4.0 OCEAN CARBON AND OTHER ACTIVITIES

4.1 International Ocean Carbon Coordination Project

ABOUT THE IOCCP
(Version May 2005)

Brief History

In January 2003, the SCOR-IOC Advisory Panel on Ocean CO_2 and the IGBP-IHDP-WCRP Global Carbon Project initiated a collaborative pilot project to gather information about on-going and planned ocean carbon research and observation activities, to identify gaps and duplications in ocean carbon observations, to produce recommendations that optimize resources for international ocean carbon observations and the potential scientific benefits of a coordinated observation program, and to promote the integration of ocean carbon observations with appropriate atmospheric and/or terrestrial carbon activities. During its first 2 years of activity, the IOCCP undertook several projects to aid communication and coordination among research and observation programs, with a particular emphasis on carbon measurements on the repeat hydrography cruises of CLIVAR and on underway pCO_2 measurements and systems. The IOCCP hosted 2 major international workshops that involved more than 100 scientists from 17 countries. *For more information about IOCCP activities from 2003-2005, please read (all on-line at http://ioc.unesco.org/ioccp/about.htm)*

- *the IOCCP Progress Report, October 2004.*
- *IOCCP Workshops -Results and Documents*
- *Sabine,C. and M.Hood, "New Levels of Cooperation Among Ocean Carbon Scientists", EOS Trans. AGU, June 10 2003.*

From mid-2004 to early 2005, in response to the development of several new global and national research programs dealing with various aspects of ocean carbon, the IOCCP hosted 2 international ocean carbon stakeholders' meetings to bring together representatives from major research or observational programs to determine the needs for communication and coordination among them. The sponsors of the IOCCP agreed to broaden its mandate to deal with all aspects of ocean carbon (not just CO_2 issues) and to provide communication and coordination assistance (as needed) to the research programs. The sponsors also agreed that the IOCCP should be formalized with new terms of reference and the establishment of a Scientific Steering Group to provide guidance on coordination activities for this expanded range of topics and activities.

- *For more information about the Stakeholders' Meeting, read the Meeting Report (http://ioc.unesco.org/ioccp/about.htm)*

Terms of Reference for the IOCCP –2005
(*approved by the SCOR Executive Committee in March and by the IOC Assembly in June 2005*):

General Description:
IOC and SCOR provide financing, in-kind assistance, and stewardship for the IOCCP. The

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IOCCP will undertake specific tasks (as listed in Specific Terms of Reference, below) and provide ready expertise on ocean carbon observations and research, including ocean carbon sequestration issues, as required by SCOR, IOC, their programs (e.g., IMBER, SOLAS, OOPC, GOOS, GCOS, and JCOMM) and their Member States.

General Terms of Reference:

- Work with the ocean carbon research projects and broader international community to collect and compile information on current and planned ocean carbon observations and research activities, and develop and maintain a central international information center on ocean carbon research and observations.
- Provide an international forum for initiatives to promote high-quality observations needed to understand the ocean component of the global carbon cycle.
- Advise IOC, SCOR, OOPC, GOOS, GCOS, and JCOMM on observations and data products needed for large-scale monitoring of the global carbon cycle.

Specific Terms of Reference:

i. To develop an international communication center on ocean carbon activities through the development and maintenance of Web-based compilations and syntheses of ocean carbon observation and research activities, and through e-mail and/or Web-based newsletters and other publications;

ii. Provide an international forum for initiatives to promote high-quality observations to understand the ocean component of the global carbon cycle, through international agreements on standards, including:
   a. Methods / Best Practices
   b. Quality Control and Quality Assurance Procedures
   c. Data and Meta-data Formats
   d. Use of Certified Reference Materials

iii. To facilitate data collection, management, data product development, and archival of ocean carbon and related data by:
   a. Aiding regional and global data syntheses being developed through ocean carbon research programs, as requested;
   b. Facilitating and aiding the development of historical data bases for ocean carbon, including data recovery activities, as necessary;
   c. Ensuring long term data availability by working with data management groups and World Data Centers to archive data sets beyond the lifetime of the individual projects.

iv. To work with global research and observation programs to promote and document the development and status of a sustained ocean carbon observing system;

v. To liaise with integrated programs (IGCO, GCP) to promote the integration of ocean carbon into earth system studies.

The Scientific Steering Group
Chair: Christopher Sabine, NOAA/PMEL (USA)
Repeat Hydrography: Masao Fukasawa, JAMSTEC (Japan)
Underway pCO_2: Bronte Tilbrook, CSIRO (Australia)
Time Series: Nick Bates, BBSR (Bermuda)
Remote Sensing/Ocean Colour: Cyril Moulin, LSCE (France)
Process Studies: Cindy Lee, SUNY-Stonybrook (USA)
Data set development: Dorothee Bakker, UEA (UK)
Coastal Observations: Helmuth Thomas, Dalhousie Uni. (Canada)
IMBER representative: Arne Koertzinger (Germany)
SOLAS representative: Truls Johannessen, Uni. Bergen (Norway)

2005 IOCCP Activities
(tentative, subject to modification by SSG after September meeting).

Approval of New Terms of Reference
The SCOR Executive Committee approved the IOCCP Terms of Reference on 14 March 2005 and the IOC Assembly approved them at its 23rd Session in June 2005.

Planning First Steering Group Meeting
Plans are to host the 1st SSG meeting in conjunction with the International CO_2 Conference in late September in Colorado, and jointly with the SOLAS/IMBER carbon coordination group. Several groups also have proposed to have a one-day meeting of all ocean carbon programs during the conference (SOLAS, IMBER, CLIVAR, LOICZ, U.S. Ocean Carbon Program, EU Carbo-Oceans, IOCCP, etc)
***Action**:* Chris and Maria will contact the relevant groups to make plans for a 1-day meeting of all ocean carbon programs, and a 1-day follow-up meeting for the IOCCP SSG.
Status May 2005: An Ocean Carbon Open House is planned for Wednesday, September 28th, tentatively from 6:30 – 8:30, with a reception to follow. The SSG meeting will be planned according to the International CO_2 Conference Schedule to avoid interference with other sessions.

Planning a Repeat Hydrography Workshop
CLIVAR and IOCCP, under the leadership of Masao Fukasawa, have begun making tentative plans for an International Repeat Hydrography Workshop. There is a general agreement to hold the meeting in Japan in November 2005 in conjunction with the Argo Steering Team meeting (7-9 November). Proposed objectives for the workshop include

- To re-organize (if needed) the implementation plan of each country after reviews of quick results of completed plans;
- To reach agreement from countries and PIs on data management issues, specifically that CCHDO will serve as the data center for CLIVAR;
- To reach agreements about the best way to make data (hydrographic, meteorological, bathymetric, etc.) available in sufficient time for hydrographic observations to contribute to ocean reanalysis in the near future.

- To streamline and integrate the carbon and tracer information databases and maps with CLIVAR (e.g., agreements between CLIVAR IPO, CCHDO, CDIAC, IOCCP)

***Action**:* Masao, Chris, Maria, Katy Hill / Nico Caltibiano (CLIVAR), John Gould (CLIVAR and Argo), Jim Swift, Dick Feely, and Alex Kozyr will continue discussions to finalize dates, number of participants, financial support, and a draft agenda.
***Status May 2005*:** The Organizing Committee and the scope and objectives are being finalized. The meeting will be held during 3-4 days in the 3rd week of November (14-18) The CLIVAR IPO (Nico Caltibiano) and the IOCCP, along with Jim Swift and Alex Kozyr, will be developing compiled, updated information tables about post-WOCE cruises, plans, and data submission for use as a background document.

Continuation of the CLIVAR Basin panel representatives
From 2003-2004, the following representatives were chosen to attend CLIVAR Basin Panel meetings:

BASIN REPRESENTATIVES NEXT MEETING:

- Pacific Ocean: Dick Feely (USA) and Kitack Lee (Korea) Tentatively: October 10-13, Concepción, Chile
- Atlantic Ocean: Arne Körtzinger (Germany) October 20-21, Venice, Italy
- Indian Ocean: Bronte Tilbrook (Australia) March 30- April 2, Hobart, Australia
- Southern Ocean: Chris Sabine (USA) June 27-30, Cambridge UK

The representation has operated in a very flexible manner, with some substitutes being made owing to proximity to the meeting location or conflicts of scheduling. We will continue with this flexible arrangement for this year, and see how things develop after the repeat hydrography meeting in November, which may develop new oversight structures.
Actions: Maria will contact representatives to see if they are still willing to serve and arrange their participation.
Status May 2005: The Indian Ocean Panel meeting was held and Bronte Tilbrook attended. (report pending). Bronte and Raleigh Hood have written a report for the IO Panel on biogeochemical measurement requirements in the Indian Ocean Basin as a contribution to a planning report by the Panel. The IO Panel is currently re-organizing, but plans are developing to continue the ocean component and to develop a pilot observing system for climate research in the region. Mario Hoppema will be invited as a possible replacement for Chris Sabine on the Southern Ocean Panel.

Technical Paper on Underway Measurement Systems
Bronte, Maria, Ute Schuster (who gave a presentation to JCOMM Ship Observations Team in 2004), and Nathalie Lefevre (who gave the JCOMM SOT presentation this year) have begun drafting a technical paper on the development status of underway pCO_2 systems. The idea is to write a short (maximum: 10 pages) technical report outlining where we are with underway pCO_2 measurements in terms of making this a systematic component of the observing system (and eventual integration into the JCOMM SOOP or VOS program). This document should outline major issues: results of intercomparison tests, the state of automation of the systems/need for observers, technical requirements on board, lack of a single system used by the community and

lack of a commercially available system, ability and/or willingness to release data in near-real time, if/how data are synthesized into basin and global scale products, etc. Once completed, this paper could lay the foundations for a targeted workshop to reach agreements on the best way forward, and this technical paper could also be turned into an article for *Sea Technology* or *Ocean Systems* journal.
Actions: Maria will work with Bronte and the wider community to try to have a draft of this technical document available by September for the first SSG meeting.
Status May 2005: After the OOPC and JCOMM meetings, Maria reported that there is a wider call for a more comprehensive document outlining observation requirements and technical capabilities for all surface pCO_2 measurements as well as other biogeochemical variables that could be feasibly integrated into the observing system in the coming years. The SSG needs to discuss this broader context and how to work with a number of other groups working on similar activities (e.g., GOOS / John Field and OOPC / Tommy Dickey for chlorophyll and other optical measurements, IO Panel for biogeochemistry in the Indian Ocean, etc.).

GlobCOLOUR Project
The European Space Agency has asked IOCCP (via Trevor Platt at IOCCG) to provide expertise for the GlobCOLOUR project, which will define, develop and demonstrate an Earth observation service for global ocean colour research. The primary objective is to identify and fulfill user requirements of the global ocean colour and carbon-cycle research community. Cyril has agreed to participate as the expert on this group. I have signed a commitment letter with the ESA project on behalf of IOCCP project office. The project is scheduled to start in the last quarter of 2005.
Actions: Cyril will begin work with this group in late 2005. Cyril attended the NASA Ocean Colour Research Team meeting in Portland, Oregon, USA in mid-April to represent the IOCCP. He provided a report on the restructuring of ocean colour missions within NASA, and ocean colour mission planning for both systematic observations and new technologies and research.
Status May 2005: GOOS is also discussing a new project to establish a global chlorophyll-a measurement network (John Field, Chair), which may be of interest to integrate with ocean carbon activities and/or measurement platforms. Maria will contact the GOOS Chair to find out more about their plans.

Ocean Carbon Directory
Maria has developed an ocean carbon portal (called "directory" since it doesn't actually use portal technology) as agreed at the December international stakeholders' meeting. The directory is almost complete, although the "process studies" pages section has been intentionally left blank to allow SOLAS and IMBER to determine how they would like to use this section of the portal for their needs. As we develop new activities and information tools for coastal observations, time series, etc, we will build these pages into the site.
Actions: The SSG will provide guidance for the continued development and maintenance of the ocean carbon directory, especially working with SOLAS and IMBER to determine their information needs.
Status May 2005: Nick Bates is leading an effort to create time series maps and tables for carbon work that build on the OceanSITES maps, but provide more detailed information required by our community. Chris, Cindy, and Maria have added a new "High-CO_2 World" link to the ocean acidification / sequestration information as a follow-up to the May 2004 Symposium and the

requests from the community to maintain the site. The Process Studies section is still under development.

New Activities

Inventories and compilations (maps, tables, etc) need to be made for time-series stations, coastal observations, and process studies. The IOCCP also needs to investigate the status of the development of a compiled uniform-format data set of global pCO_2 data carried out under the ORFOIS project, which may need support to continue.

4.2 SCOR/IOC Symposium on the Ocean in a High-CO_2 World

Committee Charge:
The planning committee will determine the scope of the symposium, plan the agenda, develop the list of invited participants, and handle any publications that result from the symposium.

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Peter Brewer	USA
Peter Haugan	NORWAY
James McWilliams	USA
Liliane Merlivat	FRANCE
Takashi Ohsumi	JAPAN
Silvio Pantoja	CHILE
Hans-Otto Pörtner	GERMANY

IOC Liaison: Maria Hood
Executive Committee Reporter: Bob Duce

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The SCOR/IOC symposium on the Ocean in a High-CO_2 World resulted in several products:

- Cicerone et al. 2004. The Ocean in a High-CO_2 World. *Oceanography Magazine* 17(3):72-78. **(see publication in plastic folder following)**
- Cicerone et al. 2004. The Ocean in a High CO_2 World. *EOS* 85:351, 353 **(see publication in plastic folder following)**
- A special section of the *Journal of Geophysical Research-Oceans* that will include 16 papers from the symposium, plus an introductory paper. This special issue will appear in late 2005. The papers will be cited in the Special Report on Carbon Dioxide Capture and Storage of the Intergovernmental Panel on Climate Change (IPCC).

The symposium also resulted (in part) in a special study by the UK Royal Society, which was released on 30 June 2005 (see http://www.royalsoc.ac.uk/displaypagedoc.asp?id=13314 and following summary).

IOC has expressed an interest in creating a continuing series of symposia on this topic and the SCOR Executive Director has related SCOR's preliminary interest, assuming that (1) the symposia are separated by enough time to allow research progress to be made, (2) the timing of the symposia are designed to link to the process for the regular IPCC reports (however, this area of science may be moving quickly enough that it would not be advisable to wait to begin planning the next symposium until the next IPCC assessment is under way), and (3) adequate funding can be found to conduct the symposia. The IPCC Fourth Assessment Report is expected to be released in 2007. SCOR should determine whether it wants to work with IOC to plan another symposium and when to do this. Do SCOR and IOC want to convene a symposium on this topic every 4 to 5 years?

Printed background book includes here pages 50-62 of the Intergovernmental Oceanographic Commission's 2004 Annual Report, available at **http://unesdoc.unesco.org/images/0013/001395/139555e.pdf**.

Ocean acidification due to increasing atmospheric carbon dioxide[1]

Summary

The oceans cover over two-thirds of the Earth's surface. They play a vital role in global biogeochemical cycles, contribute enormously to the planet's biodiversity and provide a livelihood for millions of people.

The oceans are absorbing carbon dioxide (CO_2) from the atmosphere and this is causing chemical changes by making them more acidic (that is, decreasing the pH of the oceans). In the past 200 years the oceans have absorbed approximately half of the CO_2 produced by fossil fuel burning and cement production. Calculations based on measurements of the surface oceans and our knowledge of ocean chemistry indicate that this uptake of CO_2 has led to a reduction of the pH of surface seawater of 0.1 units, equivalent to a 30% increase in the concentration of hydrogen ions.

If global emissions of CO_2 from human activities continue to rise on current trends then the average pH of the oceans is projected to fall by a further 0.5 units (equivalent to a three fold increase in the concentration of hydrogen ions) below the levels in 2000, by 2100. This pH is probably lower than has been experienced for hundreds of millennia and, critically, this rate of change is probably one hundred times greater than at any time over this period. The scale of the changes may vary regionally, which will affect the magnitude of the biological effects.

Ocean acidification is essentially irreversible during our lifetimes. It will take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times (about 200 years ago). Our ability to reduce ocean acidification through artificial methods such as the addition of chemicals is unproven. These techniques will at best be effective only at a very local scale, and could also cause damage to the marine environment. **Reducing CO_2 emissions to the atmosphere appears to be the only practical way to minimise the risk of large-scale and long-term changes to the oceans.**

All the evidence collected and modelled to date indicates that acidification of the oceans, and the changes in ocean chemistry that accompany it, are being caused by emissions of CO_2 into the atmosphere from human activities. The magnitude of ocean acidification can be predicted with a high level of confidence. The impacts of ocean acidification on marine organisms and their ecosystems are much less certain but it is likely that, because of their particular physiological attributes, some organisms will be more affected than others.

Predicting the direction and magnitude of changes in a complex and poorly studied system such as the oceans is very difficult. However, there is convincing evidence to suggest that acidification will affect the process of calcification, by which animals such as corals and molluscs make shells and plates from calcium carbonate. The tropical and subtropical corals are expected to be amongst the worst affected, with implications for the stability and longevity of the reefs that they build and the organisms that depend on them. Cold-water coral reefs are also likely to be adversely affected, before they have been fully explored.

Other calcifying organisms that may be affected are components of the phytoplankton and the zooplankton, and are a major food source for fish and other animals. Regional variations in pH will mean that by 2100 the process of calcification may have become extremely difficult for these groups of organisms particularly in the Southern Ocean. Some shallow water animals, which play a vital role in releasing nutrients from sediments, also calcify, and may be affected by changes in the chemistry of the oceans. Some studies suggest that growth and reproduction in some calcifying and non-calcifying marine species could be reduced due to the projected changes in ocean chemistry.

From the evidence available it is not certain whether marine species, communities and ecosystems will be able to acclimate or evolve in response to changes in ocean chemistry, or whether ultimately the services that the ocean's ecosystems provide will be affected. **Research into the impacts of high concentrations of CO_2 in the oceans is in its infancy and needs to be developed rapidly. We recommend that a major, internationally coordinated effort be launched to include global monitoring, experimental, mesocosm and field studies. Models that include the effects of pH at the scale of the organism and the ecosystem are also necessary. The impacts of ocean acidification are additional to, and may exacerbate, the effects of climate change. For this reason, the necessary funding should be additional and must not be diverted from research into climate change.**

Oceans play a very important role in the global carbon cycle and Earth's climate system. There are potentially important interactions and feedbacks between changes in the state of the oceans (including their pH) and changes in the global climate and atmospheric chemistry.

[1] The full report, of which this is the summary, conclusions and recommendations, is *Ocean acidification due to increasing atmospheric carbon dioxide.* London: The Royal Society. Both these documents are available from the Royal Society and can be found at www.royalsoc.ac.uk/policy

Changes in the chemistry of the oceans will reduce their ability to absorb additional CO_2 from the atmosphere, which will in turn affect the rate and scale of global warming. The knowledge of these impacts and effects is currently poor and requires urgent consideration. **The understanding of ocean acidification and its impacts needs to be taken into account by the Intergovernmental Panel on Climate Change and kept under review by international scientific bodies such as the Intergovernmental Oceanographic Commission, the Scientific Committee on Oceanic Research and the International Geosphere-Biosphere Programme.**

The socio-economic effects of ocean acidification could be substantial. Damage to coral reef ecosystems and the fisheries and recreation industries that depend on them could amount to economic losses of many billions of dollars per year. In the longer term, changes to the stability of coastal reefs may reduce the protection they offer to coasts. There may also be direct and indirect effects on commercially important fish and shellfish species.

Marine ecosystems are likely to become less robust as a result of the changes to the ocean chemistry and these will be more vulnerable to other environmental impacts (such as climate change, water quality, coastal deforestation, fisheries and pollution). **The increased fragility and sensitivity of marine ecosystems needs to be taken into consideration during the development of any policies that relate to their conservation, sustainable use and exploitation, or the communities that depend on them. If the risk of irreversible damage arising from ocean acidification is to be avoided, particularly to the Southern Ocean, the cumulative future human derived emissions of CO_2 to the atmosphere must be considerably less than 900 Gt C (gigatonnes of carbon) by 2100.**

In setting targets for reductions in CO_2 emissions, world leaders should take account of the impact of CO_2 on ocean chemistry, as well as on climate change. These targets must be informed by sound science.

Ocean acidification is a powerful reason, in addition to that of climate change, for reducing global CO_2 emissions. Action needs to be taken now to reduce global emissions of CO_2 to the atmosphere to avoid the risk of irreversible damage to the oceans. We recommend that all possible approaches be considered to prevent CO_2 reaching the atmosphere. No option that can make a significant contribution should be dismissed.

Conclusions

1 **The oceans are absorbing CO_2 produced from human activities from the atmosphere and this is causing chemical changes which make them more acidic (ie there is a decrease in the pH of the oceans).**

a **Ocean acidification, like global warming, is a predictable response to those human activities that increase the atmospheric concentration of CO_2. The magnitude and rate of the acidification of the oceans can be predicted with more confidence than the rise in temperature due to global warming, as they are less dependent on climate-system feedbacks.**

b Predictions of the consequences of CO_2 emissions must take into consideration the close chemical and physical coupling between the oceans and the atmosphere. For example, changes in the chemistry of the oceans will affect its ability to absorb additional CO_2, which will in turn affect the rate and scale of global warming. Rising sea temperatures caused by global warming also affect ocean chemistry, as well as other physical and biological processes.

c The oceans are currently taking up about one tonne of human-derived CO_2 per year for each person on the planet. Almost a half of the CO_2 produced in the past 200 years from burning fossil fuels and cement manufacture has been absorbed by the oceans. Calculations based on measurements of the surface oceans and our understanding of ocean chemistry indicate that this uptake of CO_2 has already reduced surface seawater pH by about 0.1 units, which corresponds to an increase of about 30% in the concentration of hydrogen ions.

d As CO_2 continues to enter the atmosphere from human activity, a proportion will be taken up by the oceans. If CO_2 emissions are not regulated, this could probably result in the pH decreasing by a further 0.5 units below levels in the year 2000 by 2100. This is beyond the range of current natural variability and probably to a level not experienced for at least hundreds of thousands of years and possibly much longer. Critically, the rate of change is also probably at least 100 times higher than the maximum rate during this time period. These changes are so rapid that they will significantly reduce the buffering capacity of the natural processes that have moderated changes in ocean chemistry over most of geological time.

e The chemical changes in the oceans caused by increases in the concentration of CO_2 in the atmosphere will include a lowering of the pH, an increase in dissolved CO_2, a reduction in the concentration of carbonate ions, and an increase in bicarbonate ions. All of these will affect the organisms and processes in the oceans.

f **There appears to be no practical way to remove this additional CO_2 from the oceans after it has been absorbed, nor any realistic way to reverse its widespread chemical and probable biological effects.** It will take many thousands of years for natural processes to remove this excess CO_2 and return the oceans to a level close to their pre-industrial state. Thus, it appears that the only practical way to minimise long-term consequences for the oceans is to reduce CO_2 emissions to the atmosphere.

2 **These changes in ocean chemistry will impact on marine organisms and ecosystems.**

a Seawater pH is a critical variable in marine systems; even small changes will have a large impact on ocean chemistry. These changes are likely to alter the biodiversity of marine ecosystems, and may affect the total productivity of the oceans. The impacts will be greater for some regions and ecosystems. However, apart from a few ecosystems such as coral reefs and the Southern Ocean, the direction and magnitude of these impacts are very uncertain. Most of the available evidence suggests that these changes are likely to reduce the resilience of marine ecosystems.

b The best scientific information currently available suggests that these changes in ocean chemistry will almost certainly have major adverse effects on corals and the reefs they build in tropical and subtropical waters. This will affect the stability and longevity of the structures supporting these ecosystems with implications for the biodiversity and their ecological sustainability. Cold-water coral reefs are also likely to be adversely affected, before they have been fully explored.

c Future changes in ocean chemistry, resulting from enhanced atmospheric CO_2, specifically the likely reduction in the concentration of carbonate ions, will make it more difficult for animals to produce hard structures such as carbonate skeletons and shells.The evidence available suggests that this will probably adversely affect most of these organisms. For example many coastal animals and specific groups of phytoplankton and zooplankton will be affected.

d Increased CO_2 and the associated reduction in seawater pH may be particularly stressful for organisms with a high metabolism such as squid. Some studies indicate that the physiology of other large marine animals may also be affected, possibly restricting their growth, reproduction or both.

e Ecosystems near the ocean floor, especially on the seabed of shallow waters, provide an essential service for other organisms in the surface oceans: receiving food from the sunlit waters above in the form of sinking particles, they also recycle nutrients from the sediments, which are required for the growth of other organisms. Differences in the response of these diverse organisms to reduced pH could have a considerable impact on the functioning of marine sediments and the 'ecosystem goods and services' they provide.

f Organisms will continue to live in the oceans wherever nutrients and light are available, even with ocean acidification. However, from the data available, it is not known if organisms at the various levels in the food web will be able to adapt or if one species will replace another. It is also not possible to predict what impacts this will have on the community structure and ultimately if it will affect the services that the ecosystems provide. Without significant action to reduce CO_2 emissions into the atmosphere, this may mean that there will be no place in the future oceans for many of the species and ecosystems that we know today.

3 **Oceans play a very important role in the global carbon cycle and Earth's climate system.**

a There are potentially important interactions between changes in the state of the oceans (including their pH) and changes in the global climate and atmospheric chemistry. Our knowledge of these impacts and effects is currently poor and requires urgent consideration.

b Both ocean acidification and climate change result from increasing atmospheric CO_2 emissions. Effects of climate change, particularly increases in ocean temperature, will impact on marine ecosystems. Occurring at the same time, the impacts of climate change will be additional to (and possibly synergistic with) those due to increased CO_2 and ocean acidification.

4 **The socio-economic effects of ocean acidification could be substantial.**

a Serious damage to coral reef ecosystems, and the human activities that are based on them, such as fisheries and recreation, could amount to economic losses of many billions of dollars per year. This will have very serious impacts on the vulnerable societies that depend upon these ecosystems.

b Ocean acidification is likely to have significant impacts on some marine fish and shellfish species. It is very hard to determine the economic value of many of these impacts, but would present a risk to some unknown fraction of the global economic value of these resources (about $100 billion per year).

Ocean acidification will probably cause significant changes in the whole marine biogeochemical system and the ecosystem services that it provides, to an extent and in ways that cannot at present be foreseen.

d Changes to the stability of coastal reefs in tropical and subtropical parts of the globe may lead to serious decreases in coastal protection over longer time periods. These changes could fundamentally change the nature of entire coastlines and the resources available to human societies that depend on these coastal reefs.

5 **Reducing the scale of future changes to the chemistry and acidity of the oceans is only possible by preventing the accumulation of CO_2 in the atmosphere.**

a Solutions other than preventing CO_2 emissions reaching the atmosphere, such as adding chemicals to counter the effects of acidification, are likely to be only partly effective and only at a very local scale. It would be impossible at a regional or global level, and could also cause damage to the marine environment.

b There are many possible approaches to preventing the accumulation in the atmosphere of CO_2 produced by human activities: for example improved energy efficiency, use of renewable energy and carbon sequestration in geological reservoirs. Some approaches, such as direct injection of CO_2 into the deep oceans, have the potential to further exacerbate chemical changes to the oceans.

c **Unless significant reductions are made in global emissions of CO_2 (to ensure atmospheric CO_2 concentration is under twice its current levels by 2100) the entire depth of the Southern Ocean will become undersaturated for aragonite, which is required by some organisms to make carbonate skeletons and shells.** Further increases in atmospheric concentration of CO_2, above this doubling, would make the impacts progressively worse for the oceans as a whole.

6 **We conclude on the basis of current evidence that ocean acidification is an inevitable consequence of continued emissions of CO_2 into the atmosphere, and the magnitude of this acidification can be predicted with a high level of confidence. However, its impacts, particularly on marine organisms, are much less certain and require a substantial research effort.**

a Research into the impacts of an ocean with a high CO_2 concentration is in its infancy and needs to be developed rapidly. Among the priority areas for further research are: the identification of those species, functional groups and ecosystems that are most sensitive to increased surface ocean CO_2, and the rate at which organisms can adapt to these changes; the interaction of increased CO_2 in the surface oceans with other factors such as temperature, the carbon cycle, sediment processes, and the balance of reef accretion and erosion; feedbacks of increased ocean surface CO_2 on air–sea exchange of CO_2, dimethylsulphide and other gases important for climate and air quality; and larger-scale manipulation experiments on the effect of increased CO_2 on biota in the surface oceans.

7 **Ocean acidification is a powerful reason, in addition to climate change, for reducing global CO_2 emissions.**

Recommendations

1 **There is a clear risk of significant adverse effects of ocean acidification.** We recommend that this risk should be taken into account by policy makers and other relevant national and international bodies (perhaps including the United Nations Framework Convention on Climate Change) at all discussions and negotiations about climate and other global changes

2 **Any targets set for CO_2 emission reductions should take account of the impact on ocean chemistry and acidification as well as climate change.** We recommend that if the risk of irreversible damage arising from ocean acidification is to be avoided, particularly in the Southern Ocean, the cumulative future emissions of CO_2 from human activities to the atmosphere must be considerably less than 900GtC by 2100.

3 Ocean acidification and its impacts on the oceans needs to be taken into account by the Intergovernmental Panel on Climate Change and kept under review by international scientific bodies such as the Intergovernmental Oceanic Commission, the Scientific Committee on Oceanic Research and the International Geosphere-Biosphere Programme.

4 Tackling ocean acidification cannot be done by any country alone. We believe that the UK could and should take a lead internationally on both policy and research. However, it will only be able to do so by developing and extending its research activity and its international scientific networks.

5 Marine ecosystems are likely to become less robust as a result of the changes to the atmosphere and will probably to be more vulnerable to other environmental impacts (for example climate change, deteriorating water quality, coastal deforestation, fisheries and pollution). **This increased fragility and sensitivity of marine ecosystems needs to be taken into consideration during the development of any policies that relate to their conservation, sustainable use and exploitation, or effects on the communities that depend on them.**

6 Research into ocean chemical changes needs additional investment. Given the potential impacts of these changes, we recommend that a major internationally coordinated research effort (including monitoring) should be launched. The scale of this needs to be commensurate with that on the effects of climate change arising from enhanced greenhouse emissions. The impacts of ocean acidification are additional to, and may exacerbate, the effects of climate change. For this reason, the necessary funding should be additional and must not be diverted from research into climate change.

7 International research collaboration should be enhanced, particularly on the questions associated with effects of enhanced atmospheric CO_2 on ocean chemistry and the resulting impacts on sensitive organisms, functional groups and ecosystems. These efforts need to focus on establishing a better understanding of the various metabolic processes at different parts of the life cycle and how these are expressed at an ecosystem level. Approaches required include global monitoring as well as laboratory, mesocosm and field studies. Models that include effects of pH over a range of scales from the level of the organism to that of the ecosystem will also be necessary. Greater understanding of the likely changes to the oceans resulting from acidification will help inform the management strategies by which human populations can mitigate or adapt to these changes, and can also be linked to climate change models to predict synergistic impacts. The existing research projects of the Surface Ocean–Lower Atmosphere Study (SOLAS) and the Integrated Marine Biogeochemistry and Ecosystem Research Project (IMBER) should be part of any new initiative.

8 **Action needs to be taken now to reduce global emissions of CO_2 to the atmosphere to avoid the risk of large and irreversible damage to the oceans. We recommend that all possible approaches be considered to prevent CO_2 reaching the atmosphere. No option that can make a significant contribution should be dismissed.**

Working Group, Review Group and Secretariat members

Working Group

Chair	Prof John Raven FRS	School of Life Sciences, University of Dundee
Members	Dr Ken Caldeira	Energy and Environment Directorate, Lawrence Livermore National Laboratory, USA
	Prof Harry Elderfield FRS	Department of Earth Sciences, University of Cambridge
	Prof Ove Hoegh-Guldberg	Centre for Marine Studies, University of Queensland, Australia
	Prof Peter Liss	School of Environmental Sciences, University of East Anglia
	Prof Ulf Riebesell	Leibniz Institute of Marine Sciences, Kiel, Germany
	Prof John Shepherd FRS	National Oceanography Centre, University of Southampton
	Dr Carol Turley	Plymouth Marine Laboratory
	Prof Andrew Watson FRS	School of Environmental Sciences, University of East Anglia
Secretariat	Richard Heap	Manager, The Royal Society
	Robert Banes	Science Policy Officer, The Royal Society
	Dr Rachel Quinn	Senior Manager, The Royal Society

This report has been endorsed by the Council of the Royal Society.

A selection of relevant Royal Society reports

Food crops in a changing climate: Report of a Royal Society Discussion Meeting held in April 2005 (June 2005, 10/05)
Joint science academies' statement: global response to climate change (June 2005, 08/05)
Joint science academies' statement: science and technology for African development (June 2005, 09/05)
Response to Defra review of the UK Climate Change Programme (May 2005, 02/05)

Further copies of reports can be obtained from:
Science Policy Section,
6-9 Carlton House Terrace,
London SW1Y 5AG
science.advice@royalsoc.ac.uk
www.royalsoc.ac.uk

4.3 Other Activities

4.3.1 The Global Iron Cycle

A set of fast-track initiatives was approved by IGBP at their meeting in Punta Arenas, Chile in January 2003. The idea for a fast-track initiative on the global iron cycle was developed primarily by Robert Duce and Peter Liss at the IGBP meeting. A proposal was submitted to ICSU by IGBP, with SCOR as a supporting applicant, and was funded, with $40,000 from ICSU. IGBP assigned the responsibility for planning coordination and logistical arrangements to IGBP's Global Analysis, Integration, and Modeling (GAIM) office, although the SCOR Secretariat also was involved in the continued planning. Tim Jickells (UK) and An Zhisheng (China-Beijing) co-chaired the meeting. The *Science* paper is contained in the plastic folder following.

4.3.2 SCOR Meeting on Coordination of International Marine Research Projects

Large-scale ocean research programs and projects are sponsored by several different international organizations, each with a different focus. For example, SCOR focuses on all areas of ocean science, IGBP focuses on biological and chemical aspects of global change, the World Climate Research Programme (WCRP) focuses on physical aspects of global change, and IOC brings together national governments to sponsor research and infrastructural activities related to aspects of ocean science that are of greatest importance to society. Some research programs, such as the Census of Marine Life and InterRidge, are independent but affiliated with related organizations. The programs and projects have interacting interests, but because they are not all sponsored by a single organization, they do not typically come together to discuss opportunities for cooperative activities and ways to address common concerns. The programs and projects tend to operate under tight budgets and are usually reluctant to spend their funds for coordination meetings. SCOR received support from the Alfred P. Sloan Foundation to convene a meeting of the representatives of these projects, which was held in a suburb of Venice in the week before the 2004 SCOR General Meeting. The recommendations from the meeting follow.

Quote from iAnZone report to SCOR (see Tab 7): "In September 2004 the Chair represented iAnZone at a SCOR Marine Coordination workshop in Venice. This proved to be a stimulating meeting which has led to a number of initiatives and future collaborations, as well as increased awareness and communication."

The Sloan Foundation has expressed an interest in supporting another project coordination meeting in 2006. SCOR needs to decide whether to convene the meeting in conjunction with the 2006 SCOR General Meeting in Chile.

SCOR Meeting on Coordination of International Marine Research Projects

Recommendations to Projects

- Identify individuals that are members of more than one project Scientific Steering Committee (SSC). If there is not joint membership between relevant projects, identify new people as liaison people between projects. In either case, the responsibility for communication between groups should be made clear to the linking individuals.
- Where projects have regional nodes or structures, they should develop channels of communication at regional levels. Projects should consider convening inter-project coordination meetings at regional levels, where appropriate.
- Use GBIF standards for species-level geo-referenced data, and species-specific data should be put into OBIS.
- GOOS presentations should be made at SSC meetings to inform SSCs about GOOS plans and to encourage projects to provide input to GOOS.
- Links to GOOS should be considered when project SSCs are formed.
- GOOS and projects should work together to create joint working groups/workshops on topics such as biogeochemical measurements, sensor technology, and environmental indicators. SCOR should consider a working group on these topics.
- Both GOOS and research projects should link their Web sites to one another.
- Projects should overlay their needs for time-series sites on the OceanSITES map of sites (see http://www.oceansites.org/OceanSITES/networkmap.html).
- Research projects should consider the desirability of forming links between themselves and SCAR, and vice versa, where they have strong Southern Ocean interests.
- Projects should consider whether to provide data to the next IPCC and/or MA assessments and, if so, to initiate a process to do so.

Recommendations to SCOR

- Investigate setting up a list-server system/email aliases that can be used for communication between projects, IPO Executive Officers, Chairs, or both. Such aliases might be set up at Johns Hopkins University.
- Seek funds for projects to hold annual coordination meetings, with the agenda items set by the projects. Potential topics for future meetings include standardisation of Web sites and project data management.
- Meeting participants and SCOR staff should write a short *EOS*-type paper to be published in programs newsletters, *EOS*, Challenger Society, *OCEANOGRAPHY Magazine*, etc., giving the main recommendations from the Liverpool meeting, abstracting and updating information from the meeting report, including the lessons learned from previous projects' successes and failures. It would also be helpful to provide (on the Web) tutorials and visualizations regarding data management.
- Prepare a letter to project managers and funding agencies to convey the high priority of preparing and budgeting for data management as an important part of projects, and to ensure

inter-operability of data from different projects, in terms of metadata, data discovery, data transport, data archival, and data access.

- SCOR and other relevant organizations should implement ways to guarantee long-term archiving and management of ocean data, not depending on individual agencies/national policies, and encouraging the use of the World Data Centers.
- Develop a Web portal to all available quality controlled-ocean databases, with short descriptions and available tools for exploitation.
- Circulate to meeting participants any announcements about IPY.

4.3.3 Panel on New Technologies for Observing Marine Life

Terms of Reference:

- To review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects.
- To communicate with CoML project leaders on a regular basis to discuss project technology needs.
- To identify and bring to the attention of the international community of fisheries scientists, marine biologists and others, the potential benefits of emerging technologies in the detection of marine life.
- To explore the relative merits of different technologies and identify those that deserve further research based on their potential for making significant contributions to the detection of marine life.
- To summarize the Panel's discussions on its Web site and in published articles, so as to make it as widely available as possible.

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Full Members		**Liaisons**	
Yogi Agrawal	USA	William Karp	ICES and NOAA)
Geoff Arnold	UK	Ron O'Dor	CoML
David Farmer	USA	Peter Pissierssens	IOC
Gaby Gorsky	FRANCE	Edward Vanden Berghe	IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices)
John Gunn	AUSTRALIA		
Antonio Pascoal	PORTUGAL		
Alex Rogers	UK		
Heidi Sosik	USA		
Song Sun	CHINA-Beijing		
Bob Ward	AUSTRALIA		

Executive Committee Reporter: Annelies Pierrot-Bults

SCOR Panel on New Technologies for Observing Marine Life

Meeting Summary

Meeting #1
Goa, India
14-16 February 2005

The Panel on New Technologies for Observing Marine Life of the Scientific Committee on Oceanic Research (SCOR) met for the first time in Goa, India on 14-16 February 2005. Participants included the panel members Elga de Sa (chair), Yogi Agrawal, David Farmer, Gaby Gorsky, Alex Rogers, Heidi Sosik, Song Sun, and Bob Ward. Panel members Geoff Arnold, John Gunn, and Antonio Pascoal were unable to attend. Other participants included Edward Vanden Berghe (Chair of the IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices), D. Chandramohan (member of CoML Scientific Steering Committee), P.A. Lokabharathi (Indian Ocean CoML Secretariat), and Ed Urban (SCOR Executive Director).

Elgar de Sa made some opening remarks about the Panel. It has been founded on the excellent work that was initiated by SCOR Working Group 118 with the same name (www.coml.org/scor/scor.html/). The Panel will evaluate and recommend new and emerging technologies for CoML. The Panel will have its own Web site on new and existing key technologies. The Panel will operate initially for a period of three years. The tasks for this meeting include

- Examine the CoML Research Plan and identify technologies that are being used by the projects. Can the technologies identified in this meeting be used in the CoML Program and, if so, which projects? The Panel should be seen as a body that can provide reliable technological advice to requests from CoML projects. The Panel Web site should project this image.
- Assign Panel members to different technology areas in the CoML research plan, for example, DNA techniques, optics, acoustics, platforms, imaging systems, etc.
- Discuss structure of the beta version of the panel Web site (www.scoml.org), and make suggestions on how it can benefit CoML projects, and also act as a forward-looking source of information about emerging technologies of oceanographic sciences. Panel members will be responsible for updating and providing content for their technology area on the Panel Web site.
- Make recommendations that will be disseminated to CoML projects and will be posted on the panel Web site.

Elgar de Sa finished by stating that the Panel needs to interact with manufacturers who understand the reality of building reliable instruments. Regular annual updates of emerging technologies by the panel should feature in *Sea Technology* magazine.

Ed Urban, the SCOR Executive Director, added some additional thoughts about what the Panel can contribute:

- Help CoML leave a technology legacy
- Help CoML contribute to the biological portion of GOOS
- Transfer successful technologies among projects
- Serve as a major source of ocean technology information by bringing together information from many different sources
- Help CoML enlarge the "knowable" about ocean organisms and ecosystems

David Farmer presented an overview of the status of all CoML projects. He reiterated the expectations of the SCOR panel from CoML, namely to summarize technologies, to identify the greatest needs and to look for the most promising opportunities for CoML projects. Panel members presented their areas of research that are relevant to the Census of Marine Life and began implementation of all of their terms of reference:

1. **"To review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects."**

A significant amount of time was spent at the meeting discussing the CoML Research Plan and the panel developed recommendations to CoML and its projects (see Recommendations section at end of document). The Panel spent most of its time and discussion on the newer projects.

In general, some of the best equipment for the projects is available "off the shelf," because it is well tested and potentially less expensive. The size of the organism to be observed will determine which technology is appropriate. Advances might be achieved by coupling technologies, such as acoustical and optical techniques, or barcoding and optics.

Meeting participants noted that many CoML projects are using, or could use, the same technologies. They should develop a mechanism to cooperate in the technologies they use. For the new projects, optimal imaging should be useful for CMarZ and the Continental Margin Ecosystems on a Worldwide Scale project. Molecular barcoding and voucher specimens should be employed by CeDAMar; barcoding is already being used by ChESS. CenSeam should use AUVs and ROVs. ChESS needs devices to use in combination with hyperbaric samplers, to keep animals alive for observation and experimentation after reaching the sea surface.

Census of Seamounts (CenSeam)—Alex Rogers reviewed the CenSeam project. He noted that there are probably 100,000 seamounts worldwide. Seamounts tend to be high exposure, with swift currents, so that they have little sediment cover. Seamounts are oases in the open ocean because they promote upwelling, hard substrates, shallower depths, and attract breeding aggregations of some species. Seamounts create significant complexity in currents and mixing and can exert an influence on the ocean up to 50-100 km away. Upwelling caused by seamounts can cause polynyas in ice-covered seas. Biological exploration of seamounts has resulted in the discovery of many new species and indicates that seamounts tend to have high diversity and high endemism. For example, a survey of the Tasman Seamounts found 850 species of animals, 29-

34% of which are new to science and are potential endemics. There is a low overlap of species among the Tasman Seamounts. The Norfolk Ridge Seamounts off New Caledonia feature more than 2000 species so far, more than half of which are previously undescribed. On the Nasca and Sala y Gomez Seamounts, 52% of the invertebrates and 44% of the species are endemic to this chain. Some seamounts feature cold water coral formations that are 8,000-10,000 years old.

Unfortunately, these biological resources are endangered by deep-sea fishing on seamounts on the breeding aggregations of some fish species, such as orange roughy and oreos. In every seamount range where bottom-trawling and deep-sea coral ecosystems coincide, severe damage has been observed. One of the most fundamental scientific questions in relation to seamounts is how species disperse among seamounts, including the role of physical oceanography in dispersal and larval trapping.

Technologies currently used to study seamounts includes trawls and dredges, but these destructive methods create a bad impression of scientists studying seamounts. ROVs and submersibles have also been used, as well as multibeam acoustics. It would be much better to switch to more observations by ROVs and AUVs, such as the Autonomous Benthic Explorer (ABE: http://dsg.whoi.edu:90/ships/auvs/abe_description.htm) and Autosub (http://www.soc.soton.ac.uk/PR/Autosub.html). CenSeam should focus on good video transects, as well as selected sampling for barcoding, microsatellite DNA studies, and taxonomic work. It is important to add Doppler current profiling (including towed Doppler) and acoustic imaging of the biological layers in the vicinity of seamounts. CenSeam should work cooperatively with CeDAMar, MAR-ECO, CoMarE, and TOPP.

Biogeography of Chemosynthetic Ecosystems (ChEss) —Alex Rogers gave an overview of the ChEss project. It is a study of chemosythetic habitats, which include areas of venting or diffusion of hydrogen sulfide, hydrocarbons (methane), and ammonia-rich hypersaline fluids, and diffusion of lipids from dead whales. Many organisms in these areas live by having chemosymbionts: bacteria that break down hydrogen sulphide or methane for energy. Vent and seep areas are rare habitats in the deep sea. Like seamounts, chemosynthetic habitats feature a high level of endemism although, unlike seamounts, the species diversity is usually low. The sampling technology is well developed for chemosynthetic ecosystems for most purposes, including for mapping, chemistry, and studies of megafauna. Molecular biology is well incorporated into studies of evolution and taxonomy. The microbial communities of chemosynthetic ecosystems are understudied, including metagenomic studies, particularly the Chile Margin and the Southern Ocean. The technology is available for such studies, but it is not currently funded. Additional technologies that could be beneficial to use in chemosynthetic habitats include ADCP (towed), echosounders, and high-frequency acoustic methods.

Arctic Ocean Diversity (ArcOD)—ArcOD already is working, through compilation of existing data in OBIS and a research cruise in the Chuckchi Sea in 2004. Plans are developing for activities during the International Polar Year, to be coordinated with the Census of Antarctic Marine Life. In the future, ArcOD will continue to compile existing data, process unprocessed samples, and conduct new collections to fill gaps. Since much untapped information and samples exist in Russia, this project has an emphasis on Russian partners and activities.

Census of Antarctic Marine Life (CAML)—Bob Ward presented the new CAML project. It will focus on inventories of species (Antarctic fauna of slopes and abyssal plains, benthic fauna under disintegrating ice shelves, and plankton, nekton and sea-ice biota, and defining critical habitats for top predators. CAML's main technologies include net sampling for pelagic animals; underwater video recording; CTD/Niskin bottle water sampling; benthic trawls, grabs, and sleds; and barcode of life sampling with high throughput DNA sampling; archiving of voucher specimens will also be important. CAML obviously overlaps with some other CoML projects with Southern Ocean activities, and with other projects, such as EBA (Evolution and Biodiversity in Antarctica) project. Data from CAML will need to be interoperable with databases from other projects, for example, for EurOBIS. In the future, CAML will proceed with entry of data into the MarBIN database of Antarctic data and will coordinate cruise activity. MarBIN data holdings will be used to identify data gaps. CAML will take advantage of SCAR-led physical benthic mapping to be combined with biological data. At the end of CoML in 2010, CAML will integrate MarBIN with OBIS to produce an Antarctic Biodiversity Atlas.

Patterns and Processes of Ecosystems in the Northern Mid-Atlantic (MAR-ECO)—David Farmer made a presentation about the status of MAR-ECO. This project focuses on mid-water and near-bottom macrofauna, including fish, cephalopods (squids, octopods), gelatinous plankton, and crustaceans. The project uses mid-water trawls (3 types, 2 with multisampler), vertical nets, optical profiling, acoustics (organisms, current), and temperature and salinity profiles. The project also does near-bottom sampling with bottom mapping, ROV dives, bottom trawls, benthic landers, longlines, and traps. They employ bait traps and acoustic landers at medium to long term. Project scientists adjust net sampling to sample acoustically located layers of biological activity. The project has collected 50 species of cephalopod, some of which were not named previously. Regarding fish, 179 mid-water species have been recovered, but the number probably will increase to beyond 200 after final analysis. 87 near-bottom fish species have been recorded. Many of these species have been recorded for the first time in the North Atlantic Ocean, and many still are not identified with certainty. MAR-ECO should be requested to document the technology lessons it has learned, so that these can be shared with other projects.

Pacific Ocean Shelf Tracking (POST)—POST technology is described at http://www.postcoml.org/project/technology.php. David Farmer provided information relevant to the POST project. POST uses high-frequency sound, multiple receivers, and short ranges. Each tag has a distinctive coded signal. Propagation is restricted by absorption, and boundary and internal scattering. POST is implanting the tags in salmon and sturgeon. Another method that could be useful for POST-type studies would be a RAFOS approach, in which the tags are passive (and thus low power), with the few fixed sources being powered, rather than the other way around. This is the concept behind the Fish Chip. This approach allows the use of very small tags, low frequencies for long-range detection, and continuous measurement far from choke points. POST tags are commercially available. Alternatively, in the next generation of such observations, they should evolve to having the receiving systems occasionally transmit a trigger signal, so that the tags only need to transmit when they are near a receiver. Farmer described the Fish Chip, which is a passive receiver implanted in fish that can record where the fish travels. The tag includes a thermistor, hydrophone, and memory.

Census of Marine Zooplankton (CMarZ)—Song Sun described the CMarZ project. CMarZ is a taxonomically comprehensive, global-scale census of marine zooplankton, to produce accurate and complete information on zooplankton species diversity, biomass, biogeographical distribution, genetic diversity, and community structure by 2010. CMarZ will analyze the about 6,800 described species (and will likely discover at least this many new species) of marine metazoan and protozoan holozooplankton (animals that drift with ocean currents throughout their lives). It will include gelatinous zooplankton, but not the larvae of non-drifting forms. CMarZ has some relevance to CenSeam. CMarZ will use standardized sampling methods, based on GLOBEC methods, so that samples can be compared from different locations. It will use a nested sampling approach, with net sampling and barcording of organisms collected. CMarZ will be based on standardized sampling gear, including the Multiple Opening-Closing Net and Environmental Sensing System (MOCNESS) and the Continuous Plankton Recorder (CPR). Sampling of gelatinous zooplankton requires nets with large cod-ends and manual sampling. Zooplankton sampling approaches will be designed to obtain specimens and data from a variety of taxa using protocols that will yield specimens suitable for morphological and molecular analysis, as well as samples that are suitable for quantitative analysis. Traditional morphological analysis of zooplankton samples will remain a central component in the processing of new and existing collections of zooplankton. Such analysis continues to provide an ecological context for most groups. CMarZ will ensure that additional efforts will be applied to sample analysis to improve the quality of data, especial rare species, which are typically under-represented in zooplankton studies.

The project could benefit from adding acoustic observations. It is also important that they use noiseless nets, which can be tested by deploying on-net cameras and/or acoustic sensors to determine whether any organisms are regularly able to avoid the nets. Lights can be used to attract some species. One difficulty in the project is getting research groups to modify or give up their traditional methods. There is a great potential for re-analysis of samples collected earlier.

Ocean Biogeographical Information System (OBIS)—OBIS should integrate barcoding data in some way with barcoding databases, to make sure that molecular data are accessible with other data about species, and to avoid duplication.

Questionnaire Results—The panel received questionnaire responses from a high percentage (57%) of the CoML field projects. The purpose of the questionnaire was two-fold: (1) to determine what technologies are being used by the projects and (2) to determine what kind of information (and with what frequency) the projects would like information on the Panel Web site. The questionnaire results also provided information about the other ways that projects obtain technology information. These results were used to form recommendations to the projects, help direct the future work of the Panel, and design the Panel Web site.

2. **"To communicate with CoML project leaders on a regular basis to discuss project technology needs."**

The panel began its communication with CoML projects and their leaders through a questionnaire that was developed to obtain information about the technologies currently being used by the projects and their need for information on available technologies. Future communication will be both direct and through the panel Web site.

The panel concluded that it could provide the greatest benefit to CoML projects that are in their development phase, that is, CenSeam, CMarZ, CAML, ArcOD, CeDAMar, ICoMM, and the reefs and margins projects, if approved. Two panel members will attend the CenSeam planning meeting in the Azores and other panel members will be identified to attend the other meetings if the other projects. The role of panel members at these meetings will be to learn about the projects and to convey in person any advice from the panel.

3. **"To identify and bring to the attention of the international community of fisheries scientists, marine biologists and others, the potential benefits of emerging technologies in the detection of marine life."**

Barcoding—Alex Rogers and Bob Ward made presentations about how new molecular techniques are being used to study marine biodiversity. "Barcoding" involves using specific regions of genes to assess the genetic and taxonomic diversity of organisms, comparing observed sequences against each other. The selected gene regions depend somewhat on the organism studied, although an attempt is being made to use gene regions that can be used widely with different taxa. For higher organisms, the recommended barcoding gene is the mitochondrial DNA cytochrome oxidase I gene (COI, see barcoding.si.edu or www.barcodinglife.org).

Rogers has worked on nematodes collected with box corers and multicorers in the equatorial Pacific Ocean at the Clarion-Clipperton Fracture Zone as part of the CeDAMar project, using 18S ribosomal genes. The results of these studies indicate that there are many rare species. Using a BLAST search against known 18S sequences, no sequences were found showing 100% identical matches to any known nematode species. Barcoding detects more species, especially single specimens of a species. Some larvae can be identified to species level by molecular analysis, but others only to the family level. In general, however, barcoding allows better discrimination among species than do morphological methods, particularly for larvae.

New studies are being conducted on Antarctic zooplankton, to assess how genetic expression is caused by environmental effects and lead to ecosystem effects. Zooplankton were compared using cytochrome oxidase enzyme (COI), 18S, 28S regions, using a variety of primers. For example, temperature can affect the expression of genes in Antarctic organisms (e.g., for production of as many as 5 different anti-freeze proteins in fish), leading to changes in physiology and behavior that can ripple up through food webs. The results of such analyses could help predict the effects of climate change on Antarctic systems. The BIOFLAME (Biodiversity: function, limits and adaptations from molecules to ecosystems diversity) project is studying how genetic expression affects ecosystems. The BIOFLAME approach involves (1) experiments using different temperatures, (2) identification of genes that respond, (3) detailed studies of gene expression in animals from populations at different latitudes, and (4) sequencing of affected genes.

Shotgun sequencing of genetic material found in seawater samples from the Sargasso Sea has demonstrated that

- 1800 species of bacteria, Archaea, and viruses were present, including 148 new bacterial phylotypes.
- 1.2 million previously unknown genes were discovered.
- Organisms previously considered characteristic of eutrophic or terrestrial environments were found in the this oligotrophic open ocean area.
- Widespread genes for rhodopsin-like photoreceptors were found.

as reported by Venter et al. (2004) in *Science*.[1]

Bob Ward has worked on barcoding of fish species, particularly in Australian waters. Fish are the largest vertebrate group, are morphologically and genetically diverse, and feature an interesting evolution. The value of global fisheries is about US$200 billion annually and employ 35 million people. The cytochrome oxidase I enzyme (COI) is contained in ribosomes and is a conserved region that can be used in barcoding of shark fins, fish eggs, and fish larvae.

Ward discussed ongoing international barcoding activities, including the Consortium for the Barcode of Life (CBOL: http://barcoding.si.edu/index.htm) and the Barcode of Life Database (BOLD: http://www.barcodinglife.org/). BOLD can be used to search for genetic sequences that closely match newly identified sequences. Most species included in BOLD are represented by voucher specimens. CBOL is presently supporting major projects on birds, fish, and plants, and will soon add zooplankton (ZooGene).

It would be useful to be able to barcode museum specimens, but it is difficult to use specimens that have been preserved in formalin. Barcoding studies can identify which groups of organisms need attention from taxonomists.

Applications of fish barcoding include

- Identification of fish, fillets, fins, and fragments to detect substitutions, and conduct quota and bycatch management.
- Identification of processed product (e.g., canned fish, dried fish, mixtures) to detect species substitutions.
- Identification of threatened, endangered and protected species for conservation purposes, from parts of the animals, such as shark fins.
- Identification of fish eggs and fish larvae for ecosystem research and fisheries management.
- Identification of prey items in stomach contents to study food webs and trophic interactions.
- Identification of historical, archived and museum material for taxonomic purposes.

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[1] Venter, J.C. et al. 2004. Environmental genome shotgun sequencing of the Sargasso Sea. *Science* 304:66-74

- Identification of new species and possible fusions, insights into phylogenetic relationships (fish biology, evolution).

To date, COI barcoding of Australian fish has yielded 901 sequences from 264 taxa (209 'good' + 55 "undescribed/to be identified" species). This work will continue to barcode Australia's marine fish (about 4,000 described species, maybe 30% endemic, and about 500 undescribed) and freshwater fish (about 195 described species and about 20 undescribed). This database will be made available to the general public and will be compared with similar databases now being developed for North American and South African fish. A Global Fish Barcode Network is being established, which will aim to barcode all the marine fish species of the planet. About 15,500 species are currently recognised, expected to increase to 20,000 species as a result of CoML and other activities. There will be an international workshop in June 2005 in Guelph, supported by the Alfred P. Sloan Foundation, including geneticists, taxonomists, database managers, delegates from fisheries organizations. The Global Fish Barcode of Life could be completed (except for rare species) within about 5 years subject to funding.

Protein electrophoresis—Methods to study the protein products of genes are less sensitive than molecular techniques, but also less expensive, and thus could be good for monitoring gene expression at lower cost. Gel electrophoresis of proteins resolves most species, but has limited use in detecting community change and closely related species. The equipment for electrophoresis is relatively inexpensive and potentially could be miniaturized.

In the Australian fish retailing (and probably elsewhere), species are not always correctly identified. An Australian handbook of gel electrophoresis patterns has been created with 380 domestic commercial species and another handbook includes 175 imported commercial species. Unfortunately, protein "fingerprints" won't always separate closely related species, so barcoding of Australian fish has started using COI.

Autonomous Surface Vehicles—Elgar de Sa described a small autonomous surface vehicle (ASV) being developed in his laboratory. ASVs are robot platforms that navigate along programmed transects on the sea surface using GPS satellite and line-of-sight guidance. They can be used to map surface chlorophyll distributions for sea-truthing of satellite ocean color images, monitor surface pollution hotspots in coastal areas, follow shallow water bathymetry if modified with path-following guidance, and detect and map surface blooms of harmful algae, such as *Trichodesmium*. Examples of ASVs include Delfim from Portugal, Autocat from the United States, and ROSS from the National Institute of Oceanography in India. ROSS is made from inexpensive, off-the-shelf components, as much as is possible so that they can be constructed for about US$15,000 each. (The greatest cost is for the motors.) The vehicle is heading controlled and has an endurance of 7 hours. It currently carries a fluorometer and has been used in transects in coastal areas. In the future, it could be possible to implement sensor-based navigation, so that the ASV could map and follow tracer fields.

Drifters—A near-bottom drifter with cameras could be particularly useful for several of the projects, such as CeDAMar and the margins project.

Particle Size and Number Sensors—Yogi Agrawal made a presentation about his instruments that are used to determine particle size distributions using laser detection (see http://www.sequoiasci.com). The instruments developed by his company can discriminate 32 size classes, from 1.25 to 1500 microns in different models. These types of instruments are important for studying sediment transport in bottom boundary layers, settling rates of different sized particles, and other applications. The shape of the detector in the instrument can be modified for different purposes. The company is studying the effects of shape on measurements. Agrawal stated that detectors for particles of less than one micron in size would be difficult to design and market.

Acoustic Methods—David Farmer discussed a variety of acoustic approaches to the detection of marine life, including (1) propagation, as in use of tags for fish tracking (active or passive tags), (2) scattering, as in fish and zooplankton sonars (scattering inversion and acoustic imaging), and (3) passive detection, as in use of vocalizations from marine mammals and fish.

Active acoustic tags are being used by the CoML Pacific Ocean Shelf Tracking (POST) project (see above).

Passive receiver tags have been shrunk to about 2-3 centimeters diameter. They have a range of about 100 km and can measure temperature and salinity. It could be possible to add sensors that would allow the monitoring of the tagged organism's eating activities, heart rate, and other physiological parameters.

Scattering of sonar signals can be used to study aggregations of fish and plankton. Scattering models are developed by measuring the signals of known concentrations of organisms in tanks. Multi-frequency sonar can be used to determine the size distribution of plankton, as is being done by Van Holiday. Thin layers of concentrated organisms have been discovered this way. Acoustical techniques can also be used to detect organisms up to 8 km way (at 12 kHz and typical fish sonar power). "Acoustic cameras" can be used to provide high-resolution images of fish, even in turbid waters. Optics can be added to improve the images.

Passive acoustic detection can be used to help understand distributions of marine organisms that make distinctive vocalizations, such as fish, marine mammals, snapping shrimp, etc., potentially of use to some CoML projects. Passive acoustics could provide new information in coral reef environments, in terms of grazing and other activities in reef areas. Adding optical observations would be necessary to identify the organisms making the observed noises.

Optics—Gaby Gorsky noted that it is a long way from an original idea to the prototype of an instrument. It takes a long time to get the prototype operating and to demonstrate its usefulness. It is even a longer struggle to make the instrument commercially available to the scientific community. Gorsky described optical tools available for observing marine life. The laser-optical particle counter (LOPC: http://www.brooke-ocean.com/lopc.html) can be towed at a speed of 12-14 knots, to 6000 meters. The Video Plankton Recorder (VPR: http://www.whoi.edu/instruments/viewInstrument.do?id=1007) II can be used in undulating mode, as well as put on Remote Environmental Monitoring Units (REMUS:

http://www.whoi.edu/science/AOPE/dept/OSL/remus.html) or observatories. With VPR, there is a strong emphasis on image analysis. The FlowCAM (see http://www.bigelow.org/flowcam/) has a depth maximum of 300 meters. Particles are photographed and lasers used to determine the pigments in the particles. ZOOSCAN is a commercialized particle scanner. It can be used to analyze samples collected in the past and archived. ZOOSCAN can be used to detect changes in zooplankton populations over time. The ZOOVIS system (http://www.whoi.edu/institutes/oli/activities/participants/mb.html) is a high-resolution zooplankton imaging system. IFREMER also has developed a High-Definition Video System (HDVS) for ocean observations and an autonomous vertically profiling plankton observatory. These instruments are all designed for operation in the water column. Other instruments have been developed for near-bottom observations. The Autonomous Vertically Profiling Plankton Observatory (AVPPO: http://4dgeo.whoi.edu/vpr/vpr_overview.html) takes repeated vertical profiles (over days to months), including VPR observations, from the surface to the bottom in up to 100 m depth. In the future will be the Exocet/D Video Acquisition and Storage unit, a compact, low-power camera system that can be deployed on a variety of platforms. Further in the future will be "virtual holotypes", three-dimensional images of organisms that can be used as standard images against which to compare samples.

Heidi Sosik described the FlowCytobot (see http://www.whoi.edu/science/B/Olsonlab/insitu2001.htm) that she helped develop. The FlowCytobot has been deployed since 2001 at the Martha's Vineyard Coastal Observatory and is open to new users. This instrument is a flow cytometer that is anchored at the seafloor and water is pumped down to it. It is similar to lab-based flow cytometers. It counts phytoplankton and samples continuously and thus can be used to track phytoplankton abundance and growth over hourly to seasonal scales and to help understand variability in nano/picoplankton communities over time. FlowCytobot can also determine phytoplankton growth rates over time. For each particle, the instrument measures forward scattering, side scattering, red fluorescence, and orange fluorescence. Base-line data are available in real time and as archived data. The Imaging FlowCytobot is optimized for large cells. Measurements can be triggered on fluorescence or light scattering. Data analysis is a problem, so they are trying to automate and increase the speed of the process. So far, they have been able to achieve 85-96% correct classifications, at a rate of 1200 images analyzed per minute.

Zooplankton Sampling—Sun Song described the various methods available for sample zooplankton, including net sampling, optical particle counters (OPCs), the CPR, acoustical techniques, VPRs, molecular techniques, and sampling pumps. The methods can be implemented singly or together on various platforms, such as moorings, ROVs, and AUVs. Acoustical techniques are quick and are particularly useful for ecological studies. The BIo-Optical Multi-frequency Acoustical and Physical Environmental Recorder (BIOMAPER) is a new-generation towed vehicle (see http://www.ccpo.odu.edu/Research/globec/3sciinvest/wiebe1.htm) that can be used to map zooplankton distributions. Intercalibration among the different methods is important, to make their results comparable.

Remote Sensing—Remote sensing is not suitable for studying biodiversity, per se, but can be helpful for understanding the distributions of marine organisms, by providing the environmental context (e.g., temperature, currents, chlorophyll) for the observed distributions, particularly for surface ocean dwellers.

Volunteer Observing Ships—Some projects might use instruments towed behind, or otherwise deployed from, volunteer observing ships (VOSs). Parameters such as temperature, salinity, and chlorophyll can be observed from engine intake water on ships. Commercial ships follow regular routes, so can provide time-series measurements. Volunteer observing ships have been used for many years with the CPR and deploying XBTs. VOSs provide a lower–cost way to deploy instruments and make measurements than research vessels for some measurements, because the ship time is free. The ships also operate around the clock and in all seasons. It may be possible to modify the CPR package to include other sensors, such as for temperature and chlorophyll. The CPR has been successful because it is simple and robust, and can be towed at the high speed of commercial ships. Other measurements might be made with XBT-like expendable instruments. Other potential commercial "platforms of opportunity" include drilling rigs and pipelines.

Ocean Observatories—Several ocean observatories have been developed in the past decade, with many new ones under development (see http://www.oceansites.org/OceanSITES/). CoML projects that are making observations in sites where observatories will be deployed should take advantage of opportunities to add CoML-relevant equipment. Particularly important could be observatories in high-latitude areas and, potentially, sonar added to the global ocean bottom seismometer (OBS: http://obslab.whoi.edu/nobsip.html) network.

Data Management—Edward Vanden Berghe presented information about the MarBEF activity (see http://www.marbef.org/), which is an EU Network of Excellence designed to integrate data management and communication activities. Linked to MarBEF is EurOBIS, the European node of the CoML OBIS. EurOBIS is a metadatabase that can be examined for gaps in species information. It is a distributed system, using the Darwin protocol. The European Register of Marine Species is also connected to MarBEF. Eventually, the goal is to capture the distributed data in an archive/depository, through the International Ocean Data and Information Exchange's Group of Experts on Biological and Chemical Data Management and Exchange Practices (IODE/GE-BICH). The objectives of GE-BICH are to

- document the systems and taxonomic databases currently in use in various data centers;
- document the advantages and disadvantages of different methods and practices of compiling, managing and archiving biological and chemical data;
- develop standards and recommended practices for the management and exchange of biological and chemical data, including practices for operational biological data;
- encourage data centers to compile inventories of past and present biological and chemical data holdings; and
- encourage data holders to contribute data to data centers for the creation of regional and global integrated oceanographic profile and plankton databases.

GE-BICH's pilot projects include a distributed system for metadata, a distributed system for nomenclature, and a catalogue of systems in use to store/archive biodiversity data. GE-BICH has held two conferences so far, on "The Colour of Ocean Data" and "Ocean Biodiversity Informatics."

The IODE Ocean Teacher system (http://www.oceanteacher.org/) provides a tool box of methods to deal with biodiversity data sets.

4. "To explore the relative merits of different technologies and identify those that deserve further research based on their potential for making significant contributions to the detection of marine life."

The panel discussed a variety of different technologies that could be used for the detection of marine life, as described above. The Panel believes that several technologies deserve to be explored in workshop settings (see list in Recommendations section of potential workshops on technologies that could be useful to CoML projects and more broadly). Funding for such workshops would need to be obtained from other sources, as the funding for the panel from the Sloan Foundation is not adequate to fund workshops. Panel members and SCOR staff will seek other funding sources.

5. "To summarize the Panel's discussions on its Web site and in published articles, so as to make it as widely available as possible."

The panel reviewed the input from CoML projects in relation to the Web site content and received a presentation from the Web site developers.

The Panel will produce a variety of written products, including

- Article about formation of the panel, in *Sea Technology* and/or *EOS*
- End-of-the-year summary to be published in *Sea Technology*
- Minutes/summaries of discussions from Panel meetings, to be posted on the Panel Web site.
- Annual letter to CoML projects, with recommendations from the Panel
- Concept article

Other topics were discussed during the meeting:

Indian Ocean CoML—D. Chandramohan described efforts to develop and strengthen activities related to CoML in the Indian Ocean (see http://www.coreocean.org/Dev2Go.web?id=248310&rnd=30946). Planners must overcome several limitations found in the region: (1) rigid hierarchy that exists among organizations and between organizations and the national governments, (2) slow process of securing bureaucratic approvals, (3) restrictions on exchange of information on biodiversity, especially related to intellectual property rights and biopiracy, and (4) the frequent requirement of national or in-house funds to complement the contribution of international agencies.

Several programs funded by India fit with CoML objectives. An Indian Ocean CoML (IO-CoML) committee has been formed and a secretariat set up. This followed a 2003 workshop on Coastal and Marine Biodiversity of the Indian Ocean. IO-CoML hosts a listserver to encourage information exchange in the region and also hosts a database on Indian Ocean taxonomy (see http://www.ncbi.org.in). The Natural Geography in Shore Areas (NaGISA) project will be implemented as part of IO-CoML in the near future. Indian scientists have conducted a lot of deep-sea benthic sampling in relation to deep-ocean mining plans, which could contribute data and samples to CoML projects. IO-CoML is also interested in the CenSeam project. IO-CoML is expected to contribute to marine ecosystem-based management, science education and communications, and ocean observing systems in the region.

Interactions of the Panel with Industry—Yogi Agrawal briefed the Panel about how it might interact with industry. He reminded the Panel that industry's driving motivation is profitability. Industry will not commercialize instruments identified by CoML projects or the Panel unless there is a sufficient market for the instruments. They will not produce one-of-a-kind instrument to be used by a small number of scientists. Many companies do not protect their instruments with patents because of the disclosure required and because they cannot afford to defend against patent infringement. Scientists tend to underestimate the knowledge that industry representatives have regarding what is going on in science relevant to their area of instrumentation. It could be useful for Panel members to attend instrument trade shows to learn about new instruments that have been developed.

Meetings—The Panel should be represented at CoML project planning meetings, for the new projects, as well as at other related meetings. Specifically, the meetings of CenSeam, ArcOD, CAML, CMarZ, CeDAMar, and ICoMM should include Panel members to help these projects incorporate appropriate technologies. Other meetings that Panel members should attend to help achieve the Panel's terms of reference include the 2006 Deep-Sea Biology meeting at Southampton Oceanographic Centre and the 2006 ASLO/AGU/TOS Ocean Sciences Meeting in Hawaii (20-24 February).

There was a specific request from Mark Costello to endorse a workshop on marine acoustics on 17-21 October 2005 in New Zealand. There was no request for funds. The Panel believes that representatives from POST and TOPP should be invited to attend. David Farmer will contact Costello for more information about how many people are expected at the workshop, as well as other details.

The Panel should find funding for and convene some specific meetings that would advance CoML projects and, more generally, observations of ocean organisms beyond the life of CoML:

- State of the art and research needed to make progress on barcoding ocean organisms. Also needed is a methods manual. Particularly important is to take samples for barcoding before a sample is destroyed for some other measurement. A protocol for ship-board sampling would be useful and the panel will draft a protocol to post on the Web site, in consultation with the Barcode of Life project. This meeting should focus on how the technology is best implemented. It should include forensic scientists and discuss software for handling barcodes and databases for barcode data. Such a meeting would be a chance to get together CoML projects to discuss the use of barcoding in each project and to bring bar-coders together with taxonomists.

- Use of nanotechnology for small sensors on fish tags, Argo floats, towed vehicles, and other platforms. Such a meeting could also explore how to miniaturize existing technologies, such as protein electrophoresis and con-focal microscopy. What new sensors could be deployed on next-generation Argo floats and/or gliders?
- New uses of platforms of opportunity. What new instrument packages could be towed behind, or otherwise deployed by, ships of opportunity?
- Image recovery/enhancement techniques
- Passive acoustics for automatically identifying fish
- Microfluidics
- Transferring techniques from medical sciences to oceanography
- Advances in instrumentation
    - Combinations of existing technologies
    - Better batteries
    - Instruments to observe fast-swimming mid-water organisms
    - Combination of remote sensing imaging from satellite sea surface height/gravity sensors and ocean color/sea surface temperature sensors to determine the impacts of seamounts on ocean productivity
    - Smart instruments that make decisions when interesting events occur.

Panel Web site—The developers of the Panel's Web site (the beta version is available at www.scoml.org) made a presentation to the Panel, explaining the features of the Web site, and receiving feedback from the Panel on desired changes. The Web site contains an open section that is accessible to the public, as well as a password-protected area for discussions among Panel members. The projects were enthusiastic about a Panel Web site that would provide the following information:

- Links to forums for different kinds of CoML-relevant instrumentation
- Relevant technology conferences
- Reviews of equipment: summaries, not evaluations
- A vendor list, input by interested companies
- Cruise schedules
- Resource-sharing possibilities: ships, equipment, samples
- Success stories

Changes need to the Web site include

- Redesign banner to simplify. The colors look washed out. Use the same color for all the words in the left navigation bar.
- Put links to CoML project Web sites in the top bar areas
- Make it possible to navigate events calendar better

- Keep the older articles in an archive
- Put meeting announcements in events and subsections
- Allow comments to be submitted by anyone, unmoderated for now
- Change “Electronic Tags” to “Tags”
- Change “New Sensors” to “Biosensors”
- Change “DNA Techniques to “Molecular Techniques”
- Change “Imaging Systems” to “Image Processing”
- Search engine to search all articles
- For “Library Resources”, make a pull-down menu
- Give Panel a periodic update of discussion threads
- Never have a page without a graphic
- Try to make the site live by the time of the April 26-29 IODE meeting and 26-27 April CoML Scientific Steering Committee meeting

Assignments for Providing Technical Information for the Panel Web site

Molecular Techniques: Alex Rogers and Bob Ward
Acoustics: David Farmer
Optics: Gaby Gorky, Heidi Sosik, and Yogi Agrawal
Tags: Geoff Arnold and John Gunn
Platforms: Elgar de Sa

ArCOD: Bob Ward
CAML: Bob Ward
ChEss: ??
CeDAMar: Alex Rogers
CenSeam: Alex Rogers
CmarZ: Sun Song
GOMA: ??
ICoMM: Heidi Sosik
MAR-ECO: Gaby Gorsky
NaGISA: ??
POST: David Farmer
TOPP: David Farmer

<u>Acronyms</u>

ABE	Autonomous Benthic Explorer
ADCP	Acoustic Doppler Current Profiler
ArcOD	Arctic Ocean Diversity
ASV	autonomous surface vehicle
AUV	automated underwater vehicle
AVPPO	Autonomous Vertically Profiling Plankton Observatory
BIOMAPER	BIo-Optical Multi-frequency Acoustical and Physical Environmental Recorder
BOLD	Barcode of Life Database

CAML	Census of Antarctic Marine Life
CBOL	Consortium for the Barcode of Life
CenSeam	Census of Seamounts
ChESS	Biogeography of Chemosynthetic Ecosystems
CMarZ	Census of Marine Zooplankton
COI	cytochrome oxidase I
CoMarE	CoML continental margins project
CoML	Census of Marine Life
CPR	Continuous Plankton Recorder
CTD	conductivity-temperature-depth sensor
DNA	deoxyribonucleic acid
EBA	Evolution and Biodiversity in Antarctica project
EU	European Union
GE-BICH	Group of Experts on Biological and Chemical Data Management and Exchange Practices
GLOBEC	Global Ocean Ecosystem Dynamics project
GOMA	Gulf of Maine Area project
GOOS	Global Ocean Observing System
GPS	Global Positioning System
HDVS	High-Definition Video System
ICoMM	International Census of Marine Microbes
IFREMER	Institut Francais de Recherche Pour l'Exploitation de la Mer
IO-CoML	Indian Ocean Census of Marine Life
IODE	International Ocean Data and Information Exchange
LOPC	laser-optical particle counter
MarBEF	Marine Biodiversity and Ecosystem Functioning EU Network of Excellence
MarBIN	Marine Biodiversity Information Network
MAR-ECO	Patterns and Processes of Ecosystems in the Northern Mid-Atlantic project
MOCNESS	Multiple Opening-Closing Net and Environmental Sensing System
NaGISA	Natural Geography in Shore Areas project
OBIS	Ocean Biogeographical Information System
OBS	ocean bottom seismometer
OPC	optical particle counter
POST	Pacific Ocean Shelf Tracking project
RAFOS	SOFAR spelled backwards. SOFAR signifies Sound Fixing and Ranging float
REMUS	Remote Environmental Monitoring Units
ROV	remotely operated vehicle
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
TOPP	Tagging of Pacific Pelagics project
UVP	Underwater Video Profiler
VOS	volunteer observing ship
VPR	video plankton recorder

XBT	expendable bathythermograph
ZooGene	A DNA sequence database for calanoid copepods and euphausiids

Recommendations to Census of Marine Life Project from the SCOR Panel on New Technologies for Observing Marine Life

Meeting #1
Goa, India
14-16 February 2005

The Panel on New Technologies for Observing Marine Life of the Scientific Committee on Oceanic Research (SCOR) met for the first time in Goa, India on 14-16 February 2005. The first term of reference of the panel is to "review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects." A significant amount of time was spent at the first meeting discussing the CoML Research Plan and the panel makes the following recommendations to CoML and its projects:

- Many of the projects are using the same technology (see attached inventory of technologies used) and could benefit from sharing information about the observation technologies and work together to improve the use of the shared technologies. For example, the experience of MAR-ECO scientists in using existing and new technology at sea can be documented and shared with other CoML projects.
- CoML should provide a database of CoML-related cruises on its Web site.

. From the information about technologies being used, as well as knowledge about the kinds of observations and sampling the projects will pursue, the Panel offers the following advice:

- All projects that will actually sample organisms, particularly fragile specimens, should (1) collect the samples in a way that is compatible with molecular barcoding techniques (2) preserve voucher specimens, and (3) where voucher specimens cannot be maintained, collect three-dimensional images. CeDAMar, the margins project, and CenSeam particularly fall into this category, because of the expense of collecting the samples and the difficulty of re-sampling.
- CMarZ and ICOMM should consider employing sampling from volunteer observing ships.
- Projects should take advantage of opportunities to make observations from new observatory systems being planned. Ocean observatories might be especially useful for CeDAMar, ChEss, and MAR-ECO. Observatories in high-latitude areas, greatly under-observed, would benefit ArcOD and CAML.
- Projects should involve oceanographers and make oceanographic measurements to the extent that the project is attempting to understand what controls the distribution of marine organisms. For example, seamounts are significantly influenced by the hydrodynamics of current flows that surround them, and hence physical processes do affect the biology of seamounts. Therefore, it would be useful to involve and obtain inputs from physical oceanographers in the project.

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Some projects could benefit from the passive detection of sound from marine organisms, including both data collection and "voice recognition." Projects that could benefit from knowing about sounds from marine organisms should involve experts on animal acoustics. The TOPP project already does this.

4.3.4 Activity Proposed by SOLAS and the International Nitrogen Initiative (INI)

Proposal to Conduct a Review of Anthropogenic Nitrogen Impacts on the Open Ocean

Scientific Rationale

Human actions on continents have greatly altered the nitrogen cycle of many regions of the world. These alterations of the N cycle have numerous consequences for human health and ecosystems. The most important positive effect is the increased food production resulting from the anthropogenic introduction of N into agro-ecosystems. There are, however, a large number of negative impacts on the atmosphere, and on terrestrial, freshwater and coastal ecosystems with consequences for both human and ecosystem health. The International Nitrogen Initiative (INI) is developing a coordinated plan to address these issues for the world's continental regions and their coastal margins. However, there may also be changes to the open ocean that occur as a consequence of human action on the continents. The changes are of two types: direct and indirect. Direct changes in marine productivity may occur due to atmospheric deposition of N to the open ocean from continental (or marine transport) anthropogenic N emissions, and in some regions the direct injection of riverine N from anthropogenic sources across the continental shelf from major rivers and via groundwater inputs. Potential indirect changes could be associated with anthropogenically increased emission of Fe-containing dusts to the atmosphere and subsequent deposition to the mid-ocean that as well as having the potential to directly increase marine productivity in Fe-limited (HNLC) regions, can also indirectly increase marine productivity in N-limited regions by increasing marine biological nitrogen fixation. This latter process appears to be very sensitive to the availability of iron (Falkowski, 1997). The (current or potential future) magnitude of these and other effects has not been adequately assessed in recent times. Indeed, the last assessments of anthropogenic nitrogen inputs to the global ocean via the atmosphere were made more than a decade ago (Duce, *et al*., 1991; Galloway *et al*., 1994). We are not aware of any recent attempts to quantitatively assess the likely impact of such nitrogen deposition on global ocean productivity and consequent feedbacks to the climate and air quality through altered trace gas air-sea exchanges (CO_2, N_2O, DMS, organo-halogens and hydrocarbons).

The INI and SOLAS are jointly considering a review of the current understanding of the potential for changes in open ocean health due to human alteration of the marine N cycle either directly or indirectly. This is an issue of central importance to SOLAS and is the subject of Activity 1.5 of its Science Plan & Implementation Strategy (2004). The INI/SOLAS review would be accomplished, in part, through a small workshop on this topic.

The INI is conducting an integrated assessment of the magnitude of the human alteration of the nitrogen cycle, and the resulting impacts on human and ecosystem health. As part of this effort, INI has established regional centres in Africa, Asia, Europe, Latin and North America. Each centre will focus on nitrogen-related issues in their respective regions, including associated coastal zones. Since the regional centres do not address the open ocean, the workshop proposed here is designed to determine whether the input of anthropogenic N into the open ocean has impacts on marine systems. As such it is an integral component of INI's assessment mission.

Practicalities

At this early stage, it is envisioned that the workshop would be small (~12 participants), and might be held at University of East Anglia. The products would be several papers for submission to journals such as *Deep-Sea Research* or *Global Biogeochemical Cycles*, and a review paper, submitted to *Science* (or *Nature*), as was done for the recent workshop led by Jickells *et al*. (2005) on global iron connections between the desert, the oceans and climate. Support from SCOR (SOLAS and any others sponsors) will be acknowledged in all publications and communications arising from the work.

We suggest Co-Chairs for the workshop, one more on the oceanographic dimension and the other more atmospheric. So far we have approached Bob Duce (USA) for the latter role and Julie LaRoche (Germany) for the former, and both have now confirmed their acceptance. It will be up to the Co-Chairs to establish a small planning committee which can interact electronically and may meet in the autumn of this year. Their task will be to establish the *modus operandi* of the workshop, including the topics to be covered (which will probably include *inter alia* atmospheric transport and transformation, deposition and modelling, marine transport and N dynamics, as well as effects) and selection of the workshop participants. At this stage it is not appropriate to list participants but they will be selected for their scientific standing and ability to contribute to the task, paying particular attention to gender and inclusion of scientists from less developed countries (of which there are several who can make substantial contributions to the workshop, for example, Naqvi and Sarin from India, and Wang from China). The planning committee will keep SCOR, SOLAS and INI informed and ask for suggestions. It is planned to hold the workshop in late 2006.

The cost of the workshop would be approximately 20,000 USD (12 participants @ 1500 USD each, plus 2000 USD for additional expenses (e.g. publications, secretarial help). The SOLAS SSC has agreed to fund 3 participants (at a cost of about 5000 USD). We are, thus, requesting funding for the remaining participants at a cost of up to 15,000 USD. Currently the INI does not have funds to make a contribution, but will work with SOLAS in raising additional support, as needed.

Jim Galloway (Chair INI)
Peter Liss (Chair SSC SOLAS)

13 July 2005

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