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GLOBAL IGBP CHANGE

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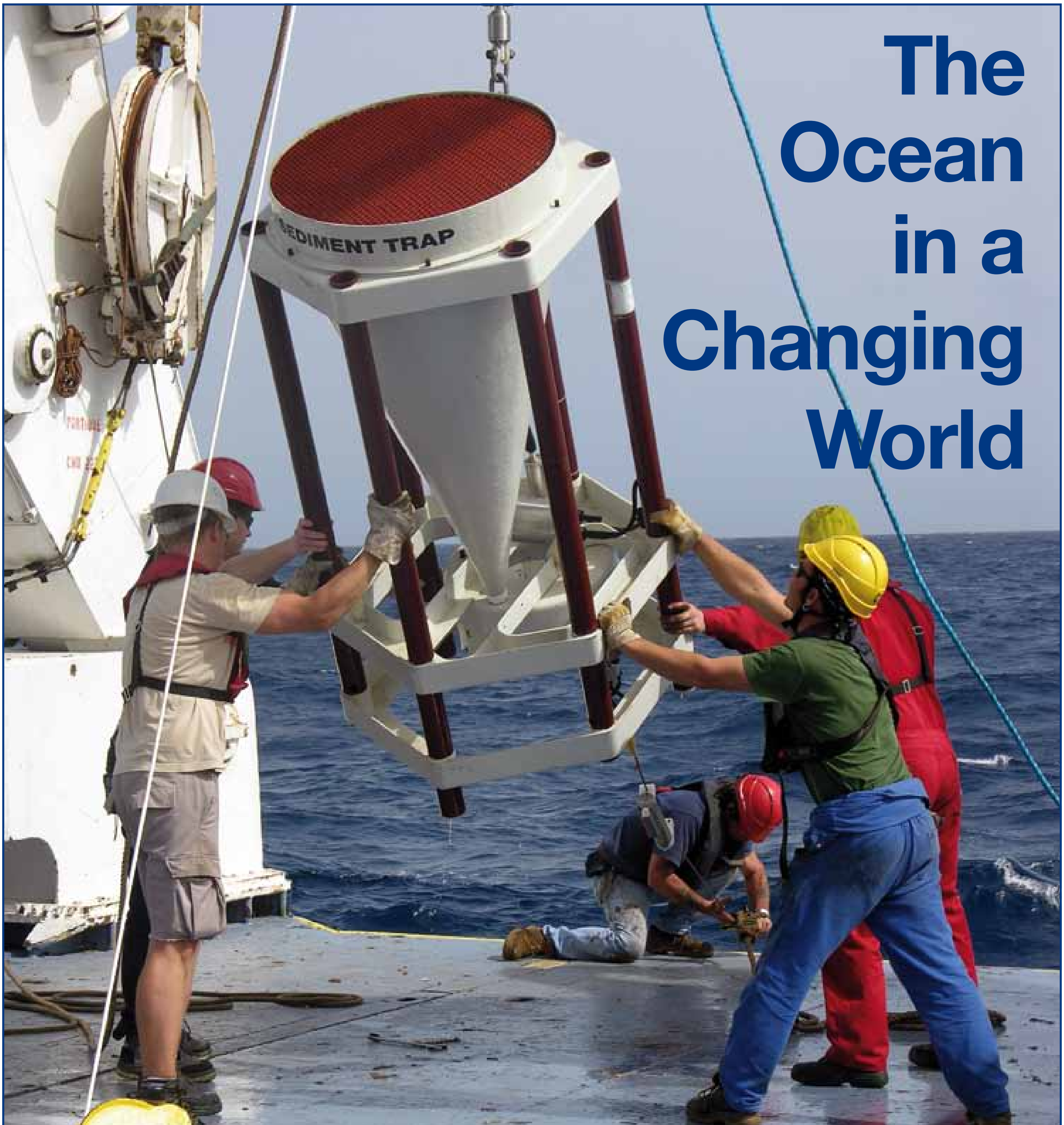
The Ocean in a Changing World



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Cover photo: Arne Körtzinger, IFM-GEOMAR, Kiel/Germany
Recovery of a sediment trap from a long-term mooring at the Cape Verde Ocean Time Series site (tenatso.ifm-geomar.de, see article page 6) on the French ship *L'Atalante* in February 2008 as part of the German SOPRAN project (sopran.pangaea.de).

Ocean science towards informed decisions

The role of the ocean in regulating climate change is now recognised as being critical. But there are consequences for marine ecosystems and human livelihoods. IGBP scientists are at the forefront of research, tackling how both climate change and other global changes – such as fishing, loss of biodiversity and nutrient deposition to name a few – interact. One of our objectives is to provide scientific knowledge upon which informed decisions can be made to minimise impacts on the Earth System.

This edition of the Global Change NewsLetter allows readers to wet their feet and sample marine results from across IGBP core projects. Ian Perry and Manuel Barange (p. 9) introduce the Global Ocean Ecosystem Dynamics (GLOBEC) analysis of marine socio-ecological systems and describe how human communities and marine ecosystems are intimately connected and offering policy options for adapting to changes. Fish to microbes are the focus of an article from the Integrated Marine Biogeochemistry and Ecosystem Research leadership (IMBER, p. 12). The *end-to-end food webs* approach paves the way for integration of scientific questions from GLOBEC into IMBER at the end of this year when GLOBEC reaches its conclusion (see John Field, p. 14).

Testing hypotheses such as the feedback between ocean ecosystems and climate requires large, coordinated field campaigns. IGBP projects such as the Surface Ocean – Lower Atmosphere Study (SOLAS) have planned experiments to test such hypotheses. Barry Huebert questions whether the funding mechanisms to implement these ambitious experiments are adequate. (p. 4).

Continuous observations over time are fundamental for identifying and understanding global changes and SOLAS is working to improve global coverage of time-series stations. The Cape Verde Observatory (p. 6) is an example that combines both atmospheric and ocean measurements, supported by a consortium of national funding agencies. It not only brings international scientists and funding to this remote island, but the project is committed to improving facilities and training local scientists, who are integrated into the management and operation of the project from the start.

The new Chair of the Land-Ocean Interactions in the Coastal Zone (LOICZ) Project, Alice Newton, invites collaboration in the case-study approach to understanding coastal problems and in creating solutions and tools for policy makers (p.17).

Most of IGBP's marine activities over the decades have been conducted in close collaboration with the Scientific Committee on Oceanic Research (SCOR, p.18). SCOR provides invaluable scientific guidance and helps creates opportunities for our joint activities. The 2008 Symposium on the Ocean in a High-CO_2 World is an example of a successful collaboration, which brought together scientists from SOLAS, IMBER, GLOBEC, LOICZ, PAGES and beyond to present the latest results on ocean acidification and its consequences. Highlights of the Symposium include scientific, economic and policy perspectives and are presented in this issue (p. 24 onwards).

The Symposium participants produced the Monaco Declaration (see article p. 20), which called for urgent action to limit damages to marine ecosystems due to increasing ocean acidity. The Symposium and Declaration, with the support of Prince Albert of Monaco, received wide media coverage on the consequences for marine systems and the need to urgently reduce CO_2 emissions. A Summary for Policymakers has also been prepared, designed to influence the political decisions being made, above all, at the Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change being held in Denmark this coming December. This conference will meet to decide on a future agreement for greenhouse gas emission reductions.

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IGBP and big observational campaigns

B. Huebert

How successful have IGBP projects been at bringing together international groups to do observation programmes that no one nation could manage? International collaboration on big programmes certainly helps bring more people into the enterprise and has unequivocal benefits for scientists in countries that lack the resources to create their own Science Plan, but are the overarching goals achieved? Certainly the development of stationary facilities (Mace Head, Large-scale Biosphere Atmosphere Experiment in Amazonia towers, Cape Verde – see following article by D. Wallace – and other research sites) has facilitated observations by international groups.

Both the IGAC science plan addressing global atmospheric chemistry, and the SOLAS science plan examining the ocean surface and the lower atmosphere, have talked about testing the CLAW Hypothesis (Figure 1). This hypothesis proposes a feedback loop that operates between ocean ecosystems and the Earth's climate, connecting marine biota to DMS fluxes, aerosols and cloud properties. Yet in almost two decades of experiments, we have never managed to get coordinated studies of each of the critical parts funded. In IGAC programmes, the marine biological work always got cut off, leaving just (very good) studies of atmospheric sulphur chemistry. The cross-disciplinary linkages rarely appeal to discipline-oriented reviewers and programme managers.

Projects from both the IGBP and the World Climate Research Programme (WCRP) make plans for observations by groups from many countries. Unfortunately, one can never be sure in advance which of these groups will be funded to participate, so implementation plans can't include strategies that depend on having any one group or platform. Any programme officer in any country, whether well-informed or not, can decline a grant for critical participating groups or platforms. The experiment planners are at the mercy of reviewers, panelists, and programme managers, many of whom have, by choice, not worked in this field recently. Since many agencies conduct their assessments in secrecy from those planners, some judgments will inevitably be poorly informed.

In the US, the National Science Foundation is most likely to support biogeochemical research. Most programme managers take the view that only peer-review can determine funding, to the exclusion of unified planning. Even though an experiment goes through extensive reviews of its science plan to be awarded aircraft or ship time, this is no guarantee that any of its participants will be funded. This makes it difficult to assure that even the most critical observations can be made.

The VOCALS programme (Ocean-Cloud-Atmosphere-Land Study, under the aegis of the Variability of the American Monsoon Systems) is an excellent example. This is a study in the South East Pacific of linkages between ocean heat budgets and mixing, upwelled nutrients, marine biota, aerosols, clouds, and radiative transfer. It could have been the ideal IGBP/WCRP collaborative programme (initiated by CLIVAR – Climate Variability and Predictability), in which all the related programmes (the WCRP working group on surface fluxes, and the IGBP projects: SOLAS studying the surface ocean-lower atmosphere interface, IGAC addressing global atmospheric chemistry, and IMBER that investigates marine biogeochemistry and ecosystems, etc.) could find issues their community could address. So that is what was written into the Science Plan and Implementation Strategy: we will all go to the South East Pacific together, testing portions of the CLAW Hypothesis, studying the factors that control air-sea exchange, and connecting biogenic gas emissions to the particles on which cloud droplets condense.

SOLAS was actively involved in organizing VOCALS: participating in planning meetings; writing plans, brochures, presentations, and platform requests; organizing informational meetings; and pitching participation in VOCALS during every talk possible. There was real enthusiasm as planners and their constituencies thought of participating in a grander enterprise than any one could do alone. Ancillary groups also took this bait, no doubt in part because the scientific justification had already been written. Anything they do would be enhanced by proximity to the larger VOCALS programme.

In a big programme, each platform has its niche: the oceanographic questions of nutrient upwelling, mixing, eddies, and heat transport in VOCALS would be best studied using a continuously-moving ship, doing butterfly patterns and pulling a SeaSoar that could profile throughout the mixed layer. Atmospheric measurements, cloud radars, and gas fluxes would be best measured from a (nearly) stationary ship, pointed into the wind so that flow distortions are minimized. Airmass mixing, *in situ* particles, photochemical budgets, and entrainment of free-tropospheric air would be best studied from long-range aircraft. The implementation strategy described the role of each, but had to be worded so that the loss of any one group or platform would not jeopardize funding for the folks who *were* able to get resources to do their part. Everything and everyone had to appear expendable.

Happily, NOAA made the *R/V Ronald H. Brown* available for VOCALS. However, a second ship could not be funded, so the Brown had to split its time between the surveying and stationary strategies. The good news is that one set of biological productivity observations was made from the *Ronald H. Brown*, alongside eddy correlation DMS flux measurements: some SOLAS-inspired biology and flux measurements survived the funding process. Unfortunately, neither oxidants, NO, nor OH was measured, so the programme could not observationally be able to constrain the photochemical link between the measured DMS fluxes and the growth of aerosols that control the clouds. Furthermore, the cloud-oriented C-130 flight profiles could not support budget studies of sulphur gases and aerosols, so the SOLAS observations and the aerosol/cloud studies evolved into *coincident-but-independent experiments*.

VOCALS Rex went into the field in the fall of 2008 as planned. Some very successful SOLAS-inspired experiments were conducted. Many valuable insights are emerging, especially with regard to the relationships between ocean dynamics, biology, and dimethyl sulphide chemistry on sub-kilometer scales. CLAW will have to wait again. The IGBP-type interdisciplinary objectives that got many of us excited about VOCALS could not be achieved. Again.

This same problem plagues many IGBP programmes: without some agency that is willing to agree in advance to fund a coherent set of observations and platforms, certain essential measurements will inevitably come up against an oppositional reviewer or other obstacle, and not be funded. Many valuable studies will be done, but the discipline-connecting goals that motivate these large programmes often are not. This problem may be too much for the International Group of Funding Agencies for Global Environmental Change (IGFA) to resolve. We have the scientific interest and the observational tools to test the CLAW hypothesis, for instance, but we still lack the institutional ones.

This is a challenge IGBP must address if we are ever to test our most significant conceptual models against observations on the necessary scales.

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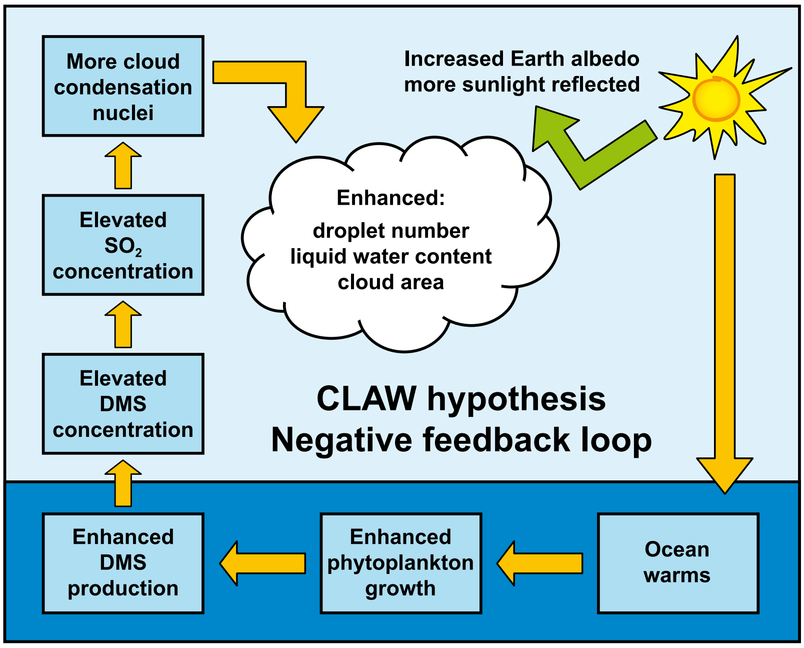

A schematic diagram of the CLAW hypothesis of Robert Charlson, James Lovelock, Meinrat Andreae and Stephen Warren (1986), *Nature*, 32:655-66 (Reproduced with permission)

The Surface Ocean-Lower Atmosphere Study (SOLAS)

SOLAS and Cape Verde scientists establish an atmosphere and ocean observatory off North West Africa

D. Wallace

The tropical ocean and atmosphere

The tropics play a critical role in the Earth System. Their importance for weather and climate is exemplified by the generation of hurricanes, the significance of *El Niño* for global weather patterns and inter-annual climate variability, and the effect of tropical Atlantic sea surface temperature on rainfall in drought-threatened sub-Saharan Africa (Sahel). The tropics are truly a "weather-factory" for the planet.

The tropical atmosphere is also our planetary "waste incinerator": here, high concentrations of the OH radical are maintained, cleaning the atmosphere of pollutants as well as certain key greenhouse gases (e.g. methane). These gases are delivered from sources in the north and south and are destroyed in the tropics.

Tropical winds on western sides of continents drive upwelling of nutrient-rich subsurface waters and fuel the ocean's food chain. Eastern sides of tropical oceans sustain some of the most productive and economically important fisheries on Earth (e.g. off Peru and Mauritania). The upwelling zones of the tropical oceans are, in effect, vast, natural "fish farms".

The tropical Atlantic Ocean receives the largest input of mineral dust of the world ocean. The associated input of iron, and possibly other elements, stimulates ocean nitrogen fixation. Further, the tropical oceans play host to the key regions of low oxygen in today's ocean ("oxygen minimum zones"). Major changes to sources and sinks of important nutrients (N, P, Fe) occur when oceanic oxygen concentrations decrease below threshold levels. These spatially limited zones impact nutrient budgets, biological productivity, greenhouse gas production and CO_2-fixation of the global ocean. Tropical oceans are the "fertilizer plant" for the world ocean.

All these critical, natural processes in both the ocean and the atmosphere are highly sensitive to temperature, sunlight and wind, (i.e. to climate).

Vulnerabilities

Climate change in the tropics, both natural and anthropogenic, has the potential to alter:

- the intensity and frequency of *El Niño* and the African monsoon with further consequences for climate change;
- the rate at which pollutants and greenhouse gases accumulate in the atmosphere;
- upwelling and marine food chains with consequences for food supply and, especially, the economies of coastal nations.
- the intensity and extent of oceanic oxygen minimum zones with consequences for higher trophic levels as well as for oceanic nutrient budgets

A lack of infrastructure

Despite their significance for, and sensitivity to, global change the tropical ocean and atmosphere are remarkably little studied, especially for biological and chemical processes. Many tropical nations are unable to afford the sophisticated scientific infrastructure, equipment and training required for modern climate, ocean and atmospheric research. Even research infrastructure to study marine ecosystems remains limited for many tropical waters, despite decades of heavy fishing by richer nations. Sophisticated atmospheric measurement stations, science logistic bases and fishery research laboratories now exist throughout the richer countries of Europe, North America and Asia as well as in uninhabited ice-covered regions of the world. They remain rare in the tropics.

Origins of the Cape Verde Observatory

Since 2002, a team of scientists from Germany, the UK and Cape Verde have been working to address this problem. The problem of lack of data and logistical difficulties for global change research in the West African coastal region was recognized in 2002 simultaneously by Doug Wallace (of the Leibniz-Institute for Marine Sciences in Kiel, and now SOLAS Chair) and Martin Heimann (of the Max-Planck-Institut für Biogeochemie in Jena). They asked the Volkswagen Foundation to

Photo credit: Doug Wallace, IFM-GEOMAR

The research boat Islandia travels between the port of Mindelo, Cape Verde, and the atmospheric observatory on São Vincente.

support a workshop to explore the potential of Cape Verde to support long-term observation. The workshop was hosted by two Cape Verde institutions and revealed a cadre of highly motivated scientists within Cape Verde's National Institute for Meteorology and Geophysics (for the atmosphere) and National Institute for the Development of Fisheries (for the ocean). The local scientists explained their needs to the visiting European scientists. The Europeans explained their needs. It became clear that European interests in global change research, and especially in long-term observation, could be compatible with Cape Verdean needs for scientific capacity with which to better understand pressures on their own fragile environment.

At this point, the international connectedness of modern science played a key role. A new SOLAS initiative in the UK (funded by the Natural Environment Research Council) was considering establishment of a long-term field site. Dr. Lucy Carpenter of the University of York and Dr. Phil Williamson of the University of East Anglia had heard about the workshop in Cape Verde and decided to visit the island of São Vicente, Cape Verde, themselves. They recognized that this island location was ideal for the needs of UK SOLAS. The UK initiative could be combined with a new German research initiative SOPRAN (Surface Ocean Processes in the Anthropocene) which is funded by the Federal Ministry of Education and Research (www.sopran.pangaea.de). The Cape Verde Observatory was more or less born at that time with trilateral support from Germany, the UK and Cape Verde linked via support from a European Union project (www.tenatso.com).

What is the Cape Verde Observatory?

The Observatory has an atmospheric and an oceanic site, both based on or near the island of São Vicente. The atmospheric site, the "Cape Verde Atmospheric Observatory Humberto Duarte Fonseca", named in honor of a Cape Verdean climatologist of the last century, was selected on the windward side of the island on an ancient lava field, close to the ocean. Here, steady NE trade winds bring air directly from the ocean to the measurement systems without risk of land-based contamination. A road was built, power lines and a 30m high sampling tower were constructed. Custom laboratories housed within shipping containers, were installed. There are presently five container labs on the site, contributed by groups from the Universities of York and Leeds, the Max-Planck-Institute in Jena and the Leibniz-Institute for Tropospheric Research in Leipzig. The labs house a wide variety of sophisticated instrumentation that makes continuous measurements of trace gases, greenhouse gases and aerosols as well as meteo-

Photo credit: Ally Lewis, University of York

Cape Verde Atmospheric Observatory "Humberto Duarte Fonseca" on the island of São Vicente, Cape Verde.

rological parameters. A wind turbine was recently installed to supplement the power supply for the site.

The ocean site is located 40 nautical miles "upwind" of the atmospheric site in a water depth of 3700 m. It is now visited regularly with the small Cape Verde research vessel *Islandia*, which has been completely rebuilt for the task. Continuous measurements are made from an oceanographic mooring which was established in June 2006 as well as from unmanned gliders and floats deployed around the mooring. Every few days these autonomous platforms come to the surface and relay their most recent data via satellite to shore before returning on their mission. The mooring and autonomous systems provide long-term data for basic parameters such as temperature, salinity, chlorophyll fluorescence, turbidity, dissolved oxygen and dissolved CO_2. More complex biological and chemical measurements rely on water sampling from the *Islandia*. Samples are returned to a newly-equipped laboratory ashore for processing.

Both sites are being developed to support visits of scientists interested in studying tropical atmospheric and oceanic processes in the context of a long-term data set. The sites are also nested within international observation programmes such as the Global Atmospheric Watch and OceanSITES.

Training, education and capacity building

The Observatory has already trained and employed four Cape Verdean site-managers and technicians. Increasingly, Cape Verdean scientists are becoming involved in site operations and the associated science. In 2007, the Observatory hosted a major atmospheric research campaign involving long-term stays by scientists from Europe and North America. Research vessels from the USA, Netherlands, Germany, France and the UK now sample the ocean site and visit it regularly. Efforts are underway to finance graduate training opportunities for Cape Verdean Masters and PhD students in the context of the scientific projects associated with the Observatory. The project partners view the long-term commitment to science in the region as an excellent opportunity for capacity building: not just for Cape Verdeans but also for other West African nations. The key is to establish long-term scientific interests and capabilities which sustain a commitment from international scientists to work closely with their regional partners. In addition to development of education, consideration is being given to use of the port of Mindelo and Observatory-associated facilities as a logistics centre for the support of international research activities in the region (e.g. research vessel support).

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Global Ocean Ecosystem Dynamics (GLOBEC)

Ten years of research

R. I. Perry and M. Barange

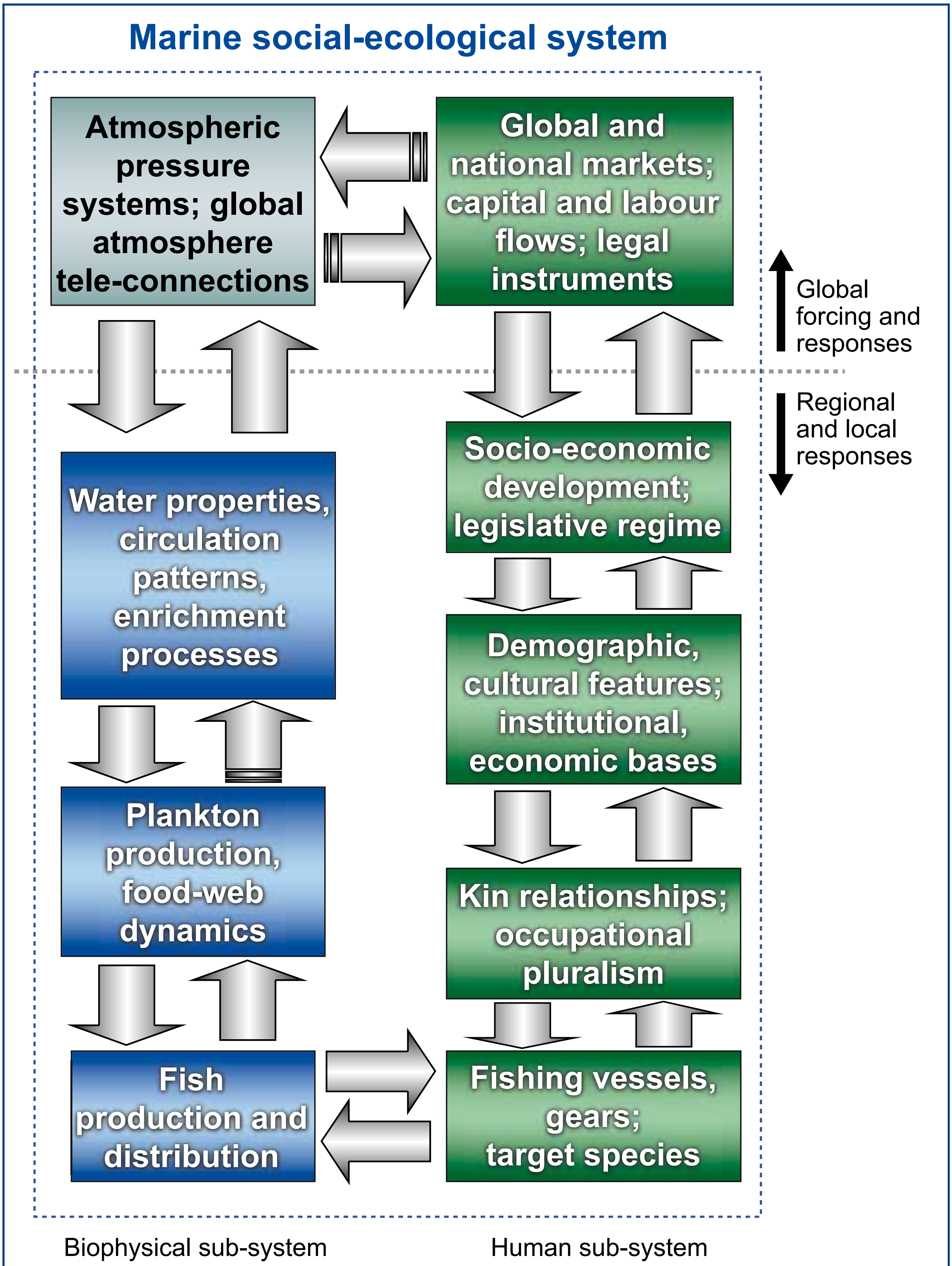
The international Global Ocean Ecosystem Dynamics (GLOBEC) project, a core project of IGBP, the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanic Commission (IOC), reaches the end of its more than ten years of intensive research at the end of 2009. This short article provides an overview of GLOBEC studies of marine biophysical systems, their associated human systems, and on the interactions between these systems and global changes. It also points towards some of the tools and policy options needed for humans to begin adapting to these changes.

Marine ecosystems and global change: towards policy options for human adaptations

The goal of GLOBEC has been to advance understanding of the structure and function of the global ocean ecosystem, its major subsystems, and its responses to physical forcing so as to develop a capability to forecast the responses of marine ecosystems to global change. GLOBEC accomplishments include advancing knowledge on marine ecosystems, physical and anthropogenic forcings, and improved understanding of physical, biological, and human interactions with changing marine environments. GLOBEC has also contributed to marine policy and management debates by providing conceptual understanding of how ecosystems respond to global changes, and by providing tools which incorporate uncertainties caused by climate-driven variability. Marine ecosystems (which can be called marine social-ecological systems when they include humans) are expected to be significantly affected by the interactive combination of climate change, over-exploitation of resources, and habitat disruption.

General impacts on marine systems as a result of large-scale changes related to temperature, winds, and acidification can be predicted, in some cases with a high degree of confidence [1]. At "rapid" time scales (a few years) there is high confidence that increasing temperatures will result in changes in distributions of marine species. Changes in the timing of life history events, such as the timing of reproduction, are also expected, with short life span species such as plankton, squid, and small pelagic fishes being the most quickly affected. At intermediate time scales (a few years to a decade), temperature-mediated physiological stresses and further changes to life history processes will impact the recruitment success and therefore the abundances of many marine populations. These impacts will be most acute at the extremes of species' ranges and for shorter-lived species. Changes in abundance will, in turn, alter the species composition of marine communities, which is likely to affect the structure and productivity of these ecosystems. At longer time scales (multi-decadal), the predicted impacts of climate changes depend upon changes to the net primary production in the oceans and its transfer to higher trophic levels. Current models show high variability in results and so all these predictions have low confidence. Overall, the responses of wind-driven upwelling ecosystems, which are the most productive per unit area, to global climate change are the most uncertain because the effects on their wind forcing lack predictability.

Marine social-ecological systems, however, are impacted by other changes occurring at global and local scales in addition to climate: these include intensive fishing and habitat disruption. A key conclusion [2] is that modern research and management of such marine systems must take account of the interactions between climate, fishing, and habitat disruptions rather than try to disentangle their effects and address each separately – hence the evolved emphasis on *global* change rather than climate change alone. In the biophysical (non-human) sub-system, climate conditions and circulation affect the physical characteristics of the regional and local ocean, which influence the productivity of the upper ocean and ultimately the production of fish. In the human sub-system, the impacts of global and national markets, capital and labour, and legal agreements flow through successively smaller



Characteristics and processes within the biophysical and human sub-systems of marine social-ecological systems, and their connections. Predominant connections between the biophysical (non-human) sub-system and the human sub-system occur at large scales (regional to global) and at the local scales (local to region) at which fish production and distributions interact with fishing. Solid arrows represent stronger interactions; dashed arrows represent weaker effects.

spatial and lower organisational scales from region, community, fishing fleet and household to individual vessels and fishers. It is the fishing vessels, fishing gear, the target species selected by fishers (in the human sub-system) and the production and distribution of fish (in the biophysical sub-system) that interact most directly [3] (see figure). More diffuse interactions between sub-systems do occur at other levels, ranging from local impacts of point-source contaminant releases to larger-scale impacts such as anoxic "dead zones". But, along with acidification, it is intensive fishing which has the global reach. Fishing reduces the life span, reduces the age at maturity, and reduces the "richness" (numbers) of distinct marine populations. These changes combine, in sometimes surprising ways, to alter marine populations, marine communities, and marine ecosystems and to bring them into states which track climate forcing more closely.

From the human side, how human communities respond to marine ecosystem variability can ameliorate or exacerbate these changes [3]. At shorter time scales, coping responses by both human and non-human marine systems have common elements, such as searching harder for prey, searching in new locations perhaps farther from home (and with greater exposure to predators or poor weather), diversifying to other sources of food, and migration. At longer time scales, however, many adaptive responses by human communities, such as networking, skills upgrading, political action, and closure of the community, have no analogues in non-human marine ecosystems. Such global changes can drive non-human systems to be more flexible and to adapt more quickly to variability, whereas these same changes may reduce the adaptive capacities of human systems. To achieve sustainability, marine resource managers must develop approaches which maintain the resilience of individuals, populations, communities and ecosystems to the combined and interacting effects of climate, fishing, and habitat disruptions. Overall, a less-heavily fished marine system, and one which shifts the focus from individual species to functional groups and fish communities, is likely to provide more sustainable goods and services when faced with climate variability and change than would a heavily fished system.

When faced with the interacting challenges of these global changes, a marine social-ecological systems approach to the management of marine resources is needed. Such an approach should involve all scales from local fishing sectors to regional and national governments in order to identify societal choices and to set objectives, which would include ecological, economic and social considerations [4]. Clear objectives need to be established recognising that the future may not be like the past. This will require identifying the appropriate scales (temporal, spatial, and organisational) and down- and up-scaling effects for both the problems and the solutions, identifying indicators and reference points for all the sectors expected to be impacted, close collaborations with multiple stakeholders, and monitoring for unanticipated surprises in other sectors and at other scales. Decision support tools and rules which evaluate their performance need to be established, which include explicit recognition of their uncertainties in such a world of change. Although the details of a future under climate change remain unknown, the outlines of appropriate adaptive responses for managing human interactions with marine ecosystems are becoming evident.

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Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

Three IMBER *imbizo* workshops on ecological and biogeochemical interactions

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An *imbizo*, in the Zulu language, is a forum for enhancing dialogue and interaction. It defines the IMBER approach to it's first set of three concurrent interacting workshops held in Miami in November 2008. The workshops covered Ecological and Biogeochemical Interactions in (a) End-to-End Food Webs, (b) the Mesopelagic Zone and (c) the Bathypelagic Zone. Each workshop was structured to provide a synthesis of current knowledge and key questions for future research within IMBER. The workshops had common plenary, poster and summary sessions.

End-to-End Food Webs

There is increasing recognition that analyses of biogeochemical cycles, climate impacts and the effects of exploitation in ocean ecosystems requires the development of integrated views of food web operation. With this focus on integration, a new term has appeared – *analysing the end-to-end operation of food-webs* – encompassing the concept of linking food web operation from microbial systems (that dominate the carbon flows in marine systems) through to the highest trophic level species that may also be subject to exploitation. Attempts to define the end-to-end food web — or *e2e* for short — have led to broad definitions that are equivalent to the widely used definition of an ecosystem.

The term *e2e* has brought attention to the complexity of the interactions involved in food-webs. Dealing with that complexity was recognised early in the workshop as probably the central challenge we face. The importance of and therefore the need to consider the emergent properties of food webs generated through complex interactions at a wide range of scales. The meeting also demonstrated that many of the major issues faced in *e2e* analyses are already being tackled by groups working on a range of regional systems. The major scientific task is now one of integration, building on previous and ongoing regional analyses and detailed process studies. Comparative studies between regional systems such as the Arctic-Antarctic and Benguela-Humboldt are also emerging and global comparisons of ecosystem structure and function are being developed. At the same time, generic models (e.g. based on size or simplified functional group representations) are being applied globally or as standard model frameworks parameterised for different regions. The challenge for IMBER, as GLOBEC comes to an end, is to develop the interdisciplinary integration capacity, linking scientists with interest in biogeochemistry and food web operation, while accounting for the complexity of oceanic ecosystems. This emphasis on integration requires both a major shift in thinking and a stronger focus on the perennial issues of ensuring iterative links between modelling and observation programmes and maintaining multidisciplinary teams. Developing a range of analysis and modelling approaches will be crucial, with a requirement for comparison based on both general ecosystem properties (e.g. size structure and patterns of energy flow) as well as specific metrics (e.g. productivity, harvesting yield or stoichiometric balance).

The Mesopelagic Zone

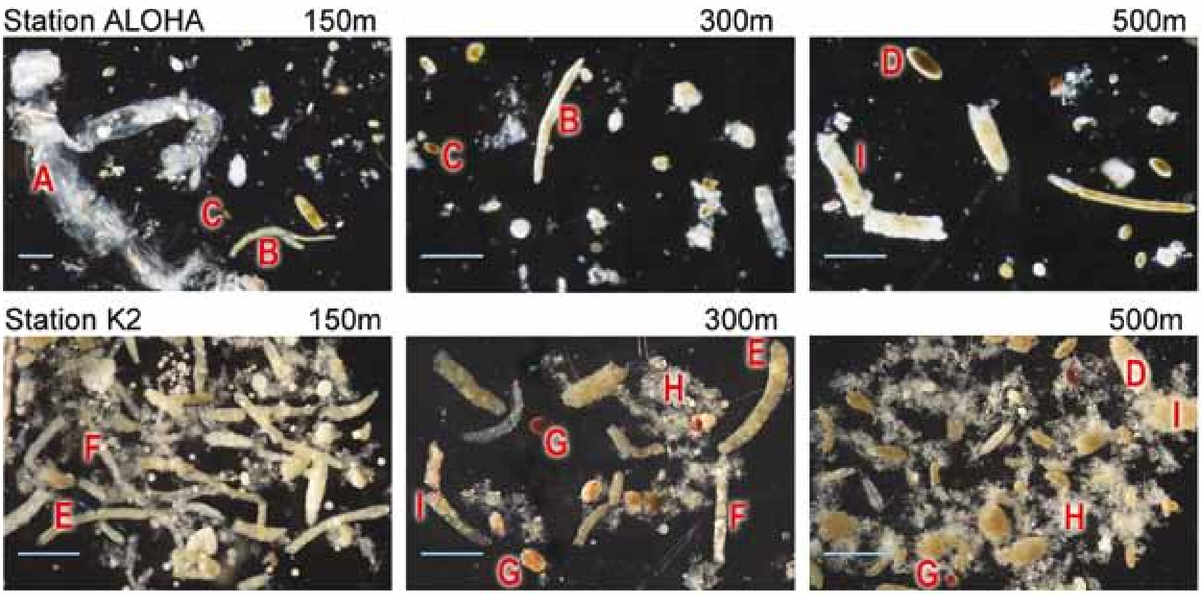
The mesopelagic zone, between depths of about 100 and 1000 m, is a zone of significant decomposition, recycling, and repackaging of particulate and dissolved organic matter. The interplay between biological and geochemical processes in this zone has significant effects on the magnitude of the biological pump, which regulates in part atmospheric carbon dioxide and hence can impact climate. While important processes regulating organic matter transformations and remineralization in the mesopelagic zone can be tightly coupled with the euphotic zone, the time and space scales of these processes are different in the mesopelagic zone, which is critical to predicting the ability of the biological pump to sequester carbon in the deep ocean.

The aim of the workshop was to identify the current state of our knowledge about mesopelagic food-web processes, particle flux and dynamics, and biogeochemical cycling, and to identify gaps in our knowledge. The workshop addressed the following topics: particulate and dissolved organic matter (POM and DOM) distribution, characterization, and flux; planktonic food web controls on vertical transport, cycling, and composition of POM and DOM; linking microbial and metazoan diversity to function; ecological and biogeochemical approaches to estimating remineralization rates; models; methods and new technologies; regional comparisons in food-web structure and biogeochemistry; and potential responses of the mesopelagic zone to environmental change. The workshop participants recommended that future research programmes on the mesopelagic zone should integrate across disciplines (chemistry, microbiology, ecology, physics), and throughout water column (i.e. link with surface processes). The location of future studies may include time-series sites, places of contrast, sites with strong gradients and where effects of global change are large. Spatial and temporal variability must be considered. It was also recommended that species or functional groups should be the focus. In addition to measuring stocks, mechanisms need to be understood to contribute to mechanistic models. Characterization of physical processes (e.g., lateral advection, deep- and mode-water formation) is important for constraining mesopelagic carbon and nutrient budgets. Technological advances to help address future challenges in the mesopelagic zone include: pressure samplers for measuring *in situ* respiration, neutrally buoyant sediment trap designs, remotely operated vehicles with sampling capabilities, automated underwater vehicles and floats for increased spatial coverage, and underwater observatories for long-term monitoring.

The Bathypelagic Zone

The bathypelagic zone is one of the great unexplored realms of the global ocean. The biological pump connects surface processes to the deepest ocean layers, where biological processes occur at very low rates relative to the upper ocean. With deep ocean residence times at centennial to millennial scales in time and global scales in space, the system is only slowly ventilated and circulated. Biogeochemical signals in the deep ocean are integrative of processes occurring over very long periods. Biological processes in the deepest ocean layers are intimately tied to particle dynamics and microbial food webs, much of which are still only poorly characterized.

The central aim of the workshop was to gather the expertise required to identify what is known about this system, and to identify and pursue outstanding uncertainties. The cross section of disciplines represented included biogeochemistry, organic geochemistry, microbial



Changes in fecal pellet types with depth indicate zooplankton repackaging of sinking particles in the mesopelagic zone. This figure shows changes in major types of zooplankton fecal pellets from sediment trap samples from the subtropical Pacific (Hawaii Ocean Time-series, HOT, station ALOHA) and subarctic Pacific (Japanese time series site K2). Scale bar is 500 um: A) heteropod Carinaria sp., B) large copepod or euphuasiid, C) small copepod, D) larvacean, E) Neocalanus spp., F) euphausiid, G) unknown carnivorous zooplankton, H) fecal “fluff”, I) broken pellet [1] dynamics, trace element and isotope geochemistry, genomics, particle flux and dynamics, and modeling. Presentations on the biogeochemistry of organic matter covered composition, structure, distribution, fluxes, reactivity, etc., while those on microbial dynamics considered the turnover of the organic matter, processes controlling microbial abundance, as well as deep autotrophic production. Three papers are under development to synthesise our understanding of, (i) deep sea microbial dynamics, (ii) the biogeochemistry of organic matter and (iii) deep ocean metabolism, focusing on the relative roles of autotrophic and heterotrophic processes. The first two syntheses will consider the same deep ocean system, but from the unique perspectives of biogeochemistry and microbes.

The presentations from the *imbizo* can be found at http://www.confmanager.com/main.cfm?cid=1185

Two special issues of *Deep Sea Research* (Elsevier, The Netherlands) will be published: *The Dark Ocean*, and *End to End Food Webs.* These will include both presented papers and synthesis papers resulting from the workshop discussions.

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New developments in marine ecosystem research

Recommendations for IMBER II

J. Field

A Transition Task Team has been set up to recommend to SCOR and IGBP how the second phase of the Integrated Marine Biogeochemistry and Ecosystem Research programme (IMBER) should proceed to accommodate new developments in marine ecosystem research that need addressing after the completion of the Global Ocean Ecosystem Dynamics research programme (GLOBEC) at the end of 2009.

The Team was asked to make recommendations to SCOR and IGBP for a second phase of the biogeochemistry and ecosystem research programme (IMBER) after 2009, bearing in mind:

1. Key new scientific questions arising from global ocean ecosystems dynamics research by GLOBEC
2. Scientific results of IMBER on marine and biogeochemistry and ecosystem research, to date
3. New developments in marine ecosystem science
4. Projects currently within GLOBEC that are planned to continue after 2009

With accelerating global change the urgency of achieving the IMBER vision and goal is even more apparent five years after the IMBER Science Plan was written. The Transition Task Team identified areas that need new or renewed emphasis so that IMBER Phase II will achieve its scientific vision and goal, and will build on the IMBER activities to date. These areas are:

- integrating human dimensions into marine global change research
- regional research programmes
- comparative studies

Transition Task Team members at the National Academy of Science, Washington, DC, December 2008.
From left to right: Ken Drinkwater, Qisheng Tang, Roger Harris, Kathleen Miller, John Field (Chair), Eileen Hofmann, Hugh Ducklow, Mike Roman. Inset: Olivier Maury. Absent: Raleigh Hood, who is thanked for his participation on SIBER discussions on 15 December.

within and across regional programmes, including ecosystem models that incorporate the human dimension
- incorporation of emerging scientific themes.

The report from the Transition Task Team, currently undergoing peer-review, lists IMBER activities to date, outlines some GLOBEC science highlights (taken from the GLOBEC synthesis book *Marine Ecosystems and Global Change* which will be published by Oxford University Press in 2009) and lists some emerging scientific issues such as CO_2 enrichment and ocean acidification, new metabolic and biochemical pathways, the role of viruses, thresholds and surprises, coupled biogeochemical-ecosystem model projections, and the characterization of uncertainty.

The main recommendations include a number of research approaches that could be adopted in the second phase of IMBER:

1. Innovative approaches
2. Innovative technologies
3. Process studies
4. Sustained observations
5. Palaeo-oceanography
6. Molecular genetics and functional groups
7. Integration of human dimensions in ecosystem models
8. Comparative approach between ecosystems
9. Synthesis and modelling.

IMBER II will have regional programmes that were not established when the original implementation strategy was written. The research approaches listed above have been adopted in several of the regional programmes. In order to achieve global coverage, the Transition Task Team strongly recommend that seven regional programmes be incorporated into IMBER II, provided that they agree on terms of reference with the IMBER SSC. These include Integrating Climate and Ecosystem Dynamics Programme (ICED) (Southern Ocean), Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER), CLimate Inpacts on Oceanic TOp Predators (CLIOTOP), Ecosystem Studies of Subarctic Seas (ESSAS), Small Pelagic fish And Climate Change (SPACC, upwelling regions), Basin-scale Analysis, Synthesis and Integration (BASIN, a proposed North Atlantic comparative studies) and Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Ecosystems (FUTURE, a proposed PICES North Pacific Programme).

Recommendations are also made with regard to funding, potential sponsors, data management, implementing mechanisms and a timetable.

This report, which includes a draft Implementation Strategy for a second phase of IMBER (2010-2014) will form the Appendix to the *IMBER Science Plan and Implementation Strategy* (SPIS) which was published by IGBP in 2005. The Transition Task Team had input from the IMBER and GLOBEC SSCs and the report has been posted on the IMBER and GLOBEC websites for community comment before peer-review by IGBP and SCOR.

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Land-Ocean Interactions in the Coastal Zone (LOICZ)

Global change and the coastal zone: current LOICZ science activities

A. Newton

Winston Churchill said "*All men make mistakes, but only wise men learn from their mistakes*"...and maybe wise men should learn from the mistakes of others? It is a grave concern that the same mistakes are repeated time and time again at different locations and times around the coast of the world. There are many examples and case studies of problems in the coastal zone and LOICZ – the Land-Ocean Interactions in the Coastal Zone core project – is now synthesizing these and organizing them into categories. The categories include erosion, from damming of rivers and physical disruption of the coastal dynamics by coastal engineering; eutrophication and hypoxia from agriculture, animal rearing, processing of organic matter and sewage; changes in land use leading to the destruction of mangroves, salt-marshes and wetlands; urban development in a flood prone low-lying coastal zone; as well as overexploitation of biotic and abiotic resources. In extreme cases, these problems result in massive loss of life and property, as well as translocation of populations.

Case studies

LOICZ has invited coastal scientists from around the world to submit well-documented case studies of such problems and are now analyzing the case studies using a similar methodology. The project has developed a series of simple questions that are based on the DPSIR (driver-pressure-state-impact-response) framework (OECD, 1993)[1]. This framework links economic drivers through to the impacts on the environment, on the ecology, on the economy, on society and health. Societal responses are also being categorized as governance, policy, management, technological and engineering, educational and scientific responses.

Solutions

But LOICZ scientists are interested in solving, not just studying coastal environmental problems. LOICZ is seeking to provide innovative solutions to these common coastal problems rather than yet more studies. One of the major challenges is the different scales of the systems, but also the degree of development. Although several mega-cities are coastal, many of them still lack adequate infrastructure, such as urban wastewater treatment. The intent of LOICZ scientists is to inspire, manage and produce timely syntheses and assessments on key coastal issues and the watershed. We are developing a user-friendly toolbox to help coastal scientists and managers. These include well-established tools such as the biogeochemical budgets as well as new tools such as conceptual diagrams and report cards. LOICZ is at present researching how to link the biogeochemical model with the LOICZ typology and ASSETS, an assessment of estuarine eutrophication methodology.

LOICZ is using cross-cutting workshops to test these tools in the global coastal context and thus achieve regional syntheses. The current theme of the cross-cutting workshops and research is coastal lagoons. LOICZ has carried out a study of Indian lagoons (see the LOICZ newsletter *INPRINT* 3 (2008). The next study will be of the lagoons of the Middle East and North Africa region, and a workshop will be held in Rabat 11-16 May 2009.

LOICZ scientists are also working with scientists from other projects to bridge and link their initiatives together. For example, LOICZ and IGBP's Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project have been working together to develop an implementation strategy for continental margins research.

Climate tourism in coastal zones

LOICZ and the International Human Dimensions Programme (IHDP) have also been investigating water consumption by the tourism sector in Southern Europe. The Mediterranean climate with warm, wet winters and hot, dry summers makes this region an attractive tourist destination for North Europeans and also the site of many second homes. Whole coastal stretches are devoted to the socio-economic activity of tourism, such as the Algarve (Portugal), the Costa del Sol (Spain), the Côte d'Azur (France) and the Amalfi coast (Italy). The peak tourist season during

July-September, when excessive water extraction supports the consumption by tourists and their activities (eg. golf courses and swimming pools), also coincides with the driest season of the year. A pilot study of the use of water by tourists was made in the coastal area of the Algarve, Portugal. The results of the study will be used for a larger-scale study of water use by tourism in the Mediterranean region, including seasonal migration, environmental change, water scarcity, governance and human security. The report will be communicated to stakeholders and decision makers such as the regional tourist office, the regional water provider, the regional environment agency and the National Water Institute.

LOICZ hopes to replicate this pilot study in the coming years throughout the Mediterranean and in other regions of the world that experience "climate" tourism.

Scientists are increasingly aware that many coastal zones are experiencing regime changes. Management measures are often insufficient to reverse the damage done to coastal ecosystem structure and function. The effect of global change on the coastal zone is difficult to quantify, but in many cases the degradation of coastal systems seems to have passed a threshold. We are walking along a cliff-top in thick fog, not knowing where the edge is. Although we are navigating through a "perfect storm" of economic turbulence, mankind cannot consider environmental issues to be a luxury. Coastal ecosystem goods and services continue to be misunderstood, undervalued and mismanaged, taking us ever further from sustainable use of the very ecosystems that we ultimately depend on.

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References

1. OECD. 1993. OECD Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment. OECD, Paris.

How to get involved in LOICZ science

If you wish to participate in the global survey of case studies on coastal zone depredation, please submit your study to Alice Newton, anewton@ualg.pt. You should describe the case study in two to three paragraphs, attach a visual for which you have copyright and answer the questions below:

- What was the main driver of the change?
- Why did things go wrong and how?
- What were the main pressures?
- Were there any indicators of change of state; what were they and why were they ignored?
- Was there any foresight or environmental impact assessment?
- Was this ignored or did no-one think about the consequences and impacts?
- Were ecosystem goods and services ravaged or misunderstood?
- Were the impacts environmental, ecological, economic, social?
- Is it reversible with appropriate response or are we now so far into another "stable" state that we may not be able to go back?
- What can we learn from this?

To participate in the pilot study on coastal tourist areas in the Mediterranean, and other coastal tourist localities, contact Alice Newton at anewton@ualg.pt.

And for more information:

- **on the biogeochemical budgets**, with new tools such as conceptual diagrams and report cards, please contact Dennis Swaney, dps1@cornell.edu. And look up
  - ASSETS, the assessment of estuarine eutrophication methodology, see http://www.eutro.org/.
  - conceptual diagrams and report cards, see http://ian.umces.edu/
- **on Lagoons**
  - Workshop on Indian Lagoons, in the LOICZ newsletter *IMPRINT* 3 (2008) page 16, http://www.loicz.org/products/publications/newsletter/index.html.en
  - Participate in the workshop on Lagoons in the Middle East and North Africa, Rabat 11-16 May 2009, contact Prof. Maria Snoussi, snoussi@fst.ac.ma.

Advancing priority ocean science topics

Working groups of the Scientific Committee on Oceanic Research (SCOR)

E. Urban

The Scientific Committee on Oceanic Research (SCOR) is one of IGBP's major partners, in terms of co-sponsoring large-scale ocean research projects and other marine activities. As the oldest of the interdisciplinary committees of the International Council for Science (ICSU), SCOR recently celebrated its 50th anniversary with a symposium that highlighted its contributions to ocean science over the past five decades, as well as discussing ideas for priority research in the future.

An important part of SCOR activities is the establishment and support of working groups intended to advance specific areas of science identified as priority topics. SCOR working groups can be proposed by anyone in the global ocean science community and, before working groups are established, SCOR invites comments on the proposals from the entire community. Some groups are supported solely by SCOR, whereas others are co-sponsored with other organizations, including IGBP projects.

Currently, SCOR has 14 working groups in various stages, from three newly formed ones to some that have held their final meetings and are working on peer-reviewed journal issues or books. Some highlights from SCOR working groups are outlined in this article.

Global Comparisons of Zooplankton Time-Series

This group has compiled a global database of representative zooplankton time-series observations in order to examine what factors control zooplankton populations, including testing for the kind of climate-dependent teleconnections that are seen in fish populations. A better understanding of the effects of climate and oceanographic conditions on zooplankton is very important for improved management of marine fisheries. Scientists from the Global Ocean Ecosystem Dynamics science community have been very involved in this group.

Thermodynamics and Equation of State of Seawater

The equation of state of seawater describes the dependence of seawater density on its temperature, salinity, and pressure. It has been several decades since the equation of state was last revised and this group is working to provide new definitions and algorithms for salinity, density, entropy, enthalpy, and many other properties. These more accurate quantities will help improve global models of circulation and climate. The International Association for the Physical Sciences of the Oceans (IAPSO) is a co-sponsor of this group.

The Legacy of *in situ* Iron Enrichment: Data Compilation and Modelling

A major debate is raging on whether scientists should be allowed to conduct *in situ* mesoscale iron enrichment experiments. A meeting sponsored by the National Science Foundation (USA) and the Surface Ocean - Lower Atmosphere Study that synthesized the results from past iron-enrichment experiments, concluded that the data and metadata from past experiments would be more useful if they were gathered into a single database. This working group is in the midst of this task, with the ultimate aim of using the relational database to conduct modeling studies of the oceanographic factors that influence the outcomes of iron enrichment experiments. The better understanding from these activities will help policymakers as they continue to debate whether to allow future iron-enrichment experiments.

Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems

There is good evidence that coastal areas in many parts of the world are experiencing both increased nutrient levels and increased harmful algal blooms, but the causal link between the two is uncertain. This group, co-sponsored by IGBP's Land-Ocean Interactions in the Coastal Zone project and the Chinese Academy of Science's Institute of Oceanology, is integrating nutrient and harmful algal bloom data in a geographic information system format to study this important question. The results of this group will help coastal policymakers in decisions to prevent or mitigate harmful algal blooms. Sybil Seitzinger, Executive Director of the IGBP, is a member of this working group.

OceanScope

Some aspects of the ocean environment can be monitored from commercial ships, including ocean-going vessels and ferries plying coastal waters. Although ocean scientists have more than 50 years' experience using commercial vessels to monitor composition of the plankton community, temperature, salinity, dissolved carbon dioxide, and other parameters, arrangements are typically between individual scientists and individual shipping companies. This group seeks to develop a new paradigm for partnering with the merchant marine fleet. It will identify new measurements, sampling techniques and technologies optimized for commercial vessels, and develop new broad-scale interactions between the scientific and shipping communities in order to establish and maintain high-resolution studies of the ocean over time. IAPSO is co-sponsoring this group.

Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycle

Deep-sea hydrothermal vents in mid-ocean ridge-crest areas are known to have profound influences on the surrounding ecosystems in fueling communities of chemosynthetic organisms. Circulation though vent areas and relatively young crust also controls the oceanic concentrations of many elements. Yet, the potential contribution of hydrothermal energy transfer and materials to the ocean carbon cycle is unknown. This working group, co-sponsored by the InterRidge project, will bring together the information necessary to provide quantitative estimates of such contributions

The Microbial Carbon Pump in the Ocean

Microorganisms can shape the chemical composition of organic matter and consequently influence the residence time of carbon in the ocean. This process is analogous to the known "biological pump" (the biological processes that draw down carbon from the atmosphere into the deep ocean) in consequence, but different in mechanisms, and can be called "microbial carbon pump". This group will address the state-of-the-art techniques for studying microbial processing of organic matter to acquire new insights in mechanisms controlling carbon cycling in the ocean.

As we see, SCOR working groups cover the entire range of ocean science topics. SCOR welcomes IGBP co-sponsorship of new working groups and is interested in participating in new IGBP Fast-Track Initiatives related to ocean science. SCOR has co-funded three Fast Track Initiatives, on the global iron and nitrogen cycles, and on ocean acidification over time.

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Photo credit: Christopher Sabine, PMEL

Scientists collect sea water samples which have been brought to the surface from different depths by a rosette sampler.

Water in a Changing Climate

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The Ocean in a High-CO_2 World

The Second Symposium on Ocean Acidification

Back in 2004 the Scientific Committee on Oceanic Research and the Intergovernmental Oceanographic Commission held the ground breaking international symposium *The Ocean in a High-CO_2 World* that brought ocean acidification as an important anthropogenic CO_2 issue to the forefront of research. Important outputs were a report on future research needs, a communications policy, and heightened concern about the possible consequences of ocean acidification on marine organisms and the food webs that depend on them. Since then, research into ocean acidification has grown and it has been communicated so widely that it was reported as a new finding by the IPCC in their 4th Assessment on Climate Change (2007) only three years later. IGBP was one of the sponsors [1] of the 2nd symposium on *The Ocean in a High-CO_2 World* held on 6-9 October 2008 at the Oceanography Museum of Monaco under the High Patronage of His Serene Highness Prince Albert II. The increase in sponsors itself is an indicator of the growing concern of the international science community.

The meeting doubled the attendance of 2004, bringing together 220 scientists from 32 countries to reveal what we now know about the impacts of ocean acidification on marine chemistry and ecosystems, to assess these impacts for policy makers, and to decide what the future research needs are. The three science days reported on what had been learned in the last four years from all aspects of this rapidly emerging research issue — from future scenarios of ocean acidification, effects of changes in seawater chemistry on nutrient and metal speciation, palaeo-oceanographic perspectives, mechanisms of calcification, impacts on benthic and pelagic calcifiers, physiological effects from microbes to fish, adaptation and micro-evolution, fisheries and food webs, impacts on biogeochemical cycling and feedbacks to the climate systems. The science days consisted of invited and submitted papers, discussion sessions on future research priorities and a large poster display, all of which offered an intensive symposium in the wonderful Oceanography Museum, set high over Monaco overlooking the blue waters of the Mediterranean Sea and close to numerous restaurants where discussions continued on into the evening. A *Report on Research Priorities* has been completed and a subset of the science results from the Symposium will be reported in a special issue of the peer-reviewed journal *Biogeosciences*.

Photo credit: Jean Louis Teyssie, IAEA

James Orr together with HSH Prince Albert of Monaco at the Symposium.

On the fourth day there was a session for policy makers and the press which consisted of a summary of the science findings from the symposium, and presentations on the potential socio-economic impact of ocean acidification and on engaging with policy makers. To better achieve this, in addition to the science outputs, a *Summary for Policymakers* is being prepared. HSH Prince Albert II not only supported the Symposium, but also addressed those present, recognizing the important scientific challenges of ocean acidification and called on climate change policy makers all over the world to recognize that CO_2 emissions must be reduced urgently and drastically in order to prevent serious impacts of ocean acidification on marine organisms, food webs and ecosystems.

Rather than alleviate the concerns that emerged from the meeting four years ago, the symposium brought home our worst fears about how serious the issue of ocean acidification is, and will be, as we continue burning fossil fuels. It was recognized that marine scientists of all disciplines must convince the climate change negotiators to take ocean acidification seriously, particularly in this important year when negotiations at COP-15 [2] take place in Copenhagen in December. A suggestion from the floor that we produce a conference declaration, was widely supported.

The Monaco Declaration has been carefully crafted based on the symposium findings, and was launched on 30 January 2009, receiving wide media coverage. It has been signed by 155 of the conference participants. If you have five minutes, read it, if not read the extracts below:

Ocean acidification is underway … is already detectable … is accelerating and severe damages are imminent … will have socioeconomic impacts … is rapid, but recovery will be slow. … Ocean acidification can be controlled only by limiting future atmospheric CO_2 levels.

Despite a seemingly bleak outlook, there remains hope. We have a choice, and there is still time to act if serious and sustained actions are initiated without further delay. First and foremost, policymakers need to realize that ocean acidification is not a peripheral issue. It is the other CO_2 problem that must be grappled with alongside climate change. Reining in this double threat, caused by our dependence on fossil fuels, is the challenge of the century. Solving this problem will require a monumental world-wide effort. All countries must contribute, and developed countries must lead by example and by engineering new technologies to help solve the problem. Promoting these technologies will be rewarded economically, and prevention of severe environmental degradation will be far less costly for all nations than would be trying to live with the consequences of the present approach where CO_2 emissions and atmospheric CO_2 concentrations continue to increase, year after year.

Products from the Symposium

IGBP's research on ocean acidification is conducted in collaboration with SCOR, primarily by IGBP Core Projects SOLAS, IMBER and PAGES. The Second Symposium on the Ocean in a High-CO_2 World, in collaboration with SCOR, the Intergovernmental Oceanographic Commission (IOC) and the International Atomic Energy Agency (IAEA), resulted in a number of products, aimed at different audiences:

- Research priorities report on ocean acidification
- The Monaco Declaration
- A special issue of the journal *Biogeosciences*
- *Oceanography* magazine article (in preparation)
- Press Releases
- Fact Sheet
- Summary for Policymakers (in preparation)

All publications, when completed, are available from http://ioc3.unesco.org/oanet/HighCO2World.html and can be accessed from the "Ocean in a High CO_2 World" page of the portal www.ocean-acidification.net

Fortunately, partial remedies already on the table, if implemented together, could solve most of the problem. We must start to act now because it will take years to change the energy infrastructure and to overcome the atmosphere's accumulation of excess CO_2, which takes time to invade the ocean.

Therefore, we urge policymakers to launch four types of initiatives:

- to help improve understanding of impacts of ocean acidification by promoting research in this field, which is still in its infancy;
- to help build links between economists and scientists that are needed to evaluate the socioeconomic extent of impacts and costs for action versus inaction;
- to help improve communication between policymakers and scientists so that i) new policies are based on current findings and ii) scientific studies can be widened to include the most policy-relevant questions; and
- to prevent severe damages from ocean acidification by developing ambitious, urgent plans to cut emissions drastically.

An example to illustrate the intense effort needed:

To stay below an atmospheric CO_2 level of 550 ppm, the current increase in total CO_2 emissions of 3% per year must be reversed by 2020. Even steeper reductions will be needed to keep most polar waters from becoming corrosive to the shells of key marine species and to maintain favourable conditions for coral growth. If negotiations at COP-15 in Copenhagen in December 2009 fall short of these objectives, still higher atmospheric CO_2 levels will be inevitable.

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Endnotes

1. The symposium was again sponsored by SCOR and IOC-UNESCO as well as the IAEA-Marine Environment Laboratories and IGBP. Additionally, it was supported financially by the Prince Albert II Foundation, the Centre Scientifique de Monaco, the U.S. National Science Foundation, the International Council for the Exploration of the Sea, the North Pacific Marine Science Organization, the Oceanography Museum, and the Monaco Government.
2. The overall goal for the 2009 (COP15) United Nations Climate Change Conference is to establish an ambitious global climate agreement for the period from 2012. COP stands for Conference of Parties and is the highest body of the United Nations Climate Change Convention consisting of environment ministers who meet once a year to discuss the convention's developments. Ministers and officials from around 189 countries and participants from a large number of organizations will take part.

The Ocean in a High-CO_2 World

Science highlights from the symposium

Reef development in a high-CO_2 world: Coral reefs of the eastern tropical Pacific

Many coral reefs in the eastern tropical Pacific develop at slow – or even marginal – rates: they grow slowly and erode quickly. This has been blamed on the upwelling of cold, nutrient-rich waters to the surface that can depress calcification and stimulate bioerosion. Our study suggests that the increased carbon dioxide content of the upwelled water, which lowers the pH and depresses the aragonite ($CaCO_3$) saturation state, is also an important factor in the poor reef development. We verified the low saturation state of waters from the eastern Pacific (Galápagos, Gulf of Chiriquí, and Gulf of Panamá), and then compared coral samples from nearby reefs with samples from the Bahama Islands, a region with high aragonite saturation state. The Bahama samples contained abundant inorganic aragonite cements that tend to fill the pore spaces within corals and the reef, while the eastern Pacific samples contained few to none. The lack of cements are thought to reduce the resistance of the corals and reefs to bioerosion; in fact, bioerosion rates in the eastern Pacific are ten times those of other reef regions. This study shows that increasing atmospheric carbon dioxide, which lowers the aragonite saturation state of seawater, threatens not only the coral calcification rates, but also the reef-structures that support high biodiversity and protect shorelines [1].

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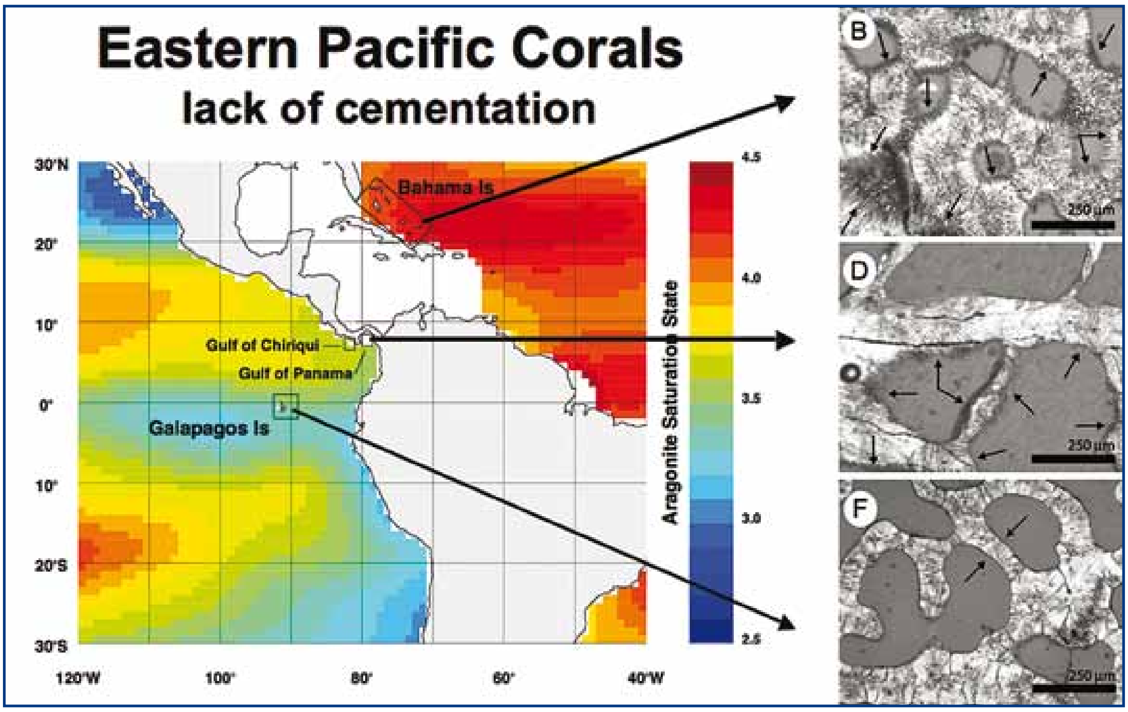

Carbonate cements within the pore spaces of corals from areas with naturally different CO_2 levels. The Galapagos sample (where seawater is similar to what is expected for the rest of the tropics with a tripling of atmospheric CO_2) contains no cement. The absence of cement is evidenced by a clearly defined boundary between the inner skeletal wall and open pore space. This is contrary to the sample from the Bahamas (where seawater has very low CO_2 levels) — the boundary between the skeletal wall and pore space is blurred by the abundance of cements. Minor amounts of cement are present from the intermediate CO_2 environment from Pacific Panama, but these are still trivial relative to the Bahamas.

High vulnerability of eastern boundary upwelling systems to ocean acidification

Eastern boundary upwelling systems, such as the California Current, are particularly sensitive to ocean acidification: the pH of their surface waters is already comparatively low and their change in pH for a given uptake of anthropogenic CO_2 is particularly high. Eddy-resolving simulations [1] for the California Current System show that between pre-industrial times and present, the mean pH of the surface ocean has decreased by about 0.1 pH units. As a result, the aragonite saturation horizon has shoaled by ~100 m, bringing waters corrosive to calcifying organisms into the surface (euphotic) zone in a few eddies and in near-shore environments during upwelling (Figure). The model data agree with recent observations. Projections for 2050 (IPCC SRES A2-scenario) suggest an additional drop of pH by ~0.2 units and a widespread and year-round shoaling of the saturation horizon into the euphotic zone. Due to the high temporal and spatial variability that characterizes eastern boundary upwelling systems, organisms are exposed to a wide range of pH (variations of up to 0.3 to 0.4 units) and saturation states, making it difficult to define when critical thresholds are crossed. At the same time, these systems may today offer opportunities to study the response to organisms to low and varying pH and saturations states likely to be widely experienced in the future.

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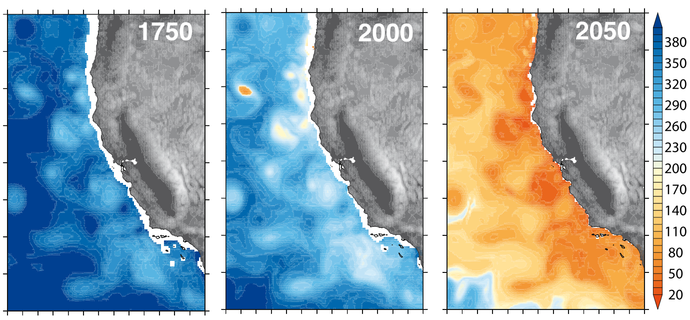

Model simulations of the shoaling of the aragonite saturation horizon (depth in m) in the California Current from 1750 to 2050 (snapshots for the month of August). White areas depict saturated (non-corrosive) waters to the sea floor.

Footnote

1. Produced with the ETH-UCLA Regional Oceanic Modeling System.

Changes in the carbonate system of the global oceans

Increasing atmospheric carbon dioxide is rapidly changing seawater chemistry as a result of the acidifying effects of CO_2 on seawater. This acidification makes it more difficult for marine organisms (e.g., corals, plankton, calcareous algae, and molluscs) to build skeletons and shells of calcium carbonate. Impacts on these calcifying organisms will lead to cascading effects throughout marine ecosystems. Repeated hydrographic cruises and modelling studies in the Atlantic, Pacific and Indian oceans show evidence for increased ocean acidification. The dissolved inorganic carbon increases in surface waters of the Pacific Ocean over the past 15 years are consistent with pH decreases (Figure). These changes can be attributed, in most part, to anthropogenic CO_2 uptake by the ocean. These data verify earlier model projections that ocean acidification is occuring as a result of the uptake of carbon dioxide released by the burning of fossil fuels. From these results we estimate an average upward migration of the aragonite saturation horizon of approximately 1-2 metres per year in the Pacific and Indian oceans. Thus making water corrosive to calcifiying organisms that are closest to the surface.

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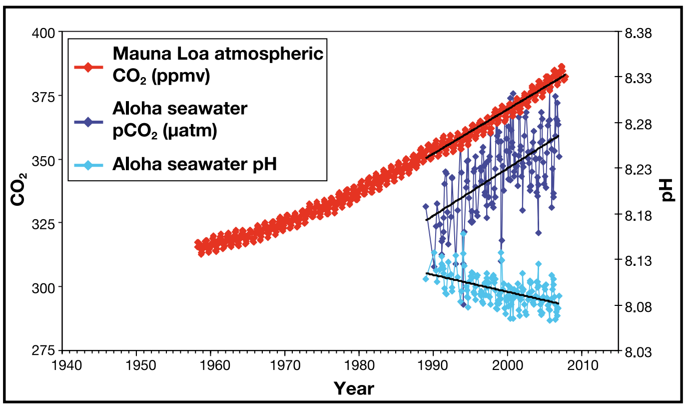

Time series of atmospheric CO_2 at Mauna Loa and surface ocean pH and pCO_2 at Ocean Station Aloha in the subtropical North Pacific Ocean. Mauna Loa data: Dr. Pieter Tans, NOAA/ESRL; HOTS/Aloha data: Dr. David Karl, University of Hawaii (modified after Feely, 2008).

Reference

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Salmon pHishing in the North Pacific Ocean

The northern North Pacific is home to salmon populations that have sustained human societies throughout their history in the region. Salmon are potentially linked to CO_2 emissions by one of their prey, a marine snail or shelled pteropod called *Limacina helicina*. The shells of this mollusk are made of the aragonitic form of calcium carbonate ($CaCO_3$), which may begin to dissolve as the oceans acidify so that their fate as a component of the holoplankton is potentially threatened by an increasingly acidic ocean. What if pteropods simply disappeared from the North Pacific? During the 20th century they received little attention from the scientific community but they were found routinely in salmon diets. Historical data reveal considerable variability in where and when they are important as prey. During the last five decades, chum salmon (*Oncorhynchus keta*) stomachs from the northwestern Pacific contained about 15-25% pteropods and this trend has been increasing. During the 1960s in the Gulf of Alaska, humpback salmon (*O. gorbuscha*) stomachs contained about 15% pteropods on average in April. The current situation is poorly known as studies of salmon ecology are rare in this part of the Pacific, but if pteropods continue to form a component of salmon diets, it is likely that ocean acidification will increasingly affect this food source.

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Sockeye salmon haul off the Canadian coast in the mid 1980s.
Insert: Chum salmon caught in the high seas of the North Pacific Ocean.

Consequences of ocean acidification for fisheries

Ocean acidification can affect fish both directly through physiological processes and indirectly through changes in the marine food webs, such as food quality, quantity and availability, and through the deterioration of fish habitats, such as tropical and deep-sea coral reefs. Alone, or in combination with other factors, ocean acidification can affect reproduction, growth and mortality in fish populations. Early life stages, hence recruitment of young fish into the fish stock, may be particularly vulnerable. This is bad news because recruitment governs the dynamics of fish stock biomass. Observations and model predictions of ocean acidification show that the changes occur faster and are stronger in high latitude oceans. This can have significant consequences on fisheries in the north Pacific and Atlantic that hold some of the most important fish stocks in the world, among them Alaska pollock, Atlantic herring, blue whiting, and north-eastern Arctic cod. The collapse of fish stocks is most likely to occur when overfishing coincides with unfavourable environmental conditions that reduce recruitment. Institutions responsible for fisheries management need to be adaptive and respond quickly to new environmental knowledge, enabling them to maintain healthy and robust fish stocks that are not overfished and have suffered a minimum loss of genetic diversity. This can secure a high potential for adaptation to changes in the environment.

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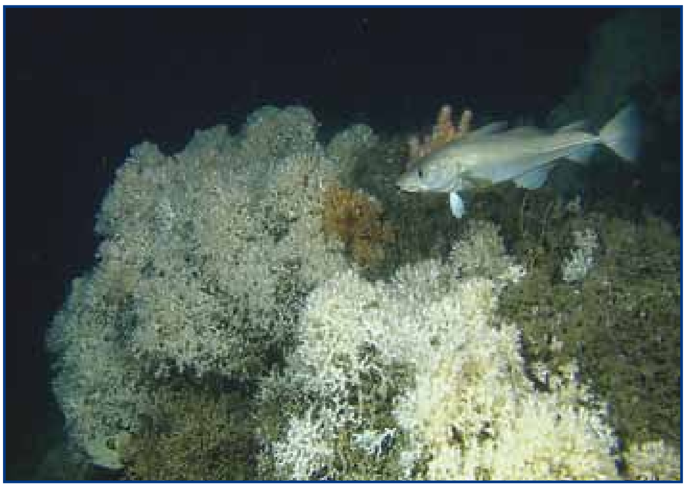

Cod in a deep-water coral habitat at 200 m depth. The NE-Arctic cod stock is one of the few cod stocks that so far have not been fished down due to mismanagement. But problems may soon come: the cod lives in a high latitude ecosystem that will experience significant ocean acidification within a few decades. Modelling predicts that deep-water coral reefs off the coast of Norway may meet undersaturated conditions within this century. Photo: Jan Helge Fosså and Pål B. Mortensen, Institute of Marine Research, Norway.

Impact of ocean acidification on underwater sound

Thirty years ago, scientists trying to determine the absorption of low frequency sound in seawater in order to develop new navy sonar systems, discovered, somewhat surprisingly, that this absorption is pH dependent: the lower the pH the less the absorption. Today this discovery has an implication for ocean acidification: as the ocean acidifies it will become noisier! Lower absorption (the pH change predicted in a recent Royal Society Report [1] would cut the absorption in half) will result in a smaller propagation loss which means that at a given distance from a noise source (such as a ship's propeller) the sound level will be louder than it previously was. It is presently the subject of legal contention whether noise levels can cause significant distress to marine mammals but if there is a problem ocean acidification could make it worse. As with other predicted effects, the absorption change would have the greatest impact soonest in specific situations. For example underwater sound typically propagates along the axis of a naturally occurring sound channel – in many areas this axis is over 1,000 meters deep which means that it would take a significant time for pH change to work down the water column. In some locations such as the North Pacific Ocean, however, a shallow secondary sound channel exists where the impact should be observed sooner. For a more detailed explanation of the ocean chemistry see: Hester K. C., E. T. Peltzer, W. J. Kirkwood, P. G. Brewer. "Unanticipated consequences of ocean acidification: A noisier ocean at lower pH", *Geophysical Research Letters*, 35: L19601 (1 October 2008).

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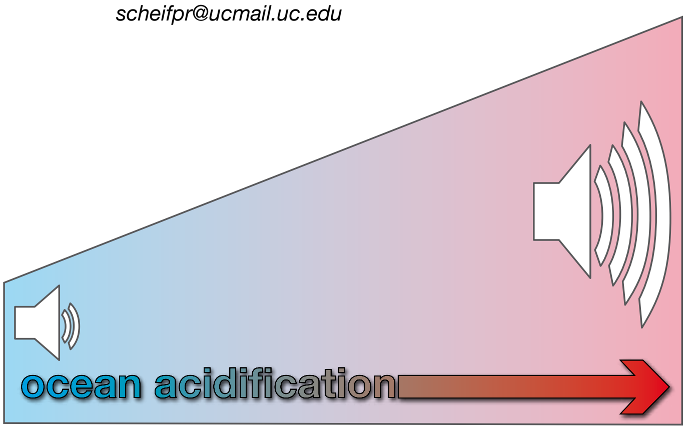

Acidification of the ocean results in a noisier ocean.

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The early development of oysters: synergistic effects of ocean acidification and temperature

Studies have found that projected elevations in atmospheric carbon dioxide (CO_2), as early as 2065, will reduce the calcification of adult organisms in oceanic environments. Less is known, however, about how the combined effects of elevated dissolved CO_2 (pCO_2) and temperature will impact the sensitive early development stages of marine organisms. In a series of studies, we investigated the synergistic effects of elevated pCO_2 (375, 600, 750 and 1000 ppm) and temperature (18, 22, 26 and 30 °C) on the fertilisation, development and growth of the early life history stages of two ecologically and economically important estuarine molluscs, the Sydney rock oyster, *Saccostrea glomerata,* and the Pacific oyster, *Crassostrea gigas*. We found that exposure to elevated pCO_2 and temperature had deleterious effects on the reproduction, growth and development of the early life history stages of *S. glomerata* and *C. gigas*. Overall as pCO_2 increased and temperature deviated from 26 °C, fertilisation, development and growth decreased and abnormality and mortality increased (Figure). Furthermore, *S. glomerata* was more sensitive to elevated pCO_2 and temperature than *C. gigas*. This implies that if our oceans continue to acidify and warm, the Pacific Oyster, *C. gigas,* may become the dominant species along the South Eastern coast of Australia.

Laura Parker received the prize for the best student oral presentation at the Symposium.

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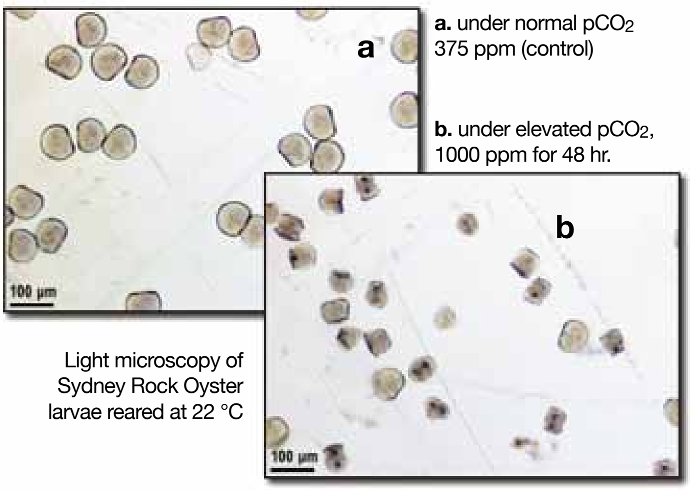


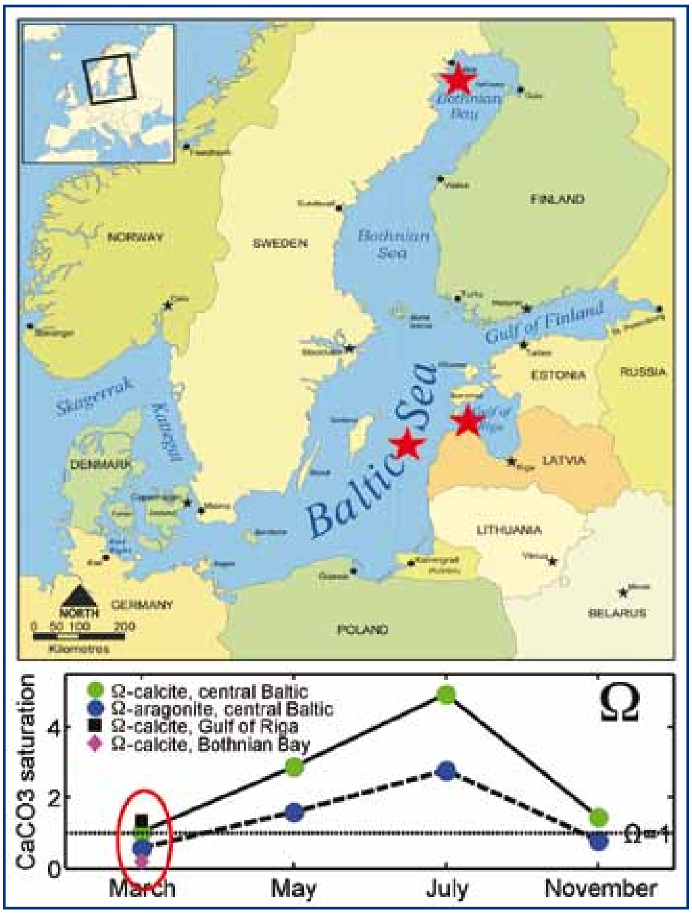
a. under normal pCO_2 375 ppm (control)

b. under elevated pCO_2, 1000 ppm for 48 hr.

Light microscopy of Sydney Rock Oyster larvae reared at 22 °C

Low winter $CaCO_3$ saturation in the Baltic Sea: consequences for calcifiers

Ocean acidification lowers the calcium carbonate ($CaCO_3$) saturation state (Ω) of seawater and thus the ability of calcifying organisms to form shells or skeletons. All surface oceans are presently supersaturated with respect to $CaCO_3$ (Ω>1) but under continued emissions of CO_2 this will change. The first oceans to experience surface undersaturation (Ω<1) will be the Arctic and Southern Oceans, and it will most likely occur in wintertime, the time of the year at which Ω is typically lowest. Measurements in the Baltic Sea show that a similar situation already pertains there: the central Baltic becomes undersaturated (or nearly so) in winter, with respect to both aragonite and calcite mineral forms of $CaCO_3$ (Figure). Undersaturation appears even more severe in the most northerly part of the Baltic Sea, the Bothnian Bay. Low wintertime Ω is matched by unusual patterns of chemical etching (dissolution) of $CaCO_3$ shell fragments in sediments. We are taking advantage of this natural analogue to better understand future impacts of ocean acidification, by comparing biogeographical distributions of calcifying organisms in the Baltic with carbon chemistry (mindful that there are also strong gradients in salinity and other parameters). For instance, while many calcifiers are scarce in the Baltic, the blue mussel *Mytilus edulis* occurs even in the low Ω Bothnian Bay.



Calcium carbonate saturation state of Baltic seawater over the seasons. Ω<1 indicates undersaturated waters where carbonate dissolution occurs.

Map: Norman Einstein

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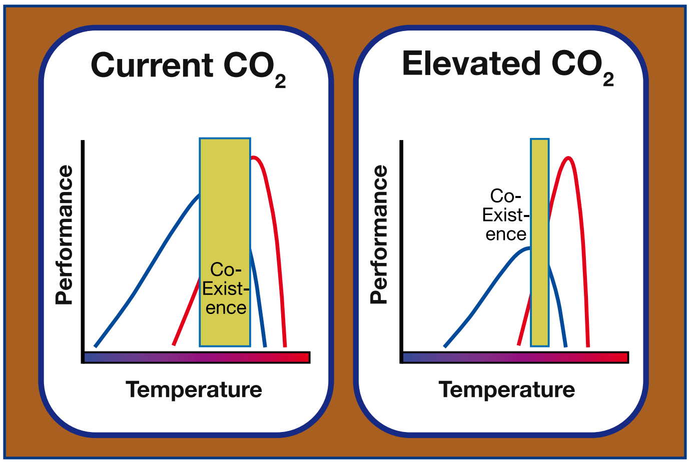
Mechanisms linking climate to ecosystem change: physiological background and ecological implications

Climate change causes ocean warming and acidification on global scales. In contrast to well established effects of warming, evidence for the effects of rising carbon dioxide (CO_2) on marine ecosystems is only just emerging. However, future scenarios also indicate threats to marine life through combinations of rising CO_2 levels, warming and more frequent oxygen depletion (hypoxia) in the ocean. There is a need to understand the causes and effects of realistic future climate scenarios on ecosystems. We need to identify key physiological mechanisms and their responses to combined effects of progressive acidification, warming and hypoxia. In the changing ocean, these are physiological mechanisms which define species performance, including their capacity to interact, e.g. in food webs [1]. Many current ecosystem changes likely occur when ambient temperature drifts beyond the species-specific temperature limits of survival (thermal



Conceptual model of CO_2 dependent effects on species interactions at ecosystem level (modified after [1]). Species differ in their thermal windows of performance and coexist where these windows overlap (left). Changes in species interactions are elicited by warming and also by the specific sensitivity of species to ocean acidification under elevated CO_2 levels. The narrowing of thermal windows and differential loss of performance will affect coexistence ranges, relative performance, and thus the patterns of competition and susceptibility to predation (right).

tolerance window) and causes a shift in phenology resulting in the species no longer being able to survive in this location. High sensitivity to elevated CO_2 levels may involve a low capacity for acid-base regulation, as seen in lower marine invertebrates [2]. The disturbed extracellular acid-base status affects processes involved in growth, calcification, neural functions, blood gas transport and behavioural capacities [2]. Metabolic pathways shift to new equilibria. Current evidence indicates elevated sensitivity to higher CO_2 levels towards the extremes of thermal windows [3]. The ultimate consequence may be a narrowing of thermal tolerance windows and associated ranges of geographical distribution and of the performance at ecosystem level. Thus, CO_2 may exacerbate warming effects on marine ecosystems. Future research will have to test these concepts under realistic climate and ocean acidification scenarios and in various marine ecosystems between the tropics and the poles.

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Impact of ocean acidification on marine snails and deep-sea corals

The impact of ocean acidification on calcification has been investigated for over 20 years. However, few taxonomic groups of calcifying organisms have been studied in acidified conditions: among them are reef-building corals and phytoplankton (coccolithophores). Yet, there are more than 16 phyla of calcifying organisms, some of them critically important due to their role in biogeochemical cycles or because they are host to ecosystems with high biodiversity.

Arctic pteropods, or marine snails, and deep-sea corals thrive in areas that will be among the first affected by changes in ocean acidification. The polar pteropod *Limacina helicina* (Figure 1) is a major dietary component for zooplankton and higher predators such as herring, salmon, whale and birds. Its fragile aragonite shell plays a vital protective role and forms an external skeleton. Perturbation experiments, carried out under controlled pH conditions representative of carbonate chemistry for 1990 and 2100, show calcification rates decreased by 28% for the pteropod *L. helicina* when pH was lowered by 0.3 units. An even larger reduction of 50% was seen in response to a decrease of 0.3 pH units for the cold-water coral *Lophelia pertusa* (Figure 2). While tropical coral reefs are formed by a large number of coral species, the structure of a cold-water coral reef is made by one or two coral species that form the basis of a very diverse ecosystem. A reduction in skeletal growth as a consequence of ocean acidification can therefore become detrimental to the whole ecosystem.

These first results presented during the Monaco Symposium raise great concern for the future of pteropods and cold-water corals, and organisms that depend on them as a food source or habitat. One role of the recently launched national or international research projects on ocean acidification will undoubtedly be to generate data on other taxa, longer time scales and on the interactive impacts of ocean acidification and other global changes such as temperature on these organisms.

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Figure 1. The Arctic pelagic snail (pteropod) *Limacina helicina* (surface water, Spitsbergen).

Figure 2. The cold-water coral *Lophelia pertusa* (150 m depth off the Hebrides in the North Atlantic)

Natural CO_2 vents reveal ecological tipping points due to ocean acidification

Investigation into the long-term biological effects of permanent exposure to high CO_2 concentrations in a natural ecosystem has taken research into ocean acidification an important step forwards. Effects were studied on rocky and sedimentary marine communities around underwater volcanic vents that release millions of litres of CO_2 per day. The vents lacked the poisonous sulphur compounds that characterise many vents. The high CO_2 levels had major impacts on marine life including 30% reductions in species diversity at average pH 7.8, compared with normal seawater (pH 8.1).

This work provides the first confirmation of modelling and short-term laboratory experiments which predict severe reductions in the ability of marine organisms to build shells or skeletons from calcium carbonate due to the dramatic effects of CO_2 on seawater chemistry. Seagrasses thrived at increased CO_2 (Figure) levels but major groups such as corals, sea urchins and calcified algae were removed from the ecosystem and replaced by invasive species of algae. Such studies will help us to predict the future effects of ocean acidification and demonstrate, for the first time, what happens to marine ecosystems when key groups of species are killed due to rising CO_2 levels.

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Venting of CO_2 at a Mediterranean site provides the opportunity to observe changes in ecosystems along gradients of decreasing pH close to the vents. Sea grasses and brown algae grow well at the vents but groups such as sea urchins, coralline algae and stony corals are killed by the acidified water.

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From the lab to models: algal calcification and ocean acidification

Global modellers are called upon to predict the future uptake of fossil fuel carbon dioxide (CO_2) by the ocean. The impact of ocean acidification on marine calcifiers may be important in this calculation, so we construct model parameterizations for plankton carbonate production based on biological experiments. However, for a major carbonate producer in the open ocean, algae called coccolithophores, no consistent calcification response to acidification (pH) is apparent in laboratory studies. This gives us a real headache – how to write a single equation for wildly differing experimental responses? Which, if any, is the "correct" response? Two clues may help: firstly, a peak in calcification is observed in some experiments, hinting at an environmental pH "optimum" for this process. Secondly, in manipulations of more complete ecosystems such as mesocosms (large partly submersed bags) and shipboard incubations of seawater samples, calcification is consistently lower in more acidic conditions (higher CO_2). The existence of pH optima for calcification would allow the use of the same quasi-empirical trick as we already employ for modelling the response of algal growth rate to temperature – the "Eppley curve". Marine ecosystems may then be expected to respond to future acidification in an analogous way to increasing temperature – by gradual transition in dominance from more to less heavily calcified coccolithophores and progressively reduced carbonate production globally, as illustrated below.

See the full article in Ridgwell et al. (2009) *Biogeosciences* 6 (2): 3455-3480.

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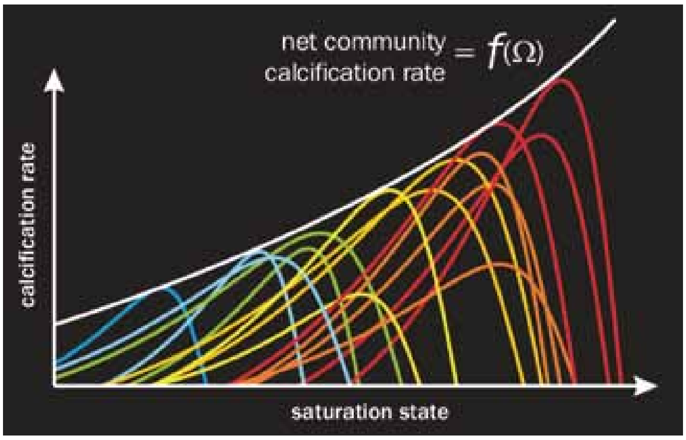

Potential ecosystem level response of carbonate production with increasing acidity – a simplification based on individual pH optimum curves for different (hypothetical) species of calcifying phytoplankton

Economic impacts of ocean acidification: costs and savings

Stringent mitigation of further carbon dioxide (CO_2) emissions seems more feasible now that the costs have been projected as relatively low. Transforming the worldwide energy system to meet a 450 ppm CO_2-equivalent target would cost only 0.5% to 2% of the GDP, our global gross domestic product [1], [2], [3]. At the same time, the findings of the ocean acidification community add to the overall conclusion that CO_2 impacts have been under-estimated in the past. Both of these observations imply sharper emission cuts than had been foreseen.

With the estimate of a potential development of carbon markets and international agreements to cap CO_2 emissions, a price tag can now be assigned to the acidification-driven degradation of the ocean's large capacity to absorb CO_2. The ocean's current carbon uptake may soon represent an annual subsidy to the global economy of about 0.1 to 1% GDP. However, any fraction of the ocean's uptake leads to degradation through ocean acidification, which in the future would imply an economic loss in proportion to the damage this causes, thus adding another slice to the overall costs of CO_2 emissions.

The upcoming years will witness a heated debate on the adequate mix of mitigation technologies, such as sub-seabed CO_2 sequestration or massive-scale deployment of solar thermal power, in view of costs and risks. The ocean acidification community could supply some of the necessary metrics for a rational discourse on how to judge the risks of CO_2 leakage after sub-seabed CO_2 sequestration against the benefits from reduced atmospheric CO_2 concentration.

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Ocean acidification: connecting the science to policy

Over the last ten years the political and public awareness of the many consequences of the increase in greenhouse gas emissions to the planet's climate has increased dramatically. The complexity of many of the issues that we face means that it is a great challenge for anyone to be an expert or even well-informed about everything, and there is a very real danger that some issues may be overlooked. Ocean acidification is one such issue, but most certainly one where we can't afford for this to happen.

Our understanding of the chemistry and physics of these processes is increasing and evidence is growing of the biological consequences of a declining seawater pH. The key is to communicate these findings to the policy makers and decision takers in such a way that the key messages can be received and understood and that action results.

Cooperation and communication are needed at all stages between the scientists and policy-makers. Scientists, by nature, are curious and look to answer the interesting and intriguing questions that will stretch the boundaries of our knowledge and understanding. This is good and laudable but in order to generate action to address the issues that threaten the oceans it is ever more important to distinguish between what we would like to know and what we need to know. Providing answer to the latter is what is required to make the connection between science and policy.

Where there is a large programme of work it is possible to make such a connection through the establishment of a Reference User Group that provides an interactive forum throughout the lifetime of the project where the researchers and the 'policy customers' can exchange ideas. This guides scientists to consider how their research can answer questions that need to be addressed to reach key policy decisions. Complex answers must be presented in an accessible manner whilst not detaching these from the underlying science. The UK Marine Climate Change Impacts Partnership Annual Report Card (ARC) is an example of how this can be successfully done and the 2009 ARC (publication in April) seeks to demonstrate the complex and linked relationships between various aspects of climate change, including ocean acidification, that policy makers must take into account.

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People

Peter Liss, Past Chair of the SOLAS Scientific Steering Committee (2001-2007) and former Chair of the Scientific Committee for the IGBP (1993-1997), formally received the Commander of the Order of the British Empire (CBE) from Prince Charles in March 2009. Peter was elected Fellow of the Royal Society in May 2008, and in June was on the Queen's birthday list of honours to receive the CBE for his services to science.

New Director of Communications at the IGBP Secretariat

In May **Owen Gaffney** joins IGBP as director of communications. Currently he is head of publications at the Natural Environment Research Council. NERC is the UK's largest funder of environmental science and makes substantial contributions to IGBP, largely through the SOLAS and GLOBEC programmes.

His background is in journalism and science writing. In what he feels is the dim and distant past he earned a degree in Aeronautic and Astronautic Engineering so when people ask if he is a scientist, he can truthfully say that he has a degree in rocket science. But it is not quite the same thing: it's engineering really.

For over ten years he has worked as a journalist, science writer and broadcaster. Within NERC he was the editor of the award-winning magazine *Planet Earth* and he recently launched the news site, Planet Earth online, www.planetearth.nerc.ac.uk. He has written for the BBC's Focus magazine and the American journal *Science*. He still occasionally writes for the Irish daily newspaper, the *Irish Examiner.*

He is very much looking forward to joining IGBP and moving to Stockholm. As environmental change continues to rise up the international agenda, the coming few years promise to be an interesting and important time for this area of science and for IGBP.

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New Executive Officer at IMBER

Lisa Maddison will take up the position of executive officer of IMBER at the end of April. She succeeds Sylvie Roy who has returned to Ottawa in Canada.

Lisa's background is in marine biology. She worked for several years as a researcher in the Marine Biology Research Institute at the University of Cape Town, and was involved with several projects relating to ecological processes and interactions and the sustainable utilization of intertidal resources. She has also worked as an environmental consultant. She writes: "One of the most exciting programmes that I worked on was the development of the Coastal Management Policy for South Africa. It was one of the first policy formulation processes that took into consideration the issues and values of the majority of South Africans. It was a wonderful process to be involved in, and the Integrated Coastal Management Act that culminated from the process is a really great piece of legislation."

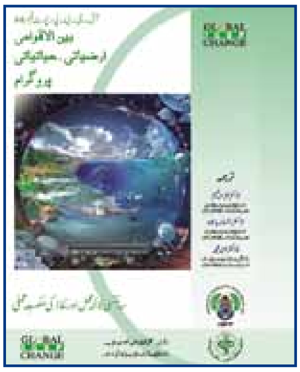
She enjoys kayaking and cycling and is looking forward to doing both of these activities in Brest, on the Brittany coast of France, where the IMBER Core Project Office is located.

E-mail: lisa.maddison@univ-brest.fr

Pakistan NC translates the IGBP Science Plan into Urdu

Assistant professor Ghazala Nasim of Punjab University, Director Professor Dr. Rukhsana Bajwa, and Dr. Amir Mohammed, Rector of FAST National University of Computer and Emerging Sciences, have now completed a translation of the IGBP Science Plan (Report 55) into Urdu, the Pakistani national language.

In translating IGBP titles the authors provide detailed information to the Pakistani scientific community on global change in general and the changing conditions in Pakistan in particular. The publication is also



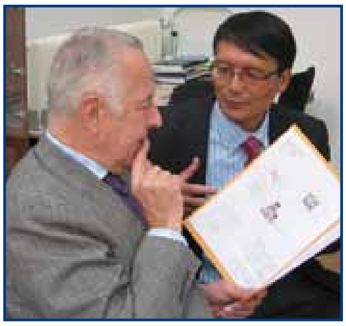
designed to help graduate and post-graduate students in the departments of environmental and other relevant sciences.

The announcement in the Punjab University Newsletter (Dec. 08) suggests that "we in Pakistan, categorizing our priorities, should award global environmental change a more central place in human affairs; thrust our science into the unfamiliar and uncomfortable role of a major player in a heated and potentially divisive international debate about the nature and severity of global change and its implications for ways of life."

The report is dedicated to Waheeda Sultana (70 years old, shown in picture), mother of Ghazala Nazim, the lead translator. She had learned to use a laptop in order to type the IGBP manuscripts in Urdu.

The Urdu translation by the Punjab University Press is available at: http://www.igbp.net/page.php?pid=222

ICSU's former Executive Director chairs CGIAR Challenge Program



Thomas Rosswall, the former director and founder of IGBP, now chairs the Steering Committee of the CGIAR Challenge Programme "Climate Change, Agriculture and Food Security" a major collaborative endeavour between the Consultative Group on International Agriculture Research (CGIAR) and their partners, and the Earth System Science Partnership (ESSP). The first meeting of the Steering Committee was held 29-30 April at ICSU in Paris.

Here he chats with Deliang Chen, his successor as Executive Director at ICSU.

New members IGBP Scientific Committees 2009 – 2011

Many new three-year terms started in January 2009: some members are new, and others have renewed their terms for another three years. We are pleased to welcome them all to the IGBP community, and thank them for the commitment they are willing to assume.

First, the Scientific Committee for the IGBP (SC-IGBP), the leading body for the programme, elected two new members and renewed four terms that begin this year. The SC-IGBP members are appointed by the International Council for Science (ICSU), our governing body.

IGBP Scientific Committee

Appointments renewed:

Chair: Carlos Nobre
Biosphere-atmosphere interactions, earth system science
Centro de Previsão de Tempo e Estudos Climaticos, Instituto Nacional de Pesquisas Espaciais Brazil

Vice Chair: Olga Solomina
Palaeoclimatology
Institute of Geography, Russian Academy of Sciences, Russia

Member: Henry Jacoby
Environmental economics
Joint Programme, Global Change, Massachusetts Institute of Technology, USA

New appointment:

Vice-Chair: Chen-Tung Arthur Chen
Chemical oceanography, biogeochemistry
SSC Member since 2008, Institute of Marine Geology and Chemistry, National Sun Yat-sen University, Taiwan

New SC Members:

Christiane Lancelot
Marine sciences, ocean-atmosphere interaction
Université Libre de Bruxelles, Belgium

Jan Willem Erisman
Atmospheric sciences, linking GEC science to policy
Energy Research Centre of The Netherlands

IGBP Network News

IGBP Core Projects

The Scientific Steering Committees (SSC) guide each Core Project. The members of these committees are appointed by the IGBP Officers (Executive group of the SC-IGBP) and the Chairs and Co-chairs are members of the SC-IGBP.

AIMES – Analysis, Integration and Modelling of the Earth System

New SSC Member:

Peter Cox
Climate system dynamics, modelling land-atmosphere interactions
School of Engineering Computing and Mathematics, Exeter University. United Kingdom

GLP – Global Land Project

Appointment renewed:

Chair: Anette Reenberg
Ecological cultural geography
Department of Geography, Geocenter Copenhagen, University of Copenhagen, Denmark

IGAC – International Global Atmospheric Chemistry

Co-Chair: Tong Zhu
Environmental chemistry, air-surface exchange of mass and energy
Cheung Kong Scholar Programme, Centre for Environmental Sciences, Peking University, China

New SSC Members:

Olga Mayol-Bracero
Analytical chemistry, atmospheric aerosols
Institute for Tropical Ecosystem Studies, University of Puerto Rico

Karla Longo
Atmospheric science, environmental model development
Space and Atmospheric Science Center, National Institute for Space Research–INPE, São José dos Campos, Brazil

Kobus Pienaar
Atmospheric chemistry, environmental management
Faculty of Natural Science, North-West University, Potchefstroom Campus, South Africa

iLEAPS – Integrated Land Ecosystem-Atmosphere Processes Study

New SSC Members:

Nobuko Saigusa
Boundary-layer meteorology, land-atmosphere interactions
National Institute for Environmental Studies, Tsukuba, Japan

Sonia I. Seneviratne
Land-climate interactions
Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

IMBER – Integrated Marine Biogeochemistry and Ecosystem Research

New SSC Members:

Ken Drinkwater
Physical oceanography/marine ecosystem focus
Institute of Marine Research, Bergen, Norway

Eugene Murphy
Ecosystem modelling
British Antarctic Survey, Cambridge, United Kingdom

Hiroshi Ogawa
Marine biogeochemistry
Department of Chemical Oceanography, Ocean Research Institute, University of Tokyo

Katja Philippart
Marine ecology
Department of Marine Ecology and Evolution, Royal Netherlands Institute for Sea Research, Netherlands

Alberto Piola
Physical oceanography
Servicio de Hidrografía Naval, Dept of Oceanography, Buenos Aires, Argentina

Sinjae Yoo
Biological oceanography
Marine Ecosystem Dynamics Laboratory, Korea Ocean Research and Development Institute, Republic of Korea.

IGBP Network News

LOICZ - Land-Ocean Interactions in the Coastal Zone

New Chair: Alice Newton
Biological and chemical oceanography
University of Algarve, Faro, Portugal

New SSC members:
Zhongyuan Chen
Geomorphology
State Kay Laboratory for Estuarine and Coastal Research, East China Normal University, Shanghai

Antonio Diegues
Anthropology
Research Center on Human Population and Environment, Universidade de Sao Paulo, Brazil

Remigius Laane
Marine biogeochemistry
Deltares, Marine and Coastal Systems Division, Delft, The Netherlands

Masumi Yamamuro
Marine geology, biogeochemistry
Department of Natural Environmental Studies, Graduate School of Frontier Sciences, University of Tokyo, Japan

PAGES – Past Global Changes

Co-Chair: Bette Otto-Bliesner
Palaeoclimate modelling
Climate and Global Dynamics Division, NCAR, USA

New SSC Members:
Fatima Abrantes
Paleoceanography
Marine Geology Dept., INETI, Portugal

Steven Colman
Geomorphology, limnogeology
Large Lakes Observatory & Dept. Geological Sciences, University of Minnesota Duluth, USA

SOLAS – Surface Ocean-Lower Atmosphere Study

New SSC Members:
Minhan Dai
Marine biogeochemistry
College of Oceanography & Environmental Science, Xiamen University, China

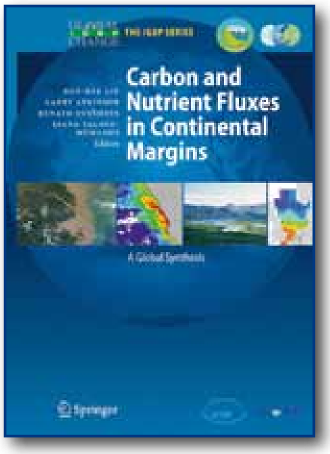
Cecile Guieu
Hydrology, biogeochemistry
Laboratoire d'Océanographie de Villefranche, Villefranche-sur-Mer, France

Patricia Quinn
Chemistry, atmospheric aerosols on climate and air quality
National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory, Seattle, United States

Rafel Simó
Marine biogeochemistry, chemical oceanography
Institut de Ciències del Mar, Barcelona, Spain

Products

Just published March 2009



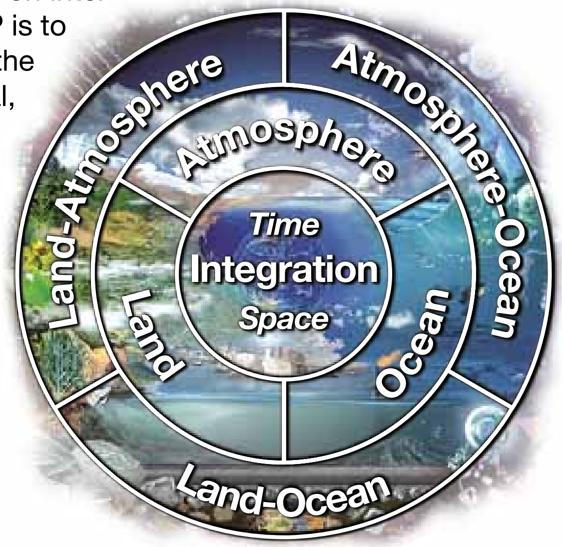
Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis, by Liu, K.-K.; Atkinson, L.; Quiñones, R.; Talaue-McManus, L. (Eds.) Global Change - The IGBP Series, Springer, 2009, XII, 500 p. 278 illus., 90 in color. Hardcover, ISBN: 978-3-540-92734-1.

The book is the result of collaboration between the Joint Global Flux Study (JGOFS) and Land-Ocean Interactions in the Coastal Zone (LOICZ) projects through the Continental Margins Task Team (CMTT) and is written by 188 contributors.

IGBP scientists get a 10% discount. To order books at 10% discount, please send your order to Maurer@Springer.de Please note that the subject line should read: "IGBP series 10% discount". See also: http://www.springer.com/earth+sciences/oceanography/book/978-3-540-92734-1

The International Geosphere-Biosphere Programme

IGBP is an international scientific research programme built on interdisciplinarity, networking and integration. The vision of IGBP is to provide scientific knowledge to improve the sustainability of the living Earth. IGBP studies the interactions between biological, chemical and physical processes and human systems, and collaborates with other programmes to develop and impart the understanding necessary to respond to global change. IGBP research is organised around the compartments of the Earth System, the interfaces between these compartments, and integration across these compartments and through time.



IGBP helps to

- develop common international frameworks for collaborative research based on agreed agendas
- form research networks to tackle focused scientific questions and promote standard methods
- guide and facilitate construction of global databases
- undertake model inter-comparisons
- facilitate efficient resource allocation
- undertake analysis, synthesis and integration of broad Earth System themes

IGBP produces

- data, models, research tools
- refereed scientific literature, often as special journal editions, books, or overview and synthesis papers
- syntheses of new understanding on Earth System Science and global sustainability
- policy-relevant information in easily accessible formats

Earth System Science

IGBP works in close collaboration with the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP), and DIVERSITAS, an international programme of biodiversity science. These four international programmes have formed the Earth System Science Partnership (ESSP). The International Council for Science (ICSU) is the common scientific sponsor of the four international global change programmes.

Participate

IGBP welcomes participation in its activities – especially programme or project open meetings (see meetings list on website). To find out more about IGBP and its research networks and integration activities, or to become involved, visit our website (www.igbp.net) or those of our projects, or contact an International Project Office or one of our 74 National Committees.

Contributions

The Global Change NewsLetter primarily publishes articles reporting science undertaken within the extensive IGBP network. However, articles reporting interesting and relevant science undertaken outside the network may also be published. **Science Features** should balance solid scientific content with appeal to a broad global change research and policy readership. Articles should be between 800 and 1500 words in length, and be accompanied by two or three figures or photographs. Articles submitted for publication are reviewed before acceptance for publication. Items for the **IGBP Network News** may include letters to the editor, short announcements such as new relevant web sites or collaborative ventures, and meeting or field campaign reports. These items should not exceed 250 words.

Photographs should be provided as TIFF or high resolution JPG files; minimum of 300 dpi. Other images (graphs, diagrams, maps and logos) should be provided as vector-based EPS files to allow editorial improvements at the IGBP Secretariat. All figures should be original and unpublished, or be accompanied by written permission for re-use from the original publishers.

The Global Change NewsLetter is published quarterly. The deadline for contributions is two weeks before the start of the month of publication. Contributions should be emailed to the editor.

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