Second Symposium on "Effects of Climate Change on the World's Oceans"

by Suam Kim, Luis Valdés, Svein Sundby and Hiroaki Saito

Ocean Expo 2012, Yeosu, Korea.

Like the first in Gijón, Spain, in 2008, the 2nd international symposium on "*Effects of Climate Change on the World's Oceans*" was organized jointly by PICES (North Pacific Marine Science Organization), ICES (International Council for the Exploration of the Sea), and IOC (Intergovernmental Oceanographic Commission of UNESCO). It was convened from May 15–19, 2012, in a newly constructed conference centre located on the Ocean Expo 2012 site in Yeosu, Korea. Our symposium was the first of several international scientific events related to the Ocean Expo theme of "The Living Ocean and Coast – Diversity of Resources and Sustainable Activities." The venue offered a unique blend of carnival on the outside and science on the inside that is rarely encountered at marine conferences. A total of 326 participants from 31 countries contributed 208 oral and 79 poster presentations to the symposium. Each day began with a plenary session that featured three talks by invited speakers. The remainder of the day was occupied by parallel Theme Sessions (see a Text Box for the list of sessions). In addition, seven workshops were held in conjunction with the symposium, and their reports can be found in this issue of PICES Press.

The symposium venue.

Symposium Theme Sessions

1. Climate variability *versus* anthropogenic impacts; analysing their separate and combined effects on long-term physical, biogeochemical and ecological patterns
2. Systematic, sustained and integrated global ocean observations
3. Projections of climate change impacts on marine ecosystems and their uncertainty
4. Climate change effects on living marine resources: From physics to fish, marine mammals, and seabirds, to fishermen and fishery-dependent communities
5. From genes to ecosystems: genetic and physiological responses to climate change
6. Marine spatial planning and risk management in the context of climate change: The living ocean and coast under changing climate
7. Coastal and low-lying areas
8. Trend and impacts of de-oxygenation in oceanic and coastal ecosystems
9. Marine tipping points in the earth system
10. Changes in the marine carbon cycle

It was apparent to the participants of the 2008 Gijón Symposium that the Fourth Assessment Report (AR 4) of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, had placed only limited emphasis on impacts of climate change on marine ecosystems. After Gijón, the marine science community took the initiative to accelerate research and publication on a diversity of oceanic themes so that the emerging Fifth Assessment Report (AR5) will have two chapters dedicated to marine ecosystems and biogeochemistry.

The marine scientific community is concerned about a rich variety of issues related to climate change but the overarching messages from the symposium are important.

Ecosystem responses to climate change are diverse – because critical factors and processes, structure and function vary among regions. Marine ecosystems are not responding to globally-averaged climate change, but to the nature of climate change in each region.

Ecosystem responses are a combination of climate change and natural climate variability – at various periods from inter-annual to multi-decadal. Care should be taken not to interpret all kinds of past climate change as anthropogenic climate change. Moreover, not all observed changes are due to ocean climate change.

A better understanding of local and regional processes is needed – to improve global models and interpret their results, and because many of the critical ecosystem processes are only captured by downscaling.

Impact studies should be used to define what kind of physical processes are to be studied – because the physical science does not resolve ocean processes that are needed for impact studies on marine ecosystems. Natural climate variability has clear impacts on regional marine ecosystems but they are poorly represented by global climate models. Examples include variations in upwelling regions and inflow of warm Atlantic water to the Arctic.

Model validation – is not a new theme, but it becomes increasingly important as model output becomes more influential. We need to continuously work on evaluating the relevance of the processes in models and to validate their results against observations….and we still need faster computers.

Corinne Le Quere summarizes the outcomes from the symposium.

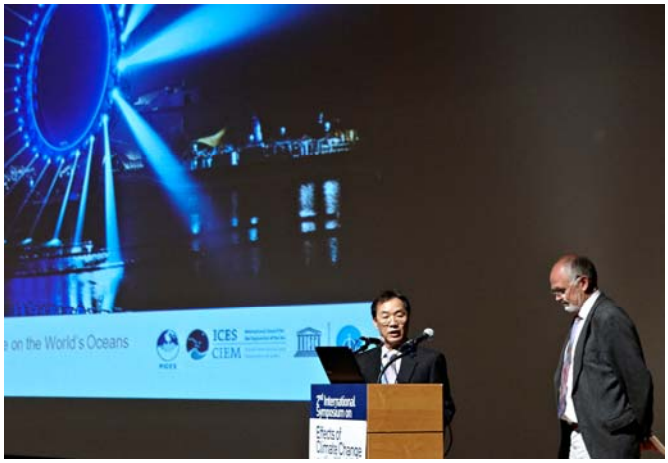
At the Closing Session, Corinne Le Quere (UK) offered a remarkable overview of the week and suggested cutting-edge research directions for future marine ecosystem science. High concentrations of carbon dioxide and other greenhouse gases in the atmosphere are causing ocean warming and ocean acidification, both of which are affecting marine ecosystems of the World's Oceans. Warming has direct impacts on ice caps, sea level, seasonal stratification, species distribution and migratory routes, physiology, and phenology. There is consistency in observed anomalies of temperature, salinity, sea level, heat content, snow and ice cover, and humidity through last century. Understanding will improve from emerging modeling techniques that will refine the anthropogenic and natural components of change.

Ocean acidification is a partner of increasing atmospheric carbon dioxide. The oceans are now more acidic than they have been for the last 800,000 years. Increasing acidity reduces the oceans' capacity to absorb carbon dioxide, leaving more anthropogenic emissions in the atmosphere. Observed trends in carbonate system parameters appear to be persistent and coherent. Global observations are incomplete but they are progressing to a better quantitative understanding. Ocean acidification is causing irreversible changes in the chemistry of the oceans. Acidification also is reducing the availability of carbonate minerals that are important building blocks for marine plants and animals. This change will have adverse impacts in marine biodiversity, particularly species that rely on calcareous structures like coral reefs, shellfish, and echinoderms, *etc*.

Other stressors of anthropogenic origin, such as the transport of invasive species, eutrophication, fisheries, pollution and coastal urbanization have detrimental effects on marine ecosystems. They tend to generate non-linear ecosystem responses causing significant changes in biodiversity, oxygen

Cross-cutting Research Directions

- Multi-variable detection and attribution
- Decadal predictions
- Non-linearity and tipping points in ice melt and ocean currents
- Detection of ocean pCO_2 trend and inventory departures from expected values
- Attribution of the contribution of increasing atmospheric CO_2, climate variability and climate change on regional trends
- Impact of ecosystems changes on the ocean carbon cycle
- Stock and vulnerability of coastal carbon and their valuation
- Quantifying the uncertainty in trends
- Impacts of ocean acidification in marine biota
- Attribution of recent oxygen changes to climate change and/or variability
- Explanation of the tropical deoxygenation
- Effective impact on marine life
- Effective management practices to reduce coastal deoxygenation
- Integrating multiple data streams (including genetic) into information
- Understanding the impact of multiple stresses, including climate change, fisheries, ocean acidification and deoxygenationon species, size distribution, life stages and trophic dynamics
- Ecosystem shifts and tipping points
- Capacity of ecosystems to adapt
- Integrating ecosystems, fish, and fishers in models
- Management options in coastal areas and socio-economic impact (including livelihoods and adaptation to climate change)
- Attribution of the climate change contribution to individual events



Left photo: Opening remarks by the symposium convenors, Luis Valdés (IOC) and Hiroaki Saito (PICES).
Right photo: Closing remarks by the symposium convenors, Suam Kim (Korea) and Svein Sundby (ICES).

depletion, water circulation, and habitats (Fig. 1). Existing subsurface oxygen trends offer only an incomplete understanding of patterns of change. The full implications of deoxygenation are still poorly known. Oxygen stress causes the reduction in available habitat and growth performance on fish.

Food web structures, and the distribution and abundance of marine life have been altered in accordance with expectations from ocean warming. Qualitative trends in ecosystem components are persistent and coherent, but data are inadequate for a quantitative understanding.

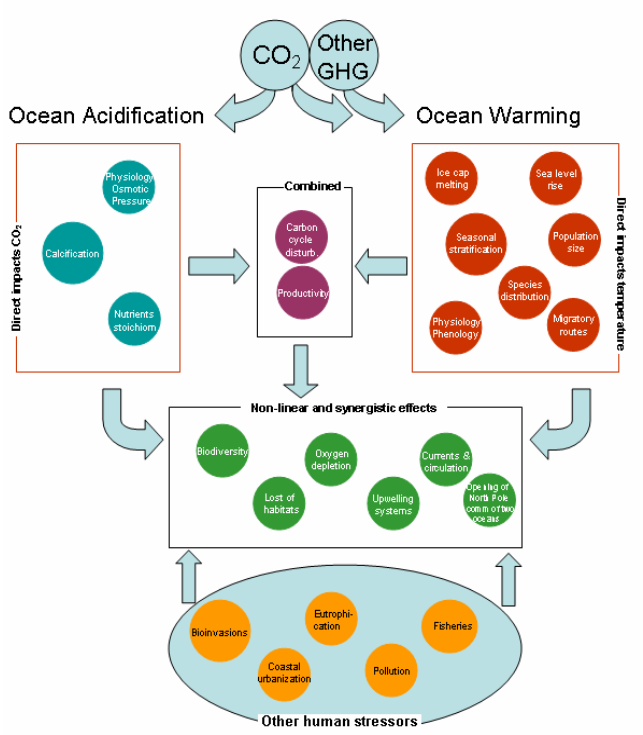


Fig. 1 Conceptual model of oceanic stressors (Reid, P. C., and Valdés, L. 2011. ICES status report on climate change in the North Atlantic. ICES Cooperative Research Report No. 310, 262 pp).

There is a consensus among policymakers to accept a world that is 2ºC warmer on average. While it may be an acceptable threshold for terrestrial ecosystems, it is probably too high for marine ecosystems. Research should be encouraged to evaluate the effects of higher ocean temperatures on marine life, especially in subtropical coastal waters or enclosed seas, where the stability of proteins may be compromised. Integrated analysis and marine spatial planning should be the basis for the efficient management of marine resources so that more and new research has to be done to fully understand and evaluate the impacts of climate change.

The symposium aimed to bring together experts from different disciplines to exchange observations, results, models and ideas at a global scale and to discuss the opportunities to mitigate and protect the marine environment and its living resources. Societies are demanding the sustainable use and management of natural resources and solutions that will mitigate the impacts of global warming. During the next decade, social pressure will encourage policymakers to reach agreements regarding limits on carbon emissions and establish limits for other anthropogenic impacts. The human dimension of climate change in the oceans is very often ignored so that information received by the general public about climate change is incomplete and biased to the terrestrial experience. To bridge the gap between what the scientific community understands about marine climate change impacts and what the public knows and cares about, the gap must first be identified. To have oceanic observations with better spatial and temporal resolution is a crucial and necessary step to take the pulse of the oceans at a planetary scale. A survey at global scale (~50 countries) was proposed as a tool to identify gaps. A new program entitled "*Future Earth: Research for global sustainability*" indicated that interdisciplinary research on global environmental change for sustainable development will be conducted through international research coordination starting from 2013.

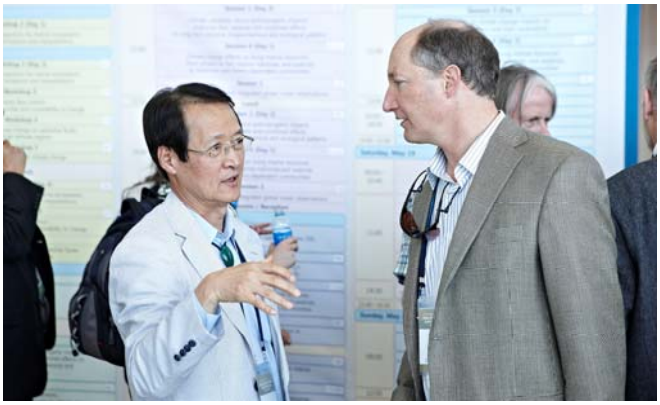
Symposium in session – the first plenary.

Discussion around posters.

Les grandes dames of international marine science: Ann Bucklin (left) and Anne Hollowed (right).

Interactions: Villy Christensen (Canada, left), Dosoo Jang (Korea, center) and Icarus Allen (UK, right).

Interactions: Sinjae Yoo (Korea, left) and Joji Ishizaka (Japan, right).



Interactions: Young Jae Ro (Korea, left) and Jack Barth (USA, right).

Interactions: Lothar Stramma (Germany, left), Martin Visbeck (Gerrmany, center) and Peter Brewer (USA, right).

Dr. Wendy Watson-Wright addresses the participants at the Opening Ceremony (left); Dr. Lev Bocharov, PICES Chairman, welcomes the participants at the Symposium Dinner (center); Dr. Michael Sinclair, President of ICES, toasts the participants at the Welcome Reception (right).

Awards for best presentations by early career scientists were given to: Jong-Yeon Park (Korea Ocean Research and Development Institute, Korea) for his talk on "*Bio-physical interaction in the tropical Pacific*", to Marie-Fanny Racault (Plymouth Marine Laboratory, UK) for her presentation on "*Integration of ecological indicators with the global network of ocean observations*", to Malin Pinsky (Princeton University, USA) for his paper on "*How predictable are species distribution shifts? Testing ecological hypotheses against four decades of observations*", to Jennifer Sunday (Simon Fraser University, Canada) for her talk on "*Marine species' latitudinal distributions conform better to their thermal tolerance than terrestrial species: Implications for range shifts*", and to K. Allison Smith (Princeton University, USA) for her presentation on "*Predicting future habitat changes above oxygen minimum zones*".

Selected papers from oral and poster presentations from the symposium and workshops will be included in a special issue of the ICES *Journal of Marine Science* scheduled for publication in July 2013. In addition, it is anticipated that selected sessions and workshops will develop their own proposals for special volumes.

As the symposium convenors, we would like to sincerely thank all those who participated in organizing this event. The symposium was made possible by the hard work of the local organizers, the Korea Ocean Research and Development Institute (KORDI) and Korea Oceanographic Commission (KOC). Special thanks go to the staff of the International Cooperation Department of KORDI who put an enormous amount of time and effort into making this symposium a success. The PICES Secretariat is to be thanked for providing professional assistance in the planning, development, coordination and the smooth running of the symposium. In addition to primary international (PICES, ICES and IOC), the following organizations and agencies made financial or in-kind contributions to the symposium:

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- Global Ocean Observing System
- Institute for Marine and Antarctic Studies (Australia)
- Integrated Marine Biogeochemical Ecosystem Research
- International Pacific Halibut Commission
- Korea Meteorological Administration
- Korea Tourism Organization
- National Aeronautics and Space Administration (USA)
- National Fisheries Research and Development Institute (Korea)
- National Oceanographic and Atmospheric Administration (USA)
- North Pacific Anadromous Fish Commission
- North Pacific Research Board (USA)
- Ocean Climate Change: Analysis, Projection, Adaptation Project (Korea)
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- Pusan National University (Korea)
- Scientific Committee on Oceanic Research (SCOR)
- United Nations Environment Programme
- World Climate Research Programme
- Yeosu City

Without support these sponsors provided, it would have been impossible to convene a symposium of global scope.