these have now reached the stage where their predictions are becoming a serious research and management tool.

And so what of my overall impression? It would be unfair, both to the contributors and to the editor, flippantly to describe the book as a curate's egg: the good parts (and there are many) are indeed very good and even the less good parts are more inappropriate than poor. The core material on quantitative beach processes is excellent and many readers might well purchase the book for this part alone. The chapters on larger scale coastal morphology and temporal changes are also very valuable, although I personally find the division of the topics between sections a little strange and would rethink this for a future edition. I would also question the inclusion of some peripheral material mentioned above. Indeed, perhaps the term 'Handbook' is itself somewhat misleading, since the book offers little of the codified engineering guidance usually associated with such texts. However, I would not wish to end on the wrong note. Andrew Short's book is a deep and well researched account of beach morphodynamics and coastal evolution. I have greatly enjoyed reading it for my review and warmly recommend it to you if, like me, you find beaches places of fascination, both for scientific study and simply for their own sake.

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Coastal Geomorphology: An Introduction by Eric C. F. Bird (2000). John Wiley & Sons, 340pp. £27.50 (flexicover, ISBN 0-471-89977-1); £70 (hard cover, ISBN 0-471-89976-3).

If you type 'bird, e.c.f' into an internet search engine you end up with a tremendous number of entries. Eric Bird, it seems, has been writing books on coasts and shorelines (in addition to publishing in scientific journals) for about 40 years. I checked him out on the University of Melbourne website, and discovered that he was born in the UK in 1930, and went to the Australian National University in 1960 to do his Ph.D after completing a Masters in geomorphology at London University in 1955. He has penned 260 scientific papers (!) and written five major books. His 1985 book, *The World's Coastline* (with M. L. Schwartz), is a particular gem and contains many spectacular aerial shots of coastal features. He has worked in Australia, south-east Asia, the South Pacific, the Mediterranean, Europe, the Baltic, East Africa, Arabia and north-east America; and he still provides advice on coastal management to national, state and local governments and NGOs in Australia, south-east Asia, the UK and USA. Since 1970, he has advised various UNESCO and UNEP commissions and has supervised research projects for the IGU commission on the coastal environment (1972–92). Who better, then, to write an up-to-date introductory text on coastal geomorphology?

This book gives – in 12 chapters – a systematic approach to the subject, dealing with the shaping of land-forms, the changing levels of land and sea, and the array of coastal processes that supply energy to the shoreline and which are responsible for geomorphologic change. Bird covers the following topics: coastal processes, land and sea-level changes, cliffs and rocky shores, beaches, spits and barriers, coastal dunes, intertidal landforms, salt marshes and mangroves, estuaries and lagoons, deltas, and coral and algal reefs. As usual, there is a more than liberal sprinkling of photographs and case studies from localities all around the world. Finally, there is a useful chapter on 'future coasts' which examines the influence of climate change on physiographic units (i.e. beaches, deltas etc.). As an appendix, Bird approaches the tricky subject of classification, contrasting genetic schemes against purely descriptive ones.

Perhaps the easiest way for me to appraise the book is to give an overview of the chapters closest to my own sphere of interest. These are Chapters 8 and 9, which deal with intertidal landforms, and with estuaries and lagoons, respectively. These chapters reflect a trend seen in the book as a whole, namely that Bird is highly descriptive, with comparatively few references in the text. Other similar books, in my experience, contain far more reference material and illustrate specific processes (e.g. sand-bar formation) using a specific journal publication. In this case, it's a bit like walking along the beach with Bird as he explains all there is to see, and if you had to read the entire book as part of a course you'd be exhausted! Nonetheless, if you concentrate and use a bit of imagination you can grasp the essentials of the processes. He does occasionally use conceptual diagrams to illustrate his ideas and various processes, but more often he uses photographs. Pretty, but not necessarily that informative.

Bird describes well most of the common physical features found on beaches, such as sand bars, ripples and megaripples, and uses examples from Australia, Wales and the north-west European coastline. Again, however, there is an annoying lack of contemporary examples, and some references are woefully dated (two from 1953). He goes into considerable detail in particular areas, which is possibly why he refers to specific studies only infrequently (an over-abundance of references would be just as bad as a lack). There is a noticeable dearth of any quantitative data, which (with respect) I have always felt to be a characteristic of geomorphology generally. I tend to think of geomorphology as descriptive geography; at most, it is semi-quantitative. Of course, page after page of equations puts most people off, but this book is at the other end of the spectrum. In his defence, Bird does include a section on Coastal Processes (Chapter 2), which provides the usual equations relating wave speed, energy, period etc.

There is just over a page on mudflats, with mention of the most dramatic examples from Korea and the Dutch Wadden Sea. Bird describes a variety of mudflat surfaces and channel networks, and mentions the dominant processes (erosion, transport, deposition, consolidation); however, he doesn't get to the real nub of mudflats in either geomorphologic or process terms: Why/how do mudflats exist and why is the geomorphology as it is, especially if mud is so soft and squishy? The answer (so far as we know) – biological stabilisation. Research involving the forced removal of the biogenic component shows that surficial mud layers are washed away by even the weakest tidal currents. Moreover, the surface morphology is controlled fundamentally through the interplay of sediment strength (itself a function of myriad other things including atmospheric exposure) and tidal and wave forcing, which vary according to tidal state. None of this is mentioned. Bird describes dissecting channels but again fails to illuminate the reader on how these are formed. Altogether rather disappointing.

He mentions, for example, that mudflats are more cohesive than sandflats because of 'organic stickiness'. And that's it. And yet the organic mucus he refers to does have geomorphological implications (to an extent, it can govern the intertidal profile) as well as ecological ones. In an up-to-date book on coastal sediments, one might have expected inclusion of some of the more recent studies that have described and quantified this important aspect of estuarine muds.* Again, the lack of up-to-date relevant information is alarming. The INTRMUD project, in particular, was predominantly concerned with the morphology and classification of estuarine mudflats. There have also been some recent interesting numerical studies by Bill Roberts of HR Wallingford & Co., and also Carl Friedrichs at VIMS in the USA, contrasting the importance of wave action and tidal scour in forming the intertidal profile (either convex or concave). None of this key work appears. The section on marshes is a bit better, but then again does not reference seminal review works such as that by Lüternauer (1995).

In conclusion, the book is, on the whole, disappointing. As an introduction to coastal landforms perhaps it will be of use to junior honours level students, to familiarise them with the nature of the coastline and some of the fundamental driving forces – it does cover the subject in considerable breadth, if not depth. For anyone above that level (i.e. senior Honours/postgraduates/researchers), I imagine greater detail would be preferred, and information would need to be sourced from elsewhere. For example, there is, surprisingly, nothing in the book on geomorphological techniques or methods, and one is left wondering what Bird is trying to achieve here that he hasn't already covered in his other books. Altogether not impressive, in spite of my earlier hope that Bird is the man to write such a book! I reckon *Process Geomorphology* by Dale F. Ritter is a much better buy.

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*E.g. *The LOIS Study of Humber Estuary Muds* published as Black, K.S., *et al.* (1998) *Journal of the Geological Society of London, Special Issue* 139, and the follow-on publication covering the EU-funded INTRMUD project; see Dyer, K.R., (2000) *Continental Shelf Research* **20**, Nos.10–13). Lüternauer, J.H., Atkins, R.J., Moody, A.I., Williams, H.F.L., and Gibson, J.W. (1995) Saltmarshes. In: (Perillo, G.M.E., Ed.), *Geomorphology and Sedimentology of Estuaries, Developments in Sedimentology* **53**, Elsevier Press, 307–33.

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

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