# OCEAN

# Challenge

The Challenger Society for Marine Science

Volume 11, No. 3

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# OCEAN Challenge

## The Magazine of the Challenger Society for Marine Science





SCOPE AND AIMS

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

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


*The next issue of* Ocean Challenge, *due out next month, is a special European issue.*

# News & Views

## CFP reform – too little, too late?

In late May it was announced that stringent cuts are to be made in European Union fishing fleets, leading to withdrawal and decommissioning of some 8600 fishing boats and the loss of nearly 30 000 jobs. Perhaps more importantly, there will be no more subsidies to build and renovate fishing boats. Instead, subsidies will be used to decommission vessels, and funds will also be made available to support fishing communities affected by the cuts – though whether such funds prove adequate remains to be seen. These changes seem to have originated with Franz Fischler of the European Commission, who expressed concerns that commerical fish stocks were in bad shape because scientific advice was not heeded and there are still too many boats catching too few fish. He has evidently built upon earlier attempts by Steffen Smidt, the Danish official who was Director of the CFP until last April, when he lost his job after putting forward proposals that would have required a cut of 40% in the Spanish fishing fleet.

Unsurprisingly, Spain objected strongly to this, and it was reported that in mid-April the Spanish Prime Minister (Jose-Maria Aznar) phoned the Commission President (Romano Prodi), demanding – and achieving – dismissal of the offending Dane. Apparently judging it impolitic to cite his plan to reduce Spain's fishing capacity as a reason for sacking him, the Spanish had focussed on another part of Smidt's proposals, which was to allow Holland and Denmark to continue industrial fishing. This activity effectively 'hoovers' small fish from the sea (including the young of other commercially valuable fish such as cod), to make feed for livestock, and probably fish farms too – so objections to the practice are understandable. The story goes that Spain objected also to Britain being granted 'sanctuaries' (exclusion zones) in the North Sea, because this would breach the EU's equal access policy – despite the fact that those zones were set up to protect breeding populations and thus conserve fish stocks. For the record, Spain subsequently denied pressuring the EC President to get Smidt sacked, even though a number of other EU countries confirm that they did!

To be sure, since the CFP was set up there have been major reductions in fishing fleets throughout the EU – by 10% in Britain over the last year alone, according to our Fisheries Minister, Elliott Morley (who, incidentally, also failed to acknowledge that Smidt was sacked because of pressure from Spain). The UK now musters only about 16 000 active fishermen, while there are still some 65 000 in Spain, which also still has the largest fishing fleet – getting the biggest subsidies – in the EU. So Spain will fiercely oppose the cuts, and it appears that they will be joined by France and Portugal.

Protests from Britain are likely too, because on a recent visit to these shores, Franz Fischler asserted also that stocks of commerical fish in northern waters (North Sea and north-east Atlantic) are more depleted than in southern waters (Mediterranean and adjacent Atlantic). This may in part be because global warming has led to northwards migration of the copepods that are the main food for cod (cf. *Ocean Challenge*, Vol.11, No.2, p.17). At all events, while the average cut in fishing strength is said to be of the order of 9%, Fischler warned that quotas for northern fleets will be less than those allocated to southern fleets.

The 24 April issue of the American magazine *Newsweek* carried a persuasive story about 'staggering' levels and costs of corruption and waste throughout the EU. Can it be that the reason for the parlous state of the CFP is merely another manifestation of the sleaziness that seems to pervade all levels of the EU? Certainly, the brouhaha attending these latest proposals has featured phrases like 'dirty tricks' and 'underhand deals'.

An average cut of 9% still leaves over 80 000 fishing vessels and more than a quarter of a million people employed in the industry. The new proposals may go some way to protecting fish stocks in European waters, but don't help fishing grounds in other parts of the world, such as off West Africa, where EU boats are now licensed to fish, with huge ships like the *Atlantic Dawn* (*Ocean Challenge*, Vol. 11, No. 2, p.3). Still, she may be the last of her line, if there really are to be no more subsidies for building new boats.

## Mercury in tuna – déjà vu or something new?

In the early to mid-1970s there were newspaper scare stores about high mercury concentrations in fish such as tuna – levels were reported to be of order 1–2 parts per million (p.p.m.). The source of the mercury was alleged to be military–industrial complexes in western Europe, North America, the (then) Soviet Uniion, and Japan, which liberated the metal to the atmosphere, whence it was washed out to end up in the ocean.

The result was a sharp decline in sales of tinned tuna – this was a time when fresh tuna was less fashionable in Britain than it is now, though it had long been popular in Japan. There was something of a decline in the tuna-fishing industry, but it didn't last for long, chiefly because analysis of tuna samples from a wide range of oceanic regions revealed that the alleged contamination probably resulted from food-chain enhancement. So people who wanted to eat tuna were going to ingest 1–2 p.p.m. of mercury along with their fish regardless, because tuna are top predators (though not as 'top' as humans), with a physiology that enriches trace metals like mercury.

Now mercury is back in the news as a potential hazard to fish-eating humans, not only in tuna but also in other top predators, notably swordfish, marlin. and even sharks. Medical advances since the 1970s have narrowed the field of persons at risk, to women who are pregnant or planning to become so, and to persons less than 16 years old. Interestingly, the concentrations reported in a new crop of broadsheet stories last May are of the order of 1.5 p.p.m., which is very similar to levels cited 30 years ago.

However, this time the culprit is not simply the element mercury *per se*, but its organic form, methyl mercury. Just how methyl mercury gets into these top predators is not revealed in the newspaper stories, beyond a passing reference to 'conversion by bacteria'. However, the methyl mercuty which caused the famous Minamata Bay disaster of 1963, in Japan, was traced to industrial effluents. Unless bacteria have evolved to convert inorganic dissolved mercury into organic forms over the last thirty years, methyl mercury in fresh fish must surely also have industrial sources. Or perhaps this is a case of a story older than 25 years being forgotten, then 're-discovered' and recycled as new. It happens often enough in the scientific literature, why not in newspapers too?

## Nuclear power – not finished yet

Amid all the excitement about offshore wind farms and ambitious plans to harness waves and tides off the Hebrides (*Ocean Challenge*, Vol.11, No. 2, pp.2–3), the nuclear option shouldn't be forgotten. Until quite recently the anti-nuclear lobby had been so strong that the prospect of new nuclear power stations being built anywhere in Europe seemed very remote indeed. However, the prospect has lately become less remote, what with the Russians helping Iran to 'go nuclear' for its electricity supply (despite strong objections from the US, fearing nuclear weapons proliferation); while in this country there is renewed interest from British industry and some government departments. In the next twenty years, as the present generation of nuclear stations is decommisioned, there will be an energy deficit that – so it is claimed – renewable energy sources will be unable to meet.

There is still a long way to go before the anticipated energy deficit becomes critical, however, so there is still plenty of time for the renewables lobby to try and fill the gap. Thus, the Government recently granted permission for erection of thirty-eight 2 MW wind turbines on Scroby Sands, a large sand bank off Great Yarmouth, famous as a seal colony and – until the advent of improved navigation equipment – notorious as a wrecking ground for ships. Even at full capacity, the Scroby Sands offshore wind farm will generate no more than 75 MW, less than a tenth of what a nuclear power station can provide. There are plans to put up more wind farms in Cardigan Bay, in the Irish Sea, and off England's south coast. Local objections to land-based wind farms seem to be increasing by the day, so putting the turbines offshore may be preferable. Wind remains a 'dilute' energy source, however, and many hundreds of 2 MW turbines will have to be commissioned – not to say a whole array of other renewable energy sources – if the need for more nuclear power stations is to be obviated. Perhaps the most telling argument against the nuclear lobby is the simple fact that nuclear power needs fuel and the fuel needs re-processing which, despite best efforts, releases radioactivity into the environment – witness objections to pollution of the Irish Sea by effluents from Sellafield (*Ocean Challenge*, Vol. 11, No. 2, p.3). However, since September 11, ships carrying nuclear fuel for reprocessing could be in greater danger of highjacking.

## Desalination by nuclear power

A plant being built near Madras in south-east India will use nuclear fuel to process 35 000 $m^3$ of water daily, supplying more than 5000 $m^3$ of freshwater for local needs. India, Russia, Canada, USA, South Korea, Indonesia – the list of countries planning to use nuclear energy for desalination is growing. That should surprise nobody, for the world is shorter of water than ever, there being now over a billion people without access to clean supplies. These people are of course in developing countries, which are mostly too poor to afford the necessary capital for construction. Nor do most of them have the legal and regulatory infrastructure that can ensure both safe operation and proper storage of nuclear waste. Nuclear desalination plants probably don't use much fuel, but it all has to be stored and eventually re-processed.

Although nuclear desalination may seem to be a new idea, the Japanese have been using the technology for more than 20 years. But most desalination plants use fossil fuels, especially those in the Middle East where natural gas is abundant (*Ocean Challenge*, Vol. 8, No. 2, pp. 8–9). So, meeting humanity's water shortage by desalination using fossil fuels pumps more $CO_2$ into the atmosphere, which can only exacerbate climate change – droughts could become commoner and more severe, so there'd be even less water to go round.

## Reprieve for Alaskan wildlife

In April it was reported that the US Senate – perhaps surprisingly – had vetoed plans by America's oil industry to drill in Alaska's wild life refuge (cf. *Ocean Challenge*, Vol. 11, No. 2, p.3). It is widely anticipated. however, that the mid-term elections next November will restore a Republican majority in the Senate, which would probably let the drilling go ahead. That could be a timely decision for the US, because Arctic oil would enable them to reduce dependence on oil from the Middle East, which is considered politically unstable – and if oil supplies run down, the price of gasoline will rise, alienating many American voters.

In this context, a recent short report from Reuters may be relevant. It related that the presidents of Iran, Azerbaijan, Turkmenistan, Kazakhstan and Russia had failed to agree on how the vast oil reserves of the Caspian Sea should (or indeed, could) be divided up between them. Cynical observers might be forgiven for believing that the failure to reach agreement had mainly to do with which country might benefit most from the huge tax revenues that must be owed on the vast profits being made by the (mainly) western oil companies extracting Caspian oil. However, it seems unlikely that such disagreements would lead to developments serious enough to threaten supplies of oil to the USA – or indeed, to anywhere else.

**DON'T FORGET!**

**Marine Science 2002 is in Plymouth on 3–9 September**

***See full-page advert on p.5.***

## Marine Conservation Bill

At the beginning of July, the Marine Wildlife Conservation Bill (to give it its full name) moved closer to becoming law, when it passed through the Committee Stage of the House of Lords. The Bill, which was a Private Member's Bill, was put forward by John Randall, MP for Uxbridge, and is stongly supported by a wide range of conservation organisations, including the Marine Conservation Sociery and the RSPB.

Britain currently has three 'marine reserves' – Strangford Lough, and the Islands of Skomer and Lundy (but not the waters surrounding them). The Bill proposes setting aside areas within the UK territorial sea, for the protection of important marine habitats and species – effectively marine SSSIs.

Currently, the European Habitats Directive provides for the management of activities within Special Areas of Conservation, but these can only be designated for species and habitats of European importance, and there are many marine species, habitats and areas of high natural diversity that are of national importance and are currently threatened by human activities and either have no protection, or rely on voluntary measures.

## Earth Summit for All

Notwithstanding John Wright's tirade about sustainability (p.18) there are still people who believe in the concept. Some members of the Open University have set up a website called 'Earth Summit for All', specifically relating to the Johannesburg Summit, which is scheduled to open on 27 August with an anticipated 65 000 participants.
The website can be found at:
http://earthsummit.open.ac.uk


**The First Scientific Conference of the European Federation of Marine Science**

**Oceanographic Aspects for a Sustainable Mediterranean**

**will be held in Athens 27–29 September 2002**

***For more information, see p.28***

## Seals again at risk from PDV

According to the Common Wadden Sea Secretariat, since the middle of June, more than 120 common seals have been found dead in the Dutch part of the Wadden Sea, and 2190 have been found in the Danish and Swedish waters of the Kattegat/Skagerrak. It has been confirmed that the dead seals have been infected by the phocine distemper virus (pdv), which causes damage to the seals' nervous and respiratory systems (see *Science*, **297**, 12 July, p.209). This is the virus which caused the seal epidemic in 1988, when about 8 600 seals died in the Wadden Sea.

A number of dead seals have also been found in Norwegian waters, but so far no evidence of the disease has been found in the the Baltic, or in the Danish and German parts of the Wadden Sea, or in other Danish areas.

The Common Wadden Sea Secretariat (CWSS) compiles the information about dead seals and publishes the data on the CWSS website at http://waddensea-secretariat.org/news/news/Seals/01-seal-news.html. The information is updated every two or three days as new information becomes available.

## Brains and climate change

Evidence from ice cores and deep-sea sediments suggests that climate change could occur on decadal to annual time-scales during both glacial and interglacial episodes of the (current) Pleistocene Ice Age. That began a couple of million years ago, and a novel idea about human evolution suggests it is no coincidence that early humans began using tools at the same time.

The thesis is simple: frequent and severe changes of climate forced humans to adapt rapidly to alternating flood and drought, heat and cold, and it was these climatic fluctuations, rather than dietary preferences (as suggested by some anthropologists), that led to the development of our large brains. This in turn enabled early humans to develop tools, technology and cultures, and form communities.

But what about the rest of the animal kingdom? Did they adapt to rapid climate change too? Followers of Stephen Jay Gould would argue that evolutionary changes are less likely during periods of rapid environmental change than during periods of relative environmental stability. Perhaps rapid environmental change leads to technological evolution, not biological. If so, it will be interesting to see how human societies handle the effects of global warming – how will we cope if (when?) North Atlantic Deep Water switches off and north-west Europe freezes? (For more on this possibility, see pp.12–13.)

## Meteorite impacts – an evolutionary symmetry?

Forget – for the moment at least – the impact that (allegedly) wiped out the dinosaurs 65 million years (Ma) ago, the K–T boundary. The symmetry alluded to in the title comes from a novel proposition, namely that 200 Ma ago, when dinosaurs were little more than a gleam in evolution's eye (much as the mammals were 65 Ma ago) a large impact wiped out the Triassic reptiles, setting the scene for dinosaurs to rule the world throughout the next 135 Ma.

Most of the evidence comes from analysis of tetrapod footprints and examination of skeletal remains from sediments near to the Triassic–Jurassic boundary (*Science*, **236**, pp.1215–16, 1305–7). Supporting evidence for the proposition is persuasive, but not abundant. There is a rather weak iridium 'spike' in sediments at the Triassic–Jurassic boundary, which is about 5 times the background value (50 parts per trillion) and only a third of the size of the anomaly at the K–T boundary. Other evidence in sediments near the boundary includes lots of spores of ferns, which tend to proliferate on devastated land areas (e.g. after a meteorite impact), also some impact-shocked quartz. The combination is unlikely to persuade the sceptics, especially those who consider volcanism to be the principal agent of extinctions for Life on Earth.

We can, however, be fairly certain that, while the next impact will more than decimate the human population, Life on Earth will go on, especially microbial life. It is a moot point whether the impact would extinguish more species than we humans have managed to kill off in the last few centuries. But it's an academic question, not likely to be uppermost in anyone's mind at such a time.


# CHALLENGER CENTENARY CONFERENCE MARINE SCIENCE 2002

## Plymouth, 9–13 September, 2002

There will be a programme of talks across the fields of biological, chemical, optical, geological and physical oceanography, plus trade exhibits and social events. We look forward to welcoming marine scientists from the UK, Europe and further afield.

Keynote speakers include:

- Paul Falkowski
- Harry Elderfield
- Jochem Marotzke
- Margaret Deacon
- David Prandle
- Mike Zubkov
- Bob Duce
- The Challenger medallist
- The Buckland Society lecturer

The conference will run from 9 a.m. Monday 9 September until lunchtime Friday 13 September.

Please note that registrations received after 31 July 2002 will incur a surcharge of £50.
You can register online at www.challenger2002.org.uk

Further information is available at www.challenger2002.org.uk, via the conference email address challenger@mail.pml.ac.uk or by post from Dr Carol Robinson, Plymouth Marine Lab, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK.

**For information about other forthcoming oceanographic conferences, please see the *Challenger Wave*.**

# The Volvo Ocean Adventure

**Val Byfield and Simon Boxall**

## A Brief History

The Volvo Ocean Race (formerly the Whitbread) has been running every four years since the first Whitbread in 1973–74. The scientific adventure began in the autumn of 1998 when Volvo approached Southampton Oceanography Centre (SOC) for ideas on how to bring marine science and education into the race programme, scheduled to begin in September 2001. Over the next couple of years, plans were made to:

- Develop self-contained, low-cost ocean colour sensors, which could be tested on the yachts in the race, and later used on ships of opportunity, such as cargo ships, ferries and other vessels.
- Present the data collected by the yachts on an education website, together with background information and advice on how to interpret the data.
- Follow the progress of the race on daily satellite images of ocean colour, and of wind and wave fields, and provide information about the features seen in the images.
- Provide a window on the world of marine environmental research through material from universities and research institutes along the route of the race.
- Increase awareness of environmental issues relating to the ocean and the world's climate.
- Encourage young people to participate actively in solving environmental problems globally and locally.

The ideas were approved by Volvo in spring 2000, and SOC started recruiting science partners around the world to provide material for the website, and act as education contacts for schools in their home countries, particularly during the port stopovers. By the time of the race start from Southampton on 23 September, 2001 some 25 organizations were contributing to the Adventure.

During the race, activities in the stopover ports were organized locally for schools, and varied in content and scope, depending on local resources and interests. These activities provided 'hands on' experience with marine science, and gave students of all ages a chance to talk to local marine scientists and to members of the race teams.

## Optical Sensors on all Volvo Yachts

All eight yachts taking part in the Volvo Ocean Race were equipped with prototype optical sensors to measure ocean colour from above the sea surface. Over the last two decades ocean colour has become increasingly important as a tool for mapping phytoplankton distribution in the world's oceans (Figure 1). Daily measurements from satellites such as NASA's SeaWiFS sensor provide a unique capability to map chlorophyll concentration over large areas, and complement traditional research methods. However, satellite measurements are not always able to provide the data required for some applications. For instance, clouds are a problem in many parts of the world, and may limit the data available at certain times of year. Measurements from ships and boats do not give the overview unique to satellite observations, but may provide information when satellite data are unavailable or unreliable for various reasons.

Developing a self-contained optical instrument package, and testing the prototype onboard the Volvo yachts during the race, was the first step in a wider programme. This aims to make regular, frequent ocean colour measurements from ships of opportu-

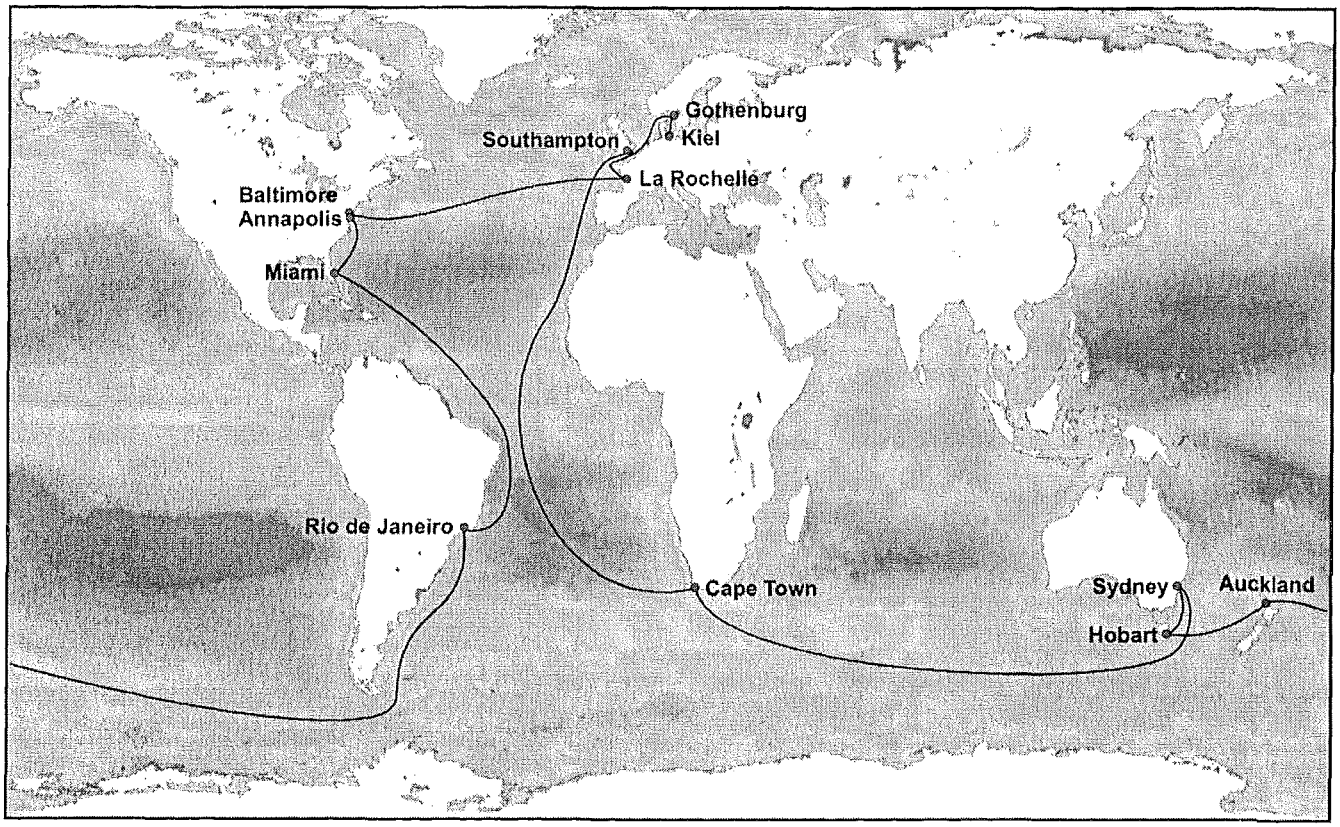



***Figure 1*** *The route of the Volvo Ocean Race 2001–2002. The intensity of the grey shading in the background is an indication of the biological productivity of the waters: the lighter the shading, the more productive the water.*

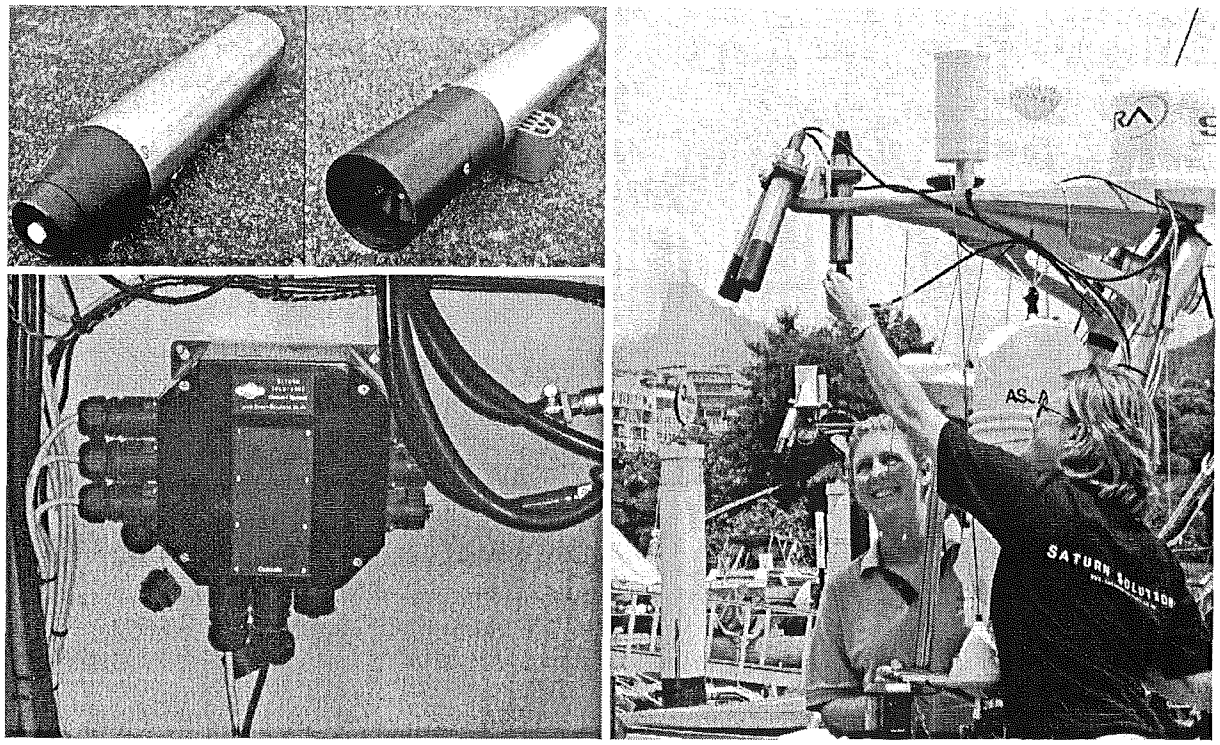


***Figure 2*** *The optical instrument package mounted on the yachts in the Volvo Ocean Race.* ***Top left:*** *The two types of sensors: cosine collector (left) and radiance sensor (right).* ***Right:*** *The sensors mounted on the stubmast as seen during instrument maintenance in Rio de Janeiro.* ***Bottom left:*** *The Ocean-i control unit mounted on the wall inside the yacht.*

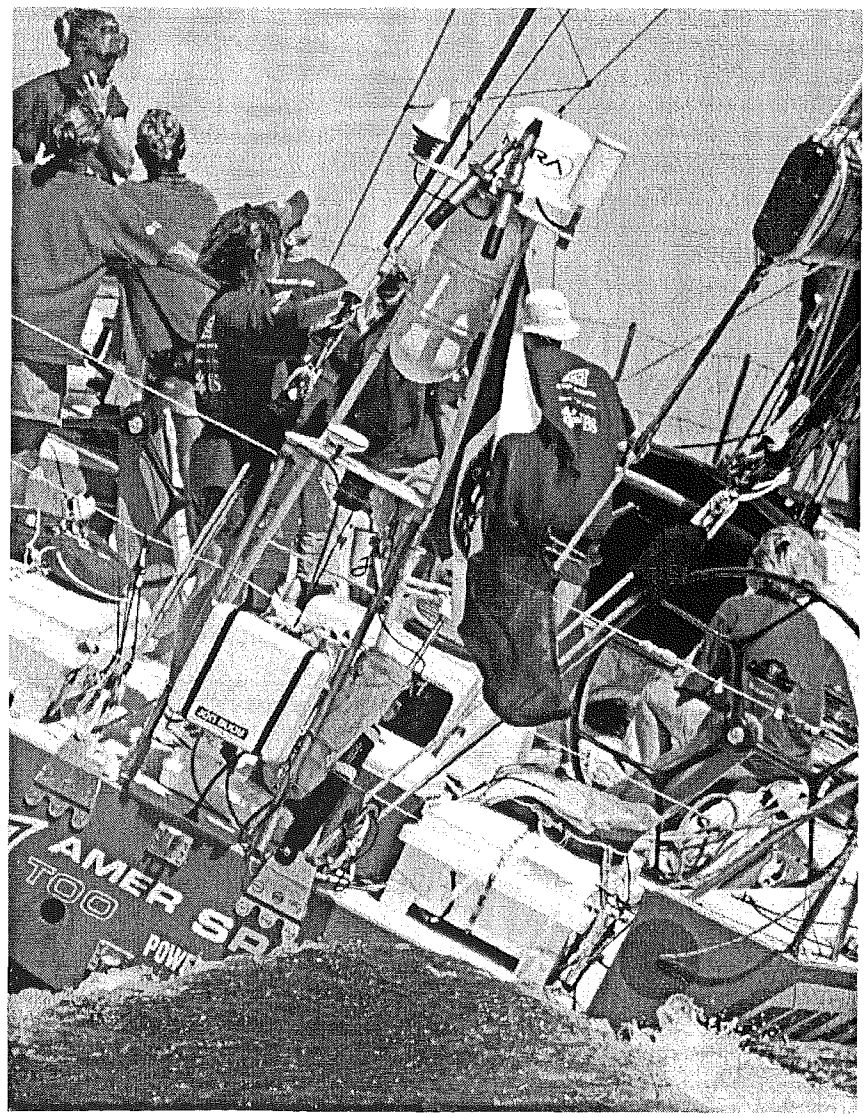


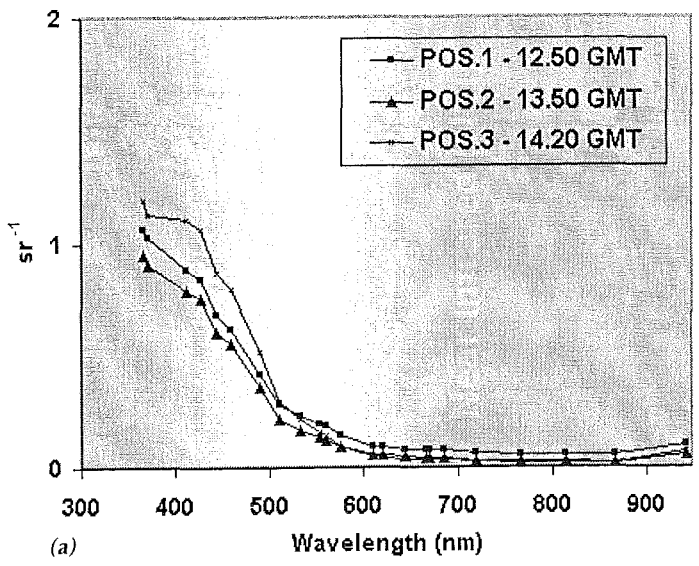

***Figure 3*** *The women's team* Amer Too *approaching Rio de Janeiro. The photo illustrates why it was necessary to have two sensors measuring water-leaving radiance. When tacking, the heel of a yacht could be considerable, and might give unacceptably large viewing angles. However, with two sensors, one would always be looking down at an angle reasonably close to the vertical.*

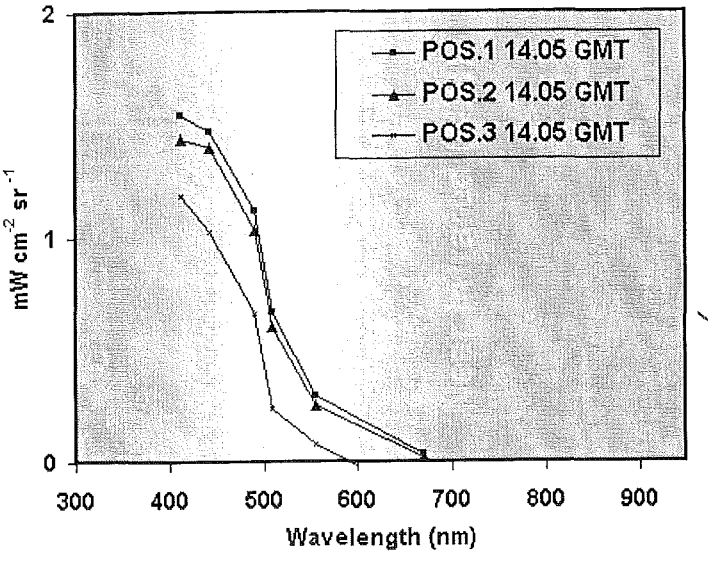
*(Photo: Carlo Borlenghi/ SEA&SEE)*

nity, and bring the data to researchers in near real-time. The sensors chosen for the yachts are part of a new generation of hyperspectral sensors – instruments with a large number of narrow wavebands, potentially capable of providing more detailed information about water quality than traditional instruments with fewer and broader wavebands.

The optical sensors chosen measure light in 255 evenly spaced bands ranging from 350 to 950 nm wavelength. Each yacht was fitted with three such sensors on a stub-mast at the stern (Figure 2):

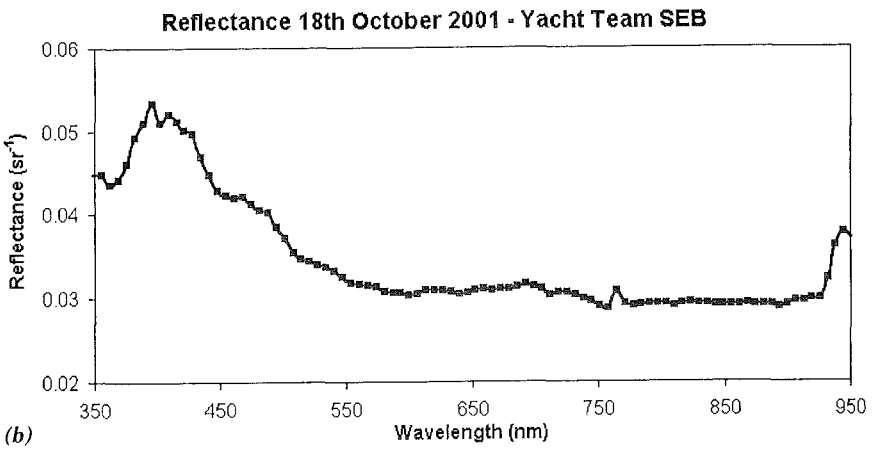
- A cosine collector (180° field of view) pointing upward to measure the incident light conditions. The sensor was shielded from light reflected off the sails and rigging, which reduced the true field of view.
- Two radiance sensors (7° field of view) pointing downward to collect light reflected by the sea at a viewing angle of 20° from the vertical, to either side of the yacht.




(a)

***Figure 4(a)*** *Example near real-time spectra from the website data archive.* ***Left:*** *Remote sensing reflectance in 24 channels measured by one of the yachts on 5 October 2001.* ***Right:*** *Normalized water-leaving radiance from the SeaWiFS pixel most closely corresponding to the yacht measurements. The two spectra are not directly comparable, but in both cases the spectral shape is characteristic of the North Atlantic open ocean, where the measurements were made.*




*(b) Example of the full spectral data recorded by the yachts in the South Atlantic during Leg 1.*

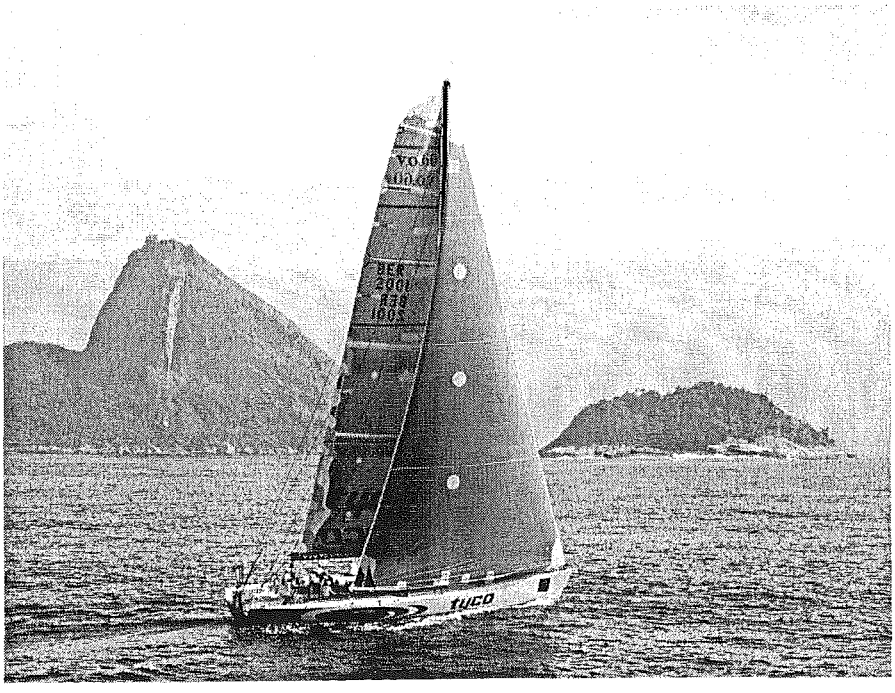
The sensors were controlled by the 'Ocean-i' unit inside the yacht (Figure 2). This unit triggers data collection when conditions are right, performs basic quality control tests to select the best of the two radiance measurements, and stores the measurements along with position, time and date from the in-built motion sensor (which records pitch, roll and yaw).

The complete spectral data were stored onboard, and downloaded during instrument maintenance when the yachts finally returned to port. After recalibration of the instruments, this data will be analyzed at Southampton Oeanography Centre. However, a small proportion of the data from each yacht was transmitted back to Southampton every hour.

The track of each yacht was plotted daily on satellite images from NASA's SeaWiFS Project. Using the yacht positions, the SeaWiFS Project also identified those yacht measurements that most closely corresponded to local SeaWiFS overpasses, and extracted the corresponding SeaWiFS-derived parameters (normalized water-leaving radiance and chlorophyll-*a* concentration). The images, with the yacht measurements and corresponding SeaWiFS parameters (e.g. Figure 4(a)), were then uploaded daily to the education website in near real-time.

***Figure 5*** *Team Tyco approaching Rio de Janeiro at the end of Leg 5. In the calm conditions, progress was frustratingly slow, but such moments gave some of the best ocean colour measurements of the race.*

*(Photo: Rick Tomlinson)*



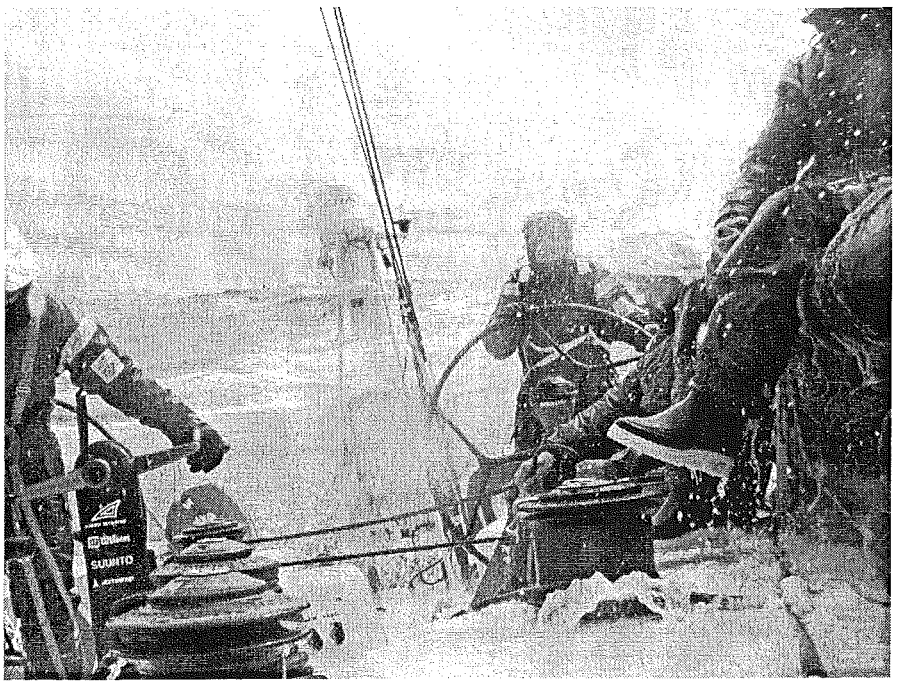


***Figure 6*** Amer Too *in the Southern Ocean. High winds and overcast skies were the order of the day for the two Southern Ocean legs. With the persistent cloud cover, only a few of the satellite images could show the varied phytoplankton distribution in the area.*

*(Photo: Amer Sports Too)*

## The Volvo Ocean Adventure Website

During the race the daily satellite images were an exciting way to follow the progress of each yacht. They also provided a crucial link to the environmental background information on the website, encouraging students to look at the area surrounding the yachts in a wider context. By following the images – and supplementary larger images on the SeaWiFS website – students could relate the prevailing conditions around the yachts to information about regional and seasonal changes in phytoplankton productivity, and link this to physical and biological processes in the ocean. Other material on the Adventure website, and the websites of NASA and other sicence partners, related this information to issues such as climate change and human impacts on the marine environment.

This 'Race and Space Zone' of the website also contained daily satellite images of wind speed and significant wave height, provided by British National Space Centre and Satellite Observing Systems from European and NASA satellites – with the yacht positions superimposed on each image. As with the ocean colour data, these were linked to more general information on meteorology and oceanography.

Close connections with the official race website at www.VolvoOceanRace.org allowed students to relate the environmental information to the daily experiences of the race crews through photographs, emails from crew members, tactical analyses, and other race material. The satellite images and background oceanographic information proved extremely popular, and were largely responsible for the large number of pages downloaded daily from the website, peaking at over 80 000 pages per week during some of the more exciting periods of the race.

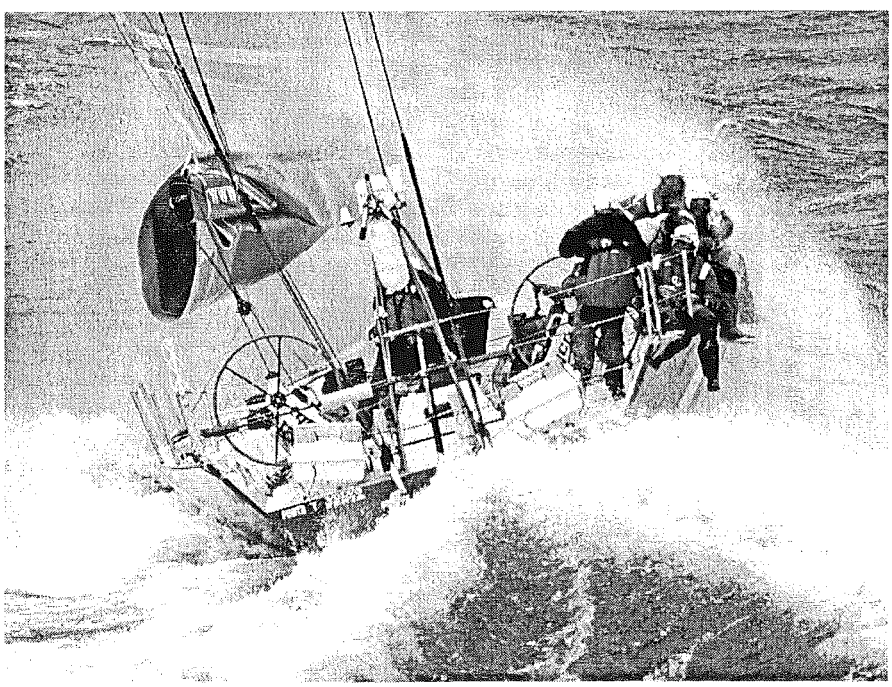
In addition to material dealing directly with the race, the website also contained scientific information of a more general nature, aimed at the 10–16 age group. Here topics such as weather and climate, physical oceanography, and human impact on the marine environment were presented partly through interactive games and quizzes, partly through texts and pictures. Another important and popular part of the website was the 'Action Zone', aimed primarily at schools and youth groups wanting to take part in the Volvo Young Environmentalists Awards.

## The Volvo Young Environmentalists Awards

One of the main aims of the education project has been to increase the awareness of our own impact on the environment, locally and globally, without becoming overwhelmed by the size of the problem. Instead, the website and the environmental competition encourage active participation and try to foster a feeling that responsible action can lead to positive results.

***Figure 7*** *Full speed ahead during Leg 3 (Sydney–Hobart). This image illustrates one of the problems with making ocean colour measurements from racing yachts. The only safe place for the instruments was on the stubmast, where they spent much time looking through foam in the wake of the yacht.*

*(Photo: Rick Tomlinson)*



Through the Action Zone and the Volvo Young Environmentalists Awards, young people are encouraged to:

- Research environmental issues and increase their own awareness;
- Look for solutions to environmental problems;
- Take practical environmental action in their own homes, schools and local areas;
- Exchange ideas with their peers locally and across national borders.

Schools and youth groups in fourteen countries responded by entering the Awards for 2001–2002. Many entries were submitted electronically and may be found on the website. However, paper copies were also accepted, so as not to limit the competition to more affluent communities. The competition closed at the end of April 2002, and is currently being judged. In addition to their prizes, the winning group from each country will be invited to a Young Environmentalists Conference in Gothenburg, Sweden, in September 2002. Here they will participate in various activities and discussions, and compose a petition to the 2002 Earth Summit in Johannesburg. The youth conference and follow-up activities will be reported on the website in September.

### The Future

Over the next couple of years the instrument package will be deployed on cargo ships, which provide a more stable platform than yachts and are likely to give more reliable measurements. As with the yachts, a selection of measurements will be sent back via communication satellites for analysis on a daily basis. The rest will be stored on board and retrieved when the ship enters a convenient port. However, unlike the yachts, where data transmission was restricted to 24 channels, the cargo ships will transmit the full set of 255 wavebands.

With the 2001–2002 Volvo Ocean Race only recently completed – the winners were the German-backed team *Illbruck* – future plans for the website and the Young Environmentalists Awards have yet to be agreed. However, the rewards of working on such an exciting and challenging project, and the positive feedback from a myriad of website users, has left those of us who took part with a strong desire to continue the work.

For more information please contact Val Byfield or Simon Boxall at the Southampton Oceanography Centre. The Volvo Ocean Adventure website can be found at http://www.VolvoOceanAdventure.org.

**Val Byfield** and **Simon Boxall** are both with the James Rennell Division for Ocean Circulation and Climate, at the Southampton Oceanography Centre;
Email: V.Byfield@soc.soton.ac.uk
Tel: +44-(0)2380-596405.

## Presidents' Photographic Competition

***Inspired by the photos of the Volvo race? Then get snapping!***

*The Marine Science 2002 Conference will include the judging of entries for the photographic competition sponsored by past and present Presidents of the Society. There is still time to take new photographs or reappraise old ones (not previously entered).*

*This year, photographs may be entered under the heading*

***Colour and the Sea***

*Photographs should not be larger than A3 and should be submitted to the Registration Desk by noon on 11 September. Please do not send pictures in advance by post.*

## Can You Produce Winning Words?

*As at the last three Challenger Society Conferences, a prize of £50 will be awarded for the best report of the meeting, which will be published in* Ocean Challenge.

*The report should be a personal impression – highlights and lowlights – rather than a blow-by-blow account of the sessions. The emphasis should be on lively writing and good communication. For an example of the type of piece we are looking for, see Vol. 10, No. 3, p.4.*

*Entries should be sent to the Editor within three weeks of the end of the conference, and should be about 1000 words long (about one page of* Ocean Challenge).

# *Isis*: the UK's deep ROV

**Jan Paterson**

In 2001, the Joint Infrastructure Fund (JIF), through NERC, made 4.5 million pounds available to Southampton University for the purchase of a Remotely Operated Vehicle to be used by UK Scientists for research into the deep oceans. Southampton Oceanography Centre is to run the project, with Paul Tyler, Chris German and Gwyn Griffiths as Principal Investigators.

The UK science community have needed access to an ROV able to plumb the deep ocean for many years, and although much excellent research has been done with towed vehicles, UK scientists have never previously been able to hover over a patch of sea-bed, manipulate objects such as samplers, and undertake photographic surveys.

A competitive tendering exercise was begun for the supply of a 6500 m-rated ROV, with ten companies and institutions around the world quoting for the work. After much deliberation, it was decided to award the contract to Woods Hole Oceanographic Institution. WHOI have over ten years' experience of operating *Jason I* (6000 m-rated) and at the time of the tender were just getting ready to build *Jason II,* using the lessons learnt from their decade of operational experience.

Contractual terms were agreed, and the delivery date set for 19 January 2003, giving WHOI fifteen months to build the vehicle and its systems. On completion of dock trials at Woods Hole, the vehicle – to be named *Isis* – will complete a delivery cruise on a WHOI vessel in March 2003, when it will be taken to depths in excess of 5000 m in the Caribbean to test its systems, and will then be delivered to SOC. A cruise to the Azores is planned for later in the year.

The ROV has a very high equipment specification. Its camera suite includes broadcast-quality 3-chip CCD cameras as well as lower specification, general inspection cameras and third-generation low-light CCD cameras for work in turbid water where using too much light gives reflection problems. High-Definition TV can also be made available.

A complete Sonar suite is provided, including both forward-looking and profiling sonars that can complete terrain mapping. As well as all this, the vehicle will carry two state-of-the-art manipulator arms linked to a miniature duplicate set which are manipulated by an operator at the surface; whenever the operator moves these 'master' arms, the arms on the ROV replicate the movement. In addition, force feedback is provided, allowing operators to 'feel' what they are doing.

The communications system that allows the exchange of data up and down ten thousand metres of cable is also state-of-the-art. Because of the volume of data that has to be exchanged, and the constraints of the umbilical link, the telemetry system uses a single-mode fibre-optic waveguide in the umbilical via which it communicates on two frequencies for the uplink and a further two for the downlink. This allows very large amounts of data to be exchanged over 60 serial data channels, in addition to allowing 8 channels of video.

More information and specifications can be found at the UK Deep ROV Web site at: http://www.soc.soton.ac.uk/OED/ROV/index.php

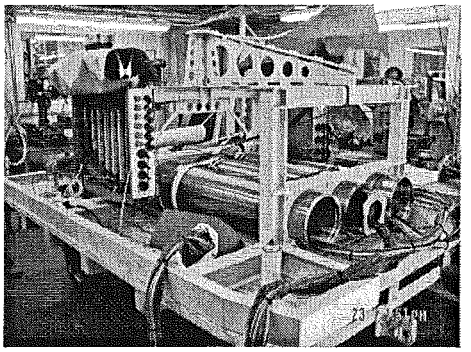
**Jan Paterson** is the UK Deep ROV Facility Manager,
Email: wjp@soc.soton.ac.uk

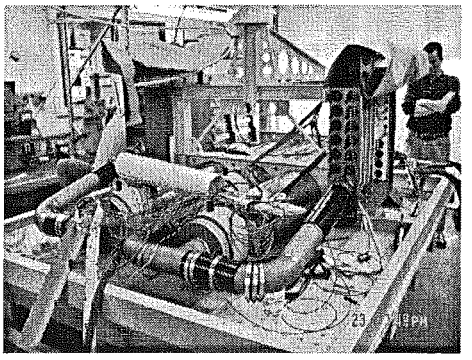
## Using the ROV

With the delivery of the new ROV, Marine Science in the UK will have the opportunity to observe and carry out experiments in the deep sea down to 6500 m. The ROV can be used for physical, chemical, geological and biological observations from the shelf-edge down to the abyssal plain and will be able to work on steep, difficult-to-sample slopes and in canyons. In addition, at any selected site the ROV will be able to deploy equipment for long-term observation, or carry out manipulative experimentation in mid-water or at the sea bed. These may be investigations of natural processes or of those that have been anthropogenically induced. This is the first time UK marine scientists will have regular access to such a facility.

Access to use of the ROV will be through the standard NERC grant-application procedure, and proposals should highlight why use of the ROV is a necessary major part of the proposed experiment. The exact details of the funding for the use of the ROV are ongoing but should be available in the near future.

***Paul Tyler***





**Jason II *being built at WHOI***

# Catch-22 for Climate Change

**Mark Maslin**

In March of this year, the Larsen-B ice shelf completely disintegrated, sending 500 million billion tonnes of ice into the ocean around Antarctica. This seems to be a stark warning that global warming is starting to melt the world's ice-sheets. What we do not know, however, is the rate at which the Antarctic and Arctic are melting, and how the fresh water released will affect the circulation of the deep ocean.

It seems we are standing on a knife edge – on one side, the prospect of change in the rate of production of North Atlantic Deep Water, heralding severe winters in Europe, and on the other, an even greater change in the production of Antarctic Bottom water, leading to a 2 metre rise in global sea-level.

We are all familiar with concerns that global warming could melt significant parts of the Arctic pack-ice and the Greenland ice-sheets, resulting in widespread climatic change. Fresh water released during the melting would spread out over the surface ocean, preventing it from becoming sufficiently dense to sink, and stopping the winter formation of North Atlantic Deep Water (NADW), which presently consists of over thirty thousand million gallons of water per second sinking to depths of over 3 km, before gently flowing southward. The 'pull' exerted by this sinking deep water helps maintain the strength of the warm Gulf Stream. This ensures that warm tropical water flows northwards, sending mild air masses across the European continent. The Gulf Stream currently delivers 27 000 times more energy than all of Britain's power stations put together. The influence of the Gulf Stream is felt mainly during winter, and although its weakening would cause colder and stormier European winters, global warming effects would continue to heat the summers. Thus Europe would experience extreme seasonal changes in its weather.

Less familiar is the recent realization that the circulation of the world's deep ocean is a coupled system, maintained by deep water formation in both the North Atlantic and the Southern Ocean (see Figure 1). Thus there may be an even greater threat lurking around Antarctica. At present, deep water forms around Antarctic polynyas – holes in the sea-ice opened up by powerful frigid winds. The Antarctic Bottom Water (AABW) formed here is the coldest and most dense water mass in the world. It flows sluggishly into the deepest parts of the other ocean basins. For example, in the Atlantic it flows under the less dense and warmer southward-flowing NADW. We now know that the northern and southern deep and bottom waters are inextricably linked, and variations in one directly influence the other.

Recent studies by myself and colleagues at Pennsylvania State University (especially Prof. Dan Seidov) tested the possible effects of future melt-water pulses in the North Atlantic and the Southern Ocean, using a detailed ocean circulation model. The Southern Ocean results were astonishing (see Figure 2). They showed that the rates of deep and intermediate water formation in the Southern Ocean are three times more sensitive to new fresh water at the

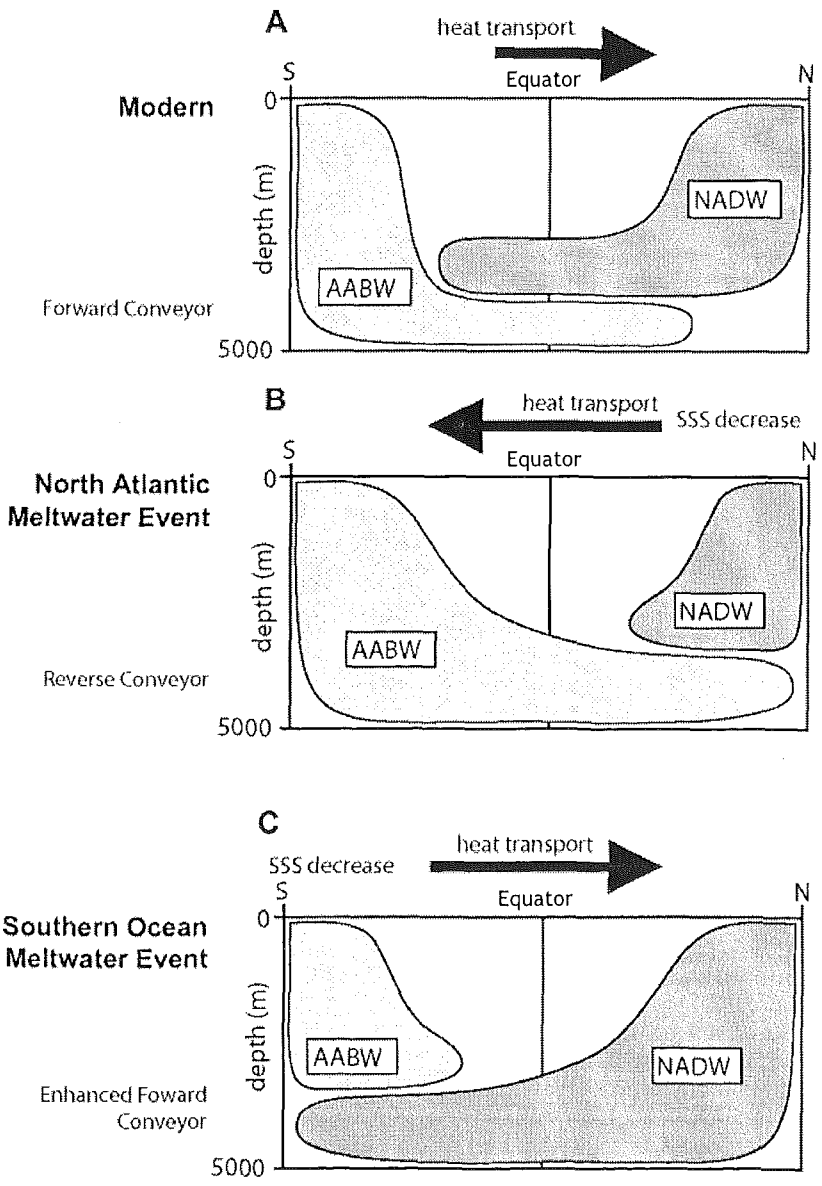



***Figure 1*** *A cartoon illustrating three different states of the deep ocean conveyor (SSS = sea-surface salinity).*
***A*** *Modern circulation or 'Forward Conveyor' with NADW dominant and heat transport to the Northern Hemisphere;*
***B*** *Melt-water perturbation in the North Atlantic, which results in a Reverse Conveyor with dominance of AABW and heat transport to the Southern Hemisphere;*
***C*** *Melt-water perturbation in the Southern Ocean, which results in an Enhanced Forward Conveyor with reduction of AABW and enhancement of NADW, and increased heat transport to the Northern Hemisphere.*

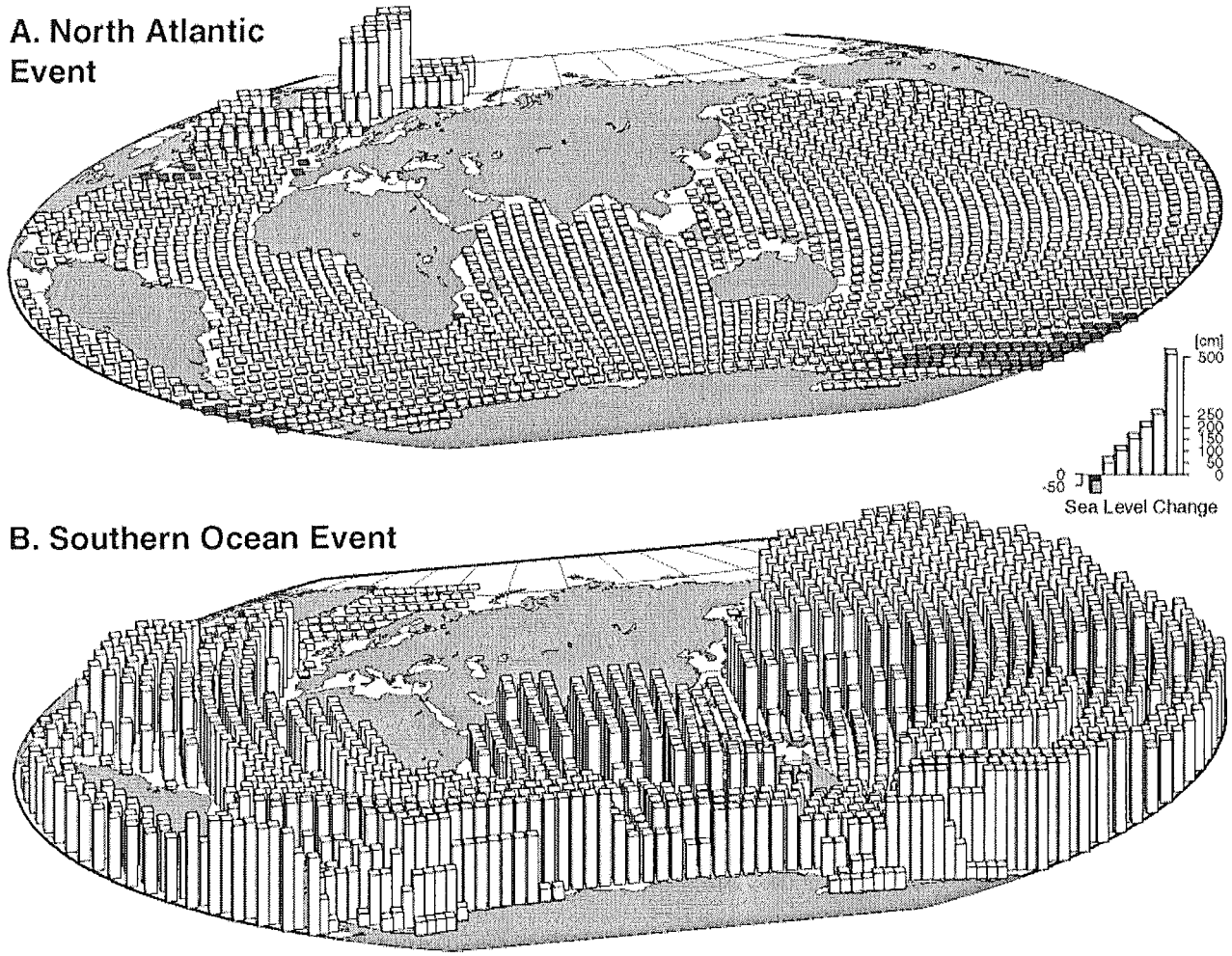



***Figure 2*** *Predicted sea-level changes a few decades after either:* ***A*** *Meltwater event in the northern North Atlantic, or* ***B*** *Meltwater event in the Southern Ocean. (In a few locations, the water column becomes sufficiently colder and denser for sea-level to fall.)*

surface than is the northern Atlantic. Even more worryingly, the models show that once AABW production is curtailed, NADW spreads throughout the deep basins of the world to replace it. The northern deep water is about 5 °C warmer than its southern counterpart, so as it spreads out it takes up more space. This expansion causes a predicted rise in sea-level of 2 to 3 metres over the course of a few decades. In oceanographic terms this is very small, less than 0.1% expansion of the ocean, but in human terms it is catastrophic. Two metres of sea-level rise would see the disappearance of the Maldives in the Indian Ocean and the Marshall Islands in the Pacific. Populations living on deltas would also be badly affected – Bangladesh would lose 16% of its land. Other deltas, such as the Nile and the Niger, would suffer from increased flooding and salt contamination of vital ground water. In the UK, 2 metres of sea-level rise would wreak havoc on our already stretched coastal defences.

So we do know that as global warming continues, small quantities of melt-water will enter the high-latitude oceans. What we do *not* know is which source of deep water wil fail first, the northern or the southern. Exactly how much melting will it require? Answers to such questions will determine whether we are facing future severe weather in Europe or catastrophic global sea-level rise.

The threat is being taken seriously. In March of this year the UK Natural Environment Research Council launched a £20 million, six-year project called RAPID to study this very problem (see www.nerc.ac.uk/rapid/). Hopefully, the new research will more accurately reveal the vulnerability of the deep ocean circulation, and provide us with a more reliable prediction of our climate's future.

This article was adapted from 'Living on the Edge' published in the *Guardian*, 9 May 2002.

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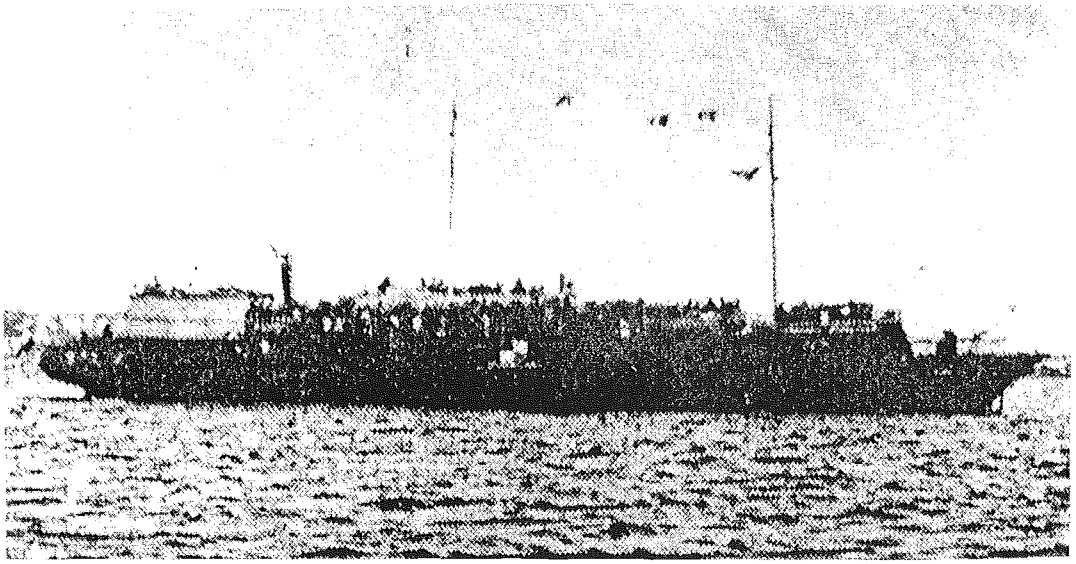
# The tale of the *Struma*

**Greg Buxton**



***Photograph of the* Struma *in Istanbul harbour taken in 1942 (from a Turkish newspaper)***

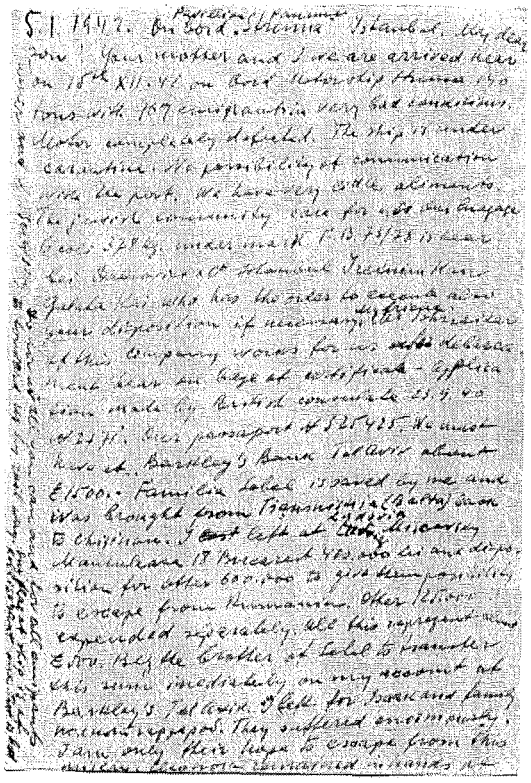
On 24 February, 1942, a Russian submarine, commanded by Senior Lieutenant Denezhko, surfaced about 8 miles offshore from Istanbul harbour in the Black Sea and fired a single torpedo at a ship packed full of Jewish refugees fleeing from Romania. This ship was the *Struma*, a vessel organized by the refugees to take them eventually to Palestine. Nearly 800 people, each of whom had paid $1000 in today's money, had boarded the ship in Constansa, Romania, in December 1941. The ship was woefully overcrowded, with appalling conditions for those on board. She was only just seaworthy, and engine failures had plagued the voyage. The engines failed for the last time close to a minefield near the Bosphorus entrance, at which point a Turkish tug brought *Struma* safely into the port of Istanbul.

The ship's occupants were then caught in a bitter row between the British Colonial Office and the Turkish Government. The British flatly refused to allow further passage to Palestine, whilst the Turks (who were trying to remain war-neutral) did not want to offer sanctuary to any more Jewish refugees. For 70 days, the *Struma* lay in the outer harbour of Istanbul, until on 23 February 1942, Turkish police took control of the vessel, easily overcoming the passengers' efforts to repel them. They cut the anchor chains and attached lines. The *Struma* was towed back into the Black Sea. The passengers' cries for help were clearly heard by local residents along the Bosphorus. Sheets with 'SAVE US' written on them in Hebrew and English were hung over the sides.

*Struma* sank instantly when she was hit by the torpedo. No rescue boats appeared, although the explosion was clearly heard from the shore. By the following morning, some 20 hours after the *Struma* had sunk, there was just one man left alive, clinging to a piece of wreckage. He was David Stoliar, who now lives in the USA. He was plucked from the water by a rowing boat crewed by men from a local lighthouse. Altogether, 103 children, 269 women and 406 men died, amongst them my paternal grandparents, Grigori and Enta Buchspan.

In September 1998, while returning from an expedition in the Aegean to explore the *Britannic* (sister ship of the *Titanic*, sunk by a mine during World War I), I decided to mount an expedition to locate and dive my grandparents' last resting place. As I researched, I came across many other people who had relatives on the *Struma* or were in some way connected to the story. I discovered I was not alone in my desire to connect with this piece of largely forgotten history. I put together an international project which included David Stoliar, the finest team of British exploration divers, Gary Fones (an oceanographer now at Woods Hole Oceanographic Institution), Neil Dobson (a marine archaeologist), a UK survey company owned by Quentin Huggett and Pete Schultheiss of *Geotek*, the US Holocaust Museum, a Canadian film crew, and a rapidly growing group of relatives. Initially we conducted an extensive site survey using side-scan technology to locate the ship. The

***John Chatterton (left) and Greg Buxton, decompressing after a dive***
*(Photo: Mark Brill © 2000)*

***Postcard sent from the ship by my Russian grandparents, Grigori and Enta Buchspan***
*It begins: 5.1.1942 On board 'Struma' Istanbul*
*My dear son Your mother and I are arrived here on 15th XII.41 on board motorship Struma 140 tons with 769 emigrants in very bad conditions .... The ship is under quarantine. No possibility of communication with the port.*

survey was hampered by difficulties in getting the equipment out of Turkish customs, bad weather in the form of strong north-easterly winds, and protracted negotiations over diving permissions. There were eight bottom divers working in pairs with one videographer per pair. The divers carried all their own gas, and for added safety there were two further support divers at 39 m and 6 m, as well as a lazy shot* and decompression station, each with 42% Nitrox (which has 42% oxygen) and 100% $O_2$, at the appropriate depths. Three emergency drop stations, also with 42% Nitrox and 100% $O_2$ were set up on the boat, in case a diver failed to make it back to the shot line. The remaining team members provided boat support.

A total of nine days of diving regrettably failed to locate *Struma*. However, we had an interesting time, including several switches of dive boat as fishermen came and went, and not-so positive visits from the Turkish customs and coastguard. We found ships that looked like rocks and rocks that look like ships (including a previously unknown submarine), and a personal – and very positive – intervention by Euhud Barak, then Prime Minister of Israel. Our experiences and findings have been collated into a final report, and Channel Four recounted the tale of the *Struma*, and our diving expedition to find her, as part of their 'Secret History' series. A longer version of this documentary was recently given a special showing at film festivals in Toronto, Israel, Istanbul, and the US Holocaust Museum in Washington. This longer version will be shown in London at the end of 2002.

3 September 2000 was the day chosen to commemorate the victims of the *Struma*. Over 60 relatives attended, along with representatives of the Jewish community in Turkey, the Israeli Ambassador, the Israeli Prime Minister's envoy, the British Ambassador, and delegates from the US embassy. The day was hosted by the Koc family, who kindly provided the boat which took the group to the site in the Black Sea where the wreck of the *Struma* is believed to lie. Kadish – the traditional prayer for the dead, usually said at the burial site – was spoken by the Deputy Chief Rabbi of Turkey, and relatives of the victims added their own memorials, saying poems in dedication and throwing flowers into the sea. It is perhaps this ceremony, more than physically finding the wreck that, for many people, will close the circle broken in 1942.

For further information, see:
www.struma.org

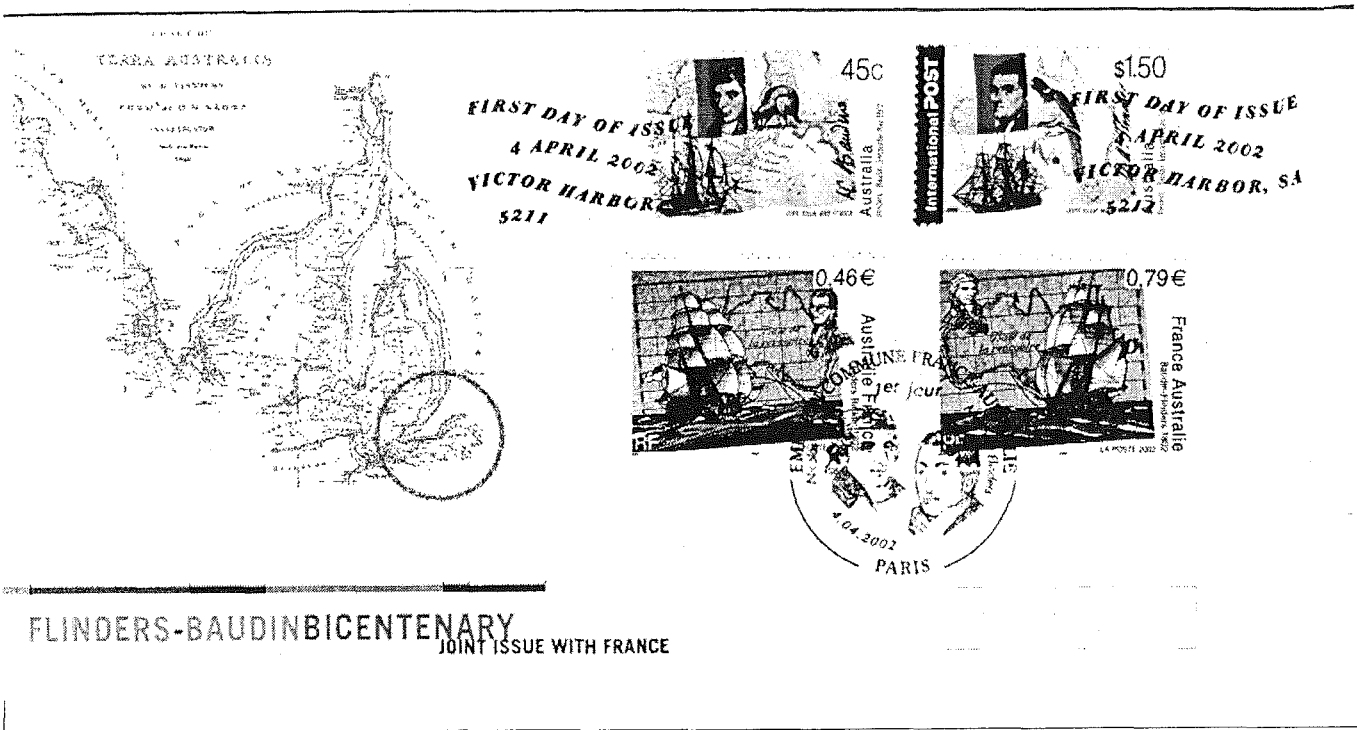
***One of the fishing boats we used as a diving platform***
*(Photo: Mark Brill © 2000)*

* A shot is a line from a surface buoy to the wreck; a lazy shot is a system of ropes and poles to support divers returning to the surface after long, deep dives.

# The voyages of Matthew Flinders and Nicolas Baudin

## commemorated by a joint Australian and French stamp issue, April 2002

**Tony Rice**




***First-Day Cover of the joint French and Australian stamp issue to mark the bicentenary of the meeting between Matthew Flinders in the* Investigator *and Nicolas Baudin in the* Géographe *and* Naturaliste *in Encounter Bay, South Australia, in April 1802***

On 4 April this year, the postal authorities of France and Australia issued jointly a series of four handsome stamps to mark the bicentenary of two remarkable and important expeditions in the island continent's early history – a French expedition under the command of Nicolas Baudin in the corvettes *Géographe* and *Naturaliste,* and a British one under Matthew Flinders in the *Investigator.* The objective of both expeditions was to find out as much as possible about the geography and natural history of Australia (or New Holland as it was still usually called), particularly the southern and western coasts.

The main reason for the interest was that it was still uncertain whether Australia was a single enormous island or whether it was split from north to south into two separate pieces. The Brits were, of course, already well-established in their penal colony on the east coast, but if there was a gap in the middle of the landmass, the western half might still be up for grabs. By the time the expeditions returned home, this was no longer a possibility, for between them they had completed the charting of the whole of the Australian and Tasmanian coastlines, at least in outline. And both brought back superb collections of animals and plants gathered during their travels, as well as hundreds of drawings and paintings produced by their respective artists, particularly Charles-Alexandre Lesueur on the French side, and Ferdinand Bauer who travelled with Flinders.

As usual with such dangerous undertakings at that time, by no means all the expedition members returned unscathed. But even by the standards of the day, these were particularly unfortunate, not to say disastrous, voyages. When they left their respective bases, Baudin from Le Havre in October 1800 and Flinders from Spithead almost a year later in July 1801, the two nations were still at war and, with the exception of a brief respite in 1802–3, would remain so until 1815. But this was the least of their worries since each of the commanders carried documents giving them immunity from interference from the opposing nation's navy. In fact, the two expeditions met twice and amicably exchanged information and help, once in Encounter Bay, near present-day Adelaide, in April 1802, exactly 200 years before the stamp issue date, and once at Port Jackson (Sydney) in June the same year, by which time peace had temporarily broken out.

But aboard the *Géographe* and *Naturaliste* there was enough home-grown discord to make up for the absence of external enmity. Baudin was such an unpopular and ruthless disciplinarian that by the time his ships had reached the Canaries on the way out, only three weeks into a voyage which was to last three-and-a-half years, almost every one of the expedition's 230 or so men, including about 60 specialist zoologists, botanists, geologists, geographers, astronomers, engineers, artists and gardeners, already hated their leader.

The resulting bad blood, coupled with mismanagement and the usual share of bad weather, disease and mishap, resulted in a very unhappy voyage, largely overshadowing the excellent cartography which was achieved, and the more than 200 000 natural history specimens, and two live kangaroos, which were brought back to France. Twenty-five of the expedition participants perished during the voyage, including Baudin, who died, totally unmourned, in September 1803 at Île de France (Mauritius) on the way home. The *Géographe* finally arrived at Lorient in March 1804 having covered 63 000 miles, including the whole of the southern and western coasts of Australia. In Baudin's absence, the official report of the voyage was written mainly by Francois Péron, one of the expedition naturalists. But relations with Baudin had been so bad that the commander was not mentioned by name once – surely a record! Not that Péron himself was a model of rectitude, for his own selfishness and determination to monopolize the expedition results ensured that most of them never were properly worked up and published.

In the meantime, Flinders was having his own problems, not the personality clashes that beset the French, but potentially even more catastrophic: basically, his ship fell apart! Having reached Cape Leeuwin in south-western Australia in December 1801, Flinders proceeded to survey the southern coast and then, after meeting Baudin in Encounter Bay, to sail on to Port Jackson. By now, ten months after leaving England, the *Investigator* was in urgent need of repairs, so Flinders stayed in port until July, giving Bauer and the expedition botanist Robert Brown the opportunity for several important collecting expeditions.

Flinders now set out on his main task, an anticlockwise circumnavigation and charting of the Australian coast. However, by the time the ship had successfully navigated the dangerous waters of the Great Barrier Reef, and then the Gulf of Carpentaria and the coast of Arnhem Land, it was once more in such a bad state, with many rotten timbers, that Flinders decided to give up charting and get back to Port Jackson as soon as possible. But contrary winds forced him across to Timor, so that by the time they reached Port Jackson in June 1803 the crew were exhausted, several had died of dysentery, and the ship was no longer fit to continue. Flinders decided to return to England with some of his ship's company to bring out a replacement vessel to pick up the *Investigator's* naturalists who were to be left in Australia to continue the work.

But his bad luck persisted. First, his new ship was wrecked on a coral reef only a week after setting out and he had to return to Port Jackson and start all over again. His second attempt, in a tiny 29-tonne vessel, the *Cumberland,* was even more disastrous. The *Cumberland* was very difficult to handle and sustained so much damage as she rounded northern Australia that Flinders realized that she would never reach the Cape of Good Hope, his intended landfall. So instead, he made for the French possession Île de France, not realizing that the two countries were once more at war. Flinders' passport ensuring his immunity was theoretically valid only if he was in the *Investigator* and, almost unbelievably, the mean-spirited local Governor therefore ignored it and imprisoned him as a suspected spy. Despite protests from England, and even from France, poor Flinders remained a prisoner until the Governor was replaced and he could return home to England six-and-a-half years later in October 1810!

In the meantime, the *Investigator* naturalists had continued with their work, including collecting trips as far afield as Tasmania and Norfolk Island. Finally, having given up any hope of being collected by Flinders (though, of course, they had no idea where he was), they had the decrepit old ship refitted and sailed for England in May 1805 with vast numbers of specimens, sketches and paintings – and a live wombat! The collected material fared somewhat better than that brought back by the French expedition, for all of the preserved material and the drawings and paintings were transferred to Sir Joseph Banks' house in London where Brown worked on the collections while Bauer produced hundreds of superb finished paintings. The bulk of the material eventually went to the British Museum. Although much of it, like the French material, was never published, Brown and Bauer saw at least part of their work in print as an appendix to Flinders' official account, *A Voyage to Terra Australis,* which he managed to see through the press shortly before he died in 1814.

This joint stamp issue is a fitting tribute, not just to Flinders and Baudin, but also to the more than 300 men of the two expeditions who risked, and in many cases lost, their lives in the peaceful pursuit of knowledge when their nations were otherwise at war. Wouldn't it have been nice if it could have been a tripartite affair with the UK Post Office joining in too?

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## From Finisterre to FitzRoy

At noon on Monday 4 February 2002, listeners to the BBC Shipping Forecast were introduced to the new sea area FitzRoy – after 53 years, the lyrical name of Finisterre will no longer be used for the area off the western tip of Spain (thought of by early European mariners as the ends of the Earth – hence 'finis terre'). The area to the west of Biscay, to the south of Sole and to the north of Trafalgar, is now known as FitzRoy.

The change became necessary as a result of an agreement between Britain, France, Spain, Portugal and Morocco, to use a co-ordinated set of sea areas. The area Finisterre used by the UK Met Office was considerably larger than the area with the same name defined by the Spanish Meteorological Service, and Spain had requested that the name Finisterre be retained for the smaller area.

So why 'FitzRoy'? Robert Fitzroy (1805–65) was the founder of the Met. Office. He was primarily a seaman, eventually becoming Admiral, but he was extremely interested in science, particularly the tides. It was because he wanted stimulating and congenial company on the voyage to the Galápagos, that Darwin, as a naturalist and person of culture, was invited to join him on the *Beagle.*

# Sustainable development – the bandwagon rolls on

As the tenth anniversary of the Rio Summit draws near, a meeting was held at Bali (Indonesia) in early June, ostensibly to prepare the agenda for the main meeting on sustainable development, to he held in Johannesburg in August. Taxpayers in many countries will have paid for hundreds of government officials to enjoy the luxuries of Bali's up-market tourist resort. The jaunt even rated a special feature in the *Telegraph's* travel supplement.

What an irony! Principal features of Agenda 21, the document that came out of the 1992 Rio Summit, were concerns about sustainable development (sustainability) and global warming. Yet large jet aircraft converging on Bali from all over the world will have made their contribution to global warming, and the conspicuous consumption of luxury goods and services indulged by delegates at the so-called World Environment Meeting must have been the very antithesis of sustainability. And as for protecting biodiversity and the environment ...

The luxury foods offered to the government officials at Bali may well have included turtle meat, a local delicacy. They probably didn't know that to ensure top quality and top prices, the turtles are skinned and butchered *while still alive.* Killing them first allegedly taints the meat. The turtles can't scream, but they can weep with pain. The reporter who described this practice a year ago (*The Guardian,* 24 November, 2000), saw large numbers of weeping turtles. Bali was home to about a third of the world's green sea turtles a hundred years ago. Now the proportion is less than 5%. Tourism to Bali is not likely to have been damaged by this horror story. Typically, most seekers after sun, sand, sea, and luxurious facilities for their meetings, are not much concerned about species loss or animal welfare, and in any case they are unlikely to learn about the cruelties inflicted daily on hundreds of green sea turtles.

Sustainable development means living in equilibrium with Nature. That in turn means reducing dependence on oil-extraction and metal-mining, recycling all manufactured goods, stopping pollution and over-use of renewable resources – including fish and other endangered species. Nowhere in the world is any of that even being approached. On the contrary, the whole course of industrial civilization has been predicated on the 'conquest of Nature', on 'harvesting Nature's bounty' on 'protecting ourselves from Nature's destructive ravages'. Recorded history is an almost unbroken record of failure to try and live in equilibrium with Nature – and we're not going to start trying now.

Human nature being what it is, most of us actually *prefer* sustainable economic growth to sustainable development. That's because without continual increases in consumption there can be no profits, without profits there can be no investment or taxes, and without taxes there can be no health service, no armed forces, no salaries for academics, no savings, no pensions. If sustainability ruled, we'd all be a lot poorer. That goes a long way to explaining why sustainable development isn't a major preoccupation for most countries outside the developed world. Four-fifths of the global population are too poor to care about environmental issues anyway. Could anyone seriously believe that sustainability is an issue in southern Africa – where famine rages – let alone in India and Pakistan, where conflict simmers. There are exceptions of course, like Arandati Roy of dam-busting fame, and Vandana Shiva, one of the Reith lecturers (on Sustainable Development) in 2000. But they are part of a tiny minority, and can do little to hinder the juggernaut of consumerism. Just one example of how that juggernaut progresses is the new Disney park being built in Hong Kong. To be completed by 2005, it will aim to attract millions of extra tourists, create thousands of new jobs and 'help sustain economic growth in the region'. According to newspaper reports last April, preliminary land reclamation work, before constuction had even begun, muddied coastal waters, killing an estimated 7 million fish and threatening the viability of local dolphin populations.

It's no good appealing to the scientific community for help either. I know from experience that most scientists are not really interested in sustainability, and may not even realize that to achieve it we must stop the economic growth upon which the very funding of science itself depends. Scientists need to be good consumers too, though some may pay lip-service to sustainability by teaching and writing about it, and they welcome research grants to monitor the progress of pollution and global warming.

Not long ago, I re-discovered a short article by Robert Constanza and others in *Science* (**281**, 1998, pp.198–9), entitled 'Sustainable Governance of the Oceans'. It's a great little article, settting down six principles for the guidance of maritime nations. Four years have elapsed, and the global depredation of fish stocks, coral reefs and marine biodiversity continues unabated. Nobody seems to have adopted the six principles, and even if they had, it's difficult to see how (and by whom) the oceans could have been policed to ensure compliance.

The sad truth is that none of us – scientists included – can *afford* to do anything practical to promote sustainability (apart from using our bikes to take cans and bottles to the recycling centre, buying local foods, and so on). Imagine what would happen to international conferences if the scientific community decided to stop travelling by air! If most scientists are not interested in sustainability, most politicians – including British politicians – don't really understand what sustainability means.

Anyway, the delegates at Bali failed to reach agreement because of widely divergent views about globalization, free trade and the environment. Old cynic that I am, I do not find that surprising. Like the man said, we don't *want* to live in harmony with Nature. If you live in harmony with Nature, you may be happy, but you will be poor. Yes indeed. Green turtle fillet anyone?

**John Wright**

# Benthic dynamics: *in situ* surveillance of the sediment–water interface

**Catherine Biles**

Recent advances in *in situ* monitoring of sediments were discussed in a broad range of enjoyable and informative talks at the first benthic dynamics conference, held at the University of Aberdeen in March of this year. The conference organizers, led by Martin Solan, invited delegates from as far afield as Iran, USA, Australia and Japan, and arranged a total of 59 talks over the five-day conference. A major strength of this conference was its relatively limited size, which provided a friendly forum for discussion and networking. A diverse range of topics was covered in both talks and workshop sessions, including biogeochemistry, organism–sediment interactions, hydrodynamics, benthic monitoring, and imagery. A number of talks provided impressive footage of benthic processes on scales ranging from deep-sea landers to sediment properties on the microscale.

The first session, 'Porewater biogeochemistry and diagenesis', covered advances in *in situ* monitoring of oxygen, carbon, trace metals and nutrients, using new sensor technology in a range of environments, including deep-sea sediments, harbours, lakes, subtidal sands, lagoons and salt marshes. It was an informative introductory session, documenting key processes of relevance to all members of the conference. This provided a good link to the second session, 'Organism–sediment relations'. Talks ranged from descriptive assessment of the biota to mathematical explanations of sonar bathymetry data and video mosaics.

The third session, 'Hydrodynamics at the sediment–water interface' gave an impressive account of the technological developments in benthic research. Both generation and measurement of water flow were covered in this diverse session on river, estuarine and deep-sea systems. Bob Whitlatch described his latest addition to 'Graceland', his collection of Elvis-inspired benthic monitoring equipment. Elvis and Lisa-Marie have been joined by a new autonomous, *in situ* benthic invertebrate plankton sampler. Several deployments on a New Zealand tidal flat and in a New England estuary have demonstrated the effect of the hydrodynamic regime on infaunal recruitment. The new sampler allows collection of multiple samples over the tidal period, automatically preserving them for later collection, thereby preventing disturbance for the duration of the experiment.

Frank Bohlen described the difficulties of assessing sediment erosion and transport. He described a variety of devices and highlighted the importance of *in situ* measurement. Recent advances in acoustic instrumentation were described by Kyle Proudman. Data from devices used to measure suspended sediments, near-bed velocities and bed-form morphology, were shown to predict interactions between hydrodynamics and sediment. Descriptions of the latest generation of sea-bed landers, designed to carry instrumentation capable of measuring variables such as currents, suspended load, particle size and contaminant load, were given by Jon Rees, John Howarth and Allen Haden in three separate talks about research carried out in the UK and USA.

Boris Holscher also described a new flume system for lab simulation of the sediment–water interface, with the help of an *in situ* benthic sample-collector with a pressure-proof transfer chamber. Research has focussed on how increasing pressure affects the way the bacterial community feeds on phytodetritus, a topic which linked several research areas covered at the conference. The effects of biota on sediment properties were discussed by Kevin Black in an interesting talk describing how different species of sponge within the sediment matrix influence sediment shear strength and particle resuspension. This session was notable for crossing the boundaries in marine science, including aspects of benthic invertebrate recruitment and biology, bacterial adaptation, ecological principles, and the influence of other abiotic processes on the benthos.

A mid-week break in the proceedings provided an opportunity to visit Ocean Lab, the new facility of Aberdeen University in Newburgh. Ocean Lab is the result of a successful Joint Infrastructure Fund (JIF) bid between the Universities of Aberdeen, Bristol and St Andrews, and the Scottish Association for Marine Science. On arrival at Ocean Lab, delegates were welcomed by the Director, Prof. Monty Preide, who outlined the facilities available. Members of the Lab then described and demonstrated the equipment and techniques they work with, including benthic landers, laser holography, and image-processing methods. Having just returned from sea, the group were able to give up-to-date information on the working of the landers, and some idea of preliminary results from the data collected.

After the visit to Ocean Lab, the group divided into two parties to drive north and experience two examples of Scotland's key tourist attractions – welcome to the distilleries tour! An informative commentary of the surroundings was given *en route*, and delegates arrived for afternoon tea and an opportunity to discuss the proceedings so far. After a full tour of the distillery, including a lesson in 'nosing' the whisky, they were given a wee dram and an opportunity to purchase more – no doubt to encourage more lively discussion later in the evening!

The conference dinner provided an opportunity to thank those most involved in the organisation of the conference, most notably Martin Solan, Monty Preide, Dave Raffaelli and Joe Germano – also an opportunity to dress up, with several delegates wearing kilts. Joe Germano, however, did not think this occasion particularly deserving and sported his special 'utility kilt' all week. After a lavish dinner of local fish, sweets and whisky, we were all entertained by brave singers and instrumentalists until the whisky finished.

Two final sessions, on *in situ*

benthic monitoring and *in situ* benthic imagery, provided the most technologically impressive talks of the conference. Footage taken from the sea bed, both from landers and sediment profile imagery (SPI), gave stunning visual accounts of benthic processes. Both sessions demonstrated the most exciting developments in benthic dynamics research, covering a variety of areas and providing a memorable end to the conference.

A number of concurrent workshop sessions were held, on topics including porewater biogeochemistry and diagenesis, imaging the benthos, *in situ* benthic monitoring (artefacts and interpretation), hydrodynamics at the sediment–water interface, organism–sediment interactions, and benthic food webs. Each workshop discussed the recent advances in their fields and debated those questions of most interest to the members present. The results of the discussions were then informally reported to all the delegates at the end of the meeting.

Altogether, the conference provided a great opportunity to gather some of the most prominent researchers in the marine world, and gave everyone a chance to hear about the latest technological advances in benthic research. Much credit should be given to Martin Solan for organizing the meeting, and also to all the delegates who gave talks, presented posters and participated in workshop sessions during this enjoyable week.

The meeting was sponsored financially by the British Ecological Society, the Challenger Society, Dredging Operations Technical Support, Germano and Associates, the Marine Biological Association of the United Kingdom, NOAA Coastal Services Centre, and the US Office of Naval Research.

The proceedings of the meeting will be published in a peer-reviewed special issue of the *Journal of Experimental Marine Biology and Ecology*.

**Catherine Biles** is a Ph.D student working on the effects of flow and biodiversity on ecosystem functioning at the Sediment Ecology Research Group, Gatty Marine Laboratory, St Andrews University, East Sands, Fife, KY16 8LB.

# NOW There's a FUNNY THING...

## *BSc. in Surf Science?*

A joke? Far from it, so don't mock. But you should forget visions of lazing on beaches with tanned young lotharios and long-limbed goddesses with sun-bleached hair. They may well be around, but Surf Science will – as indeed it should – be about wind and waves, tides and currents, beaches, and the physics of sediment transport and deposition. In short, it's largely about coastal oceanography, with outdoor labs and practicals that will keep you pretty fit. There will be related courses on the design of boats, boards and equipment, and it is to be hoped there will also be advice on avoiding the 'surf rage' caused by too many people chasing big waves, which seems to be endemic in the US and Australia, and has spread to Britain (*Ocean Challenge*, Vol. 10, No. 2, p.7). Interested persons should contact the Science Faculty, University of Plymouth.

## *If it's not tunnels, it's bridges*

The desire not to use boats to get across shortish stretches of water seems never-ending, the urge to spend lotsa money on alternative routes insatiable. A proposed tunnel link between Ireland and North Wales at an estimated cost of £14 billion (*Ocean Challenge*, Vol. 10, No. 1, p.10) is dwarfed by plans to tunnel beneath the Bering Straits and link Russia with the US. The estimated £40 billion cost must be an underestimate if road and/or rail communication is to be achieved, since the nearest Russian road ends 1600 km from the Straits, while the nearest US railhead is nearly 2000 km away. Now the Italians want to bridge the Strait of Messina by a 3.6 km road and rail link between Sicily and the toe of Italy, at a relatively modest cost of £3 billion. Since September 11, such grandiose schemes seem likely to be shelved for a while, not least because tunnels and bridges tend to fill with traffic and can become targets for sabotage. Simple old-fashioned ferry boats, on the other hand, mostly come to grief because – especially in poorer countries – greedy operators let them get overcrowded, not because of terrorist activity. Another reason is that both private enterprise and taxpayers have to pay for these projects, and just now global recession is in progress.

## *Mammoths of the Sea*

The concept of giant luxury cruise ships featured in these columns a couple of years back (*Ocean Challenge*, Vol. 10, No. 2, p.10), and at the time it seemed a bit unreal. But it's all been happening. At the last count, a month or two ago, 80% of the £1 million to £5 million appartments on the ship known as *The World* had been sold. Before the end of the year, the ship will have visited 120 ports in 40 countries, which gives a different meaning to the slogan 'See the world from your own home'. Other distractions/facilities include swimming pools, library, theatre, cinema, art gallery, casinos, driving range and putting green, 24-hour medical care, top-class cuisine – and there's even a residents' committee. How will anyone have time to see anything of the ports the ship will visit?

## *Heyerdahl's legacy*

Isn't it odd that the simple notion of using the Trade Winds and equatorial current systems to sail half-way across the Pacific would meet with such opprobrium from the anthropological community? Admittedly, Heyerdahl was trying to demonstrate that humans reached the western Pacific from the east, whereas nearly all other lines of evidence pointed to colonisation from Eurasia. But making use of prevailing winds is just what all sailors used to do (and many indeed still do). Heyerdahl's error lay in his notions that the pyramids in Egypt, Mexico and Peru were linked by a common culture, that the Easter Island statues came from Europe via South America. But at least he wasn't among the lunatic fringe who claim that these features were built or brought to Earth by extraterrestrials. It is to be hoped that at least his pioneering voyages will be remembered, even if his ideas have ended up in one of history's cul-de-sacs.

**John Wright**

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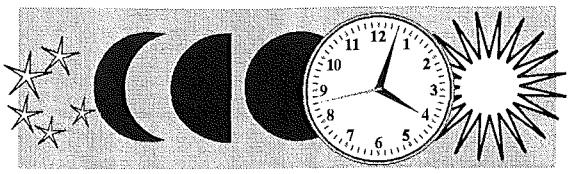
**John Wright**

# Coastal Animals that Anticipate Time and Tide



Ernest Naylor

Animals and plants between tidemarks are exposed to a range of physical variables associated with tidal immersion and emersion, pounding by waves, and tidal currents. Some rocky shore species are adapted to such conditions through natural selection for structural features that permit adhesion to rocks and resistance to desiccation, and some sandy shore species have adapted by burrowing. Such organisms are usually distributed in zones on tidal shores, reflecting a range of adaptive evolutionary solutions to the problems caused by variability within intertidal environments. For mobile species, however, many of which are also zoned within coastal habitats, the adaptive solutions have been quite different. Many of these animals often disperse or migrate at one state of the tidal (12.4 hr) or diel (24 hr) cycle and return to a characteristic zone at another. Such behaviour poses interesting questions as to how random dispersal by waves and tides is avoided, and how cyclical changes in orientation are achieved. Do coastal animals simply respond to tidal and diel environmental cycles, or have they become adapted to anticipate particular phases of such cycles?

Some answers to these questions have been obtained through studies of the behaviour of mobile inshore crustaceans, as reported below for the following examples: the sandhopper *Talitrus*, the sand beach isopod *Eurydice*, the estuarine copepod *Eurytemora*, and adults and larvae of the common shore crab *Carcinus* (Figure 1). All of these animals are able to behave as living clocks, their internal timing mechanisms enabling them to anticipate environmental changes so that, in general, they are in the right place at the right time.

## Avoiding tidal immersion

Some semi-terrestrial animals that occupy the zone just above high-water mark (HWM) often forage downshore. Sandhoppers of the species *Talitrus saltator*, important consumers of algal debris along the strandline, behave in this way. They move downshore, particularly during darkness, returning upshore to their preferred burrowing zone before dawn.

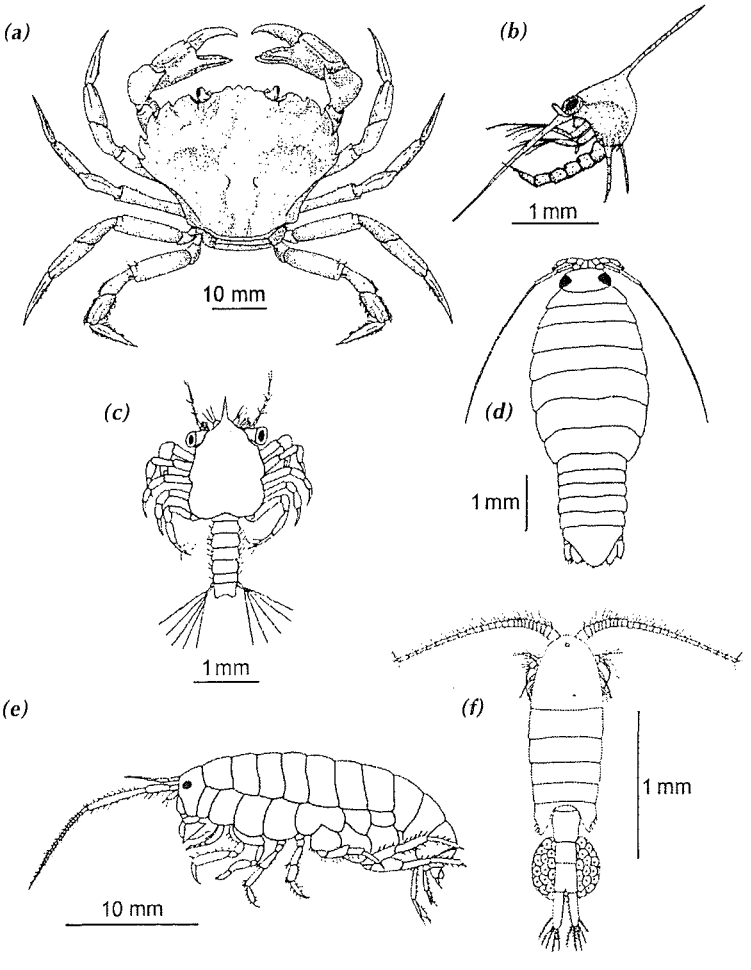



***Figure 1*** *The cast of crustaceans considered in this article:* ***(a)*** *the shore crab* Carcinus, *with* ***(b)*** *its zoea larva and* ***(c)*** *its megalopa larva;* ***(d)*** *the sand beach isopod* Eurydice; ***(e)*** *the sand hopper* Talitrus; *and* ***(f)*** *the estuarine copepod* Eurytemora. *(a),(d),(e), and (f) after P.J. Hayward and J.S. Ryland 1990; (b) and (c) after G.E. and R.C. Newell, 1963.*

***Experiments under constant conditions show that sand hoppers are most active after midnight when they are initally attracted to the bright sea and wet sand; towards dawn they are attracted back up the beach towards the light/dark boundary between the dunes and the pale sky***

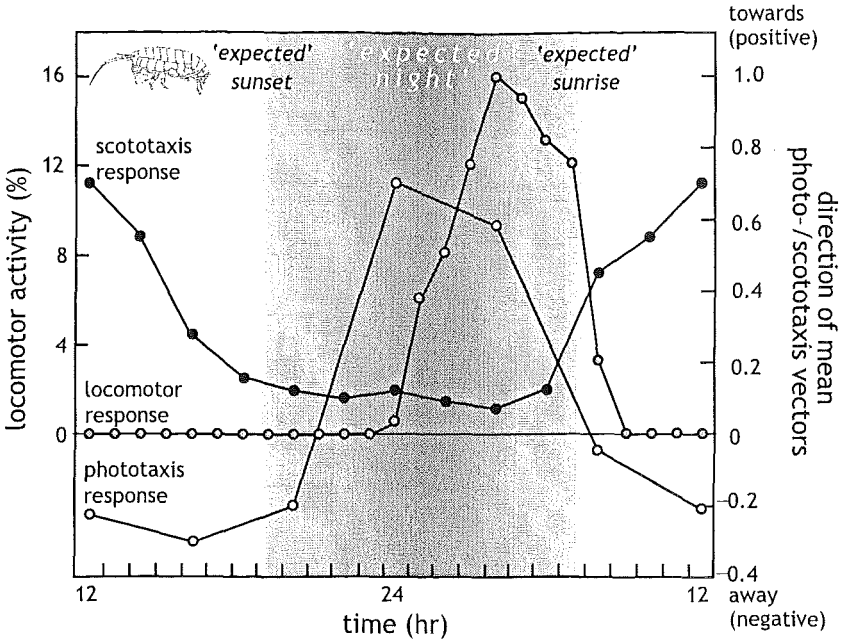



***Figure 2*** Talitrus: *Spontaneous patterns of locomotor activity, scototaxis and phototaxis over 24 hours in constant conditions in the laboratory. The scototaxis curve indicates attraction towards a light/dark boundary during 'expected' day and indifference during 'expected' darkness: the phototaxis curve indicates attraction to light during 'expected' darkness and repulsion by light during 'expected' daytime.*

Movement upshore before daylight implies anticipatory behaviour, indicating possession of an internal biological clock mechanism.

That *Talitrus* possesses such a circadian (c. 24 hr) clock system can be demonstrated by recording the locomotor activity of sandhoppers in the laboratory, under conditions of constant temperature and continuous dim red light. Under these conditions, such animals exhibit spontaneous bursts of walking activity for a few hours during 'expected' darkness approximately every 24 hours. In addition, they show similar clock-controlled changes in how they respond to the environmental cues they use to determine the direction of movement down and then up the beach surface during their episodes of nocturnal activity. More specifically, in constant conditions in the laboratory, it can be shown that the hoppers change their directional responses to light (phototaxis) during a 24 hr period, exhibiting positive phototaxis (being attracted to light) during subjective night, and negative phototaxis (being repelled by light) during subjective daylight hours. Moreover, they move towards a dark/light boundary (positive scototaxis) by day, and are indifferent to such a boundary at night. When the circadian rhythms of spontaneous locomotor activity and orientational responses to environmental cues are superimposed (Figure 2), an explanation for the control of downshore/upshore migrations of *Talitrus* can be postulated.

Maximal positive phototaxis occurs when the hoppers first become active on the sand surface at night, a response that directs them downshore towards the brighter surfaces of the sea and wet sand, and away from the less reflective dunes. In contrast, the peak positive scototaxis response (movement towards a dark/light boundary) begins around dawn, a response that directs the hoppers upshore towards the dune/sky boundary, reinforced by a reversal of the phototaxis response (from positive to negative) which directs the hoppers away from light reflected off the sea and wet sand. Return to the preferred daytime burrowing zone just above high-water mark is accompanied by a complete cessation of locomotor activity, which persists until the animals emerge again onto the sand surface after nightfall. This nocturnal pattern of foraging behaviour has presumably evolved as an adaptation that minimizes predation by daytime-feeding birds.

So far, in Atlantic coast populations of *Talitrus saltator* there is no evidence of navigation by the celestial cues that are utilized by Mediterranean sandhoppers which, in non-tidal localities, forage inland from coastal dunes. Of course, the use of celestial cues for orientation implies even more sophisticated internal timing mechanisms. In such cases, being able to return to the 'home zone' requires continuous adjustment to apparent changes in the position of celestial cues resulting from the Earth's rotation, thus implying that the animals have 'continuously-consulted' biological clocks.

## Anticipating tidal ebb

Use of a face mask when swimming between tide marks at high tide confirms that many mobile animals are moving freely over the substratum or within the water column. Some of these species are hidden or burrowing forms which emerge as the tide floods, and some migrate upshore with the rising tide; but most then return to a preferred zone

between or below tide-marks at low tide. The common green shore crab *Carcinus maenas* is such a species. It shelters beneath rocks at low tide but, during repeated observations by divers throughout a tidal cycle, has been seen to emerge and often follow the edge of the rising tide. Interestingly, the crabs have been less commonly observed at the water's edge at high tide, and during the ebb; they appear to seek shelter or move downshore in anticipation of the falling tide. Laboratory recordings of crabs in constant conditions show that their bursts of walking activity occur spontaneously at the time of 'expected' high tide (Figure 3, top), indicative of control by an internal biological clock that permits the anticipation of tidal ebb. In the locomotor activity trace of *Carcinus* (Figure 3, top) there is evidence not only of circa-tidal (c. 12.4 hr) rhythmicity, but also of circadian (c. 24 hr) periodicity. The circadian bursts of activity are nocturnally phased, reflecting the fact that *Carcinus* can often be seen moving actively on the open shore during low tides at night time.

A similar pattern of anticipation of tidal ebb is seen in the sand beach isopod crustacean *Eurydice pulchra*, a relative of woodlice and hogslaters. Normally found burrowed in sand to a depth of a few centimetres on the upper half of the shore at low tide, the isopods emerge to feed in the water column during the flooding tide. After high tide they re-burrow in the sand in their preferred zone above mean tide level (MTL), normally without being carried further downshore. When kept in laboratory aquaria with sand, *Eurydice* show a very clear circa-tidal pattern of swimming, alternating with burrowing, bursts of swimming occurring around the times of 'expected' high tides (Figure 3, bottom). This free-running rhythm, which in the laboratory can be re-set by tidal cycles of simulated wave action, provides a mechanism whereby *Eurydice pulchra* on sandy beaches, like *Carcinus maenas* on rocky coasts, have a behaviour pattern which ensures that they are in the right place at the right time, irrespective of tidal state.

Moreover, for both of these crustaceans, additional experiments show that responsiveness to light also varies over the tidal cycle, further enhancing the zonal recovery process. For example, the dashed line in Figure 4 clearly shows for *Eurydice* that during flood tide, when the isopods first emerge from the sand to swim, they are attracted to light at the sea-surface by positive phototaxis. In contrast, during the ebb when their bout of swimming activity begins to subside, they are repelled by light, exhibiting negative phototaxis which ensures their return to the sand before low tide.

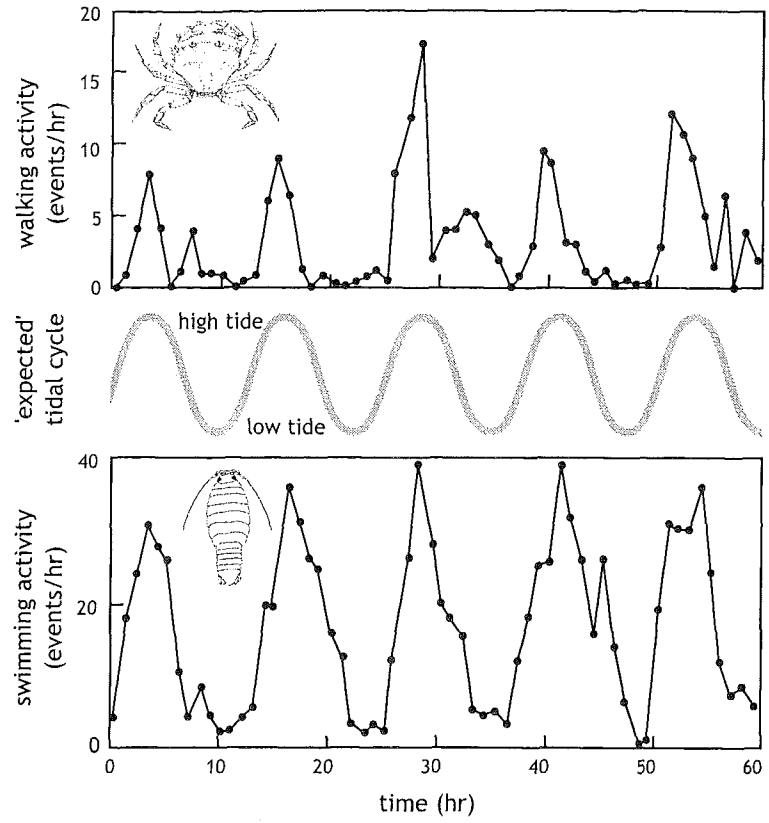
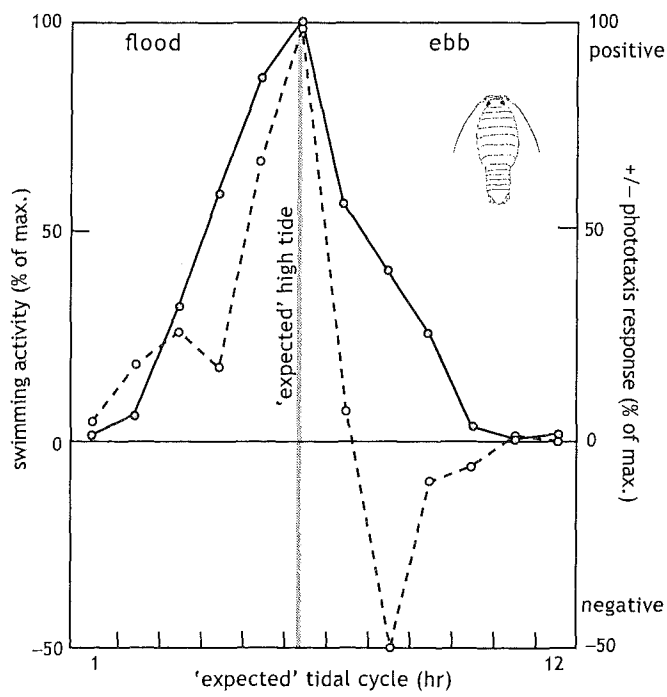



***Figure 3*** Carcinus *and* Eurydice: *Spontaneous patterns of locomotor activity of groups of animals maintained for 60 days in constant conditions in the laboratory, along with their 'expected' tidal cycle (middle curve).*

**Carcinus *and* Eurydice *are most active at high tide, even when kept in constant conditions in the laboratory***

***Figure 4*** Eurydice: *Spontaneous patterns of swimming activity and phototaxis of groups of animals over an 'expected' tidal cycle in the laboratory.*

***When the isopods* Eurydice *emerge from the sand to swim around high tide, they are attracted upwards by the light at the sea-surface***



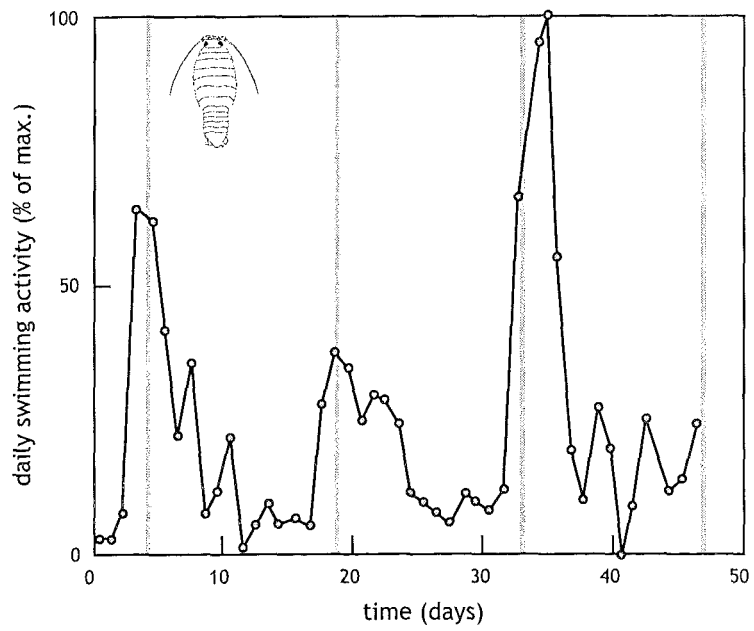
## Avoidance of 'neaping'

Neaping is a phenomenon well known in coastal localities where tidal amplitudes are large, and craft moored at the level of high spring tides may be left high and dry for several days at neaps. In such localities, neaping is also a potential risk for intertidal migrant animals, some of which have evolved adaptations which minimize that risk. For example, sieving sand from the intertidal zone at low tide reveals that the isopod crustacean *Eurydice pulchra* can be found above the level of high water neaps (HWN) during spring tides, but not during neaps. It has been shown that when kept in aquaria with sand, these isopods emerge spontaneously at times of the 'expected' high tides More than this, however, similar experiments carried out over a lunar month show that by far the greatest numbers emerge and swim at times of 'expected' high tides on the days immediately following spring tides. Such behaviour is clearly adaptive in ensuring that the bulk of the population swim during reducing spring tides and therefore move downshore before the onset of neaps.

Evidence that this neaps/springs pattern of behaviour is controlled by biological clocks of approximately 14-day (circa-semilunar) periodicity is given in Figure 5 which plots the total daily swimming activity of a batch of twenty *Eurydice pulchra* recorded for 46 days under constant conditions in the laboratory. Moreover, phasing of this neaps/springs rhythm can be re-set in the laboratory by 2-hr bursts of artificial tidal agitation applied at those times of the day when high spring tides occur on the home beach.

**Eurydice *swim in greatest numbers at fortnightly intervals, on the days immediately following highest spring tides***

***Figure 5*** Eurydice: *Total daily swimming activity of a group of animals maintained for 46 days in constant conditions in the laboratory. The toned lines are marked off at 14-day intervals starting with the initial peak of swimming, and indicate a circa-semilunar rhythm of swimming intensity.*




## Problems for zooplankton

It is a paradigm that most open ocean planktonic organisms undergo diel patterns of vertical migration behaviour, the proximate stimulus for which is the level of ambient illumination. The biological significance of such migrations is variously attributed to enhanced feeding, predator avoidance, and horizontal dispersion by exploitation of current differentials in layered water masses. For estuarine and coastal zooplankton in tidal localities, however, the situation is rather different. In tidal estuaries, where net water transport is seawards, zooplankton populations must maintain position or, if transported seawards during ebb tides, re-recruit on flood tides. Also, in such localities, and along open coastlines, many plankton animals are larvae of shore-living adults, to the habitats of which their dispersed larvae must return at the time of metamorphosis. Accordingly, some estuarine and coastal planktonic animals exhibit behaviours which challenge the paradigm that plankton vertical migrations are diel: some exhibit vertical migration rhythms of tidal periodicity.

In some North American estuaries that are markedly stratified in the absence of strong tides, several examples are known of vertical swimming behaviour which has a tidal periodicity. Larvae of benthic forms or permanently planktonic species maintain their horizontal position by vertical movements between the seaward-flowing surface water and the subsurface, landward flowing water, their vertical migration rhythms being centred on the depth of zero net flow. In more strongly tidal estuaries, where stratification is less marked or absent, the problems of position maintenance for plankton are quite different. In the estuary of the River Conwy in North Wales, for example, the small planktonic copepod *Eurytemora affinis* maintains its position in mid-estuary, despite the absence of exploitable stratification, albeit being carried somewhat further upstream at springs than at neaps. Intensive sampling over time throughout the length of the estuary (Figure 6) showed that in the middle and lower reaches the copepods were more abundant at mid-depths on the flood tides than on the ebbs, at which time they tended to sink towards the bottom. In contrast, in the upper reaches of the estuary, the reverse pattern occurred: the copepods were more abundant on the ebbs than on the floods. Since water velocity increases logarithmically above the estuary bed, the pattern of upward swimming would tend to favour retention in the middle estuary. Net transport of *Eurytemora* in the water column would be upstream in the lower reaches of the estuary and downstream in the upper reaches. Upward-swimming rhythms in *Eurytemora* are endogenous, under internal biological clock control, and differential phasing of the rhythms along the length of the estuary may be salinity-determined.

Though there are several published examples of tidal vertical migration rhythms in estuarine plankton, possibly the first recorded example of such rhythms in an open coastal organism is afforded by the larvae of the common green shore crab *Carcinus maenas*. In recent years it has been demonstrated that not only do green shore crabs exhibit endogenous tidal rhythms of locomotor activity, but that females kept in constant conditions release their larvae at times of expected high tides. Furthermore, the newly hatched nauplius larvae have been shown to undergo vertical migration rhythms of tidal periodicity, even in constant conditions in the laboratory. In nature, the combined rhythms of release and swimming at the sea surface after high tide ensure that the newly released nauplius larvae of *Carcinus* are carried offshore on ebbing tides. Offshore, over a period of a few weeks, the larvae undergo development through three more zoea stages, finally moulting to the megalopa, the stage at which recruitment back to the shore takes place. At the time of recruitment back to the shore in late spring, megalopa larvae of *Carcinus maenas* (Figure 1(c)) can often be seen in huge numbers at the water's edge at the high tide level, where they settle out from the plankton, metamorphosing to the first crab stage as they do so. Like the zoea larvae (Figure 1(b)), megalopa larvae also exhibit a tidal rhythm of vertical migration in the water column, but in the case of megalopas, upward swimming occurs during the flood tide which carries them inshore. Moreover, the tidal 'clockwork' of the larvae continues through metamorphosis to the first crab stage. The late larvae appear to 'queue' for metamorphosis; thus, batches of megalopas which were collected at the water's edge and observed through to metamorphosis in constant conditions in the laboratory, moulted to the first crab stage only at times of 'expected' high tide (Figure 7).

## Coping with catastrophe

Position-maintenance behaviour by mobile coastal crustaceans involves adaptation not only to spatial differences but also to temporal changes. Endogenous locomotor activity rhythms and patterns of rhythmic responses to environmental variables of tidal, daily and semilunar periodicity seem to endow adaptive advantage. Yet rigidly programmed behaviour patterns could be maladaptive against a background of environmental variability that is sometimes unpredictable. How then do such animals cope with unpredictable, or even catastrophic, events?

The endogenous free-running rhythms driven by the biological clocks of the animals concerned, prefixed by 'circa-', are by definition only approximate to the periodicity of the equivalent environmental cycle. Indeed, they are repeatedly fine-tuned on each cycle of environmental change, thus endowing some flexibility of response to

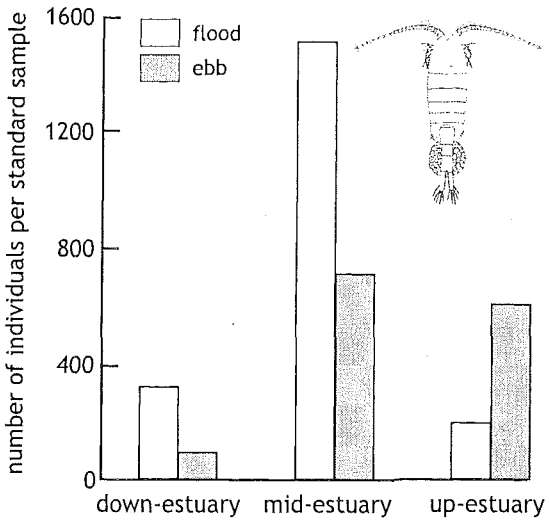


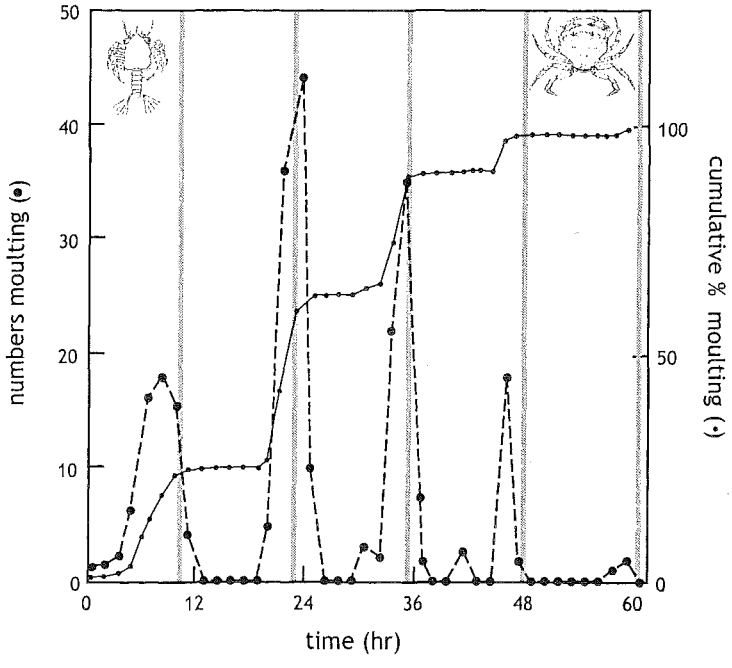

***Figure 6*** Eurytemora: *Numbers of copepods taken at mid-depths in standard plankton samples on the ebb and flood tides at three positions along the estuary of the River Conwy, North Wales.*

***In the lower and middle estuary,* Eurytemora *were most abundant in the water column during flood tides; in the inner estuary, they were most abundant in the water column during ebb tides***

minor environmental perturbations. In contrast, occasional storms sometimes displace intertidal species above or below tidemarks. In such circumstances, recovery is not usually possible for species displaced above HWM but recovery from displacement downshore can be achieved. For example, the intertidal isopod *Eurydice pulchra* is sometimes found below tidemarks in company with a normally subtidal species *Eurydice spinigera*. Under such circum-

***Figure 7*** Carcinus: *Numbers and cumulative percentages of crab megalopa larvae metamorphosing to the first crab stage during constant conditions in the laboratory. An initial sample of about 250 larvae was collected in the surf on day 0; numbers moulting are at 90-minute intervals over 61 hr of observations; toned lines correspond to times of 'expected' high tide at the collection site.*

***Even in the laboratory, green crab megalopas moult at times of high tide on their home beach***



stances it has been observed that the former species, but not the latter, is able to move inshore, probably as a response to the sound of breaking waves.

## Conclusions

Position maintenance behaviour in mobile coastal crustaceans appears to result from a combination of locomotor activity rhythms and rhythms of orientational responses to environmental cues. Some of these rhythmic patterns of behaviour persist in animals subjected to sensory deprivation experiments in the laboratory, suggesting that they are at least partially controlled by inherited internal biological clocks, indicative of adaptation to cyclical changes in the environment.

## Further Reading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# Book Reviews

## *Fluid flow, in the environment and in engineering*

**Gravity Currents: In the Environment and the Laboratory** by John E. Simpson (1999). Cambridge University Press, 258pp. £18.95 ($29.95) (flexicover, ISBN 0-521-66401-2); £52.20 ($85) (hard cover, 0-521-56109-4).

This is the second edition of a book that has justifiably attracted wide admiration from research workers, students and scholars in many different disciplines. To a large extent, the general appeal of the book is attributable to the use made by the author of illustrations derived primarily from laboratory experiments and field observations, and to his ability to provide clear physical interpretations of flow phenomena without recourse to complicated mathematical analysis.

The second edition contains a number of new topics, such as gravity currents revealed by satellite imagery, glaciers, purging in pipes, and flow in porous media. There is a description of recent fieldwork on the generation of atmospheric bores, and of gravity current frontogenesis in sea breezes, and discussion of aspects of wind-shear hazards associated with the motion of spreading currents formed by microbursts. The important field of ventilation of buildings by buoyancy-driven exchange flows is also covered; and discussion of new work on currents with large density differences updates the material on laboratory experiments on these phenomena.

All of these additions enhance significantly the worth and attractiveness of the book. The material is well-ordered, and the disarmingly relaxed style of the writing allows the reader to progress easily through the text. The author has the ability not only to treat complex flow phenomena at a level that permits the non-specialist to comprehend the associated physics (not least through the use of interpretative sketches and photographic evidence), but also to provide sufficient detail to satisfy specialist researchers and guide them to original papers. Achieving such a balance is not easy and it is to the great credit of the author that his communication skills and physical insight have produced such a satisfying book, and one that will appeal to a wide audience.

The only slight disappointment is that the examples used to illustrate the new chapter on satellite images of gravity currents do not reproduce particularly well in black-and-white. This is particularly noticeable if the images are compared with some of the high quality photographs from laboratory experiments. In spite of this minor deficiency, the book is an excellent and comprehensive source of reference on gravity currents in the natural world and in many engineering applications. It will find wide acceptance with specialist researchers as well as those having general interests and curiosity in buoyancy-driven fluid flows. It deserves to be found on all book shelves of this broad constituency.

**Turbulent Flows** by Stephen B. Pope (2000). Cambridge University Press, 806pp. £29.95 ($49.95) (flexicover, ISBN 0-521-59886-9); £80 ($130) (hard cover, ISBN 0-521-59125-2).

It is a challenge to produce a new monograph on turbulent flows, particularly because of the availability of other reputable, well-established texts on the subject, and because of the difficulties in making this complex subject accessible to researchers working in a wide range of disciplines. The author has risen admirably to the challenge and he has written a carefully constructed and elegant book that will serve as an excellent and up-to-date reference source for the fluid dynamics research community.

The book is based upon a series of lectures given by the author to engineering students at Cornell, and it is inevitable, therefore, that the examples of turbulent flows on which most emphasis is placed are drawn from engineering applications. The main strength of the book is its focus on fundamental aspects of turbulent flows; it is characterized by a careful and rigorous mathematical development of the properties of turbulence and an illuminating interpretation of turbulent flow behaviour. Not least, the text includes many recent aspects of turbulence research (e.g. direct numerical simulation, simulation of large eddies) that have been developed in the specialized literature relatively recently, but have not yet found their way into an integrated monograph treatment of the subject. The appearance of the book is therefore very timely.

The reader should be warned that the mathematical analysis in the book is not for the faint-hearted; the author assumes high standards, but he presents the material very well. It is clear that in this respect (and in the style of presentation of the subject) he has profited significantly from delivery to graduate student classes over a number of years.

Though the author intends that the book will be valuable to the meteorological and oceanographic community, the primary readership is likely to be limited to engineers, physicists and applied mathematicians. Oceanographers, for example, will find the book to be a useful background reference text but will encounter little that is related explicitly to oceanographic turbulence *per se*. In a general sense, there is almost nothing in the book concerning turbulence in stratified fluid systems, and very little on the effects of background research. It would be churlish to criticise the book for these omissions in view of the primary focus being placed explicitly by the author on the engineering context of the work. The book will still be appealing to fluid dynamicists across a wide range of disciplines, including those researchers in meteorology, oceanography and environmental fluid mechanics looking for a general, in-depth and careful background treatment of the subject, rather than a specialized text dealing with turbulence in environmental and/or geophysical fluid systems.

**Peter Davies**
*Department of Civil Engineering*
*University of Dundee*

*First EFMS Scientific Conference*

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## ADVICE TO AUTHORS

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

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