OCEAN Challenge

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SCOPE AND AIMS

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

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

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

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

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

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

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

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

Membership provides the following benefits:

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

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

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

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The subscription for 2005 costs £40 (£20.00 for students in the UK only). If you would like to join the Society or obtain further information, contact the Executive Secretary, Challenger Society for Marine Science, Room 251/20, Southampton Oceanography Centre, Waterfront Campus, Empress Dock, Southampton SO14 3ZH, UK; Fax: +44(0)23-80-596149; Email: jxj@soc.soton.ac.uk

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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.

For further information, please contact the Editor:

Angela Colling, Department of Earth Sciences,
The Open University, Walton Hall, Milton Keynes, Bucks MK7 6AA, UK.
Tel. +44-(0)1908-653647
Fax: +44-(0)1908-655151
Email: A.M.Colling@open.ac.uk

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

The cover was designed by Ann Alded Associates.

The cover photograph of the ROV Isis *descending into the water is by Chris German.*

Marine Science on Merseyside

Recollections of the 2004 Challenger Society Conference

Finlo Cottier

Do marine scientists have a natural tendency towards nostalgia? If so, perhaps it comes with spending stretches of time at sea, wistfully spinning yarns of former ships and shipmates. Perhaps it comes with being a part of the historic Challenger Society and discovering your place in the time-line of UK oceanography. Perhaps nostalgia is simply inherent in academic circles where there is an acknowledged lineage of teacher and pupil, the wheel keeps turning, and the 'Do you remember when …' frame of mind ensues.

At the 2004 Challenger Conference in Liverpool, there was a distinct thread of nostalgia running through the weave. Certainly there was a sense of history in the Mersey air as the Proudman Oceanographic Laboratory completed its move across the river from the historic Bidston site to become integrated into the Liverpool University campus. This move marks the close of another chapter in the rich history of that Laboratory – and of course the beginning of a new one.

There was also plenty of nostalgia in the surroundings. Liverpool, as one of the great redbrick universities, retains much of the undergraduate experience that many of us lived. Cavernous, sweeping lecture theatres, a jumble of architectural styles slotted into the precinct, a rambling Student Union building, and a seemingly infinite selection of fine public houses in which to spend many a happy hour. Gill Malin of the University of East Anglia (UEA) reminisced on her return to the exact place where, as a student, she had 'sat through so many tedious biochemistry lectures', before delivering her own dynamic keynote lecture on biogenic trace gases. That sounds like biochemistry to me!

There were also a number of delegates recalling previous Challenger Conferences, contrasting attendance levels then with now. It would seem that fewer people attended this year and fewer still who stayed for the entire week. Apparently, 'it's not what it used to be', though I have no hard data nor sufficient personal experience to confirm the basis of these sentiments. Have conference habits evolved too far beyond those of the original meetings? Do we seek out shorter, more focussed conferences? Can we now attend a big European conference for the same cost as a week with Challenger? Does the Challenger Conference need a major overhaul rather than a biennial tweak of the same formula? There may be some tough questions to answer before the Conference travels to Scotland in 2006.

Nostalgia aside, Liverpool proved to be a showcase for the present *and* future of UK oceanography, and the efforts of the organizing committees were well rewarded. I see the Challenger Conference performing two invaluable functions. First, it is a chance to become acquainted with all that is current and new in UK marine science. Second, it gives young scientists the experience of sharing the stage with established academics and presenting their work to a large audience. These two pillars of the conference remain firm. Once again, there was plenty to give and much to learn at Liverpool, either within your own sphere of expertise or through sitting in on something a little beyond your field of research.

I particularly enjoy the depth and quality that keynote presentations can give to a conference, and at Liverpool there were twelve invited talks during the course of the week. The content of these spanned raw, undiluted science, realistic policy and a few grand visions for the future. It was, however, rather disappointing that the 2004 Challenger Fellow, John Allen, of the Environmental Research Institute in Thurso (part of the UHI Millennium Institute), was not able to give a talk. Here is a fine speaker whose contribution to UK Marine Science has been recognized by the Challenger Society, but for the younger scientists present, John and his science remained somewhat enigmatic. He is the newest Fellow of the Society, so let its members hear about his work.

Of the keynote talks, my personal favourite was that by Jonathan Sharples on his investigations of phytoplankton communities in the seasonal thermocline. He truly embraced the interdisciplinarity of marine science, combining elements of physiology, productivity, nutrient chemistry and turbulent mixing to understand primary production in the thermocline of shelf seas. He also showed the value of combining observations with relatively simple models to help unravel the relationships between competing factors. So why did this one do it for me? I admire the polymaths of this world – those who can appreciate and blend the fruits of many disciplines. I also feel comfortable in the presence of a sea-goer, someone who enjoys going out to observe the ocean as it really is. Finally, I appreciate those who can gather together seemingly eclectic themes and cast them in a story that has a fresh message, a new insight.

Amongst the broad spectrum of offerings there were some superb examples of clarity and delivery. Claire Evans, recently doctored by UEA and now at Plymouth Marine Laboratory, delved deep into the interaction between viruses, phytoplankton and the production of bio-gases. A complex subject for certain but she carried her audience (including a physical oceanographer or two) without allowing the details to cloud the science or obscure the message.

Another fine performance by a young scientist was that of Caroline Bain, from David Marshall's group in Reading, who described a powerful advance in numerical modelling. She blew away the traditional approach of a fixed mesh with one that adapts to changes in the flow field so that the model effectively changes its focus – 'dynamical mesh adaptivity'. Stealing an idea from the engineering world and applying it to oceanography has given us a new tool that balances resolving fine details in large flows in a reasonable time using desk-top computing power.

There was yet more variety in the poster session. In contrast to so many poster sessions at conferences, which often degenerate into an airless, congested brawl, the Liverpool Guild of Students provided acres of space to move about in. There were few occasions when it was necessary to squeeze down an aisle or limbo past people reading the posters. More often than not there was the necessary peace and calm to allow us to really read and take in the content.

Aside from the main events, the organizing committee cooked up something fresh for the conference menu with a Marine Science Policy debate *à la* 'Question Time'. The recipe was quite simple. Take a rich stock of marine scientists and add to it a dash of academic, a splash of industrialist, the zest of one TV producer and a twist of politician. Ed Hill kept the pot simmering for a couple of hours and the result was a rare brew of opinion and comment. Topics ranged from political priorities to public awareness, to the organization of UK marine science. Additional comments from the audience contributed much to the flavour and it proved to be a source of rumination through the week.

My own contribution to the discussion was rather truncated by my forgetting the second of the two points I wished to make. The topic under discussion was how to attract fresh talent into marine science, particularly those with a leaning towards maths and physics. My first point was that many students equate marine science with marine biology; there is apparently little awareness of the scientific diversity we offer. The second point I had hoped to make was that potential students are focussed on employment opportunities – they have to be able to see a career path. Perhaps the onus is on us to be more proactive and really market the scope of our subject.

The Lord Mayor of Liverpool illustrated beautifully the limited perception of what marine science encompasses when he received the assembled conference in St George's Hall towards the end of the week. Granted he was battling with a temperamental microphone, but he must have caused some dismay when he began, 'I'm very pleased to address this marine science conference. Now I don't exactly know what marine biology is, but …'! Is there really little more to oceanography than the 'Blue Planet' TV series?

Without doubt, St George's Hall provided the most magnificent setting for a conference dinner. Ball gowns, black tie and carriages at midnight would have been entirely appropriate that night. As it transpired, our carriage at midnight was a fire engine as we were all ushered outside back into the 21st century when the fire alarms sounded. There was nothing else for it but to make for the heart of Merseyside nostalgia at the Cavern Club to end the night with The Beatles and a rendition of 'Yesterday'. Thank you, Liverpool.

Postscript: I hope the singing will continue in Scotland in 2006, with classic anthems such as 'Donald where's your troosers'!

Finlo Cottier is a Research Associate in the Marine Physics Group at the Scottish Association for Marine Science, Oban. His current research interests are in Arctic marine systems and the balance between Atlantic and Arctic waters in coastal areas. He has recently joined the *Ocean Challenge* Editorial Board.

A New Director for SOC

The new Director of the Southampton Oceanography Centre will be Ed Hill, currently Director of the Proudman Oceanographic Laboratory. Ed will take over from Acting Director Howard Roe.

Marine Science 2004

Finlo Cottier's account of the conference (opposite) conveys something of the spirit of the 2004 Challenger Society conference in Liverpool. Judith Wolfe and colleagues did a splendid job of organizing an excellent event. Attendance may not have been as high as in previous years at other venues, but that did nothing to detract from the high standard of talks and posters. There were no fewer than nine keynote speakers as well as the Buckland Lecture (see below). In addition, the two Challenger Medallists, John Scott and Tony Heathershaw, gave lectures based on their naval experience of – respectively – operational and acoustic oceanography.

Between sessions, there was a chance to talk science, exchange news, and study the entries for the President's Photographic Prize. The theme, 'Time and Tide', was interpreted in a variety of ingenious ways. The winner (amongst entries of a very high standard) was a clever image by Colin Stevens of the Proudman Oceanographic Laboratory (see below).

As mentioned by Finlo, a novel feature of MS2004 was the evening panel discussion, based on the format of BBC 2's 'Question Time' (or Radio 4's 'Any Questions?'), in which questions on various issues were posed by the audience, and dealt with by a panel made up of Ian Gibson MP, Colin Grant of BP, Penny Allen of the BBC (Natural History Unit), and Andy Watson of UEA. The discussion was entertainingly chaired by Ed Hill of POL. Among the topics discussed were the issue of numeracy in schools, renewable energy – mostly about offshore wind farms, less about waves and tides as energy sources – and job prospects for students graduating in marine sciences.

It is interesting that sustainability was not mentioned by anyone during this discussion. Admittedly, earlier in the day John Roberts of Defra had given a keynote talk on the subject of sustainable exploitation of the oceans; it would have been interesting to hear about enforcement of the plentiful laws and regulations formulated to prevent and/or control misuse of the marine environment.

This raises a more general question about where marine science is going. Technological advances are allowing us to measure properties in greater detail and at increasing resolution. Nobody illustrated this better than Graham Shimmield in his keynote presentation about benthic observatories, during which he mentioned probes that can resolve (for example) porewater properties at millimetre resolution. A cynic might wonder whether scientists are now asking more and more about less and less, but perhaps the opposite is true: Having mostly answered questions of the kind 'What happens and how does it happen?', scientists are now addressing questions of the kind 'Why does it happen?' As one distinguished oceanographer commented: 'There are so many big questions still to answer.'

Colin Steven's winning photograph shows the New Brighton sea front on a bright sunny day, together with the same location affected by a tidal surge. The technique for including a picture within a picture comes from the American photographer Ken Josephson.

Long-term monitoring was repeatedly mentioned as an essential tool for recording changes in, for example, climate and ecosystems, and it has surely by now become obvious that long time-series measurements are an essential feature of environmental research.

In the context of environmental science, it is unfortunate that the Buckland Lectures are not better known. They were inaugurated to commemorate the life and work of Frank Buckland, a nineteenth century pioneer, not only of research into fish and fisheries, but also of communicating his findings to the public at large. He has been called the David Bellamy of his day, and you can find out more about him in *Ocean Challenge*, Vol. 7, No.1, p.31. The Buckland Professor for 2004 is Julian Addison, who works at CEFAS (Lowestoft), and the subject of the 2004 Buckland Lecture was 'Science and the Management of UK Crab Fisheries'. In some parts of Britain the tonnage of crabs landed at fishing ports exceeds that of some fish – especially these days when so many whitefish stocks are grossly overfished.

Prizes and Awards

The Challenger Medal was awarded jointly to Dr Anthony Heathershaw and Dr John Scott for major contributions to military oceanography. Dr John Allen was made a Challenger Fellow for his achievements in dynamic oceanography.

There were also joint winners for the Norman Heaps Prize for the best verbal presentation by a young scientist. These were Sally Thorpe of BAS, for her talk on 'Modelling circumpolar transport of Antarctic krill: the effect of ocean and sea-ice variability' and Alberto Naveira Garabato (UEA) 'Closing the meridional overturning circulation of the Indian Ocean: the mixing perspective'. Both dealt with complex subjects using clear explanations and excellent graphics.

The Cath Allen Prize for the best poster presentation was won by Sandy Thomalla (SOC) for '$^{234}Th/^{238}U$ disequilibria calculations of organic carbon and nitrogen export flux from surface waters in the North and South Atlantic gyres' (with Mike Lucas, Robert Turnewitsch, Howard Waldron and Richard Sanders). Four posters were highly commended. They were: 'Air–sea gas exchange in the Atlantic: interactions of DMS and ammonia' by Tom Bell (UEA) and colleagues; 'Phytoplankton physiology as measured by FRR fluorometer: does it suggest iron limitation in the western South Atlantic?' by Claire Holeton (SOC) and colleagues; 'Natural iron fertilisation induces export' by Toby Tyrrell (SOC) and colleagues; and 'A new adiabatic approach to data assimilation in ocean models' by James Percival (University of Reading) and colleagues.

Challenger Society Council 2004/5

At the AGM, held during the Conference week, Chris German (SOC) took over from Richard Burt as President (Richard remains on Council as Past President). Jane Read continues as Hon. Secretary and Sarah Cornell continues Hon. Treasurer. Richard Geider (University of Essex), Ruth Parker (CEFAS), Jennifer Pike (University of Cardiff) and Toby Tyrrell joined Council, replacing Hilary Kennedy, Duncan Purdie, Julian Priddle and Paul Ridout, who were warmly thanked for their service. Continuing members are Eric Achterburg, Rachel Shreeve, Roland Rogers, Jonathan Sharples and Willie Wilson.

Eds

A Century of Discovery

Antarctic Exploration and the Southern Ocean

This short conference was held at the Southampton Oceanography Centre in June 2004. We record here some impressions of this excellent event, which succeeded in its aim to celebrate *Discovery*'s Centennial by setting modern-day accomplishments within a historical perspective. This broad scope was reflected in the variety of backgrounds of those present, which made the meeting all the more stimulating.

A central feature of the event was the *Discovery* exhibition, where black-and-white movies shot on the two *Discovery* expeditions of the early 1900s and the 1930s were run on continuous loops. Also on display were numerous memorabilia, including letters and journals written by participants of those earlier cruises, as well as early current meters, sampling bottles and other equipment.

In the lecture theatre, there were 20 presentations in all, and we include here just a selection of interesting nuggets gleaned from the talks. A full account will be published later in 2005 (see p.31).

According to Malcolm Walker, it was the International Geographical Congress in 1895 that initiated exploration of Antarctica and the Southern Ocean, when it resolved that there was a need for 'exploration of the Antarctic continent' and urged that 'expeditions be mounted to that end'. At the other end of the historical time span, John Turner spoke about Antarctic meteorology and pointed out that changes in technology are nowadays so rapid that a book written in 1984 about the International Geophysical Year (IGY) of 1957–58, now looks somewhat dated because little space is given over to modern data and technological developments. On the other hand, he also noted that all the original IGY stations around the coast of Antarctica are still active and now have more than 50 years' worth of measurements of temperature, precipitation and other important meteorological properties.

Eric Mills made an important point about Broecker's 'conveyor belt' model of ocean circulation: it represents only the transfer of water *properties*, it is *not* intended to portray actual currents or the movement of water masses. Sadly, that is what a majority of non-oceanographers (and many students) believe.

According to Martin Angel, the suggestion that iron can be a biolimiting (micro)nutrient for phytoplankton originated in 1942 with a marine scientist named Hart. Martin also made the point that a possible reason why the *Discovery* Reports have not been consulted as widely as they might have been is that they were published in massive volumes occupying metres of shelf space. The result was that only some specialists had the time and expertise to consult the reports, and they never reached the wider scientific community – which could explain why we still know rather little about biodiversity in the oceans.

During the meeting, we all encountered new areas of interest. For many present, the most refreshing talk was that by William Fox on 'Terra Antarctica: a history of cognition and landscape'. The history of Antarctica is rich in cartographic, artistic and scientific images – our attempts to understand the polar desert in terms of landscape.

Eds

Awards for BAS scientists

The Polar Medal is awarded for 'service in support of acquisition of knowledge of polar regions'. Ealier this year, the Queen presented the prestigious medal to oceanographer Keith Nicholls, glaciologists Adrian Jenkins, Elizabeth Morris and David Vaughan, and drilling engineer Keith Makinson.

Communicating science

Tips from a top journalist

Clive Cookson

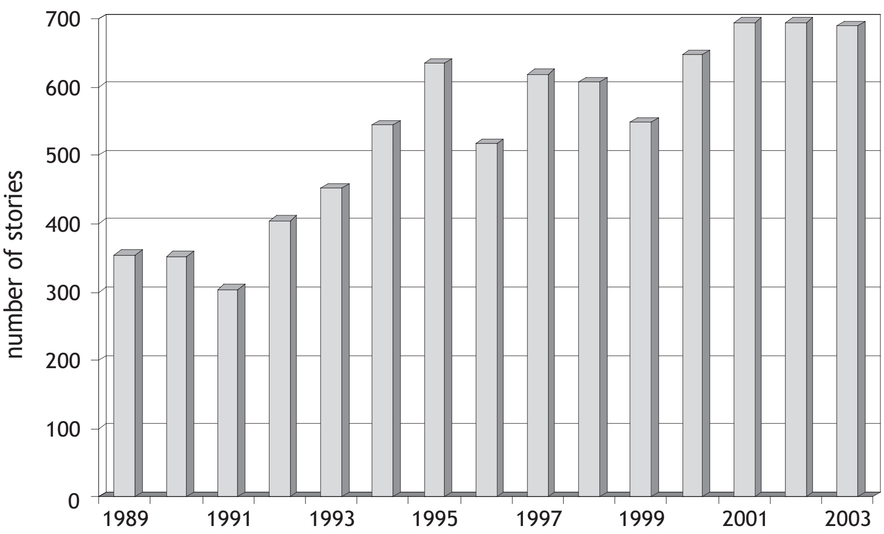
Scientists now appreciate the importance of communicating their work through the media to the general public, with the help of journalists. Here, I hope to give you some idea of the way journalists work and how we differ from scientists; where the media get their stories from; and a few 'do's and 'don'ts' of dealing with the press.

Room for improvement

The amount of coverage given to marine science in the general media has certainly increased substantially since the 1980s. The graph below shows the number of articles containing the phrase 'marine science' in the world's main English-language newspapers for each calendar year from 1989 to 2003, according to the Lexis–Nexis news database (if you search for articles about 'oceanography', you get very similar results). Coverage more or less doubled during the 1990s, with a particularly steep increase during the first half of the decade – the peak in 1995 could have been related to the *Brent Spar* controversy that year.

Of course, more doesn't necessarily mean better. But my impression over 20 years in science journalism is that the quality of science coverage has improved – not so much because journalists have got better but because science-based organizations and individual researchers have become better in their approach to the media. By 'better', I mean more open, responsive to journalists, and proactive in their public relations policy. But there is still room for improvement.

The number of newspaper articles containing the phrase 'marine science' approximately doubled between 1989 and 2003



Scientists and journalists

To help bridge the gap between science and the media, let's look first at what scientists and journalists have in common as individuals. Typically, we are:

- Curious
- Analytical
- Sceptical
- Discovery-loving
- Competitive
- Highly motivated
- Free-thinking
- Self-critical.

But we have little in common when it comes to reporting results. In the scientific world you start with the detailed evidence. Journalists – and most other people – start with the conclusion, then go on to broad facts and then (maybe) down to the details.

Many scientists don't really understand the operating constraints on science journalists in the mass media. The challenge uppermost in the journalist's mind is often not so much to get the scientific truth across to the reader or viewer as to sell the story to the news editor, or whichever other internal gatekeeper the newspaper, magazine or TV programme employs. The media always has a vast oversupply of potential stories, even at slack periods like the Christmas/New Year lull or the August 'silly season'. If your story isn't sensational enough, the editors will ignore or delete it –'spike' it, in journalists' jargon.

I myself would rather read a serious science story than anything about the entertainment business or the Royal family or most things about politics; but news editors have different values, even on serious newspapers, and a scare story about 'Frankenstein salmon', for example, may tune in better with those values than a measured attempt to communicate the real risks and benefits of genetically engineering fish. Remember that the mass media are about entertainment as much as about information.

So if I pick up what I believe is a good story, I normally negotiate with the appropriate newsdesk (the UK desk, world news, financial and so on) before I even think of writing it. If it's really important I may go straight to the overall news editor, who controls what appears on the front page. For longer, in-depth articles known as features, I would run things through with the appropriate features editor. As the writer, I agree a word count, the outline of the piece and its delivery time.

The point is *to avoid writing for the spike* – something that happens very frequently on papers like the *Daily Mail,* where the science correspondent often writes four stories a day, only one of which actually appears in the paper. On the *Financial Times* most of the pieces that are written do appear, though they may be cut substantially during the editing process; the writer is not usually consulted about the cutting (unless the story is particularly sensitive) or about the headline that appears above the piece.

The processes that determine which stories are picked up and run in the media, while others never get started, are quite chancey, even capricious. Coverage will depend on how many other stories are around on the day, and who happens to be on duty among the writing and editing staff. If I am away at a conference, for example, there are likely to be fewer science stories in the *FT* than if I were on duty in London.

Where do news stories come from?

Science journalists' news sources fall into five broad categories. Firstly, there are **press releases and official announcements.** These arrive in gigantic quantities by mail, fax and email. On a typical day I'll get maybe 70 press releases and publicity materials such as corporate magazines – a pile of paper about half a metre high if they're all printed out. I'm afraid the vast majority go straight into the 40-gallon oil drums that we use for waste paper at the *FT*.

continued

Secondly, **personal contacts by letter, phone or email** can give the best stories of all – those sought-after scoops and exclusives. But we have to beware of the false exclusive: all too often, a PR person rings up and says: 'You can have this story all to yourself if you agree to run it prominently in the *FT*', when in fact it's so obscure that no-one else will want it.

Thirdly, **visits to press conferences, scientific meetings, academic and industrial laboratories** etc. will usually produce a worthwhile story. With modern communications technology, it would be possible to work as a reporter without leaving the office, but I think it's essential to get out at least once a week to meet people and see their working conditions.

Fourthly, there are the **academic journals**. Original papers in *Nature*, *Science* and so on are a vital source of news for science and medical journalists. The journals normally give us access to their most interesting papers a few days ahead of publication (on an embargoed basis) to provide time for us to prepare stories. Two web-based services are important sources of embargoed information for registered science journalists: one is AlphaGalileo, based in the UK and focussed on Europe, and the other is Eurekalert, which is run by the American Association for the Advancement of Science.

Finally there is the source that we like least but which we are often forced to use**: following up something from another paper or magazine, or radio or television**. Once a story starts in one newspaper, it may well develop what journalists call 'legs' and run in many others. The advent of computer databases has made it much easier to follow up stories than it used to be in the old days of paper cuttings, but it means that an error in one newspaper is more likely to be imitated elsewhere unless you get it corrected in the database.

Non-journalists often ask me what attracts media attention – what makes a 'good story'. Unfortunately this is extremely hard to define for outsiders. You can list some attractive ingredients: sex; intrigue; corruption; death and disease; bizarre events; genuine scientific breakthroughs. If someone doesn't want you to publish the story, that adds a frisson of excitement. Above all, a good story is about something unexpected. Does it pass the 'Guess what, darling!' test – i.e. is the story interesting enough to tell your beloved about over supper?

I cannot over-emphasize the vast number of science stories that I *could* write, compared with my time and the space available for them in the paper. Given unlimited time and resources, I *could* produce thousands more pieces than I actually do. And the longer I do the job, the longer grows my list of subjects to cover in the future.

Establishing the rules

One particular question that scientists often ask nervously, before giving information to journalists, is whether they have any right to see the copy after it's been written but before it's published, to give them the chance to correct any errors.

Of course there's no general answer that applies in every circumstance but there are some general guidelines. First, if you are going ask to see the copy or check your quotes in advance of publication, it's best to do so at the beginning of the interview or before providing the information. If you wait until afterwards before asking, the journalist is under no obligation to comply, whereas if you agree the ground-rules beforehand the journalist should feel obliged to stick to them.

The *Financial Times* policy is that writers must *never* show their whole story to a source or anyone else outside the paper before publication. This is mainly because, as a financial paper, we dare not let price-sensitive stories leak out. But *FT* writers are allowed, at our discretion, to let sources check specific quotes or statements attributed to them. We can also let a source check facts or complex technical passages for accuracy.

If asked, I'm usually happy to read out or email quotes and specific pieces of information to a source. However, I have to say that, if I'm writing an article with potential quotes from several people to choose between, I tend to use the ones that don't need approval, if only to save bother. Other people and publications have different policies; for example, Roger Highfield, Science Editor of the *Daily Telegraph*, always checks a story with a source if he has time.

If you're worried about being misquoted or misinterpreted, it's always worth asking in advance if the journalist will check quotes with you. The bargain struck between source and writer over checking copy will depend on who needs whom more. A PR person desperate to get a story into the paper will not be able to insist on anything, but if you're a uniquely valuable source for a good story and you don't care whether you're mentioned or not, then you're in a strong bargaining position.

A case-study in success

I'd like now to move from generalities about communicating science to a specific example of how well things can work for marine science, if sufficient effort and resources are put in. The news story in question was about the dramatic decline in stocks of large predatory fishes, and began with a paper by Ransom Myers and Boris Worm, published in May 2003 in *Nature* (and put on its cover). This was one of the biggest marine science stories of the year, as far as the mass media were concerned.

Here are some of the ingredients that made it work:

- There was a well thought-out programme to reach out to the media.
- The paper appeared in a leading journal – and on the cover.
- The scientists involved were committed to communication, and willing to put in a great deal of time talking to journalists and getting their message across.
- The research results were striking and the message relatively simple.
- The findings had policy implications.
- And finally, Lady Luck was on-side – there were no big competing news stories at the time.

The outcome was excellent worldwide media coverage, including – the ultimate measure of success – cartoons as well as articles.

For this example I'm indebted to SeaWeb (www.seaweb.org) – a wonderful organization based in Washington DC which has done a lot in North America to raise public awareness about the oceans and life in them .

What journalists want

To summarize, journalists are looking to scientists for:

- A story that is compelling – or at least interesting.
- Access both to the scientists who did the research and to others who can put the work in context.
- Responsiveness: if you get a call from a journalist on a daily paper with an immediate deadline, make an effort to return it quickly.
- Ability to answer the 'So what?' question.
- Good sound bites for broadcasters and metaphors for the print media.
- A willingness to guide journalists to other people with different perspectives.

It's important to remember that your future as marine scientists depends on communicating and engaging with the public, because funding for your research depends on public and political support. If people don't understand what you're doing, they won't pay for it.

Clive Cookson is Science Editor of the *Financial Times*. This article is a based on his keynote talk at the EurOcean Conference in Galway, May 2004.

100 years of GEBCO

The fascinating story of the General Bathymetric Chart of the Oceans

John Wright

The History of GEBCO 1903–2003 is a splendid book: It's a glossy flexi-cover compilation, written and edited by distinguished hydrographers and oceanographers, including (as principal editor) Commander Desmond Scott (the man who occupied Rockall for Britain in 1955), also Rear Admiral Steve Ritchie, Sir Anthony Laughton (who wrote the preface too), and marine historian Jacqueline Carpine-Lancre, along with several others. A handsome coloured frontispiece of Prince Albert I of Monaco aboard one of the yachts he used for his pioneering oceanographic work, is accompanied by a message from his great-grandson, the present Prince. It is a wonderfully illuminating book that details the many vicissitudes of compiling the hugely important World Ocean Floor Map, without which oceanographic research would be all but impossible.

Steve Ritchie's short opening chapter on the early history of sounding technology describes older methods used for exploration and sounding of the ocean's depths. I had not realized that the earliest depth measurements were being made as early as the sixteenth century, nor that at the turn of the 20th century there would be much discussion about how sub-oceanic features should be named: the British tended to be a mite cavalier in their approach, naming features after shipmates or national luminaries, while the Germans were more formal, using proper terminology and indicating the geographic location of named features. In this chapter there is a poignant passage describing how – once longitude could be reliably determined, following Harrison's development of accurate ships' chronometers – there was a consensus that Greenwich should be the prime meridian; the result was that the French had to re-draught their maps, which had used Paris as their zero line of longitude.

Jacqueline Carpine-Lancre's chapter covers the period from the late 1890s to the early 1920s. It outlines development of the concept of 'la carte générale bathymétrique des océans' and reveals *inter alia* that there was some resolution of the nomenclatural problems, priority being recognized, provided that geographic location was stated. Nonetheless, comparison of Figures 14 and 15 in the book shows that there were still substantial disagreements about the areal extent of the deepest regions of the ocean – what we would now presumably recognize as the abyssal plains In this chapter we learn that the first edition of the bathymetric chart consisted of 16 Mercator sheets between 72°N and S (scale 1:1 million along the Equator) and eight sheets using the gnomonic projection (in which great circles are mapped to straight lines) for polar regions. All 24 sheets were published as a set in 1905. Bathymetric coutours were in metres rather than in fathoms, despite objections from Sir John Murray.

Second and subsequent editions of the ocean bathymetric chart took a good deal longer to get into print, but Jacqueline Carpine-Lancre makes it clear that guidance and support (often financial) from Prince Albert of Monaco helped enormously to keep the project going in the early years of the 20th century. This chapter also describes the academic disputes and wrangles, not to mention personality clashes, that arose between otherwise distinguished and eminent contributors (so what's new?). These disputes included arguments about whether to include details of terrestrial as well as oceanic relief. With modern digital technology it's easy enough to produce maps showing both, but it wasn't available in the 1920s, plus which many land areas were still not properly mapped.

Not surprisingly, the two world wars seriously interrupted bathymetric work, although both conflicts led to advances in hydrographic and oceanorgraphic technology, especially World War II, when continuous profiling echo-sounders were developed, also electronic positioning systems, which were an advance on the earlier systems based on wireless telegraphy that had been developed during and after World War I. The dramatic improvements in the amount of detail available for later editions of the bathymetric chart are beautifully illustrated by facsimile copies of maps from those editions, which occupy the middle part of the book. They illustrate very well the extent to which new techniques of depth measurement and sea-bed mapping (including modern multi-beam sonar technology) have vastly increased the amount of data available for compilers of GEBCO charts.

Nonetheless, in the years following World War II, financial and logistic difficulties continued to plague the GEBCO project, and in his chapter on the International Hydrographic Bureau period (dealing with the third and fourth editions) Adam Kerr records that while no fewer than seven draughtsmen had been employed on the first edition, between 1933 and 1952 the Bureau never employed more than two. This was in spite of the vast amounts of additional data then available, and the consequently much increased complexity of the charts. Perhaps partly because of the greater complexity, sheets of the third edition were not published simultaneously, appearing at various times between 1928 and 1955; indeed, two of the Arctic sheets didn't get published until 1968! In this chapter it is also recorded that in some cases only the shallowest soundings were selected, on account of the perceived need to emphasize potential dangers to navigation. This was deemed to be an unsatisfactory procedure, in that it failed to portray the true geomorphological form of the sea floor, obscuring important and geologically interesting features such as trenches and submarine valleys.

The fourth edition of the bathymetric chart was so beset by problems similar to those hampering publication of the third edition, that in the end only six sheets were ever published, between 1958 and 1967 (i.e. only a year before the two remaining Arctic sheets of the third edition appeared). The fourth edition was in fact the last to use gnomonic projections for polar regions (above 72° latitude), because for the fifth edition – dealt with in Desmond Scott's chapter – there was a change to polar stereographic projections for both poles (above 64° latitude), while sticking to the Mercator projection for the rest (the scale was 1:10 million at the Equator and 1:6 million at 75° latitude). The fifth edition comprised 18 sheets in total and was identified as GEBCO 5.00 in 1984, although it too was published in stages, between 1975 and 1982.

The eighth and final chapter of this fine book is by Meirion Jones and is about the GEBCO Digital Atlas (GDA), describing how digitization of the fifth edition started in the 1980s and continued to the early years of the new millenium. Digitization has made monitoring and updating information much easier, and these tasks are nowadays done at the British Oceanographic Data Centre In Liverpool, where soundings and sea-floor data are checked for quality, labelling and geographic registration, not to mention – of course – comformance with the hard-copy charts, which are also much easier to produce from the digitized compilation.

I noted earlier that ventures such as GEBCO, which perforce must make use of data from numerous sources, involve much work of committees made up of contributing scientists, who may fall out with one another. I was therefore entertained by some trenchant comments from Bob Fisher in his chapter about GEBCO's role in Sea-Floor Terminology, which neatly summarises how scientists (including marine scientists) sometimes operate. After noting that 'there are occasional instances of perplexity, acrimony and controversy,' he goes on: 'In making decisions, members [of committees] are expected to be unbiassed, apolitical, free of chauvinism, given to appreciate cleverness or appropriate humour, quick to deplore coarseness, sycophancy or nepotism. No such restrictions limit the proposers, often colourful seagoing scientists – authors impatient for recognition. One traditional perquisite of exploration and discovering is the 'right' to name the feature discovered. The maps of some remote land areas are replete with surviving personal legacies of nepotism, self-promotion or rough humour … Political statements via the seafloor tend to be unsubtle and transitory; one cartographer's charismatic terrorist can become history's thug, a political prison's parolee can become President …' How true, how true.

The History of GEBCO 1903–2003 (eds D.P.D. Scott *et al.*), published by GITC bv, Lemmer, The Netherlands, is obtainable from the International Hydrographic Bureau, 4 Quai Antoine 1er, BP 445, MC 98011 Monaco Cedex, Monaco; Tel./Fax: +377-93-10-81-00/04; Email: info@ihb.mc Price 20€.

News & Views

Gas hydrates: a cause for concern

A recent report produced for the Benfield Hazard Research Centre (details below*) has highlighted the dangers posed by gas hydrates as a result of global warming. Gas hydrates – ice-like deposits containing a mixture of water and gas (commonly methane) – are stable under high pressures and at relatively low temperatures, and are found in the oceans within the sediments of the continental margin, and on land in permafrost regions. As much as 10 000 gigatonnes of carbon may be stored as gas hydrates – more than ten times the amount of carbon currently in the atmosphere. The size of this reserve is such that economic production of methane from gas hydrates may be a future possibility, despite the safety issues associated with extraction.

Even if they are not extracted, gas hydrates are likely to constitute a serious hazard in the near future, as a result of the effect of global warming, and consequences could be severe at both local and global scales. This will probably not be the first time that hydrates have contributed to global change – it is thought that their release was responsible for the dramatic rise in global temperature that occurred at the end of the Palaeocene, 55 million years ago.

In the present-day oceans, warming at intermediate depths (as predicted by climate models) will tend to destabilize gas hydrates, resulting in the release of large quantities of methane. As methane is 21 times more powerful a greenhouse gas than carbon dioxide, this release would accelerate global warming. This in turn could lead to more oceanic warming, more methane release and increased warming. Currently predicted sea-level rise will, however, tend to stabilize marine gas hydrate deposits, by increasing the weight of water above them. The potential global threat posed by gas hydrates is therefore finely balanced and will depend upon the relative rates of ocean warming and sea-level rise.

While sea-level rise will be effectively the same everywhere, the degree of ocean warming will vary regionally. In certain areas, the effect of warming will exceed the counteracting effect of enhanced sea-level rise, and gas hydrates within ocean sediments will be released, with safety implications for shipping and marine oil and gas production.

Climate models predict that high-latitude regions will be disproportionately affected by global warming. The melting of permafrost and the breakdown of gas hydrates into water and gas will trigger sediment slides and avalanches and threaten infrastructure such as buildings, roads and oil pipelines. In some cases the trapped methane gas could burn or be released explosively.

Melting of the Greenland and Antarctic ice sheets may also destabilize gas hydrates. As ice sheets shrink, the weight removed from coastal regions allows them to rise. This can also raise the adjacent continental slope, reducing the weight of overlying water; the resulting destabilization of gas hydrates could lead to massive slope failure and tsunamis up to 15 m high.

**Gas Hydrates: A Hazard for the 21st Century* by Mark Maslin, No.3 of *Issues in Risk Science*, from the Benfield Hazard Research Centre: Email: info@benfieldhrc.org; Tel./Fax: +44-(0)20-7679-3637/2390.

Missing marine carbon sink found?

At the UEA Challenger Society Conference in 2000 (*Ocean Challenge*, Vol. 10, No. 3, p.5), Axel Miller suggested that the shortfall in the carbon budget might be in the oceans as dissolved organic carbon (DOC). It now turns out that jellyfish are more likely to be the missing marine carbon sink. Recent submersible surveys have revealed great diversity and vast populations of these animals at mid-depths (*Nature*, **426**, pp.12–14). Some can absorb nutrients direct from the water column, others make nocturnal migrations to the surface to feed on plankton and krill, then sink back down to digest their meal at depth; and a large proportion of oceanic biomass is tied up in jellies that feed on each other.

Apparently there isn't enough marine snow sinking through the water column to supply all the nutritional requirements of deep-sea benthos, and the shortfall may be made up by mucous 'globs' shed from living jellies (including clogged and discarded webs from larvaceans), while dead jellies contribute large amounts of fast-sinking carbon-rich particles to the sea-bed. There is now much more research into jellyfish, the need for which was emphasized by Ferdinando Boero in Vol. 12, No.1 (Special EFMS issue). Sampling nets destroy the gelatinous bodies of the animals, and underwater observation and photography remain the principal research methods.

Plankton and global warming

Scripps researchers have found that algal blooms absorb enough solar radiation to warm surface waters by 0.1–0.6 °C, possibly enough to offset any 'greenhouse cooling' from photosynthetic CO_2 drawdown. Unless, that is, the phytoplankton are coccolithophores, which reflect sunlight and are more likely to cause cooling. Overall, the results suggest that it's a bad idea to try and encourage phytoplankton growth by iron fertilization.

A coherent maritime policy for the UK?

Martin Angel

In 2004, the Greenwich Forum held a debate at the Royal Society, to address the motion: 'The meeting considers the UK should develop a coherent maritime policy, with instruments of government to implement it'. The format of the debate worked well thanks to some skilful chairmanship, and it could be a format the Challenger Society might consider following, if and when it needs to take controversial decisions.

The motion was proposed by Admiral Sir James Eberle, former Director of the Royal Institute of International Affairs, and seconded by Brian Orrell, General Secretary of NUMAST; it was opposed by John d'Ancona, former Director of the Offshore Supplies Office, who was seconded by Dr Eric Grove, University of Hull. Prior to the meeting, the 65 attendees had been provided with a fairly comprehensive set of fact-sheets covering most aspects of maritime activity, from shipping, naval resources and maritime law, to institutions, recreational activities, living and non-living resources, and safety and security (but not much science). The proposers and seconders each spoke for 15 minutes and the meeting was then thrown open to speakers who had previously registered a willingness to talk (for a maximum of five minutes).

Admiral Eberle opened by remarking that the UK does not have a coherent policy – unless the policy is to have no policy! International relations have now shifted from ideological battles to coping with terrorism, either by deterrent or by pre-emption. At the same time, container transport has increased exponentially, and has created many new security problems. Maritime interests in Exclusive Economic Zones are expanding, and yet the UK has not formally adopted an EEZ. The Common Fisheries Policy has been an inglorious failure. Will the current monopoly that air transport enjoys persist? Unlikely.

In Whitehall, departments are good at making policy but poor in implementing it. Inter-departmental wars are inhibiting good government. A Maritime Ministry or Agency might overcome these hurdles, but how could it be financed and operated?

Opposing the motion, John d'Ancona questioned what sort of instruments of Government could be set up and whether they were likely to be workable. The diversity of maritime interests makes this a major problem: for example, could the Royal Navy ever be transferred from the MoD to the new Maritime Ministry/Agency? Who would handle international affairs, especially links with the EU? How would subsidiarity and devolution be handled? Admittedly Government needs to be 'joined up', but super-Ministries have consistently failed. Also, with an over-arching control structure, and hence fewer funding ministries, funds would dwindle.

Seconding the motion, Brian Orrell addressed the problems we will soon be facing as the number of ships' officers being trained continues to diminish. There are 132 000 shore-based jobs that rely on recruiting personnel with sea-going experience. Maritime resources are fundamental in many ways, and with a world shortage in ships' officers, and the UK running out of port capacity, we face many problems. For example, getting our armed forces to the Gulf relied on the availability of commercial shipping. The effectiveness of our shipping is dependent on a coherent policy.

Seconding the oppostion, Eric Grove emphasized that there is a basic functional divide between maritime interests, but while there was a real need to have better co-ordination – for example between merchant shipping policy and transport policy – a single overarching Maritime Agency would be bureaucratic and wasteful. The French tried having a single maritime Ministry and are now abandoning it.

After the opening addresses, about 20 speakers contributed to the debate; here are some of the points raised:

- Decline in ship-building means no one UK company could build the *Queen Mary II*. And where in the UK can the Navy's two new aircraft carriers be built?
- There has been a sharp decline in students enrolling for courses on marine policy and shipping.
- Leading UK companies such as P&O are getting out of shipping, so there is no assured career path for new entrants.
- Simple satellite technology offers major potential improvements in ship safety and routeing.
- Manufacture of marine equipment has an annual turnover of £1.7 billion, of which £1.1 billion is exported; but these exports are not helped by Government policy.
- Japan has a small maritime unit, which is highly effective because it is run by a single powerful guru with instant access to all ministers and industrialists.
- Underwater cultural heritage and ecosystems are inadequately protected.
- The UK has four legal maritime boundaries, relating to fishing, pollution, renewable energy (see next point), and the continental shelf; these need to be consolidated into an EEZ.
- The Energy Bill will define renewable energy zones where wind farms can be established. Commercial confidentiality inhibits the minimization of impacts of wind farms on other sea-users. The only UK manufacturer of wind turbines is going into receivership because of cash-flow problems, yet 3000 such turbines are due to be built offshore in the next three years.
- Wind power is not wholly suitable for the UK's needs – in calm weather the lights go out! Tidal power is a better option, but there is no Government investment in the technology.
- The EU is beginning to co-ordinate marine policies.
- Any policy – coherent or not – must be underpinned by the best possible marine science.
- Australia has set up a maritime agency that is beginning to work well.
- The Marine Foresight Panel was set up later than all the other Foresight Panels, and is the only one still functioning. It has established the following as priority areas: renewable energy, conservation and marine biotechnology.
- There was a Maritime Affairs Committee in the Cabinet Office in the early 1980s, but it was unpopular with Civil Service Departments who viewed it as undermining their power and influence.
- Security problems are growing; incidents of piracy worldwide are increasing by 30% per year. Last year there were 425 incidents and no seas were safe. Since July 2004, all ships must have a security officer.
- The UK is the leader in ship financing; after crewing costs, insurance is the highest expense. Security concerns are likely to push these costs up substantially.
- The setting up of the Marine Pollution Unit is a good example of how – when Government has the will *and* delegates power effectively – policies can be implemented rapidly, cheaply and effectively. The penalties for lack of co-ordination are demonstrated by the fact that if the *Prestige* had been allowed to seek shelter in Spanish waters the disaster would have been avoided.

It was evident that the majority of those who spoke were in favour of greater coherence in maritime policy, but there was little if any agreement as to whether any instruments of government could be established that would be effective in delivering the policy. There was no support for a super-Department, for a variety of reasons; for example, the MoD would never pass control of naval affairs over to another Ministry; also, devolution has resulted in the transfer of responsibility for fisheries to Cardiff and Edinburgh; furthermore, with the EU having an increasingly great influence on maritime issues, the role of the new Ministry *vis-à-vis* the Foreign Office would be a major problem.

After brief closing statements by proposer and opposer, a vote was held. The motion was carried by a rather narrow margin.

Martin Angel

The Greenwich Forum (greenwichforum.org.uk) represents all facets of the maritime sector, and champions the importance of the sea, and the dependence of humanity on its sustainable use.

EurOcean 2004 in Galway, and FP7

This conference took place in the beautiful and wonderfully hospitable city of Galway (western Ireland) in May 2004. Over 550 marine scientists, policy-makers and representatives of the maritime industry sector from all corners of the EU, including prospective member states (EU+25), were captivated by the friendliness of Galway's citizens.

It was an Irish Presidency Event, and was sponsored by the European Commission, the Marine Institute (Ireland) and the Marine Board of the European Science Foundation. The stated objective of the event was to determine how marine science and technology can contribute to making the EU the most competitive knowledge-based economy in the world, based on the application of science and technology and the principles of sustainable development.

For delegates accustomed to academic conferences like MS2004, it was a novel and sometimes bizarre occasion – and it was clear that the budget available would have been unimaginable to the organizers of MS2004.

Although one of the main aims of the Conference was for marine scientists to present the results of research funded by the EU, the only verbal presentations were keynote talks. Almost all reports on EU-funded projects (each with a cunning acronym) were relegated to 'posters' in the form of presentations fed from PCs to LCD screens. For all to be seen, these had to turn over fairly frequently, so you could start to study a 'poster' only to have it suddenly replaced by a completely different one. Black and white print-outs of the posters were available, but unfortunately researchers were rarely close enough to their 'posters' to be engaged in discussion about their work.

Scientific keynote presentations were in parallel sessions on two successive mornings, followed by plenary sessions plus discussions in the afternoons. On the first day, a session on the role of ecosystem and biodiversity research in conservation ran in parallel with a session on maritime transport and security; the second day covered natural and anthropogenic impacts on coastal ecosystems, and exploration of the European margin, plus deep-sea resources and ecosystems. There were also some excellent presentations by young scientists on Marie Curie fellowships.

Despite the emphasis of Conference objectives on sustainability, it seemed that some speakers didn't really understand what sustainable development actually means – an impression reinforced when Pierre Mathy (Directorate General for Research) spoke of sustainable development and the importance of economic growth in consecutive sentences. As a result, some of the statements emphasizing the importance of sustainable development and conservation of biodiversity rang somewhat hollow.

The Galway Declaration and FP7

The event culminated with delegates endorsing a 'declaration' relating to the future of marine science in Europe. The full Galway Declaration can be found on http://www.eurocean2004.com. In summary, its message is as follows:

The marine science community will work collectively to ensure that recognition is taken at Member State and European Community Level of:

- *the crucial role of the oceans in climate, the carbon cycle and Life on Earth;*
- *the major contribution maritime industries can make to the achievement of the objectives outlined in the Agenda arising from the Lisbon conference on European Marine Science;*
- *the essential role of marine science and technology in generating the knowledge needed to fuel this economic achievement in harmony with the environment;*
- *the critical role the European Research Area/7th Framework Programme must play in supporting world class excellence in marine science and technology.*

In June 2004, an invited Workshop, 'The Ocean and Future Aspects of the European Marine Research Area', hosted by the Mission of Norway to the EU, attracted over 130 participants. The Workshop supported the Galway Declaration and called for priority to be given to Marine Science in the 7th Framework Programme(FP7). Later in June the European Commission circulated a Discussion Paper 'Science and technology, the key to Europe's future – guidelines for future EU policy to support research'.

In many ways, marine science in Europe is well developed, but it still suffers from fragmentation, a lack of coherence and, some would say, a lack of vision. Therefore, when Ireland, Norway and Portugal issued an invitation to other Member and Associate States to attend an informal meeting in Brussels in October to discuss the status of marine science in FP7, the invitation was accompanied by a Background Paper (see www.eurocean2004.com/marinescience.html) suggesting that marine science should not only be identified as a priority in FP7, but also become a 'horizontal initiative' with across-the-board relevance to all of its six proposed research 'axes' (Mobility, Launching technology platforms, Developing infrastructure, Improving coordination etc.).

After the October meeting (attended by representatives of 16 European countries) the organizers drafted 'The Oceans and Framework Programme 7', highlighting the need for 'proper visibility, focus and integration of marine research' (*see website cited above*). Members were asked to consider this statement when preparing their own initial position papers on FP7.

Feedback sought urgently

In November, the Commission launched a public consultation to define Thematic Priorities to be included in FP7, providing an opportunity for the oceanographic community to influence the new FP7 Programme (http://europa.eu.int/comm/research/future/themes/index_en.html). Contributions were requested by the end of 2004, so an item on this has been put into *Challenger Wave*. (A consensus opinion was also sought on the broad outline of FP7 in time for the Dutch Competitiveness Council meeting on 26 November.)

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NOW There's a FUNNY THING...

How to cure global warming

Not long ago I wrote about an 'ultimate remedy' for global warming (Vol. 12, No. 2, p.10), and the topic came round again, in *The Observer* no less, under the headline 'Giant space shield plan to save planet'. The 'space shield' would be made by seeding the stratosphere with billions of thin metallic plates transparent to infra-red but opaque to ultraviolet, to cut down incoming radiation while allowing Earth's own heat to radiate back out. This 'shield' would be supplemented by billions of tiny helium-filled balloons, also in the stratosphere, providing a secondary barrier to solar radiation (though descriptions suggest that out-going radiation might be trapped too; that's a bad idea, given that greenhouse warming is on the increase).

Activities that might supplement these stratospheric 'reflector' arrays included:

1. Build giant salt-water reservoirs on land 'to offset rising sea-levels caused by melting of polar ice-caps'. How would that work?

2. Float massive solar-powered 'cloud-making machines' across the ocean surface to spray seawater droplets 'of a precise size' into the sky to encourage cloud formation.

3. Pump more nutrients into the sea to encourage algal growth and draw down CO_2, an idea discussed many times in this journal, with respect to iron fertilization in particular.

4. 'Bury' carbon dioxide emissions underground.

None of these hugely expensive projects will ever happen of course, despite assertions that 'climate change is the most severe problem facing civilization'. Many nations have now signed up to the Kyoto agreement on greenhouse gases, but aircraft and road vehicles still depend on fossil fuels. So does nearly all electricity generation. There is no chance that any more nuclear power stations will be commissioned, since both they and their waste products are considered environmentally unacceptable by the public. Will global warming and climate change continue unabated?

Global dimming – *it's got to be a joke…*

Not so. I checked the publication date in *The Guardian* – so it's not an April fool. In the last couple of years the amount of solar radiation received at the Earth's surface has actually decreased, in spite of the general increase in solar radiation over the past 150 years or so. Of course, solar activity varies on a roughly decadal time-scale anyway, while the intensity of radiation received by the Earth varies with distance from the Sun, on kiloyear time-scales.

The boringly simple reason why we're getting less sunlight is air pollution. Atmospheric particulate loads are rising, producing more cloud condensation nuclei. On sunny days there's not a lot of difference apparently, but cloudy days are darker than they used to be. Scientists working on this topic in Switzerland and Israel consider that 'global dimming' can affect rates of photosynthesis, especially at high latitudes where cloud cover tends to be greater. Apparently a 1% decrease in received solar radiation results in a 1% fall in plant productivity. Implications for phytoplankton – and marine food webs generally – could be considerable, and although heavy industry has declined in recent years, there has been no let-up in deforestation, added to which there may well be more forest fires, as global warming brings more droughts.

You'd think that 'global dimming' caused by atmospheric pollution would have been greater in the heyday of heavy industry during the 19th and early 20th centuries, but that must have been mainly low-altitude stuff which settled or got washed out quite quickly.

Methane is not a renewable resource

A company called Alkane Energy has had the bright idea of building small gas-fired power stations using the methane that escapes from Britain's many abandoned coal mines. But there's a snag: the company wants government to classify coalfield methane as renewable and include it in their 'renwables obligation', to help subsidise both construction of the power stations and the electricity produced.

The government has refused on the grounds that methane comes from a fossil fuel – true enough, but couldn't they make an exception in this case? Methane is about 20 times more potent as a greenhouse gas than CO_2, and burning the waste gas would slow climate change, if only a little. Admittedly the methane would eventually oxidize to CO_2 in the atmosphere anyway, but burning it directly must surely ameliorate the climatic warming effect of 'raw' methane. Alkane estimate that 600 000 tonnes of methane leak from the abandoned mines each year, enough to produce around 1200 MW of electricity. I reckon Government needs to be a bit more flexible, because with every day that passes methane goes on leaking from old coal seams and warming the climate.

Offshore cities of the future

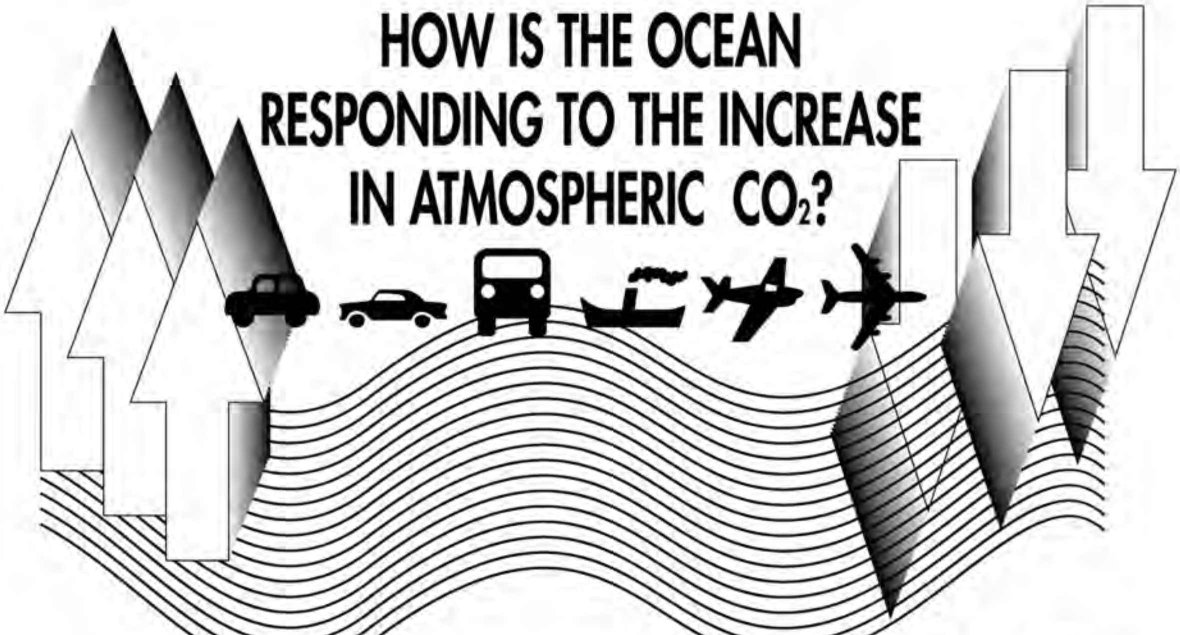
In the last issue of the magazine (p.12), in an item under this head, I wrote about 'futuristic loonies in the 1960s … who envisaged establishing human communities on the sea-bed ...' Those 'loonies' are alive and well and have plans for at least one luxury hotel ('Hydropolis') on the sea-bed, in this case off the coast of Dubai, to be built of plexiglass, concrete and steel. The fortunate (?) guests will have access to 'marvellous undersea views', not to mention 19 bars and restaurants, a casino and cosmetic surgery clinic, cinema facilities, an auditorium for concerts, a museum, library, prayer rooms, and – best of all – a marine biology research institute. Access will be by shuttle train along a plexiglass tunnel, and there will also be a 'beach area' from which guests will be able to 'snorkel over their bedrooms'. Well, at (up to) £3500 a night, you need to be sure you're getting value for money.

… and the past

The latest location for the lost city of Atlantis is south-east of Cyprus in the eastern Mediterranean, where apparently artificial structures (2 km of straight walls, on flat-topped hills) have been discovered under water. At first sight, neither this location, nor an alternative much further west, in the Straits of Gibraltar, is incompatible with Graham Hancock's theory that numerous relics of early human civilisation on present-day continental shelves were submerged by rising sea-level after the last glaciation (*Ocean Challenge*, Vol. 11, No.2, p.2). But these 'walls' are at a depth of 1500 m, far too deep to have once been on land. It must remain a matter of conjecture as to whether (a) Atlantis in fact ever existed, and (b) it will turn out to have been on Santorini – which blew up at about the right time and is geographically consistent with at least some of the legends about Atlantis.

John Wright

HOW IS THE OCEAN RESPONDING TO THE INCREASE IN ATMOSPHERIC CO_2?

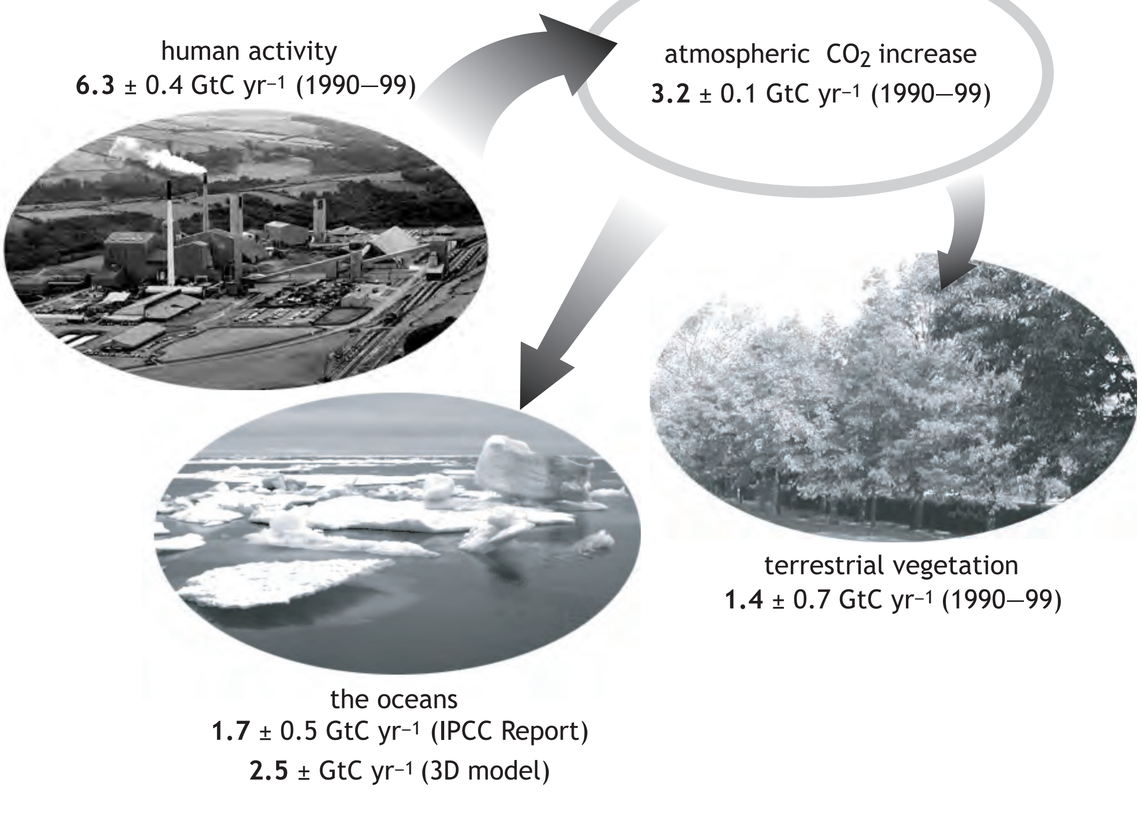


Nathalie Lefèvre

The ocean is the strongest sink for atmospheric CO_2, and absorbs about one-third of atmospheric CO_2 emissions (Figure 1). However, there is still uncertainty about the size of this sink, with estimates ranging from 1.7 ± 0.5 GtC yr^{-1} using observed atmospheric O_2/N_2 ratios (IPCC data) to 2.5 ± 0.4 GtC yr^{-1} given by ocean carbon model simulations. CO_2 emissions from human activities are well quantified. Atmospheric CO_2 is increasing at a rate of about 1.5 μatm yr^{-1} and as a result the CO_2 flux to the terrestrial biosphere and to the ocean are likely to be modified. How will the ocean behave in response to the atmospheric increase? Can the ocean continue to absorb CO_2 at the same rate as at present?

Figure 1 *The global carbon cycle with CO_2 fluxes in GtC yr^{-1} and their uncertainties. (For examples of how the CO_2 flux is affected by wind speed, temperature and pCO_2 of seawater and atmosphere, see the Box overleaf.)*

About a third of the CO_2 added to the atmosphere each year is taken up by the ocean



Calculating the CO_2 flux and the ‘CO_2 climatology’

CO_2 gas in solution is quantified by measuring the partial pressure of CO_2 (pCO_2). Measurements of seawater pCO_2 are made by bringing an aliquot of water into equilibrium on a short time-scale with gas in the headspace above the water. After equilibration, the headspace gas is analyzed using a standardized infra-red detector, which measures the difference in absorption of infra-red radiation passing through two cells, one of which is a reference cell flushed with gas of known CO_2 concentration. The concentration of CO_2 in the outside air (pumped in well forward of the ship’s funnel to minimize contamination from the ship’s emissions), is also measured (cf. Figure 3, opposite).

The CO_2 flux between the ocean and the atmosphere can then be calculated using the following equation:

$$F = k\,S\,\Delta pCO_2 \qquad (1)$$

where $\Delta pCO_2 = pCO_{2\ ocean} - pCO_{2\ atmosphere}$, k is the gas exchange coefficient, which depends on the wind speed, and S is the solubility of CO_2 in seawater, which depends on the temperature and salinity of the water.

Under equilibrium conditions, the CO_2 concentration is the same in the seawater and the air and the net flux, F, is zero. When the oceanic pCO_2 is below the atmospheric level, the flux is negative, there is absorption of atmospheric CO_2 by the ocean, and the ocean is referred to as a sink (Figure 2). When the oceanic pCO_2 is higher than the atmospheric pCO_2 the flux becomes positive, there is a net outgassing of CO_2 and the ocean is a source of CO_2 for the atmosphere. The strength of the source or the sink depends on the wind speed, through the exchange coefficient, k.

One approach to calculating the global air–sea CO_2 flux is to map all existing CO_2 observations and then apply equation (1) using sea-surface temperature (SST) and wind speed. Takahashi and colleagues (1997) interpolated CO_2 observations to produce monthly maps of ΔpCO_2 and CO_2 flux for the world ocean, gridded by 5° of longitude by 4° of latitude. This climatology, used as a reference, includes data from several decades, grouped together by month, and neglects interannual variability.

In reality, because atmospheric CO_2 concentration is increasing, the oceanic CO_2 concentration is likely to change over time as the ocean absorbs CO_2, so seawater pCO_2 measured in (say) 1981 is likely to have been lower than the value in 1990, everything else being constant. In order that data from different years can be combined, seawater pCO_2 is assumed to increase at the same rate as atmospheric CO_2, so that the difference in partial pressure between sea and air (ΔpCO_2) can be assumed to be constant over the years. This is a reasonable assumption in stratified regions like the subtropical gyres, where the upper ocean is quite isolated from the deeper layers, and surface waters have time to equilibrate with the atmosphere.

However, in high-latitude regions there is little stratification and the upper layer of the ocean is well mixed with deeper layers, so surface waters

The flux of CO_2 into or out of the ocean depends on the relative concentrations of CO_2 either side of the sea-surface

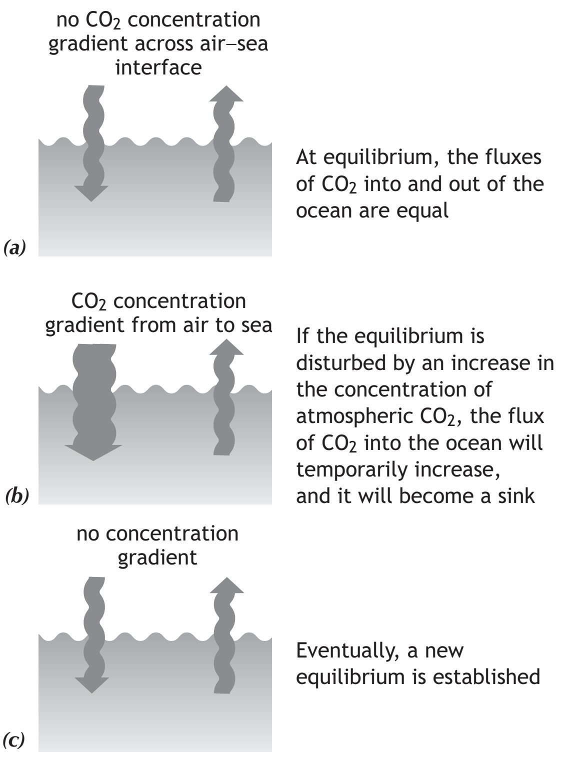


Figure 2 *Schematic illustration of the change from one equilibrium situation to another.* ***(a)*** *At equilibrium, the fluxes of CO_2 into and out of the ocean are equal.* ***(b)*** *If the equilibrium is disturbed by an increase in the concentration of CO_2 in the atmosphere, the flux of CO_2 into the ocean will temporarily increase.* ***(c)*** *Eventually, a new equilibrium is established.*

Units used in CO_2 studies, and some typical values

Various units are used in studies of atmospheric and oceanic CO_2. Below are examples of flux estimates for two contrasting areas of ocean. As these illustrate, wind speed has a marked effect on the flux, which is why for many purposes it is more convenient to work using partial pressure, pCO_2, rather than fluxes.

In the tropical Atlantic, typical conditions might be: temperature 25 °C, wind speed 6 m s^{-1} (giving a gas exchange coefficient of 15.7 cm hr^{-1}), seawater pCO_2 = 370 μatm, and atmospheric pCO_2 = 365 μatm; the CO_2 flux will be 0.55 mmol m^{-2} day^{-1}, which, for the area of ocean between 20° S and 20° N, and 60° W and 0°, would correspond to an outgassing of 0.07 GtC yr^{-1}. (1 mol CO_2 = 44 gCO_2 = 12 gC; 1 GtC = 10^{15} g of carbon, which is equivalent to 3.7 x 10^9 tonnes of CO_2.)

For the northern North Atlantic between 50° and 80° N, with a temperature of (say) 10 °C, wind speed = 10 m s^{-1} (gas exchange coefficient of 29.7 cm hr^{-1}), seawater pCO_2 = 322 μatm and atmospheric pCO_2 = 365 μatm, the CO_2 flux is –13.8 mmol m^{-2} day^{-1}, which corresponds to an absorption of 0.56 GtC yr^{-1}, i.e. the area is acting as a sink. If the wind speed decreases to 8 m s^{-1} (gas exchange coefficient of 19 cm hr^{-1}) then the uptake is lower, with a value of 0.36 GtC yr^{-1}.

CO_2 is less soluble in warm water, and for this example solubility, S, was 4.5 mol l^{-1} atm^{-1} for the northern North Atlantic, whereas for the tropics it was only 2.9 mol l^{-1} atm^{-1}.

are assumed to have a similar CO_2 concentration to deeper waters (older water, exposed to atmospheric CO_2 levels lower than at the present day). Takahashi and colleagues assumed that as water at high latitudes is not at the surface long enough for equilibrium to be attained between atmosphere and ocean, seawater pCO_2 is not changing there. As atmospheric pCO_2 is increasing, the air-to-sea flux would be increasing at the same rate as the CO_2 concentration in the atmosphere is increasing. However, it is possible that the seawater *has* had time to take up some of the 'extra' atmospheric CO_2 and that the current uptake of CO_2 by the ocean is therefore not as high as these authors assume. These different assumptions need to be checked in order to improve our mapping of CO_2 fluxes, and this requires collecting many CO_2 observations over time.

Observational programmes

Recent technical developments have enabled us to measure seawater and atmospheric pCO_2 on board ships while they are underway, with the equipment unattended, which is a good means of collecting large datasets at high spatial and temporal resolution. Such systems (Figure 3) have been installed to run unattended on board ships since 1993 (see Further Reading). In the North Pacific Ocean a programme set up by a Japanese laboratory, the National Institute for Environmental Studies, has been collecting data between Japan and Canada since 1995 (http://ah.soop.jp).

A CO_2-observing network has been set up for the North Atlantic, as part of the European project CAVASSOO (**Ca**rbon **Va**riability **S**tudies by **S**hips **o**f **O**pportunity, http://tracer.env.uea.ac.uk/e072), to improve our understanding of the processes giving rise to the oceanic sink, and hence to enable us to make projections of its future magnitude. In addition, although the terrestrial sinks for CO_2 are much more difficult to estimate, we could deduce them if we knew the oceanic sink with greater accuracy, because CO_2 emissions and the atmospheric CO_2 increase are relatively well known.

The CAVASSOO observing network (Figure 4) includes four ships equipped with CO_2 systems:

• The RV *Nuka Arctica* runs approximately monthly from Aalborg in Denmark to Nuuk in West Greenland.

• The MV *Falstaff* operates on a six-week round trip connecting European ports such as Bremerhaven, Gothenburg, Zeebrugge, Southampton and Santander with North American ports such as New York, Charleston, Brunswick, Galveston, Vera Cruz and Jacksonville.

• The MV *Santa Maria* trades between Portsmouth (UK) and the Windward Islands (Caribbean).

• The RV *Hespérides* is an Antarctic supply vessel, which runs twice a year from Spain to Antarctica.

In addition, atmospheric and oceanic pCO_2 are measured underway during the Atlantic Meridional Transect (AMT) programme (http://www.pml.ac.uk/amt) on board the RRS J*ames Clark Ross* as it sails from the UK to the Falklands twice a year. A new European project CARBO-OCEAN will maintain the current observational network and extend it to sample the tropical Atlantic ocean by installing pCO_2 systems into two merchant ships sailing from France to French Guiana, and from France to Brazil.

Measuring pCO_2 underway on board a number of ships generates a vast amount of data and one objective of CAVASSOO is to store past and future observations in a database to allow studies of temporal and spatial variability at different scales.

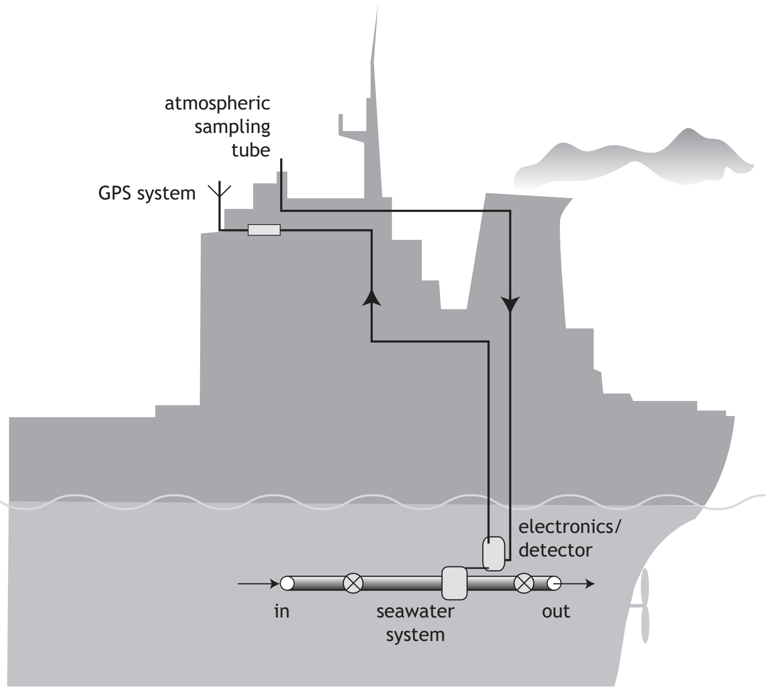
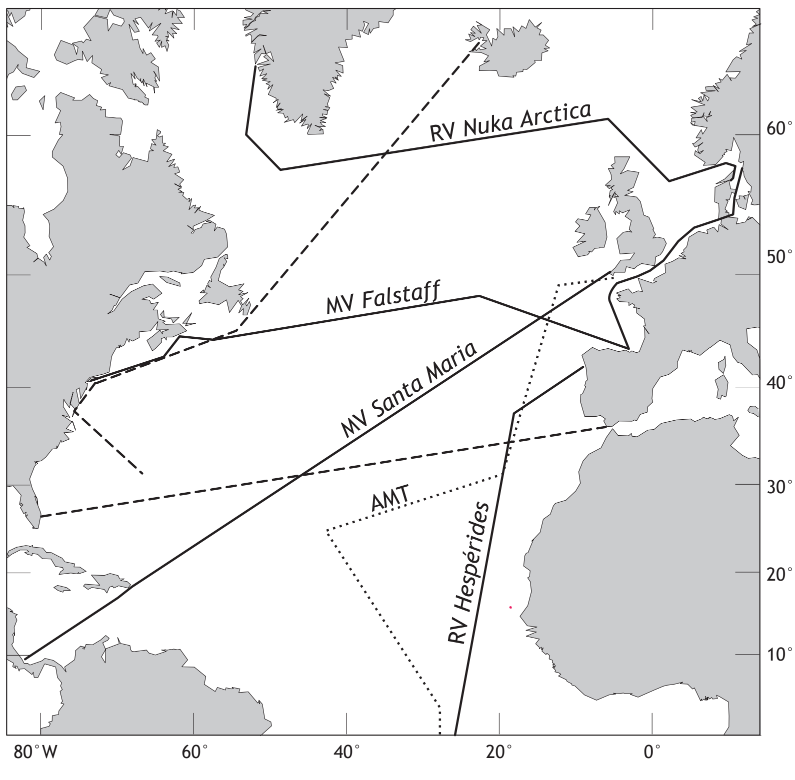
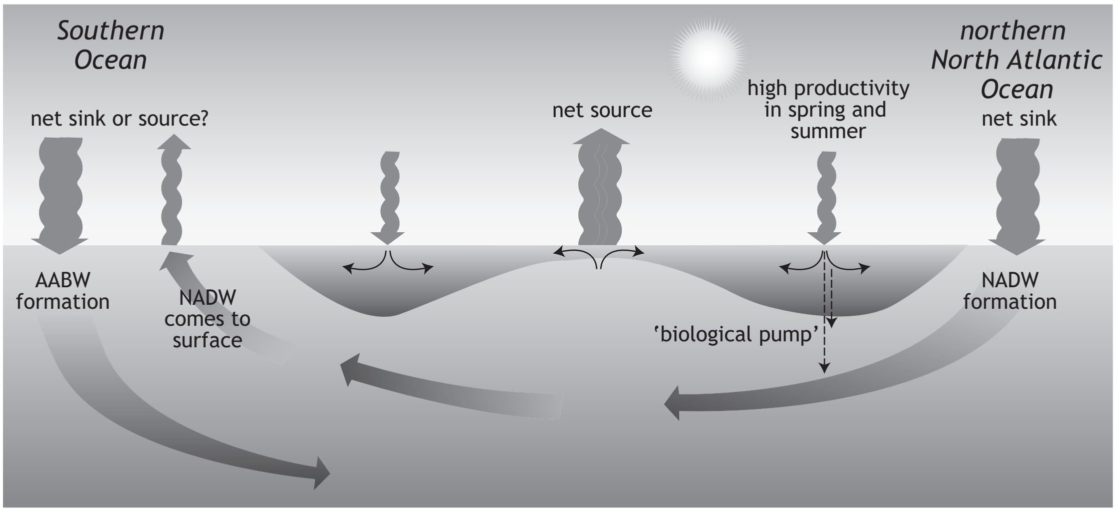


Figure 3 *Schematic diagram of the layout of a* pCO_2 *system installed on board a merchant ship.*

CO_2 concentrations can now be routinely collected by ships of opportunity

Figure 4 *Track of the ships of the CAVASSOO network equipped with an automated* pCO_2 *system. The dashed lines correspond to routes proposed by American colleagues. The dotted line is a typical AMT route undertaken by the* James Clarke Ross.





Sources and sinks of CO_2 in the ocean

Although globally the ocean absorbs CO_2, this absorption is far from uniform, and there are strong oceanic sources and sinks of CO_2 (Figures 5 and 6; cf. examples in Box). Surface pCO_2 is affected by temperature and salinity changes, biological activity, mixing and upwelling. Warming of seawater will cause its pCO_2 to increase by about 4% per °C and cooling will do the reverse. A decrease of surface salinity will decrease pCO_2 by about 4% per unit of salinity. Biological activity will consume CO_2 by photosynthesis, hence decrease the seawater pCO_2. Water from greater depth is CO_2-rich and will tend to increase the surface CO_2 content when it comes to the surface as a result of upwelling or convection. All these processes occur together at different time-scales, so that the overall CO_2 concentration at the surface will depend on which process dominates and the time-scale under consideration. On average, tropical regions where upwelling takes place are source areas, whereas regions where cooling is the strongest, like the northern Atlantic, are net sinks of CO_2.

Figure 5 *Schematic cross-section of the Atlantic Ocean showing the main sources and sinks of CO_2. Northern and southern high latitudes act as sinks for CO_2 because they are regions of water mass formation (for North Atlantic Deep Water, NADW, and Antarctic Bottom Water, AABW, respectively). However, NADW eventually comes to the surface again at the Antarctic Divergence, and it is not clear whether the Southern Ocean is a net source or a net sink for atmospheric CO_2. The diagram is drawn for the northern summer and so high primary productivity, contributing to drawdown of CO_2 (the 'biological pump') is shown for the North Atlantic.*

The tropical oceans are generally sources of CO_2 for the atmosphere, and high latitudes are generally sinks

In pre-industrial times the ocean was a weak source of CO_2 balanced by carbon input from rivers. However, this does not mean that the CO_2 flux was close to zero everywhere in the ocean. As tropical regions were warmer than high-latitude regions, there was outgassing of CO_2 in the tropics and absorption of CO_2 at high latitudes, so the major features of the pCO_2 distribution were about the same as today.

Although we know the general distribution of oceanic sources and sinks of CO_2, we have little idea about how they might increase or decrease over time under increasing atmospheric CO_2 concentrations. Most of our understanding of CO_2 variability with time comes from simulations using three-dimensional models. This is because, until very recently, observations were too sparse to allow a direct detection of trends. Models predict

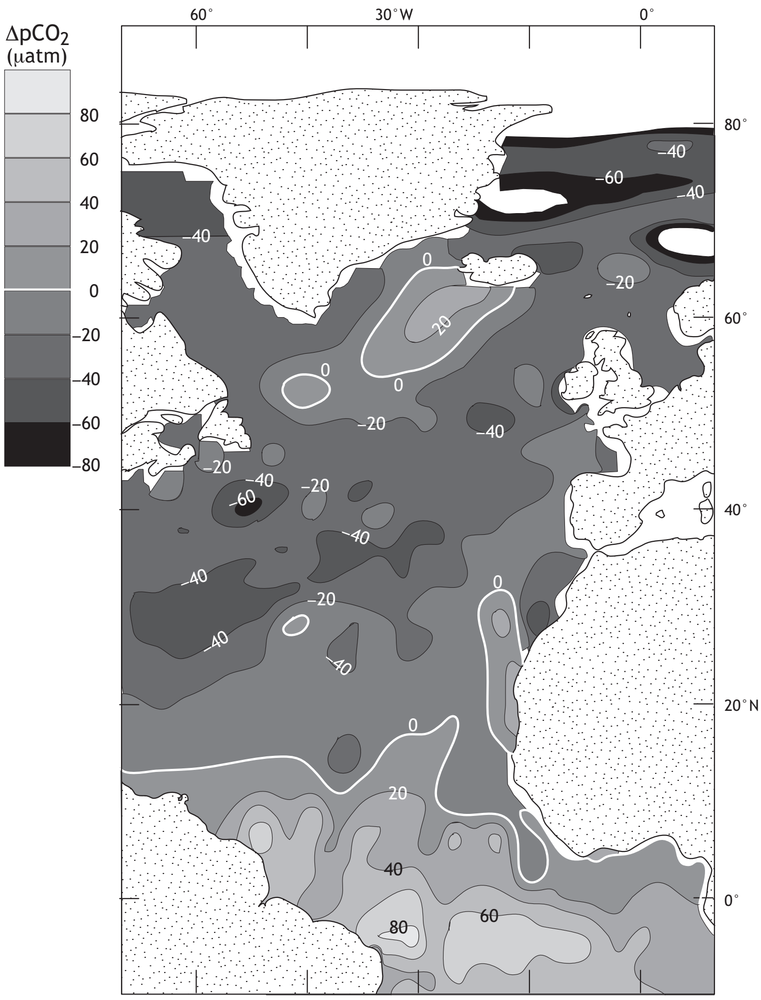
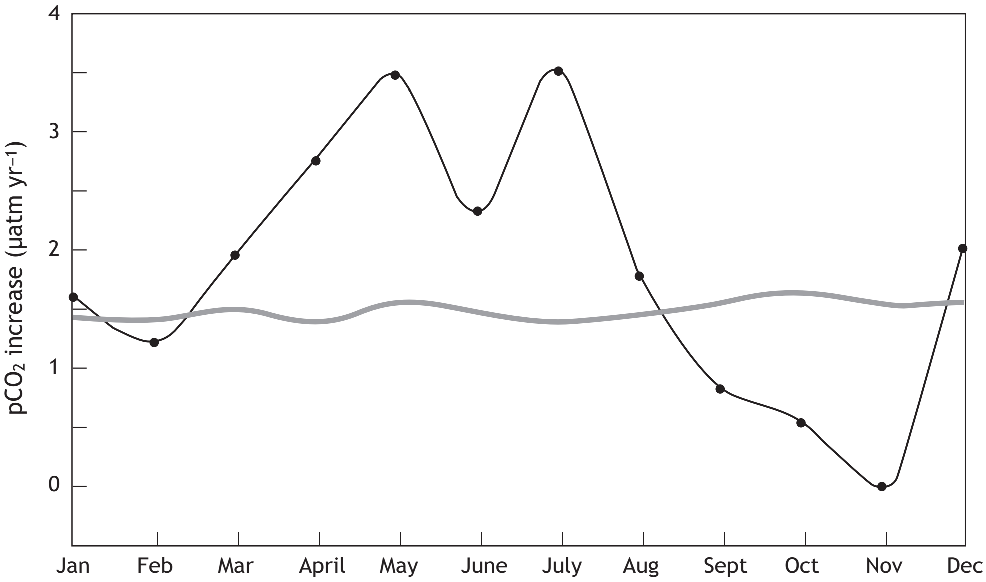


Figure 6 *Map of the Atlantic showing the difference in partial pressure between the ocean and the atmosphere (ΔpCO_2) in μatm for January–March, constructed using an objective analysis technique which involves interpolating on the basis of observations. Positive values (as in the tropics) correspond to an outgassing of CO_2 whereas negative values correspond to CO_2 uptake.*



In contrast to previous assumptions, observations suggest that seawater pCO_2 is increasing slightly faster than atmospheric pCO_2

Figure 7 *Increase in seawater pCO_2 in µatm yr^{-1} for the Atlantic north of 50°N, from 1981 to 1998, as a function of the month. The grey line represents the atmospheric pCO_2 increase. Seawater pCO_2 was estimated for different years using empirical relationships between measured pCO_2 and temperature, position and year.*

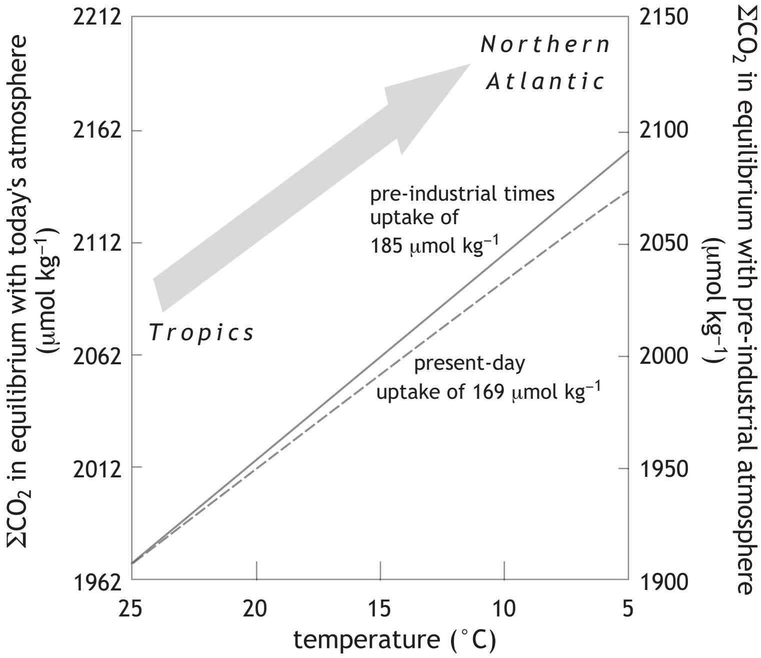
a strengthening of the ocean sink at high latitudes as a result of the atmospheric CO_2 increase. However, simulations are performed without taking into account any change in the biology or in the ocean circulation. The only perturbation introduced in the models is the increase of atmospheric CO_2. The setting up of observational programmes, and the effort to gather all CO_2 measurements together in a database, now offer an opportunity to test the results of the carbon models independently.

How variable is the oceanic sink of CO_2?

The North Atlantic Ocean (>10° N) is the strongest sink of atmospheric CO_2 and absorbs about 0.6 GtC yr^{-1}, but the strength of the sink is expected to vary seasonally, interannually and decadally. Ideally, a time-series station, where atmospheric and oceanic CO_2 could be recorded continuously, would provide information about the temporal evolution of ΔpCO_2. However, there are very few time-series stations in the ocean. Information about temporal trends has to be obtained from all the available CO_2 data. As data are sparse, we often try to find empirical relationships between seawater pCO_2 and other parameters (such as temperature) to fill the gaps. Using year as a parameter as well, seawater pCO_2 could be calculated over time. Surprisingly, for the northern Atlantic (50°–70° N), there was an increase in seawater pCO_2 from 1981 to 1998. Far from being contant, it was actually increasing at a higher rate than the atmospheric pCO_2 (an annual average of 1.8 µatm yr^{-1} as opposed to 1.5 µatm yr^{-1}). This rate of increase of seawater pCO_2 was strongly dependent on the season (Figure 7) and was larger in spring than in autumn. This suggests a possible decrease in biological carbon fixation, associated with a decrease in chlorophyll biomass, as the main cause. A recent comparison of ocean chlorophyll between the Coastal Zone Color Scanner (CZCS) satellite images (1979–86) and the Sea-viewing Wide Field-of-view Sensor (SeaWIFS) satellite images (1997–2000) showed a decrease in chlorophyll concentration, especially in high-latitude regions, believed to be due to natural variability. There are other factors that could explain such an increase in seawater pCO_2: an increase in sea-surface temperature, an increase of salinity, and an increase of dissolved carbon in this region. Currently, these factors are not considered in global carbon models, but simulations using an interannual forcing are underway and might produce results closer to the observations.

Although a weakening of the oceanic sink of CO_2 was not expected, this could happen even without changes of biology and ocean circulation. The amount of CO_2 that the ocean can take up depends on the buffer capacity of seawater, which depends on the concentration of dissolved carbonate ion. As more and more CO_2 is added to seawater, the concentration of dissolved carbonate ion decreases, and hence the capacity for uptake of CO_2 is reduced at higher oceanic pCO_2 (see Further Reading).

The upper waters of the Atlantic are transported from the tropics to the northern Atlantic via the meridional circulation. During this journey, the surface water cools from ~25 °C in the tropics to ~5 °C in the northern Atlantic, so that the solubility of CO_2 increases, which tends to draw down CO_2 from the atmosphere to the ocean. Also, this water has had sufficient time to equilibrate with the atmosphere. In pre-industrial times the atmospheric CO_2 concentration was about 280 µatm, whereas today it is around 370 µatm. During the journey from the tropics to the North Atlantic the uptake of carbon needed to maintain equilibrium with the atmosphere would have been about 185 µmol kg^{-1} whereas for the present-day atmosphere the uptake needs to be only 169 µmol kg^{-1} (Figure 8, overleaf). This represents a decrease of uptake of 16 µmol kg^{-1}. So it is possible that a decrease in CO_2 uptake could result from increasing atmospheric CO_2.



The uptake of CO_2 by surface waters flowing north in the Atlantic today is less than it was in pre-industrial times

Figure 8 *Variation of the concentration of ΣCO_2 (total dissolved carbon) for a parcel of seawater in the upper part of the ocean, during a journey from the tropics to the northern Atlantic (1) in equilibrium with a pre-industrial atmosphere at ~280 μatm (full line) and (2) in equalibrium with a present-day atmosphere at ~370 μatm (dashed line).*

In reality, the weakening of the CO_2 sink in subpolar regions is more likely to be caused by a combination of different processes. There is a clear pattern in the rate of increase of seawater pCO_2 which suggests that the main cause may be primarily biological in origin. This is also consistent with the decrease in primary production observed from satellite at high latitudes. From the same satellite images, an increase in primary production was detected at low latitudes, which are a source of CO_2 for the atmosphere. This might imply a weakening of the oceanic sources if more carbon is being taken up through biological activity. This weakening of the source, if confirmed, might compensate for the weakening of the sink in the northern Atlantic. However, regional changes of sources and sinks are likely to affect the global ocean CO_2 uptake.

At present, we have little information on the evolution of a given source or sink region because most of the available CO_2 measurements were made during research cruises, and an observational network for CO_2 has only just started to emerge. This highlights the importance of long-term monitoring of CO_2 to obtain information on the dynamics of the sources and sinks of CO_2 which will determine whether the global ocean is likely take up more or less CO_2 in the future.

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Nathalie Lefèvre is a research scientist at IRD-LODYC (Institut pour la Recherche et le Développement, Laboratoire d'Océanographie Dynamique et de Climatologie) in Paris.* Her main research interests are the marine carbon cycle and the flux of CO_2 across the air–sea interface.

*Universite Pierre et Marie Curie, 75252 Paris cedex 05, France.

Email: Nathalie.lefevre@lodyc.jussieu.fr

Spreading the Word about the Oceans and Climate Change

With climate change coming more to the fore in the public agenda, there is a need for authoritative and clearly explained information about the likely causes and effects of global warming, particularly as far as the role of the ocean is concerned. The Challenger Society is planning a special public event for September 2005, with the aim of addressing 'everything you wanted to know about climate change, but were afraid to ask'. Further information will be available later in the Spring.

Discovery, George Deacon, and the Hydrology of the Southern Ocean

Eric Mills

In 1894, John Murray – naturalist on the *Challenger* Expedition, and Editor of the *Challenger* Reports – made the following appeal to the Royal Geographical Society:

A dash at the South Pole is not, however, what I now advocate, nor do I believe that is what British science at the present time desires. It demands rather a steady continuous, laborious and systematic investigation of the whole southern region with all the appliances of the modern investigator.

Murray's appeal for a thorough scientific investigation of the Antarctic region, including its oceans, was not realized in his own time, even though out of the southward-directed zeal at the turn of the century came Robert F. Scott's National Antarctic Expedition, William S. Bruce's Scottish National Antarctic Expedition, and a number of expeditions from other countries, notably Belgium, Germany, Sweden, France and Norway. Each provided new information, all of it geographically limited, on the Southern Ocean or Antarctica, based, at most, on only a couple of years' investigation, often conducted under trying circumstances. The rigours of the environment, limited time, restricted scientific programmes, divergent interests, and sometimes just bad luck, prevented what Murray had called for – 'a steady continuous, laborious and systematic exploration of the whole southern region.'

In the event, it was whaling rather than disinterested scientific zeal that provided the impetus for scientific investigation of the Southern Ocean. In this context, nothing was more important than the formation, in 1923, of the *Discovery* Committee to conduct scientific investigations of the environment of the increasingly important whale fishery centred at South Georgia. The scientific studies at sea – the *Discovery* Investigations promoted by the Committee – began in 1925 with the launching of the RRS *William Scoresby* and the first *Discovery* Expedition using Scott's first ship. During the next four years both ships worked the Southern Ocean intensively, concentrating on the area between the Falkland Islands, South Georgia, the South Shetland Islands and the Antarctic Peninsula. During this time a large amount of information accumulated on the plankton and hydrography of the area, particularly the Atlantic sector of the Southern Ocean, as well as data from work on whales, primarily at South Georgia. Then in 1929 a new ship, *Discovery II*, came into service and made possible a great leap forward in knowledge of the Southern Ocean.

In only a little over 50 years, between 1885 (when the physical results of the *Challenger* Expedition were first summarized) and 1937, knowledge of Antarctic circulation went from virtually zero to being effectively established, mainly as a result of the *Discovery* Investigations. In this article, my aim is to explore how this knowledge developed, concentrating on one of the most famous results of the *Discovery* Investigations, George Deacon's monograph, *The Hydrology of the Southern Ocean*, published in 1937. How did it come to be? What was in it? What lay behind it? And what was its effect?

A picture of the Southern Ocean emerges

George Deacon (1906–1984) first trained as a chemist, and it was in this capacity that he joined the *Discovery* Investigations in 1927; on Christmas Eve of that year he was on his way to the Antarctic on *William Scoresby*. Deacon spent the first two years of his new career on *Scoresby* (Figure 1), then

Figure 1 *George Deacon (right) with James Marr, probably on South Georgia in about 1928.*

Photograph by courtesy of Margaret Deacon

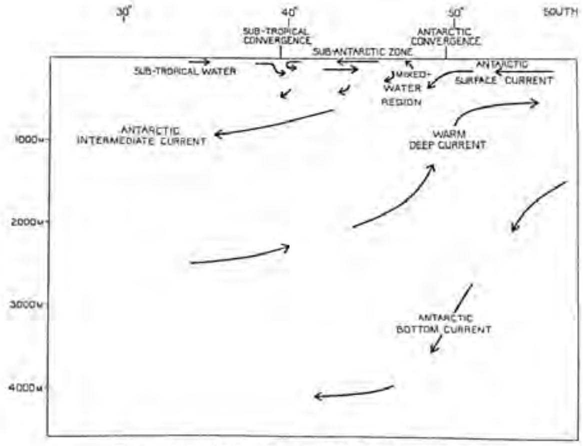


Fig. 1. The vertical circulation of water in the South Atlantic Ocean.

***Sverdrup's classic diagram was based mainly on Deacon's interpretations in* The Hydrology of the Southern Ocean**

Figure 2 ***(a)*** *The circulation of the South Atlantic Ocean from near Antarctica to the subtropics, a general pattern found around Antarctica, according to Deacon's* The Hydrology of the Southern Ocean *(1937).* ***(b)*** *Currents of the Antarctic according to Harald Sverdrup in the authoritative text* The Oceans *(1942).*

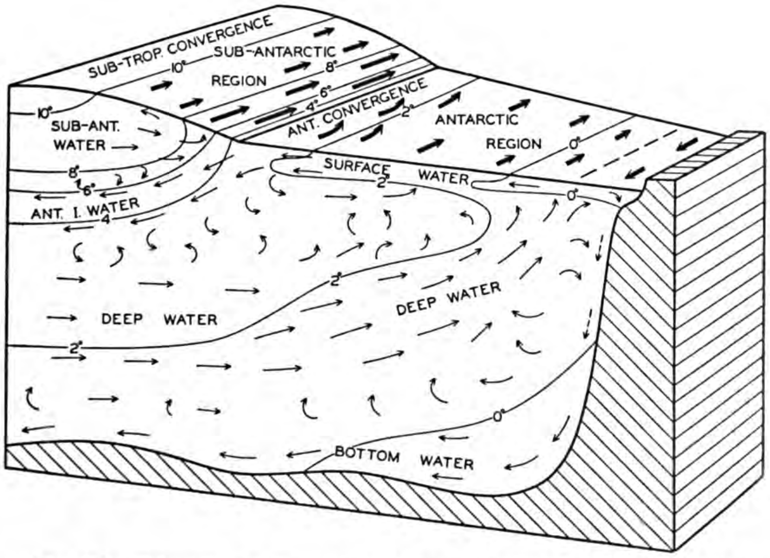


Fig. 164. Schematic representation of the currents and water masses of the Antarctic regions and of the distribution of temperature.

after a brief time in England he joined the new *Discovery II* at Cape Town in August 1930.

By 1931 he had accumulated enough temperature, salinity and oxygen data to construct a broad picture of Atlantic Antarctic circulation. This was published in 1933 as *A General Account of the Hydrology of the South Atlantic Ocean*. From this introductory monograph came much of the terminology since used to describe the Southern Ocean circulation, including *Antarctic Convergence, Antarctic Intermediate Water, Antarctic Bottom Water* and *North Atlantic Deep Water*. And it was clear, too, that Deacon had transformed himself from a chemist to a hydrologist, that is, into what we now call a physical oceanographer.

Four years later, after a greatly expanded series of stations taken all around Antarctica, Deacon published his great work on the region, *The Hydrology of the Southern Ocean*. This work and its predecessor of 1933 entered the canon of descriptive physical oceanography almost immediately, partly on their own merits, but also because their results were incorporated into the first great English-language textbook of oceanography, Sverdrup, Johnson and Fleming's *The Oceans – their physics, chemistry and general biology*, when it was published in 1942.

In 1937, Deacon depicted the circulation around Antarctica in a superficially simple diagram (Figure 2(a)). Harald Sverdrup's diagram of the same circulation (Figure 2(b)) shows little obvious similarity to Deacon's figure (except in the basics of the currents involved), but if one reads Sverdrup's account of the Southern Ocean (he calls it the Antarctic Circumpolar Ocean) it is clear that the prime authority is George Deacon and that the diagram in *The Oceans* is only a somewhat expanded and prettied-up interpretation of Deacon's earlier diagram, with some of Sverdrup's dynamic oceanography thrown in.

Figure 3 *The three sections on which Deacon's 1933 monograph was largely based. (Deacon 1933, p.191.)*

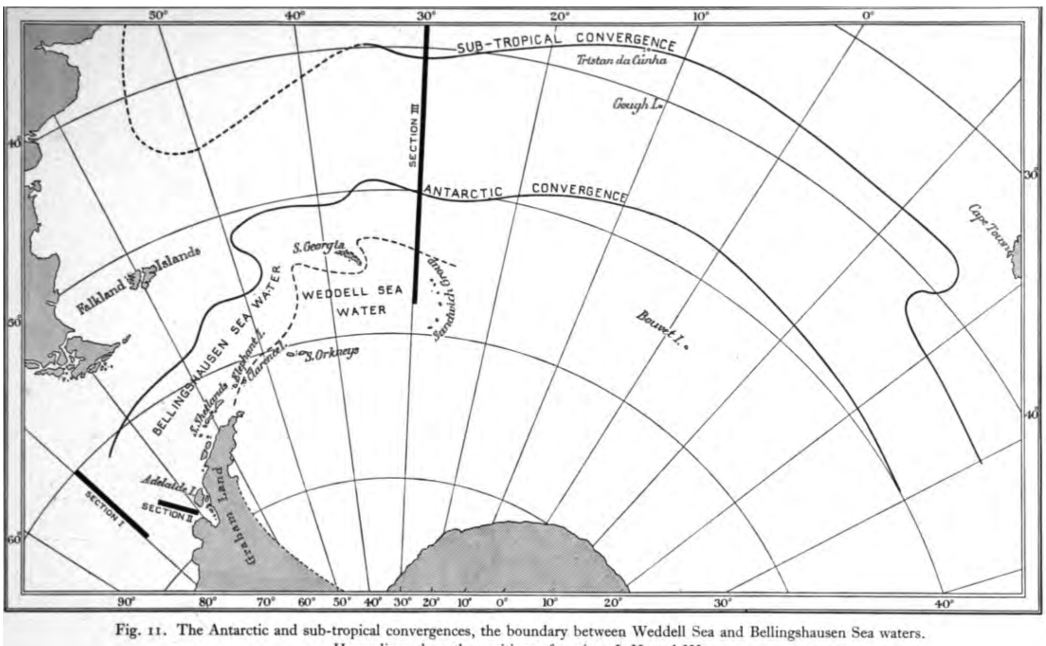


Fig. 11. The Antarctic and sub-tropical convergences, the boundary between Weddell Sea and Bellingshausen Sea waters. Heavy lines show the positions of sections I, II, and III.

For his 1933 monograph, Deacon had to rely mainly on three sections in the vicinity of South America and the Antarctic Peninsula

In fact, in this section of Sverdrup's discussion, only George Deacon is quoted directly – and it is clear that he had provided the basis on which the whole section was built. In this form, and in this way, Deacon's studies of the Southern Ocean became classics, and his interpretations of Southern Ocean circulation were passed on to several generations of oceanographers through *The Oceans* and later generations of textbooks.

The anatomy and ancestry of a classic oceanographic monograph

What lay behind this comprehensive interpretation of the remote and little explored Southern Ocean, as set out in Deacon's *Hydrology of the Southern Ocean* of 1937? The broad answer is the remarkable cruises that provided data for it, chief amongst which was the heroic circumpolar cruise of *Discovery II* in 1932–33, during which the ship worked alone and unsupported south of Australia and New Zealand through the southern winter of July–September 1932.

In 1931, when the manuscript of *A General Account of The Hydrology of the South Atlantic Ocean* was written, Deacon had available only three complete sections, two of them south of South America (Figure 3), along with scattered data from earlier expeditions. After the cruise of 1932–33 (Figure 4) the whole Southern Ocean lay before him. In addition, by 1933 information was beginning to appear from the German *Meteor* Expedition of 1925–27, although it was geographically restricted to the South Atlantic, mainly north of the Antarctic Convergence (Figure 5). The great contributions of the 1932–33 cruise – and of *The Hydrology of the Southern Ocean* when it appeared in 1937 – were to show the extent, indeed the continuity around the Southern Hemisphere, of the Antarctic Convergence and of Antarctic Intermediate Water, to infer the motions of North Atlantic Deep Water and its derivatives, to examine carefully the origins of Antarctic Bottom Water, and also to show the relationship between meridional currents and the main wind-driven zonal circulation.

This was the basis of George Deacon's still famous 1937 monograph. But what were its antecedents? In the 1930s the idea of a prevailing meridional deep circulation of the oceans was new, and still controversial. Much of the immediate information came from the work of Alfred Merz (1880–1925) and Georg Wüst (1890–1977) of the Institut für Meereskunde of the University of Berlin. Merz had long wanted to conduct a great German oceanographic expedition. In preparation for what became the *Meteor* Expedition of 1925–27 Merz and Wüst compiled all the available information on the deep circulation of the Atlantic. Their summary and analysis of this information, along with a lengthy discussion, was published in 1922, showing a series of trans-equatorial meridional currents in the Atlantic (Figure 6, overleaf).

Figure 4 *The cruise track of* Discovery II *around Antarctica during 1932–33, upon which Deacon's 1937 monograph* The Hydrology of the Southern Ocean *was based. Sections 9–15 were made through the southern winter. (From Deacon 1937, Plate I.)*

The available data was boosted by the 1932–33 cruise of **Discovery II*****, as well as the southernmost tracks of the*** **Meteor**

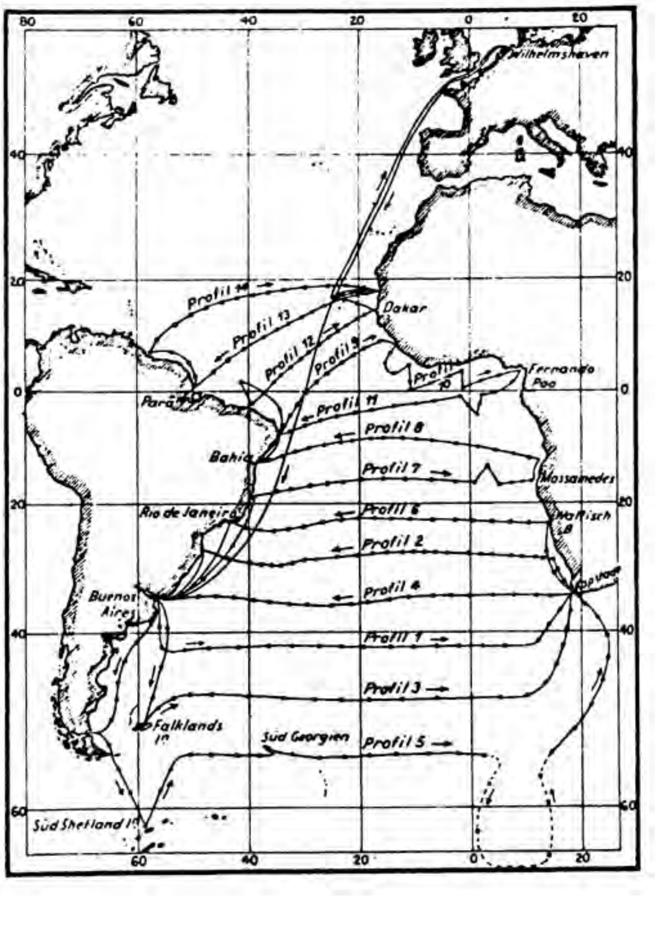
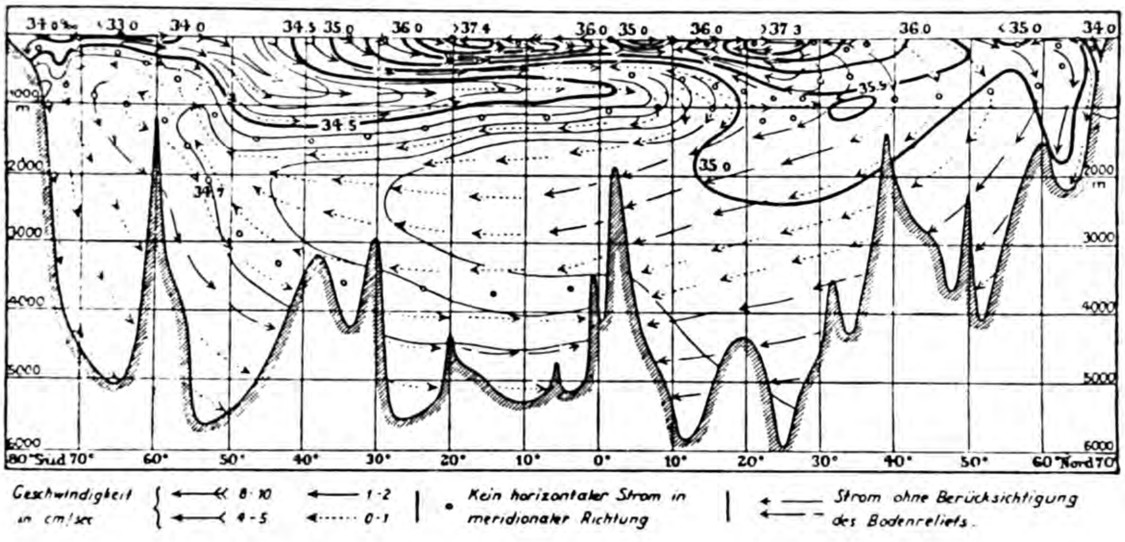


Figure 5 *Transects made during the German* Meteor *Expedition of 1925–27. (From the cruise plan, Merz 1925, p.576.)*



The meridional circulation of Merz and Wüst showed many of the features we understand today, but their NADW formed in northern mid-latitudes

Figure 6 *Alfred Merz and Georg Wüst's 1922 depiction of the Atlantic meridional circulation, showing the distribution of salinity, and currents (arrows) inferred from the distributions of temperature, salinity and pressure. (From Merz 1925, p.567.)*

Careful inspection of Figure 6 shows a picture familiar even today, including the northward tongue of Antarctic Intermediate Water, Antarctic Bottom Water flowing north, and the southward motion of North Atlantic Deep Water (although they believed that North Atlantic Deep Water formed at mid-latitudes in the North Atlantic, rather than in subpolar waters).

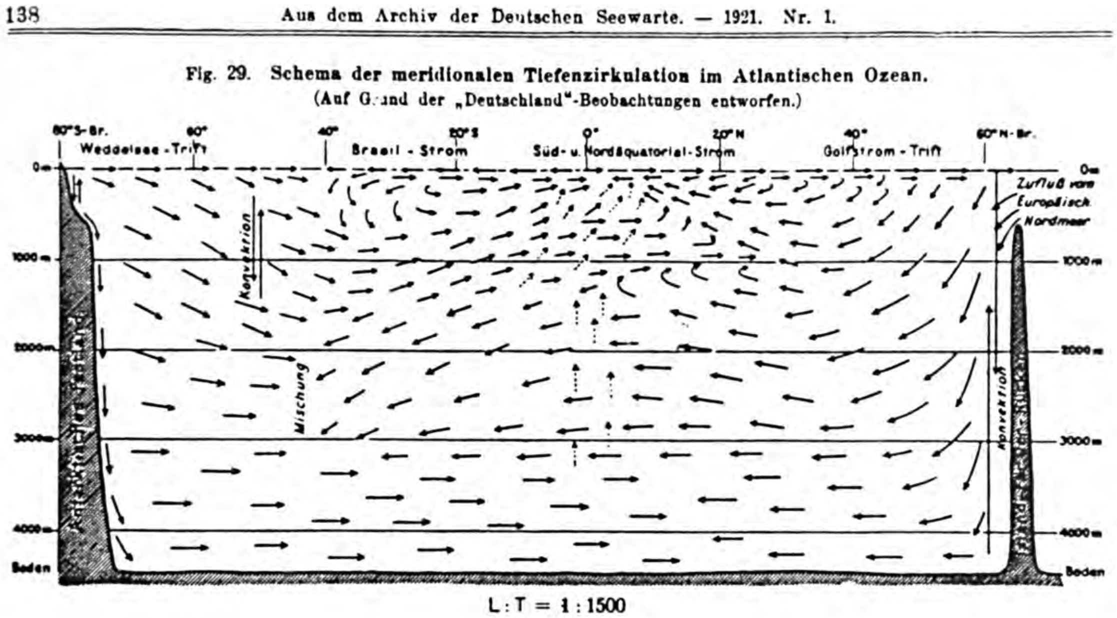
Merz and Wüst's model resulted in a bitter controversy over interpretations and priority with oceanographers at the Deutsche Seewarte in Hamburg, especially Gerhard Schott (1866–1961) and his junior colleague Wilhelm Brennecke (1875–1924) (Figure 7). Certainly it was Brennecke who was best qualified to assess and evaluate Merz and Wüst's model, for in 1921, long delayed by political wrangling and the First World War, Brennecke had published the physical oceanographic results of the troubled German Antarctic Expedition of 1911–12 on the ship *Deutschland* (under Wilhelm Filchner), on which he had been the lone physical oceanographer. Travelling south through the Atlantic and then overwintering in the ice of the south-eastern Weddell Sea (not particularly by choice), *Deutschland* gave Brennecke the opportunity to gather a unique dataset. From it he constructed his own model (Figure 8), which appeared only a year before that of Merz and Wüst.

Figure 7 *Wilhelm Brennecke of the Deutsche Seewarte in Hamburg, oceanographer on the* Planet *Expedition (1906–1907) and the German Antarctic Expedition (1911–12). (From W. Schott 1987, p.29.)*

Wilhelm Brennecke was the most experienced and insightful physical oceanographer of his generation

Once again, the pattern looks familiar – Brennecke detected Antarctic Intermediate Water, the northward flow of Antarctic Bottom Water, and the southward movement of North Atlantic Deep Water (which, unlike Merz and Wüst, he regarded as originating in an overflow into the Atlantic abyss from the Norwegian Sea). But there are also the puzzling dashed arrows below the Equator (derided by Merz and Wüst as physically impossible) intended to indicate generalized upwelling. Note too the formation of Antarctic Bottom Water in the shallows of the Weddell Sea, for it was Brennecke, using his winter data from *Deutschland*, who first suggested that it had to originate somewhere along the continental shelf of the Antarctic peninsula, in the south-western Weddell Sea.

But to understand these descriptive models and the controversies they caused, as well as their influence on George Deacon's work, we must go back even farther, to the first attempt to conceptualize large-scale oceanic circulation on the basis of reliable temperature measurements. This was due to the German/Russian physicist Emil von Lenz (1804–1865), best known for his distinguished studies of electromagnetism. As a young man, Lenz had accompanied Otto von Kotzebue's circumnavigation of the globe for the Imperial Russian Crown in 1823–26. In the 1830s, and definitively in 1845, Lenz published interpretations of all the deep-water temperature data that he believed to be correct – that is, the measurements that were taken using protected thermometers or were of water from insulated water bottles. He found very cold deep water (temperatures as low as 1 °C) everywhere, contradicting the



Brennecke's 1921 picture of the Atlantic circulation (left) built upon Schott's ideas, and had its roots in Lenz's concept, outlined in 1845 (below)

Figure 8 *Meridional circulation of the Atlantic Ocean according to Wilhelm Brennecke in 1921, based on his work on* Planet *(1906–1907) and* Deutschland *(1911–12), including a winter drift in the ice of the Weddell Sea. (From Brennecke 1921, p.138.)*

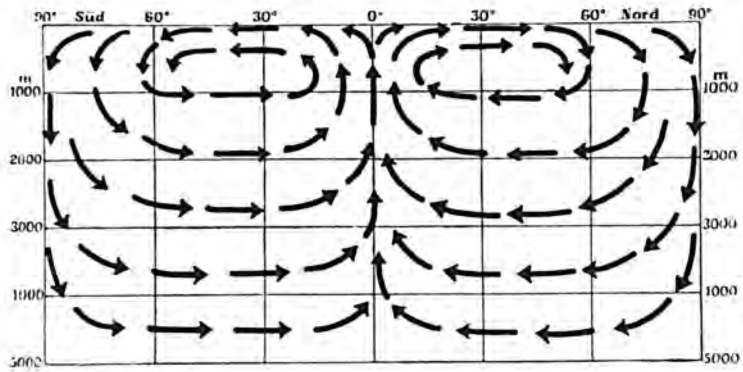
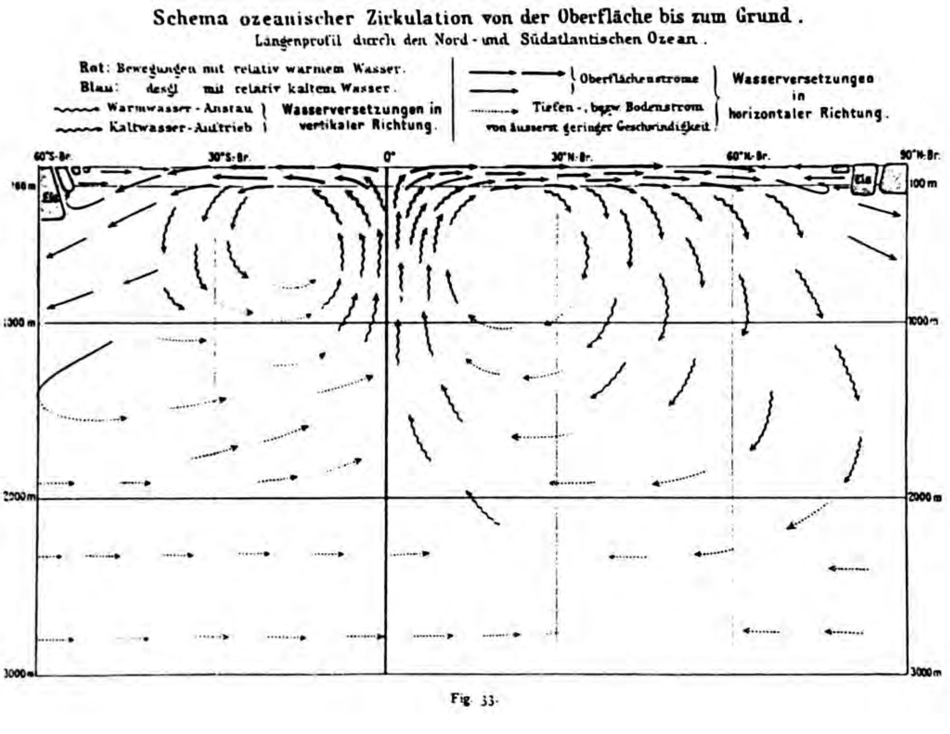


Figure 9 *The scheme of Atlantic circulation proposed by Emil von Lenz in 1845, based on measurements made during the circumnavigation of 1823–26 and later work. Lenz's work was virtually unknown until unearthed by Joseph Prestwich in 1875.*

common misconception that the deep water could not be colder than 4 °C, and noted cooler near-surface temperatures at the Equator than in the tropics to the north and south. Lenz summarized his conception (verbally) as mirror-image cells of meridional circulation (Figure 9) centred on the Equator, and driven by cooling at high latitudes.

Lenz's model, published in St Petersburg, was little known for more than thirty years. It was resurrected by the English geologist Joseph Prestwich in a magisterial treatise of 1875 in which he surveyed and critically evaluated all the deep-water temperature measurements recorded since 1749. Little by little, Lenz's ideas began to occupy the thoughts of those who puzzled over oceanic circulation, among the first of whom was Gerhard Schott of the Deutsche Seewarte, who as

Figure 10 *Circulation of the Atlantic proposed by Gerhard Schott in 1902; it undoubtedly owed much to Lenz (see Figure 9). (From Schott 1902, p.64.)*



Schott's 1902 two-cell Atlantic circulation was based upon his work at sea on Valdivia *but undoubtably owed much to Lenz's ideas (cf. Figure 9)*

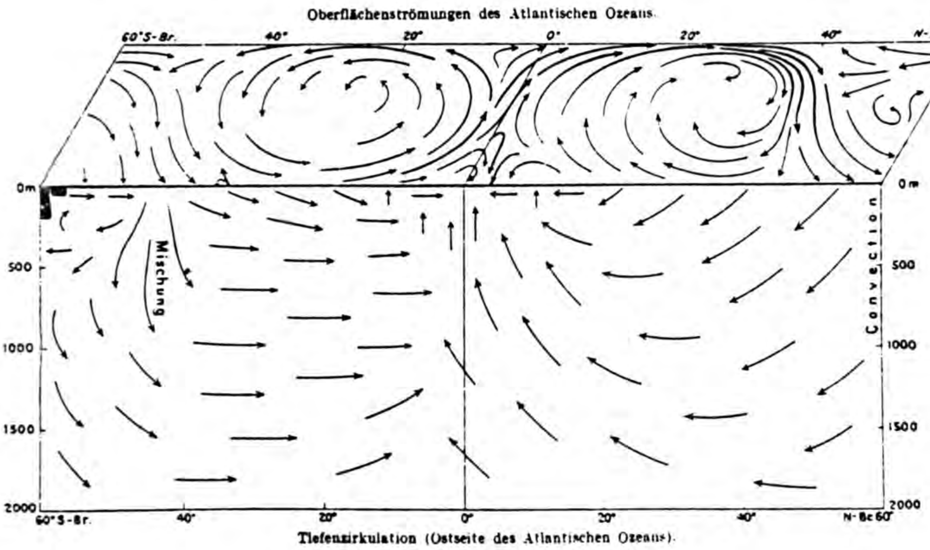


Figure 11 *Wilhelm Brennecke's 1909 scheme of Atlantic meridional circulation, based primarily upon his work aboard the* Planet *in 1906–1907, and owing much to Schott's model (Figure 10) and ultimately to Lenz (Figure 9). Brennecke soon made major changes to this scheme as a result of his work in the South Atlantic and the Antarctic during 1911–12 (see Figure 8). (From Brennecke 1909, p.98.)*

a young man went to sea as the oceanographer of Carl Chun's mainly biological expedition on the German ship *Valdivia* in 1898–99. Schott's classic account of the oceanography of the expedition, published in 1902, used the two-cell system of meridional circulation suggested by Lenz more than half a century before, but added a trans-equatorial bottom current from the south and some additional complexities to surface waters at high latitudes (Figure 10).

We should not be surprised that Schott had a great influence on Brennecke, who joined the staff of the Seewarte in 1904, just two years after the publication of Schott's model. Brennecke soon had the chance to go to sea for the first time, as oceanographer of the Reichsmarine's Expedition on *Planet*, travelling southward into the South Atlantic, then on into the south-western Pacific. His report on the physical results, published in 1909, shows the influence of Schott (Figure 11) – and before him of Lenz (cf. Figures 9 and 10).

Of course, by 1921, with Brennecke's expanded experience in the Antarctic in 1911–12 and much additional thought by this experienced and intuitive oceanographer, we can see the deepening and broadening of his knowledge and experience, which came together in his later meridional section, shown in Figure 8. It is not surprising that Merz and Wüst found him a formidable enemy and that George Deacon took Brennecke's work very seriously, as his own ideas matured in the early 1930s.

The Antarctic Circumpolar Ocean

This article has aimed to show that there were deep historical roots to George Deacon's monograph *The Hydrology of the Southern Ocean*. These may be excavated mainly from the German oceanographic literature of the early twentieth century, but also by going well back into the nineteenth century. Although it was Brennecke, along with Merz and Wüst, who played the largest role in Deacon's monograph, I hope I have shown that there was an underpinning of evolving ideas going back much earlier than the 1920s. No great work of synthesis is independent of its precursors. In its own time, Deacon's monograph was given star billing and scientific prominence by its inclusion in *The Oceans*, which we can expose to historical analysis in its turn.

Now, early in the twenty-first century, the global circulation of the oceans has become central to what has been called 'the global thermohaline conveyor' – the planet-wide transport of water and, especially, heat that governs climate on a planetary scale. It is not clear to me that this broad interpretation of oceanic circulation would have occurred without the *Discovery* Investigations, the imagination of George Deacon, the great circumpolar cruise of 1932–33, *The Hydrology of the Southern Ocean*, and the promotion of George Deacon's work in the *The Oceans* in 1942. The modern ubiquity of interest in the global thermohaline circulation began here. Deep-ocean physical oceanography might well have taken another direction without the work of George Deacon more than seven decades ago and the influence of his *Hydrology of the Southern Ocean* upon his contemporaries and the rest of us since 1937.

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* Halifax, Nova Scotia, Canada, B3H 4JI
Email: E.Mills@Dal.ca

This article is based on a talk given at the symposium 'A Century of Discovery', held at the Southampton Oceanography Centre in June 2004. The proceedings of the symposium will be published in Autumn 2005 *(see p.31)*.

High Seas Bottom Trawling: Time for a Moratorium

Only a small fraction of oceanic ecosystems below 200 m have been investigated, but it is clear that the deep ocean is a major reservoir of biodiversity, with estimates of numbers of species ranging between 500 000 and 100 million. Now, as shallow shelf seas are increasingly depleted of fish, the fishing industry is moving into deeper waters, and this wealth of biodiversity is under threat.

About 80% of the high seas catch of bottom species (groundfish, prawns etc.) is caught by bottom trawling (the rest are caught by bottom longline and gillnet fishing). Currently, however, bottom trawling in high seas waters is limited, with high seas bottom trawling probably supporting no more that a few hundred fishing vessels, out of a total of about about 3.1 million worldwide. The global catch from bottom trawling reported in 2001 was of the order of 200 000 tonnes, which corresponds to only about 0.2% of the 83.7 megatonnes caught globally, according to the UN Food and Agriculture Organization. The economic significance of the catch is correspondingly small, with the value estimated to be of the order of 0.5% of the global marine fish catch. Furthermore, most of the catch of high seas bottom trawl fisheries is destined for high-value markets in the EU, the US and Japan, and does not form a vital food supply for any vulnerable population. All this means that – in theory at least – it is still possible to implement international management measures to protect deep-sea ecosytems.

Bottom trawling takes place on seamounts, ocean ridges and plateaux; it also takes place along the continental margins where they extend beyond 200 n.m. from the coast, an area where coastal states have sovereign rights to exploit (and a duty to conserve) benthic species). Bottom trawling is extraordinarily destructive – for example, on seamounts it can destroy up to 90% of the coral cover and the community it supports. At present, the largest part of the bottom trawl catch is taken in a relatively small area in the north-western Atlantic, in the international waters over the shelf and slope of the Grand Banks and the Flemish Cap. It also takes place in the north-eastern Atlantic Ocean, the south-western Indian Ocean and the south-western Pacific Ocean. The fisheries in these areas are more extensive, and the scope for damage to bottom communities proportionately greater.

In 2002, the UN General Assembly called upon the international community to address the threats to biodiversity of communities on seamounts and other vulnerable deep-sea ecosystems as a matter of urgency. High seas bottom trawl fisheries are currently unregulated as far as their impact on deep-sea biodiversity is concerned. They are nearly all conducted in an unsustainable manner, and there are serious problems with misreporting and under-reporting of catches.

To quote from the Report's conclusion:

> 'If the international community cannot prevent the destruction of of the wealth of deep-sea biodiversity on the global commons from bottom fishing by a relatively small number of of countries and vessels, what hope is there that we can halt and reverse the Earth's biodiversity overall for future generations?'

The report, *High Seas Bottom Trawl Fisheries and Their Impacts on the Biodiversity of Vulnerable Deep-Sea Ecosystems,* was prepared by Matthew Gianni for IUCN (the World Conservation Union), the US Natural Resourses Defense Council, WWF International and Conservation International. The whole 90-page report may be downloaded from the IUCN website: http://iucn.org/themes/marine

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