

Appendix 6

Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) Project

A. Introduction

IMBER (www.imber.info) is an international global environmental change research project with the goal to develop a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society. The challenge of the scientific community is to understand inter-relationships between biogeochemical cycles and ecosystems, and to quantify and predict responses of the marine system to natural and anthropogenic perturbations, on time scales ranging from years to decade, with local, regional and global focus.

IMBER research activities are organised around four themes that focus on interactions between biogeochemical cycles and marine food webs, the sensitivity to global change, feedbacks to the Earth System, and responses of society. IMBER research is supported by a network of 35+ national contributions, and by four regional research programmes, seven topical working groups, more than 35 endorsed projects, and a range of approaches to facilitate synthesis and integration, and strategic collaboration with other international research projects, programmes and initiatives.

Since its initiation in 2005, IMBER has placed a priority on coordination and networking activities that bring together diverse research communities to address IMBER research goals. IMBER has accomplished much during its first eight years, as evidenced by the many special issues of peer-reviewed journals and books that have been produced by the working groups and regional programmes (www.imber.info/index.php/Products/Publications).

IMBER is now entering the last two years of its initial 10-year science plan. At the same time, the global environmental change (GEC) research landscape is evolving. The Future Earth initiative, which is focused around three themes (*Dynamic Planet*; *Global Development*; and *Transformations toward Sustainability*), is developing, and the International Geosphere-Biosphere Programme (IGBP), IMBER's other sponsor, will end in December 2015. The transition towards Future Earth is potentially important for all GEC projects such as IMBER. IMBER has a history of undertaking activities that interconnect natural and social marine sciences and promoting integration across disciplines. As a result, the IMBER community is well placed to take the lead on developing the marine-focused efforts under Future Earth and proposing new research directions.

The IMBER Open Science Conference, which will take place in June 2014 in Bergen, Norway (www.imber.info/index.php/Meetings/IMBER-OSC-2014), will be important in developing directions for marine research at the international level for the next 5-10 years. The outputs from the Open Science Conference will provide a basis for a request to SCOR for a five-year project extension in the fall of next year.

A. Selection of IMBER Science Highlights, 2012-2013

Salihoğlu, B., S. Neuer, S. Painting, R. Murtugudde, E.E. Hofmann, J.H. Steele, R.R. Hood, L. Legendre, M.W. Lomas, J.D. Wiggert, S. Ito, Z. Lachkar, G.L. Hunt Jr., K.F. Drinkwater, and C.L. Sabine. 2013. Bridging marine ecosystem and biogeochemistry research: Lessons and recommendations from comparative studies. *Journal of Marine Systems*, 109-110 161-175.

Linked to IMBER IMBIZO II Workshop on regional comparative studies

Oceanic and coastal systems are integrated across space and time scales that span several orders of magnitude and include complex interactions among and within diverse and interlinked communities with implications for biogeochemical cycling. To understand and predict the effects of anthropogenic global change (e.g., warming temperatures, increasing acidification, harvesting resources) on the marine ecosystem, and its responses, there is growing interest in combining information on oceanographic and biogeochemical processes and on organisms and communities, ranging from microbes to higher trophic levels. Comparative studies of similar marine and coastal biomes offer a means to improve our understanding of the sensitivity of the key features of an ecosystem (e.g., habitat quality, food web components, and biogeochemical cycles) to planned and unplanned perturbations at different time and space scales, by bringing attention to the critical processes that differentiate one system from

another and result in differences in ecosystem response to a changing ocean system.

Comparative studies based on long-term observations at fixed time-series stations make it also possible to evaluate long-term changes in the physical and biological environment, such as those driven by climate patterns. Moreover, based on a minimalistic observational framework grounded within a conceptual model, comparative studies could sometimes be a suitable alternative to costly and complex research endeavours designed to provide detailed end-to-end assessment of marine ecosystem status. The understanding gained from these comparative studies allows development of models for investigating of potential future states and predicting responses of present-day marine and coastal ecosystems (Fig. 1).

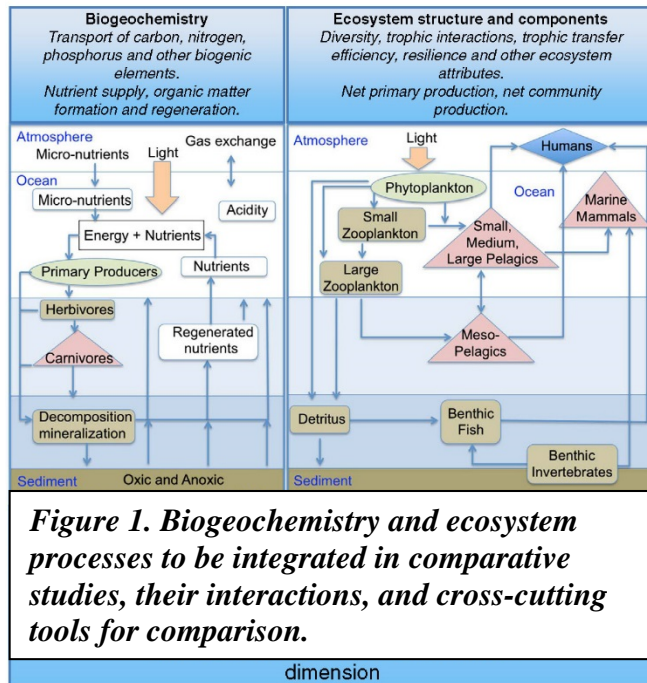


Figure 1. Biogeochemistry and ecosystem processes to be integrated in comparative studies, their interactions, and cross-cutting tools for comparison.

Recently, for improved ecosystem-based management, end-to-end models that combine bottom-up and top-down components have been developed (Table 1). These large, complex models are intended for “strategic management evaluations” of particular ecosystems, rather than comparisons across several systems. An alternative is to combine aggregated versions of existing food-web models of the upper trophic levels, with NPZD formulations of the microbial web, and with simplified representations of the main physical forcing. Cross-ecosystem, multi-model comparisons are difficult to conduct, but essential to evaluate the robustness of the ecosystem responses to climate change and/or anthropogenic forcing. To conduct these kinds of studies, support by international activities such as IMBER is needed. The focus of the IMBER project on interactions and feedbacks between food webs and biogeochemical cycling brings together two areas of marine science that have typically proceeded in parallel, with little cross integration.

The observational and modelling activities now underway through IMBER have a focus on end-to-end ecosystem studies, which is already influencing the structure of models and the types of observations. Within the IMBER regional programmes, comparative studies are underway which are providing synthesis and integration of historical and diverse data sets, the results of which provide a basis for across-region comparative studies. The IMBER focus on comparative studies from the outset will help ensure that the datasets and models are appropriate to undertake these studies. One challenge to the science community is to extend the comparative studies of the natural system to include human, social, economic and cultural effects. The global vision for clean, safe, biologically diverse and productive oceans and seas is the basis for managing sustainable human utilization of the goods and services provided by the seas.

This challenge requires the development of methods/metrics to describe the state of an ecosystem and mechanisms to minimize the impacts of human activities to avoid undesirable disturbances and tipping points. Ecosystem studies typically focus on key linkages between hydrography, pelagic food webs, benthic food webs and higher trophic levels such as fish.

Model	Description
NPZD (Nutrients, Phytoplankton, Zooplankton and Detritus)-type models	Represent lower trophic levels and biogeochemical cycles in marine ecosystems as Eulerian state variables with mathematically specified flows between each compartment.
Ecosim with Ecopath (EwE)	Defines the food web in the form of functional groups representing species and/or groups of species linked by trophic interactions.
ERSEM and ERSEM II	Among the first examples of end-to-end models, fish and seabirds were inclusions in the original models.
NEMURO.FISH	Formed by addition of a fish model to the detailed NPZD (nutrient, phytoplankton, zooplankton, detritus) model NEMURO.
SEAPODYM	A complex example of the coupled approach, which includes a biogeochemical model, vertically structured mesopelagic fish and an age-structured fish population.

Integrated studies of biogeochemistry and food webs need to be underpinned by one or more conceptual models of key ecosystem processes relevant to the study, and identification of the key high level (e.g., policy or societal) and scientific questions to be addressed. Together these can be used to inform field measurements required and the appropriate selection of models and other investigative tools.

New research endeavours should ensure that the results obtained are relevant for regional comparative works, especially as responses of marine ecosystems to global change are expected to differ among biogeographical or biogeochemical provinces. Understanding and defining what these responses might be is critical to the development of mitigation strategies and management policies. Well-designed comparative analyses, based on observations, models or both should be applied within and across ecosystems. As such, they provide an approach for identifying key processes and constraining the range of potential ecosystem responses.

Table 1. Examples of models combining (green-shaded) lower (light blue, top) and higher (light blue, bottom) trophic levels suitable for comparative studies.

ATLANTIS	<p>focusing on top predators.</p> <p>Involves the explicit inclusion of physical and biogeochemical system components to higher trophic levels and incorporates the potential to consider human dynamics in some detail.</p>
OSMOSE	A multispecies and Individual-based model (IBM) which focuses on fish species.
Multispecies Virtual Population Analysis (MSVPA) model	A trophic dynamics model focusing on interactions between fish species within exploited communities

Bakker, D.C.E., B. Pfeil, K. Smith et al. 2013. An update to the Surface Ocean CO₂ Atlas (SOCAT version 2). *Earth System Science Data Discussion*, 6, 465-512.

[DOI:10.5194/essdd-6-465-2013](https://doi.org/10.5194/essdd-6-465-2013)

Linked to the SOLAS-IMBER Carbon – ‘Surface Ocean System’ and ‘Interior Ocean Carbon’ Groups

As a result of a large, international, collaborative effort of the marine carbon research community, the Surface Ocean CO₂ Atlas (SOCAT, www.socat.info) project was initiated in 2007 with the aim of providing a comprehensive, publicly available, regularly updated, quality-controlled, global data set of marine surface carbon dioxide measurements for the global oceans and coastal seas, following internationally agreed procedures and regional review. In addition, SOCAT gives open access to a 1° latitude by 1° longitude gridded product of mean monthly surface water *f*CO₂ (fugacity of carbon dioxide) data with minimal temporal or spatial interpolation and with a higher 0.25° latitude by 0.25° longitude resolution for the coastal seas.

The culmination of much hard work in data collection, data assembly and quality control by many seagoing marine carbon scientists around the world, SOCAT version 2, with 10.1 million surface water *f*CO₂ values from 2,660 cruises spanning more than four decades (Nov. 1968 – Dec. 2011), was presented publicly in June 2013 at the 9th International Carbon Dioxide Conference (ICDC-9) in Beijing, China (Figs. 2, 3).

The SOCAT products highlight the response of surface water *f*CO₂ and the oceanic CO₂ sink to increasing levels of atmospheric CO₂ in a changing climate, and are used in process studies of spatial and temporal (seasonal, inter-annual and decadal) variability and trends in surface water *f*CO₂, for example, in the North Atlantic, in the Pacific

Ocean, in coastal seas, in the Arctic Ocean, in seasonally ice-covered Southern Ocean regions, near remote islands and oceanographic fronts.

The international importance of SOCAT is evident from the many recent scientific articles using SOCAT data products for quantification of the ocean carbon sink, process studies and ocean carbon modelling. Applications of SOCAT include process studies, quantification of the ocean carbon sink and its spatial, seasonal, year-to-year and longer-term variation, as well as initialisation or validation of ocean carbon models and coupled-climate carbon models.

Regular updates to SOCAT will extend its data record, improve its quality control, and will become a crucial tool in quantification and modelling of changes in oceanic CO₂ uptake and in global climate change research and assessments. Regular future SOCAT releases will require sustained funding for key players.

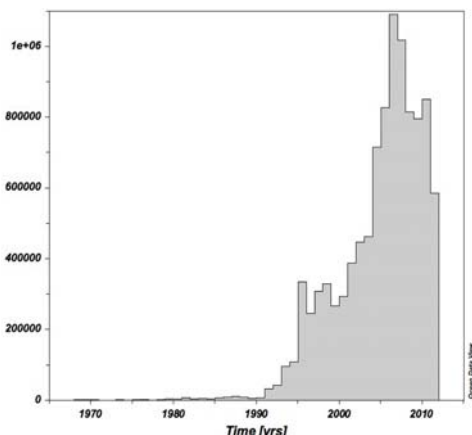


Figure 2. Number of annual data points for the 1968-2011 period included in SOCAT v.2

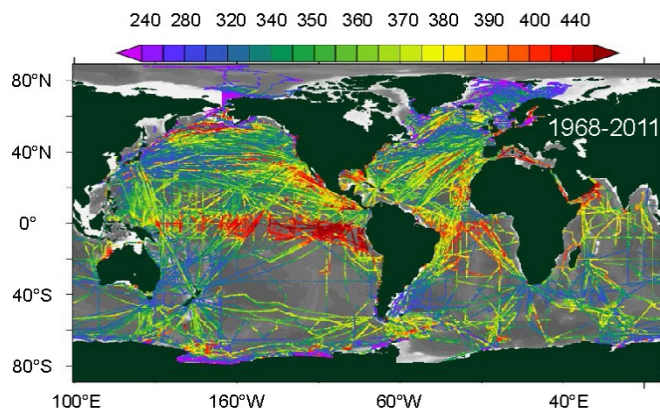


Figure 3. The global distribution of surface water fCO₂ values in SOCAT v.2 for 1968 to 2011 (from Bakker et al. (2013), *ESSDD*, 6, 465–512)

Gaichas, D., R. Gamble, M. Fogarty, H. Benoit, T. Essington, C. Fu, M. Koen-Alonso, and J. Link. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. *Marine Ecology Progress Series*, 459, 275-292.

Linked to the IMBER ESSAS regional programme

The concept of biological production has long served as a cornerstone in the development of the theory of resource management. An early focus on this issue in fisheries management research distinguished it from other approaches in population biology in the emerging field of ecosystem-based fisheries management (EBFM) that emphasizes sustainability at multiple levels of organization beyond single target species. Biological reference points (BRPs) for aggregated specific groups are then required, that help optimize yields while preventing overexploitation of individual species. The tradeoffs between yield and biodiversity objectives must be evaluated for a wide range of aggregation strategies using multi-species surplus production models and comparing several simulated fish communities.

Fish production parameters and BRPs (e.g., maximum sustainable yield, MSY) were estimated using a simple assessment model applied to each aggregated time series. Multi-species precautionary reference points could be defined that meet both yield and biodiversity objectives across full system, taxonomic, habitat, feeding, and size-based aggregations. Aggregation strategies were best able to meet both objectives when species with broadly similar productivity, life history, environmental sensitivity, and species interactions were aggregated. Implementation of EBFM requires a better understanding of the consequences of stock-aggregate management in achieving the maximization of sustainable fishery yields and biodiversity, that is, the prevention of collapse or extinction. The simulation modelling of hypothetical fish communities make it possible to explore how the estimation of BRPs at different levels of species aggregation affects the simultaneous achievement of the objectives of yield and of biodiversity, that is, maintaining ecosystem structure (Figs. 4, 5).

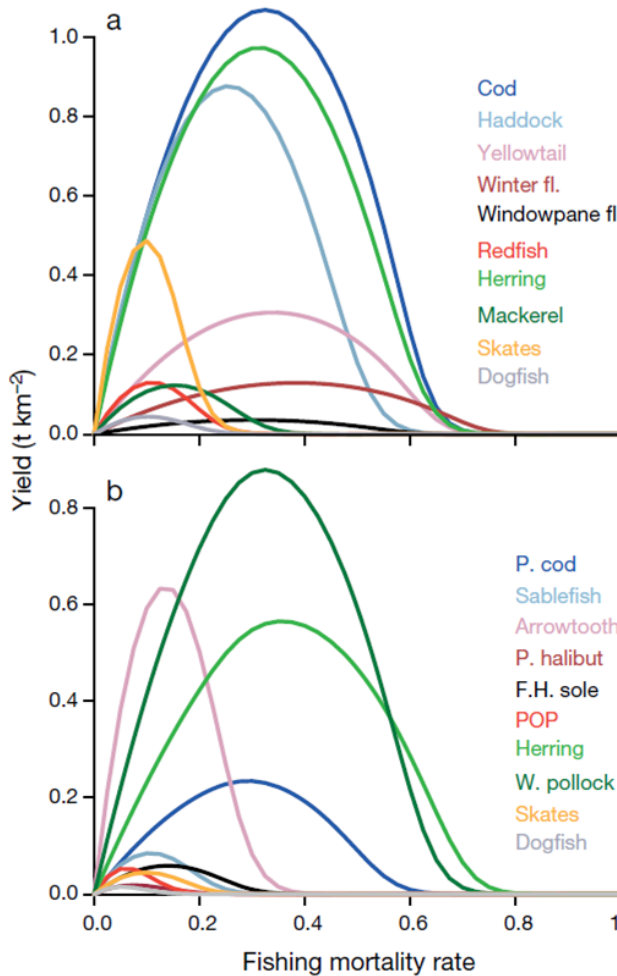


Figure 4. Yield curves for simulated 10-species interacting fish communities: (a) Georges Bank; (b) Gulf of Alaska; comparable species have similar colours. fl.: flounder; P.: Pacific; F.H.: flathead; W.: Walleye

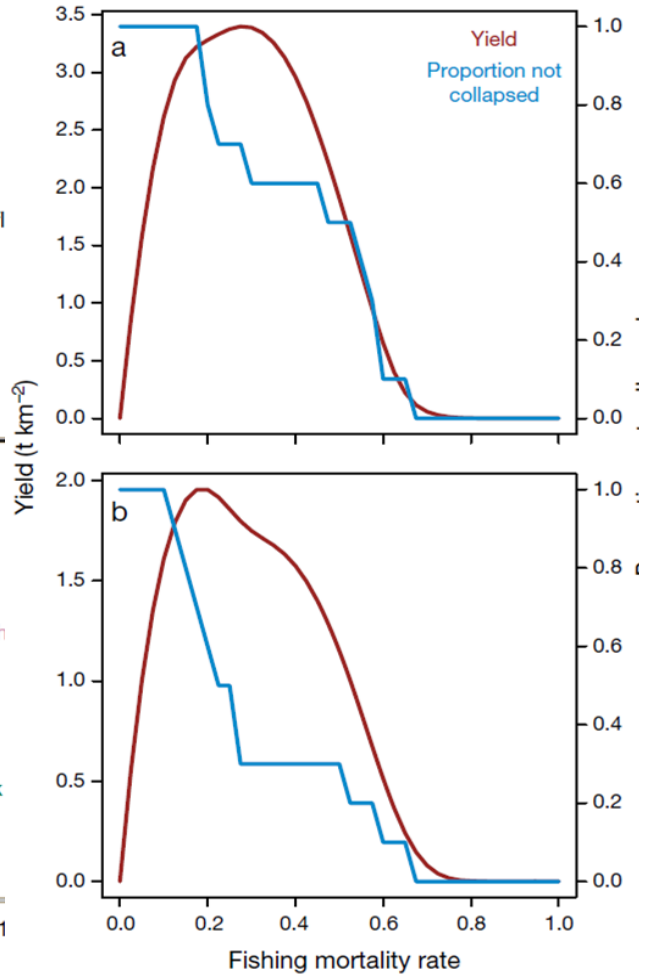


Figure 5. Full 10-species system aggregate yield and collapse curves (where collapse is defined as biomass <10% of unfished biomass) for (a) Georges Bank; (b) Gulf of Alaska

Management considerations based on simple extensions of traditional single-species production models provide one avenue for recasting the harvesting problem in a context that is familiar to fishery managers while accommodating a broader multi-species perspective, particularly for those stocks that are caught together in multi-species fisheries, interact highly, or have similar production characteristics. It is possible to achieve multiple EBFM objectives by managing aggregate species groups. And our simple assessment method estimated BRPs reasonably well for many species and aggregates without explicitly including species interactions, but showed some bias even with the high-quality simulated ‘data’ we used. However, poor aggregations sacrifice biodiversity for yield, leading to severely depleted (or extinct) stocks within the aggregate, as well as more subtle effects such as loss of genetic diversity. In managing species complexes, it appears that modest reductions from aggregate fishing mortality rate at MSY have the dual benefits of maintaining biodiversity and buffering against environmental uncertainty (Figs. 6, 7).

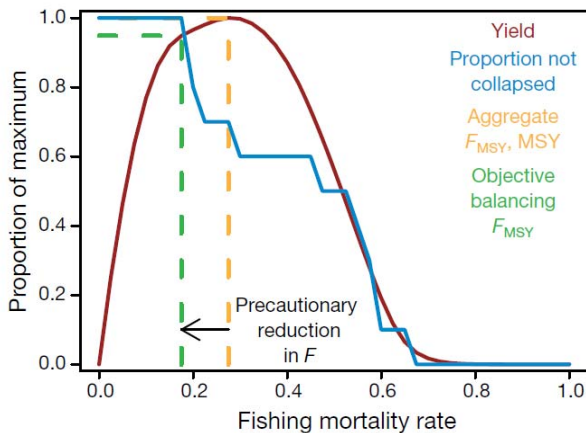


Figure 6. In multispecies complexes, fishing mortality rate F can be reduced from aggregate F_{MSY} (MSY , maximum sustainable yield) to prevent collapses. For the full 10-species Georges Bank model, nearly 95% of MSY can be achieved with no species dropping below 10% of unfished biomass

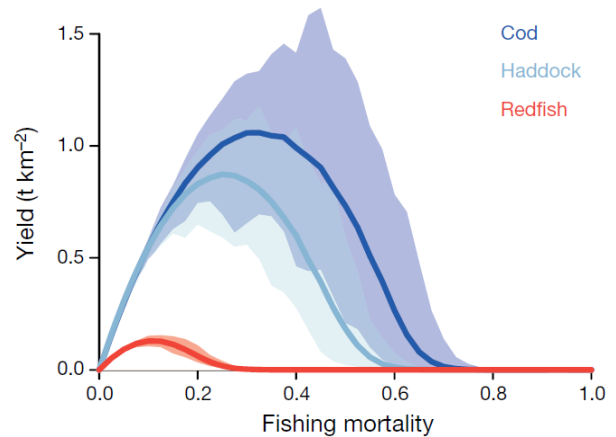


Figure 7. Average yield curves (lines) with ranges (shading) from 1000 stochastic runs for the Georges Bank groundfish complex

Glaser, M., P. Christie, K. Diele, L. Dsikowitzky, S. Ferse, I. Nordhaus, A. Schlüter, K. Schwerdtner Mañez, and C. Wild. 2012. Measuring and understanding sustainability-enhancing processes in tropical coastal and marine social-ecological systems. *Current Opinion in Environmental Sustainability*, 4, 300-308.

Linked to IMBER HDWG and CMWG activities

Tropical coastal and marine social-ecological systems (CM-SES) are diverse, complex and dynamic, facing special challenges as hotspots of biodiversity and centres of population growth, with high rates of direct human dependence on natural resources and a great diversity of stakeholders, institutions and scales of processes. CM-SES are also frequently beset by poverty, conflict, human security and well-being problems, weak social policy regimes and globalization-related economic and cultural pressures. Bio-geophysical and social vulnerabilities reinforce each other. In a collaborative effort between natural and social scientists, a number of processes have been identified that drive desirable social-ecological dynamics, link the debates on ecosystem services and social-ecological systems analysis and offer a framework for identifying key social-ecological processes. The social-ecological systems (SES) framework highlights the complex feedbacks between humanity and nature which can create unsustainable dynamics such as over- and destructive fishing, coastal erosion and pollution and undesirable outcomes such as degraded ecosystems and impoverished ecosystem users (Fig. 8).

Indicators are required to help identify the processes in a system, its state evolution and its management needs. Single measurements of state indicators show a system's position along multiple axes, while process indicators assess and explain its trajectory and speed of change. Sustainability science focuses on the state of such systems and mostly analyses undesirable social-ecological outcomes. Sustainability objectives need to be negotiated between disciplines and stakeholders and effective monitoring needs to create transparency on processes and outcomes. Social-ecological sustainability in CM-SES is closely linked to system resilience and capacity to transform, but identification of the conditions under which sustainable human-nature feedbacks occur requires greater attention. Undesirable processes such as ocean acidification, over-fishing, biodiversity loss, and nutrient and chemical pollution drive oceanic and coastal systems to and beyond sustainability thresholds and must therefore also be a focus of scientific attention. Indicators on key, and often context-specific, ecological, socio-economic, and social-ecological processes are needed to provide meaning to regular measurements of system state by allowing for an understanding of the underlying causes of identified system changes.

More comparative research on sustainability policy is required, including the linkages between research, policy making, and stakeholder decision-making. As social-ecological analyses become more complex and increasingly global, stakeholder engagement in analysis and decision-making needs to expand, and research and policy-making need to diversify ways of actively engaging stakeholders at multiple levels.

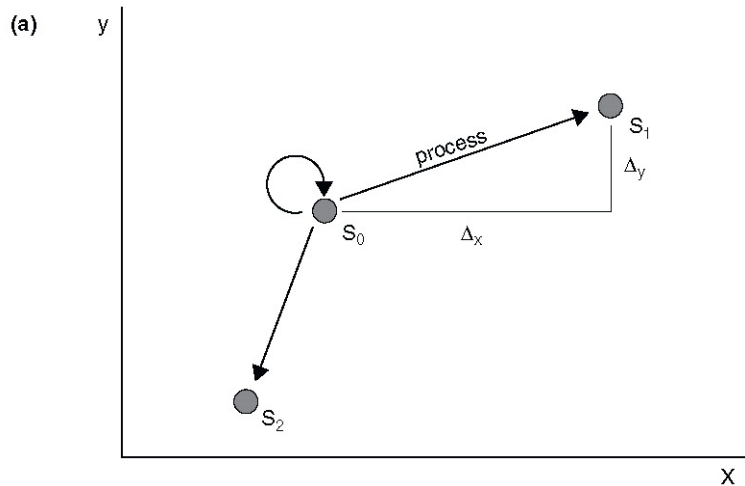
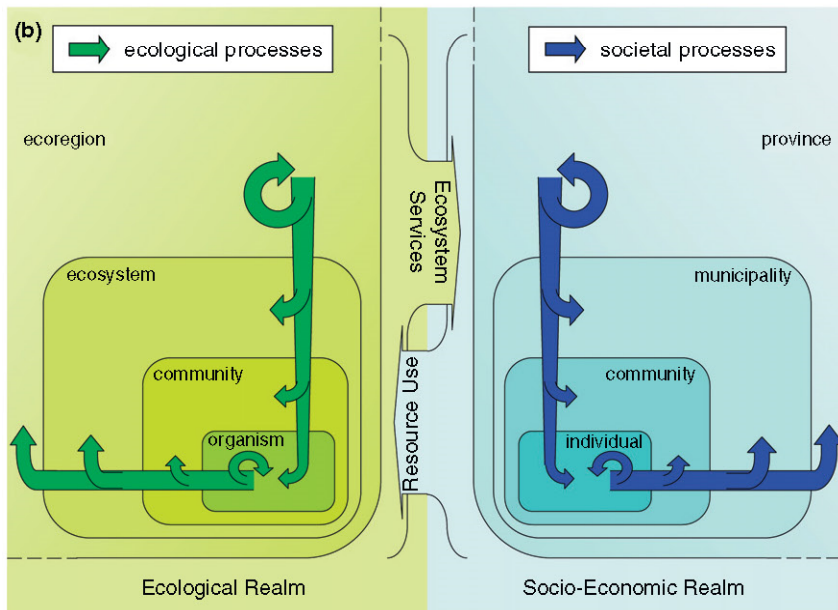


Figure 8

(a) System status (S_0 , S_1 , S_2) and processes of change. Only two axes are presented but n dimensions are theoretically possible in the coordinate system. Processes (defined as change over time) are indicated by deltas / arrows. A process can maintain or alter the system state.

(b) Realms of a social-ecological system contain multiple levels, and the processes connecting them. Shown system levels are exemplary and extendable to include further lower or higher levels. Social-ecological systems analysis needs to identify the important components and processes of the system under study by applying indicators.



B. IMBER Regional Programmes

Ecosystem Studies of Sub-Arctic Seas (ESSAS) Regional Programme

The ESSAS programme (www.imr.no/essas) focuses on the impacts of climate change on sub-Arctic marine ecosystems and their sustainability. The ESSAS Annual Science Meeting (January 2013, Hakodate, Japan) entitled, ‘*Spatial Dynamics of Subarctic Marine Ecosystems*’ focused on bioenergetics of sub-polar fish species; Arctic-Subarctic interactions; human dimensions of Subarctic seas exploring fisheries and fishing communities; and future directions and activities of ESSAS.

At the annual ESSAS SSC meeting, also held in January 2013, Dr. Sei-Ichi Saitoh (Hokkaido University, Japan) was appointed as the third SSC co-chair, the ‘*Working Group on Bioenergetics of sub-Arctic fishes*’ was launched, and three new Working Groups (*Human Dimension*, *Comparative Paleo-Ecology in Sub-Arctic Seas* and *Arctic-Subarctic Interactions*) were accepted for further development.

ESSAS held a joint workshop with the IMBER ICED programme in May 2012, in Yeosu, Korea during the 2nd ICES/PICES/IOC International Symposium on, *Effects of Climate Change on the World's Oceans*. This workshop, *Effects of climate change on advective fluxes in high latitude regions*, reviewed the role of advection on the ecology of these high-latitude regions, including heat and nutrient fluxes as well as the advection of flora and fauna, and developed likely scenarios of these advective fluxes under climate change, and comparative studies of the responses in the Arctic and Antarctic regions.

ESSAS also organised sessions on, *Subarctic-Arctic Interactions: Ecological Consequences*, at the ICES Annual Science Conference (September 2012, Bergen, Norway) and the PICES Annual Meeting (October 2012, Hiroshima, Japan). These examined the influence of water exchange between the Arctic basin and surrounding shelves, and the warmer sub-Arctic basin on the physical and biological/ecological conditions in the two regions.

www.ices.dk/iceswork/asc/2012/themesessions/Abstracts%20Session%20M_ED.pdf and
www.pices.int/meetings/annual/PICES-2012/2012-background.aspx

The 28th Lowell Wakefield Fisheries Symposium, *Responses of Arctic Marine Ecosystems to Climate Change* (March 2013, Anchorage, Alaska), organized by Franz Mueter (ESSAS co-chair) focused on present and future responses of Arctic marine ecosystems to climate change at all trophic levels, from plankton to marine mammals to humans.

ESSAS-related publications include several papers, special issues, and special sections in the *ICES Journal of Marine Science*, *Marine Ecology Progress Series*, *Deep Sea Research Part II: Topical Studies in Oceanography* and *Progress in Oceanography*; derived from the ESSAS-related projects (ISE, BEST/BESIRP, TROPHARCT, NORCAN, MENUUI, CAMEO and CANUSE) and from the May 2011 ESSAS OSM; and focusing on topics such as subarctic fish and crustacean populations - climate effects and trophic dynamics; comparative analysis of marine fisheries production; understanding ecosystem processes in the eastern Bering Sea; and harvested fish stocks in a changing environment. A special volume of *Progress in Oceanography* dedicated to former ESSAS SSC member, Bernard Megrey, is in preparation on the theme "Modeling and observational approaches to understanding marine ecosystem dynamics".

Future ESSAS activities:

- The ESSAS ASM and SSC meeting will be held in April 2014 in Copenhagen, Denmark.
- ESSAS will convene a session on "*Changing ecosystems in sub-Arctic and Arctic regions*" at the **IMBER OSC** in June 2014, Bergen, Norway.

Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) Regional Programme

The ICED programme aims at a better understanding of the climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of sustainable management procedures. See www.iced.ac.uk/index.htm

During the IPY 2012 Conference (April 2012, Montreal, Canada), ICED scientists co-convened a session on *'Polar marine ecosystems: status and change'*, that focused on advances in research in polar marine ecosystems, particularly those relating to IPY. ICED scientists were also prominent at the Polar Educators workshop, APECS workshop and at discussion panels.

As mentioned above, an ESSAS-ICED workshop at the 2nd ICES/PICES/IOC International Symposium (May 2012, Yeosu, Korea) compared the Arctic and sub-Arctic sectors for the Atlantic and Pacific and the Antarctic regions, with particular emphasis on the role of advection.

ICED sponsored the *'Southern Ocean Sentinel'* Workshop (May 2012, Hobart, Australia), to help develop the *'Southern Ocean Sentinel Monitoring'* programme entitled *'Southern Ocean Ecosystem Change and Future Projections'*. It focused on the state of Southern Ocean food webs, how these might change in the future, and how to measure the specific impacts of climate change and ocean acidification.

During the XXXII SCAR Open Science Conference, July 2012, Portland, USA, a multidisciplinary ICED session was organised on *'Understanding the response of Southern Ocean ecosystems to climate change and exploitation'*.

In the framework of the EUR-OCEANS flagship programme on *'Polar Ecosystem Change and Synthesis'* (PECS),

the European branch of ICED held two workshops on “*Identifying key links between biogeochemical processes and food web structure*”, in November 2012, Bremerhaven, Germany and in May 2013, Brussels, Belgium, to further discuss the coordination, integration and leadership of polar marine ecosystem science within Europe, and to develop a strategic briefing entitled “Polar Marine Ecosystems Research: Strategic directions for the EU Research Area”. This document highlights why research on polar marine ecosystems should be an essential component of the EU Research Area through the Horizon 2020 Work Programmes, and promotes collaborative research within Europe and internationally. www.eur-oceans.eu/sites/default/files/activities/2011/25935/Strategy%20EU%20Polar%20MER.pdf

ICED-related Publications include several papers, special issues, and special sections in *Nature Geoscience*; *Global Change Biology*; *Annual Review of Ecology, Evolution, and Systematics*; *Deep Sea Research Part II: Topical Studies in Oceanography*; *Marine Ecology Progress Series*; *Journal of Marine Systems*; *Progress in Oceanography*; *Current Opinion in Environmental Sustainability* and *Deep Sea Research Part I: Oceanographic Research Papers*; along with several contributions to the 2012 book entitled “*Antarctic Ecosystems: An Extreme Environment in a Changing World*” ([DOI:10.1002/9781444347241](https://doi.org/10.1002/9781444347241)).

Future ICED activities:

- An ICED workshop on “*Circumpolar food webs and scenarios of change*” will be held in Cambridge, UK, November 2013.
- ICED will convene a session on “*Detecting, projecting and managing the impacts of change in Southern Ocean ecosystems*” at the **IMBER OSC** in June 2014, Bergen, Norway.
- The re-development of the online fieldwork map tool is underway, and a Southern Ocean wiki is under development, led by the ‘Sentinel’ programme.

CLimate Impacts on Oceanic TOP Predators (CLIOTOP) Regional Programme

The CLIOTOP programme aims to use a worldwide comparative approach to identify the impact of both climate variability and fishing on the structure and function of open ocean pelagic ecosystems and their top-predator species. See www.imber.info/CLIOTOP.html

The 2012 CLIOTOP SSC meeting held in September 2012 in Hobart, Australia, reviewed the progress of the CLIOTOP working groups, including synthesis publications, database development, analytical tools, dedicated workshops, and conference sessions and presentations. Olivier Maury stepped down as CLIOTOP SSC co-chair but remains as an SSC member, and has been replaced as CLIOTOP co-chair by Kevin Weng, University of Hawaii, USA, from January 2013.

The 2013 CLIOTOP SSC meeting and the 2nd CLIOTOP Symposium focusing on ‘*Certainty of change in pelagic systems – detection, attribution, and prediction*’ were held in February 2013, Nouméa, New Caledonia. The symposium brought together experts with different physical, biological, social perspectives to discuss cross-cutting themes such as ‘*Blue economy – what role for pelagic species and ecosystems?*’; ‘*Pelagic conservation-fisheries management conflicts – maximising dual objectives*’; ‘*Pelagic-coastal linkages – food and conservation*’ (www.imber.info/index.php/News/Newsletters/Issue-n-23-April-2013).

In an attempt to align CLIOTOP’s overall plan and working group objectives with the goals of IMBER as earlier requested by the IMBER SSC, the CLIOTOP SSC is taking a more applied outcome-oriented approach that should also be more compatible with national funding initiatives. Indeed, national programmes remain the dominant source of funding, which have limited several of the global comparative approaches proposed by CLIOTOP. In some countries, the focus of global change research is shifting from understanding the impacts of climate change to developing adaptation options. Consequently, developing adaptation options for open ocean and fisheries management bodies are likely to become a major focus beyond the current phase of CLIOTOP research. The CLIOTOP SSC also recognized that the connections with the activities of the other IMBER regional programmes relevant to research on top predators should be improved.

A CLIOTOP-associated session on ‘*Interdisciplinary Approaches to Cephalopod Biology*’ was organised at the ‘Cephalopod International Advisory Council’ Symposium, in October 2012, Florianópolis, Brazil.

CLIOTOP-related publications include several papers, special issues, and special sections in *Climatic Change*; *Deep Sea Research Part II: Topical Studies in Oceanography*; *Journal of Marine Systems*; *Reviews in Fish Biology* and

Fisheries; Aquaculture Environment Interactions; and Fish and Fisheries, and focusing on topics such as: Climate and oceanic fisheries; Squids and top predators.

Future CLIOTOP activities:

- A special issue of *Deep Sea Research Part II: Topical Studies in Oceanography* is in preparation following the 2nd CLIOTOP Symposium.
- CLIOTOP will convene a workshop entitled “*Beyond ‘Z’: what modelers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models*” and a session on “*The pivotal role of the mesopelagic functional groups in biogeochemical cycles*” at the IMBER OSC in June 2014, Bergen, Norway.
- The 3rd CLIOTOP Symposium is scheduled for June 2015.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) Regional Programme

SIBER (co-sponsored by the Indian Ocean Global Ocean Observing System, IOGOOS), is the newest IMBER regional programme, and focuses on understanding climate change and anthropogenic forcing on biogeochemical cycles and ecosystems in the Indian Ocean (www.imber.info/index.php/Science/Regional-Programmes/SIBER and www.incois.gov.in/Incois/siber).

The 3rd SIBER SSC meeting took place in October 2012 in Cape Town, South Africa, in conjunction with the Chapman Conference on the Agulhas Current System, in close liaison with CLIVAR Indian Ocean Panel (IOP), IOGOOS and the IndOOS Resource Forum (IRF), and to help reaching out to the relevant South African research community. The 4th SIBER SSC meeting took place in July 2013, Lijiang, China, again in close liaison with the CLIVAR IOP.

SIBER organised a session on ‘*Physical and biogeochemical processes in the Indian Ocean: Recent progress and toward future collaborations*’ during the Asia Oceania Geosciences Society (AOGS) – AGU Western Pacific Geophysics Meeting (WPGM) Joint Assembly meeting in August 2012, Singapore.

The SIBER mid-term symposium will be held in 2015, in conjunction with the 50th anniversary celebration of the International Indian Ocean Expedition (IIOE-2) (www.incois.gov.in/Incois/iioe/index.jsp and http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=11117).

SIBER researchers are making substantial contributions to the design and deployment of the Indian Ocean Observing System (IndOOS) / Research moored Array for African-Asian-Australian Monsoon Analysis and prediction (RAMA) for physical and biogeochemical observatories. Biogeochemical sensors deployed at a few sites have already provided data that was presented at the AOGS 2012 meeting, and in late 2013, additional biogeochemical sensors will be deployed at two other reference sites, provided by the Bay of Bengal Large Marine Ecosystem (BOBLME) project and by NOAA/RAMA. Under the IOGOOS framework, relevant activities also focus on issues of local or global importance, such as monsoons and ENSO, and also include capacity building, modelling and forecasting.

Efforts are proceeding to establish and support a SIBER Regional Office in Australia, sponsored by the Australia’s Integrated Marine Observing System (IMOS) and the IOC Perth Office.

Overall, SIBER has strong collaboration with various regional actors (e.g., Indian Ocean Panel of the Variability and predictability of the ocean-atmosphere system project CLIVAR, and IOGOOS) and in this respect has developed a useful model for CLIVAR-IMBER collaboration.

Future SIBER activities:

- A SIBER special issue of *Biogeosciences* is in preparation on *Current biogeochemical and ecosystem research in the Northern Indian Ocean*. This will highlight results of benthic and pelagic process studies in the Arabian Sea, and more recently the Bay of Bengal and Andaman Sea, coastal studies in the Northern Indian Ocean, and numerous physical and biogeochemical modelling studies relevant to the wider Indian Ocean.
- SIBER will convene a workshop entitled, ‘*Eastern Indian Ocean upwelling research initiative planning Workshop Phase 3: physical dynamics and ecosystem responses*, and a session on ‘*Biogeochemical and ecological impacts of boundary currents in the Indian Ocean*’ at the **IMBER OSC in June 2014**, Bergen, Norway.

C. IMBER Working Groups and Task Teams

SOLAS-IMBER Carbon (SIC!) Working Group

To oversee the marine carbon process studies, there are currently three joint SOLAS-IMBER carbon (SIC!) groups dealing with carbon in the surface ocean systems (SOS), carbon in the interior ocean (IOC) and ocean acidification (SIOA). A proposal submitted by the SCOR Working Group 134 on 'The Microbial Carbon Pump in the Ocean', to develop a new SIC! activity focusing on dissolved organic carbon production, transformation and storage was not accepted by the IMBER SSC. However, it was suggested that the remit of the existing SIC! Working Groups could be revisited to incorporate this topic, its possible interactions with the existing SIC! WGs, and potentially improve the studies of the various forms, sources, sinks and interactions of all pools of organic matter. It was also agreed that this should be done in collaboration with SOLAS and GEOTRACES.

Surface Ocean Systems (SIC!-SOS)

This working group focuses on data synthesis for the carbon in the surface ocean systems (SOS), and on instrumentation and technology development, Voluntary Observing Ships (VOS) and mixed layer sampling strategy.

The Surface Ocean CO₂ Atlas (SOCAT, www.socat.info) was first presented at the 'Ocean Carbon Cycle at a Time of Change: Synthesis and Vulnerabilities' meeting, convened by SIC!-SOS, SIC!-IOC and IOCCP in 2011. The updated SOCAT v.2 was released at the 9th International CO₂ Conference (ICDC-9) in June 2013, Beijing, China. (see also the science highlight above). This atlas is a publicly available, high-quality dataset that can be used for: (i) process studies, (ii) quantifying ocean carbon sinks and its seasonal, year-to-year, decadal variation; and (iii) initialization and validation of ocean carbon cycle models. Regular updates are planned, and work has already commenced on SOCAT v.3. This will become a keystone dataset for carbon cycle science and is worthy of support.

A new activity supported by the SIC!-SOS is now underway which focuses on the comparison of different techniques for mapping pCO₂ in the global ocean. This effort also builds on the Regional Carbon Cycle and Process (RECCAP, www.globalcarbonproject.org/reccap) project which is now finalising a special issue of *Biogeosciences* (www.biogeosciences-discuss.net/special_issue83.html).

Future SIC!-SOS activities:

- A meeting with members of the Southern Ocean Observing System (SOOS, www.soos.aq) on the science of detecting change in the high-latitude ocean is being considered.
- SIC!-SOS members will co-convene, with SIC!-IOC and IOCCP, a session on 'The ocean carbon cycle at a time of change: Data syntheses, analyses and modelling' at the IMBER OSC in June 2014, Bergen, Norway. It aims to focus on surface-to-interior connections.

Interior Ocean Carbon (SIC!-IOC)

This working group co-ordinates international research on interior ocean changes in carbon and biogeochemistry, undertakes synthesis activities, and aims to develop sustainable observing systems, including the addition of oxygen sensors to the international ARGO float programme (ARGO-O₂).

A new SCOR Working Group 'Quality Control Procedures for Oxygen and Other Biogeochemical Sensors On Floats and Gliders' (http://scor-int.org/Working_Groups/wg142.htm), proposed by members of SIC!-IOC, was launched this year. Measuring dissolved oxygen from profiling floats adds greatly to our understanding of both physical and biogeochemical process. To date, almost 300 floats carrying dissolved oxygen sensors have been deployed, in the Pacific, the Southern Ocean and the tropical and subpolar Atlantic. The development and deployment of other biological sensors are also on-going for a "full Bio-Argo" network.

Several SIC!-IOC-related sessions were organised at the 9th International CO₂ Conference (ICDC-9) in June 2013, Beijing, China.

Currently, the focus of SIC!-IOC is to move forward with the inter-comparison study of the different methods to determine the changes in carbon in the ocean's interior (Fig. 9), and especially the global-scale oceanic accumulation of anthropogenic CO₂ since the 1990s. In this respect, the global synthesis of repeat hydrography, mainly based on work from the CARINA and PACIFICA projects, is on-going. Progress has been slower than anticipated, due to data quality control issues, but the aim is to complete it in 2014.

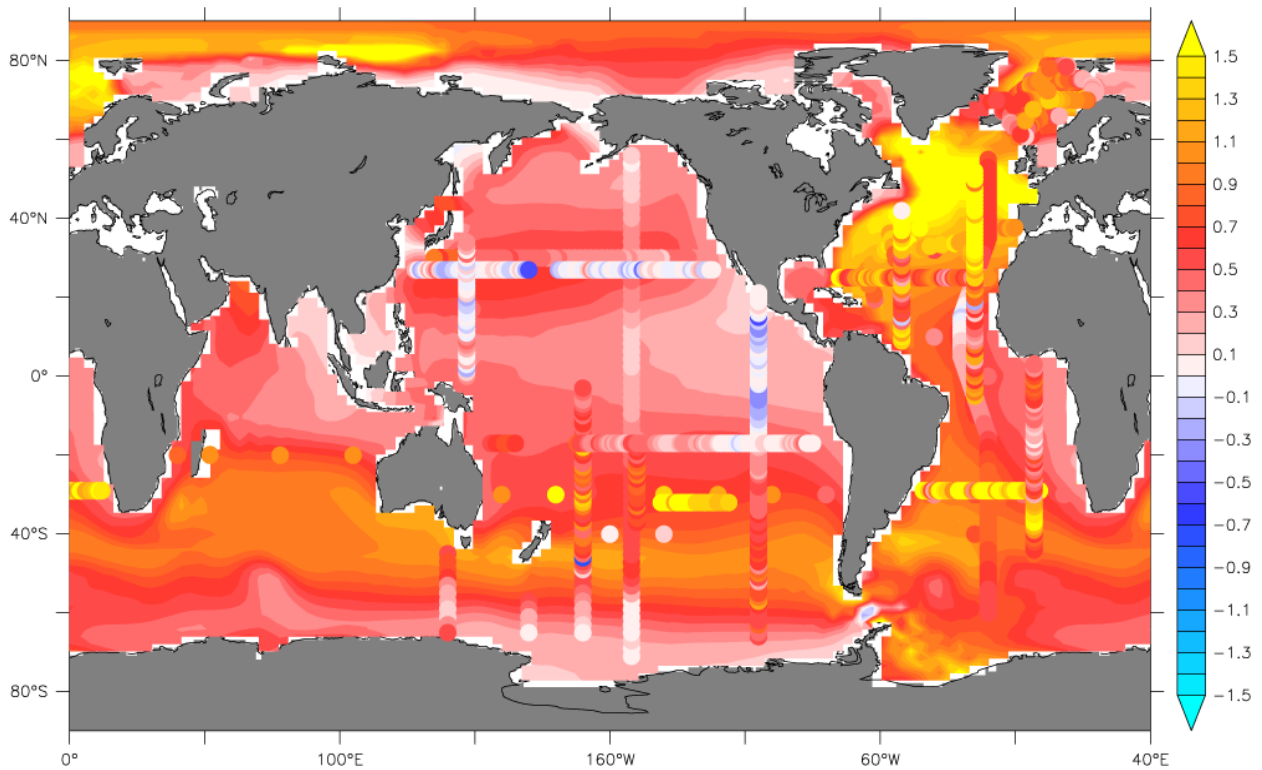


Figure 9 Interior trends of anthropogenic CO₂: It appears that an Atlantic-versus-Pacific pattern emerges clearly, but substantial differences exist between different methods. after Gruber et al. (unpublished, 2012), in mol m⁻² yr⁻¹

Future SIC!-IOC activities:

- The 3rd SIC!-IOC WG meeting will be held in conjunction with the ASLO/TOS/AGU 2014 Ocean Sciences Meeting in February 2014, Honolulu, Hawaii, USA.
- SIC!-IOC will convene, in partnership with SIC!-SOS and IOCCP, a session on “*The ocean carbon cycle at a time of change: Data syntheses, analyses and modelling*” at the IMBER OSC in June 2014, Bergen, Norway.

Ocean Acidification (SIOA)

This working group co-ordinates international research efforts and synthesis activities in ocean acidification. Within a single decade, ocean acidification has grown from involving only a few scientists to a research topic that has recently been considered the #1 research front in ecology and environmental sciences. While exciting, this rapid expansion has not been without its problems. For example, it has not been easy for experts to share information and train newcomers from different countries, which is essential to avoiding unnecessary duplication.

The SIOA was instrumental in the establishment of the *Ocean Acidification - International Coordination Centre (OA-ICC)* in summer 2012, IAEA's Environment Labs, Monaco, in coordination with the Ocean Acidification Reference Users Group (OA-RUG). Its goals are to foster international scientific collaboration, promote best practices, improve observational capacities and databases, and facilitate communication, outreach and synthesis (see www.iaea.org/nael/OA-ICC and <http://news-oceanacidification-icc.org>).

The first OA-ICC Advisory Board meeting, chaired by SIOA member Carol Turley, included all SIOA members and other representatives (including the IMBER Chair, Eileen Hofmann), and was held in May 2013 in Monaco, following the SIOA meeting. The focus of the meeting was to discuss and organise future activities. The scientific credibility of the OA-ICC relies almost entirely on the SIOA. Through the recent interactions between OA-ICC staff and the SIOA Chair, Jim Orr, also OA-ICC Scientific Coordinator, the SIOA set the priorities and what should be done, also taking into account the context of the IAEA, host institution of the OA-ICC. To be cost effective, the current SIOA membership will most likely be maintained without changes until December 2015.

Future SIOA and OA-ICC activities:

- SIOA members will convene a session on “*Regional responses to climatic and non-climatic drivers in a high-CO₂ ocean*” at the IMBER OSC in June 2014, Bergen, Norway.
- OA-ICC has already begun to promote a series overarching international activities to serve not only the scientific community but also science users, including policy makers, media, and the general public. Recent and ongoing OA-ICC activities include: (1) helping to run an international exhibition stand that highlighted ocean acidification at the UNFCCC COP18 Climate Change Conference, in November 2012, Doha, Qatar; (2) running a comparison exercise for 7 publicly available packages that compute marine carbonate chemistry, in collaboration with IOCCP, and (3) supporting the 2nd International Workshop of the Global Ocean Acidification Observing Network (GOA-ON) held in July 2013, St. Andrews, UK, www.pmel.noaa.gov/co2/GOA_ON/2013; and the 6th SOLAS summer school to be held in Aug.-Sept. 2013, Xiamen, China, <http://mel.xmu.edu.cn/solassummerschool/>.
- During the next year, OA-ICC will also organize or help organize several workshops, including a GOA-ON observational workshop, a natural-social science connection workshop, an OA data curators' workshop, a OA-related capacity building workshop in South America), and further promote international collaboration and sharing of international ocean acidification research platforms and facilitating exchanges of early-career researchers.

Continental Margins Working Group (CMWG)

The joint IMBER-LOICZ CMWG held its first meeting in June 2012, Halifax, Canada. It was decided to rename the group the Continental Margins Working Group because, unlike its predecessor, the Continental Margins Task Team (CMTT), which was tasked only with drafting the Continental Margins Implementation Plan, the group has multiple responsibilities. These include convening the ‘*Biogeochemistry-ecosystem interactions on changing continental margins*’ workshop at IMBIZO III and revising the Science Plan and Implementation Plan (SPIS) drafted by the CMTT in order to develop a new strategy for continental margins research in light of the Grand Challenges in earth system science research for global sustainability.

The 2nd CMWG meeting was held in January 2013 in Goa, India. A strategic paper “*Living on the Margin in the Anthropocene: from Frontier to Engagement Arenas for Global Sustainability*” is in preparation for submission to a peer-review journal (see Fig. 10).

The SPIS for CM research will be structured according to this paper, to fit the requirements of the Future Earth Initiative and to facilitate the transition of on-going CM projects into this transdisciplinary research phase. Material from the original draft may be repackaged into the new structure, but new material is also needed, especially, on the human dimensions.

During the IMBIZO III continental margins workshop it was recognized that specifically developed models would provide guidance to effective governance of social-ecological systems on CMs, which in turn would rely on communication and mutual understanding of the issues and capabilities of social and natural scientists.

Future CMWG activities:

- CMWG members and colleagues will convene two sessions on “*Impacts of anthropogenic stressors and climate change on biogeochemistry-ecosystem in continental margins and feedbacks to earth system and society: Challenges and solutions*” and “*Environmental changes in Eastern Boundary Upwelling Systems: drivers, mechanisms and implications for the ecosystems*” at the IMBER OSC in June 2014, Bergen, Norway.
- A special issue derived from the IMBIZO III continental margins workshop and entitled “*Biogeochemistry-ecosystems interaction in changing continental margins in the Anthropocene*” has been accepted for the *Journal of Marine Systems*.

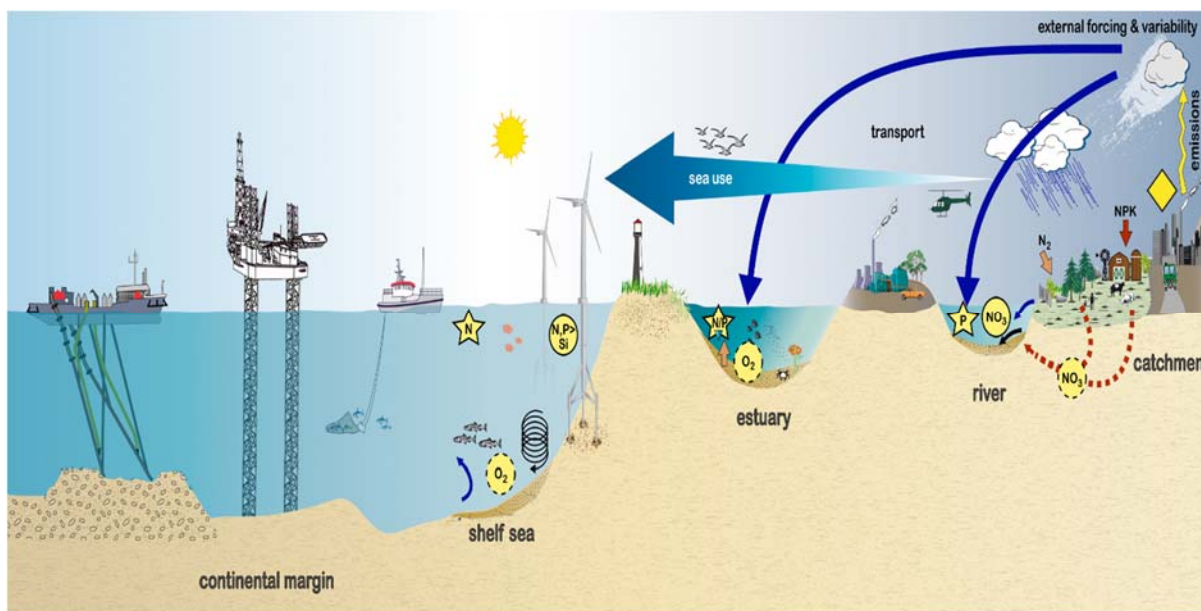


Figure 10: The Margin, comprising the coastal zone, continental slope and shelf
(after K. Emeis, pers. comm.)

Data Management Committee (DMC)

The DMC promotes a cooperative data management approach - involving experienced data management specialists, from the start of a project, and training young scientists in good data management procedures.

As with previous IMBIZOs, the DMC organised an IMBER *Data management training course and workshop* the day before the start of IMBIZO III in Goa, India. About fifty IMBIZO III participants and local NIO researchers and students attended. Overall, the presentations and discussions provided useful information on how their science will benefit from improved data management practices and this will facilitate data sharing. The presentations are available at www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III/Data-Management-Workshop.

In addition to its usual capacity building goal, this event made it possible for IMBER researchers to further identify data management needs of IMBER research projects, to start addressing the emerging challenges of the social and natural marine science integration and especially the marine social science data management, and start elaborating new recommendations specific to the management of new types of marine data. A revision/addendum is now under consideration for the IMBER Data Management Cookbook (2011), to consider such new marine data, related to – omics research (e.g., genomics, proteomics) that delivers huge amount of new data, and social science research where data and information are often not geo-referenced and have confidentiality-related access restrictions.

The IMBER metadata portal (<http://gcmd.nasa.gov/portals/imber>) within the NASA's Global Change Master Directory (GCMD) is actively populated and currently contains description of 32 endorsed projects and related activities.

The IMBER poster entitled, ‘*Contributions from the IMBER Data Management Committee to the scientific challenges of the changing marine ecosystems*’, was presented at several events, including the 3rd *International Symposium on the Ocean in a High CO₂ World*, September 2012, Monterey, CA, USA; the 2012 *ICES Annual Science Conference*, September 2012, Bergen, Norway; the *CLIVAR international workshop on interdecadal variability of the global monsoons*, September 2012, Nanjing, China; and the *PICES 2012 Annual Meeting*, October 2012, Hiroshima, Japan.

Future DMC activities:

- DMC will convene a workshop entitled “*Data Management for IMBER*” at the **IMBER OSC** in June 2014, Bergen, Norway.

Capacity Building Task Team (CBTT)

The CBTT objectives are to enhance marine research capabilities in less developed countries, enhance research capabilities globally in relevant IMBER activities, and strengthen graduate education in ocean sciences.

The CBTT organised a workshop on the “*Needs assessment for capacity development for integrated marine biogeochemistry and ecosystem research in the Asia-Pacific*” in July-August 2012, Shanghai, China. There were about twenty participants from 14 countries, including scientists, capacity building (CB) experts and representatives from IMBER, SCOR, the Asia-Pacific Network for Global Change Research (APN), the IOC Sub-commission for the Western Pacific (IOC-WESTPAC), and the Partnership for Observation of the Global Oceans (POGO). Included were presentations about CB experiences and case studies, and assessment of CB needs. Consideration was also given to potential collaborative activities for capacity development regionally and globally to help IMBER deliver its objectives. The capacity development needs for IMBER-related research in the Asia-Pacific region were identified using an information matrix developed from the capacity building efforts and challenges reported by the workshop participants.

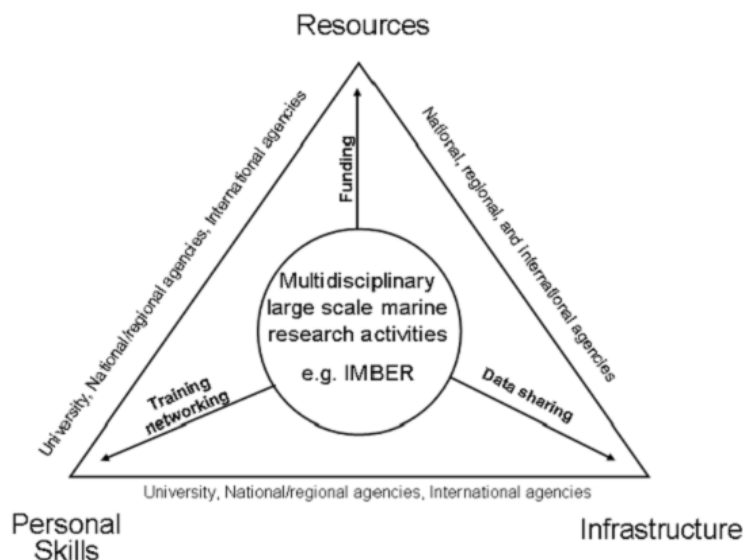


Figure 11. Three key components involved in capacity building, while national/regional agencies focus more on resources and infrastructure building, and universities provide more opportunity on personal skills development. Multidisciplinary large-scale marine research activities, such as IMBER, contribute to the three components through training, networking, financial support, data sharing, etc. (from “Developing Human Capital for Successful Implementation of International Marine Scientific Research Projects”. R.J. Morrison et al., *subm.*)

A meeting report titled, ‘*Capacity Building for Sustainable Marine Research in the Asia-Pacific Region*’, was also published in *EOS*, January 2013, and the main workshop report is available at www.apn-gcr.org/resources/items/show/1766. A small writing meeting held in March 2013, in Shanghai, China made it possible to further develop a strategic paper, ‘*Developing Human Capital for Successful Implementation of International Marine Scientific Research Projects*’, which was recently published on-line in *Marine Pollution Bulletin* (see <http://www.sciencedirect.com/science/article/pii/S0025326X13005377>).

Future CBTT activities:

- CBTT will convene a workshop entitled “*Capacity Development for IMBER*” at the **IMBER OSC** in June 2014, Bergen, Norway.
- CBTT is also encouraging the development of the next IMBER summer school, ClimEco4 in August 2014, Shanghai, China (see below).

Human Dimensions Working Group (HDWG)

The HDWG focuses on the interactions between human and ocean systems, and aims to create an integrated and interactive natural-social science marine research community within IMBER. Marie-Caroline Badjeck stepped down as HDWG Co-Chair at the end of 2012, but remains as an associate member.

HDWG members and colleagues convened the IMBIZO III workshop on ‘*Understanding and forecasting human-ocean-human interactions, drivers and pressures, with respect to global change*’ in January 2013 in Goa, India. Presentations analyzed the vulnerability and adaptation of marine-dependent communities to global change and

governance response and methodological approaches to assess and mitigate the impacts of global change. A range of locations, issues and scales were covered, but several common themes and issues emerged: informal social networks are important for adaptation; responses can and should occur at several levels; lessons can be learned from comparative analyses; local issues are affected by local, regional and global drivers; greater interdisciplinarity is required to address these issues; there are several major disconnects between natural and social sciences; between science and policy; and between the public perception and the “reality” of global change.

The HDWG held its third meeting in conjunction with IMBIZO III, to further develop the HDWG work plan for the next five years and also the ‘*Assessment from Description, Appraisal and Typology*’ (ADApT) conceptual framework and template for case studies. IMBER-ADApT is an integrated decision support tool to enable decision makers and resource managers to identify options to improve their response to global change for the coastal and marine environment and related, vulnerable communities. IMBER-ADApT is based on a broad suite of case studies, focusing on fisheries and aquaculture, from a diversity of social, natural and governance systems, of activity sectors, including those related to fisheries and aquaculture, and of factors that can affect these, such as poverty and social justice.

Future HDWG activities:

- The IMBER-ADApT template will be soon widely distributed to solicit about 100 case studies
- A “Ghoti” paper on IMBER-ADApT will to be soon submitted to *Fish and Fisheries*
- A special issue of *Regional Environmental Change* on the contributions from the IMBIZO III HDWG-related workshop is in preparation.
- HDWG Meeting in March 2014, Halifax, Canada
- Analysis of case studies and development of the ADApT typology
- HDWG members and colleagues will convene three sessions entitled “*Not so simple: developing robust approaches to the use of indicators for ecosystem based fisheries management*”, “*Responses of society to marine and global changes as a core mandate for IMBER: ways forward*” and “*Future Oceans’ stewardship: roles, responsibilities and opportunities in small-scale fisheries*” at the **IMBER OSC in June 2014, Bergen, Norway.**

D. IMBER Project-wide Activities

IMBIZO III

IMBIZO is a Zulu word for a ‘gathering’. IMBER organised IMBIZO III in January 2013 in Goa, India, focusing on ‘*The future of marine biogeochemistry, ecosystems and societies - Multi-dimensional approaches to the challenges of global change in continental margins and open ocean systems*’. The aim was to explore the linkages and interactions between humans and marine systems and deepen our understanding of future ecological and biogeochemical systems in the continental margins and open ocean and their societal implications. IMBIZO III was co-sponsored by EUR-OCEANS Consortium (EU), IMR (NO), RCN (NO), NASA (US), OCB (US), PICES (INT), SCOR (INT), ECNU (CN) and SKLEC (CN). IMBIZO III brought together about 120 researchers, from the natural and social research fields, who represented 29 countries.

Following the proven IMBIZO format, three concurrent, but interacting, workshops dealt with (1) *Biogeochemistry-ecosystem interactions on changing continental margins*, (2) *Impacts of anthropogenic perturbations on the biological and microbial carbon pumps in the ocean*, and (3) *Understanding and forecasting human-ocean-human interactions, drivers and pressures, with respect to global change*. Joint daily plenary and poster sessions provided the opportunity for interdisciplinary discussion among participants from the three workshops. The meeting presentations are available online at www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III.

A mentoring programme was activated prior to IMBIZO III and matched about fifteen students and early-career researchers with experienced scientists. Advice and assistance was given on poster or presentation preparation, and on career development. A “lunch with scientists” was also held. At the end of IMBIZO III, a 3-hour tutorial session on ‘*Scientific Writing and Publishing*’ was attended by about 35 participants.

As mentioned above, a “*Data management training course and workshop*” was organised by the DMC the day before the start of IMBIZO III.

A meeting report, *'The Future of Marine Biogeochemistry, Ecosystems, and Societies'*, was published in *EOS*, May 2013, and the IMBER Update Newsletter issue n°24 focused on science highlights from IMBIZO III (see below).

Future IMBIZO III-related activities:

- A synthesis of the outcomes of IMBIZO III *'The Future of Marine Biogeochemistry, Ecosystems, and Societies'* is in preparation as an article in the *"Breaking Waves"* section of *Oceanography*.
- Syntheses of the ideas and concepts presented and new scientific discoveries reported at IMBIZO III will be published in special issues of *Journal of Marine Systems* (Continental Margins Workshop), *Biogeosciences* (Open Ocean Workshop) and *Regional Environmental Change* (Human-Ocean Interactions Workshop).

ClimEco Summer Schools

IMBER ClimEco Summer Schools are held every two years and have proved to be a successful capacity building mechanism for students and early-career scientists. The first edition (2008) was co-organised by IMBER, GLOBEC and CLIVAR.

IMBER organised ClimEco3, in July 2012, Ankara, Turkey, focusing on *'A view towards integrated Earth System models. Human-nature interactions in the marine world'*. There were 10 lecturers and about 60 students from 26 countries with an array of social and natural science backgrounds. The participants were selected from the 168 applicants to facilitate hands-on training. The summer school was designed to provide participants with an overview of methods, models and approaches for analyzing the impact of climate change on marine ecosystems and the consequences for society. All the lectures were webcast live and were followed by several people from around the world. Recordings of the broadcasts are available at www.imber.info/index.php/Science/Working-Groups/Capacity-Building/Summer-Schools/ClimECO3-July-2012-Ankara-Turkey. Sponsors included IMBER, METU (TR), PICES (INT), CLIVAR (INT), SCOR (INT), EUR-BASIN (EU), OCB (US), KORDI (KR, now: KIOST).

Future ClimEco activities:

- ClimEco4 entitled, *'Delineating the issues of climate change and impacts to marine ecosystems: Bridging the gap between research, assessment, policy and management'*, will be held in early August 2014, Shanghai, China. It should focus on indices for evaluating marine ecosystems - what they are, how to construct them (for process/observation scientists), how to use them (for modellers from natural to social sciences), and how to combine them so that they can be used to inform policy and decision-making.

Funding from SCOR has been kindly requested to support participants from developing and emerging economies to attend the ClimEco4 summer school.

Open Science Conference (OSC) 2014

IMBER has been underway for eight years and it is now appropriate to begin elaborating a broad synthesis of its achievements and developing a strategic plan for the next phase of marine biogeochemical and ecosystem research.

The IMBER Open Science Conference, *'Future Oceans – Research for marine sustainability: multiple stressors, drivers, challenges and solutions'*, to be held from 23 to 27 June 2014 in Bergen, Norway, is a key step in this process and is intended to provide a venue to the larger marine science community for presenting key findings of IMBER-relevant research, for promoting integrated syntheses of IMBER research, and for developing a new research agenda to guide future marine biogeochemistry and ecosystem research. We expect about 300 to 400 participants to attend.

Innovative discussion formats will be promoted, such as world cafés, panel discussions, breakout groups, poster sessions and exhibition booths. Facilitated scenario-testing/strategic sessions are also being considered for discussing future research needs, particularly those relevant to societal issues, such as marine food security, or vulnerability assessments of marine systems under global change.

The OSC will feature:

- keynote plenary presentations;
- multiple contributed parallel sessions focusing on IMBER achievements, ambitions and strategy development;

- several one-day topical workshops focusing on integration across the IMBER research themes, results from IMBER regional programmes and working groups, and IMBER-relevant research at the interface of natural and human sciences;
- targeted breakout groups focused on defining a new research agenda and implementation strategy for the next phase of marine research;
- a mentoring programme for students and early-career researchers; and
- poster sessions.

The list of accepted sessions and workshops is available at www.imber.info/index.php/Meetings/IMBER-OSC-2014/Sessions-Workshops.

Several scientific side-events and additional IMBER-related activities will be held in conjunction with the IMBER OSC 2014, including pre-conference events such as workshops for early-career researchers on new research challenges, capacity building, and data management, and the IMBER SSC meeting to be held on 27-28 June 2014 in Bergen, Norway. Several social events, such as an ice-breaker, conference reception and conference dinner, will also be organized. These are funded by sponsorship raised locally or provided by local organizations. This is especially important for the OSC because it is an attempt to bring together and facilitate interactions and collaborations between the natural and social science marine research communities, both globally and locally. Current environmental issues facing society are at the interface between natural and social science, and it is imperative to support the development of an interdisciplinary community of researchers who understand and have the skills to address complex issues at this interface.

The OSC will help disseminate IMBER science results to a broader community, with both natural and social science representation. The keynote presentations will be broadcast live and subsequently posted on the IMBER website. Social media outlets will facilitate the involvement of a wider audience of marine researchers and research end-users, allowing a broader engagement in the strategic discussions. Results from the OSC will be published as peer-reviewed synthesis publications and special issues with contributed and solicited papers.

To facilitate future planning, the IMBER Scientific Steering Committee (SSC) is developing a strategic document to stimulate discussions that help define and implement the next phase of research in biogeochemical cycling-ecosystem interactions and human-ocean-human interactions. The general outline of this strategic document should include the following: a self-evaluation report; some highlights of success; new questions and new challenges; an overview of the new research landscape; some proposed new themes, issues, priority questions; some proposal for a new research agenda; a draft science plan and implementation strategy; and timeline. This document will be made available to participants in advance of the OSC. It will also be posted on the IMBER website for comment from individual researchers, research partners and marine organisations. Following this open consultation period, the document will be revised and updated by the IMBER SSC to reflect the inputs and suggestions of the community and to take into account the status of the IMBER dialogue with its current sponsors (SCOR and IGBP) and the 'Future Earth' initiative. It will then be sent to SCOR during late summer 2014, along with a request for a potential five-year project extension.

SCOR has agreed to support the participation of several researchers from developing and emerging economies in the OSC. Other confirmed sponsors are the North Pacific Marine Sciences Organization (PICES); Research Council of Norway (RCN); Institute of Marine Research (IMR), Bergen, Norway; University of Bergen, Norway; Norwegian Research School in Climate Dynamics (ResClim); and City of Bergen, Norway. Additional financial support has been requested from the International Council for the Exploration of the Sea (ICES), U.S. National Aeronautics and Space Administration (NASA), U.S. Ocean Carbon and Biogeochemistry (OCB) Program, Korea Institute of Ocean Science and Technology (KIOST). Additional funding proposals are being prepared for the Inter-American Institute for Global Change Research (IAI), Partnership for Observation of the Global Oceans (POGO), Japan Society for the Promotion of Science (JSPS), and several national research funding agencies and private philanthropic foundations.

The funding provided by external sponsors will especially facilitate participation of early-career researchers at an international science conference, thereby providing these individuals the opportunity to experience international science and to learn about advances in marine science that are being made as part of IMBER activities. They are potentially the next generation of leaders in marine science and entraining them in international science at an early stage will benefit them and the larger marine research community, and ensure that all regional communities are an integral part of planning the future directions of a marine global environmental change research agenda.

China-Japan-Korea (CJK) IMBER Symposia

The 6th China-Japan-Korea (CJK) IMBER Symposium focusing on “*Ocean Ecosystem Dynamics and Integrated Marine Biogeochemistry and Ecosystem Research*” will be held in October 2013 in Tokyo, Japan.

Continuation of the IMBER Regional Project Office

The IMBER Regional Project Office (RPO), established under a MoU with the East China Normal University in 2010 for an initial three-year period, has been renewed for another three years (2013-2016). The RPO is an essential facilitator in the IMBER efforts to reach out to the related research community in the Asia-Pacific region, and a very active partner of the International Project Office in many of its activities.

E. IMBER SSC membership

There are currently 15 IMBER SSC members. At the end of 2012, Dr. Mike Roman (Vice Chair) completed his second term of office on the SSC. The IMBER SSC nominated Dr. Tatiana Rynearson to fill this vacancy, and her nomination (2013-2015) was endorsed by IMBER’s sponsors (SCOR and IGBP). Dr. Alida Bundy replaced Dr. Roman as Vice Chair of the IMBER SSC.

At the end of 2013, Prof. Javier Aristegui (Vice Chair), Dr. Carol Robinson (Vice Chair), Dr. Jean-Pierre Gattuso and Prof. Nicolas Gruber will complete their second terms of office on the SSC. In February 2013, IMBER solicited the research community for nominations for their replacements with the following expertise, identified by the IMBER Executive Committee: human-ocean-human interactions, marine anthropology; marine/environmental economics; microbial ecology and biogeochemistry, meso-pelagic processes; carbon fluxes and budgets; biogeochemical modelling, carbon-climate interactions and ocean acidification. Fifty-seven submissions were reviewed extensively and a short list of nominees is now presented to SCOR and IGBP for their approval.

F. IMBER Cooperation

Cooperation with the ‘Variability and predictability of the ocean-atmosphere system’ project (CLIVAR)

CLIVAR (www.clivar.org), a core project of the World Climate Research Programme (WCRP), focuses on the role of the oceans in climate variability and change. Following several earlier, informal interactions, and thanks to the help of Ken Drinkwater, member of both IMBER and CLIVAR SSCs, the collaboration between the two projects have been increased: A joint meeting of the Scientific Steering Committees of IMBER and CLIVAR was held in June 2012 in La Paz, Mexico, to explore possible topics and ways for active CLIVAR-IMBER collaboration. The presentations from this meeting are available at www.clivar.org/node/2509. There is already interaction between the CLIVAR ‘Pacific Implementation Panel’, ‘Asian-Australian Monsoon Panel’ and ‘Indian Ocean Panel’ and the IMBER regional programmes. CLIVAR is also a co-sponsor of the IMBER ClimEco summer schools.

There has been discussion on the possibility of establishing a joint IMBER-CLIVAR working group to establish stronger links with the climate research community, on specific topics, such as upwelling regions; natural decadal/multi-decadal variability; bio-physical feedbacks; oxygen minimum zones; impact of ocean acidification on marine ecosystems; and ocean carbon uptake. Consideration is also being given to how both projects could evolve partly together also in the context of the ‘Future Earth’ initiative (with which WCRP will partner). Joint studies on marine biophysical interactions and the dynamics of upwelling systems, which are productive fisheries areas, were suggested as starting points. Eastern boundary upwelling systems, upwelling systems associated to western boundary currents and equatorial upwelling systems should be considered, in their geophysical and ecological variability and the anthropogenic changes (e.g., global warming, extreme events, ocean acidification) affecting them, that could be observed or forecasted therein. There is already a research effort underway by the IMBER regional programme, SIBER, and the CLIVAR Indian Ocean Panel on upwelling in the Eastern Indian Ocean. An informal IMBER-CLIVAR working team was assembled in early 2013 to consider possible research questions that an upwelling research initiative should address. Representatives from the IOC and the former GLOBEC regional programme on small pelagics (SPACC) were also included.

Future IMBER-CLIVAR-related activities:

- A workshop entitled “*Eastern Indian Ocean Upwelling Research Initiative Planning Workshop Phase 3 – Physical Dynamics and Ecosystem Responses*”, and two sessions on “*Environmental changes in Eastern Boundary Upwelling Systems: drivers, mechanisms and implications for the ecosystems*” and “*Climate-biogeochemistry interactions associated with open-ocean oxygen minimum zones*” will be co-convened by IMBER and CLIVAR researchers at the **IMBER OSC** in June 2014, Bergen, Norway.

Partnership with Too Big To Ignore (TBTI)

IMBER has partnered with the *Too Big To Ignore* initiative (<http://toobigtoignore.net>), a research network that aims to promote and revitalize small-scale fisheries around the world. Its main goal is to improve understanding of the real contribution of small-scale fisheries to food security, nutrition, sustaining livelihoods, poverty alleviation, wealth generation and trade, as well as the impacts and implications of global change processes such as urbanization, globalization, migration, climate change, aquaculture, and communication technology on small-scale fisheries. Many of the objectives of the IMBER HDWG coincide with those of the initiative, which is led by IMBER SSC member Ratana Chuenpagdee. The TBTI inaugural meeting was held in September 2012 in St. Johns, Canada and focused on working principles guiding the partnership, on workgroups and regional activities, and on partners’ and individual members’ contributions to TBTI network. Among other activities, TBTI is currently running two surveys on *who’s who in small-scale fisheries research* and on the *research priorities for small-scale fisheries*. Key publication of TBTI interest: Bavinck, M., Chuenpagdee, R., Jentoft, S. and Kooiman, J. (Eds.) (2013). *Governability of Fisheries and Aquaculture: Theory and Applications*. Springer. [ISBN 978-94-007-6107-0](https://doi.org/10.1007/978-94-007-6107-0).

Contributions to international assessments

- Many SIC!-related research projects have contributed to a series of synthesis chapters for the Regional Carbon Cycle Assessment and Processes (RECCAP) effort (www.globalcarbonproject.org/reccap/). Several ocean-related papers are being published in *Biogeosciences* (see www.biogeosciences-discuss.net/special_issue83.html).
- Many of these syntheses and other contributions from the IMBER-related research projects and IMBER regional programmes are included in the *fifth Intergovernmental Panel on Climate Change Assessment Report (AR5)* of the Intergovernmental Panel on Climate Change’ (IPCC, www.ipcc.ch). Richard Feely; Eileen Hofmann; Yukihiro Nojiri and James Overland are involved in Working Group I (*The Physical Science Basis*), and Kenneth Drinkwater; Jean-Pierre Gattuso; Yukihiro Nojiri and Carol Turley in Working Group II (*Impacts, Adaptation and Vulnerability*).
- IMBER researchers are involved in the United Nations ‘*Regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects*’, aka, UN World Ocean Assessment (UN-WOA; www.worldoceanassessment.org).
- IMBER has provided comments on the European Space Agency (ESA) science strategy (2006), as inputs to the *ESA Living Planet Symposium* (www.livingplanet2013.org), taking place in September 2013, Edinburgh, UK.
- IMBER is now considering how best to contribute to the activities of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net).

G. Communication, Publications

Communication and Outreach

The IMBER Website, www.imber.info, remains our main communication tool, with about 250 unique visitors/days and about 14 clicks per visit.

The *IMBER Update Newsletter*, www.imber.info/index.php/News/Newsletters, is emailed to ~1,600 scientists three times a year, and re-directed through multiple channels to about 10,000 researchers:

- **Issue n°24** - August 2013, included articles about Science highlights from IMBIZO III, new endorsed project and the endorsed project POMAL
- **Issue n°23** - April 2013, included articles about Science Highlights from CLIOTOP, new National Contacts and the endorsed projects GENUS and AMT, and IMBER-related future events
- **Issue n°22** – Dec. 2012, included articles about research in the China Seas and Southern Ocean, the MEcoPAM endorsed project and the ICED regional programme.

- **Issue n°21** – Sept. 2012, included articles about the IMBER ClimECO3 summer school, the workshop organised by the IMBER Capacity Building Task Team, and Norwegian IMBER-related research.

The IMBER eNews Bulletin is published electronically every month, providing information about IMBER and IMBER-relevant activities and events. Calls for funding proposals, job opportunities, workshop and conference announcements are also included.

The IMBER contact database is continuously improved with about 3,600 contacts and detailed information for about 1,600 marine researchers.

The IMBER IPO YouTube channel was opened in October 2012 to disseminate the ClimEco3 e-lectures, www.youtube.com/channel/UCinZjRz7_TKHEsn6uggCKlw and has gathered more than 400 views. Recently, an IMBER Twitter channel, https://twitter.com/imber_ipo has been developed.

The IMBER GCMD metadata portal has already been mentioned earlier (see, DMC).

Finally, the IPO and RPO staff and several IMBER researchers have presented more than a dozen IMBER poster and oral presentations at many national and international meetings.

Selection of IMBER Publications, 2012-2013

Ashjian C.J., H.R. Harvey, M.W. Lomas, J.M. Napp, M.I.F. Sigler, P.J. Stabeno and T.I. Van Pelt (2012).

Understanding Ecosystem Processes in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 65-70, 1-316 – [23 papers](#)

Dawe E.G., F.J. Mueter, Ö.K. Pálsson (2012). Theme Section on “Effects of climate and predation on subarctic crustacean populations”. In: *Marine Ecology Progress Series*, 469, 191-306 – [9 papers](#)

Drinkwater K. and P. Pepin (2013). Norway-Canada Comparison of Marine Ecosystems (NORCAN). *Progress in Oceanography*, 114, 1-126. – [8 papers](#)

Drinkwater K.F., R.R. Hood and N. Mihalopoulos (Eds.) (2013). Large-scale regional comparisons of marine biogeochemistry and ecosystem processes - research approaches and results. *Journal of Marine Systems*, 109-110, p.1-176. – [13 papers](#)

Drinkwater K.F., G.L. Hunt Jr, O.S. Astthorsson and E.J.H. Head (Eds.) (2012). Comparative Studies of Climate Effects on Polar and Subpolar Ocean Ecosystems: Progress in Observation and Prediction. *ICES Journal of Marine Science*, 69(7), p.1119-1327 – [22 papers](#)

Friedland K.D., Stock C., Drinkwater K.F., Link J., Leaf R., Shank B., Rose J., Pilskaln C.H. and Fogarty M. (2012). Pathways between primary production and fisheries yields of Large Marine Ecosystems. *PlosOne*, 7: e28945. doi:1371/journal.pone.0028945.

Friedrich T., Timmermann A. et al. (2012). Detecting regional anthropogenic trends in ocean acidification against natural variability. *Nature Climate Change*, 2, 167-171; doi:10.1038/nclimate1372

Gaichas S., Gamble R., Fogarty M., Benoît H. et al. (2012). Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. *Marine Ecology Progress Series*, 459, 275-292.

Gruber N., Hauri C., Lachkar Z., Loher D., Frölicher T. and Plattner G.K. (2012). Rapid progression of ocean acidification in the California Current System. *Science*, 337(6091), 220-223. doi: 10.1126/science.1216773.

Hauri C., Gruber N., Vogt M., Doney S.C., Feely R. A., Lachkar Z., Leinweber A., McDonnell A. M. P., Munnich M., and Plattner G.K. (2012). Spatiotemporal variability and long-term trends of ocean acidification in the California Current System. *Biogeosciences Discuss.*, 9, 10371-10428, doi:10.5194/bgd-9-10371-2012.

Hunsicker M.E., Olson R.J., Essington T.E., Maunder M.N., Duffy L.M., Kitchell J.F. (2012). Potential for top-down control on tropical tunas based on size structure of predator-prey interactions. *Marine Ecology Progress Series*, 445, 263-277

Krause E., Wichels A., Giménez L., Lunau M., Schilhabel M. B. & Gerds G. (2012). Small changes in pH have direct effects on marine bacterial community composition: a microcosm approach. *PlosOne*, 7: e47035. doi:10.1371/journal.pone.0047035.

Nisumaa A.M., Schlitzer R., Hansson L. & Gattuso J.P. (2012). EPOCA data management activities: a summary. See www.imber.info/index.php/Science/Working-Groups/SOLAS-IMBER-Carbon/Subgroup-3/Publications-and-reports/EPOCA-data-management

Pedrotti M.L., Fiorini S., Kerros M.E., Middelburg J.J., & Gattuso J.P., (2012). Variable production of transparent exopolymeric particles by haploid and diploid life stages of coccolithophores grown under different CO₂ concentrations. *Journal of Plankton Research*, 34(5), 388-398. doi: 10.1093/plankt/fbs012.

- Perry I., A. Bundy and E. Hofmann (Eds.) (2012). Aquatic and marine systems. *Current Opinion in Environment Sustainability*, 3(3), p.253-374. – 17 papers
- Renner A.H.H., S. E. Thorpe, et al. (2012). Advective pathways near the tip of the Antarctic Peninsula: Trends, variability and ecosystem implications. *Deep Sea Research Part I: Oceanographic Research Papers*, 63, 91-101.
- Roy A.S., Gibbons S. M., Schunck H., Owens S., Caporaso J. G., Sperling M., Nissimov J. I., Romac S., Bittner L., Mühling M., Riebesell U., LaRoche J. & Gilbert J. A. (2013). Ocean acidification shows negligible impacts on high-latitude bacterial community structure in coastal pelagic mesocosms. *Biogeosciences*, 10: 555-566.
- Salinger J. (Ed.) (2013). Climate and Oceanic Fisheries. *Climatic Change*, 119(1) - 16 papers
- Steele J.H., E.E. Hofmann, D.J. Gifford and K. Aydin (Eds.) (2012). End-to-End Modeling: Toward Comparative Analysis of Marine Ecosystem Organization. *Progress in Oceanography*, 102, p.1-114. – 8 papers
- Wang Z.A., Wanninkhof R., Cai W.J., Byrne R. H., Hu X., Peng T.H. & Huang W.J., 2013. The marine inorganic carbon system along the Gulf of Mexico and Atlantic coasts of the United States: insights from a transregional coastal carbon study. *Limnology & Oceanography*, 58(1): 325-342.
- Williamson P., Wallace D.W.R., Law C.S., Boyd P.W., Collos Y., Croot P., Denman K., Riebesell U., Takedai S., Vivian C. (2012). Ocean fertilization for geoengineering: a review of effectiveness, environmental impacts and emerging governance. *Process Safety and Environmental Protection*, 90(6), 475-488. doi: 10.1016/j.psep.2012.10.007.

Overall, IMBER has produced about 900 refereed research papers since its implementation, including about 150 papers and 8 special issues published in 2012-2013.

H. Support from SCOR

IMBER greatly appreciates the ongoing, key support received from SCOR, and the additional support to specific IMBER activities (especially, IMBIZO III and OSC 2014) provided by or channelled through SCOR, from other funding sources. In addition, IMBER welcomes the advice, assistance and information received from the SCOR President and secretariat, especially its Executive Director, Ed Urban, and Financial Officer, Liz Gross.

IMBER is requesting sponsorship to assist students and early career researchers from developing countries to attend the IMBER ClimEco4 summer school (August 2014, Shanghai, China).

I. Strategic development

IMBER is concerned about the potential impact of the emergence of the Future Earth initiative (FE) and the discontinuation of IGBP in late 2015 on the future of the project. Overall, IMBER welcomes the development of FE as a global platform that will further research on global environmental change, with a focus on challenges and solutions that have been recognised as critical for global sustainability. In this respect, SCOR's views and guidance would be greatly appreciated by the IMBER research community.

IMBER is already engaged in research topics that address several of the FE objectives, and many of its coordination and networking activities match the integrated approaches desired by FE. IMBER researchers undertake mainly basic (i.e., fundamental, disciplinary, curiosity-driven) natural science research; however, IMBER is also engaged in interdisciplinary and integrated activities focused on research at the interface between human and natural sciences. Expanding the IMBER research community and its impacts through cooperation with other research initiatives (e.g., SOLAS, LOICZ, CLIVAR, GEOTRACES) and partner organizations (e.g., PICES, ICES, EUROMARINE, US-OCB) will facilitate furthering IMBER goals within the context of FE. Several telecons between the core projects of the GEC programmes and FE and its sponsors, including ICSU have taken place in the past 1.5 years. A dedicated IMBER-FE teleconference is scheduled in late October 2013, and the SCOR Executive Director will participate in this meeting.

IMBER would like to develop an open dialogue with FE in cooperation with its current sponsors, IGBP and SCOR. In this respect, IMBER has already received input from SCOR Executive Director regarding the FE initiative and possible co-sponsoring of IMBER in the future. This information has been transmitted to FE.

Along with these new developments, a request for a five-year IMBER project extension will be presented to SCOR by late summer/fall 2014, in order to help deliver further the IMBER mission and deepen and widen its overall impact.



ANNEX 1 – New Endorsed Projects (as of August 2013)

IMBER has endorsed 35 research projects to date that contribute to the delivery of its objectives. During the last year, 5 new projects were endorsed:

Variability of Ocean Ecosystems around South America (VOCES) (July 2013)

The overall goal of this project (January 2013 - December 2017) is to assess the impact of climate variability - both natural and anthropogenic - on the Humboldt, Patagonia and South Brazil Large Marine Ecosystems (LMEs). These ecosystems are amongst the most productive of the Southern Hemisphere, sustaining more than 20% of the global fish catch, hosting unique biodiversity and with CO₂ absorption rates comparable with the most significant uptake regions of the world's oceans. To achieve the project's goal we propose a two-pronged activity plan that, on the one hand, will synergize extant research programs through coordination efforts and, on the other hand, will fill research gaps left by those programs by encouraging collaborative research. We will link the efforts of scientists, educators and program managers from Argentina, Brazil, Chile, Peru, Uruguay and the USA.

(<http://sacc.coas.oregonstate.edu/~sacc>)

Biogeochemical cycles in the SOUTHERN Ocean: Role within the Earth System (BIGSOUTH) (July 2013)

The BIGSOUTH project (January 2010 - November 2014) aims at achieving a detailed understanding of the processes controlling functioning and strength of the oceanic biological pump for representative key areas of the Southern Ocean (Atlantic sector (Weddell Gyre); Indian sector (30°E to Kerguelen Plateau); Australian sector (115° - 147°E); Ross Sea), including open ocean and sea-ice covered areas, in order to upgrade present-day assessments of the carbon sequestration capacity and nutrient cycling in the Southern Ocean and possible impacts on the global ocean. Therefore, we apply a unique combination of stable isotope (natural and spiked isotopic abundances), geochemical tracers, trace element and modelling tools to study the relevant biogeochemical processes and control factors (including Fe) acting on the fluxes of carbon and the two major macronutrients N and Si in the open and seasonally sea-ice covered water column. (www.co2.ulg.ac.be/bigsouth)

Sustainability of Marine Ecosystem Production under Multi-stressors and Adaptive Management (MEcoPAM) (June 2013)

The objectives of the MEcoPAM project (January 2011 - December 2015) are to identify and characterize the interactions of marine biogeochemical cycles and marine ecosystems, and to understand the response of typical marine ecosystem production to multi-stressors (such as physical processes, eutrophication, over-fishing and aquaculture), thereby improving our knowledge of the impact of multi-stressors on the sustainability of marine ecosystem production. The research areas include several unique sub-ecosystems in the Bohai Sea, Yellow Sea, and East China Sea (e.g., the hypoxia zone off the Changjiang Estuary, and aquaculture sites in the Shandong Peninsula). The program is structured around five sub-projects: (1) Biogeochemical Dynamics of Marine Ecosystems; (2) Nutrient Cycles and Response to Multi-stressors; (3) Hydrodynamic Response to Multi-stressors and its Impact on the Supply of Nutrients; (4) Microbial Loop and Coupling with Biogeochemical Cycles; (5) Feedback Mechanisms of Ecosystem Structure and Function to Climate Change and Human Activities. In addition to field observations of the physical, chemical and biological properties of ecosystems in East China Sea, Changjiang Estuary and the coastal area of the Shandong Peninsula, historical data analysis, numerical modelling and microcosm experiments will be undertaken. (www.imber.info/index.php/Science/National-Network/CHINA/MEcoPAM-project-website)

Atlantic Meridional Transect (AMT) (November 2012)

The Atlantic Meridional Transect (AMT) is a multidisciplinary programme (1995-present) that undertakes biological, chemical and physical oceanographic research during an annual voyage between the UK and destinations in the South Atlantic - previously the Falkland Islands, South Africa and Chile. These ~50°N to ~50°S Atlantic transects cross a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres. AMT informs on trends and variability in biodiversity and function of the Atlantic ecosystem during this period of rapid change to our climate and biosphere. AMT is unique in its ability to repeat measurements of core parameters on basin scales on long NS transects of the Atlantic and to provides a platform for excellent multi-disciplinary oceanographic research. This unique spatially extensive decadal dataset continues to be deposited and made available to the wider community through the British Oceanographic Data Centre. An integral part of the AMT, which has resulted in more than 60 completed PhD theses, is to provide a training arena for the next generation of oceanographers. This aim has been enhanced recently through the development of the POGO-AMT fellowship programme (<http://ocean-partners.org>) which supports the participation of students or early career professionals from developing nations. Participants in this fellowship programme benefit from working alongside experienced researchers in the development of research skills, the formation of collaborative links and capacity building for their home institutes and countries. (www.amt-uk.org)

Marine Ecosystems Response in the Mediterranean Experiment (MERMEX) (November 2012)

MerMex (2011-2016) focuses on the understanding of the effects of key natural and anthropogenic forcings on ecosystems (from coastal zones to open-ocean, from pelagos to benthos) and organisms (from viruses to fishes) in Mediterranean Sea including western and eastern basins. Most of the Research objectives studied in MerMex were deduced from the Mermex article (*Progress in Oceanography*, 2011) in which ~100 co-authors so-called 'the MerMex group' presented current knowledge on biogeochemistry in the Mediterranean Sea and highlighted the uncertainty on the responses to global change in the 21th Century. (<http://mermex.com.univ-mrs.fr>)