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OCEAN Challenge

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The European Federation of Marine Science and Technology Societies was founded in December 1998 in Paris. It consists of European non-governmental scientific and technological associations specializing in research and education pertaining to the marine environment.

The objectives of the EFMS are:

- To contribute to the advancement of research and education in marine science and technology.
- To disseminate information to promote the advancement of marine science and technology in Europe.

The EFMS website is: www.efmst.org

The EFMS Secretariat is at Institut océanographique, 195 rue Saint-Jaques, F-75005 Paris.

The views expressed in *Ocean Challenge* are those of the authors and do not necessarily reflect those of the Challenger Society or the Editor.

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.

***Ocean Challenge* is sent automatically to members of the Challenger Society.** For more information about the Society, or for queries concerning individual subscriptions to *Ocean Challenge*, please see the Challenger Society website (www.challenger-society.org.uk) or contact the Executive Secretary of the Society (see inside back cover).

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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

MEMBERSHIP SUBSCRIPTIONS

The subscription for 2004 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, National Oceanography Centre, Waterfront Campus, Empress Dock, Southampton SO14 3ZH, UK;
Fax: +44(0)23-80-596149; Email: jxj@soc.soton.ac.uk

ADVICE TO AUTHORS

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

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CONTENTS

Message from the EFMS President

Europe opens a window onto the ocean: the significance of the new EU Marine Strategy *Panayotis Panayotidis*

Researchers and policy-makers discuss high-seas management in Southampton (News from the 11th International Deep-Sea Biology Symposium) *Kerry Howell*

The legacy of BIOFAR: a study of benthos around the Faroes (book review) *Sigmar Arnar Steingrímsson*

Priority Areas for Scientific Research: protecting scientific investments *Hjalmar Thiel*

Europe's role within the Census of Marine Life (CoML) *Brigitte Hilbig*

Understanding sea-level rise and variability (Report of UNESCO Workshop, Paris, June 2006) *John Church, Stan Wilson, Philip Woodworth and Thorkild Aarup*

The impacts of sea-level rise *Robert J. Nicholls with* **Recent sea-level rise** *Anny Cazenave*

Long-term studies reveal climate-induced changes in benthic communities of the North Sea *Ingrid Kröncke, Gunther Wieking, Hermann Neumann and Joachim Dippner*

The present and future of Greek fisheries *Kostas Kapiris*

Tsunamis affecting Greece in ancient and modern times *Serafim Poulos, George Alexandrakis, Theodora Paramana and Aikaterini Karditsa*

Marine corrosion: a widespread, under-estimated and poorly understood phenomenon *Jaques Daret, Samuel Pineau and Thierry Braisaz*

A century of marine research in Europe: 1906–2006 *Antonio Pusceddu*

Exchange and mobility of scientists and students Report of Open Forum discussion (coordinated and summarized by Ilse Hamann)

Report from the 2006 EFMS General Assembly in Paris

An introduction to new EFMS members

Post script: Navigating the future – identifying research priorities in the marine sciences

EFMS

CONTENTS

2 **Message from the EFMS President**

3 **Europe opens a window onto the ocean: the significance of the new EU Marine Strategy** *Panayotis Panayotidis*

4 **Researchers and policy-makers discuss high-seas management in Southampton** (News from the 11th International Deep-Sea Biology Symposium) *Kerry Howell*

5 ***The legacy of BIOFAR: a study of benthos around the Faroes*** (book review) *Sigmar Arnar Steingrímsson*

6 **Priority Areas for Scientific Research: protecting scientific investments** *Hjalmar Thiel*

8 **Europe's role within the Census of Marine Life (CoML)** *Brigitte Hilbig*

12 **Understanding sea-level rise and variability: Report of UNESCO Workshop, Paris, June 2006** *John Church, Stan Wilson, Philip Woodworth and Thorkild Aarup*

13 **The impacts of sea-level rise** *Robert J. Nicholls* *with* **Recent sea-level rise** *Anny Cazenave*

19 **Long-term studies reveal climate-induced changes in benthic communities of the North Sea** *Ingrid Kröncke, Gunther Wieking, Hermann Neumann and Joachim Dippner*

24 **The present and future of Greek fisheries** *Kostas Kapiris*

31 **Tsunamis affecting Greece in ancient and modern times** *Serafim Poulos, George Alexandrakis, Theodora Paramana and Aikaterini Karditsa*

38 **Marine corrosion: a widespread, underestimated and poorly understood phenomenon** *Jaques Daret, Samuel Pineau and Thierry Braisaz*

44 **A century of marine research in Europe: 1906–2006** *Antonio Pusceddu*

45 **Exchange and mobility of scientists and students** Report of Open Forum discussion (coordinated and summarized by Ilse Hamann)

46 **Report from the 2006 EFMS General Assembly in Paris**

47 **An introduction to new EFMS members**

48 **Post script: Navigating the future – identifying research priorities in the marine sciences**

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Message from the EFMS President

Although it was only founded in 1998, the European Federation of Marine Science and Technology Societies (EFMS) already has a significant presence in the field of marine science in the European Union. However, the EFMS must become more active if it is to contribute to the advancement of research and education in marine science and technology in Europe, and promote their dissemination. At a time when there are problems relating to marine pollution, biodiversity, fisheries and climate change in all the seas around Europe, there is no overall integrated policy for the protection and effective sustainable management of the marine environment. It is therefore particularly important for European marine scientists to play an active role as the EU attempts to introduce new policies for the marine environment, such as the Marine Strategy Directive, the Green Paper etc.

The European Marine Research Area is not well established; it is becoming developed, but not sufficiently fast. In the 7th Framework Programme, which will regulate all European activities for the next seven years, the budget for the Environment, which includes marine research, is only 5.5% of the total Cooperation Programme. Meanwhile, the European Higher Education Area, which will certainly affect marine science education, is becoming realized; for the future of marine science, it is important that education in this field remains both proficient and attractive to prospective students.

Under the Presidency of Roberto Danovaro, the previous Executive Committee (2004–2006) succeeded in expanding the EFMS. The Italian Society of Marine Biology (SIBM), the Swedish Society for Marine Sciences (SHF) and the Israeli Association of Aquatic Sciences (IAAS) have joined the Federation, making a total of 14 societies (see pp.47–48). Other improvements over the last two years have included the production of new publicity material and revamping of the EFMS website, which has now had more than 12 000 visitors. A questionnaire about the state of marine science and technology research in Europe has been designed, and analysis of the responses will provide useful information about the status and the opinions of marine scientists (see p.46). Amongst its activities, the EFMS organized (in collaboration with the Union des océanographes de France) the conference '1906–2006: A century of marine research in Europe' (see p.44). Last but not least, the financial situation of the Federation has improved.

The new Executive Committee will continue current activities and pursue new ventures. We must work to establish contact with marine science societies or other suitable associations/organizations in EU countries that are not yet represented in the EFMS. We must also create a network for communication and exchange of experience with scientifically developed countries in other continents, as well as countries with fewer scientific research resources. We must also try to have contacts and collaboration with other international organizations working in similar fields to the EFMS, e.g. UNEP, UNESCO, the ESF, and the EEB. We should continue with the updating of the website and the further production of publicity material. Also, proposals for the establishment of new Working Groups are needed from the member societies.

In the coming year, we aim to support a number of initiatives relating to young scientists (e.g. the Forum for Young Oceanographers, which has run in previous years. We will also work at promoting EFMS views to the European Commission and other relevant national and international organizations, as well as to a wide non-scientific audience. We will be actively participating in the EurOcean 2007 Conference in Aberdeen (see p.37). We must also be involved in the consultation procedure concerning the Green Paper (see opposite).

Today, as globalization continues, the marine sciences have a key role to play in the holistic study, effective protection and sustainable management of oceans and seas, which being interconnected, already show the effects of our increasing capability to influence the natural world. The marine environment, so vital for human survival, yet so sensitive, is in danger, and its sustainability must be considered a high priority. European marine scientists, through their national societies and the EFMS, and other international organizations – but mostly through their everyday work in all aspects of marine science and technology – will be providing an important contribution. By integrating experiences from different countries, the EFMS will act to arouse public awareness of the oceans, and compel policy-makers to comprehend that they are still largely unexplored, and that enormous benefits can be gained through investing in improving our knowledge and understanding of the sea.

With best wishes from myself,
and the EFMS Vice-Presidents,
Roberto Danovaro and Graham Shimmield

Manos Dassenakis

Europe opens a window onto the ocean

The significance of the new EU Marine Strategy

Panayotis Panayotidis

Did you know that under the sovereignty of the European Union Member States there is more sea (territorial waters and exclusive economic zone) than land surface? The European Union is a maritime superpower – but is it ready to manage its maritime welfare?

Europe's oceans are faced with a number of threats, including loss or degradation of biodiversity and changes in its structure, loss of habitats, contamination by dangerous substances and nutrients, and impacts of climate change. There are measures to control and reduce pressures and impacts on the marine environment, but they have been developed in a sector-by-sector approach, resulting in a patchwork of policies, legislation, programmes and action plans. For example, EU member states respect international maritime law, and the EU Commission, as a legal entity, has signed international maritime conventions. In addition, certain specific EU legislation is concerned with the sustainable management of the seas: the 'Habitats' Directive (92/43/EEC) covers nine important marine habitat types and the Water Framework Directive (2000/60/EC) aims for a 'good ecological status' of all water bodies within 1 nautical mile of the coast by 2015.

However, if we wish to see EU policy as an advance on the policies of member states, and we agree that sustainable management of the sea is more than just coastal management, these measures are simply not enough. The general picture that emerges from the existing policy framework is a mixed one. On the positive side, some progress has been made in certain areas, e.g. in reducing nutrient inputs and pollution from hazardous substances, particularly heavy metals. Nevertheless, the overall state of the marine environment has deteriorated significantly during recent decades. Current policy frameworks and institutional arrangements are not delivering a sufficiently high level of protection for the marine environment, and a strong, integrated EU policy on marine protection could significantly contribute to improving the situation. Two main options have been considered:

- A review of the existing legal instruments, in order to cover offshore habitat types in the 'Habitat' Directive and/or extending the Water Framework Directive out to the limit of territorial waters or even out to the limit of the exclusive economic zone.
- A new flexible legal instrument combined with non-binding recommendations set out in a Communication from the EU Commission. This legal instrument would be ambitious in its scope but not overly prescriptive in its tools.

The Commission is oriented towards the second option and a new 'Marine Strategy' Directive is being drafted. Several working groups are collaborating with the European Environmental Agency, and the debate about the relevant Green Paper is well underway (see Box below).

The new legislative instrument will require global indicators (i.e. measurements of key parameters) describing the state of the marine environment; if there is a decline in the ecological status of a particular environment, the state of these indicators will indicate the measures needed for restoration. To take just one example, the extent of seagrass cover is considered to be a good indicator of the ecological quality of coastal waters.

It is thought that in the short term there may be important social and economic costs for the sectors most dependent on the marine environment and most directly affecting it (e.g. fisheries). Sectors where the environmental regulatory framework is comparatively less developed (e.g. extraction, dredging and, to a lesser extent, shipping) are also likely to be relatively more affected.

Bearing in mind the uncertainties about the combined impacts of measures, and about their potential costs, there needs to be provision for compulsory impact assessments and cost–benefit analyses at the regional level.

In the medium to long term, benefits from successful implementation of the new Marine Strategy would include: effective protection of the marine environment and restoration of the key ecological services it provides; the sustainable future of marine 'industries' (fisheries, aquaculture and tourism); reduced risks to health from polluted bathing sites and from contaminated fish products; and new economic opportunities from increased research prospects and emerging sectors (ecotourism etc).

The new European Marine Strategy is a very ambitious project; it is also a huge challenge for European oceanographers.

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The Green Paper on Maritime Affairs: the Background

In June 2006, the EU Commissioner for Maritime Affairs, Joe Borg, presented a Green Paper outlining development towards an integrated maritime policy for Europe. The Green Paper* – also referred to as the 'Green Book'– was launched at a maritime policy conference held at Turku (Finland), on the Baltic. This conference focussed on maritime transport safety, sustainable development of coastal areas, and developments in shipbuilding technology. Other maritime topics have been addressed by various conferences throughout Europe

The Green Paper is open for consultation until 30 June 2007. If marine scientists want to get their voices heard, they must engage with the consultation process. One way to do this is to participate in EurOcean 2007 in Aberdeen (see right). The EU Council will summarize the results of their consultation, and propose a way forward, before the end of 2007.

See http://ec.europa.eu/maritimeaffairs/ for more about the Green Paper, the consultation process, and contributions already received.

**Towards a Future Maritime Policy for the Union: A European Vision for the Oceans and Seas.*

EurOcean 2007

Aberdeen, Scotland, Friday 22 June

At this event, the scientific community will have the opportunity to provide input to the European Commission in the context of the Green Paper, so contributing to a vision for maritime science and a strategy for the future.

EurOcean 2007 follows on from Oceans '07 (see p.37). To register, go to the Oceans 07 website:

http://www.oceans07ieeeaberdeen.org

Researchers and policy-makers discuss high-seas management in Southampton

News from the 11th International Deep-Sea Biology Symposium

Kerry Howell

The development of Marine Protected Areas inside the European exclusive economic zone (EEZ), outside in the wider OSPAR area, and in high seas regions in general, requires, above all, good communication between the deep-sea research community and the management and policy community. How can this be achieved? One approach adopted at the 11th International Deep-Sea Biology Symposium was to ask policy-makers directly 'What would you like to know?'

In July 2006 deep-sea biologists from around the world gathered in Southampton, UK, for the International Deep-Sea Biology Symposium. This meeting, held once every three years, provides deep-water scientists with an opportunity to share their latest research with their peers, and in that respect this meeting was no exception. Over 300 participants presented a total of 135 papers and nearly 200 posters, most of which outlined new research findings. However, this meeting was exceptional in that, for the first time ever, a special afternoon session was held on the topic of ocean management.

Deep-sea scientists have become increasingly concerned about the impacts of human activities on the deep-sea ecosystem. This concern has become so great in recent years that, at the 10th Deep-Sea Biology Symposium in Coos Bay, Oregon USA, in August 2003, many within this small research community signed a joint statement calling for a moratorium on bottom trawling in deep waters and on seamounts. In the three years since that initial statement, progress in developing ocean management has been made in the political arena. Ocean management and threats to deep sea-bed biodiversity are now important topics within international and regional political organizations. In February 2006 the United Nations convened an Informal Ad Hoc Working Group to study issues related to the conservation and sustainable use of biological diversity in areas beyond national jurisdiction. In 2004, and again in 2006, Parties to the Convention on Biological Diversity highlighted the need for action to improve conservation of marine biological diversity in the high seas, including through the creation of marine protected areas (MPAs). At the 2002 World Summit on Sustainable Development (WSSD), world leaders committed to establish representative networks of MPAs by 2012. At the European level, the Oslo–Paris Commission for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Commission), and the European Habitats Directive, both call for the establishment of MPAs to conserve biodiversity, by 2010 and 2012 respectively. Both policies include deep-water areas within their jurisdiction.

To contribute to the development of management strategies for deep-sea ecosystems (high seas and EEZs) deep-sea biologists felt there was a need for a special session to be held during the 11th International Deep-Sea Biology Symposium with the aim of facilitating communication between science and its users. To provide the research community with an understanding of the information needs of policy-makers, speakers from IUCN (the World Conservation Union), OSPAR and the UK government were invited to give short presentations on the current political situation with regard to ocean management at international and European levels. Following these presentations a discussion session was held with the aim of providing advice to policy-makers on important questions in deep ocean management. In collaboration with managers, policy-makers and scientists, six key questions were devised and then posed to the assembly of the world's leading experts in deep-sea biology.

The key questions were:

- What are the most significant threats to the deep-sea environment?
- What species and habitats are most sensitive / under threat?
- What are the policy gaps with regard to our current understanding of deep-sea ecosystems?
- What are the science gaps?
- How do we ensure better communication between the research community and management bodies?
- How can the science community contribute to the policy requirements for a network of high seas/deep-sea MPAs, as called for by the WSSD and the OSPAR Commssion?

The discussions held around each of these key questions, and the conclusions agreed by all 300+ participants of the symposium, are presented in a paper to be published in 2007, currently in submission to *Conservation Biology* (see Further Reading). Here I will briefly consider the two final points in a European context.

This meeting provides a good example of how the research community can take an active role in providing scientific advice. However, an afternoon session held once every three years is clearly not sufficient to supply policy-makers with the information required to implement the various marine policies currently in place within the EU and globally, particularly those relating to the development of MPAs. It is vital that there is good communication between the deep-sea research community (who possess the biological and oceanographic knowledge to ensure MPAs are correctly placed in terms of conserving biodiversity and ecosystem function as part of a network) and the management and policy community (who understand the policy requirements and legal framework surrounding the establishment and subsequent management of MPAs). Having once been governmental policy advisor, I am very aware of the frustration felt by many environmental managers that the research community is, in general, not proactive in providing advice. Whereas non-governmental organizations and industry representatives lobby managers and policy-makers, and are very effective in making themselves heard, scientists are less effective at communicating to a wide audience, and some do not consider it their role to promote a particular view to policy-makers. Very often the various professional communities 'talk different languages'. A researcher's interpretation of 'useable information' is often not the same as a governmental advisor's interpretation!

As an academic, however, I am also aware that many deep-sea researchers recognize the need for effective communication to a wider audience. Unfor-

*The 11th International Deep-Sea Biology Symposium, held at the National Oceanography Centre, Southampton, UK, on 9–14 July, 2006.

tunately, their professional obligations restrict their activities, and funds are not made available for such responsibilities. It is not that scientists want more money for what, it can be argued, is actually their job; it is a simple fact that attending meetings has a financial cost attached to it in travel and subsistence alone, and these costs must be met from somewhere. In general, the deep-sea research community is willing to contribute to the development of deep-seas policy but must find an appropriate and effective forum in which to achieve this.

Therse problems in positive communication are not new and were highlighted nearly a decade ago during the Third European Marine Science and Technology Conference, in Lisbon in 1998 (see Further Reading). So, what can be done? An example is provided by Dr Henning von Nordheim, chair of the OSPAR working group on MPAs and a speaker at the ocean management session in Southampton in September. Following the success of this session, Dr von Nord-heim invited deep-sea researchers to participate in a workshop to be held in February 2007, in London, to provide advice on deep-sea areas within the wider OSPAR area that may be suitable for designation as MPAs. It is hoped that, by engaging the research community directly, the best possible advice will be available for use in developing deep-water MPAs. Such meetings again provide a good example of positive communication between science and its users. However, the views presented and the proposals made by scientists are their professional opinion and not based on agreements within the scientific community.

Within Europe good communication has long been facilitated by the International Council for the Exploration of the Sea (ICES), which remains an important forum for transferring scientific knowledge into ocean management policies. The working groups rely on governmental delegates and nominated specialists for the various subjects, who are experts in their field, to attend annual meetings and produce reports providing advice to bodies such as the North-East Atlantic Fisheries Commission and OSPAR. However, ICES and workshops such as that held in February suffer from the same problem: no financial support is provided to academic research scientists (if not national delegates) to allow their attendance at such forums, and there is currently only modest professional recognition given for the time it involves to attend and/or prepare reports. As a result, many experts do not attend, and some cannot do so.

If we wish to ensure that communication between the research community and its users continues to develop, and that the most appropriate researchers are able to provide the most up-to-date advice in the development of deep-sea policy and ocean management, we must address the problems of funding and professional recognition. In an academic environment where researchers are judged on peer-reviewed publication output alone, time given over to providing advice can easily be mistakenly seen as time wasted! Communication of scientific results in the form of readily comprehensible papers for non-specialists, lectures to the public, compilation of reports for decision-makers, and participation in policy meetings, should find adequate recognition in the evaluation processes of scientists, and be adequately funded by those requiring advice.

Further reading

Howell K.L., D.S.M. Billett, C.R. Smith, P.A. Tyler, H. Thiel, R. George, *et al*. (2007) Knowledge transfer and deep-ocean management: a perspective from the deep-sea research community. *Conservation Biology* (*in submission*).

Cornaert, M. and E. Lipiatou (1999) Marine research and policy interface. Links, interdisciplinary co-operation, availability of results, case studies. Report from a session of the Third European Marine Science and Technology Conference, Lisbon 1998. European Commission, *Research in Enclosed Seas Series* **6**, 77pp. (ISBN: 92-828-5902-9)

Kerry Howell is at the Marine Biology and Ecology Research Centre, University of Plymouth. Her research interests include deep-sea ecology and offshore conservation and management.

The legacy of BIOFAR: a study of benthos around the Faroes

BIOFAR Proceedings 2005* edited by Ole S. Tendal, Arne Nørrevang and Dorete Bloch (2005). Fróðskaparfelag Føroya, Tórshavn, 272pp. (ISBN 99918-41-41-5).

Biological investigations of the Faroese benthos (BIOFAR*) was a scientific programme carried out during 1988–1990 (BIOFAR 1: ~100 to 1000 m depth) and 1995–98 (BIOFAR 2: shallow-water fauna and flora). The aim was to produce a survey of the composition and distribution of the benthic macrofauna and macroflora within the Faroese EEZ. The programme was based on collaboration between a number of Nordic scientists and scientific institutions. In addition, an international network of specialists worked on identifying the material that was brought ashore during BIOFAR.

The Proceedings are Vol. XXXXI of *Annales Societatis Scientiarum Faroensis Supplementum*. They may be obtained from Bókamiðsölan, bms@bms.fo, (http://www.bms.fo/), price DKK 190 + postage.

BIOFAR Proceedings 2005 is a record of the outcome of the second BIOFAR symposium, 'North-East Atlantic marine benthic organisms in the Faroes – taxonomy, distribution and ecology'. The proceedings can be divided into three sections: 19 scientific papers, 20 abstracts (oral and posters presentations from the symposium) and a detailed list of publications based on material from the BIOFAR programme.

The first paper gives an overview of sampling and data-collection during BIOFAR 1, and summarizes the general results of the programme. Another paper sums up the current knowledge of biogenic sediments, substrates and habitats of the Faroese shelf and slope. The majority of the papers, however, deal with the taxonomy and biogeography of benthic flora and fauna around the Faroes. There are also a few papers with ecological or synthetic aspects, reflecting on the relationships of the Faroese benthic flora and fauna with those of the wider North Atlantic.

Some of the papers give a comprehensive survey of the geographic and bathymetric distribution of groups of organisms (e.g. Stylasteridae), but in others only a preliminary account of the fauna is given (e.g. Actinaria). Although taxonomic studies of some of the Faroese benthic groups have been completed, the proceedings indicate that many studies are still in progress and it will be some years before a relatively complete survey of the Faroese macrofauna will be available. Nevertheless the BIOFAR programme has already improved our knowledge of the diversity of marine species around the Faroes and in the North Atlantic, and highlighted the existence of particular benthic communities and their possible importance for marine ecosystems, e.g. those associated with mass occurences of large sponges and the scleractinian cold-water coral *Lophelia pertusa*.

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If we wish to ensure that communication between the research community and its users continues to develop, and that the most appropriate researchers are able to provide the most up-to-date advice in the development of deep-sea policy and ocean management, we must address the problems of funding and professional recognition. In an academic environment where researchers are judged on peer-reviewed publication output alone, time given over to providing advice can easily be mistakenly seen as time wasted! Communication of scientific results in the form of readily comprehensible papers for non-specialists, lectures to the public, compilation of reports for decision-makers, and participation in policy meetings, should find adequate recognition in the evaluation processes of scientists, and be adequately funded by those requiring advice.

Further reading

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The legacy of BIOFAR: a study of benthos around the Faroes

BIOFAR Proceedings 2005* edited by Ole S. Tendal, Arne Nørrevang and Dorete Bloch (2005). Fróðskaparfelag Føroya, Tórshavn, 272pp. (ISBN 99918-41-41-5).

Biological investigations of the Faroese benthos (BIOFAR*) was a scientific programme carried out during 1988–1990 (BIOFAR 1: ~100 to 1000 m depth) and 1995–98 (BIOFAR 2: shallow-water fauna and flora). The aim was to produce a survey of the composition and distribution of the benthic macrofauna and macroflora within the Faroese EEZ. The programme was based on collaboration between a number of Nordic scientists and scientific institutions. In addition, an international network of specialists worked on identifying the material that was brought ashore during BIOFAR.

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BIOFAR Proceedings 2005 is a record of the outcome of the second BIOFAR symposium, ‘North-East Atlantic marine benthic organisms in the Faroes – taxonomy, distribution and ecology’. The proceedings can be divided into three sections: 19 scientific papers, 20 abstracts (oral and posters presentations from the symposium) and a detailed list of publications based on material from the BIOFAR programme.

The first paper gives an overview of sampling and data-collection during BIOFAR 1, and summarizes the general results of the programme. Another paper sums up the current knowledge of biogenic sediments, substrates and habitats of the Faroese shelf and slope. The majority of the papers, however, deal with the taxonomy and biogeography of benthic flora and fauna around the Faroes. There are also a few papers with ecological or synthetic aspects, reflecting on the relationships of the Faroese benthic flora and fauna with those of the wider North Atlantic.

Some of the papers give a comprehensive survey of the geographic and bathymetric distribution of groups of organisms (e.g. Stylasteridae), but in others only a preliminary account of the fauna is given (e.g. Actinaria). Although taxonomic studies of some of the Faroese benthic groups have been completed, the proceedings indicate that many studies are still in progress and it will be some years before a relatively complete survey of the Faroese macrofauna will be available. Nevertheless the BIOFAR programme has already improved our knowledge of the diversity of marine species around the Faroes and in the North Atlantic, and highlighted the existence of particular benthic communities and their possible importance for marine ecosystems, e.g. those associated with mass occurences of large sponges and the scleractinian cold-water coral *Lophelia pertusa*.

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Priority Areas for Scientific Research: protecting scientific investments

Hjalmar Thiel

Priority Areas for Scientific Research (PASRs), formerly known as Scientific Priority Areas (SPAs*), are proposed as a way of protecting high seas localities where repeated and long-term studies are being conducted. Establishment of PASRs would guarantee science complete priority over all other uses of those high seas regions. The marine scientific community needs to develop stakeholder status with respect to these regions and to lobby for the safeguarding of the interests of all marine scientific disciplines.

During the last five years there has been a great increase and continued progress in activities promoting the establishment of Marine Protected Areas (MPAs) on the high seas. At the turn of the century this topic was up in the air, and the first international workshop on high seas MPAs (HSMPAs) was instigated in 2001 by scientists who realized the seriousness of the threat from fisheries to target species in particular, the marine biological community in general, and the wider marine environment. Subsequently, NGOs and politicians have catapulted these problems to the level of the United Nations. As scientists, we should be grateful that representatives from various organizations and from governments have assumed the responsibility for navigating HSMPAs through the countercurrents and gyres of politics. Scientists alone would not have been able to achieve this goal – we have neither the necessary words and phrases, nor the experience and connections, nor the financial support and the enormous amount of time demanded by such negotiations. Great progress has been made, but it will still be many years before we arrive at the final goal – the establishment of HSMPAs.

The primary goal and responsibility of most of us who attended the Southampton Deep-Sea Biology Symposium (see pp. 5–6) is the collection of material or data relating to organisms living in the deep sea, their functions and their environment, in order to know more about, and better understand, the deep-sea ecosystem and its dynamics. Our results are stored in the form of data banks or zoological and geological collections, and they are made public in lectures and papers. They are also essential for providing arguments in support of protective measures. Our research is funded by government agencies and research councils, the financial resources of which come from the public in the form of revenue from taxation. This is government policy, and by accepting the funds we are obliged to publish the results of our investigations.

Under the terms of the UN Law of the Sea, our research area – the deep sea – is divided into two regions: (1) exclusive economic zones, which extend up to 200 n.m.† from the coast and are managed through national legislation, and (2) the high seas beyond national jurisdiction, where legal regulation is inadequate. What follows below is focussed on the high seas but may also be relevant for deep-sea areas under national jurisdiction.

The freedom of the high seas allows free use of international waters and the underlying sea-bed, including use for all kinds of research activities. But today this freedom is reduced by competition between various interests: shipping, fisheries, mining, oil and gas drilling and exploitation, waste disposal, cable laying, wildlife protection, military uses and, last but not least, research interests. Various stakeholders may appropriate areas for their own activities without any knowledge of the ongoing work and interests of other stakeholders. The possibility of incompatible uses or competitive claims is an intrinsic characteristic of freedom of the high seas.

We already know of at least one case where scientific research is being hindered by commercial interests: a new communication cable is restricting research at a permanent British station at a depth of about 5000 m on the Porcupine Abyssal Plain in the north-east Atlantic. The station was established some 20 years ago and has since provided enormous scientific benefits. For example, repeated observations at the site revealed the occurrence of a marked and long-lasting change in species dominance and community structure in the invertebrate megafauna, which occurred in the mid-1990s (this is known as the '*Amperima* event', after *Amperima rosea*, one of the species of sea-cucumber whose numbers increased dramatically).

Another cause of disruption of long-term observations and data-collection is the destruction of equipment as a result of pelagic and benthic fishing. Competition between different activities in international waters may increase during the years to come, and we therefore need regulations within the area ruled by the freedom of the high seas.

The consequence of this situation of competitive claims is the need for communication between stakeholders. Scientific communities in the various countries involved must become effective stakeholders in their own field of interest, by regional cooperation (as in Europe, for example) or through international communication. The individual scientist does not have the competence to act as an effective stakeholder, but the scientific community should be able to build up internationally accepted stakeholder status to protect scientific investments in the deep sea. The scientific community may learn from the efforts of non-governmental organizations (NGOs) how best to establish protected areas throughout the oceans. Indeed, during the last five years, NGOs, together with governmental agencies, have laid a sound foundation, widely accepted internationally, for the establishment of HSMPAs. By the year 2012 a network of MPAs will span all the oceans, and various published sources consider that between 20 and 40% of the oceans may eventually be managed as MPAs.

As well as being obliged to publish the results of their deep-sea investigations, scientists are responsible for securing scientific investments once they have been made, particularly in the case of long-term studies. Disturbance of (or lack of access to) an area in which observations have been made over the course of many years in the past, and where comparative studies are planned for the future, would result in a tremendous loss of information; it would cut a broad swathe through scientific progress. Sites used for long-term observations lose their validity once they have been disturbed. Such a disaster would result at the very least in the loss of many years of comparative datasets, of investment in resources provided by the public, and of commitment of time and effort by scientific and administrative personnel. To avoid this happening, we scientists must find our way through legal conditions and regulations.

*The acronym SPA has been taken by 'Specially Protected Area'.

†n.m. = nautical mile (≈ 1.15 statute miles.

I think these potential conflicts can be surmounted with the help of government legal experts. Government administrators, like scientists, should be obliged to secure scientific investments through the development of suitable regulations. I propose that we should establish Priority Areas for Scientific Research (PASRs), i.e. areas reserved for repeated and long-term oceanographic research.

I believe that the difficulties in developing a legal framework for PASRs should not be any different from those in developing a legal framework for HSMPAs. PASRs and MPAs clearly have different basic aims – the protection of scientific investments versus the protection of biodiversity – but their incorporation into a legal framework might follow similar pathways. MPAs are being discussed in many organizations and committees, including the Convention on Biological Diversity (CBD) and the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS), and there is no reason to exclude PASRs from these discussions.

NGOs, particularly the World Conservation Union (IUCN*) through Kristina Gjerde (High Seas Policy Advisor), has offered to establish and manage PASRs together with HSMPAs. The IUCN has for many years discussed a unified system for classifying protected areas, and there is the possibility of integrating PASRs into this system as a separate category. However, according to the IUCN (1994), the overarching definition of protected areas (emphasized again during the International World Parks Congress in 2003) is:

'An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal and other effective means.'

This definition, with its emphasis on conservation, does not reflect the character and the requirements of PASRs, although under certain conditions the aim of PASRs may be achieved through measures intended to protect biodiversity and promote conservation. At the same time, areas reserved for scientific research will also have a certain protective character with respect to biodiversity, even though they relate to active research in all marine scientific disciplines rather than to conservation.

*IUCN = International Union for the Conservation of Nature and Natural Resources. The name was changed to World Conservation Union in 1990, but the former name was well known and is still commonly used.

In earlier publications I have proposed that the PASR management system should be separate from the MPA management system, but there seem to be political difficulties or reservations about achieving such regulation solely for scientific purposes. However, the organizational system is of minor importance; what is essential is the acknowledgement that research in all marine science disciplines may be conducted in PASRs.

Scientific work and its results are integral parts of our society and its concerns, and research activities should be regulated by evaluating society's interests in scientific results on the one hand, and measures to protect the deep-sea environment on the other. A Code of Conduct should commit all sea-going researchers to apply minimally invasive methods so as to safeguard life and the environment. Indeed, perhaps research funds should be approved only when careful consideration of methods to be used at sea have been accepted by reviewers.

Scientific projects are not simply the ideas of individual scientists. Their funding is generally based on well argued hypotheses and carefully considered research proposals, and on peer review within the (national and international) scientific community, with the aim of achieving important results and an effective use of funds. This system of science evaluation and control is established – with national modifications – in all countries funding deep-sea research. It therefore seems self-evident that the national, European and international scientific communities will be supported by representatives of the public, i.e. by politicians at national, European and international levels: by cooperating together, scientists and policy-makers should be able to protect scientific investments on the high seas. In this context it is also important that scientists themselves are charged with the responsibility for protecting life and the environment, and that they should not delegate their responsibility to conservationists.

There is no doubt that conservation and MPA management need scientific information, (1) before the elaboration of a proposal for MPA designation, and (2) after MPA establishment through repeated monitoring of the ecological status of the site, and the development of communities over time. In certain circumstances, cooperative research may be useful for scientists and conservationists, but conservationists should not expect all the data they would like to receive to be collected and supplied by the scientific community. Basic and applied research are funded by public resources to build up knowledge about the oceans. The results need to be published and made available to everyone. However, monitoring of communities in MPAs does not necessarily deliver all the data scientists need to answer their questions. Scientists must continue doing their research, and conservationists must raise funds for independent monitoring within their MPA management systems.

The German Marine Research Consortium will stimulate discussion of protecting scientific investments in the European and international science communities, aiming to secure scientific investments and to ensure effective research. In June 2006 the European Commission released a Green Paper entitled 'Towards a Future Maritime Policy for the Union: a European vision for oceans and seas' (see box on p.3). This European policy paper is open for comments and suggestions until June 2007 and it offers many opportunities for all stakeholders to contribute to the final version. The protection of scientific investments through the establishment of PASRs is an issue that should be incorporated into the Green Paper.

Further reading

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Europe’s role within the Census of Marine Life (CoML)

Brigitte Hilbig

As we are faced with increasingly crowded shorelines, oceanic pollution, and exhausted fisheries, along with growing concerns about global change, we need to make decisions which might help us to conserve life in the oceans. So that we will be able to distinguish regional declines from world-wide changes, a global Census of Marine Life (CoML) was initiated in 2000 under the leadership of an international Scientific Steering Committee. Support for the project comes from government and international agencies concerned with science, environment, and fisheries, as well as from private foundations and companies. CoML in its current form will continue until 2010, but there are certain to be numerous follow-up projects.

The Census of Marine Life (CoML) now involves scientists from eighty nations on five continents. Its goal is to assess and explain the changing diversity, distribution and abundance of marine species, from the past up to the present, and to make projections about marine life some decades into the future. Being a census means going beyond a search for unknown species, to encompass the diversity of species, where each species is to be found, and how abundant it is.

The scope of the project extends back into the past. Scientists throughout the world are using historical and environmental archives to construct a picture of the oceans before fishing became important around 1500. The aim is to determine the relative impacts of human activities and environmental fluctuations over the past 500 years or so, and to compile this information into a ‘History of Marine Animal Populations’ (HMAP).

CoML is also looking forward. Researchers contributing to ‘The Future of Marine Animal Populations’ (FMAP) are using statistical models to make predictions about animal life in the oceans of the future, focussing on changes to marine ecosystems driven by climate change and the effects of fishing.

The project encompasses habitats from icy polar waters to warm tropical seas, and from tidal zones shared by humans down into dark trenches, and all the life inhabiting them, from microscopic plankton in the sunlit layers, and sea mammals plunging beneath, to worms in abyssal sediments. It encompasses organisms on the slopes of seamounts and those inhabiting fiery oceanic vents.

CoML’s field projects

‘Ocean realm’ projects

ArcOD Arctic Ocean Biodiversity

CAML Census of Antarctic Ocean Marine Life

CenSeam A Global Census of Marine Life on Seamounts

CReefs Census of Coral Reefs

CoMARGE Continental Margin Ecosystems

GoMA Gulf of Maine Area

NaGISA Natural Geography in Shore Areas

POST Pacific Ocean Shelf Tracking Project

TOPP Tagging of Pacific Pelagics

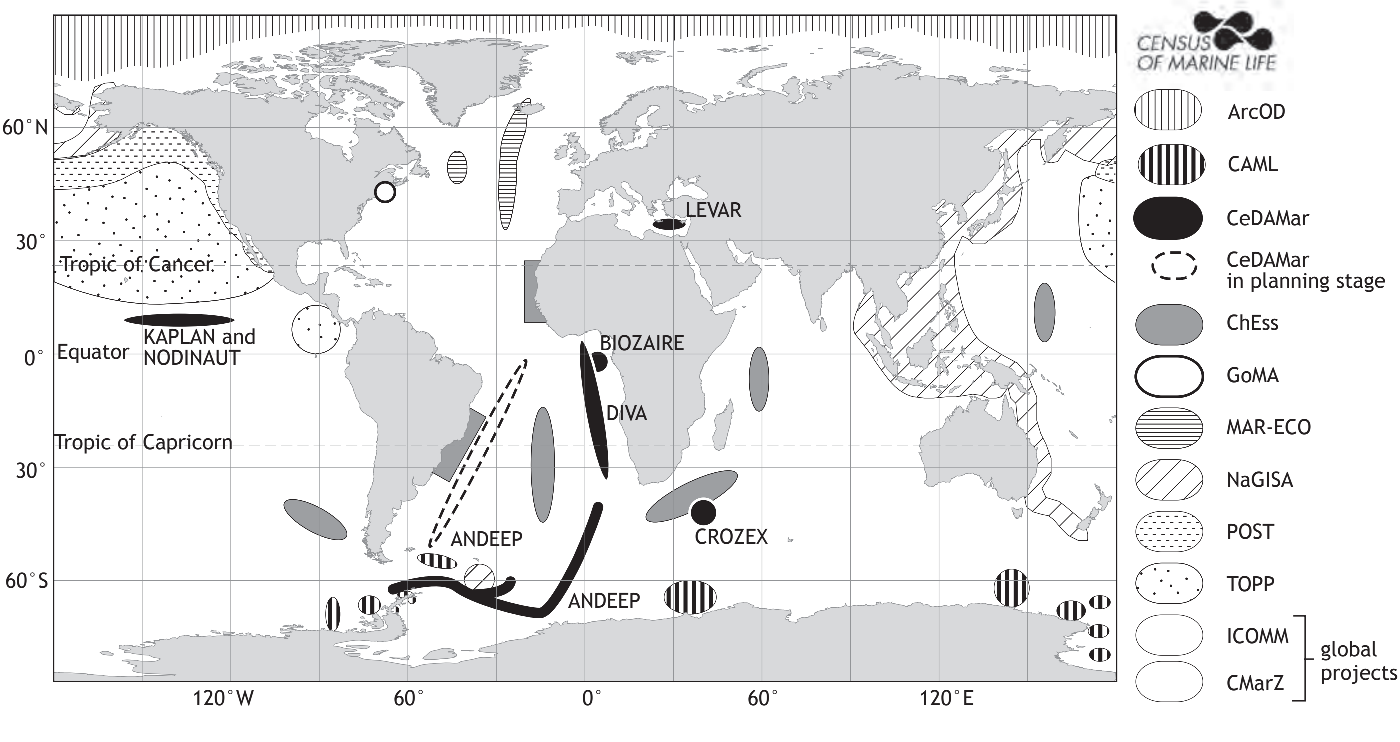
CeDAMar, **ChEss** and **MAR-ECO** are described in this article.

Global projects

CMarZ Census of Marine Zooplankton

ICOMM International Census of Marine Microbes

Map showing areas that are the focus of CoML’s field projects; CenSeam locations are too scattered to show on this map. Individual CeDAMar projects (labelled) are described in the box opposite.



For the world's few thousand marine scientists to progress beyond exploration to a global census requires wise and pragmatic strategies, including focussing on the knowable unknown within a limited time-frame. There are aspects of the ocean and of marine life that will remain unknown to us simply because it is impractical to explore them.

The map shows particular areas of the ocean which are the focus of CoML field projects. Within CoML, there are several so-called 'ocean realm' field projects which are under European leadership or have substantial European contributions. These include Mar-ECO, CeDAMar, ChEss, and several initiated more recently that are still in their planning phase (e.g. CoMargE, a project to explore continental margins).

CeDAMar – Census of the Diversity of Abyssal Marine Life – was intended to provide a platform to coordinate a number of similar projects and avoid duplication of effort at national and international levels. It began in 2002 with a major expedition to the Angola Basin, and had a major relaunch in 2004. It now includes abyssal research projects in five major areas of the world's oceans (see box, right).

Very little is known about how deep-sea species are distributed and what factors determine deep-sea species richness. CeDAMar projects address ocean-wide, large-scale patterns, and it is useful to study abyssal plains because they are relatively homogeneous environments, so excluding an unmanageable plethora of local parameters that may influence species distributions.

Deep-sea sediments are characterized by low biotic abundance and biomass, but also by very high species richness. Not unlike tropical rainforests, deep-sea sediments appear to represent reservoirs of genetic diversity and evolutionary novelties. The reasons for this astounding and counter-intuitive finding remain one of the major puzzles of our time.

Between 50 and 90% of the species collected in a typical abyssal sample are new to science and have never been seen before by anybody. Systematic and taxonomic studies of these organisms are as exciting as they are challenging and require well trained and experienced specialists. Their number, however, has been dwindling for years, and now there is a serious lack of knowledge and, above all, people with taxonomic expertise to address these questions. At the same time, it has once again been recognized that taxonomy is at the hub of all biological research.

Going to the very bottom of the ocean: Census of the Diversity of Abyssal Marine life (CeDAMar)

Project leaders: Pedro Martinez Arbizu, Wilhelmshaven, Germany, and Craig Smith, Hawaii, USA

Describing latitudinal gradients in the Atlantic Ocean: DIVA and BIOZAIRE

DIVA explores the biodiversity of abyssal basins between Cape Town and the Ivory Coast, and ultimately establishes a complete pole-to-pole transect in the Atlantic Ocean. BIOZAIRE focusses on abyssal sites in a high productivity area influenced by the Zaire Channel.

Diversity and Biogeography of Antarctic deep-sea fauna: ANDEEP

The abyssal areas of the Atlantic sector of the Southern Ocean are the focus of this project, which provides the first baseline survey of benthic deep-sea fauna of the Scotia and Weddell Seas and the Drake Passage.

Asbestopluma *sp., a newly discovered carnivorous sponge, about 1 cm in diameter, which engulfs other organisms with its 'mouth', found on the deep sea-bed of the Southern Ocean.*

© 2005. Dorte Janussen, Senckenberg Museum, Frankfurt

Diversity and gene flow in nodule regions of the central North Pacific: KAPLAN and NODINAUT

These projects are designed to exploit recently developed molecular techniques to evaluate biodiversity levels, geographic ranges, and rates of gene flow for dominant animal groups living in the area targeted for mining of manganese nodules (known as the 'Pacific nodule province').

Mediterranean Sea: Diversity patterns in a warm deep sea: LEVAR

Unlike other deep-sea areas, the Mediterranean abyss is warm (around 13 °C), extremely poor in nutrients, and in some areas extremely saline. LEVAR will study diversity patterns in the deep areas of the Mediterranean Sea in relation to distance from the coast and food availability.

Indian Ocean: Diversity versus food availability: CROZEX

This programme's intention is to characterize the diversity and community structure of the benthos, from protozoan meiofauna to large invertebrate megafauna, in a permanently HNLC (High Nutrient, Low Chlorophyll) region to the south of the Crozet Islands, and at a similar location to the north-east of the islands where the sea floor receives seasonal pulses of organic matter.

Studies of abyssal diversity and biogeography are complicated by the logistical challenges of deep-sea exploration. Today, the total sampled area of deep sea floor covers the equivalent of only a few football pitches, and generalizations made from such a small area are to be viewed with great caution.

Only a concerted international research programme can tackle the logistical challenges at such a large scale and provide a broad foundation of knowledge on the biodiversity and distribution of abyssal species. Activities of CeDAMar include the promotion of a carefully coordinated series of cruises and expeditions, standardization of sampling schemes and sample-processing methods, support of taxonomists' exchanges and workshops, and contribution to the worldwide, freely accessible database OBIS – the Ocean Biogeographic Information System – one of the legacies of CoML (see Further Reading).

The year 2005 was marked by two major expeditions to the Southern Ocean (ANDEEP III) and the Atlantic basins off southern Africa (DIVA-2), as well as publication of two special volumes reporting first results of the expeditions ANDEEP I/II and DIVA-1 (see Further Reading).

CeDAMar taxonomists also have come closer to another major goal, the description of 500 of the most common and/or ecologically important abyssal species. The count is now up to 186, including redescriptions of species that were already known about. These redescriptions become necessary as a result of re-examination of museum material containing more than one species under the same name.

While CeDAMar tries to unravel the mysteries of a habitat that seems quite uninteresting at first sight, two other projects – MAR-ECO and ChEss – focus on spectacular parts of the deep ocean: the Mid-Atlantic Ridge and chemosynthetic environments such as hydrothermal vents. For more information about MAR-ECO and ChEss, see the boxes to the right.

CoML is constantly growing. As of the start of of 2007, some 2000 participating organizations were contributing to Census projects, and new members are always welcome to join this global network of experts. The easiest way to get in contact with the Census or one of its projects is the web portal www.coml.org, and the most important requirement is open access to all data via OBIS (see Further Reading).

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Brigitte Hilbig, of the German Centre of Biodiversity Research, Senckenberg Institute, is the Education and Outreach Officer of the CeDAMar project. Her scientific interest focusses on the systematics and taxonomy of deep-sea polychaetes.

See opposite for the latest news from CAML.

Negotiating the largest mountain range on Earth: MAR-ECO

Project leader: Odd Aksel Bergstad, Norway

MAR-ECO's target area is the waters associated with the Mid-Atlantic Ridge between Iceland and the Azores, a section of the global mid-ocean ridge system. The study aims to develop and demonstrate strategies and technology for use in other mid-ocean ridge areas and hence provide a basis for world-wide exploration of ridge-associated communities and ecosystems. The focus is on animals utilizing photosynthetic production in the surface layer, including deep-sea animals dependant on vertically migrating visitors from above or food-falls (marine snow and other organic debris).

The pelagic fish fauna over the Mid-Atlantic RIdge is very diverse. Thus far, 209 species from 56 families have been recorded in the catches from mid-water trawls. A preliminary inventory of demersal fishes shows that 69 species occur in the region. The most remarkable result is that about 22% of the species identified were new for this geographical area. This shows that the level of knowledge of mid-ocean fish fauna remains low, and that MAR-ECO will significantly enhance knowledge of occurrence and distribution.

Several descriptions of new species of fish parasites are being submitted. Knowledge of deep-sea fish parasites is very limited indeed, and parasite studies also form elements of food-web studies.

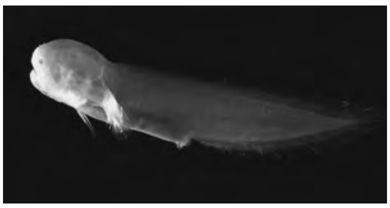
Knowledge of the mid-ocean cephalopod fauna will be enhanced by analysis of the extensive collections. At least two species new to science are being described, and for the more abundant species new community data and distribution patterns will be revealed.

About 150 species of benthic invertebrates were collected as by-catch in the bottom trawls of RV *G.O. Sars* (depth range 826–3505 m). There is also extensive footage of benthic and benthopelagic invertebrates (i.e. those living on the sea-bed and in lthe waters above it) from ROV dives, not least from dives by the Russian submersible *Mir* in the Charlie Gibbs Fracture Zone, which crosses the Mid-Atlantic Ridge at about 55° N.

This red Peniagone *sea-cucumber is one of four new species of sea-cucumbers discovered by CoML scientists along the Mid-Atlantic Ridge.*
©2004, Andrey Gebruk

One result of MAR-ECO will be inventories of the occurrence of cold-water corals along the Mid-Atlantic Ridge – new data of particular significance for management of habitats and fisheries. Among the more exotic finds so far has been the discovery of a new family of deep-sea Enteropneusta (Hemichordata) (see Further Reading).

MAR-ECO also offers a unique opportunity to study the occurrence and distribution of marine mammals (essentially cetaceans) and seabirds in a mid-ocean environment. Data collected on sightings made during several cruises have provided new distribution information for a range of small and large species. In April 2005, attempts to attach satellite tags to large baleen whales were followed up, and three sei whales (*Balaenoptera borealis*) and one blue whale (*Balaenoptera musculus*) were tagged. One of the sei whales was followed for a distance of 1920 nautical miles (3500 km) while migrating north to the Charlie Gibbs Fracture Zone where it spent an extensive period of time before migrating westwards away from the Mid-Atlantic Ridge.



Aphyonus gelatinosus*, a strange bottom-dwelling fish covered by a gelatinous layer, which has only been recorded twice. One of these times was by CoML scientists during an expedition along the northern Mid-Atlantic Ridge. ©2004, David Shale*

Life without sunlight: ChEss

Project leaders: Paul Tyler, Chris German, Great Britain, and Eva Ramirez-Llodra, Spain

Hydrothermal vents were first discovered in 1977 in the eastern Pacific, and since then many more sites have been discovered all over the world. Hydrothermal fluid, originating from seawater seeping through the Earth's crust, emerges from the sea floor at temperatures as high as 350-400 °C. The fluid is acidic, without oxygen, and rich in a variety of dissolved ions. When these ions come into contact with cold seawater, they precipitate to form minerals, and may build up huge chimneys reaching tens of metres in height.

Cold seeps are similar environments where methane and sulphide-rich fluids seep through the sediment. There are several other types of environments without (or with very little) oxygen, including 'whale falls' (the remains of dead whales), sunken wood, and places where oxygen-minimum zones in the water column intersect continental margins. The animal communities living in all of these environments seem to thrive independent of sunlight and photosynthetic production, but instead are based on chemosynthesis.

ChEss has the objective of exploring and documenting this very unusual and largely unknown type of community, to find similarities and differences among them, and to find new oxygen-depleted sites with chemosynthetic communities. For this purpose, ChEss is developing three main field programmes in target areas where different chemosynthetic systems and a number of ecological, geological, evolutionary and topographic parameters, come together:

1. The Equatorial Atlantic Belt: A range of environments, extending through the Costa Rica and Gulf of Mexico cold seeps, the Cayman Trough, the Barbados Accretionary Prism, hydrothermal vents on the Mid-Atlantic Ridge north and south of the Equatorial Fracture Zones, and on to cold seeps on the continental margin of west Africa. The aim is to understand connectivity and isolation of geographically distant chemosynthetic ecosystems.

2. South-east Pacific: Active vents on the Chile Rise, cold seeps on the Chile margin, a well established oxygen-minimum zone on the Peru–Chile continental margin, and a high potential for whale falls and sunken wood. Through a Worldwide University Network Grand Challenge Project, the aim is to investigate the phylogenetic relationships of species where distance is not a barrier for dispersal and colonization.

3. New Zealand region: Vents on the Kermadec Arc, seeps on the eastern margins of the North and South Island, an important whale migration route (with an increased likelihood of whale falls), and the potential for sunken wood in the southern fjords. These sites are also useful for comparison with the south-east Pacific region, allowing investigation of relationships across ocean basins.

Cold-seep tubeworm *Lamellibrachia luymes*

© Ian MacDonald, Texas A&M University

First hints of biological change at former site of Larsen A and B ice-shelves

The International Polar Year (IPY) is beginning with some fascinating insights into how fast life on the deep sea-floor can change when conditions at the sea-surface are altered. The Larsen A and B ice-shelves collapsed 12 and five years ago respectively, allowing 10 000 km^2 of Antarctic sea-bed to be overlain only by water for the first time in at least 5000 years – in the case of Larsen B, perhaps as much as 12 000 years. This nearly pristine area of sea-bed, previously only 'glimpsed' via drill holes, has been the subject of a biological survey (sampling and photographing) from the German ice-breaking research vessel *Polarstern*. This expedition was part of the Census of Antarctic Marine Life (CAML), which has 13 more cruises scheduled for the IPY.

The sea-bed in question is at a depth of about 850 m, and ranges from bare rock to mud. Cameras on the remotely operated vehicle (ROV) revealed that scouring by icebergs breaking away from the ice-shelf was much less than expected, although at depths of about 100 m there were many fresh ice-scour marks and animal communities at an early stage of recolonization. At a depth of 200 m there was a mosaic of life at different stages of recolonization.

For animals living on the sea-bed, the abundance was only about 1% of the that in the ice-covered eastern part of the Weddell Sea, but the species diversity was surprisingly high, especially at depths of 220 m and less.

Unusually for relatively shallow water, there were many sea-lilies (crinoids), sea-cucumbers and sea-urchins, animals typically found on the deep sea-bed (which, like ice-covered waters, receives relatively little organic material falling from the sea-surface). There were dense patches of fast-growing sea-squirts – almost certainly new arrivals – as well as numbers of slower growing glass sponges, especially in the Larsen A area.

Some new species have been discovered – amongst 400 specimens of amphipods (small crustaceans), 15 may be new species, including one of the largest ever found off Antarctica, ~10 cm long. There are also four potentially new species of cnidarians (the group that includes sea-anenomes, corals and jellyfish).

Understanding Sea-level Rise and Variability

Report of UNESCO Workshop, Paris, June 2006

John Church, Stan Wilson, Philip Woodworth and Thorkild Aarup

Most people will be aware of the pressures on the coastal zone due to growing populations and increasing urbanization, in addition to the increased risks of flooding due to storm surges and sea-level rise. It is estimated that, in 1990, 23% of the world's population (1.2 billion people) lived within 100 km of the coast and at elevations within 100 m of sea-level, at population densities about three times higher than the global average. Two-thirds of the world's largest cities are located at the coast and are increasingly vulnerable to storms – as so graphically illustrated by Hurricane 'Katrina'. Rising sea-levels will undoubtedly result in more flooding, even if storm intensities do not increase in response to the warming of the oceans; and the world's sandy beaches, 70% of which have retreated over the past century, will continue to erode. It is clear that there is a need for improved understanding of the reasons for sea-level rise and for all the spatial and temporal variations in sea-level, so as to reduce the uncertainties in sea-level rise projections, thereby contributing to more effective coastal planning and management.

During 6–9 June 2006, the World Climate Research Programme (WCRP) convened a workshop in Paris to identify the uncertainties associated with past and future sea-level rise and variability (cf. Figure 1), and to determine the research and observational activities needed if we are to narrow the uncertainties. It was hosted by the Intergovernmental Oceanographic Commission of UNESCO and was co-sponsored by 34 organizations. It assembled a wide range of expertise with the participation of 163 scientists from 29 countries. The workshop was also conducted in support of the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan with the objective of developing a consensus on the observational requirements to address sea-level change.

Participants reviewed current knowledge of sea-level changes obtained from different measurement techniques (geological, archaeological, tide gauge, radar altimeter, space gravity etc.). They also reviewed all the mechanisms which contribute to present-day sea-level rise – e.g. oceanic thermal expansion, cryospheric (ice-cover) and hydrological change, vertical land movements – or contribute to changes in extreme sea-levels (e.g. frequency and magnitude of tropical and mid-latitude storms). Recommendations were then assembled on how the uncertainties in each process could be reduced. Most recommendations were intended to guide ongoing research and observational programmes, others aimed to encourage open data sharing, data archaeology, and better use of existing data. An overview of the workshop and a Workshop Statement on research and observational priorities is available at the website given at the end.

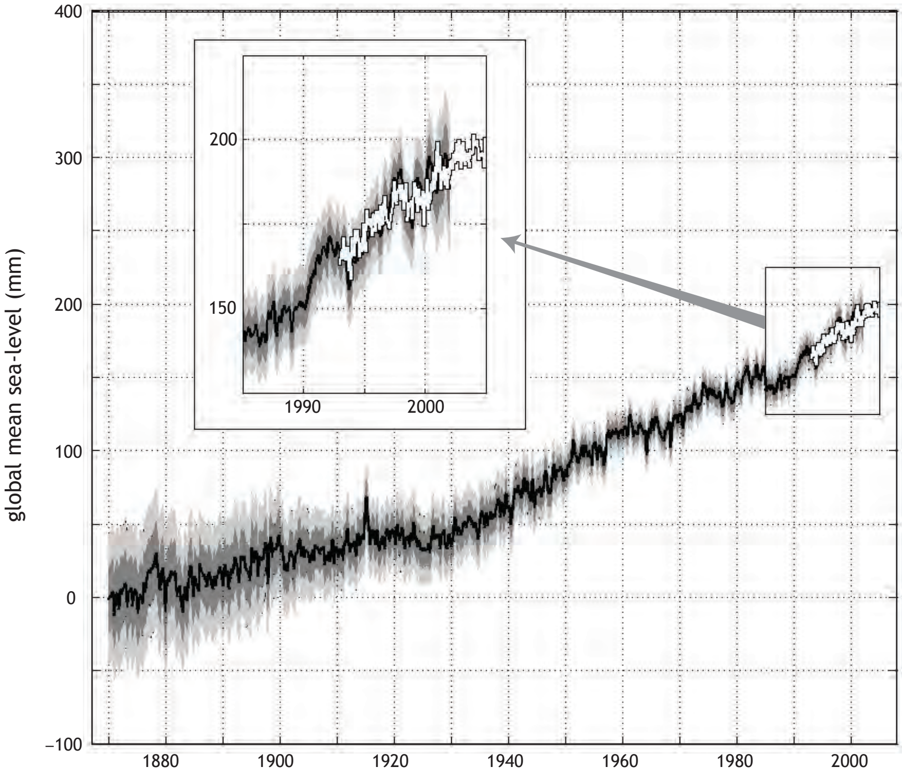


Figure 1 *Monthly averages of global mean sea-level reconstructed from data from tide gauges (black, 1870–2001) and altimeters (white, 1993–2004) (the seasonal cycle has been removed). (Courtesy: John Church and Neil White)*

A particularly important element of the workshop was concerned with the need for continuity of *in situ* and space-based observing systems, with an emphasis on all systems adhering to the Global Climate Observing System (GCOS) observing principles, including open data policy and timely unrestricted access to information. The workshop identified a number of existing and new technologies which are required to reduce sea-level uncertainties, all of which complement existing requirements for monitoring identified by study groups in related fields of research. The workshop concluded with a synthesis session on how its findings can best be taken forward so as to meet the research and monitoring requirements.

The website cited below can be consulted for further information and for copies of the posters presented by workshop participants. It is intended that an extended workshop report will be published in book form in 2007.

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For more information see: http//copes.ipsl.jussieu.fr/Workshops/Sealevel/.

The impacts of sea-level rise

Robert J. Nicholls
with Anny Cazenave

Sea-level rise is widely seen as a major threat to low-lying coastal areas around the globe. What is not always appreciated is that large populations already live below high tide, including, for example, 10 million people in the Netherlands and 4 million people in Japan. Globally, more than 200 million people live in areas at risk of coastal flooding. Many of these exposed populations depend on artificial flood defences and drainage – Hurricane 'Katrina' reminds us of what happens if those defences fail. While it is widely accepted that sea-level rise is a threat, the actual consequences of sea-level rise remain uncertain and contested. Pessimists tend to focus on possible high rises in sea-level and events like 'Katrina', and view our ability to adapt as being limited; they see an alarming future, with widespread human displacement from coastal areas. Optimists tend to focus on lower rises in sea-level, stress humanity's ability to adapt (as exemplified by the Dutch and the Japanese) and wonder what all the fuss is about. This article focusses on understanding the threat and the different views of its importance. It includes consideration of the impacts of rising sea-level on coastal areas, as well as the types of responses that might be implemented. These are divided into 'mitigation' (reducing greenhouse gas emissions and hence climate change, via climate policy) and 'adaptation' (reducing the impacts of sea-level rise via coastal management policy). The article illustrates how understanding the impacts of sea-level rise crosses many disciplines and embraces natural sciences, social science, and engineering.

Climate change and sea-level rise

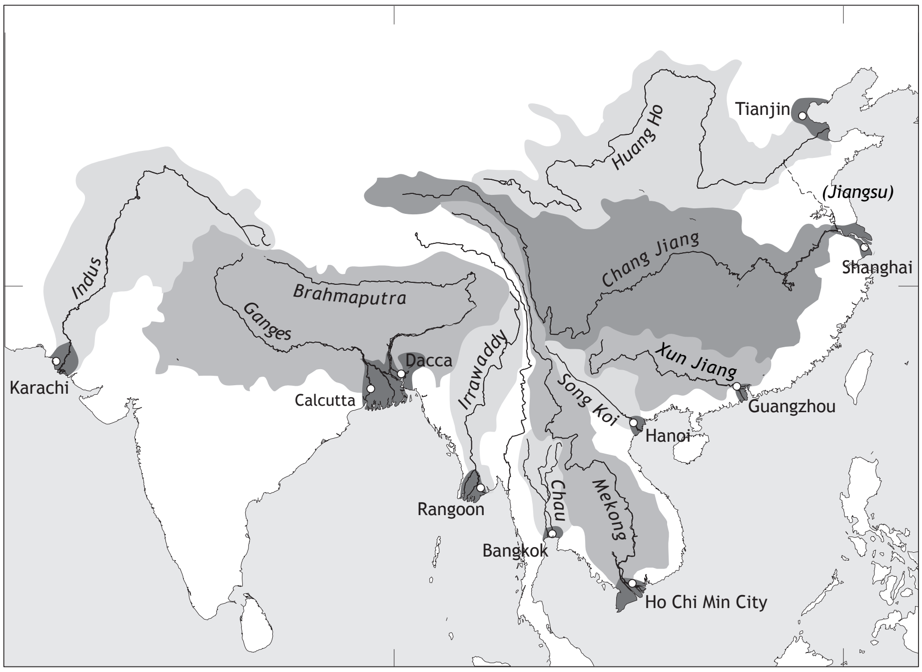
Human-induced climate change is expected to cause a profound series of changes including rising sea-level, rising sea-surface temperatures, and changing storm, wave and run-off characteristics. Rising global sea-level due to thermal expansion and the melting of land-based ice is already being observed (see Box on p.18), and this rise is likely to accelerate through the 21st century: from 1990 to the last decade of the 21st century, a total rise in the range 19–58 cm has been forecast by the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report (2007), although this range does not reflect all the uncertainties, which probably raise the upper value by at least 14 cm.. There is also increasing concern about higher extreme sea-levels due to more intense storms superimposed on these mean rises, especially for areas affected by tropical storms. These would exacerbate the impacts of global sea-level rise. Although higher sea-level only directly impacts coastal areas, these are the most densely populated and economically active land areas on Earth, and they also support important and productive ecosystems that are sensitive to sea-level change.

It is important to understand that coastal managers are concerned about relative (or local) sea-level rise rather than global sea-level rise, although these two factors are clearly linked. Relative sea-level rise takes into account global sea-level rise, regional sea-level change (as illustrated by *Topex* altimetry data; see Box) and geological uplift/subsidence and related processes which change the position of the land/sea boundary. Hence relative sea-level rise varies from place to place. Sea-level is presently falling due to ongoing isostatic adjustment (rebound) in high-latitude locations that were formerly sites of large (kilometre-thick) glaciers, such as the northern Baltic and Hudson

Figure 1 *The 'Katrina' hurricane over the Gulf of Mexico: it is possible that a warmer ocean could contribute to more intense hurricanes.*

(Courtesy: NASA/Jeff Schmaltz, MODIS Land Rapid Response Team)

More intense hurricanes could add to the problems caused by rising sea-level



In delta areas sea-level is locally rising more than average

__Figure 2__ The nine low-lying Asian megadeltas are all subsiding to some degree, so sea-level rise is already a severe threat that can only get worse. The present population of these deltas is about 250 million.

Bay. In contrast, sea-level is rising more rapidly than global-mean trends on subsiding coasts, including most deltas; subsiding deltas include the Mississippi delta, USA, and the 'megadeltas' of south and east Asia (Figure 2).

Most dramatically, human-induced subsidence of susceptible areas due to drainage and withdrawal of groundwater can produce significant rises in relative sea-level: to give three noteworthy examples, over the 20th century Tokyo subsided by 5 m, Shanghai subsided by 3 m, and Bangkok subsided by 2 m. Hence, these cities have already experienced a relative rise in sea-level much greater than the global rise expected during the 21st century. To avoid submergence and/or frequent flooding, they now all depend on sophisticated flood defences and water management infrastructure, and so demonstrate successful adaptation to large relative rises in sea-level. However, for these cities a risk of flooding always remains, and any failure of the defence system could be catastrophic.

We are fairly certain that sea-level will continue to rise because of human-induced global warming far beyond the 21st century, due to the large thermal inertia of the oceans. It takes centuries to millennia for the full ocean depth to adjust to a global warming, resulting in ongoing thermal expansion.

In some coastal megacities, sea-level rose more than 1 m during the 20th century due to groundwater withdrawal and resulting subsidence

__Figure 3__ Coastal megacities that have subsided during the 20th century. The maximum observed subsidence (in metres) is given for those five that have subsided the most. Note that a number of these megacities (including Karachi, Calcutta, Dacca, Bangkok and Shanghai) have been built on deltas (cf. Figure 2).

This inevitable rise is termed the 'commitment to sea-level rise'. If global warming passes key thresholds for the breakdown of the Greenland or West Antarctic ice sheets, the committed rise could be many metres, albeit over long time-scales (centuries). Mitigation (reducing greenhouse warming) can reduce but not avoid the commitment: it appears that sea-level rise will remain a challenge for many generations to come.

Impacts of sea-level rise

Relative sea-level rise has a wide range of effects on the natural system, which are summarized in Table 1. Along with the rising sea-level, there are changes to all the processes that operate around the coast. The immediate effect is submergence and increased flooding of coastal land, as well as saltwater intrusion into surface waters. Longer-term effects also occur as the coast adjusts to the new environmental conditions, including increased erosion and saltwater intrusion into groundwater. These lagged changes interact with the immediate effects of sea-level rise and often exacerbate them. For instance, coastal erosion will tend to degrade or remove natural protective features (e.g. sand dunes) so increasing the risk of coastal flooding.

In addition to the general rise in sea-level, changes in extreme sea-levels due to changing storm characteristics also need to be considered: for example, an increase in the number and intensity of Atlantic depressions crossing north-west Europe would generally result in more frequent and/or higher storm surges. For most coastal regions, changes in extreme sea-levels under climate change have not been investigated.

Sea-level rise does not happen in isolation (see Table 1 for interacting factors) and it is one of a number of changes that are affecting the world's coasts. This needs to be considered when assessing possible impacts of sea-level rise. A simple systems model of the coastal zone which captures the key interactions is shown in Figure 4. This characterizes the overall coastal system as interacting natural and human (sub)systems, which have the potential to constrain each other's evolution. This approach emphasizes that sea-level rise interacts with other stresses, which often lead to greater impacts; and the socio-economic system is not passive as it influences the natural system

Sea-level rise directly and indirectly affects both natural and socio-economic systems, and influences other stresses acting on them

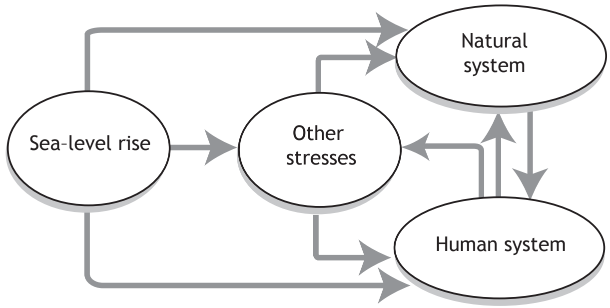


Figure 4 *Systems model of the effect of sea-level rise on the coastal system. The natural environment and coastal inhabitants are both affected by sea-level rise and other environmental stresses (caused by climate change and by other factors), and also affect one another.*

Table 1 *The main natural system effects of relative sea-level rise, including examples of interacting factors and examples of adaptations of the socio-economic system to these effects. Some interacting changes (e.g. sediment supply) appear twice as they can be influenced both by climate and non-climate factors.* ***P*** *– Protection;* ***A*** *– Accommodation;* ***R*** *– Retreat (see Figure 5 overleaf).*

EFFECT OF NATURAL SYSTEM		INTERACTING FACTORS		ADAPTATIONS
		Climate	Non-climate	
Inundation, flood and storm damage	Surge (flooding from the sea)	Wave/storm climate Erosion Sediment supply	Sediment supply Flood management Erosion Land reclamation	Raise heights of dykes/surge barriers **P** Alter building codes/build floodwise buildings **A** Improve land-use planning/hazard delineation **A/R** Operate flood forecast and warning systems **P/A**
	Backwater effect (flooding from rivers)	Run-off	Catchment management and land use	
Wetland loss (and change)		Increased plant growth in response to rising CO_2 Sediment supply Migration space for ecosystems	Sediment supply Migration space for ecosystems Land reclamation (i.e. direct destruction)	Improve land-use planning **A/R** Managed realignment/banning of hard defences **R** Nourishment (addition of sediment) /sediment management **P**
Erosion (direct and indirect morphological change)		Sediment supply Wave/storm climate	Sediment supply	Improved coastal defences **P** Nourishment of beaches etc. **P** Building setbacks **R**
Saltwater intrusion	Surface waters	Run-off	Catchment management and land use	Construct saltwater intrusion barriers **P** Reduce freshwater abstraction **A/R**
	Groundwater	Rainfall	Land use Aquifer use	Freshwater injection **P** Reduce freshwater abstraction **A/R**
Rising water tables/ impeded drainage		Rainfall Run-off	Land use Aquifer use Catchment management	Upgrade drainage systems **P** Construct polders (reclaimed land) **P** Change land-use (e.g. agricultural to saltmarsh) **A** Improve land-use planning/hazard delineation **A/R**

through, for example, deliberate adaptation and other changes (e.g. construction of sea dykes, destruction of wetlands, and building of port and harbour works), as well as a range of unintended changes (e.g. modifications to sediment and water fluxes due to catchment management, especially through the building of dams).

Changes in the natural system have many important direct socio-economic impacts on a range of sectors. For instance, flooding can damage key coastal infrastructure, the built environment, and agricultural areas, while erosion can lead to loss of buildings and adverse consequences for sectors such as tourism and recreation. In addition to these direct impacts, there are indirect impacts such as adverse effects on human health: for example, mental health problems increase after a flood. Thus, sea-level rise has the potential to be the trigger for a cascade of direct and indirect impacts through the socio-economic system.

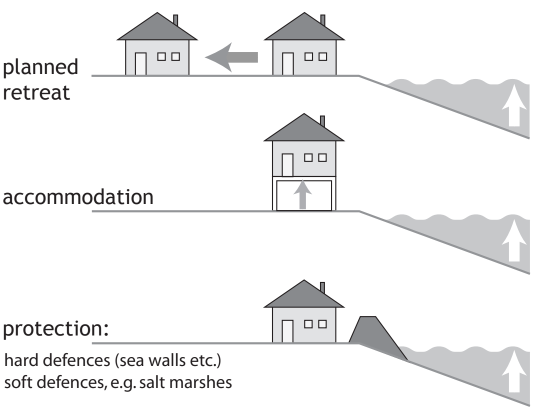
Adaptation can reduce or even avoid these potential impacts. As shown schematically in Figure 5, there are three distinct types of human response to a hazard such as sea-level rise:

- Retreat – manage the hazard by reducing exposure.
- Accommodate – manage the hazard by reducing its impacts.
- Protect – manage the hazard by reducing the probability of occurrence.

The 'Adaptations' column in Table 1 gives examples of each of the three types of approaches.

Society has three distinct choices when adapting to sea-level rise

Figure 5 *The three approaches to dealing with sea-level rise.*



Recent impacts of sea-level rise

Over the course of the 20th century global sea-level may have risen about 18 cm (cf. graph on p.12, and Box 1). Identifying the impacts of these changes is difficult as there have been so many human-induced changes in coastal areas over this period due to the rapid expansion of coastal populations and development. (These are the 'other stresses' in Figure 4, and the 'non-climate' factors in Table 1.)

There have certainly been impacts from the relative sea-level rise resulting from the human-induced subsidence of megacities (Figure 3), in terms of increased waterlogging, flooding and submergence: south of Bangkok subsidence has led to a shoreline retreat of more than a kilometre (Figure 6). On the US east coast, a linear relationship has been demonstrated between the rate of shoreline retreat and the long-term rate of relative sea-level rise. Human abandonment of low-lying islands in Chesapeake Bay in the late 19th/early 20th century has also been linked to sea-level rise. But for most coasts, the effects of sea-level rise are less apparent because of the multiple causes of coastal change and/or our incomplete understanding of the impacts of sea-level rise.

Future impacts of sea-level rise

Assessments of the future impacts of sea-level rise have taken place on a range of scales from local to global. They all confirm a potentially large impact by the effects listed in Table 1. For instance, parts of southern Asia and Africa stand out as being most vulnerable in absolute terms due to surge flooding (high sea-levels caused by low atmospheric pressure) combined with sea-level rise (Figure 7). One study estimated that for a 45-cm rise in sea-level, more than 70 million people might be impacted in Asia, and more than 10 million people in Africa. Small island regions in the Pacific, Indian Ocean and Caribbean stand out as being especially vulnerable to flooding, even though relatively few people are affected in global terms. Low islands such as the Maldives or Tuvalu face the real prospect of complete submergence and abandonment.

However, adaptation can greatly reduce the impacts. Benefit–cost models that compare protection with retreat generally suggest that it is worth investing in widespread protection as coastal areas are often of high economic value. Under the

Subsidence has caused the shoreline south of the megacity of Bangkok to move inland by about a kilometre

Figure 6 *A line of telegraph poles south of Bangkok: built on subsiding land, they are now as much as a kilometre out to sea.*

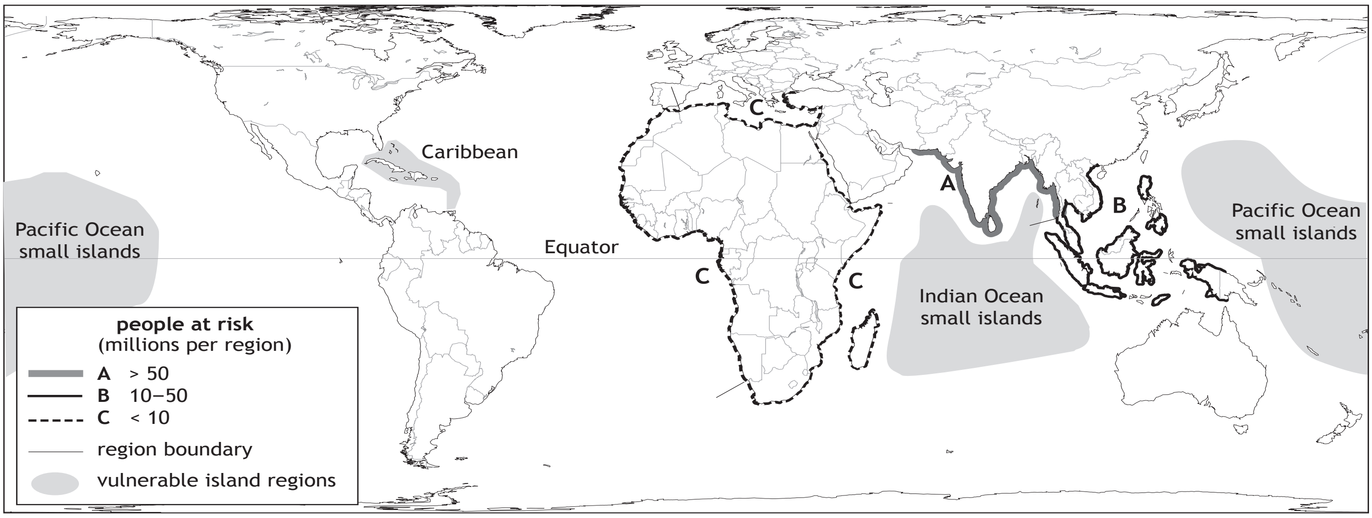


Figure 7 The regions most vulnerable to coastal flooding, based on an illustrative scenario for the 2080s, assuming a middle estimate of global sea-level rise by that time of 45 cm. (Note: The African coastline comprises three 'regions'.)

Most people at risk from sea-level rise live around the Indian subcontinent and in SE Asia

typical scenarios of economic growth assumed in most analyses, some benefit–cost climate impact models suggest that the absolute impacts of flooding will actually fall below the impacts experienced in 1990, as richer societies (including some in the developing world) become increasingly intolerant of risk and have the income to invest in defences. This again emphasizes how one's view of the threat of sea-level rise depends critically on one's view of the success or failure of adaptation.

As discussed earlier, impacts of sea-level also interact. Coastal ecosystems are threatened by sea-level rise, and these impacts are exacerbated by the hard defences that might be built to enhance human safety. Hence, even if we can adapt, there is the important challenge to coastal management of developing responses that deliver both human safety and healthy coastal ecosystems. This implies a need for more integrated responses, consistent with the ideals of integrated coastal management.

Concluding remarks

So the optimists have evidence to support their views in both empirical data (subsiding megacities that are also thriving), and benefit–cost analyses. These suggest that improved protection is much more likely and rational than is widely assumed. Hence the common assumption of a widespread retreat from the shore is not inevitable, and coastal societies will have more choice in their response to rising sea-level than is often assumed.

However, the pessimists also have evidence to support their view. First, socio-economic scenarios are usually optimistic about future economic growth: lower growth may mean less damage in monetary terms, but it will also lead to less protection. Secondly, the benefit–cost approach implies a proactive attitude to protection, while historical experience shows most protection has been a reaction to actual or near disaster. Therefore, high rates of sea-level rise may lead to more frequent coastal disasters, even if the ultimate response is better protection. Thirdly, disasters such as Hurricane 'Katrina' could trigger coastal abandonment, and hence have a profound influence on society's future choices concerning coastal protection as the pattern of coastal occupancy might change radically. A cycle of decline in some coastal areas is not inconceivable, especially in future world scenarios where capital is highly mobile and collective action is weaker. As the issue of sea-level rise is so widely known, disinvestment from coastal areas may be triggered even without disasters actually occurring: for example, the economies of small islands may be highly vulnerable if investors become cautious. Lastly, retreat and accommodation have long lead times – benefits are greatest if implementation occurs soon – but this is not happening widely as yet. For these reasons, adaptation may not be as successful as some assume, especially if rises in sea-level are at the higher end of the range of predictions.

Thus the optimists and the pessimists both have arguments in their favour. Sea-level rise is clearly a threat, which demands a response. Scientists need to better understand this threat, including the implications of adaptation and/or mitigation, and need to engage with the coastal and climate policy process so that these scientific perspectives are heard.

Given both the commitment to sea-level rise and the risk of many metres of sea-level rise due to ice-sheet collapse, a combination of mitigation (to reduce the risks of a large rise in sea-level) and adaptation (to the inevitable rise) appears to be the most appropriate course of action, as these two policies are more effective when combined than when followed independently, and together they address both immediate and longer term concerns.

See overleaf for the Box on 'Recent sea-level change' by Anny Cazenave

Further reading

Nicholls, R.J., P.P. Wong, V. Burkett, J. Codignotto, J. Hay, McLean, R., Ragoonaden, S., and C. Woodroffe (2007) Chapter 6: Coastal Systems and Low-lying Areas. In *IPCC Fourth Assessment Working Group II Report (Impacts, Adaptation and Vulnerability)* (forthcoming).

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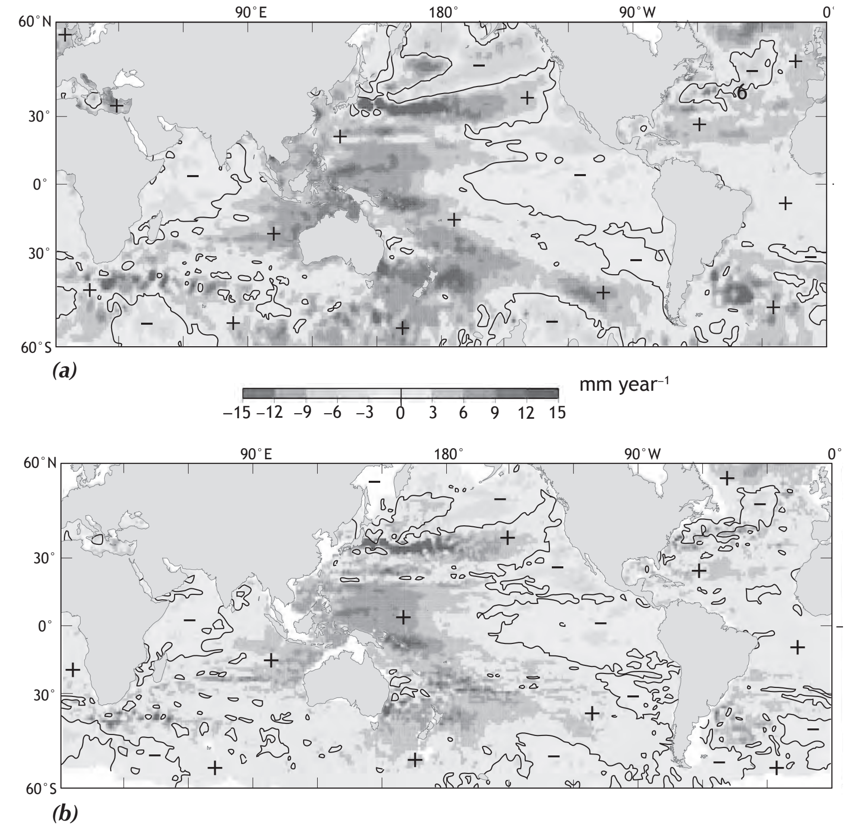
Recent Sea-Level Change   Anny Cazenave

Historical tide-gauge data suggest that during the second half of the 20th century, global mean sea-level was rising at a rate of about 1.8 mm yr^{-1} (cf. Figure 1, p.12). However, satellite altimetry observations of the shape of the sea-surface (*Topex–Poseidon* and *Jason-1* missions), available since the early 1990s, indicate a rate of rise of ~3 mm yr^{-1} for the period 1993–2005, i.e. a significantly higher rate in the past decade than during the last 50 years. Satellite altimetry also reveals high regional variability in rates of sea-level change, with some regions exhibiting rates of 5–10 times the mean global rate, while in some other regions a sea-level fall is observed (Figure 1(a) below).

On time-scales ranging from years to decades, global mean sea-level change results from ocean volume change caused by variations in the temperature and hence the density of seawater (the 'steric contribution'), and changes in the mass of water in the oceans, resulting from water exchange with continental reservoirs, mountain glaciers and ice-sheets. Recent published global ocean temperature datasets allow quantitative estimates of the contribution of thermal expansion to present-day sea-level rise (cf. Figure 1(b)). For the past 50 years, thermal expansion of ocean waters accounts for 0.4 mm yr^{-1} sea-level rise, i.e. 25% of the observed rate. For recent years (1993–2003), it accounts for 50% of the observed rate (1.5 mm yr^{-1} of 3 mm yr^{-1}). Increased thermal expansion during the 1990s was thus largely responsible for the higher rate of sea-level rise observed over that period. Non-uniform thermal expansion trends are also the main cause of regional variability of sea-level trends, as observed by satellite altimetry. But other processes, such as glacial isostatic adjustment, may also contribute to the observed spatial patterns (see main article).

For both the last 50 years and the last decade, a residual rate of ~1.5 mm yr^{-1}, not explained by thermal expansion, must have been the result of a net gain in water from the continents and land ice. Recent estimates of the melt rates of mountain glaciers indicate a contribution to sea-level rise of ~0.8 mm yr^{-1} over the last decade. Since the early 1990s, remote sensing observations (airborne laser and satellite radar altimetry, and Synthetic Aperture Radar Interferometry (INSAR) techniques) have allowed quantitative estimates of the mass balance of the ice-sheets. These observations indicate accelerated loss of ice in recent years in coastal regions of southern Greenland, about one-third by surface melting and runoff into the sea and two-thirds by the motion of outlet glaciers draining ice from the interior. In contrast, a slight ice gain is reported in central high-elevation regions. Over Antarctica, remote sensing techniques report accelerated ice loss in the western part of the continent, while the eastern region is slightly gaining mass as a result of increased snowfall.

Figure 1 *Spatial patterns of observed sea-level trends from 1993 to 2003:* ***(a)*** *from* Topex *altimetry, and* ***(b)*** *the contribution from thermal expansion only, from the ARMOR database.*



Because of these contrasting behaviours (ice loss in coastal regions and ice gain in elevated central regions), the ice-sheets are not far from balance (with loss slightly dominating gain) and thus contribute little to present-day sea-level change – only about 0.3–0.5 mm yr^{-1}. Since 2002, the GRACE* space gravimetry mission has provided a new tool for precisely measuring the mass balance of the ice-sheets, with nearly complete coverage. Over Greenland, recent GRACE results confirm previous results, i.e. ice loss, although there are some quite large differences between the results of the various investigations. Over Antarctica, GRACE observations suggest a net mass loss over the past 2–3 years. However, these results should be considered as still preliminary, considering the very short time span of GRACE observations and the significant contamination of the results by the effects of deformation of the Earth's crust as a result of post-glacial rebound.

Change in storage of water on land, due to natural climate variability and human activities, is another potential contribution to sea-level change. Model-based estimates of changes of water storage on land caused by natural climate variability suggest no long-term contribution to sea-level change although interannual/decadal fluctuations may be significant. Summing up the various climate-related contributions to sea-level rise over the past decade leads to a total in the range 2.5–3 mm yr^{-1}, in close agreement with the observed rate of rise.

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*GRACE = Gravity Recovery and Climate Experiment Satellite.

Long-term studies reveal **climate-induced changes in benthic communities of the North Sea**

Ingrid Kröncke, Gunther Wieking, Hermann Neumann and Joachim Dippner

Long-term studies in the North Sea have revealed a significant correlation between the abundance and biomass of benthic (i.e. bottom-living) animals and the North Atlantic Oscillation Index (NAO Index – see below), particularly in the second quarter of the year (April–July). This indicates that cold or mild winters have a significant effect on the structure and function of benthic communities in the succeeding summer. Our results suggest that (even in the absence of global warming) the increase in southern species will continue during times of positive NAO Index, and the resulting changes in trophic interactions will affect benthic and pelagic communities, as well as fish and bird populations and the food webs involved. Long-term studies of the benthos in coastal and offshore regions, and the correlation of community change with environmental driving forces, also allow us to predict changes in species harvested commercially, which is important for timely adjustments of fishery policies.

Why long-term benthic studies are so useful

As most benthic animals are more or less sessile (i.e. fixed in one position), benthic communities have been regarded as a possible 'tool' for monitoring environmental changes in ecosystems. Long-term studies are needed to identify changes in the environment because the spatial and temporal variabilities of the marine ecosystem are so wide-ranging. Since several studies in the Wadden Sea and coastal areas of the North Sea indicate that benthic fauna are strongly affected by cold or mild winters, effects of climate oscillations are also to be expected, even in offshore regions of the North Sea.

The North Atlantic Oscillation

The dominant signal of interannual variability in the atmospheric circulation of this area is the North Atlantic Oscillation. The NAO Index is defined as the difference between the normalized sea-level pressure anomalies (differences from mean values) during wintertime at Lisbon, in Portugal (a region of high pressure), and Stykkisholmur, in Iceland (a region of low pressure) (Figure 1). It is an indication of the position and

Figure 1 *NAO winter index between 1900 and 2005/6. The heavy solid line represents the low-pass filtered time-series. (By courtesy of James Hurrell, Climate and Global Dynamics Division, NCAR.)*

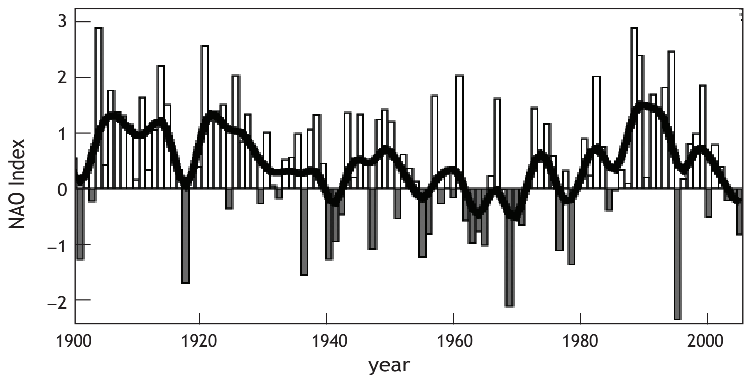
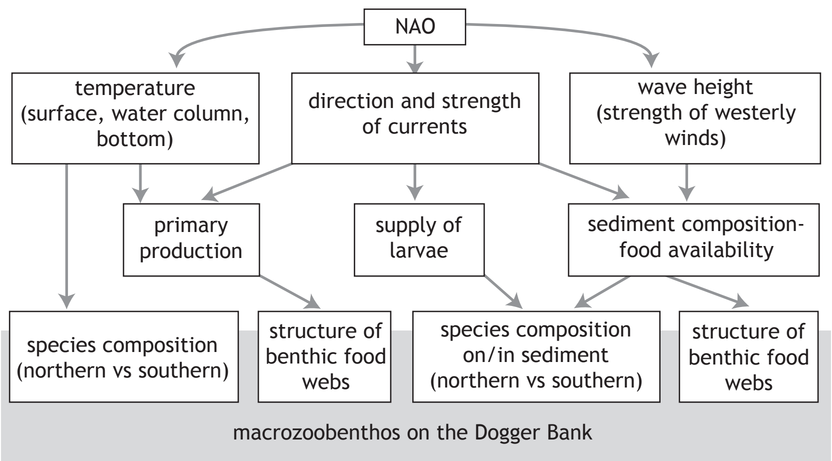
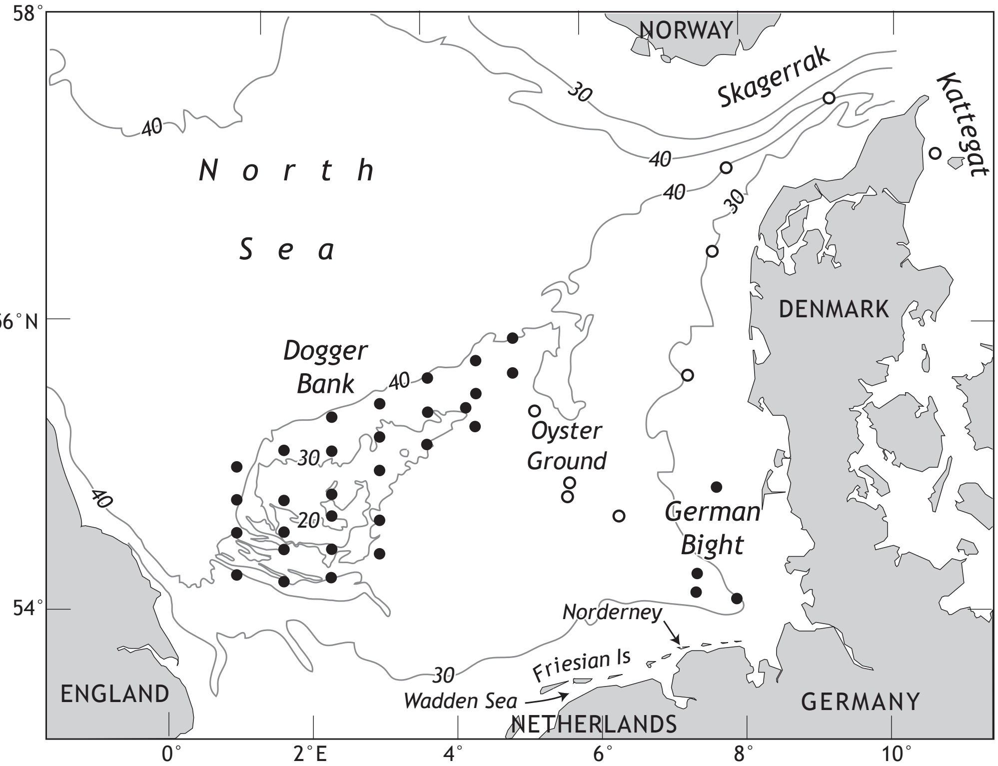


Figure 2 *Links and processes in the coupling between the water column and life at the sea-bed affected by changes associated with the North Atlantic Oscillation. Note: 'northern vs 'southern' refers to the relative dominance of species that prefer colder conditions and those that prefer warmer conditions.*



Macrofaunal communities, and the food webs on which they depend, are affected by water temperature, currents and waves, all of which vary with the state of the NAO



Our study areas included an offshore bank, a deeper offshore area, and a shallow coastal area

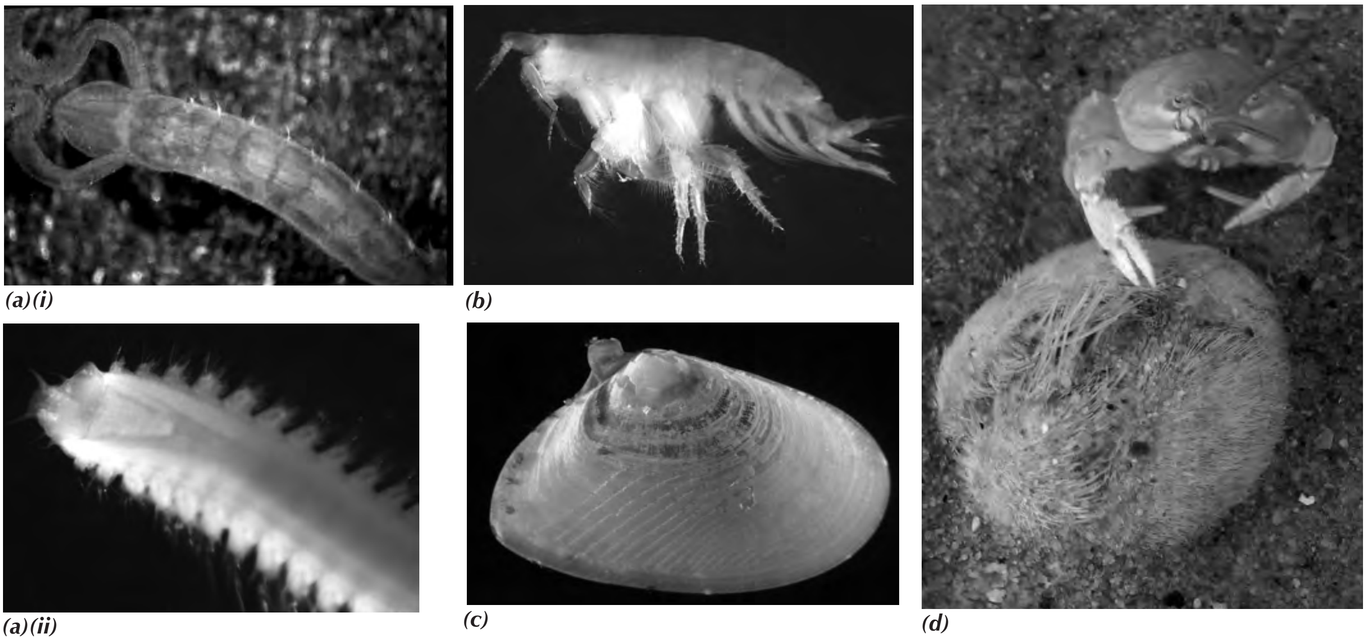
Figure 3 *The three study areas discussed in this article: the Dogger Bank, the sea-bed off Norderney, and the German Bight. Also shown (open circles) are the locations of some related studies.*

strength of weather systems as they cross the North Atlantic, which in turn determine precipitation, sea-surface temperature, direction and flow of currents, wave height, and the stability of the water column.

From 1989 onwards, mild winters caused an increase in abundance, biomass and the number of species, of the benthos off Norderney

A high positive NAO Index is associated with strong westerly winds, and a low negative one with weak westerly winds. Consequently, during high NAO winters the moderating influence of the ocean results in unusually warm winters in Europe. After a period of mainly negative values between 1960 and 1972 the NAO Index increased, attaining the highest consistently positive values of the 20th century in the 1990s (Figure 1). The winters of 1978/79, 1981/82, 1984/85, and 1985/86 were cold and related to a negative NAO Index. In 1995/96 an extremely cold winter occurred in the area, which was connected to an extremely

Figure 4 (discussed opposite) (a)(i) *The polychaete worm* Magelona johnstoni. *Worms of the genus* Magelona *were the most abundant amongst the polychaetes which dominated the sea-bed fauna off Norderney prior to 1989.* ***(ii)*** *The polychaete* Nephtys hombergi, *which became more abundant from 1989 onwards.*
Other animals whose abundance increased are: ***(b)*** *the amphipod* Bathyporeia elegans; ***(c)*** *the bivalve* Fabulina fabula; *and* ***(d)*** *the echinoid* Echinocardium cordatum *(a heart urchin), here with the crab* Corystes cassivelaunus.



low NAO Index in a period when the NAO Index was generally high. The relationship between the NAO Index and hydroclimatic parameters, mentioned above, affects biological processes in the water column and at the sea floor, as well as the coupling between them (cf. Figure 2, p.19).

Long-term studies off Norderney

The sea-bed off the island of Norderney (Figure 3) is sandy, with depths of 12–20 m. The long-term study of macrofauna (>1 mm long) in this area began in 1978 with monthly sampling. From 1992 onwards, sampling was reduced to once in each of the first, second and third quarters of the year.

Polychaete worms (also known as bristleworms) are the most abundant group in the investigation area, and prior to 1989 were dominated by species of the genus *Magelona* (Figure 4(a)(i)). Abundances of *Nephtys* species such as *N. hombergi* (Figure 4(a)(ii)) have increased remarkably since the late 1980s, as have abundances of the bivalves *Fabulina fabula* (Figure 4(c)) and *Donax vittatus,* the amphipods *Bathyporeia elegans* (Figure 4(b))*, B. guilliamsoniana* and *Urothoe poseidonis,* and the echinoid *Echinocardium cordatum* (a heart urchin) (Figure 4(d)).

The macrofaunal communities were severely affected by the cold winters of 1978/79, 1981/82, 1984/85, and 1985/86 and 1995/96, but mild meteorological conditions during the winters of 1989/90–94/95 resulted in increases in abundance, species numbers and total biomass (Figure 5) between 1989 and 1995. The results show that abundance, species number and biomass in the second quarter of the year (i.e. spring) correlated with the NAO Index (Figure 6).

The mediator between the NAO and the benthos was the sea-surface temperature in late winter and early spring (cf. Figure 2). This is a result of the ecological preferences of species resulting in lower mortality, higher production and increased reproduction in mild winters in combination with an earlier spring phytoplankton bloom which provides the benthos with food, and may have led to the increase in biomass.

Decadal change in Dogger Bank macrofauna

We are also following community changes in offshore regions of the North Sea, including the Dogger Bank (cf. Figure 3). The Dogger Bank is about 300 km long (on the basis of the 40 m depth contour) and the shallowest areas are only ~18 m deep. The sea-bed of the Dogger Bank is composed of soft sedments, predominantly fine sand incorporating shell debris, giving way to muddier sands in deeper areas. Bottom currents are strong and prevent organic matter from settling.

Five different benthic communities (groups of animals interacting/living together) can be distinguished on the Dogger Bank (Figure 7(a)). For two of these communities (those on the southern and eastern flanks of the Bank), the brittlestar *Amphiura brachiata* is a characteristic/key animal (Figure 7(b), overleaf). The community on top of the Bank is dominated by amphipods of the genus

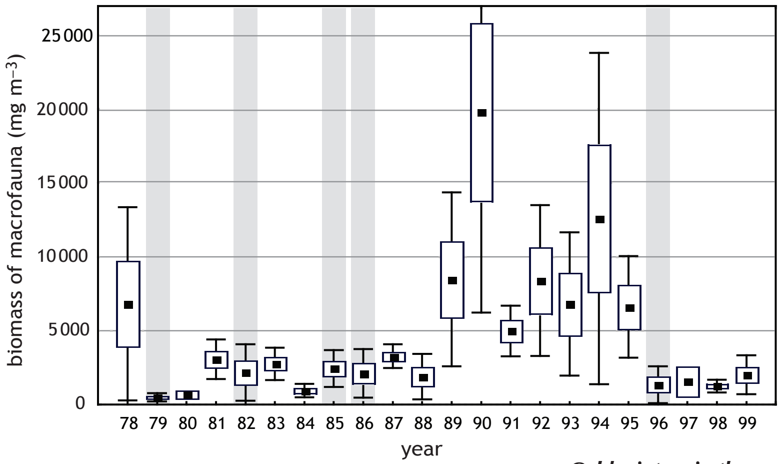
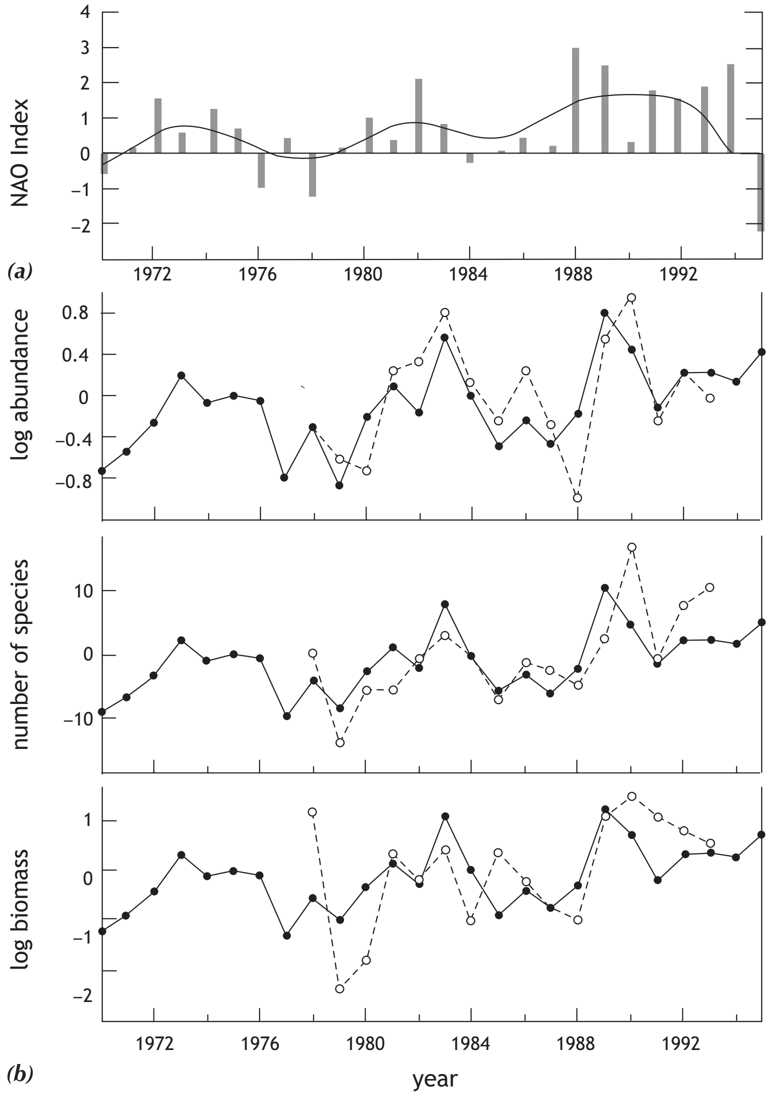


Figure 5 *Mean benthic biomass (mg ash-free dry weight m^{-2}) in the second quarter (April–July) of the years 1978 to 1999 off the island of Norderney (cf. Figure 3). A grey band indicates that the preceding winter was very cold.*

Cold winters in the 1980s and late 1990s were followed by one or more years when the biomass of macrofauna was reduced

Figure 6 ***(a)*** *Variation in the NAO Index since 1970.* ***(b)*** *Estimated (solid) and observed (dashed) anomalies of (from top to bottom) log abundance, number of species and log biomass of macrobenthos off Norderney in the second quarter of the year (April –July).*

The number of species and abundance of animals, as well as total biomass, show correlations with the NAO Index



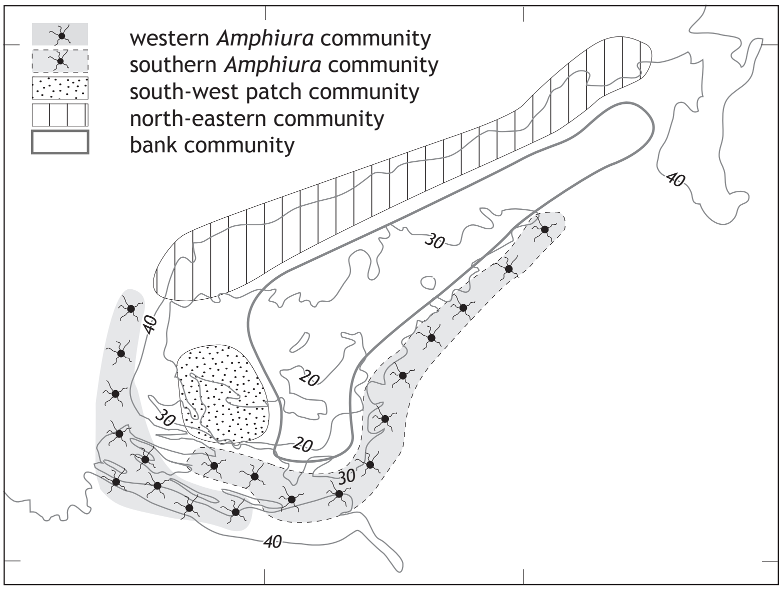
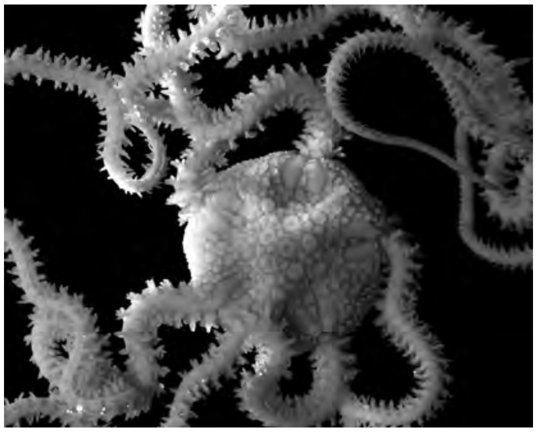
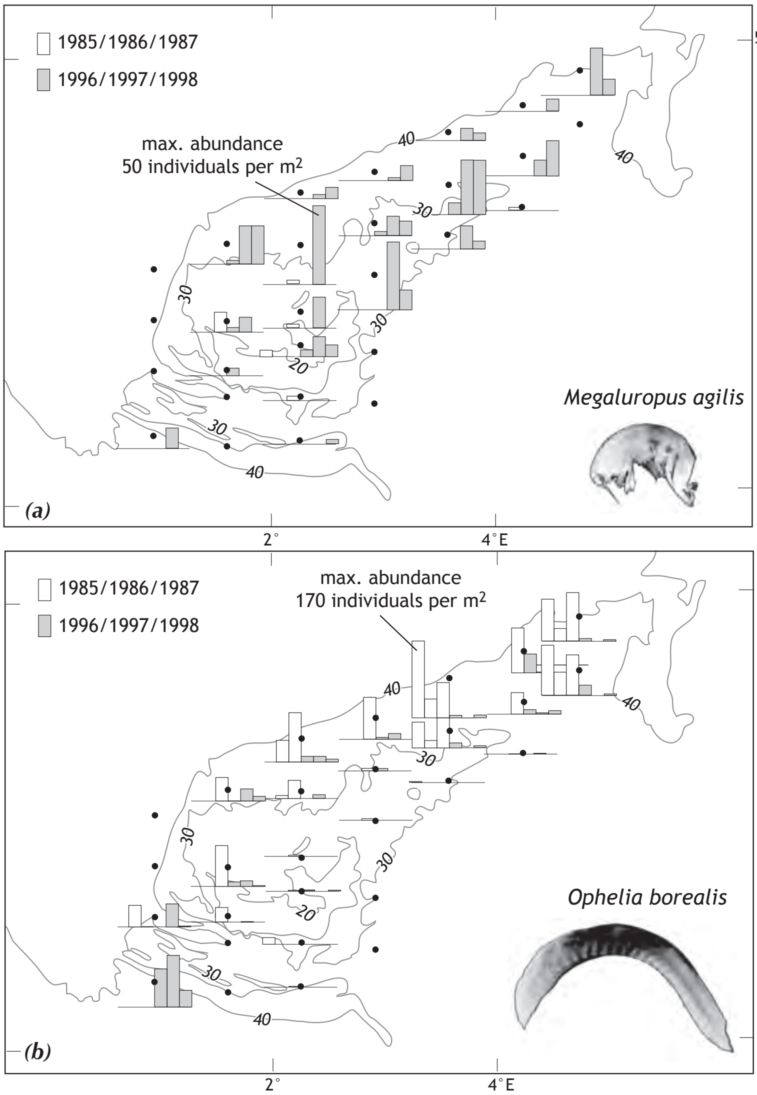


Figure 7 ***(a) (left)*** *Map showing the benthic macrofaunal communities on the Dogger Bank (see text).* ***(b)*** *The brittlestar* Amphiura brachiata, *a key member of the communities on the southern and western flanks of the Dogger Bank (cf. (a)).*



Five communities of macrofauna may be identified on the Dogger Bank, each associated with certain water temperatures and depths, sediment types and bottom currents

Figure 8 *Spatial distribution and abundance of* ***(a)*** *the amphipod* Megaluropus agilis *and* ***(b)*** *the polychaete* Ophelia borealis *on the Dogger Bank in 1985–87 (white columns) and 1996–98 (grey columns).* Megaluropus agilis, *a southern species, was rare on the Dogger Bank in the late 1980s but relatively abundant in the late 1990s. Along the northern slope, increased bottom currents resulted in a decline in* Ophelia borealis *in the late 1990s.*



Bathyporeia (cf. Figure 4(b)). The north-eastern community is similar to the 'bank' community, but more diverse with a wider range of rare species; the 'patch' commmunity has low abundance of macrofauna and poor biodiversity.

A long-term comparison of these communities between 1985–87 and 1996–98 found marked changes which, like those off Norderney, were associated with the rise in the NAO Index, and related factors such as changes in water temperature and in winds and currents (cf. Figure 2). These observed changes were not in the spatial distribution of the five communities, or of the dominant species, but in the species composition (i.e. relative abundances) of the rarer species.

For example, because of an increase in bottom temperatures during 1996–1998, southern species such as the amphipod *Megaluropus agilis* (Figure 8(a)) and the brittlestar *Amphiura brachiata* (Figure 7(b)) increased in abundance on the top and southern slope of the Dogger Bank, and even in deeper parts. In contrast, abundances of northern species (e.g. the amphipods *Corophium crassicorne* and *Siphonocoetes kroyeranus*, and the bivalve *Nuculoma tenuis*) decreased on the top and southern flank of the Dogger Bank. On the top and southern flank there were also increases in the abundance of interface-feeding species (e.g. the polychaete *Spiophanes bombyx),* which can catch their food in the bottom boundary layer or feed from the sediment surface, depending on flow conditions. This increase in interface-feeders coincided with a period of higher primary production in the central North Sea associated with the positive NAO Index.

In the late 1990s, benthic communities along the northern slope of the Dogger Bank were strongly affected by increasing wind stress and stronger currents. Changes in larval supply, food availability and sediment composition caused by resuspension of fine material led to a decrease in species occurring on fine sand, such as the polychaete *Ophelia borealis* (Figure 8(b)), compared to the 1980s; by contrast, there was an increase in abundances and total numbers of species preferring coarser and unstable sediment (e.g. the tiny sea-urchin *Echinocyamus pusillus*).

Epifaunal change in the German Bight

In a third project beginning in 1998, we have studied the epifauna living on the sea floor in the German Bight. The results revealed an increase in winter numbers of crustaceans such as swimming crabs (*Liocarcinus holsatus;* Figure 9) because temperatures in the German Bight seem to be suitable for them all year, so they no longer migrate towards the open sea in winter. The edible crab (*Cancer pagurus*) also increased in abundance and is now regularly found in the whole German Bight and also enters the Wadden Sea. Changes in populations of such important predators, as well as fish and bird species, will have far-reaching effects on various animals throughout the food web.

Conclusions

Our various studies indicate that single species as well as whole communities, and also trophic interactions, are affected by environmental changes associated with the NAO Index. But the effect varies from place to place and depends on the species composition of the different communities. Even though the NAO Index has recently been decreasing, models predict a general increase of positive NAO Index for the coming decades related to increasing sea-surface temperature as well as changes in hydrodynamics. These factors will have implications for the species composition and trophic interactions in the North Sea ecosystem which might lead to marked shifts in benthic and pelagic communities, as well as bird and fish stocks and food webs.

In contrast to the anthropogenic impacts that affect the North Sea ecosystem, such as fishing or pollution, which can be regulated, climate-induced changes are unstoppable and affect the ecosystem on a larger spatial scale. Humans can only react to them and accept them. But in times of predicted and continuously ongoing changes, the North Sea will be even more vulnerable to anthropogenic impacts. Thus fisheries policy and management strategies need careful adjustment, e.g. adjusting catch quotas in order to achieve sustainable fishing practices.

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Figure 9 *The swimming crab,* Liocarcinus holsatus, *which now remains abundant in the German Bight in winter, and no longer migrates into deeper warmer water.*

In the German Bight, various types of crabs are now more abundant, and are found all year round

Further Reading

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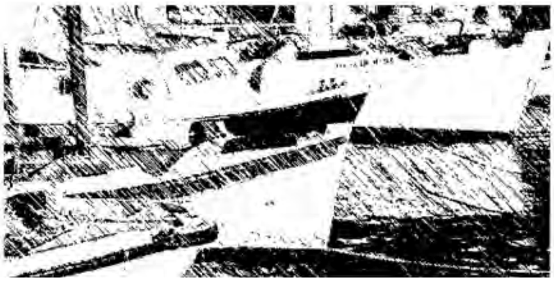
AGU Chapman Conference – Long Time-Series Observations in Coastal Ecosystems: Comparative Analyses of Phytoplankton Dynamics on Regional to Global Scales

Rovinj, Croatia, 8–12 October 2007

This conference will compare phytoplankton dynamics in coastal marine ecosystems where perturbations from terrestrial, atmospheric and oceanic sources and human activities interact to cause changes across various scales. The objective is to assemble and synthesize multidecadal observations to produce depictions of phytoplankton variability as an indicator of environmental change across the full diversity of coastal ecosystem types. The aims are a global phenology of phytoplankton at the land–sea margin and a conceptual model from which coastal ocean observing systems can be developed.

Abstract submission deadline is 7 May 2007. For more information see: http://www.agu.org /meetings/chapman/2007/bcall/



THE PRESENT AND FUTURE OF GREEK FISHERIES

Kostas Kapiris

Fishing has been undertaken in the waters around Greece and the Greek islands since ancient times, and information about it can be found in the writings of Homer, Isiodos, Aechylus, Galinos, Aristotle and Oppianos, among others. Because of the geography of Greece, the fisheries sector has traditionally been the basic source of income for the inhabitants of most coastal areas, especially in the case of the islands. The total length of the Greek coastline is over 15 000 km, so it might be expected that fisheries production would play a very important role in the national economy. In fact, its contributions to the Gross Agricultural Product and Gross Domestic Product are relatively small (5.6% and 1.0%, respectively), but fisheries are nevertheless an important sector of the Greek economy because they contribute to the maintenance of social and economic cohesion of many regions around the country. Most of the fishing activity is small-scale, or even artisanal (using traditional techniques to catch fish for local consumption). Greece (and indeed the Mediterranean in general) has not seen the development of industrialized fishing, involving large investments by companies/financial groups, such as occurs, for example, in the North Sea.

Fishing grounds exploited by Greece

On average, fish catches in Greek waters are lower than those in other areas of the world ocean. This is because the waters have relatively low nutrient concentrations, and so are not very productive. The commercial fishery mainly operates down to 400–500 m depth, and is mostly confined to the waters over the continental shelf, which is generally narrow. This is partly because fishermen lack exprience of fishing in deeper waters, and partly because of the low commercial value of deep-water species in the Greek market up until recently.

However, the northern/north-western Aegean Sea (cf. Figure 1) not only has a large area of continental shelf, but also receives a relatively large amount of freshwater runoff and hence has a relatively high concentration of nutrients (in the Aegean, nutrient concentration decrease from north to south). As a result, the density of pelagic species in the Aegean is higher than the average for the Mediterranean as a whole, and the majority of vessels in the Greek fishing fleet work there, with small-scale fishing boats taking 80% of the catch. (The Turkish fishing fleet operates along the coast of the eastern Aegean; its catch is very much smaller than that of the Greek fishing fleet.)

Very few fishing boats work in the waters to the west of Greece, in the Ionian Sea (cf. Figure 1). Here, fishing is mainly confined to the narrow continental shelf, as the flanks of the (volcanic) Ionian Islands slope down steeply to the sea-bed.

Box 1: The composition, capacity and engine power of the Greek fishing fleet

- Fishing vessels operating in distant waters, i.e. the Atlantic Ocean and north African coast (< 1% of total vessels, 19% of capacity and 6% of engine power[*]). Most of the catch (8% of total output) is frozen.
- Trawlers operating in Greek open waters (~2% of total vessels, 23% of total capacity and 17% of power). Their catch accounts for 22% of total output.
- Purse-seiners[†] operating in Greek open waters and coastal waters (~2% of total vessels)
- Coastal boats, including beach-seiners,[†] small ring-netters, drifters, liners, etc.), operating along the Greek coasts (~98% of total vessels, ~59% of total capacity and 77% of total power), accounting for approximately 70% of total output.

The above figures are based on 2003 data. In 2004, the total catch of the Greek fishery fleet was about 90 444 tonnes, and its total engine power was ~ 725 000 HP.

Notes for Box 1

[*]Engine power is a measure of 'fishing effort', the resources used in fishing Managing fishing effort is a way of managing fishing activity in order to combat overexploitation of fish stocks. Engine power is a particularly useful measure of fishing effort because it is applicable to a variety of fishing techniques; other measures of fishing effort – e.g. vessel size, days at sea, number of nets, etc. – may be meaningful for some techniques but not for others.

[†]Purse-seining involves encircling the fish with a vertical net and then pulling tight a drawstring along the bottom of the net, so enclosing the fish; in use, the net resembles an old-fashioned purse with a draw-string neck. 'Seine' is the old name for any net set vertically in the water, with floats along the top and weights along the bottom. Beach seines are vertical nets (sometimes with a 'bag') that are deployed in very shallow water, usually from small boats.

Most important Greek fishing ports are around the Aegean Sea, which is shallower and more productive than the Ionian Sea

Figure 1 *The most important Greek fishing ports. As this map suggests, the Greek fishing fleet works mainly in the Aegean Sea, with many fewer vessels working in the Ionian Sea and along the southern coast of the Peloponessus. The grey zone around the coastline is the Greek territorial sea (6 nautical miles) within which Greek fishermen have exclusive fishing rights.*

The Greek part of the Ionian Sea comprises part of a larger area in which stocks are fished by a number of other major fishing nations (especially Italy, Albania, Libya, Malta and Tunisia). Only 7% of the total Ionian Sea catch was caught in the Greek sector in the period 1982–87.

Further east, the Greek part of the Levantine Sea also comprises part of a larger area in which stocks are fished by a number of other major fishing nations (Lebanon, Turkey, Israel, Syria, Cyprus, Egypt and Gaza Strip). The Greek catch from the north-western Levantine Sea is relatively small (on average <1% of the total Levantine catch over the period 1982–87).

For the period 1982–89, of the mean annual catch of ~93 000 tonnes, ~ 87 000 t came from the Aegean Sea and ~6000 t from the Ionian Sea. Fish, cephalopods and crustaceans made up respectively 94%, 3% and 3% of the total Aegean catch, and 96%, 3% and 1% of the mean Ionian catch.

The Greek fishing fleet

As shown in Box 1, small coastal boats make up the largest part of the Greek fishing fleet (see also Table 1). Although their contribution to the total tonnage and engine power of the fishing fleet is low (~13% in both cases), fishing vessels under 20 HP make a significant contribution to the total fleet in terms of numbers of vessels (60%) and employment (46%) (see also Tables 2 and 3, overleaf).

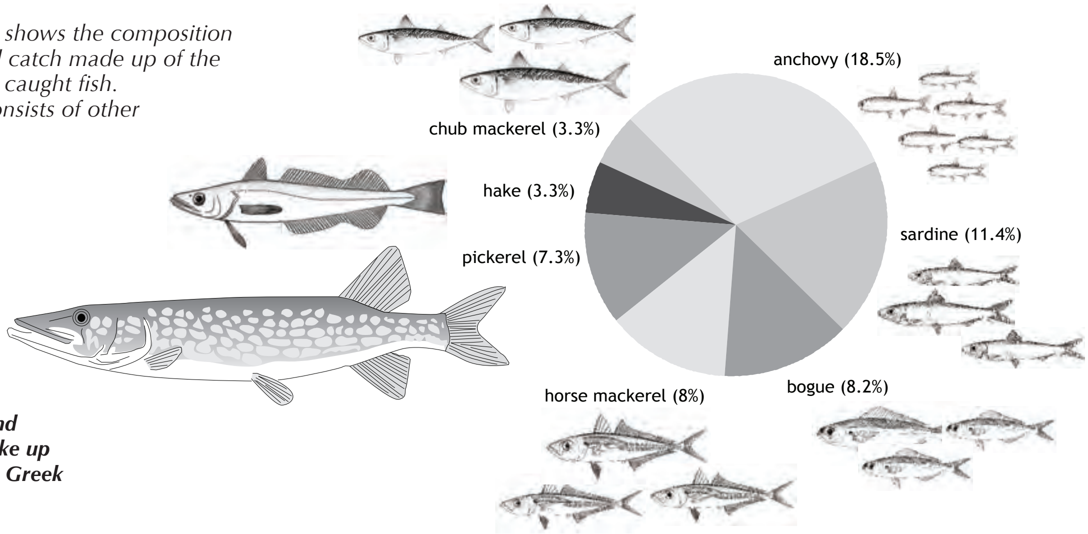
Greek fishing resources

Greek seas are characterized by a warm-water tropical and subtropical fauna, with the total number of fish species found in the waters around Greece (447) being lower than that reported from the Mediterranean Sea as a whole (579), indicating the impoverishment of the eastern Mediterranean. In all, the fish fauna of Greece consists of 447 fish species (belonging to 129 families), of which 283 species are of Atlanto-Mediterranean character, 86 species are endemic in the Mediterranean Sea, 65 species are of worldwide distribution (i.e. known in the Atlantic and Indo-Pacific), and 13 species are immigrants from the Red Sea that colonized Greek seas by following the main currents along the coasts of Syria and Turkey.

Table 1 *The Greek fishery fleet in terms of gear and numbers of vessels in different length categories. (National Project of Fishery Data Collection, 2005)*

Gear		Length category			
		< 12 m	12–24 m	24–40 m	Total
Mobile gears	Trawls	1	88	131	220
	Purse seines	7	294	21	322
	Beach seines	353	53	–	406
	Multiple gears	–	76	47	123
Passive/static gears	Hooks Fixed nets Traps	17 230	70 357 –	–	17 657
Total		17 591	938	199	18 728

***Note**: The pie-diagram shows the composition of the 60% of the total catch made up of the seven most commonly caught fish. The remaining 40% consists of other less abundant species.*



Anchovy and sardine make up 30% of the Greek marine fish catch

***Figure 2** Composition of the mean fish catch from Greek seas, in terms of the seven most commonly caught fish. The values given in brackets are percentages of the total marine fish catch; all other species contribute <3% of the total (data from 1964–89). Anchovy, sardine, horse mackerel and bogue dominate the purse-seine catches; hake, pickerel ('northern pike'), horse mackerel and red mullet dominate trawl catches.*

Fisheries in Greek waters are typically multi-species, and target mainly small pelagic fish (i.e. small shoaling fish living in the water column) and demersal fish (those living in association with the sea-bed). Demersal fish such as hake and red mullet, along with shrimps and cephalopods (squid and octopi) are mainly caught by trawling, while pelagic fish such as sardine, anchovy, bogue, Mediterranean horse mackerel, along with various species of tuna, albacore, bonito and true mackerel, are caught by purse-seiners. The beach-seine catch is typically dominated by pickerel, sardine and bogue. (Unfortunately, since 1969, local customs authorities have not recorded catches of smaller inshore ring-netters, drifters and liners.) Overall, anchovy and sardine dominate the Greek catch, together making up one-third of the total, over the period 1964–89 (Figure 2).

Although 50–60% of total domestic fisheries production consists of small pelagic fish, the main commercially valuable species are migratory species such as bluefin tuna, swordfish and albacore. According to ICCAT,* in Greek waters, stocks of highly migratory species are heavily over-exploited, although lack of data means that there is some uncertainty about the extent of overfishing.

*ICCAT is the International Commission for the Conservation of Atlantic Tunas, established in 1969. The organization is responsible not only for conservation of various species of tuna in the Atlantic and adjacent seas, but also tuna-like species such as swordfish, sailfish and various kinds of marlin and mackerel.

Seasonal variability of catches

Monthly catches of pelagic species such as anchovy, sardine, horse mackerel and Atlantic chub mackerel (as well as the monthly catches of all fish combined) increase from a minimum in January to a maximum in May–September (depending on species), and decline thereafter. This marked seasonal cycle is probably related to seasonal offshore and inshore migrations of small and medium-sized pelagic fishes and the nature of the purse-seine fishery. Also, the majority of these fishes spawn close to shore in and around summer, commencing some time in May; in winter they are more dispersed and distributed mainly offshore.

On the other hand, monthly catches of demersal species such as hake, blue whiting and red pandora, along with cephalopods and crustaceans, are very low in June–September when trawling and beach-seining are prohibited in Greek waters.

Employment

Employment in the fishery sector represents 1.9% of employment in the primary sector of the economy (that part which exploits natural resources) and 0.3% of employment in the whole economy. In 2004, 14 094 people were employed in the fishery sector, 1642 fewer than in 2002 (Table 2). Around 60% of people employed in the sector work for themselves, 24% are employees, and 11% are unpaid family workers. The majority of self-employed fishermen work in small-scale fisheries.

Employment in fisheries in Greece has a 'two-tier' structure: on the one hand there is so-called 'professional' fishing activity undertaken by full-time fishermen (inshore, open sea and overseas); and on the other, there are 'part-time' fishermen who use small low-horsepower vessels. This situation reflects the diffuse character of Greek fisheries, and of Grek rural economic activities in general.

As in other European countries, women's position in fishery enterprises differs greatly from that of men: whereas 60–70% of men involved in fishing are either 'self-employed' or 'employers', for women it is only 15–30%, with 55–70% of women being classed as 'assisting members in the family enterprise' (only 6–15% of men are occupied as 'assisting members'. Overall, men are

***Table 2** Employment in fisheries by type (2001–2004)*

Type of fishery	2001	2002	2003	2004
Overseas	157	173	185	211
Open sea	1197	1180	1257	1258
Inshore	14 541	14 383	13290	12 626
Total	15 895	15 736	14732	14 095

Source: NSSH.

more commonly identified as 'skipper or fishermen'; women are more frequently described as 'wives/daughters of fishermen' or 'skipper's helpers'.

Trends in fisheries in Greece

Decline in fishing activity and employment

The number of vessels in the Greek fishing fleet has been decreasing over the last decade and a half. In 1991, the fleet consisted of 22 237 vessels, while in 1996 it was 20 594, and in 2003 it was 18 836. In 2004, the total number of fishery vessels was 18 728 (see also Box 1 and Table 1). This considerable reduction of the fishing fleet will be discussed in more detail later.

As shown in Table 2, the number of people employed in fisheries decreased during the 1990s. There has also been a trend away from fishing as a full-time occupation, towards part-time fishing along with other economic activities. Many of those active in fisheries are relatively elderly: the Labour Force Survey data for 1997 indicate that 53% of those employed in fisheries are over 45 years of age, with the figure rising to nearly 60% for small-scale fisheries.

Decline in production

Estimates based on catch rates reinforce the view that most commercial species in Greek waters are overexploited. In particular, catch statistics for the most important species or groups of species (demersal and small pelagic species) showed a negative trend in the 1990s. In particular, in some areas, long-lived species and larger specimens have disappeared from demersal catches. In the northern Aegean, where small pelagic fish (caught by purse-seiners) constitute a large proportion of the catches, a marked decline in the anchovy stock has been observed in recent years. However, there is no evidence for overfishing of sardines in Greek waters.

Overall, marine fishery production has been steadily declining in Greece. Table 3 gives the total annual landings per fishing category in Greek seas, over the period 1997–99. Over the period 1988–98, the largest decrease was in overseas fisheries (52%), followed by the open sea Mediterrannean fisheries (21%), while in inshore fisheries there was only a small decrease (7%). In 2001, the total catch was 94 497 tonnes, in 2002 it was 99 029 tonnes, and in 2004 it was 90 444 tonnes.

Average per capita consumption of fish in Greece is similar to that in Italy and Denmark (about 26 kg in 1997), and overall fish production (capture fisheries plus aquaculture) is insufficient to meet local needs, with the result that Greece is a net importer of fishery products. This is despite the fact that aquaculture is one of the most dynamic sectors in the Greek economy, with Greece being the largest producer of farmed sea bass and sea bream in the Mediterranean.

In the 1980s, fishery imports were larger than exports, but the value of fishery consumption in Greece rose steadily in the period 1988–98. During the 1990s, the value of fishery exports exceeded the value of fishery imports (both at current prices). For example, in 1999, imports were worth 8.2€ billion (21 000 tonnes) and exports were worth about 17€ billion (50 000 tonnes). Thus, fishery production in Greece needs both to increase fishery exports and to satisfy the rising domestic demand for fish.

Table 3 *Annual landings per fishing category (1997–1999) (tonnes)*

	1997	1998	1999
Inshore fisheries (>19 HP)	71 481	47 868	50 000
Inshore fisheries (<19 HP)	42 000	43 000	43 000
Trawlers, purse-seine	76 254	59 119	60 000
Overseas fishery	5053	5914	6000
Total	194 788	155901	159 000

Source: Ministry of Rural Development and Food.

Box 2: Sources of Greek fisheries statistics

Greek fisheries statistics are collected by four independent organizations: the National Statistical Service of Hellas (NSSH), the Agricultural Bank of Greece, the National Company for the Development of Fisheries (ETANAL SA), and the Ministry of Rural Development and Food. So far, there has been no attempt at coordination between these organizations and, as a result, confusion often arises.

NSSH has recorded fisheries statistics for Greek waters since January 1964. For a better evaluation of the available data, the waters fished by our fishermen have been divided into 18 statistical fishing sub-areas. Although NSSH statistical data suffer from various biases (which are greater for inshore fisheries) and the degree of bias is hard to estimate, they are the best figures available.

The Agricultural Bank of Greece collects data on active fishing vessels and provides assessments of their landings from 1974 onwards. The Ministry of Rural Development and Food is the official administrator of the Greek fishing industry and the body responsible for management of fisheries resources. ETANAL is a non-profit organization under state control, whose role is the management of the major Greek fishing ports; it belongs to the Agricultural Bank of Greece (ATE) (75%) and to the National Bank of Industrial Development (ETBA) (25%). ETANAL has been granted by law exclusive jurisdiction over auctions (eleven in several parts of the country) and supervision of related transactions. Auction centres handle about 30% of the total fish landed in Greece. The 166 port authorities (central harbour authorities, port police stations, sub-stations and outlying stations) employ 3226 officials, of whom 250 are full-time.

Strengths and weaknesses of the fishing industry in Greece

Problems with CFP legislation

Since becoming a member of the European Community, Greece has relied on its Fisheries Code of 1970 (420/70) as the foundation of its national fisheries legislation. This law has been amended on several occasions, most recently in 1997. As in other EU countries, the Common Fishery Policy (CFP) and its legislation is directly applicable.

Market structure and market policies have been applied and enforced in the Mediterranean as in other Community areas, but in the Mediterranean implementation of some aspects of the control policy has been delayed. The first regulation covering technical measures for conserving fishery resources in the Mediterranean (Council Regulation (EC) No.1626/94) came into force on 1 January 1995. Greece was exempted until

1 January 2000 but the Greek administration attempted to overcome existing problems by introducing amendments to the relevant national legislation. Apart from the allocation of a total allowable catch (TAC) for bluefin tuna in 2003, no TAC or quota has been allocated to Greece or any other Mediterranean country.

The CFP aims to promote sustainable fishing practices in the Mediterranean, as in other EU waters,* and the high seas. However, the special characteristics of Mediterranean fisheries mentioned earlier – the fact that most fishing takes place over narrow continental shelves, and is undertaken mainly by small vessels – mean that CFP measures are sometimes not appropriate for the Mediterranean, and so have only been partially applied there. Furthermore, conservation measures specifically designed for the Mediterranean have not had the desired impact.

Beside Community law there are a variety of national measures aimed at regulating fishing effort, as well as technical measures involving mesh-sizes, maximum landing sizes etc. Management regulations currently in force for the Greek demersal, inshore and pelagic fisheries are shown in Table 4. The fact that, despite these measures, many fish stocks (and the coastal marine environment) are in a vulnerable state, has been attributed mainly to the multi-species, multi-gear nature of Greek fisheries, which mean that it is difficult to design and implement uniform protective measures, particularly for demersal and inshore fisheries.

*EU waters outside the Mediterranean are made up of the exclusive economic zones (EEZs) of the various EU states. For political and practical reasons, most Mediterranean states have not declared EEZs, only territorial seas.

Administration and resources

At a national level, four different ministries are involved in fisheries monitoring, inspection and surveillance: the Ministry of Rural Development and Food's General Directorate for Fisheries is responsible for developing and implementing fisheries policy; the Ministry of Mercantile Marine's Directorate of Port Police and the local port offices are responsible for inspecting the implementation of marine fishery policy; the Fisheries Divisions of Local Authorities of the Prefectures (Periferia, in Greek) are responsible for implementing fisheries policy; and the Ministry of Commerce studies the market for fisheries products (this organization exists because of a tradition that fisheries are managed locally or regionally and the involvement of national authorities is therefore limited).

For 1999 the total amount allocated to the administration of fisheries was 25.2 M€ (16.3 M€ from the national budget, and 8.9 M€ from the EU budget). For the period from 2000 to 2006, a six-year plan provided Greek fisheries with subsidies amounting to nearly 500 M €, 236 M € of which came from the structural fund of the EU.

Table 4 *Regulations currently in force for demersal/inshore and pelagic fisheries in Greek seas*

Vessel licensing	Limits imposed on the fishery
Purse-seiners	Closed season for 3 months in winter; minimum stretched mesh size of 14 mm for those operating at night and 40 mm for those operating in daytime. Fishing prohibited within 100 m of the coastline, at depths < 30 mm. Max. engine horsepower 300 HP.
Trawlers	Closed season from 1 June to 30 Aug., minimum stretched cod-end mesh size 28 mm. Fishing prohibited within 1–2 miles of the coast and 3 miles from estuaries. Many gulfs and bays closed to fishing. Max. engine horsepower 500 HP.
Beach-seiners	Closed season from 1 June to 30 Aug.; minimum stretched mesh size 16 mm. Fishing allowed no farther than 70 m from the coast. Many gulfs and bays closed to fishing. Fishing prohibited at night. No new entries to fishery permitted. Max. engine horsepower 150 HP.
Nets	Some areas closed to fishing; fishing not allowed with mono-filament nets. Max. engine horsepower 150 HP.
Fish size limits	Prohibited to land fish of lengths < 10 to 30 cm according to species (10 cm: red mullet, striped red mullet, red pandora, gilt sardines, crayfish, bogue: 14 cm: gilthead sea bream; 16 cm: *Mugil* sp. and sea bass; 18 cm: soles; 30 cm: eels); and lobsters and octopi of weights <320 and 500 g, respectively.

Need for modernization

Despite the growth of Greek fisheries in recent decades, the sector must deal with the following weaknesses:

- The large number of small, old and poorly equipped fishing vessels with high operating costs (75% of the vessels are over ten years old).
- The limited area of Greek fishing grounds because of the small area of shelf.
- The inadequacy of available marketing channels.
- Limited research activities, and poor infrastructure and facilities at fishing ports.

The limited area of shelf has meant that Greece has developed a multi-gear coastal fishery composed of many low-powered vessels, operating within the 100 m depth contour, which, in many areas, does not extend beyond the 1-mile zone. The 1-mile limit is the boundary between the wider coastal fishery sector and the fishery conducted mainly by trawlers (the most economically important sector of medium-sized fishery enterprises). Thus different types of fishing vessels are often operating in the same fishing grounds, which results in competition between different groups of fishermen, contributing to over-exploitation of fish stocks.

While most shallow-water stocks are over-exploited, extensive potential fishing grounds in deeper waters remain underexploited. The discovery of new fishing grounds and new resources could play an important role in the sustainability of exploited Greek marine fishing resources – for example, a potentially exploitable deep-water red shrimp stock was recently reported off the Greek coast of the Ionian Sea. However, it should be borne in mind that some deep-water resources are particularly sensitive to over-exploitation, because their habitats and ecosystems are very fragile.

Modernization of the fleet should lead to more rational and more profitable exploitation of fishery resources, improved productivity and economic viability of fishing enterprises, a wider radius for fishing activities, allowing fishing in under-exploited areas, improved working conditions on board (especially in terms of health and safety), and improved quality of catch.

In order to improve the infrastructure supporting fisheries and fisheries research, the European Regional Development Fund needs to finance a series of measures including: improvement and protection of lagoons and harbours; computerization of the departments concerned; informing the public about the operational programme for fisheries; and training for administrative staff.

Improving and marketing fish products

Measures to improve the quality of fish products must include:

- Improving facilities at fishing ports, including those for storage and chilling.
- Processing: building new processing units, extending and modernizing existing ones, including computerization and installation of biological cleaning systems for treatment of waste.
- Marketing: construction of some new auction halls, and modernization of existing ones; product promotion, and exploration of new distribution arrangements (promotion campaigns, quality certificates and product labelling, consumer surveys, trade fairs, exhibitions etc.).
- Improving co-operation among fishermen, which up until now has been limited: even today, fishery cooperatives are not very active and their impact is small. This is partly a result of the diffuse nature of fishery production, but also of the lack of specialized knowledge and skills, and the lack of state support for cooperative enterprises.

Decommissioning

The CFP is primarily looking for a sustainable balance between fish stocks and fishing activities. In order to reduce the total fishing effort there needs to be permanent withdrawal of some fishing vessels. In 2002, 18 trawlers, 7 purse-seiners, 26 beach trawlers and 490 coastal fishing vessels were withdrawn from fishing activity, reducing the fishing fleet by 940 GRT*, and resulting in the loss of about 867 permanent jobs. Temporary withdrawal of other vessels, due to unforeseen one-off events (e.g. temporary reduction of certain types of fish) will also help.

Identifying appropriate control measures

Limits on the minimum size of marketed fish are generally not recommended for multi-species fisheries (which target various fish that attain different sizes) because such measures usually result in high discard rates. This is particularly true for catches including hake and red mullet, of which a relatively high percentage of specimens are caught at lengths <120 mm and <100 mm, respectively. This part of the catch is either marketed illegally or discarded. In any case, minimum landing sizes are meaningful only when they have been adopted on the basis of sound biological reasons, and trawl and gill-net selectivity experiments conducted in Greek waters clearly show that this has not been the case for many fish species in Greek waters (e.g. hake, john dory, anglerfishes, red pandora, red mullet, striped red mullet).

*GRT = gross registered tonnage.

Although closed seasons can be effective in restricting fishing mortality of particular life-stages, they may lead to an overall *increase* in mortality if catch rates are high outside the closed seasons. In addition, they cause severe economic problems for Greek fishermen. However, restrictions on the number of licenses issued may be quite successful if introduced sufficiently early in the history of a fishery. It is worth mentioning that banning of the beach seine could be essential for conservation of demersal and inshore biodiversity in Greek waters.

At present, there is no offical information about recruitment overfishing in Greek seas (recruitment overfishing is catching too many young fish, which can never mature and breed). However, results of experimental fishing indicate that all the commercially important Greek demersal and inshore stocks are increasingly suffering from overfishing; affected stocks include hake, poor cod, blue whiting, whiting, gurnard, red mullet, striped red mullet, red pandora, pickerel, blotched pickerel and Norway lobster). In addition, many commercial catches have been consisting mainly of young immature individuals, suggesting that the spawning stocks are endangered.

General recommendations

Creation of Marine Protected Areas

Stergiou and Pollard (see Further Reading) have suggested that the managerial measures at present in use should be either replaced or complemented by the creation of marine refuges (Marine Protected Areas). Such an approach, in which fishing vessels are excluded from particular areas, is potentially a highly effective management technique, particularly for multi-species fisheries.

The creation of Marine Protected Areas will help to protect small fish, and should result in increased catches outside the reserves. Creation of areas where fish are highly concentrated, and so can be exploited with reduced fishing effort, should improve resource development and living conditions in areas such as eastern Greece, western Macedonia and Thrace.

An improved Common Fisheries Policy

The European Union started a process of revision of the CFP in 2002 and since then a series of new rules have been adopted. Discussion of a new rule concerning the management of Mediterranean fisheries, and of the Fisheries European Fund for the period 2007–2013, will be of the utmost importance for the social, economic and biological sustainability of the fishing industry in the Mediterranean. The need for decisive action aimed at recovering fish stocks has been recognized, and new tools have been introduced. Some of these are already included in Rule 2371/02 (for the conservation and sustainable exploitation of resources), while others have been drafted as measures to be implemented within the programmes to be approved within the Structural Fund.

Protecting fishing communities

Fishing plays a very important socio-economic role in Greece. To protect its future we need greater determination from all concerned, better scientific data, strengthened control of fisheries activities, improved compliance with the rules and increased co-operation among all parties involved. The efforts of those who apply conservation measures must not be undermined by those who do not.

The problems faced by the fisheries sector in Greece are most serious among those who are disadvantaged socially and economically. Thus, the target group for support and development activities should be small-scale coastal and inshore fishermen running small family businesses. In particular, small-scale coastal fishermen need support in diversifying their activities, along the lines of rural development projects set up in areas of the Greek countryside where there are few alternative employment opportunities. These projects must (1) to be better tailored to local needs than in the past, with local traditions and customs taken into account; (2) be planned at the local level; (3) be well supported by local government and state services; and (4) focus on development that is sustainable, given the coastal development and over-exploitation which has harmed many fisheries in Greece.

Concluding comments

In tackling the problems of fishing communities around Greece, the Greek government has had two aims:

- Finding the right balance between fishing effort and the available marine resources.
- Maintaining employment at a level favourable to the development of the sector, while contributing to the modernization of fishing enterprises.

In general, progress towards these aims has been in the right direction, but much still needs to be done.

Further reading

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38th SIBM Congress

Genoa, Italy, 29 May – 2 June 2007

The 38th Congress of the Italian Society for Marine Biology (SIBM) is being held at Santa Margherita Ligure, Genoa, and is being organized by the University of Genoa in collaboration with the Marine Protected Area (MPA) of Portofino, the Municipality of Santa Margherita Ligure, Portofino Coast and others. The main themes of the Congress are:

• Scientific research in and for MPAs • The coralligenous biocoenosis • The bathyal environment and fisheries

The opening presentation, 'Climate Change and Managing Marine Ecosystems', will be by Prof. Stephen J. Hawkins. There will be a workshop on MPAs in the Ligurian Sea for MPA managers, fishermen, politicians and stakeholders.

For more information, please see the SIBM website: www.sibm.it

14th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean

Seville, Spain, 10 – 14 October 2007

The objectives of the symposium are to provide opportunities for scientists of different countries to:

- Exchange recent results relating to environmental pollution and its effects on public health in the Mediterranean region
- Discuss current technological and legal measures to avoid or reduce the degradation of the environment
- Present suggestions and recommendations to the regulatory authorities on equality and safety in the Mediterranean area.

For more information see http://intarese.imperial-consultants.co.uk/,
or email Prof. Juan Cornejo (President of MESAEP): cornejo@irnase.csic.es

TSUNAMIS AFFECTING GREECE IN ANCIENT AND MODERN TIMES

Serafim Poulos, George Alexandrakis, Theodora Paramana and Aikaterini Karditsa

The disastrous tsunami in the Indian Ocean on 26 December 2004 has once again raised the issue of these catastrophic waves, how they are generated and how they might best be predicted. The thousands of casualties, and the damage worth millions of euros, have certainly focussed discussions.

Tsunamis – 'harbour waves' in Japanese – are actually gravity waves generated in bodies of water by earthquakes, submarine landslides (usually triggered by earthquakes), subaqueous volcanic eruptions or meteorite impacts. The December 2004 tsunami was generated by an earthquake which ripped apart the sea floor off the coast of north-west Sumatra, releasing energy that had been accumulating in the stressed sea-floor rocks for over 100 years.

On a global scale, tsunamis take place quite frequently. However, they may either not be felt, or not always be discussed sufficiently, because they are of low intensity and their impact on the coastal zone is minor. In the context of Greece, the great tsunami of Santorini comes to mind, as it has been linked to the devastation of the Minoan civilization. Nevertheless, a substantial number of tsunami events have affected Greek coastlines within historic times, although only a few of them were actually catastrophic (Crete, 365 AD, Santorini, 3500 BC, and Amorgos, 1956 (cf. Table 2(i) and Figures 3 and 4).

Tsunamis are characterized by very long wavelengths, ranging from 100 to 200 km; when they are in the open ocean they usually have wave heights of < 2 m – this is why they are not easy to notice while they are still offshore, especially in rough conditions. The period of tsunami waves is also very big, ranging from 10 minutes to several hours. From the moment of their generation, tsunamis (singly or in wave trains) propagate at a velocity that depends almost exclusively on the water depth (D). The velocity (C) ($m\,s^{-1}$) is given by the equation:

$$C = \sqrt{(g\ (D + H)} \approx \sqrt{(gD)} \text{ as } D >> H$$

where g (= 9.81 $m\,s^{-2}$) is the acceleration due to gravity, D is the water depth (in m) and H is the offshore tsunami height (in m). The devastating tsunami of December 2004 travelled over deep water at speeds of as much as 800 $km\,hr^{-1}$ (~ 220 $m\,s^{-1}$), allowing it to cover thousands of kilometres in several hours before crashing into coastal areas – killing approximately 250 000 people.

The destruction caused in coastal regions (water depth < 20 m) is due to the increase in wave height during the approach to the coastline, where the water depth decreases rapidly (cf. Figure 1). There, because of the abrupt deceleration (from speeds of 100s of kilometres per hour

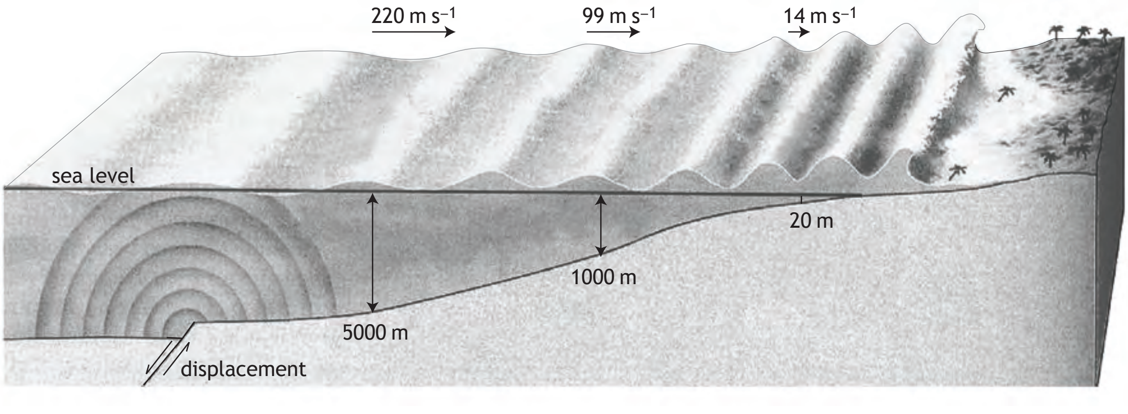


Figure 1 *Schematic drawing of a tsunami generated by a displacement of the ocean floor. Typical values of wave speed and wave height are also given for a tsunami wave approaching the shore. (Originally from Tarbuck and Lutgens, 2002; see Further Reading).*

In the open sea, tsunamis travel fast and are almost undetectable; in shallow water they slow down, and their wave height increases, often with disastrous results

Table 1 *The Sieberg–Ambraseys (1962) tsunami intensity scale, based upon observations made during catastrophic tsunami events.*

I: Very light	Wave so weak as to be perceptible only on tide-gauge records.
II: Light	Wave noticed by those living along the shore and familiar with the sea. Generally noticed on very flat shorelines.
III: Rather strong	Generally noticed. Flooding of gently sloping coast. Light sailing vessels carried onto the shore. Slight damage to light structures situated near the coast. In estuaries, there is reversal of the river flow for some distance upstream.
IV: Strong	Flooding of the shore to some depth. Light scouring on man-made ground. Embankments and dykes damaged. Light structures near the coast damaged. Solid structures on the coast marked. Large sailing vessels and small ships float inland or are carried out to the sea. Coasts littered with floating debris.
V: Very strong	General flooding of the shore to some depth. Quay walls and solid structures near the sea damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and marine animals. With the exception of very big ships, all vessels carried inland or out to sea. Big bores in estuaries. Harbour works damaged. People drowned. Wave accompanied by strong roar.
VI: Disastrous	Partial or complete destruction of man-made structures for some distance from the shore. Flooding of coasts to great depth. Large ships severely damaged. Trees uprooted or broken. Many casualties.

to less than 50 km hr^{-1}) their height increases abruptly and often exceeds 10 m, depending upon the sea-bed morphology of the inner shelf, and that of the nearshore zone in particular. This enormous volume of water floods the coastal land, covering it to a depth of a few metres. The arrival of a second or third tsunami wave in the wave train is more catastrophic than the first one, because the wave travels faster over the land once it has been flooded, and the water volume is continually increasing.

The reason that tsunamis have come to be known as 'tidal waves' even though their genesis and propagation are not related to the astronomical tide, is because the sea sometimes withdraws prior to the arrival of the tsunami wave crest. The withdrawal of the sea (corresponding to the trough of the tsunami wave) can vary in extent from several metres up to hundreds of metres, depending on the characteristics of the tsunami and the coastal topography. Whether or not a withdrawal of the sea occurs at all depends upon how and where the tsunami was generated, and the way the wave propagates over the particular marine basin. In some cases, the tsunami wave crest reaches the coast first, allowing no time for evacuation of the coastal population. In the case of the December 2004 tsunami, the waterline retreated exposing hundreds of metres of sea-bed, in theory providing some degree of warning.

On the basis of the severity of the destruction caused, tsunamis have been classified on a six-level intensity scale (Table 1) by August Sieberg and Nicholas Ambraseys (see Further Reading).

Tsunamis in the seas around Greece

Tectonic setting of the eastern Mediterranean

The genesis of tsunamis in Greek waters, as elsewhere in the world, is related to the geological setting, whilst their propagation is related to the depth of the sea-bed and the coastal morphology. An important aspect of the geotectonic setting of the Greek region is the northward motion of the African megaplate, and its sinking (or subduction) under the Eurasian megaplate along the Hellenic Trench (Figure 2). This deformation involves three other microplates: the Adriatic (continental) Plate, which is moving north-eastwards along the Cefallinia Transform Fault; the Aegean Plate (which is further divided into northern and southern parts by the western extension of the North Anatolian Fault), and the westward-moving Anatolian plate. The combined effect of the resulting forces is that Greek territory (mainland plus islands) is drifting towards the south-west. This highly active geotectonic setting results in 'rough' topography (terrestrial and subaqueous) and intensive seismicity, as well as volcanic activity along the Hellenic volcanic arc.

Along the Hellenic Trench, the sea-bed may be as deep as 5 km; while in the Aegean Sea, depths reach 2200 m in the eastern part of the Cretan back-arc basin,* and 1800 m along the North Aegean Trough (the expression of the North Anatolian Fault in the Aegean). In addition, in the Gulf of Corinth (a tectonic graben† behind the back-arc basin), depths exceed 850 m. This highly irregular topography explains the occurrence of subaqueous landslides down the steep continental slopes.

In terms of seismicity, the eastern Mediterranean has been the source of the majority of seismic shocks which have occurred in Europe, with more than half of the total being within Greek territory. This is due to the plate motions mentioned above, which cause large numbers of earthquakes along compressional/extentional stress fields (Figure 2).

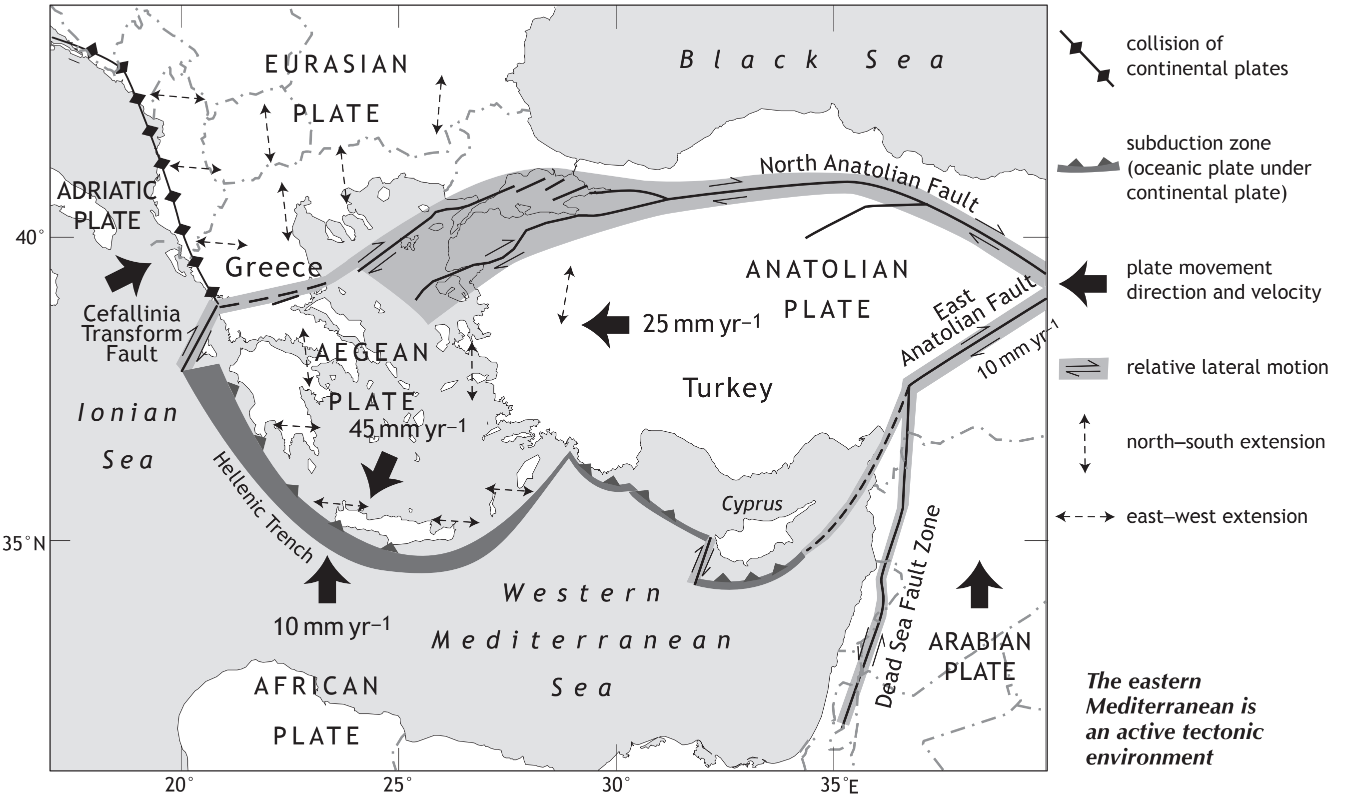
Tsunami events

According to historical records, more than 150 cases of tsunami waves have affected Greek territory between 1700 BC and the present day, with heights ranging from a few metres to more than a few tens of metres (see Papadopoulos and Chalkis (1984) and Papazachos and Papazachou (2003) in Further Reading). Historically, there have been some extremely high tsunami waves, of the order of 25–30 m, including the tsunami that followed the volcanic activity of Santorini in 1650 (earthquake magnitude 6.3 on the Richter scale**), the Aegio earthquake in 1748 (magnitude 6.8) and the earthquake of Amorgos in 1956 (magnitude

*Back-arc basins are the basins found landward of volcanic island arcs, which form where an oceanic tectonic plate sinks (is subducted) below another.

†A graben is an elongate basin formed by faulting.

** For information about the Richter scale, see note by Table 3 opposite.



The eastern Mediterranean is an active tectonic environment

Figure 2 *The motions of the lithospheric plates in the eastern Mediterranean; thick black arrows indicate their observed velocities relative to the Eurasian Plate (which is assumed to be stationary). Also shown are the plate boundaries and the stresses generated by the plate motions.*

Note: Figures 3 and 4, and Table 2, are overleaf.

7.5). (The earthquake that generated the December 2004 tsunami was of magnitude 9.3.) Table 2 (overleaf) lists all reported tsunami events from 426 BC up to the present day, including their characteristics and generation mechanism (earthquakes, volcanic eruptions or submarine 'landslides'). The magnitudes of earthquakes which occurred prior to 1935 have been estimated on the basis of the damage they are believed to have caused. The data are not always reliable, especially those relating to ancient events, because of changes in the coastline and the fact that the people who provided observations and comments sometimes exaggerated.

Figure 3 (overleaf) shows the birthplaces of the tsunamis listed in Table 2, whilst Figure 4 shows coastal regions reported to have been affected by those tsunamis. From those two maps, it can be seen that more tsunami events have occurred in the Aegean Sea than in the Ionian Sea. In addition, a considerable number of tsunami events have happened within the semi-enclosed Gulf of Corinth, as well as the Gulfs of Evoikos, Maliakos and Thermaikos. The geographical distribution of tsunami events is a reflection of the tectonic features that gave rise to them. As shown in Figure 5, 35 events occurred along the Hellenic Trench, 15 in back-arc basins and along the Hellenic volcanic arc (i.e. in the Cretan Sea), 25 were related to the westward extension of the North Anatolian Fault (in the northern Aegean Sea) and

Figure 5 *Spatial distribution of tsunami events in relation to major tectonic features (based on the data in Table 2 overleaf).*

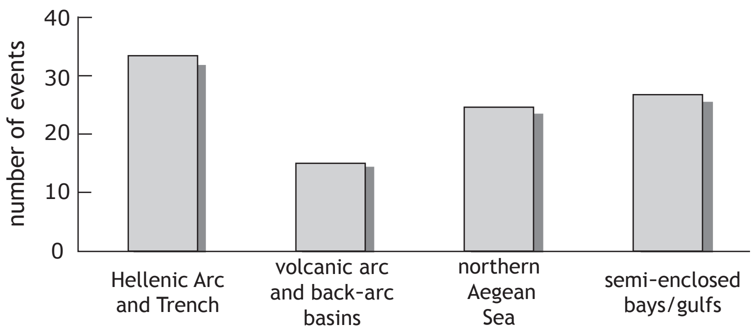


Table 3 *Tsunamis affecting Greek territory (since 426 BC) which were of intensity ≥ V, according to the Sieberg–Ambraseys scale. All were caused by earthquakes of magnitude (M_s) > 6 on the Richter scale.*

Date	Region	M_s	Most affected area	Intensity
426 BC	Gulf of Maliakos	7.1	Skarfia	V
373 BC	western Gulf of Corinth	6.8	Heliki	VI
21/7/365	Eastern Crete	8.3	Methoni	VI
6/1402	Gulf of Corinth	6.8	western Corinth	V
9/10/1650	Santorini	6.3	Santorini	V
9/7/1956	Amorgos	7.5	Amorgos	V

**Note* The Richter scale, devised in 1935, uses the maximum amplitude of seismic waves travelling along the surface of the Earth to estimate the size of shallow earthquakes using a mathematical formula. Unlike the Sieberg–Ambraseys intensity scale, it is not dependent on the subjective assessments of observers.

Table 2 *Major documented tsunamis in ancient and modern Greece since the fourth century BC, given in chronological order.* M_s *= magnitude on the Richter scale (see footnote on p.33); SA = intensity on the Sieberg–Ambraseys scale; E/q = earthquake; V = volcanic eruption; L = 'landslide'.* ***.*** *Note that for events before 1935, magnitudes (*M_s*) have been estimated on the basis of the destruction reported at the time (i.e. SA). (Data from various sources.)*

(i) Northern Aegean Sea (including islands and coastal embayments)

No.	Date	Region	Cause	M_s	SA
1	426 BC	Gulf of Maliakos	E/q	7.1	V
2	330 BC	Samothace	E/q	?	II
3	223 BC	Evoikos Gulf	E/q	?	II
4	6/9/544	Thace	E/q	7.0	III
5	7/7/551	Gulf of Maliakos	E/q	6.8	IV
6	20/3/1389	Chios	E/q	6.7	IV
7	17/2/1659	Chios	E/q	7.4	I
8	11/1667	eastern Aegean	E/q	7.2	III
9	1672	Samothace	E/q	6.8	II
10	10/7/1688	Chios	E/q	6.8	II
11	24/11/1772	Limnos	E/q	6.4	III
12	18/8/1853	Gulf of Evoikos	E/q	6.5	III
13	19/11/1856	eastern Aegean	E/q	6.3	IV
14	2/2/1866	eastern Aegean	E/q	6.4	III
15	3/4/1881	eastern Aegean	E/q	6.5	III
16	11/4/1881	eastern Aegean	E/q	6.0	III
17	9/2/1893	Samothace	E/q	6.8	III
18	27/4/1894	Gulf of Maliakos	E/q	7.0	III
19	05/07/1902	Gulf of Thermaikos	E/q	6.5	II
20	20/01/1905	western Aegean	E/q	6.3	II
21	08/08/1922	western Aegean	E/q	5.6	II
22	31/03/1928	eastern Aegean	E/q	6.5	II
23	26/09/1932	Ierisos Chalkidiki	E/q	7.0	III
24	09/02/1949	Chios	E/q	6.7	III
25	09/07/1955	Samos	E/q	6.9	III
26	02/11/1956	Gulf of Pagasitikos	E/q	5.6	IV
27	28/05/1962	Limnos	E/q	4.5	II
28	19/02/1968	Limnos	E/q	7.1	III
29	20/06/1978	Limnos	E/q	6.5	I
30	06/08/1983	Limnos	E/q	6.8	III
31	04/01/1991	eastern Aegean	E/q	6.0	III

(ii) Southern Aegean Sea/Crete/Cretan Straits

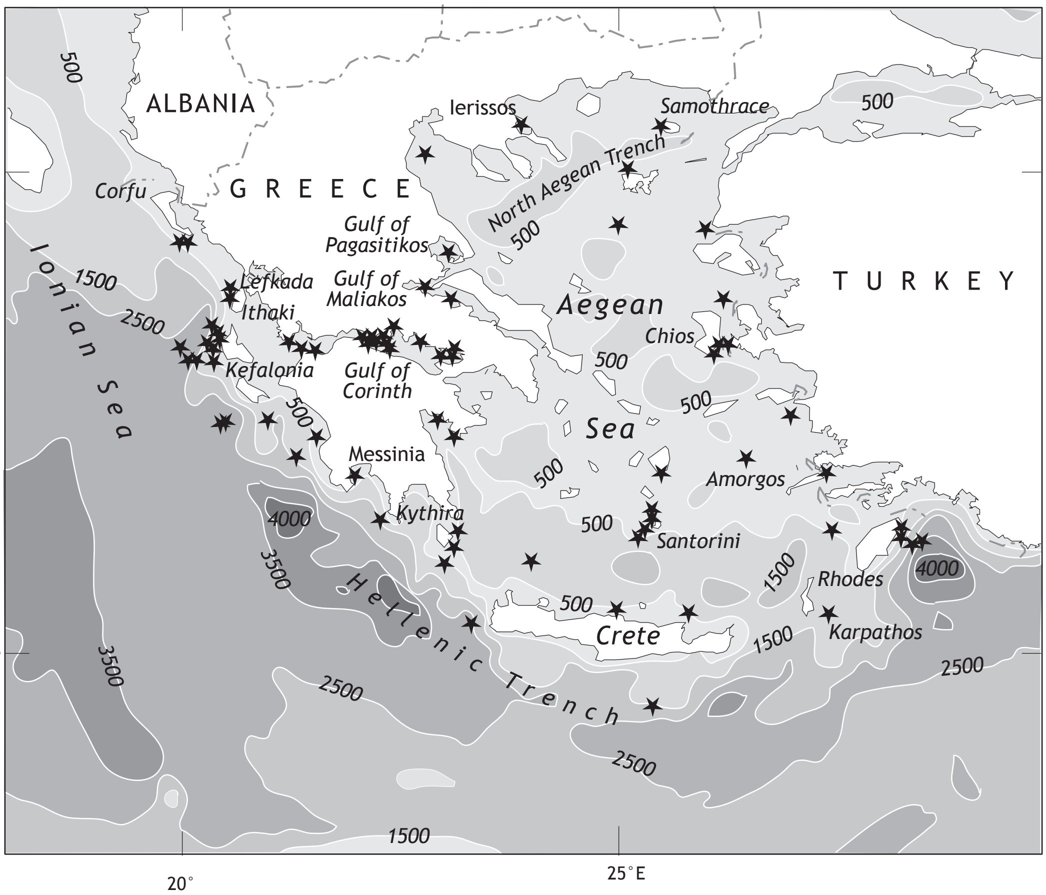
No.	Date	Region	Cause	M_s	SA
1	227 BC	Dodecanese Is.	E/q	7.5	II
2	46 AD	southern Aegean	E/q	6.5	II
3	62 AD	Crete	E/q	7.5	IV
4	148 AD	Dodecanese Is.	E/q	7.0	IV
5	21/7/365	Crete	E/q	8.3	VI
6	556 AD	Dodecanese Is.	E/q	7.2	IV
7	800 AD	Straits of Kythira	E/q	7.4	V
8	8/8/1303	Rhodes	E/q	8.0	VI
9	1489	Dodecanese Is.	E/q	?	III
10	1/7/1494	Crete	E/q	7.0	IV
11	4/1609	Dodecanese Is.	E/q	7.2	V
12	8/11/1612	Crete	E/q	7.0	IV
13	9/3/1630	Straits of Kythira	E/q	6.7	III
14	29/9/1650	Santorini	V	6.3	V
15	10/2/1681	Crete	E/q	?	?
16	21/1/1741	Rhodes	E/q	7.3	IV
17	21/1/1866	southern Aegean	V	6.1	I
18	6/2/1866	Straits of Kythira	V	6.6	IV
19	20/9/1867	Straits of Kythira	E/q	6.8	IV
20	30/08/1926	Gulf of Argolikos	E/q	7.2	II
21	06/10/1947	Messinia	E/q	7.0	III
22	19/2/948	Karpathos	E/q	7.1	IV
23	09/07/1955	Samos	E/q	6.9	III
24	09/07/1956	Amorgos	E/q	7.5	V
25	19/09/1986	Kalamata	E/q	6.0	III
26	07/05/1991	Leros	E/q	6.1	III
27	05/04/2000	Crete	E/q	5.2	III

(iii) Gulf of Corinth

No.	Date	Region	Cause	M_s	SA
1	373 BC	Eliki	E/q	6.8	VI
2	6/1402	Aegio	E/q	6.8	V
3	21/2/1742	western G. of Cor.	E/q	6.6	III
4	14/5/1748	Aegio	E/q	6.8	IV
5	1769	Galaxidi	E/q	6.5	II
6	11/6/1794	Galaxidi	E/q	6.7	III
7	23/7/1817	Aegio	E/q	6.6	IV
8	21/2/1858	Xilokastro	E/q	6.5	II
9	26/12/1861	western G. of Cor.	E/q	6.7	IV
10	15/12/1881	central G. of Cor.	L	5.0	IV
11	4/10/1887	Xilokastro	E/q	6.5	IV
12	9/9/1888	central G. of Cor.	E/q	6.1	II
13	18/02/1911	Lake Orchida	E/q	6.7	II
14	22/04/1928	eastern G. of Cor.	E/q	6.3	IV
15	07/02/1963	Aegio	L	4.5	III
16	06/07/1965	Eratini	E/q	6.3	IV
17	24/02/1981	eastern G. of Cor..	E/q	6.7	II
18	11/02/1984	western G. of Cor..	E/q	5.5	III
19	15/06/1995	Eratini	E/q	6.3	III
20	01/01/1996	Aegio	L	6.4	IV

(iv) Ionian Sea

No.	Date	Region	Cause	M_s	SA
1	3/1270	Corfu	E/q	6.8	III
2	5/11/1633	Zakynthos	E/q	7.0	III
3	12/10/1636	Kefalonia	E/q	7.2	III
4	23/2/1723	Lefkada	E/q	7.0	III
5	11/1732	Corfu	E/q	6.5	II
6	2/11/1791	Zakynthos	E/q	6.8	II
7	8/6/1804	Lefkada	E/q	6.3	?
8	19/1/1825	Lefkada	E/q	6.5	II
9	4/2/1867	Lefkada	E/q	7.2	II
10	27/6/1883	Corfu	E/q	?	III
11	27/8/1886	Gulf of Kiparissiakos	E/q	7.5	III
12	17/4/1893	Ionian Sea	E/q	6.4	II
13	6/2/1898	Gulf of Kiparissiakos	E/q	7.0	III
14	3/12/1898	Zakynthos	E/q	6.1	II
15	24/01/1912	Kefalonia	E/q	6.8	I
16	27/11/1914	Lefkada	L	6.3	IV
17	27/01/1915	Ithaki	E/q	6.6	I
18	07/08/1915	Ithaki	E/q	6.7	III
19	09/02/1948	Lefkada Is	E/q	6.5	IV
20	12/08/1953	Kefalonia	E/q	7.3	III
21	15/04/1979	Straits of Otrand	E/q	7.1	I
22	17/01/1983	Kefalinia	E/q	7.0	II



Most tsunamis affecting Greece are generated relatively close to coastlines

Figure 3 *The birthplaces of the tsunamis listed in Table 2; note that many of the generation sites have been responsible for a number of tsunamis. Depths on contours are in metres.*

Figure 4 *Locations known to have been affected by the tsunamis listed in Table 2. Note that reports of tsunamis are more likely to come from centres of population (towns/cities) and densely populated coastlines, and some of the places shown are sources of reports of a number of tsunamis. Note that tsunamis generated in the Sea of Marmara (by movements along the North Anatolian Fault) cannot propagate through the Bosphorus into the Aegean.*

Reports of tsunamis have come from numerous parts of Greece and many of the Greek islands

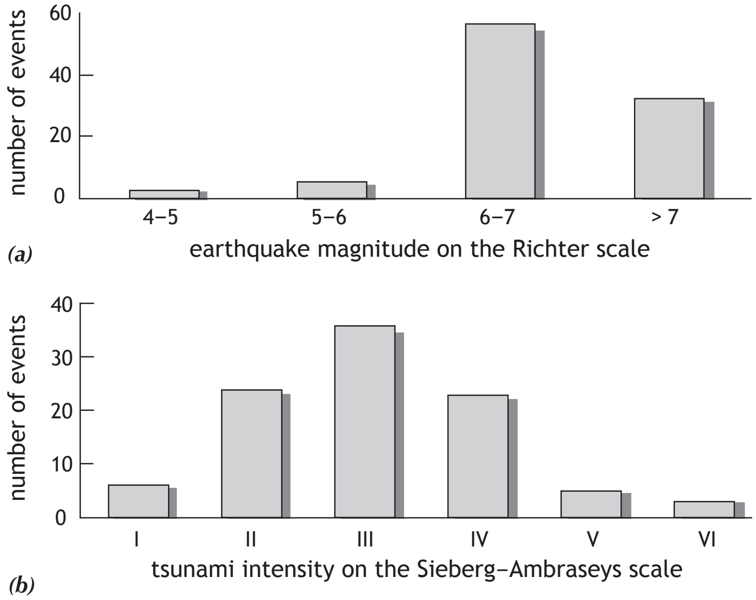


Figure 6 *Tsunami events grouped according to* ***(a)*** *the magnitude of the earthquake which caused them, and* ***(b)*** *their intensity (based on the data in Table 2).*

Most tsunamis are generated by earthquakes of magnitude 6 or greater, and have intensities described as 'rather strong', 'strong', or 'very strong'

26 occurred in semi-enclosed bays and gulfs (e.g. the Gulf of Corinth). In semi-enclosed gulfs, the propagation of the tsunami wave is constrained, which further increases the height of the wave that reaches the shore.

The majority of tsunami waves which have affected ancient and modern Greece owed their genesis to underwater earthquakes and, to a lesser extent, to underwater landslides and the excitation of the Greek volcanic arc (e.g. the volcanic eruption of Santorini in 1650). Furthermore, the majority of tsunamis were generated by earthquakes of magnitude 6–7 on the Richter scale, with 32 events being caused by an earthquake of magnitude >7; in 13 cases they were caused by earthquakes of magnitude between 4 and 6 (Figure 6(a)).

On the basis of the devastation they caused, the majority of tsunami events in Greece have been classified into the first four categories of the Sieberg–Ambraseys scale (Figure 6(b)): 6 cases in category I, 24 cases in category II, 36 cases in category III, and 23 cases in category IV. Moreover, since 426 BC, only six tsunamis have been recorded of an intensity ≥ V, two of which are in category VI (disastrous) (Table 3).

Prediction and precautions

How long to a tsunami in Greek waters?

As far as predition is concerned, it should be remembered that the frequency and wave height of tsunamis depends on a lot of factors – the way energy is released at the birthplace, the particular geometry of the fault concerned, and how long it is active, and/or the size of any volcanic explosions, and/or the rate of deformity of the marine basin. It is therefore not possible to accurately predict the height of a tsunami, which above the site of generation seldom exceeds one metre.

On the basis of statistical analysis of known tsunami events, the coastal areas threatened by tsunamis with intensity ≥ V are: the Cyclades, southern Karpathos, south-western Laconia–Messinia, the south-western part of the Gulf of Corinth, and the Gulf of Maliakos/northern Euboea, as well as the western coasts of Etoloakarnania. Furthermore, it has been estimated that the average period of recurrence of a devastating tsunami is a thousand years for a tsunami of intensity VI, and 170 years for a tsunami of intensity V. This means that a tsunami of intensity VI might be expected to occur around 3000 AD, and one of intensity V around 2100 AD. However, although the statistics suggest that a large tsunami is not expected for 100 years, we cannot disregard the possibility that it could happen before then.

Is an early warning system feasible?

Finally, there is considerable scepticism about the establishment of an effective warning system in Greek waters, and its actual efficiency. This is because of the complexity of the generating mechanisms and (especially) the relatively small distances between the known tsunami birthplaces and Greek coasts (cf. Figure 3). The expected speed of tsunami propagation in Greek waters where depths are less than 2500 m (in the eastern Cretan Sea) is of the order of 500 km hr^{-1}, while in the vicinity of the Hellenic Trench, where depths exceed 4000 m (Ionian islands, southern Crete and south-eastern Rhodes), the speed is greater than 700 km hr^{-1}. These high propagation velocities combined with travelling distances generally less than 150 km allow only a short interval (<30 minutes) before a tsunami that has been identified reaches the coast. In other words, within a very short period of time, a tsunami has to be identified and monitored, and the information passed to coastal authorities so that they can alert the coastal population. Most tsunami experts consider that this would prove to be too ambitious, if not impossible.

On the positive side, the coastal morphology of Greek coastlines (steep and rocky, with narrow shelves) would limit the extent of the damage done by any tsunami. This 'protective' morphological setting, and the small likelihood of a large tsunami, makes the Greek coastline a safe place to live in and visit – at least as far as as tsunamis are concerned!

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MARINE CORROSION

a widespread, underestimated and poorly understood phenomenon

Jaques Daret, Samuel Pineau and Thierry Braisaz

Seawater is a universal fluid – it is the medium where oceanographic moorings, ships, harbour installations and offshore platforms spend their life. Seawater is also widely used in industrial applications: for cooling and for use against fire in ships and platforms, and in coastal installations such as refineries, chemical/petrochemical plants, desalination plants and power stations. By nature, seawater is very corrosive to metallic materials; it contains, for example, dissolved oxygen, micro-organisms, and high concentrations of chloride ions and other chemical species deleterious to the integrity of metallic materials, such as hydrogen sulphide and ammonia compounds. Therefore, when designing any equipment or industrial plant that will be in contact with seawater, it is important to know about, and to take into account, the behaviour of metallic materials in seawater. It is also absolutely essential to evaluate not only the effects of corrosion, but also the environmental effects of measures taken to counteract it.

Some insights into corrosion

What is corrosion?

Corrosion is a natural phenomenon. Only a few metals (sometimes known as 'noble metals') exist in nature in their metallic non-oxidized or 'native' state. Two examples of noble metals are gold and platinum. In nature, all systems tend towards an equilibrium situation, so all non-noble metals tend to revert to their thermodynamically stable state, which is the oxidized form (e.g. an oxide, sulphate or carbonate), in which form they are found as mineral ores.

The best scientific definition of corrosion is given by the ISO 8044 European Standard, according to which corrosion is the 'physico-chemical interaction between a metal and its environment that results in changes in the properties of the metal, the environment, or the technical system, of which these form a part.' The significance of this definition is that it stresses that corrosion may alter not only the material, but also the properties of the environment, a fact that is often neglected or forgotten.

Corrosion is the result of electrochemical reactions (oxidation and reduction) at the surface of a metal. When corrosion occurs, positively charged ions leave the metallic surface and go into solution. The part of the metallic surface which corrodes (i.e. oxidizes) is called the 'anode', whereas the 'cathode' is the region where the current returns to (i.e. electrons leave) the metal, causing, in the case of seawater, the reduction of dissolved oxygen to form water or hydroxyl ions (in acidic or neutral/alkaline environments, respectively).

The currents passing across metal/liquid interfaces are governed by potential differences. Figure 1 shows a ranking of some pure metals in moving seawater, according to their standard potential with respect to a hydrogen electrode: the higher a metal is in the list, the more resistant it is to corrosion.

*ISO = International Organization for Standardization.

Why seawater is 'corrosive' to metallic materials

The terms 'aggressiveness' and 'corrosiveness' are often used to describe the destructive action of a liquid towards a material: it is widely accepted that a wide variety of factors – mechanical, physical, chemical, electrochemical and biological – may influence the aggressiveness of seawater.

Figure 1 Left *Electrochemical ranking of some metals in moving seawater. Coupling together of two metals in this list will produce a reduction in the corrosion rate of the upper, and an increase for the lower. This is the basis for the use of protective 'sacrificial' electrodes of zinc, aluminium or magnesium (in the the lower part of the list) which dissolve preferentially.*
Right *Sacrificial anode (white) used to protect a metal structure in seawater.*

'Noble end'
Gold
Platinum
Titanium
Silver
Copper
Hydrogen electrode
Lead
Tin
Molybdenum
Nickel
Iron
Chromium
Zinc
Aluminium
Magnesium
'Active end'

The composition of the seawater solution is fairly uniform all around the world, with a concentration of some 35 g kg^{-1} dissolved salts. The principal ions are chloride (~20 g kg^{-1}), sodium (~10 g kg^{-1}), sulphate (3 g kg^{-1}) and magnesium (~1 g kg^{-1}). The corrosion resistance of stainless steel alloys and aluminium depends on the natural formation of a thin oxide film approximately 10 nanometres (10^{-9} m) thick. In environments containing halides (particularly chloride ions), this film may be attacked at weak points, resulting in pitting corrosion (discussed later; see Figure 3(a)). Seawater also contains most other naturally occurring elements; although mainly at considerably lower concentrations, some of these may be important in corrosion reactions, especially in biologically related corrosion.

Dissolved gases may also be important in determining how aggressive the seawater is. Whereas nitrogen is generally considered as chemically and biologically 'inert', the availability of oxygen governs many reactions involved in corrosion. Depending mainly on the degree of contact with the atmosphere, mixing and temperature, conditions may vary from totally aerated to zero in completely anoxic seawater or mud. Other gases involved in corrosion phenomena include ammonia (produced by nitrate reduction), and hydrogen sulphide (perhaps produced by bacterial activity).

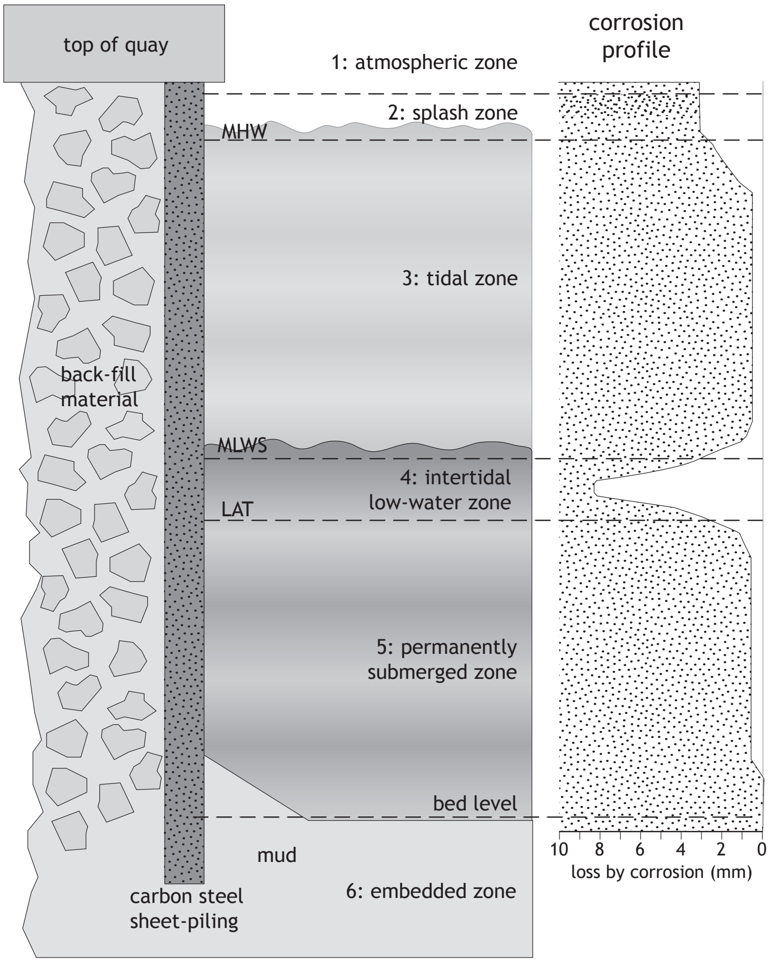
The characteristics of the marine environment are very variable. Above the water-line, conditions are essentially atmospheric, and corrosion is caused by salty spray. Lower down, in splash zones, the mechanical effect of moving water and abrasive suspended particles is important. In permanently submerged zones the concentrations of chemical species (e.g. dissolved oxygen) and the microbial communities present, can vary. Many of these scenarios may be found in the case of harbour steel sheet piling in a tidal environment, illustrated in Figure 2.

Micro-organisms have recently received a lot of attention in the context of corrosion in seawater, but at present nobody can demonstrate unequivically that they are responsible for either the initiation of corrosion or the acceleration of corrosion which has already started. The term 'microbiologically influenced corrosion' (MIC) is often used to describe situations where bacteria do not actually give rise to a new kind of corrosion, but seem to speed up the rate of corrosion (according to the vocabulary of the ISO 8044 standard). MIC is usually associated with heterogeneities in the bacterial film, or 'biofilm', that commonly covers metallic surfaces in seawater. As a rule, it does not involve any new electrochemical mechanisms of corrosion; rather, it is the result

Corrosion of steel structures is typically greatest in the intertidal low-water zone

Figure 2 ***(a)*** *Typical corrosion profile of a carbon steel structure, such as a quay sheet piling, in seawater. Note the increase in degradation in the intertidal low-water zone (4), a phenomenon often described as 'accelerated low-water corrosion' (ALWC), which may be encouraged by the activity of micro-organisms.*

(b) *Corrosion and complete failure of a steel pile in the intertidal low-water zone.*



The zones in the cross-section are as follows:

1: Between the splash zone and top of the structure
2: From mean high water (MHW) up to a height that depends on the mean wave height
3: Between mean low water springs (MLWS) and MHW
4: Between a point ~ 0.5–2 m below the lowest astronomical tide (LAT) and MLWS
5: From the mud-line (sea-bed) up to the lower limit of the intertidal low-water zone
6: Completely buried in mud, which may be low in oxygen

of a microbiologically influenced change that promotes the establishment or maintenance of physicochemical reactions not normally favoured under otherwise similar conditions. The exact nature of the relationship (direct or indirect) between the heterogeneity of electrochemical corrosion reactions and heterogeneities – microbial, chemical and physical – within the biofilm itself, remains unclear.

Protection from corrosion

Protective methods are broadly subdivided into four categories: (1) materials and design; (2) modification of the seawater electrolyte; (3) change in the electrode potential; (4) separation of the metal from its environment.

1. Materials and design Among the most important factors to be borne in mind are (i) selection of an appropriate material. One approach is to use corrosion resistant materials: for example, some oceanographic instruments are made of titanium or even plastic. (ii) Contact between metals of different standard potential should be avoided because the kinetics of attack on one metal surface will be enhanced by the presence of the second. (iii) It is important to appreciate that the geometry of a structure is relevant because rates of corrosion are strongly dependent on, for example, conditions of flow and aeration. Localized attack can be minimized by the avoidance of narrow spaces or shapes that are particularly susceptible to erosion or cavitation (discussed later). (iv) Mechanical factors play a part in encouraging corrosion, and excessive stress, internal or externally applied, should be avoided. (v) Rough surfaces, or other surface conditions that enhance susceptibility to localized attack, should be avoided.

2. Modification of the electrolyte There are two possible strategies for achieving this:
(i) Removal of the aggressive species, for example: elimination of dissolved oxygen by means of an oxygen scavenger such as hydrazine; elimination of dissolved salts by means of reverse osmosis or ion exchange; elimination of solid particles in order to prevent deposit corrosion. (ii) Addition of corrosion inhibitors – substances which, when added in small concentrations to an environment (e.g. seawater in a pipe), reduce the corrosion rate of a metal exposed to that environment. Inhibitors may act by adsorption onto the surface (e.g. in the case of phosphorus compounds); by formation of a precipitate (e.g. in the case of phosphonate salts).

3. Change in electrode potential It is theoretically possible to raise or lower the potential into a stable zone, so that the surface is anodically or cathodically protected. Cathodic protection involves using sacrifical anodes or an 'impressed current' (explained below). Sacrificial anodes are usually are made of zinc, aluminium or magnesium (cf. Figure 1). They are attached to the metallic equipment or structure and corrode preferentially. Their main advantages include: relatively straightforward installation; the fact that it is not possible to connect the electrodes so as to produce the wrong polarity; and the ease with which a uniform electrode potential can be achieved.

In impressed current cathodic protection, a power supply is employed to drive a direct current. The most serious disadvantages are the risk of overprotection and the difficulty of achieving a uniform electrode potential over the metal surface.

4. Separation of the metal from its environment
This is done using coatings, and is especially important for metal vessels. They include epoxy resins, various paints, metallic coatings such as produced by galvanizing iron, and metal oxide coatings, as in the case of anodized aluminium.

Types of corrosion

General corrosion

When the anodic and cathodic zones are evenly distributed, metal loss is fairly uniform over the metallic surface (Figure 3(b)). This form of corrosion is not particularly dangerous for the structural integrity of the metal, since it produces a predictable and measurable loss of thickness. Nevertheless, metallic dissolution over a long time period could cause a local accumulation of metal ions, with adverse environmental effects.

Localized forms of corrosion

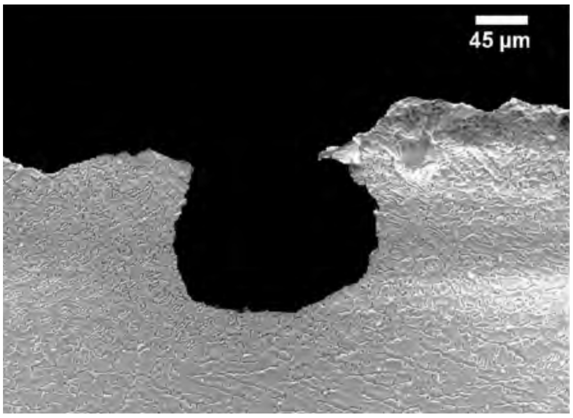
These result when anodic reactions are concentrated in certain areas of the metal/liquid interface, due to heterogeneities in the metallic material itself (resulting from cold working, heat-treatment etc.) or in the seawater (variations, perhaps with depth, of dissolved oxygen concentrations, current velocity, temperature, etc.). These localized forms of corrosion may produce dramatic failure of equipment over relatively short periods of time, and they also contribute to environmental degradation.

In seawater, the following forms of localized corrosion are frequently met:

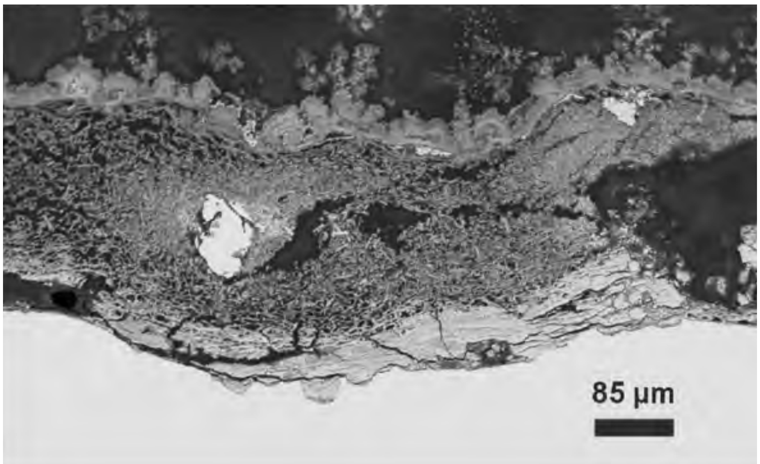
Pitting corrosion This very localized form of attack is common on stainless alloys. As mentioned earlier, the excellent corrosion resistance of this kind of alloy depends on the formation of a thin oxide film at the surface, but in an environment containing chloride ions or sulphates, these oxides are locally destroyed, producing a well known form of degradation that results in holes in the material (Figure 3(a)).

Galvanic corrosion This is promoted by the coupling of either two different materials (see Figure 1), or two zones of the same material which are under different chemical/electrochemical conditions (as in the intertidal low-water zone; cf. Figure 2). An example of the latter is the phenomenon known as 'corrosion below the waterline', which occurs on ship hulls as a result of differential aeration above and below the waterline. Surprisingly, corrosion in the less aerated zone proceeds at a higher rate than in the fully aerated zone.

Crevice corrosion This occurs in areas where chemical conditions are locally different from those for the rest of the material or structure, due to oxygen depletion and/or acidification of seawater. On ships, and in facilities in contact with seawater, this typically causes problems in flange joints.



(a)



(b)

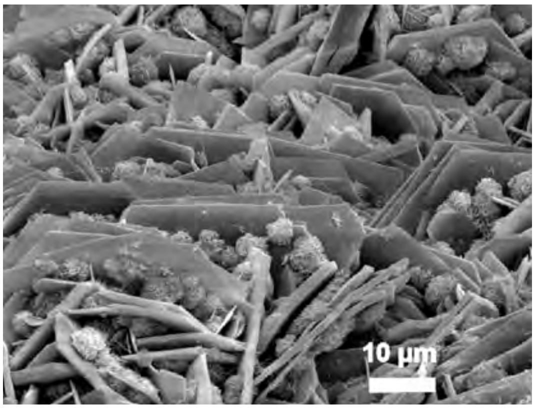
Figure 3 *Scanning electron micrographs showing examples of general and localized corrosion:*

(a) *The characteristic shape of a corrosion pit in stainless steel.*

(b) *A layer of corrosion deposit on carbon steel;* the deposit includes several minerals, including iron sulphide or 'green rust' (see Figure 4 below), magnetite (iron oxide) and lepidocrocite (iron oxyhydroxide).*

Localized forms of corrosion (e.g. pitting) are more dangerous to the structural integrity of metallic structures than is general corrosion

Figure 4 *The surface of carbon steel corroded in seawater, with typical 'green rust' or iron sulphide (thin hexagonal crystals). The round objects and elongate forms are iron oxide particles.*



In seawater installations (oil rigs etc.), mechanical stresses caused by the design and/or the effects of wind, waves and tides, are also important, as is physical damage from (say) impacts. Examples of corrosion caused by such physical factors are:

Stress corrosion cracking In circumstances where the metal is non-reactive due to the presence of a protective film, the application of stress can result in unexpected fracture of the metal. This is called stress corrosion cracking and has been known to produce dramatic failure of equipment, when there would be no damage in the absence of stress. The initial stage of failure is due to breakdown of the protective oxide film. When stresses are induced cyclically, the process is called 'fatigue corrosion'.

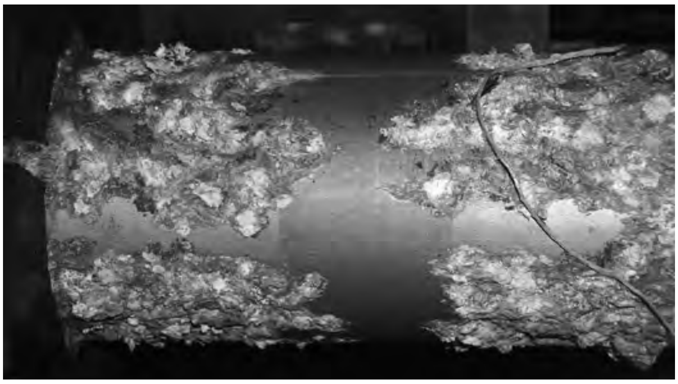
Corrosion caused by erosion/abrasion In seawater, erosion and abrasion may be caused by suspended particles impacting on the material's surface and destroying any protective layer.

Corrosion caused by bubble-bursting (cavitation) A pernicious type of corrosion, where water movement induces bubble-formation, followed by implosion, which leads to destruction of the protective oxide film. This induces a form of corrosion that is especially detrimental to rotating components, such as pumps and ship propellers.

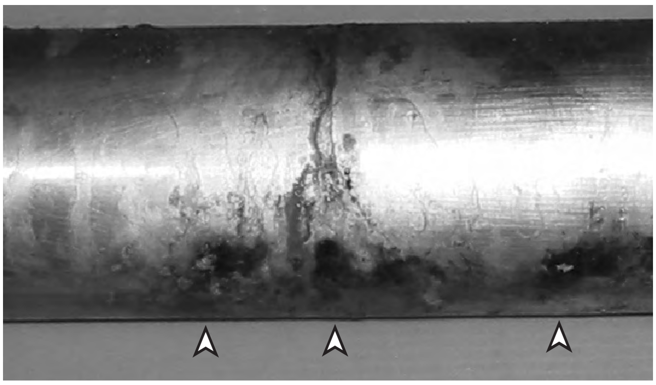
*Carbon steel is an ordinary steel (i.e. an alloy of iron and carbon) whose properties are determined primarily by the amount of carbon present. As well as iron and carbon, there may also be manganese up to 1.5%, as well as small amounts of elements such as nickel, chromium, molybdenum, etc. When one or more such elements are added in relatively large amounts it is classed as an alloy steel.

Figure 5 ***(a)*** *Badly corroded pH probe left in an estuary for about a year, covered by concretion-type deposits (carbonates, calcareous organisms, etc.). In these circumstances, corrosion products are often formed at interfaces between different materials (e.g. Teflon and steel) by crevice effects. (By courtesy of Chelsea Instruments)*

(b) *Pipeline (100 mm diameter) perforated by localized corrosion, probably induced and/or accelerated by micro-organisms. The arrows indicate the positions of the holes.*



(a)



(b)

Some industrial applications

Fire-fighting equipment

Fire-fighting equipment (pipes, sprays etc.) must comply with local regulations and those of the site. Regulations relate mainly to maintaining continuity of supply of seawater, and the resistance of material to flames. It is important that metallic spray nozzles resist corrosion, to avoid their being blocked by corrosion products (cf. Figure 3(b)).

In the case of offshore platforms, if local regulations do not allow the use of PVC-type materials (for piping), carbon steel with an organic coating and cathodic protection must be used, along with copper–nickel alloys for the main pipes where stagnant conditions (during maintainance, for instance) are very aggressive. In the case of coastal plants (refineries, processing units etc.), the weight of the installation is much less important than construction and maintenance costs, and large-diameter pipes are often made of carbon steel, and have their internal surfaces protected by a coating of cement.

Cooling systems

Seawater is widely used in cooling systems of ships, oil-rigs and sea-side industrial plants, including oil refineries and nuclear power stations. In such installations, high temperature effluents or steam must be cooled, which may cause problems with corrosion deposits and fouling (Figure 6(a)), especially in heat-exchangers where temperature and flow rate are high. Because corrosion processes such as anodic and cathodic reactions proceed faster at higher temperatures, conditions in cooling systems can be particularly aggressive, so it is necessary to use corrosion-resistant materials, including copper alloys, stainless steel and titanium.

Copper alloys are generally more resistant to biofouling than non-cuprous alloys, because copper is – in theory at least – toxic to micro-organisms. Nevertheless biofilms can be observed on copper alloy surfaces; unfortunately, sulphate- and thiosulfate-reducing bacteria are widespread in natural waters and, unless checked by chlorination or similar treatment, will produce hydrogen sulphide (H_2S). This will damage any protective film formed on the copper during commissioning, and if the water has not been circulating for a significant period, will cause pitting of the tubes (cf. Figures 3(a), 5(b) and 6(b)); in this particular case, bacteria *do* initiate corrosion. Often, prior ro circulation, seawater is filtered to remove abrasive particles and treated by the addition of corrosion-inhibitors and scale-inhibitors, an oxygen scavenger, a biocide (such as chlorine or hypochlorite), and sometimes anti-freeze liquid.

When petroleum is shipped to a refinery, to protect against spills the hydrocarbons may be cooled by seawater to cause them to solidify. To avoid contamination of the hydrocarbons by seawater, the tubular or plate heat-exchangers are generally fabricated from corrosion-resistant alloys (CRAs), such as titanium alloys. In some circumstances, air-cooling systems may be necessary.

Desalination plants

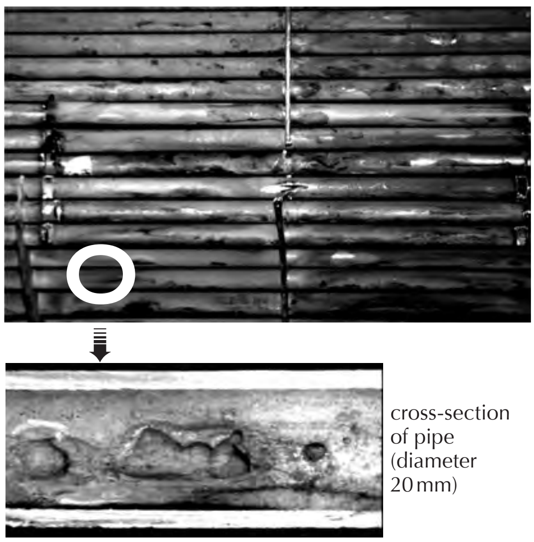
There are essentially two types of seawater desalination plants, using either distillation or membranes that selectively allow cations or anions to pass through them, but not both. Distillation methods involve temperatures in the range 120–140 °C. In addition to corrosion aggravated by high temperatures, there is the problem of calcareous deposits which can induce crevice corrosion. These deposits mean that special treatments such as decarbonation, or adding corrosion inhibitors such as polyphosphates to the seawater, are needed.

Among the methods using selective membranes, the 'reverse osmosis' process has the advantage of being possible at ambient temperature, without the production of steam. However, for parts working at high pressure, metallic materials must be used, and stainless steel or titanium are again recommended.

Heat-exchangers are particularly prone to corrosion because the high velocity of the fluid within, and the development of a biofilm, encourage erosion/abrasion corrosion and crevice corrosion

Figure 6 (a) *Biofouling on a seawater heat-exchanger (80 cm across).* ***(b)*** *Rapid failure of a copper–nickel heat exchanger. Large pits are visible in a tube which has been cut in half.*

(a)



(b)

Environmental consequences of corrosion

At first sight, the degradation of metallic structures may appear to be the main damage caused by marine corrosion. But it is important not to forget the impacts on the environment, both direct and indirect.

A terrible example of the indirect impact of corrosion-induced degradation is a shipwreck: it costs a lot of money and often also costs human lives. Indeed, some scientists think that the *Titanic* may have sunk because of galvanic corrosion of the rivets (which were of a different kind of iron from the hull).

Sinking of an oil tanker as a result of corrosion can be a disaster for the environment. In December 1999, the tanker *Erika*, which was known to have had corrosion problems since at least 1994 – broke up in rough seas off Brittany. About a third of the 30 000 tons of heavy fuel oil she was carrying were spilled – an amount equal to the total amount of oil spilled worldwide in 1998.

As mentioned above, when corrosion proceeds, metallic ions are transferred to the water. Similarly, when cathodic protection is adopted, it results in the preferential dissolution of the sacrifical anodes, and – again – transfer of metals to the environment. In a mid-ocean setting, mixing and dilution avoid locally high concentrations, but in a quasi-stagnant location such as a harbour, harmful concentrations of metals can accumulate in the sludge, with negative effects on marine life. Zinc, for instance, can easily accumulate in filter-feeding shellish such as oysters.

Anticorriosion products can also sometimes lead to serious environmental concerns. In order to protect marine life, a corrosion inhibitor that is not ecofriendly should be recirculated in a closed system, and not released into the environment.

Advances in protection against corrosion

Anticorrosion systems are becoming more and more important, and while their availability to industry becomes more critical, so does the need for both economy and lack of negative ecological impacts. As the theory of corrosion protection develops, the scope for anticorrosion techniques expands. For example, nowadays VCIs (Volatile Corrosion Inhibitors) can be used to protect metals not only against corrosion in the atmosphere (during storage, transportation etc.) but also against corrosion induced by gases such as H_2S and CO_2 which dissolve in water to produce corrosive solutions (corrosion can occur if there is an electrolyte on the surface). Besides, in recent years there has been development in the fields of application of corrosion inhibitors, related mainly to steel protection in highly corrosive media at elevated temperatures (>100 °C), such as are found in desalination plants and hydrothermal vents. Methods combining corrosion inhibitors with other means of anticorrosion protection (as discussed earlier) are being used more and more widely.

Developing anticorrosion systems that meet environmental regulations, especially those for demanding sectors like the petroleum industry, is a technological challenge that will need to be tackled. For instance, in a few years (sooner in the case of, say, Norway) chemical products will need to pass tests relating to biodegradation, bioaccumulation and toxicity before getting an 'environmentally acceptable' classification and permission for use. Such strict environmental regulations will encourage researchers and companies to develop, for many common field applications, effective anticorrosion systems which do not have negative effects on human or marine life.

Concluding comment

To avoid dramatic failures of equipment, and adverse effects on the environment, marine corrosion, and methods to combat it, should be taken into consideration before designing any industrial system that will be in contact with seawater. Once the system is working (i.e. in service), there should be a careful survey of conditions and a programme of regular inspections.

Further Reading

Circuit Eau de Mer: Traitements et Matériaux (1993) Editions Technip.

Davis, M. and P.J.B. Scott (2003) *Guide to Use of Materials in Waters*, NACE Press.

Videla, H.A. (1999) *Manual of Biocorrosion*, Lewis Publishers/CRC Press.

Jaques Daret is an engineer specializing in corrosion and mechanical engineering, working at CORRODYS.* He has studied corrosion for more than 35 years, and has particular expertise in stress corrosion cracking in nuclear power stations.

Samuel Pineau is a research and development engineer at CORRODYS.* He has a Ph.D in interactions between bacterial communities and corrosion processes in the marine environment. He has more than 10 years experience in marine biology, including research into biodeterioration of materials.

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Thierry Braisaz is the industrial manager at CORRODYS.* He has worked with materials and corrosion for more than 10 years, and has extensive experience in various industries, including the marine sector.

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*CORRODYS is the Marine and Biological Corrosion Centre at Equeurdreville, France.

Oceans '07 'Marine Challenges: Coastline to Deep Sea' will be in Aberdeen, Scotland.

For more information, see page 37.

A century of marine research in Europe: 1906–2006

Antonio Pusceddu

The Institut océanographique in Paris. The Institut and the Musée oceanographique in Monaco together make up the Fondation Albert 1er de Monaco

On the occasion of the 100th anniversary of the 'Institut océanographique, fondation Albert Ier, prince de Monaco', the Institut océanographique de Paris (IOP) hosted the celebratory event '1906–2006: A century of marine research in Europe', organized jointly by the European Federation of Marine Science and Technology Societies (EFMS) and the Union des océanographes de France. The congress, which was held in Paris from 13 to 15 September 2006, was also the occasion of the Annual General Assembly of the EFMS.

During the congress, various representatives of the EFMS provided delegates with an overview of the present, past and future activities of their respective national scientific communities. In addition, there were 19 posters illustrating recent advances in marine science in Europe.

The opening lecture of the congress was given by Roberto Danovaro (Polytechnic University of Marche), the dynamic outgoing President of the EFMS. Roberto provided a comprehensive overview of the past and future of the EFMS, including a detailed description of activities carried out since its foundation in 1998. He also highlighted the need to spread the influence of the Federation, which now represents approximately 6000 marine scientists all over Europe. Ivan Dekeyser, President of the Union des océanographes de France (UOF), then welcomed participants and gave an overview of the UOF. There followed talks by fourteen different representatives of EFMS societies, along with presentations by scientists from various European research institutions.

Lucien Laubier (Director of the Institut océanographique de Paris) delivered a fascinating talk on the heroic era of marine investigations undertaken by Albert Ist, Prince of Monaco, and gave a detailed report on subsequent successful advances in marine science achieved by renowned researchers at the Institut océanographique.

Stephen Hawkins, Director of the Marine Biological Association (UK), provided an interesting overview of the scientific work of the Association and its laboratories, including long-term research stretching back over 100 years, showing the influences of climate change and fishing on marine ecosystems. Interestingly, several scientists who worked in MBA laboratories were subsequently awarded the Nobel Prize.

The research effort devoted by the German scientific community to environmental investigations of the Wadden Sea during the 20th century was described by Hauke Bietz, so providing an intriguing philosophical point of view of environmental issues in coastal seas. Giulio Relini then reconstructed the history of the Italian Society of Marine Biology (of which he has been President for several terms of office) from its foundation in 1969 to its present involvement in research at the European level (the Society is a leader in establishing an inventory of fisheries in the Mediterranean).

Manos Dassenakis (the new EFMS President) presented a comprehensive overview of marine research carried out in Greece, from physical and chemical oceanography to applied marine ecology and coastal geomorphology. He highlighted the major environmental issues affecting Greece's coastal environments, and the scientific investigations that therefore need to be undertaken in the third millennium. Jean-Paul Ducrotoy (the new EFMS General Secretary) gave a presentation on the history and the present concerns of estuarine research in France, and the latest developments in Integrated Coastal Zone Management practices.

A detailed analysis of the historical development of oceanography in Germany was then given by Walter Lenz, while Anastasios Tselepides described advances in deep-sea research in Greece, from the pioneering era of blind sampling (only 15 years ago!) up to present and future deployments of remotely operated vehicles equipped with high-definition video cameras and a number of sensors and tools.

Anders Tengberg, Chair of the Swedish Society for Marine Sciences, provided a resumé of the marine research carried out in Sweden over the last 100 years and presented an overview of the 'hottest' topics presently being tackled by marine scientists in Sweden. The history of tropical research in Germany over the last 20 years was then described by Werner Ekau, Director of the Centre for Tropical Marine Ecology in Bremen. Werner summarized the scientific aims of the Centre and also highlighted its social engagement in tropical developing countries as a tool for improving governance of the ocean.

Stig Skreslet described the history of marine science in Norway, from its development by pioneering marine zoologists to the present programme-oriented research serving economic enterprises in fisheries, aquaculture and petrochemical industries. Paul Nival, of the Université Pierre et Marie Curie in Paris, drew participants into the fascinating history of oceanography in France since the accidental discovery of living organisms attached to telephone cables in the deep Mediterranean Sea (so disproving Forbes' azoic theory); then on through the pioneering dives of Taillez and Cousteau, up until the development of oceanic remote sensing and investigation of the deep sea. Antonio Pusceddu, delegate of the Italian Association of Oceanology and Limnology (AIOL) at the EFMS Council, presented the recent history of AIOL (1972 to present), and reviewed its internal structure. He pointed out the relative importance which the fields of ecology, geology, physics, chemistry, oceanology and limnology have had in marine research over the 30 years of the AIOL's existence.

The last talk of this session was very much about present-day concerns, as Yves Auffret presented the European Commission Green Paper of the on the future of maritime policy. The EU was also to the fore in the final session of the congress, 'Identification of cooperation links between countries and the role of the European Union'. This consisted of three 'open forum' discussions on 'The MarinERA consortium and its activity', 'Exchange of infrastructure facilities (ships, submersibles, robots)', and 'Exchange and mobility of scientists and students', coordinated by Maurice Héral, Jacques-Yves Binot and Ilse Hamann, respectively (see next item).

A particular concern was the sometimes critically low level of national funding for marine research, which in some cases was felt to be compensated for by subsidies from European funding agencies. Overall, the quality of marine research in Europe is seen to be more than satisfactory, but with room for improvement.

Another interesting development in marine research appears to be that private companies are increasingly intersted in the results of hot science arising from exploration of the ocean and its deep interior, and are now seeking out marine scientists of the 'European generation', with new professiona skills.

The general feeling of congress delegates was that oceanographic research in Europe is entering a new era in which scientists will increasingly need to act concertedly to attract more young scientists, to secure more funding, and to provide national and European governments with bottom-up advice on the needs and future of ocean management and governance.

Exchange and mobility of scientists and students

Report of Open Forum discussion (coordinated and summarized by Ilse Hamann)

The Open Forum discussion began with the coordinator presenting a few thoughts on the topic in order to set the stage. These thoughts are set out in the first part of the report, and are followed by an account of the discussion.

Coordinator's scene-setting introduction

The well-versed, highly skilled and experienced researcher is an asset to any institution and to the European scientific community, and will strive to make his or her high productivity count in his/her career. In this context, exchange and mobility have probably been experienced personally as a 'good thing' by many members of the audience. Working in a variety of scientific settings makes life interesting, and it is stimulating to exchange ideas with people who 'have been around', i.e. who have worked in different labs, countries or continents. Institutions for their part may be opening their doors and inviting 'outsiders' to join the workforce, hoping to safeguard themselves against becoming too fossilized in traditional approaches, and thereby raising their scientific standards.

Over the past 100 to 200 years, individual initiatives have resulted in joint marine expeditions and scientific collaborations; during the second half of the last century, 'exchange and mobility' also became a strategic objective, both for the individual scientist planning his/her career and for science policymakers intending to make the most of the human capital available.

In EC publications expanding on ways to structure the European Research Area the view is expressed that mobility of scientists is a prerequisite for quality research, not least for completing an individual's training, and for developing skills and pursuing career paths in the best possible environments. The EC documents acknowledge that mobility raises the level of European research through the transfer of expertise and the creation of networks of scientists. For students, exchange programmes such as Erasmus Mundus, Leonardo da Vinci, and Marie Curie Fellowships, have proven useful in that participation encourages people to enhance and perfect their technical and organizational skills.

In some circumstances, however, exchange and mobility may become too much of a good thing. For example, in Germany it has been observed that returning and reintegrating into the marine science establishment 'at home' often proves to be a much greater challenge than the original one of mastering integration into an initially foreign scientific environment. Rigid labour legislation is probably the principal cause of this problem.

To build a 'knowledge-based society' characterized by high levels of economic and demographic stability, it is therefore essential to achieve an equilibrium between, on the one hand, the potential for innovation brought about by mobility and exchange of professional scientists, and, on the other, the productivity of the scientific sector as a whole. For optimal development, the latter needs permissive and sustainable structures in both strategic and human resources. Losing tens of thousands of brains to the US, Canada or Australia – i.e. accepting the mostly one-way movement of researchers in whom a sizeable investment has already been made by European tax-payers – is *not* good management of European human resources.

This has to some extent been taken into account in the formulation of, for example, the Work Programme, Guide for Proposers and Evaluation Criteria of the Marie Curie Actions (Promoting Excellence) Human Resources and Mobility Activity in FP6. Similar foci will exist in FP7, described in 'People – Human potential and science careers' (see http://cordis.europa.eu/fp7/people.htm).

In reality, however, in many of Europe's research institutions and universities recruitment practices for mid-career scientists, and the different national scientific policy frameworks, are often inconsistent with the supposedly high value put on a scientist's multidisciplinary research profile, achieved by having been mobile.

Simply being mobile is not enough: scientific professionals also need to become motivated, enabled and empowered to apply their varied knowledge, which includes management and communication skills. In fact, highly productive scientists should be allowed to stay at their institution, and reintegration of formerly 'mobile' researchers must get higher priority than it has now. Analogous perhaps to the efforts that managers of the fishing industry make to secure a balanced age class distribution of commercially exploited fish landings, the workforce deep sea. Antonio Pusceddu, delegate of the Italian Association of Oceanology and Limnology (AIOL) at the EFMS Council, presented the recent history of AIOL (1972 to present), and reviewed its internal structure. He pointed out the relative importance which the fields of ecology, geology, physics, chemistry, oceanology and limnology have had in marine research over the 30 years of the AIOL's existence.

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To build a 'knowledge-based society' characterized by high levels of economic and demographic stability, it is therefore essential to achieve an equilibrium between, on the one hand, the potential for innovation brought about by mobility and exchange of professional scientists, and, on the other, the productivity of the scientific sector as a whole. For optimal development, the latter needs permissive and sustainable structures in both strategic and human resources. Losing tens of thousands of brains to the US, Canada or Australia – i.e. accepting the mostly one-way movement of researchers in whom a sizeable investment has already been made by European tax-payers – is *not* good management of European human resources.

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Simply being mobile is not enough: scientific professionals also need to become motivated, enabled and empowered to apply their varied knowledge, which includes management and communication skills. In fact, highly productive scientists should be allowed to stay at their institution, and reintegration of formerly 'mobile' researchers must get higher priority than it has now. Analogous perhaps to the efforts that managers of the fishing industry make to secure a balanced age class distribution of commercially exploited fish landings, the workforce in marine science needs to 'develop sustainably', reflecting civilized practices in recruitment, integration and utilization of highly qualified researchers to achieve a coherent yet dynamic staff composition.

Open Forum discussion

In the ensuing discussion it turned out that the scenario set out by the convenor was a little biased towards conditions in Germany. Whereas in that country the implementation of labour protection legislation has turned out to be a blanket ban on fixed-term employment extending more than six years (from the date of the Ph.D), the audience learned from Prof. Binot that in France an institution may not employ someone on a fixed-term basis for longer than eighteen months. However, he also pointed out that this period could be lengthened by forming an institutional partnership, thereby extending the post-doc phase of qualification to thirty-six months.

A question as to whether Germany would actively support the exchange of students was answered in the affirmative.

Myriam Sibuet (Institut océanographique de Paris) pointed out that participating in research cruises is an excellent way of getting to know professional colleagues. For several weeks one has the chance to learn about different methods of marine research while communicating with and living at close quarters with scientists from different countries and cultural backgrounds.

Addressing the question of employment opportunities, a representative from the maritime consulting industry pointed out the need for scientific expertise on the subject of gas hydrates. The coordinator acknowledged this development and predicted a rise in graduates applying to work in companies engaged in exploration for fossil fuels. Dr Sibuet added that expertise was needed not only in the exploitation of marine geological resources, but also in the fields of gas hydrate formation and gas hydrates as marine habitats/ecosystems. It was suggested that the EU should financially support basic research in these areas.

Manos Dassenakis expressed his view that mobility would always be necessary. The coordinator concurred, and thought that this should include mobility between sectors, i.e. not simply geographic mobility between different academic institutions, but also, for example, mobility between academia and industry. This would increase the chances that marine scientists would apply their knowledge and make a living within Europe. Prof. Binot voiced his impression that German institutions (e.g. the Alfred-Wegener-Institute for Polar and Marine Research) are particularly obliging in the placement of foreign Masters or Ph.D students. He saw the problem rather in the reluctance of (say) French students to commit themselves to more than a year in a comparatively 'gray' city like Bremerhaven.

Another question from the participants was whether there are any prizes with which the achievements of marine researchers are honoured, thereby raising the profile of marine sciences. The answer was in the affirmative as young, mid-career and long-serving Earth and marine scientists are awarded prizes both in Europe and abroad. However, the Nobel Foundation only bestows prizes in the categories of medicine, chemistry, literature, physics, economics, and peace – for the multi-disciplinary field of marine science there is no separate Nobel Prize.[*]

Another question was how a person from Texas, USA, for example, would be able to locate leaders in a particular field of marine science in Europe. The principal resource in this respect is the Aquatic Sciences and Fisheries Abstracts (ASFA) website.[†] A somewhat less direct approach would be to study institutional websites to find the composition of research groups (leading scientists, students and postdocs) in particular areas of marine science.

The final question was what the European Federation of Marine Science and Technology Societies could do to improve the employment situation for marine scientists in Europe. The answer was that concrete recommendations would certainly follow evaluation (by the CEMSE working group) of the EFMS questionnaire about the education and working realities of marine researchers in Europe, currently being distributed among the members of EFMS member societies and their colleagues in many marine science laboratories in Europe.

*The oceanographer Henry Stommel perhaps came closest to this high academic honour when in 1983 he won the Crafoord Prize 'for fundamental contributions to the field of geophysical hydrodynamics'. He shared the prize with Edward N. Lorenz. The Crafoord Prize is awarded annually by the Royal Swedish Academy of Sciences.

†http://www.fao.org/figis/servlet/static?xml=asfa_prog.xml&dom=org

EFMS

Report from the 2006 General Assembly of EFMS in Paris

On 13 September 2006 the Annual General Assembly (GA) of the European Federation of Marine Science and Technology Societies was held at the Institut océanographique in Paris. The Assembly was chaired by EFMS President Roberto Danovaro. Other participants were the EFMS Executive Committee members Manos Dassenakis (Vice-President), Philippe Ozanne (General Secretary), and Ilse Hamann (Treasurer), plus the following representatives of nine of the 14 member societies: Jan Mees (Flanders Marine Institute, Belgium), Stig Skreslet (Association of Norwegian Oceanographers), Stephen Hawkins (Marine Biological Association of the UK, also on behalf of the Scottish Association for Marine Science), Werner Ekau (German Society for Marine Research), Anders Tengberg (Swedish Society for Marine Sciences), Anastasios Tselepides and Manos Ladakis (Hellenic Oceanographers Association, Greece), Christelle Caplat (Union des océanographes de France), and Antonio Pusceddu (Italian Association of Oceanology and Limnology).

The President, Roberto Danovaro, who concluded his term of office at the end of 2006, presented the annual report. He highlighted the advances in the outreach activities of the Federation, the appeal of the new website (which has been visited more than 12 000 times), and the improved financial state of the Federation.

Another important matter dealt with at the GA was the need to amend the EFMS statutes in order to make expansion of the Federation easier. Possible changes discussed in detail at the GA will be presented to member societies for comment and approval. The final modifications will be approved during the next GA in Ancona (Sept 2007).

The EFMS CEMSE working group (Comparison of European Marine Science Education) is organizing the distribution and analysis of a questionnaire, responses to which should reveal the state of marine science and technology research in Europe (see end of previous item).

The Assembly elected Manos Dassenakis as the new President for the period 2007–2009. During these three years he will be assisted by the two elected Vice-Presidents, Roberto Danovaro and Graham Shimmield, by the newly elected General Secretary Jean-Paul Ducrotoy, and by Ilse Hamann who was confirmed as EFMS Treasurer.

Report courtesy of I.H.

An introduction to new EFMS members

The Israeli Association of Aquatic Sciences

On June 1988 a symposium was convened in the National Oceanographic Institute in Haifa to discuss the results of research in various aspects of marine science along the Mediterranean continental margin of Israel. The main purpose of the symposium was to bring together investigators of various aspects of the sea and coast, and to update the sea-going science community with recent findings. That first meeting included sessions dedicated to exploration in physical marine sciences, marine life sciences, and the human contribution to the environmental challenge along the continental margin; then a discussion was held regarding the effect of geological processes (e.g. the early Holocene deep-sea anoxic event) on the distribution of fauna along the margin, and the evaluation of the potential of hemipelagic fauna as a fishing resource. The meeting was a success, with good attendance and enthusiastic contributors. Investigators in one field of research were keen to know what their colleagues in other fields do when they set sail. Biologists and chemists, geophysicists and physical oceanographers, geologists and archaeologists – all shared their findings with the rest of the sea-going science community.

Thus the symposium became an annual event. Each symposium was accompanied by a bilingual booklet of abstracts, and authors were encouraged to submit extended abstracts. The booklets were made available to libraries and served as a reference to on-going research for students in universities, colleges and high schools. Since 1998 the symposia have been named after the late Admiral Yohay Bin-Nun, to commemorate his significant contribution to oceanographic research, and in 1999 the symposia became the venue for the presentation of the Yohay Bin-Nun award for outstanding graduate research in Israel.

Every spring, sea-going scientists meet, present their findings, and exchange ideas in a multidisciplinary ambience, and encourage the younger generation to join the sea-going community. Two charactersistics distinguish these meetings: first, they never include parallel sessions, so emphasizing the *raison d'etre* of the symposium – true interdisciplinary exchange; and, secondly, one session is traditionally dedicated to maritime civilizations, and the findings of marine archaeological investigations are presented to the sea-going science community.

The 15th symposium in May 2003 was also the founding symposium for the Israel Association of Aquatic Sciences (IAAS), encompassing investigators of the Red Sea, the Dead Sea and the Sea of Galilee, along with the Mediterranean research community. Zvi Dubinsky was elected to serve as the first President of the Association.

Today IAAS has some 250 members. It holds its annual symposium each spring, and maintains its multidisciplinary meetings in a genuine interdisciplinary ambience. IAAS is thus a young association standing on the shoulders of an established programme of multidisciplinary research.

Bella Galil and **Yossi Mart**

Society website: http:/research.haifa.ac.il/~y.mart/israelaquatic/index_eng.htm

The Swedish Society for Marine Sciences

In 1966, scientists from Swedish universities and government agencies met to form a society with the aim of promoting cooperation between institutions and individuals with an interest in marine research. They formed the Swedish Society for Marine Sciences, or Svenska havforskningsföreningen, SHF.

In 1967, the statutes for the new society were confirmed. The intentions of the society are to: arrange opportunities for the presentation and discussion of technical and scientific investigations; promote the use of results across disciplinary boundaries; share information about lectures, seminars, international conferences, oceanographic expeditions etc.; ensure that instruments and research vessels are used in the most efficient way.

Today, the SHF is a non-profit-making society devoted to the marine sciences. Its members are scientists and other people interested in disciplines relating to the marine environment, such as physical oceanography, marine biology, marine chemistry, marine geology and marine technology. The society's work is supported primarily by the marine research centres at the universities of Umeå, Stockholm and Gothenburg, as well as by the Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning (FORMAS), the Swedish Fisheries Board, and the Swedish Meteorological and Hydrological Institute.

One of the most important goals for the SHF is to facilitate communication between all the different groups with interests in marine research. The principle medium for this communication is the Annual Conference, which is a forum for the reporting of new findings from marine areas around Sweden, as well as from the world ocean. The meetings are held at a different location each year, with the venues being shared between universities, field stations and institutes with marine activities.

To promote studies in marine science, each year the SHF awards the Dyrssen Prize for the best marine Master's thesis. Additional prizes for young scientists, for the best poster and best presentation at the annual meeting, have recently been introduced.

In 1990 it was decided by the respective Nordic marine science associations to arrange joint meetings. The most recent of these was held in Oslo, Norway, in 2006. The number of participants during the national meetings is generally around 100, which is about the number of members of the SHF, while the Nordic meetings bring together some 150–200 people.

Even today, when everybody's diary could be completely filled by all the different international meetings and workshops offered, I think that the relatively small meetings arranged by national societies have an important role to play!

Johan Rodhe
President of the SHF

Society website: http://www.shf.se

The Italian Society for Marine Biology

The SIBM was founded on 4 June 1969 during a meeting of marine biologists and oceanographers held in Livorno and organized by Prof. Guido Bacci. It became a legally established society in 1974. Between 1969 and the present day, its membership has increased from 110 up to 800.

continued overleaf

The SIBM's main aim is to promote – particularly for the marine environment – both the conservation of nature and appreciation of its value. Since its foundation, the SIBM has promoted studies of marine life and coordinated groups of researchers and surveys in Italian seas. It strives to disseminate basic and applied technical and scientific knowledge, and so promote education and awareness of marine life; it also organizes meetings, congresses and workshops. Each year a congress and a General Assembly are organized (at a different location each time) and the proceedings are published. The 37 SIBM Proceedings, which together effectively describe the history of Italian marine biological research, will soon all be available on the SIBM website.

Within the SIBM there are five Committees, dealing with: aquaculture; benthos; managing and valuing the Coastal Zone; nekton and fisheries; and plankton. Of the working groups, those on alien species and ballast water collaborate with the corresponding ICES working groups.

Thanks to financial support obtained through special agreements with the Italian Ministry of Environment (MiATTM) and the Italian Ministry of Agriculture (MiPAAF), and also with EC DG Fisheries, the SIBM has been able to carry out a number of studies and investigations. For example, since 1994 the SIBM has been the Italian coordinator for the International Bottom Trawl Survey in the Mediterranean (MEDITS), and in 1995 it contributed to preparation of the checklist of Italian fauna. In 2005, it was charged by the Ministry of Environment with updating information about the distribution of marine animals in Italian seas (available on the SIBM website). SIBM is also the Italian National Input Centre for ASFA1 (Aquatic Sciences and Fisheries Abstracts: Biological Sciences and Living Resources).

The SIBM is responsible for the editing of the scientific journal *Biologia Marina Mediterranea*, which publishes mainly peer-reviewed proceedings of meetings, or special volumes. Members receive a twice-yearly newsletter (*Notiziario SIBM*) which describes the activities of the Society, its Committees and working groups. The editorial office and technical secretary are hosted by Dip.Te.Ris. of Genoa University (sibmzool@unige.it).

Giulio Relini
General Secretary of the SIBM

Society website: www.sibm.it

Post Script: Navigating the future

Identifying research priorities in the marine sciences

Marine scientists from across Europe have outlined what they see as the most important thematic research priorities for the seas and oceans The priorities are outlined in *Navigating the Future III,* a position paper put together by the European Science Foundation's Marine Board. The paper takes into account European legislation affecting marine research, such as the Seventh Framework Programme for research and European Maritime Policy, as well as national research programmes and international marine policies.

The 68-page publication is designed for regional, national and European decision-makers (e.g. the European Commission, the Marine Board's member organizations, and other organizations in the marine sphere). Anyone wishing to receive one or more paper copies should write to the ESF, indicating the number of copies and full postal address (see details at the end).

Given that it deals with topics ranging from climate studies to biodiversity, marine research is intrinsically an international activity with opportunities for countries throughout Europe to cooperate, addressing environmental problems of pan-European relevance and significance. Jean-François Minster, Chairman of the ESF Marine Board, writes in the foreword to the document that 'Complementary research should be coordinated to achieve optimal results towards enhanced information and knowledge of the oceans and their environments, a key research output.'

Challenges identified in the report include the need to enhance detection and assessment of the impacts of climate change on the oceans, and more research into the functional role, evolution, protection and exploitation of marine biodiversity. Linked to this last point is the need for an ecosystem approach to resource management in the seas, in fields ranging from fisheries to coastal zone management.

In the context of coastal waters, the authors of the report note that more work needs to be done on toxic algae, viruses and the ecotoxological and health impacts of pollutants; they also call for more research into deep-sea ecosystems and a greater focus on developing and implementing deep-sea observatories.

Under the heading 'marine technology', the report calls for the development of *in situ* observation systems, software for data-processing and numerical modelling, as well as materials and systems for maritime activities, and technology transfer between disciplines.

It is hoped that *Navigating the Future III* will be considered an important contribution towards strengthening networks, coordination and cooperation, and will provide a positive contribution to the development of a more integrated approach to marine research in Europe.

The full details of the publication are: *Navigating the Future III. Updated synthesis of perspectives on marine science and technology in Europe* (2006) Minster, J.-F., N. Connolly, A. Carbonnière, J. de Leeuw, M. Evrard, J. Mees, K. Nittis, G. O'Sullivan and N. Walter, N. (Eds) (2006). ESF Marine Board Position Paper, 8. European Science Foundation, Marine Board: Strasbourg, France (67pp.).

A pdf of the publication may be downloaded from:
http://www.esf.org/index.php?language=0

To receive a paper copy write to:
Mrs Ellen Degott, European Science Foundation, 1 quai Lezay-Marnesia, 67080 Strasbourg Cedex, France.

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The Challenger Society for Marine Science

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Giulio Relini
General Secretary of the SIBM

Society website: www.sibm.it

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