SCOR Working Group Proposal

Title

Eastern Boundary Upwelling Ecosystems (EBUE): inter-comparisons, variability and forecasting responses to climate and global change

Acronym

EBUE

Abstract

A SCOR working group (WG) on Eastern Boundary Upwelling Ecosystems (EBUE) is proposed. The focus of this WG would be on: 1) Assessing the trends and drivers of oceanographic, ecological and socio-economic properties in EBUE; 2) Assessing how well the current generation of coupled physical-biogeoecological models can reproduce the mean and current trends; 3) Developing a common observational and modeling framework for upwelling systems that will yield improved predictions of climate and global change; 4) Developing a list of realistic governance actions for EBUE based on current trends and model forecasts 5) Promoting integrated international EBUE scientific cooperation through organizations such as IMBER, CLIVAR, SOLAS, GlobalHAB and PICES; 6) Developing capacity so that an integrated program of comparable observations and models can be promoted across EBUE. We propose a strong team with broad scientific expertise in observations, modeling and socio-economics, and the four major coastal eastern boundary upwelling regions, i.e. California, Humboldt (Peru and Chile), Canary and Benguela. The team will review physical, biogeochemical, biological, fish and fisheries processes and trends, and their socio-economical impacts. Forecasts from global and higher resolution regional models will be analyzed. Potential effects on fisheries and other ecosystem services will be explored and a list of potential management strategies developed. The WG will develop a common observational and modeling framework for EBUE expected to yield improved predictions of climate and global change. It will promote international EBUE scientific cooperation through organizations such as IMBER, CLIVAR, SOLAS, GlobalHAB and PICES, and an integrated international program to implement the observational and modeling framework developed by the WG. The results will be published in primary scientific and socio-economic journals, and technical reports.

Scientific Background and Rationale

Eastern boundary upwelling ecosystems (EBUE) have fascinated oceanographers and fisheries scientists for decades. The strong coupling between atmospheric forcing, ocean circulation, biogeochemical cycling, and productive fisheries encouraged multidisciplinary scientific studies that have now become common. In EBUE temporal and spatial scales are intimately linked. The upwelling process and associated current system can segregate the sources (nutrients, phytoplankton, zooplankton) from the sinks (phytoplankton, zooplankton, fish) and make the biological pump a fully four-dimensional process. As a conglomerate, the EBUE produce almost 20% of the global marine fish harvest while occupying only a small fraction of the area. In the 21st Century human pressure on these productive ecosystems and their services is increasing, requiring new and evolving scientific approaches to the collection of information and its use in management. The EBUE are increasingly vulnerable to the multiple effects brought on by ocean acidification, deoxygenation, harvest of marine resources and coastal development. The complex four-dimensional nature of EBUE challenges the development of the system-level understanding that is needed to predict the effects of these stressors on marine ecosystems and humans at multiple scales. There are currently several evolving programs on EBUE, mostly focused on the impacts of a varying and changing climate on these productive ecosystems. CLIVAR (Climate

and Ocean: Variability, Predictability and Change), one of the four core projects of the World Climate Research Programme, hopes to improve how EBUE are simulated in global climate models; these systems are presently poorly represented. The Surface Ocean – Lower Atmosphere Study (SOLAS) has air-sea fluxes at eastern boundary upwelling and oxygen minimum zone systems as a mid-term strategy. There is an evolving plan presented to the United Nations Framework on the Convention for Climate Change for EBUE as sentinels of climate change and potential to be pilot programs for adaptation policies. IMBER recently convened a workshop focused on identifying key societal needs in EBUE, scientific gaps, and means to fill them. Here we propose a SCOR Working group on EBUE with the following deliverables: 1) A common observational and modeling framework for upwelling systems that will yield improved predictions of climate and global change; 2) A list of key indicators of change that can be used in such a framework; 3) An international implementation plan that integrates programs such as CLIVAR, IMBER, SOLAS, and GlobalHAB.

It is particularly timely to focus on eastern boundary upwelling ecosystems and their variability. The EBUE can serve as sentinels of marine ecosystem health and response to natural/anthropogenic perturbations. Ocean upwelling regions contain the world's most productive fisheries (Pauly and Christensen, 1995), mainly associated with eastern boundary currents (EBCs; e.g. Humboldt , Benguela, Canary current systems) but also in western boundary currents (WBCs; e.g. Kuroshio, Gulf Stream, Agulhas, East Australian), along the equator, off Antarctica, and elsewhere. Upwelling results from wind forcing against a coast in the case of EBCs, owing to change in sign of the Coriolis force at the equator, or through dynamic uplift as in WBCs. The rate and duration of upwelling influence the amount of biological production, hypoxia and pH levels. Upwelling rate determines the phytoplankton cell size (Van der Lingen et al., 2011). Small phytoplankton dominate when the upwelling rate is extremely strong or weak, resulting in extra trophic levels between the algae and fish, which reduces fish production. In contrast, large-sized phytoplankton dominate under moderate upwelling and production is then transferred more directly to fish via large zooplankton grazers. Further, upwelling rate may determine the plankton and fish community structure, given that different fish species are better suited to preying upon plankton of different sizes (van der Lingen et al., 2006).

A major current issue is anthropogenic climate variability and global change, and the individual EBUE are reacting differently. Projected increased winds under climate change in EBCs could result in increased upwelling (Bakun, 1990), but global warming should strengthen thermal stratification and cause a deepening of the thermocline and reduce upwelling (Bopp et al., 2005). Recent observational evidence in different regions have shown increases (Bakun, 1990; McGregor et al., 2007; Narayanan et al., 2010; Blamey et al. 2012), decreases (Gomez-Gesteira et al., 2008) or no change (Demarcq, 2009) in upwelling intensity. The upwelling response depends on the interactions between land, atmospheric structures and the ocean. Further work on the upwelling trends under climate change is needed to determine the balance between cooling due to increased upwelling (where it exists) and warming due to climate change as how the rate, duration and seasonality of upwelling, and hence fisheries, will be affected.

Upwelling systems typically are poorly represented in dynamic models owing to the small spatial scales of the upwelling relative to the horizontal resolution of the global models (Stock et al., 2011). Particularly. EBCs are often associated with warm temperature biases that strongly limit the prediction of future evolution. Increased model resolution improves simulations of the regional climate and affects the large-scale climate system through feedbacks (Large and Danabasoglu, 2006; Curchitser et al., 2011). Basin-scale physics are also a critical determinant of regional upwelling variability (Rykaczewski and Dunne, 2010). Using the most recent global and regional models will help to meet some of the challenges in developing upwelling scenarios under future climate change, including biogeochemical impacts (nutrients, primary production, deoxygenation, acidification), fisheries effects and subsequent influences on the dependent fishing industries and fishing

communities (Blanchard et al. 2012, Barange et al., 2014) – highly relevant in today's climate of an Ecosystem Approach to Fisheries and today's need to maximize food production and security.

Terms of Reference

This WG will:

1. Summarize and review current trends and drivers of oceanographic, ecological and socio-economic properties in each EBUE.
2. Compare trends and drivers between EBUE and summarize similarities and differences.
3. Develop a list of key indicators in EBUE that can be readily used to assess change across EBUE.
4. Prepare protocols for measuring key properties and indicators in EBUE.
5. Summarize and review model results for EBUEs and assess the strengths and weaknesses.
6. Develop a common observational and modeling framework for upwelling systems that will yield improved predictions of climate and global change.
7. Describe the usefulness of current observations and model forecasts for governance activities in EBUE.
8. Develop capacity in developing countries so that collection of comparable observations development of comparable models across EBUE can be implemented .
9. Promote international EBUE scientific cooperation through organizations such as IMBER, CLIVAR, SOLAS, GlobahHAB, and PICES.
10. Promote an integrated international program that will implement the observational and modeling framework developed by WG.

Year 1 (2017)

The first year will be focused on organizing the Working Group and assembling the information needed to achieve deliverables 1 and 2 (see below). An initial meeting of the Working Group in a location convenient to the WG is proposed, perhaps at MBARI or Rutgers. These institutions can provide local meeting venues and administrative support at no cost to SCOR. At this meeting the capacity building activities will be planned for Year 2 in addition to beginning the collection of material for deliverables 1 and 2. Clear plans and responsibilities will also be developed, identifying leads for each deliverable. Mechanisms for WG communication and exchange will be established. At this meeting we would also identify promising graduate students from developing countries who might take advantage of the WG activities and potentially lead certain aspects of the research.

Year 2 (2018)

Two one-week meetings in Peru and Chile are proposed for Year 2. The first week the WG will meet in Peru for two days followed by a 3-day short course in support of a recently established Master's Program at the Universidad Cayetano Heredia (Gutierrez is faculty). The following week the same schedule will be followed in Chile at the Universidad de Concepcion (Escribano is Faculty). The topics of the courses will be developed in close consultation with local scientists, but touch on EBUE dynamics, response to climate variability and change, and impacts on fisheries and ecosystem services. The local organizers will provide meeting venues and administrative support at no cost to SCOR. The courses will be open to students from any university, including other South American countries. The WG will request funding from SCOR and other sources to help students and early-career scientists participate. During the WG meetings the progress on deliverables will be reviewed, with particular emphasis on the Humboldt EBUE. Local experts will be invited to the WG meetings. See note at end of Year 3 plans regarding budget.

Year 3 (2019)

A similar sequence will be followed early in Year 3 but focusing on Northwest Africa and Benguela. Again, two weeks, one week in NW Africa (Aristegui lead), followed by a second in Benguela (Moloney, lead). Locations to be determined. Local organizers will provide meeting venues and administrative support at no cost to SCOR. The courses will be open to students from any university, including other African countries. The WG will request funding from SCOR and other sources to help students and early-career scientists participate. During the WG meetings the progress on deliverables will be reviewed, with particular emphasis on the North and South Africa EBUE. Local experts will be invited to the WG meetings. We expect completed first drafts and submissions of deliverables 1-3 by the end of Year 3. Having two-week meeting in two geographic locations in two years will be difficult to achieve within the budget allocated to SCOR WGs and we will seek other sources of funds to implement the proposed meeting schedule. Should funds not be found we would scale back to single meetings in South America (2018) and Africa (2019).

Year 4 (2020)

We presently do not anticipate the need for a face-to-face meeting in Year 4, although this could change depending on progress, new developments and available funds. We anticipate completion of the full set of deliverables by the end of Year 4.

Deliverables

1. Prepare a scientific review of current trends and drivers of oceanographic, ecological and socio-economic properties in EBUE. The review will compare trends and drivers between EBUE and summarize similarities and differences. Suggested target journal is *Nature Climate Change*.
2. Prepare a scientific review of numerical model results for EBUEs and assess the strengths and weaknesses of different models. Compare model results with trends and drivers developed above. Suggested target journal is *Nature Climate Change*.
3. Based on 1 and 2 develop a common observational and modeling framework for upwelling systems that will yield improved predictions of climate and global change. This framework will utilize key indicators identified by the WG for EBUE that can be readily used to assess change across EBUE. In support of the framework the WG will prepare protocols for observations of key properties and indicators in EBUE and the required model parameters and resolution. Journal TBD.
4. The WG will utilize current observations and model forecasts to develop a list of proposed governance activities for each EBUE. Journal TBD
5. A white paper describing an integrated international program that utilizes the observational and modeling framework developed by WG with proposed implementation by EBUE nations and international organizations such as IMBER, CLIVAR, SOLAS, GlobalHAB, and PICES.

Capacity Building

An online course on "EBUE dynamics, response to climate variability and change, observations, modeling and impacts on fisheries and ecosystem services " will be assembled based on the four short courses during Years 2 and 3. This course will be made freely available to graduate and postgraduate students and offered in an open system by 2019. It will be offered first in English and then other languages as well. We will also support involvement of graduate students in WG activities and meetings, including presentations and publication of results. A set of best practices for key observations and indicators will be developed, mostly by combining published protocols (i.e. ocean acidification). A similar exercise will be carried out with models.

The project will also promote the integration of an international network of scientists (observationalists and modelers) working in upwelling systems and use this network to identify common problems and experiences. By involving scientists and students from developing countries throughout the WG process we expect to increase the number and quality of scientists from these countries working in EBUE leaving a long lasting imprint.

Working Group composition

Full Members – We have sought to balance the team by discipline, participants from developed and developing countries, and gender. As a result of the overall balancing we are weaker in gender balance than we would have preferred.

	Name	Gender	Place of work	Expertise/ Area
1	Francisco Chavez	Male	USA (co-chair)	Biological Oceanography/ California, Peru
2	Javier Aristegui	Male	Spain	Biogeochemistry/ Northwest Africa
3	Colleen Moloney	Female	South Africa	Biogeochemistry, modeling/Benguela
4	Ruben Escribano	Male	Chile (co-chair)	Biological Oceanography/ Chile/ IMBER
5	Dimitri Gutierrez	Male	Peru	Biogeochemistry, Oceanography/ Peru
6	Enrique Curchitser	Male	USA	Physical Oceanography Modeling /CLIVAR
7	Nicolas Gruber	Male	Switzerland	Oceanography, Biogeochemistry, Modeling
8	Manuel Barange	Male	UK	Fisheries/Socio-economist, ecology
9	Salvador Lluch-Cota	Male	Mexico	Fishery/Socio-economist ecology
10	Sophie Bertrand	Female	France	Ecology, Conservation

Associate Members

	Name	Gender	Place of work	Expertise/ Area
1	Xosé Alvarez Salgado	Male	Spain	Biologist/Canary EBUE
2	Ryan Rykaczewski	Male	USA	Biological Oceanography/EBUE
3	Des Barton	Male	Spain	Physical oceanographer/ Modeling EBUE
4	Paquita Zuidema	Female	USA	Physical Oceanography/ Modeling EBUE
5	Veronique Garcon	Female	France	Biological Oceanography/EBUE
6	Shoshiro Minobe	Male	Japan	Oceanography/climatology Modeling EBUE

7	Lynne Shannon	Female	South Africa	Fishery/Socio-economist ecosystem EBUE
8	Holger Auel	Male	Germany	Biological Oceanography/EBUE
9	Carl van der Lingen	Male	South Africa	Fishery Oceanography/ Benguela
10	Marisol García Reyes	Female	Mexico	Biogeochemistry/EBUE

Working Group contributions

Francisco Chavez, co-chair, has published extensively on climate variability and EBUE, worked for many decades on the California and Humboldt EBUE, and has broad interests in oceanography, biogeochemistry, ecology, modeling, and new technology. He has led several synthesis efforts, edited multiple special issues and is active in national and international programs.

Ruben Escribano, co-chair, is a biological oceanographer who specializes in zooplankton, was active in the GLOBEC program and is presently on the IMBER scientific steering committee. He has worked extensively on the Humboldt EBUE and will lead the capacity building effort.

Enrique Curchitser is a physical oceanographer with interests in the dynamics of eastern boundary currents and shelf circulation and coupled bio-physical and numeric modeling. He is leading the CLIVAR Eastern Boundary Upwelling Research Focus that is trying to better understand the very large biases that climate models have in EBUE.

Sophie Bertrand is a marine ecologist who is interested in the spatial relationships between fish, seabirds, marine mammals and humans in productive EBUE so that better management can be developed to permit animals and humans to sustainably cohabitate. She is a member of MARBEC (MARine Biodiversity, Exploitation and Conservation).

Nicolas Gruber leads the Environmental Physics group at ETH in Zurich that studies interaction between biogeochemical cycles and climate from global to regional levels. One research focus is on the eastern boundary upwelling systems of the Atlantic and the Pacific Ocean where they use the Regional Oceanic Modeling System (ROMS) coupled to biogeochemical-ecosystem models (NPZD and BEC) to investigate how physical, chemical and ecological processes respond to natural and anthropogenic change.

Manuel Barange has expertise in physical/biological interactions, climate and anthropogenic impacts on marine ecosystems, fish ecology, behavior and trophodynamics, and fisheries assessment and management. Recently he has focused on the impacts of climate change and economic globalization on marine-based commodities, and on the interaction between natural and social sciences in fisheries, ecosystems and climate change in the developed and developing world.

Collen Moloney has broad research interests in the variability and dynamics of marine food webs and ecosystems under global change and locally on the marine ecosystems of the west and south coasts of southern Africa, part of the Benguela EBUE. She utilizes field and modelling studies to understand “end-to-end" ecosystem responses to global change, determined by complex interactions and feedbacks among physical,

chemical and biological processes spanning many time and space scales.

Salvador Lluch-Cota has interests in climate variability and change and its effects on living marine resources; he was one of the six lead authors of the IPCC chapter on Ocean Systems. He has worked extensively in the California Current System particularly off Baja California, Mexico and has led synthesis efforts to uncover and better understand the variability of small pelagic fish in Atlantic and Pacific EBUE.

Javier Aristegui is based in the Canary Islands and much of his work is focused on the Northwest Africa EBUE, studying the influence of mesoscale and sub-mesoscale processes on planktonic community structure and metabolism, and the role that these features play in the export of carbon from coastal waters to the open-ocean. He is a past vice-chair of the IMBER Scientific Steering Committee, led an international symposium on EBUE, is an author of IPCC reports and contributed to the Joint SOLAS-IMBER Carbon Cycle Research Plan.

Dimitri Gutierrez is head of the Oceanography and Climate Change division at the Instituto del Mar del Peru, has broad research interests in EBUE, climate variability, oceanography, benthic communities and paleo-oceanography and will co-lead capacity building activities with Dr. Escribano. He has recently led a successful proposal to the World Bank to implement a climate change adaptation program for Peruvian coastal communities where small-scale fisheries are critical elements of society.

Relationship to other international programs and SCOR Working groups

This program has clear linkages to CLIVAR, IMBER, SOLAS, GlobalHAB and UNFCC. CLIVAR (Climate and Ocean: Variability, Predictability and Change), one of the four core projects of the World Climate Research Programme, hopes to improve how EBUE are simulated in global climate models; these systems are presently poorly represented. SOLAS (Surface Ocean - Lower Atmosphere Study) has air-sea fluxes at eastern boundary upwelling and oxygen minimum zone systems as a mid-term strategy. There is an evolving plan presented to the United Nations Framework on the Convention for Climate Change for EBUE as sentinels of climate change and potential to be pilot programs for adaptation policies. IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) recently convened a workshop focused on identifying key societal needs in EBUE, scientific gaps, and means to fill them. There is also relation to IOC sponsored projects such as GOAN (Global Ocean Acidification Network), GO_2NE (Global Oxygen Observation Network), and GlobalHAB (Harmful Algal Blooms). The Humboldt EBUE relates to the Tropical Pacific Observing System 2020 initiative.

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Appendix - Key references for each full member (up to 5 papers)

Francisco Chavez

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