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The 2010 Inter-sessional Science Board Meeting: A Note from the Science Board Chairman

Our annual inter-sessional Science Board (ISB) meeting was held from April 23–24, 2010, in Sendai, Japan, immediately prior to the international symposium on "*Climate change effects on fish and fisheries: Forecasting impacts, assessing ecosystem responses and evaluating management strategies*". This was a special ISB meeting because it was the first time that we formally met as both the Science Board and as the Scientific Steering Committee of FUTURE (***F****orecasting and* ***U****nderstanding* ***T****rends,* ***U****ncertainty and* ***R****esponses of North Pacific* ***E****cosystems*), PICES' new integrative science program. So it is important that I formally welcome the three new Science Board members who will serve as Chairmen of the FUTURE Advisory Panels (APs), Dr. Thomas Therriault (Canada), *Anthropogenic Influences on Coastal Ecosystems* (AICE-AP), Dr. Hiroaki Saito (Japan), *Climate, Oceanographic Variability and Ecosystems* (COVE-AP) and Mr. Robin Brown (Canada), *Status, Outlooks Forecasts, and Engagement* (SOFE-AP).

Before reviewing the highlights of ISB-2010, I would like to thank our Japanese colleagues for doing an outstanding job of hosting both our meeting and the symposium. Special thanks to Drs. Yukimasa Ishida and Shin-ichi Ito and all the staff of the Tohoku National Fisheries Research Institute of the Fisheries Research Agency who assisted both Ishida-san and Ito-san. We enjoyed our stay in Sendai, which was filled with first-rate science, and fruitful interactions and new connections with scientists from regions that we do not usually have contact with.

On the first day of the meeting, the agenda addressed progress reports from our Scientific and Technical Committees, status of inter-sessional events and publications, preparations for PICES-2010 and plans for the Annual Meeting in 2011, which we can now report will be in Khabarovsk, Russia. We also welcomed Dr. Steven Rumrill (U.S.A.) to his first meeting as Chairman of the Marine Environmental Quality Committee (MEQ). As is our normal practice, we made selections for this year's recipients of both the Wooster Award and PICES Ocean Monitoring Service Award (POMA), but you will have to wait to hear who the recipients are at our Annual Meeting in Portland this fall.

Sendai International Center where the inter-sessional Science Board meeting and the symposium on "Climate Change Effects on Fish and Fisheries" were held in April 2010.

In This Issue

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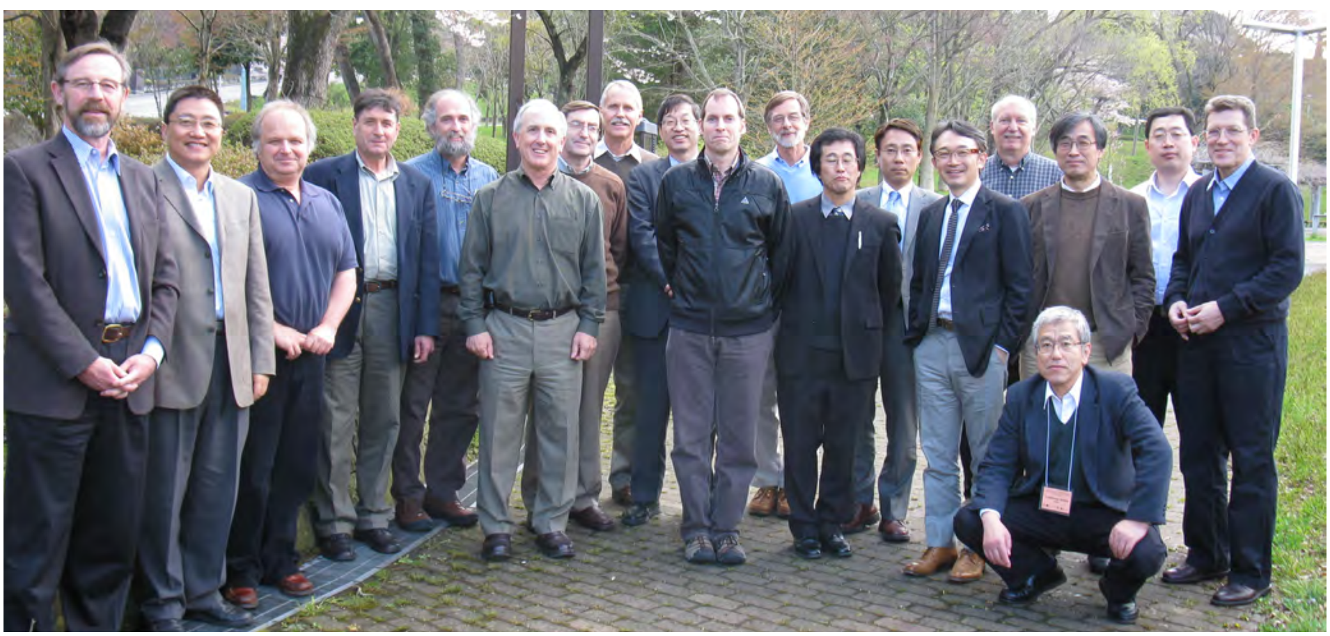
Concerning this year's Annual Meeting, Science Board agreed to pursue a special issue of *Deep-Sea Research II* to publish papers that address the PICES-2010 theme "*North Pacific ecosystems today, and challenges in understanding and forecasting change*". I encourage all who are presenting at the Annual Meeting and in particular, those presenting in the Science Board Symposium and in the Topic Sessions on "*Observations of ecosystem mixing under climate change*", "*Impact of climate variability on marine ecosystems: Understanding functional responses to facilitate forecasting*" and "*Anthropogenic forcing in North Pacific coastal ecosystems: Understanding changes in ecosystem structure and function*", to consider submitting a paper. As you know, the process has started for developing the 5th Assessment Report (AR-5) of the Intergovernmental Panel on Climate Change (IPCC), and PICES and others are working to insure that internationally we have relevant papers on marine ecosystems published, or in press, in 2011 so that they can be considered for AR-5 to substantively bolster the section on climate change and marine ecosystems.

A couple of items on the expert groups are worth noting. Dr. Kevin Amos (U.S.A.) has stepped down as Co-Chairman of Working Group (WG 24) on *Environmental Interactions of Marine Aquaculture*, and Science Board recommended Dr. Brett Dumbauld (U.S.A.) as his replacement. We welcome Brett and know that he will be ably assisted by two other Co-Chairmen Drs. Katsuyuki Abo (Japan) and Ingrid Burgetz (Canada). We also received a progress report and an updated work plan from the Study Group on *Human Dimensions* (SG-HD). Science Board is particularly interested in the work of this Study Group as it is one of our steps in addressing the human dimension issues related to FUTURE, and it is an important stage in further engaging economic and social scientists in FUTURE, which is important to the program's success. We are confident that under the leadership of Dr. Mitsutaku Makino (Japan), SG-HD will meet its objectives.

I also note here an action related to a joint activity with ICES (see PICES Press Vol. 18, No. 1 for details) in that Science Board nominated Drs. Therriault (AICE-AP) and Saito (COVE-AP) as members of PICES/ICES Study Group on *Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science*, along with our Science Board Chairman-elect, Dr. Sinjae Yoo, and the Deputy Executive Secretary, Dr. Skip McKinnell. I see this as an important activity to further our growing and productive collaboration with ICES.

While we look at the activities for this year and next, we also are also busy planning further ahead, especially when it comes to organizing international symposia. One such event is the 2nd PICES/ICES/IOC Symposium on "*Effects of climate change on the world's oceans*" to be convened in May 2012, in Yeosu, Korea, in conjunction with Ocean Expo-2012. At PICES-2009, Dr. Hiroaki Saito was appointed as the PICES convenor. At ISB-2010, we selected Drs. James Christian (Canada) and Keith Criddle (U.S.A.) to serve as the PICES members on the Scientific Steering Committee.

It is a pleasure to report that we are on schedule to publish the second version of the North Pacific Ecosystem Status



Participants of the inter-sessional Science Board meeting on the grounds of the Sendai International Center: (left to right) – Skip McKinnell (Secretariat), Gongke Tan (China), Robin Brown (Canada), Mikhail Stepanenko (Russia), Steven Rumrill (U.S.A.), John Stein (Science Board Chairman), Alexander Bychkov (Secretariat), Michael Foreman (Canada), Tokio Wada (PICES Chairman), Thomas Therriault (Canada), Michael Dagg (U.S.A.), Hiroya Sugisaki (Japan), Taro Ichii (Japan), Hiroaki Saito (Japan), Bernard Megrey (U.S.A.), Yukimasa Ishida (Japan, front), Sinjae Yoo (Science Board Chairman-elect), Fangli Qiao (China), Igor Shevchenko (Russia). Missing: Samuel Pooley (U.S.A.)

Report this summer. It is a nearly 400-page hard cover book and it will have a true Synthesis Chapter. As an indication of the progress being made, chapters are now in the galley proof stage. I have seen the Synthesis Chapter and from the quality of the science and the layout of the material, it is certainly clear that Co-Editors, Drs. Skip McKinnell and Michael Dagg, and all of the lead authors and co-authors have done an excellent job, having put in a great deal of time and high quality effort to produce this important report.

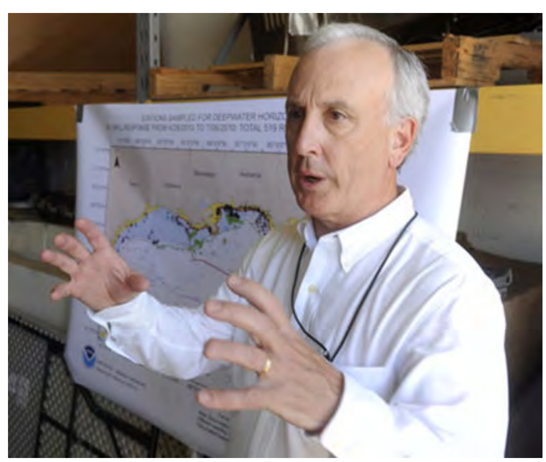
Another high priority activity of PICES is capacity building. This year, at the invitation of IMBER, PICES is co-sponsoring a summer school on "*Oceans, marine ecosystems, and society facing climate change: A multidisciplinary approach*" (ClimECO2) to be held August 23–27, 2010 in Brest, France. By having PICES involved, the goal is to provide early career scientists from the Pacific with excellent training and networking with European scientists. After a review of candidates, nine scientists from all PICES member countries were selected for travel support.

Now let me turn to our meeting as the FUTURE Scientific Steering Committee (SSC). The main objectives of the meeting were to review the work plans for each of the APs, the process for approving new expert groups, and importantly, the need for a joint meeting of the APs this summer. As we move to using the Science Board as the SSC, it will be essential that our Working Groups and Sections produce their reports and new work plans at least one month prior to our Annual Meetings. This is important to ensure that their parent Committee(s) and the relevant FUTURE AP have time to review the reports. It will be also critical for a Co-Chairman or a representative of an expert group to attend the meeting of the relevant AP in order to insure good communication and effective integration of the expert group activities into meeting the goals and objectives of FUTURE. Going back to the symposium we had in Sendai, it is again clear that what we have developed as a science plan for FUTURE is very much at the cutting edge of marine ecosystem science.

We also needed to revisit the process for nominating new expert groups so that the FUTURE Advisory Panels can provide their input. The following process was adopted. New expert groups can be suggested to the Science Board by the Committees and by the FUTURE Advisory Panels. The Committees assess proposed groups in relation to both FUTURE and the Committee's Strategic Plan and then, as in the past, make recommendations to Science Board, which then reviews the proposal and makes recommendations to the Governing Council.

Finally, to further insure that we get FUTURE off to a solid start, we concluded that it was necessary for the three Advisory Panels to meet before PICES-2010 to discuss their work plans and coordinate their activities. The workshop will be co-sponsored by the Korean government and held in August, in Seoul. I have a family commitment at the time and, unfortunately, will not be able to attend but I am confident that our Chairman-elect, Dr. Sinjae Yoo, will do an excellent job as both host and convenor of the workshop.

I close now from Pascagoula, Mississippi, U.S.A. – and you all thought I was based in Seattle. I am on detail to the Gulf of Mexico to lead NOAA's Seafood Safety Program that was put in place to respond to the Deepwater Horizon oil spill. As you are aware, the U.S. is experiencing the largest oil spill in its history. We have had to close 34% of the Gulf of Mexico to fishing – an unprecedented closure. I brought this up because it illustrates that in FUTURE we have the right pieces – we are addressing anthropogenic forcing on coastal marine ecosystems and interactions with climate, and then will need to communicate the science. In the Gulf of Mexico the amount of carbon that is being added to the ecosystem is a major concern. This year is projected to be a more active hurricane season and, along with carbon, are the associated toxic polycyclic aromatic hydrocarbons and the use of large amounts of dispersants, which means that the oil is present as a subsurface 'cloud'. What will be the interactions? How will a hurricane affect the fate and effects of the oil? What will be the overall ecological impacts and when will it be safe to re-open areas to fishing? All these are questions that need ecosystem-based science and good communication of that science. This is what we are taking on in FUTURE, and this significant incident in the Gulf of Mexico brings home the message that while climate change is the major global issue we must address, there can be human-caused events that can have critical consequences on regional scales, and our science must improve both at the global and regional scales to better address major events and to help society deal in the future with events that can change a region for years if not fundamentally while under the backdrop of global climate change.



PICES Science Board Chairman, Dr. John Stein, wearing his major "hat" as NOAA expert, briefs reporters on NOAA's Seafood Safety Program implemented to respond to the Gulf of Mexico oil spill disaster in Pascagoula, Mississippi.

2010 Symposium on "*Effects of Climate Change on Fish and Fisheries*"

by Anne B. Hollowed, Manuel Barange, Shin-ichi Ito, Suam Kim, and Harald Loeng

The North Pacific Marine Science Organization (PICES), International Council for the Exploration of the Sea (ICES) and Food and Agriculture Organization (FAO) held an international symposium on "*Climate change effects on fish and fisheries: Forecasting impacts, assessing ecosystem responses and evaluating management strategies*" from April 26–29, 2010, in Sendai, Japan, with co-authors of this article serving as symposium convenors. Unfortunately, Drs. Manuel Barange (UK) and Harald Loeng (Norway), as well as Dr. Kenneth Drinkwater (Norway; theme session convenor), were unable to attend the meeting because of the eruption of Mount Eyjafjallajökull in Iceland. Three more (out of 23) theme session convenors were unable to participate due to unexpected illnesses. Even though these were notable absences, the symposium was still considered a grand success.

The symposium was the culmination of the planning and preparation of PICES and ICES. In recognition that climate change impacts on marine ecosystems will not be limited to one region of the globe, these two organizations formed in 2009 the first joint Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (WG-FCCIFS). One of the priority tasks for WG-FCCIFS was to convene a symposium to provide a venue for the exchange of scientific information and the discussion of the issues and challenges related to predicting the future impacts of climate change on the world's marine ecosystems. The symposium in Sendai was the product of this effort.

The symposium was designed to provide an opportunity for scientists and policymakers to discuss the potential impacts of climate change on marine ecosystems, and our use of the resources provided by these ecosystems. During the meeting, we considered strategies that society can take to be prepared for anticipated impacts on fish and fisheries. A key element was the desire to publish selected papers from the symposium, with sufficient time for them to be considered by review panels responsible for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and by other review bodies, such as the Millennium Report of the United Nations Development Program.

The response to this symposium exceeded our expectations, with more than 350 abstracts submitted by scientists from over 40 countries. After the final tally, 337 scientists from 37 countries were in attendance. A total of 208 oral presentations and 105 posters were presented.

During the symposium, the global significance of the issues was highlighted in many discussions and presentations. It was a great satisfaction for the convenors to see scientists from around the world debating the issues stemming from climate change impacts on marine ecosystems. Sound scientific advice on the expected impacts of climate change requires the international research community to work together in an interdisciplinary research setting to identify, forecast, and assess strategies to respond to the impacts of climate change on fish and fisheries. The symposium provided this type of interdisciplinary exchange of information.

President of the Fisheries Research Agency of Japan, Dr. Toshihiko Matsusato, preparing to register for the symposium.

The symposium was arranged around 10 theme sessions, with 6 workshops preceding the meeting (summary reports from 5 workshops are included elsewhere in this issue of PICES Press). These sessions and workshops encompassed a broad range of topics that provided a global perspective on climate change and the future of the world's fish and fisheries.

Day 1 started with presentations by four plenary speakers: Drs. Kevin Trenberth (National Center for Atmospheric Research, U.S.A.), Akihiko Yatsu (Seikai National Fisheries Research Institute, Japan), Eddie Allison (WorldFish Center, Malaysia) and Ussif Rashid Sumaila (University of British Columbia, Canada).

The themes for Day 1 included:

- *Forecasting impacts: From climate to fish* (co-chaired by Kenneth Drinkwater, Harald Loeng, Franz Mueter, Carl O'Brien, Graham Philling and Yashuhiro Yamanaka);
- *Forecasting impacts: From fish to markets* (co-chaired by Manuel Barange, Jacquelynne King, Ian Perry and Adolf Kellermann);
- *Species-specific responses: Changes in growth, reproductive success, mortality, spatial distribution and adaptation* (co-chaired by Richard Beamish, Myron Peck and Motomitsu Takahashi).

Symposium in session.

The themes for Day 2 were:

- *Downscaling variables from global models* (co-chaired by Michael Foreman and Jason Holt);
- *Assessing ecosystem responses: Impacts on community structure, biodiversity, energy flow and carrying capacity* (co-chaired by Thomas Okey and Akihiko Yatsu);
- *Species-specific responses: Changes in growth, reproductive success, mortality, spatial distribution and adaptation* (continued from the previous day);

The themes for Day 3 focused on:

- *Comparing responses of climate variability among nearshore, shelf and oceanic regions* (co-chaired by Jurgen Alheit, Jae Bong Lee and Vladimir Radchenko);
- *Impacts on fisheries and coastal communities* (co-chaired by Eddie Allison, Keith Brander and Suam Kim);
- *Evaluating human responses, management strategies and economic implications* (co-chaired by Tarub Bahri, Kevern Cochrane and Jake Rice);
- *Contemporary and next generation climate and oceanographic models, technical advances and new approaches* (co-chaired by Jonathan Hare and Shin-ichi Ito).

The final half-day session on "*Sustainable strategies in a warming climate*" (co-chaired by Anne Hollowed and Michael Schirripa) was held in plenary. Dr. Steve Murawski provided a summary of first impressions from the symposium. He identified many issues for participants to consider (Fig. 1).

It is impossible to summarize all of the exciting outcomes and research findings that were revealed during the symposium in a short article for the PICES Press. Thus, Table 1 includes the selection of key outcomes from the plenary and theme sessions that provide a glimpse of the broad scope of issues discussed during the meeting.

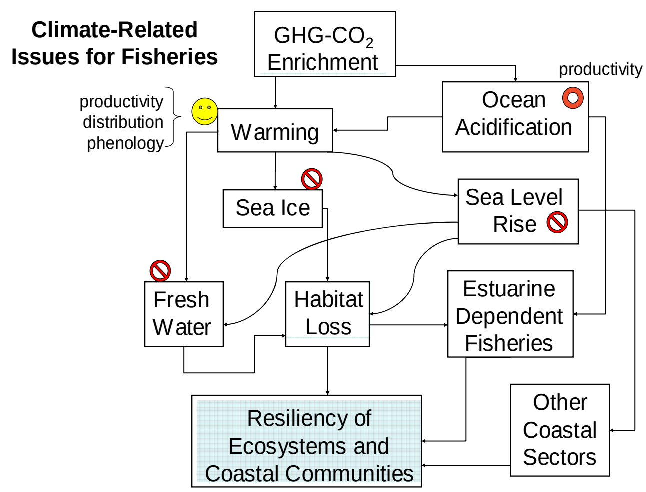


Fig. 1 Summary of climate-related issues for fisheries: smiling symbol indicates that substantial research is currently underway on this issue, open red circle indicates some research has been initiated on this subject, crossed red circles indicate that additional work is needed on this subject area (prepared by Dr. Steve Murawski).

Dr. Steve Murawski, Director of Scientific Programs and Chief Science Advisor for NOAA Fisheries, offering his impressions from the symposium.

	Table 1. Summary of key outcomes from the symposium
1	Long-term ocean monitoring programs are needed to track and understand ecosystem and climate change as they occur.
2	Networks of shelf-seas ecosystem models have already been developed within several of the world's LMEs. These models provide a basis for examining structural uncertainty within shelf sea ecosystem models (Fig. 2).
3	Three sources of uncertainty in Global Ocean Models (GOMs) are under investigation: (1) parameter uncertainty, (2) structural uncertainty, and (3) scenario uncertainty. Parameter uncertainty is being addressed to some degree with sensitivity tests; structural uncertainly is being explored via comparison of different coupled physical-biological models; and scenario uncertainty related to greenhouse gas emissions and economics can only be dealt with by using ensemble model sets.
4	There are five approaches to predicting the effects of climate change on fish and fisheries: (a) conceptual predictions, (b) inferences from laboratory studies, (c) statistical downscaling from GOM to the regional scale; (d) dynamic downscaling to regional ocean models; (e) whole earth system models. Each approach has strengths and weaknesses.
5	Fisheries oceanography and laboratory studies are critical to integrating biological and oceanographic models, evaluating species environmental tolerances and adaptation, and tracking species responses to long-term ecosystem and climate change as it occurs.
6	Models that couple marine social and economic responses are needed to evaluate management strategies; however, few examples exist (Fig. 3).
7	Issues of food security and marine conservation may require new approaches to satisfy the growing demand for marine resources.
8	Two-way communication is needed between scientists and stakeholders to develop meaningful scenarios on human responses to the impact of ecosystem and climate change.

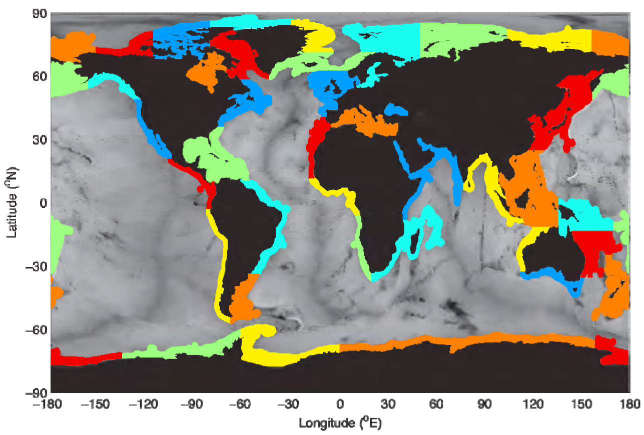


Fig. 2 The QUEST_FISH regional modeling domains (resolution 0.1 deg) defined by the 800 m contour plus 200 km of open ocean. The colors indicate that the models are regional and are only coupled through boundary conditions (Barange et al.; In: Ommer et al., Coping with climate change in marine socio-ecological systems. Blackwell FAR Series, in press).

The session on "*Forecasting impacts: From climate to fish*" consisted of 20 oral presentations and 19 posters, including invited talks by Drs. Kevin Trenberth, Akihiko Yatsu and Randall Peterman (Simon Fraser University, Canada). Dr. Trenberth provided an overview of the Earth's climate system and presented unequivocal evidence that humans are warming the world's atmosphere and oceans. He emphasized the importance of changes in the extremes rather than in mean climate states. Dr. Yatsu noted the need for interdisciplinary collaboration to incorporate the effects of climate forcing at different life stages when modeling impacts on marine fishes. Dr. Peterman discussed the major sources of uncertainty when forecasting climate effects, highlighting the importance of structural model uncertainty, which can only be addressed by considering multiple alternative models. He emphasized that inadequate communication among scientists, decision makers, and stakeholders can be a potentially important and poorly understood source of uncertainty. A key contribution of this session was the review of a variety of frameworks and methodologies employed for forecasting the effects of climate change on fish and fisheries. The majority of papers generated quantitative forecasts of future productivity or distribution of selected species based on the output of one or more global circulation models (GCMs). Based on GCMs, the approaches can be divided into global-scale static models, global-scale dynamic models, dynamic downscaling approaches, and statistical downscaling approaches. Other approaches did not produce quantitative forecasts but aimed at predicting the likely direction of future changes under global warming based on understanding the mechanisms that relate productivity of key species to climate variability. The comparative approach was similarly employed to better understand the mechanisms that favor different species during warm and cold periods. Statistical time series analyses were used to better assess past variability in climate and biological populations as an aid in understanding future variability, but forecasting future responses based on past patterns of variability is fraught with difficulties. Finally, some presentations highlighted the importance of field and laboratory studies to help estimate vital rates for fishes, which are needed to elucidate and quantify important mechanisms and to support modeling efforts.

The session on "*Forecasting impacts: From fish to markets*" consisted of 8 oral presentations, including invited talks by Drs. Eddie Allison and Rashid Sumaila. A key outcome of this session was the recognition that climate–fish–people models are beginning to be constructed, but are still in their early stages. Simpler (statistical) models which identify present fishing habitats and use of these to project fishing locations with future climate conditions are more common, and were included as the bases in most of the presentations in this session. This type of model often uses simple parameters such as SST. Future developments are needed to incorporate at least oxygen and temperatures at depth. Models of societal responses have many uncertainties, including how information is transferred within communities, and how human behavior responds to changing pressures.

The session on "*Downscaling variables from global models*" consisted of 13 oral presentations and 1 poster, including invited talks by Drs. J. Icarus Allen (Plymouth Marine Laboratory, UK) and Muyin Wang (Joint Institute for the Study of Atmosphere and Ocean, University of Washington, U.S.A.). This session focused on the techniques for estimating and communicating uncertainty in forecasts. Dr. Wang presented a framework for selecting scenarios for the Arctic and showed the importance of using models that address seasonal changes. Dr. Allen reviewed the different sources of uncertainty in climate models and outlined methods for estimating these uncertainties. He decomposed uncertainty into three categories: parameter uncertainty, structural uncertainty, and scenario uncertainty. The first one can be addressed by series of sensitivity tests that alter parameter values through a reasonable range. The second refers to the specific nature of the model, particularly the biogeochemical component, and could be explored, for example, by coupling biological models with differing complexity to the same physical model and examining the range and accuracy of the results. In the context of climate projections, the third refers to uncertainties in greenhouse gas emissions and can only be dealt with by computing ensembles that cover a range of plausible states.

The session on "*Species-specific responses: Changes in growth, reproductive success, mortality, spatial distribution and adaptation*" consisted of 28 oral presentations and 40 posters, including invited talks by Drs. Hans-Otto Pörtner (Alfred-Wegener-Institute, Germany) and John Pinnegar (Centre for Environment, Fisheries, and Aquaculture Science, UK). This session focused on the response of key fish species and fisheries worldwide to climate change. Presentations documented historical, often long-term fluctuations in abundance and distribution, discussed processes underlying current changes, and/or projected future impacts in light of adaptive capacity using a number of approaches. The research utilized a variety of methodological approaches. Most studies included topics such as observed and/or projected changes in distribution and/or productivity. A key outcome was the observation that quantitative evidence linking physiological responses to ecosystem change in various climate scenarios is scarce. Patterns identified in long-term field data or via macro-physiology and meta-analyses using various statistical tools are not sufficient to understand climate effects because the fundamental, underlying physical mechanisms are lacking. The session also revealed that additional research is needed to improve our understanding of the adaptive capacity of species to environmental change. Dr. Pörtner provided one example of the study type required. He reviewed the physiologically underpinnings that define tolerable marine habitats in fish and invertebrates, including expected cellular-level changes in metabolic scope via changes in oxygen and capacity-limited thermal tolerance. He also highlighted changes in ocean pH and the need to examine interactive effects of multiple stressors on vital rates.

The session on "*Assessing ecosystem responses: Impacts on community structure, biodiversity, energy flow and carrying capacity*" included 27 oral presentations and 15 posters. The invited speakers were Drs. Beth Fulton (CSIRO Marine and Atmospheric Research, Australia) and Jeffery Polovina (NOAA's Pacific Island Fisheries Science Center, U.S.A.). This session addressed the challenges involved in assessing the effects of climate change on marine ecosystems. A key outcome was the recognition that ecosystem models have been developed for many of the shelf-sea systems around the globe, and this network of models provides a foundation for examining shifts in the boundaries and structure of marine ecosystems.

The session on "*Comparing responses to climate variability among nearshore, shelf and oceanic regions*" included 15 oral presentations and 14 posters. The invited speakers were Drs. Nicholas Dulvy (Simon Fraser University, Canada) and Svein Sundby (Institute of Marine Research, Norway). Unfortunately, Dr. Sundby was unable to attend due to the eruption of the volcano in Iceland. Dr. Dulvy discussed climate impacts on Caribbean coral reefs and North Sea fishes. He demonstrated that Caribbean coral reef cover is at an all time low, and that the associated collapse in architectural complexity has led to severe habitat loss for coral reef fishes and resulted in declines in fish abundance. Warming of the North Sea has affected fish distribution and has led to range extensions of southern and range contractions of northern species. This session provided several case studies, showing the implications of climate change on near shore and oceanic regions.

The session on "*Impacts on fisheries and coastal communities*" consisted of 13 oral presentations and 11 posters. The invited speakers were Drs. Ian Perry (Pacific Biological Station, Canada) and Tarub Bahri (Food and Agriculture Organization). Dr. Perry reviewed the bio-physical, as well as human, drivers of changes in marine social-ecological systems and noted that we need to promote capabilities for observing, assessing, and adapting marine social-ecological systems to environmental changes to improve our ability to forecast the future impacts of climate change (Fig. 3).

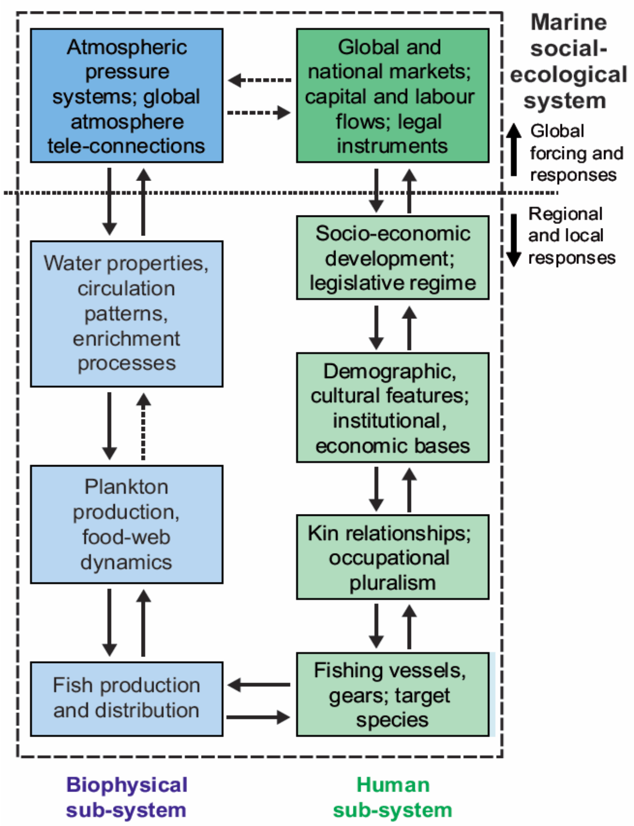


Fig. 3 Coupled marine social-ecological systems (Perry et al., 2010; In: Barange et al., Marine ecosystems and global change. OUP).

The session on "*Evaluating human responses, management strategies and economic implications*" included 13 oral presentations and 7 posters. The invited speakers were Drs. Johann Bell (Secretariat of the Pacific Community, New Caledonia) and Bonnie McCay (Rutgers University, U.S.A.). This session addressed a broad spectrum of studies that demonstrated how communities were influenced and adapted to change in the ecosystem. An important theme in many talks was underlined by Dr. McCay that despite rhetoric, people have not been treated as truly part of marine ecosystems in much research and policy.

The session on "*Contemporary and next generation climate and oceanographic models, technical advances and new approaches*" consisted of 13 oral presentations and 6 posters, including invited talks by Drs. Anand Gnanadesikan (NOAA's Geophysical Fluid Dynamics Laboratory, U.S.A.) and Michio Kawamiya (JAMSTEC's Frontier Research Center for Global Change, Japan). Dr. Kawamiya outlined the IPCC AR5 modeling plan and challenges to reduce uncertainty of future prediction, which arises from the initial condition, by applying data assimilation for the ocean part of the climate models. Dr. Gnanadesikan showed, as an example, a state-of-the-art earth system modeling which covers from climate to biochemical systems. This session provided an overview of the new modeling approaches currently under development and many of the presentations pointed out the difficulty of evaluation of complex state-of-the-art models. Continuing efforts to develop observational networks were emphasized.

The session on "*Sustainable strategies in a warming climate*" consisted of 9 oral presentations and 1 poster, including invited talks by Drs. Éva Plagányi (CSIRO Marine and Atmospheric Research, Australia) and Chang- Ik Zhang (Pukyong National University, Korea). This session focused on examples of management strategies that could be applied to sustain fisheries under a changing climate and techniques for assessing and forecasting the performance of harvest policies under changing climate. A key outcome was the need for two-way communication between scientists and stakeholders to develop meaningful scenarios on human responses to the impact of ecosystem and climate change.

The poster session, held over 2 evenings in the beautiful Sakura Hall, generated a lot of interest and resulted in many fruitful interactions.

Bottom left to right: Drs. Chang-Ik Zhang, Brian Rothschild and Takashige Sugimoto.

Early career scientists, (top left) Jörn Schmidt (Germany), (top right) Mega Laksmini Syamsuddin (Indonesia), (bottom left) Felipe Hurtado-Ferro (Columbia) accepting best poster award certificates from the symposium convenors; (bottom right) Dr. Yasuhiro Yamanaka accepting a certificate for Taketo Hashioka (Japan).

Posters, prepared by early career scientists, were evaluated during the symposium for excellence, and the recipients of these awards were:

- Jörn O. Schmidt (IFM-GEOMAR, Germany) for his paper on "*The rise and fall of snake pipefish* (Entelurus aequoreus L.) *off North Scotland*";
- Taketo Hashioka (JAMSTEC, Japan) for his paper on "*Potential impact of global warming on North Pacific spring blooms projected by an eddy-permitting 3-D ocean ecosystem model*";
- Mega Laksmini Syamsuddin (Hokkaido University, Japan/Indonesia) for her paper on "*Regional climate change impacts on bigeye tuna* (Thunnus obesus) *catch in the Indonesian Seas*";
- Felipe Hurtado-Ferro (University of Tokyo, Japan/ Columbia) for his paper titled "*Could management react to a changing climate? The case of the Japanese small pelagic fishes*".

During the symposium, a press interview booth was set up and selected experts had an opportunity to directly communicate their findings and thoughts at daily press conferences with the regional and national media (press and TV) on how climate change affects fish and fisheries. For the press conferences, an English/Japanese brochure was prepared which included summaries of the experts' presentations and selected figures. This brochure helped to encourage the communication with the public. An enlarged poster of the brochure pages was also displayed at the booth. The symposium was covered on two TV media outlets and by six newspapers.

On the day after the symposium, Drs. Anne Hollowed, Shin-ichi Ito and Akihiko Yatsu reported on the outcomes from the symposium at a public seminar held at the Sendai City Information and Industrial Plaza located next to the Sendai Station. A 4-page Japanese leaflet which contained a brief summary of the symposium was provided to the attendees. This leaflet was also distributed to policy-makers, members of Japan Fisheries Cooperatives and Japan Fisheries Industry Cooperatives.

The symposium was made possible by the hard work of the local organizers and professionals at the PICES and ICES Secretariats, by the hospitality of the people of Sendai, and by the generous financial support from our sponsors. In addition to primary international (PICES, ICES and FAO) and local (Fisheries Research Agency of Japan and Hokkaido

Drs. Akinori Takasuka (top), Michio Kawamiya (middle) and Icarus Allen (bottom) briefing reporters on science matters at a daily press conference conducted by Japanese media.

Grouped, left to right: Drs. Akihiko Yatsu, Anne Hollowed and Shin-ichi Ito describing the outcomes of the symposium to the audience at a public seminar, with moderator, Dr. Katsumi Yokouchi (far left), looking on.

University Global Center of Excellence Program) sponsors, the following agencies and organizations made financial contributions to the symposium:

- Fisheries and Oceans Canada (DFO)
- Integrated Climate System Analysis and Prediction, Germany (CLISAP)
- Intergovernmental Oceanographic Commission (IOC)
- International Pacific Halibut Commission (IPHC)
- Japan Society for the Promotion of Science (JSPS)
- Korea Ocean Research and Development Institute (KORDI)
- Australia National Climate Change Adaptation Research Facility (NCCARF)
- Japan National Institute of Environmental Studies (NIES)
- National Marine Fisheries Service of NOAA (NMFS)
- North Pacific Anadromous Fish Commission (NPAFC)
- North Pacific Research Board (NPRB)
- Pacific Salmon Foundation (PSF)
- Scientific Committee on Oceanic Research (SCOR)
- Sendai Tourism and Convention Bureau (STCB)
- World Bank (WB)

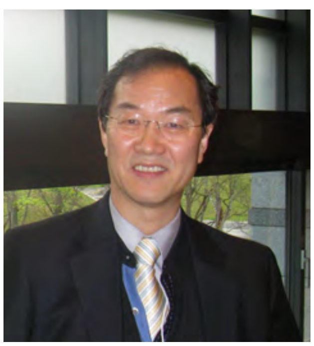
Without the funds these organizations provided, it would have been impossible to achieve the aim of convening a symposium of global scope. These funds allowed the support of 67 early career scientists and scientists from developing countries.

Immediately after the symposium, WG-FCCIFS members met to develop a report that will summarize the outcomes of the symposium. This report will be finalized over the summer and presented to ICES and PICES this fall. At this meeting, an agreement was reached to propose a Theme Session, tentatively titled "*Climate change effects on fisheries: Physics-fish-markets*", to be convened at the Second PICES/ICES/IOC Symposium on "*Effects of climate change on the world's oceans*". This symposium will be held from May 14–18, 2012, in Yeosu (Korea), as one of the official events related to the World Ocean Expo-2012. If accepted, we will strive to ensure that the PICES and ICES communities remain engaged in studies on the effects of climate change on fish and fisheries well into the future.

Dr. Anne Hollowed (Anne.Hollowed@noaa.gov) is a Senior Scientist with the U.S. National Marine Fisheries Service's Alaska Fisheries Science Center. She conducts research on the effects of climate and ecosystem change on fish and fisheries and leads the Status of Stocks and Multispecies Assessment (SSMA) program (http://www.afsc.noaa.gov/REFM/Stocks/default.php). Anne serves as Co-Chairman of the ICES/PICES Working Group on Forecasting Climate Change Impacts on Fish and Fisheries. She is also a lead author of Chapter 28, Polar Regions, of the Working Group II contribution to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Anne is an Affiliate Professor with the School of Fisheries and Aquatic Sciences at the University of Washington. She is a member of the NPFMC Scientific and Statistical Committee and the Fisheries and the Environment (FATE) Steering Committee.

Dr. Manuel Barange (m.barange@pml.ac.uk) is Director of Science at the Plymouth Marine Laboratory (UK), and Chairman of the Scientific Committee of the International Council for the Exploration of the Sea (ICES). His research interests are on the assessment of climate and anthropogenic impacts on marine ecosystems and their services, and on the interactions between natural and social sciences in fisheries, ecosystems and climate change. Manuel is the Principal Investigator of the QUEST_Fish research programme (http://web.pml.ac.uk/quest-fish/default.htm), and is particularly involved in the development of bioeconomic models of global fishmeal and fish oil, investigating the dual exposure of marine-based commodities to global environmental change and market developments. Until recently, he was Director of the International Project Office of the IOC-SCOR-IGBP core project GLOBEC (Global Ocean Ecosystem Dynamics). Manuel co-chairs the ICES/PICES Working Group on Forecasting Climate Change Impacts on Fish and Fisheries and is a founding member of the Global Partnership for Climate, Fisheries and Aquaculture (PaCFA).

Dr. Shin-ichi Ito (goito@affrc.go.jp) is Chief Scientist of the Physical Oceanography Section at the Tohoku National Fisheries Research Institute of the Fisheries Research Agency of Japan. Shin-ichi completed his graduate work in physical oceanography at Hokkaido University and became an observational physical oceanographer at the institute. His main field is the Oyashio Current and the mixed water region. He has deployed more than 30 moorings and is handling a water glider. His research includes development of a fish growth model coupled to the lower trophic level ecosystem model NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography.For Including Saury and Herring). Shin-ichi co-chairs the ESSAS (Ecosystem Studies of Sub-Arctic Seas) Working Group on Modeling Ecosystem Response. Within PICES, he serves on the Physical Oceanography and Climate Committee (POC), FUTURE Advisory Panel on Status, Outlooks, Forecasts, and Engagement (SOFE-AP), and ICES/PICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish.



Dr. Suam Kim (suamkim@pknu.ac.kr) received his B.Sc. (1976) and M.Sc. (1979) in Oceanography from Seoul National University and his Ph.D. (1987) in Fisheries Oceanography from the University of Washington. Currently, he is a Professor of the Pukyong National University, Busan, Korea. His areas of interest include fisheries ecology, especially recruitment variability focusing on early life histories of fish in relation to oceanic/climate changes. Suam has represented Korea in several international organizations and programs, such as PICES, GLOBEC, CCAMLR, IGBP, NPAFC and SCOR. In PICES, he serves as Co-Chairman of the ICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Fisheries.

Dr. Harald Loeng (harald.loeng@imr.no) has been at the Institute of Marine Science, Norway, since 1976 and has been involved mainly in projects related to physical oceanographic processes in the Northern Seas, and relations between climate and fish population parameters. Presently, Harald is responsible for the "Management and research programme on the Norwegian Sea ecosystem". He has been involved in several national and international organizations and committees. He just left the position as Chairman of the Norwegian National Polar Research Committee. Harald has been Vice-Chairman and Chairman of the Arctic Ocean Science Board and is the Norwegian member of the European Polar Board under the European Science Foundation where he is a member of the Executive Committee. Within ICES, he is chairing both the Hydrography and Oceanography Committees. He was Chairman of the Consultative Committee (2005–2008) and presently is Co-Chairman of the ICES/PICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish.

2009 Mechanism of North Pacific Low Frequency Variability Workshop

by Emanuele Di Lorenzo and Shoshiro Minobe

A 2-day workshop on "*Exploring the predictability and mechanisms of Pacific low frequency variability beyond inter-annual time scales*", co-convened by the authors of this article, was held on October 24–25 at the 2009 PICES Annual Meeting in Jeju, Korea. The workshop was well attended with over 25 contributors, and was divided into four sections: (1) *Ocean and atmosphere variability in the North Pacific*, (2) *Coupling between tropics and extra-tropics*, (3) *North Pacific western boundary variability and feedbacks*, and (4) *Discussion and synthesis*. Thanks to the support of PICES, we were able to accommodate eight invited speakers, who covered each of the focus areas: Sumant Nigam (University of Maryland, U.S.A.), Curtis Deutsch (University of California Los Angeles, U.S.A.), Lixin Wu (Open University of China) Michael Alexander (NOAA, U.S.A.), Dan Vimont (University of Wisconsin-Madison, U.S.A.), Bo Qiu (University of Hawaii, U.S.A.), Masami Nonaka and Bunmei Taguchi (Earth Simulator, JAMSTEC, Japan). The overall goal of this workshop was to review our current understanding of the dynamics underlying low-frequency fluctuations of the Pacific and to isolate potential mechanisms and linkages (*e.g.*, tropics/extra-tropics coupling, ocean/atmosphere coupling/feedbacks in the western boundary current system) that can provide the basis for low-frequency predictability.

Ocean and atmosphere variability in the North Pacific

(Invited speakers: S. Nigam and C. Deutsch)

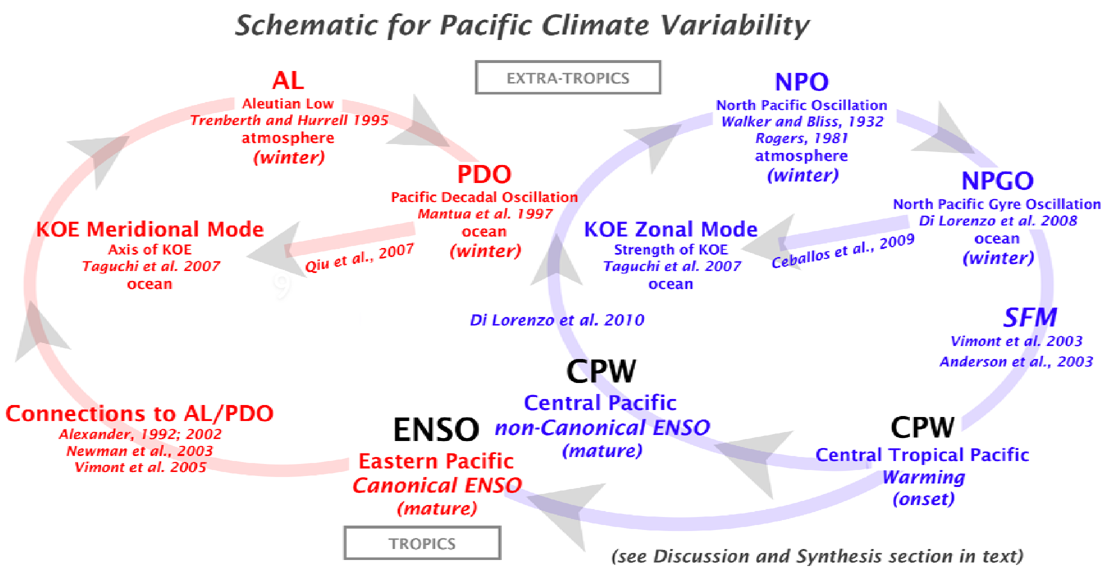
The first section of the workshop was devoted to review of our current understanding of the modes of ocean low-frequency variability that act on timescales beyond interannual, and of the relationship between modes of variability in the ocean and atmosphere (*S. Nigam*). Several talks focused on the importance of the first two dominant modes of sea surface temperature (SST) and sea surface height (SSH) variability of the North Pacific, namely the Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NPGO). Strong climate transitions of the North Pacific are likely better understood by considering both modes. For example, while the PDO has played a dominant role in the 1976–77 climate transition, the NPGO dominated the 1988–89 climate transition (*S. Yeh*). These transitions are a prominent signal in marine ecosystems and in biogeochemical tracers (*e.g.*, oxygen), although the dynamics connecting physics to ecosystems and biogeochemistry was not explored and to large extent remains unclear (*C. Deutsch*). While it was suggested that part of the Pacific low-frequency variability may be forced by the Lunar and Solar cycle (*e.g.*, PDO, *S. McKinnell*), it was generally recognized that the dynamics of the oceanic modes can be understood in the context of their atmospheric drivers. While the PDO responds to variability of the Aleutian Low (AL) (*S. Nigam*), the NPGO appears to be forced by the North Pacific Oscillation (NPO) (*E. Di Lorenzo*), which emerges as the second dominant pattern of North Pacific sea level pressure after the AL. The AL and NPO are the surface expressions of atmospheric variability associated with the Pacific North American (PNA) and Western Pacific (WP) teleconnection patterns. Statistical analysis of SST (*S. Nigam*) also isolated a Pan-Pacific decadal variability mode that is related to the Atlantic Multidecadal Oscillation (AMO), which needs further investigation in terms of ecosystem impacts and may provide means to synchronize ecosystem variations between oceanic basins (*e.g.*, Atlantic and Pacific). Understanding how modes of ocean and atmospheric variability such as the PNA/AL/PDO and WP/NPO/NPGO respond to anthropogenic climate forcing was also discussed and remains an outstanding issue (*M. Wang*).

Coupling between tropics and extra-tropics

(Invited speakers: L. Wu, M. Alexander and D. Vimont)

This section of the workshop explored the mechanisms and dynamics by which tropics and extra-tropics interact. While we have known for a while that tropical activity associated with the canonical El Niño Southern Oscillation (ENSO) excites atmospheric variability of the PNA/AL/PDO, recent studies (*D. Vimont*, *M. Alexander*) also suggest that the extra-tropical variability of the NPO/NPGO – the second dominant pattern of atmospheric/ocean variability in the North Pacific – can affect ENSO. Coupled ocean/atmosphere model experiments shown by *D. Vimont* suggest that the NPO variability in the North Pacific excites a mode of variability that is independent of ENSO. This mode – referred to as the Meridional Mode because of its north-south spatial and temporal structure – generates warm temperature anomalies in the central tropical Pacific that lead to an ENSO response about one year later. Support for this hypothesis was presented using coupled climate models (*M. Alexander*). In addition to the NPO/NPGO to ENSO connection, other studies that used partial coupling of a coupled climate model suggested that the PNA/AL/PDO North Pacific expression may exert an even stronger control on tropical variability (*L. Wu*).

There was also discussion on a new flavor of a non-canonical ENSO characterized by a central Pacific warming (CPW) pattern which drives a teleconnection to the North Pacific that affects the variability of the NPO/NPGO (*E. Di Lorenzo*). This link may provide a positive feedback between tropics and extra-tropics.



Further understanding and quantifying of these coupling dynamics is necessary to establish the physical basis for exploring the predictability of North Pacific climate.

North Pacific western boundary variability and feedbacks
(Invited speakers: B. Qiu, M. Nonaka and B. Taguchi)

In this section we discussed how the large-scale modes of North Pacific variability (*e.g.*, PDO and NPGO) have a significant delayed impact on the low-frequency dynamics of the North Pacific western boundary, and explored mechanisms by which the western boundary SST variability can feed back onto large-scale atmospheric variability. The two dominant modes of oceanic variability in the Kuroshio-Oyashio Extension (KOE) region were viewed in terms of a lagged response to large-scale atmospheric variability of the AL/PDO and NPO/NPGO, respectively. Satellite SSH and SST analyses show that the first dominant mode in the KOE, which corresponds to a change in mean location of the jet's axis and a switch between a stable and unstable state (*B. Qiu*), is forced by the arrival of Rossby waves excited by the AL/PDO in the central North Pacific. From long-term *in situ* observations, the second mode of the KOE corresponding to an acceleration of the jet forced by the NPO/NPGO was reconstructed (*S. Minobe*). Effects of the NPO/NPGO modes were also reported in regional seas (*e.g.*, Okhotsk Sea, *E. Ustinova*). In addition, multi-decadal eddy-resolving ocean simulations elucidated some important non-linear dynamics and feedbacks in the KOE. It was shown that upon the arrival of these Rossby waves in the KOE region, adjustment of Kuroshio Extension's recirculation gyres organizes the incoming signals into narrow oceanic frontal zones, causing low-frequency variability in SST and surface heat fluxes (SHF), with large amplitudes along the fronts (*M. Nonaka*). The differential SHF across the oceanic fronts can potentially force the overlying atmosphere on a large scale. This feedback was investigated using atmospheric regional model experiments (*B. Taguchi*) that confirmed the importance of the near-surface air–sea temperature gradients in shaping the seasonal (winter–spring) mean atmospheric storm-track along the oceanic frontal zones, as observed. A more direct coupling *via* atmospheric Ekman pumping was also suggested as a key process to couple the ocean mesoscale and atmospheric circulation in the KOE (*N. Schneider*).

It has been shown that there is predictability with a lead-time of several years associated with the propagation and arrival of the Rossby waves excited by the AL and NPO. If air–sea feedbacks from the KOE SST to the large-scale atmosphere are confirmed, they may provide an alternative pathway to self-sustained modes of variability in the extra-tropics, which could enhance even more the predictability of North Pacific decadal climate.

Discussion and synthesis
(Coordinators: A. Miller, S. Minobe and E. Di Lorenzo)

The discussion section was opened with an attempt to summarize our current understanding of the Pacific climate dynamics and the linkages among the various modes of ocean and atmospheric variability, including the connections between tropics and extra-tropics. The schematic above (from *E. Di Lorenzo*) depicts a synthesis of the hypothesis and dynamics discussed during the workshop. In this schematic there are two sets of dominant dynamics in the Pacific: the ENSO/AL/PDO (red path) and CPW/NPO/NPGO (blue path). These are physically linked and connected through the ENSO system in the tropics. Both the PDO and NPGO are to first order the oceanic expressions of the atmospheric forcing associated with the AL and NPO variability, respectively, and therefore, integrate the low-frequency variations of the canonical and non-canonical ENSO through atmospheric teleconnections from

ENSO→AL→PDO and CPW→NPO→NPGO. In addition to the tropics driving the extra-tropical variability, a link also exists from the extra-tropics back to the tropics through the NPO→CPW/ENSO (*D. Vimont, M. Alexander*), giving rise to the potential for a feedback between tropics and extra-tropics along the path NPO→CPW→NPO (*E. Di Lorenzo*). A link from the PDO to the tropics has also been suggested (*L. Wu*) but the relationship to the ENSO system is still being investigated.

While the AL and NPO atmospheric variability have maximum loading in the central and eastern North Pacific, their forcing also drives prominent decadal variations in the western North Pacific. Specifically, the oceanic adjustment to the SSHa anomalies of the AL/PDO and NPO/NPGO radiate Rossby waves that propagate into the western boundary. The arrival of the AL/PDO SSHa is associated with changes in the axis of the KOE, while the arrival of the NPO/NPGO SSHa modulates variations in the speed of the KOE. These two modes of KOE variability – the KOE Meridional Mode (shift in axis) and the KOE Zonal Mode (change in speed) – have been shown to capture the first two dominant modes of variability in the KOE. In the KOE, the expression of these modes is characterized by frontal scale features in SST and SHF that may feedback onto the modes of atmospheric variability (*e.g.*, AL, NPO) (*M. Nonaka, B. Taguchi, N. Schneider*).

The discussion section emphasized the need to develop quantitative approaches to evaluate the role of these ocean/atmosphere modes, especially the more recently recognized CPW/NPO/NPGO system, in explaining North Pacific (SST, circulation), sea ice, climate over land and marine ecosystem indices. PICES provides an ideal opportunity to use such quantitative models with long-term observations in the North Pacific from Canada, China, Japan, Korea, Russia, and the United States of America.

We thank PICES and the Korean government for providing a great venue for the workshop. We thank the attendees and participants and, in particular, we appreciate the effort of many of the invited speakers who are new to the PICES community and who endured a long travel to contribute to the workshop. The organizers would also like to thank Alex Bychkov (PICES Executive Secretary) and Julia Yavzenko (PICES Database and Web Administrator) for helping with the organization and logistics, and a special thanks to James Overland (PMEL, NOAA, U.S.A.) who was one of the proposers and a strong supporter of this workshop.

Group photo of the workshop participants (workshop convenors and authors of this article, Manu and Shoshiro, are at the far right). A full-size version of this and other photos are available at http://www.sci.hokudai.ac.jp/~minobe/meeting/2009_PICES_WS8. (Courtesy of N. Schneider who took the picture and is absent in the photo!)

Dr. Emanuele (Manu) Di Lorenzo (edl@gatech.edu) is an Associate Professor at the School of Earth and Atmospheric Sciences, Georgia Institute of Technology, U.S.A. His research interests and experience span a wide range of topics from physical oceanography to ocean climate and marine ecosystems. More specific focus is on dynamics of basin and regional ocean circulation, inverse modeling, Pacific low-frequency variability, and impacts of large-scale climate variability on marine ecosystem dynamics. In PICES he is a member of the Working Group on Evaluations of Climate Change Projections and of the Advisory Panel on Climate Ocean Variability and Ecosystems (COVE-AP). He also serves on the U.S. Comparative Analysis of Marine Ecosystem (CAMEO) Science Steering Committee.

Dr. Shoshiro Minobe (minobe@mail.sci.hokudai.ac.jp) is a Professor at the Graduate School of Sciences, Hokkaido University, Japan. His research interests focus on decadal climate variability and air–sea interaction. Included in his publications is a widely-referenced article proposing 50-yr climate variability and an interpretation of climate regime shifts associated with 50-yr and 20-yr climate variability. His paper on the ocean-to-atmosphere influence over the Gulf Stream was featured as the cover article of the journal Nature in 2008. Shoshiro worked as a convenor for the PICES symposium and workshops (1999, 2006, 2007) for decadal climate variability and its relation to marine ecosystem, and as a guest editor of the Progress in Oceanography special issue on "North Pacific Climate Regime Shift" (2000). He also served as a member of the Implementation Plan Writing Team for the PICES scientific program, FUTURE.

The Fourth China-Japan-Korea GLOBEC/IMBER Symposium

by Sinjae Yoo, Yasunari Sakurai, Jing Zhang and Hyung-Ku Kang

The fourth China-Japan-Korea (CJK) GLOBEC/IMBER Symposium was held from May 18–20, 2010, at Jeju National University, Korea. The purpose of the meeting was to set the future directions of international ecosystem research in the western North Pacific. About 70 scientists participated in the meeting, and 6 of them, including 5 early career scientists, were supported by GLOBEC (Global Ocean Ecosystem Dynamics) and IMBER (Integrated Marine Biogeochemistry and Ecosystem Research).

During the past decade, China, Japan and Korea have conducted research related to GLOBEC in the western North Pacific and its marginal seas. These efforts have advanced our understanding in various fields. To exchange the research results among the three countries' scientists, CJK-GLOBEC symposia have been held every two years since 2002. As GLOBEC is coming to an end, this year's symposium aimed to summarize the scientific findings of the past and to look ahead into the future.

The symposium began with overviews of GLOBEC and IMBER. Yasunori Sakurai reviewed the history and activities of GLOBEC, focusing on its major scientific achievements. Some examples of GLOBEC's outputs and highlights were shown, and some regional projects that will continue under IMBER, such as ESSAS (Ecosystem Studies of the Subarctic Seas), were emphasized. Jing Zhang explained the organizational structure of IMBER and introduced its science themes, regional programs and publications. He noted that national projects from China and Japan were already endorsed by IMBER, and discussed potential collaboration between IMBER and PICES. Finally, information on IMBIZO-II, the 2nd international conference on "*Integrating biogeochemistry and ecosystems in a changing ocean: Regional comparisons*", was presented, with explanations of the three workshop themes.

Activities related to GLOBEC/IMBER were reported from each nation. Yasunori Sakurai reviewed the achievements of Japan-GLOBEC. He indicated that Japanese research projects related to GLOBEC/IMBER have been supported by several funding agencies, and summarized the goals and major outcomes of these projects. New research projects, such as "Challenge for Future Fisheries Management", were also introduced.

Chinese GLOBEC activities were reviewed by Jing Zhang. Since 1994, China-GLOBEC projects have been developed in parallel with International GLOBEC in three phases. The last phase, sponsored by the Ministry of Science and Technology, with a budget of $5,000,000 US, is also a transitional phase to IMBER. The scientific questions and major outcomes from China-GLOBEC were presented. The scientific findings from the second phase were published recently as a *Deep-Sea Research II* special issue.

Korean GLOBEC/IMBER-like research activities were reviewed by Sinjae Yoo. He noted that although no national GLOBEC/IMBER projects were in place, many studies shared common themes with GLOBEC and IMBER. Several proposals for national IMBER projects have recently been submitted to funding agencies. The most successful activity of the Korean GLOBEC committee was capacity building – 52 early career scientists have been supported to attend various international meetings since 2004.

Scientific sessions began with biogeochemistry of the western North Pacific. Jing Zhang showed how the bio-geochemical processes on the East China Sea shelf were affected by incursion of the Kuroshio, as well as by anthropogenic factors. Jingling Ren presented the results of a survey in the south Yellow Sea, where a spring bloom occurred after an Asian dust event. She showed that the major source of aluminum was atmospheric input, and distribution of dissolved aluminum was mediated by phytoplankton (Fig. 1).

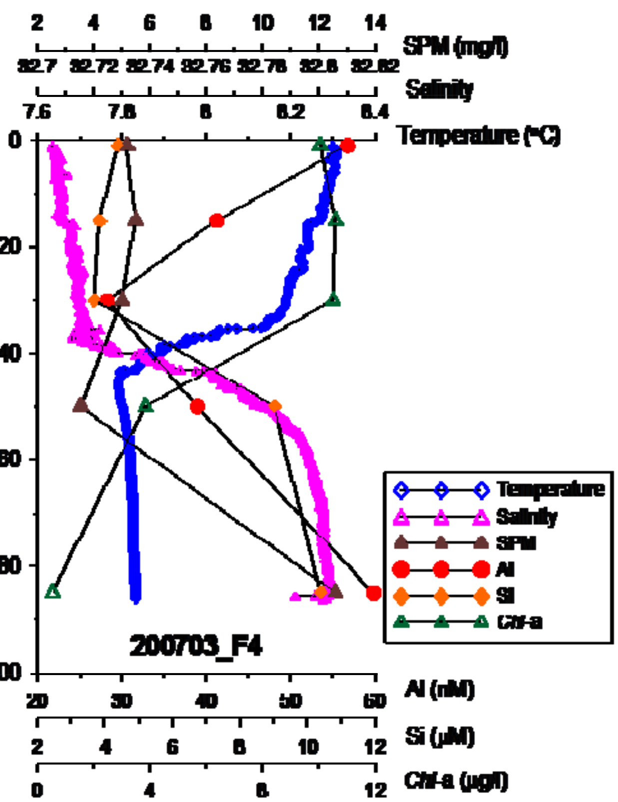


Fig. 1 Vertical distribution of T, S, SPM, Al, Si, and Chl-a from a station in the central Yellow Sea in March 2007 (courtesy of Jingling Ren).

The distribution of nutrients and chlorophyll in the northern East China Sea during 2003–2009 was analyzed by Sang Hwa Choi. Mi Hee Chung showed how the distribution of phytoplankton and zooplankton in the Seomjin estuary changed after heavy rains. Chan Joo Jang compared the projected mixed layer depth by some IPCC AR4 models and, based on this, made a further projection that primary production would be decreased by 10~30% after 100 years.

Jun Sun divided the Chinese Seas into sub-provinces based on the phytoplankton community. He also defined functional groups of phytoplankton and showed the distribution of these groups in the Yellow Sea and East China Sea. Sinjae Yoo discussed the uncertainty of primary production in the Yellow Sea and presented a new estimate of 250–300 gC m^{-2} yr^{-1} calculated using new algorithms of chlorophyll-*a* and primary production. Yunsook Kim presented the phytoplankton community structure using HPLC from a meridional survey in the East Sea in 2007. Similarly, Hyoung Chul Shin presented the phytoplankton and zooplankton distribution on a section across the Ulleung Warm Eddy in the East Sea.

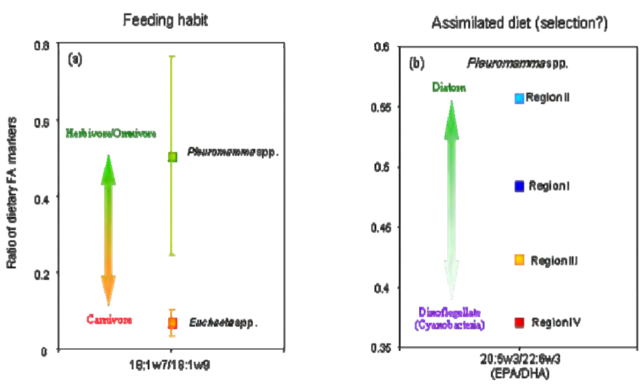


Fig. 2 (a) The ratio of 18:1w7/18:1w9 has been used to determine the feeding habit of copepods. (b) The ratio of EPA/DHA has been applied to trace the assimilated food type for herbivorous copepods (courtesy of Se-Jong Ju).

Wuchang Zhang studied the seasonal cycle of ciliates and their ingestion by *Calanus sinicus* in the Yellow Sea. The ciliate biomass peaked in May near the tidal and thermal front. He also showed that *Calanus sinicus* may need additional sources of food, as the ingestion of ciliates alone cannot satisfy its energy requirement. Se-Jong Ju presented a study on the latitudinal variation of lipids as a trophic marker of copepods (Fig. 2). The result of this study suggests that the lipid contents and compositions in copepods may indicate their nutritional condition, feeding ecology, and species-specific living strategies. Keun Hyung Choi showed that encounter rates of copepods with mates and prey can be affected by turbulence. He further conjectured that climate change can increase turbulence in coastal areas and influence the population growth of copepods. Hyeon Ho Shin showed that morphological features of resting cysts of *Scrippsiella trochoidea* were changed by hypoxic conditions at the sea bottom. Seung-Hyun Kim introduced a recent study that shows more warm-water species of dinoflagellates appeared near Jeju coasts. Based on mitochondrial DNA analysis, Yongshuang Xiao argued that the point-head flounder expanded its geographic distribution along the Japanese coastline during the late Pleistocene.

Recently, unusual events began to occur in the Yellow Sea and East China Sea, indicating that the ecosystem structure is rapidly shifting. In June 2008, a massive bloom of the macroalga *Enteromorpha* occurred in the vicinity of Qingdao. Il-Ju Moon showed that unusual wind conditions in 2008, together with nutrient-rich discharges from land, induced the massive algal bloom which then moved to the nearshore area. Since the early 2000s, jellyfish blooms have been increasing in the Yellow Sea, East China Sea and East Sea (Japan Sea). Three papers on jellyfish were presented. Kui You talked about the effect of temperature on scyphistomae strobilation of *Rhopilema esculentum*. The temperature effect on the asexual reproduction of *Aurelia aurita* was presented by Chang-Hoon Han, who also talked about the environmental effects on asexual reproduction of *Nemopilema nomurai*.

The catches of Pacific cod and walleye pollock in Korean waters have been decreasing since the 1980s. After the 1998–99 regime shift, Pacific cod came back, while walleye pollock continued to decline. Sukgeun Jung explained this by three factors: a decrease in the bottom water temperature, an increase in the volume transport of the Tsushima Warm Current (TWC), and increased zooplankton and Pacific herring. Using an individual based model (IBM), Jung Jin Kim studied propagation of hatchlings and paralarvae of common squid (*Todarodes pacificus*) in the northern East China Sea, and showed how the spawning location can affect the distribution of larvae (Fig. 3). Yuheng Wang presented the results of an IBM study indicating that the East Asia monsoon is the major reason for anchovy population dynamics in the Yellow Sea besides over-fishing.

In a study using the Ecopath model, Qun Lin reconstructed the structure and energy flow of the Yellow Sea ecosystem and demonstrated that there was an obvious downward trend in the trophic level for most fishes. The percentage of primary production required to sustain the fishery was 5.14%, which was quite low. Jong Hee Lee analyzed sea surface salinity, sea surface temperature, and fisheries catch data from Korean waters. She argued that the 1976–77 regime shift included shifts in both environmental factors and ecosystem, while the 1988–89 regime shift was identifiable only from biological changes. On the other hand, physical changes after the 1998–99 regime shift were clear, while the ecosystem shift need further analysis. Akihiko Yatsu explained the concept of regime-dependant maximum sustainable yield and argued that an adaptive management

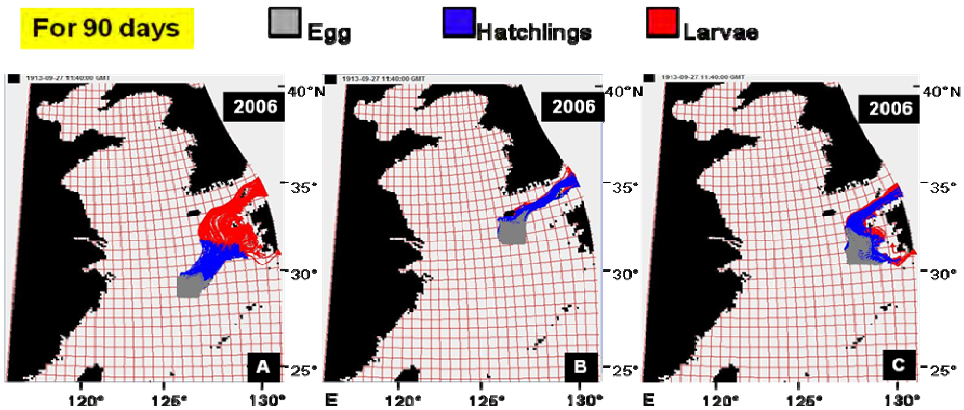


Fig. 3 Distribution of squid larvae under different spawning locations. Simulated with an individual based model (IBM) using the conditions of June 2006 (courtesy of Jung Jin Kim).

strategy depending on the regime is needed. Given the great uncertainties of productivity of a "new regime" at the beginning of the regime, development of robust management procedures (MPs) is required. With these, he also characterized an "Ecosystem Approach to Fisheries" (EAF). Jae Bong Lee introduced IFRAME (Integrated Fisheries Risk Analysis Method for Ecosystems), and applied this scheme to Korean waters. First, he made long-term predictions of habitat changes of chub mackerel and blue fin tuna, and then estimated future changes of the indices of sustainability, biodiversity, habitat, and socio-economic benefits as functions of fishing mortality. Michio Kishi calculated the optimal release number of Hokkaido chum salmon using an ecosystem approach where carrying capacity of the North Pacific was computed by the two-way NEMURO model. Competition between chum salmon and pink salmon was also considered. The cost function was total income of fishermen. The results showed that the release number in 2007 could be optimal.

(*continued on page 23*)

Dr. Sinjae Yoo (sjyoo@kordi.re.kr) is a biological oceanographer with the Korea Ocean Research and Development Institute (KORDI). He is interested in the spatio-temporal variations in primary production and its impact on the lower trophic level. Sinjae is Chairman of the Korea GLOBEC/IMBER Committee. In PICES, he has served as a member or Co-Chairman on various expert groups and committees and is Science Board Chairman-elect since 2009.

Dr. Yasunori Sakurai (sakurai@fish.hokudai.ac.jp) is a Professor at the Graduate School of Fisheries Sciences, Hokkaido University, Japan. His research focus is on reproductive biology, strategy, and stock fluctuations of gadid fish (walleye pollock, Pacific cod, and Arctic cod) and cephalopods (ommastrephid and loliginid squids) related to climate change, and the biology of marine mammals (Steller sea lions and seals). He has led a number of national research projects and programs on ecosystem-based management for sustainable fisheries. He had been Chairman of Japan-GLOBEC, and served on the Cephalopod International Advisory Counsel (CIAC), GLOBEC and ESSAS Scientific Steering Committees and the Implementation Panel for the PICES Climate Change and Carrying Capacity (CCCC) Program. Since 2009, Dr. Sakurai has chaired the Japanese Society of Fisheries Oceanography.

Dr. Jing Zhang (jzhang@sklec.ecnu.edu.cn) is a Professor at the State Key Laboratory of Estuarine and Coastal Research (SKLEC), East China Normal University, Shanghai. His research focuses on the land–ocean interaction in China Seas, particularly the biogeochemical dynamics of estuaries and coastal environment. He co-chaired SCOR Working Group 128 on Natural and Human-Induced Hypoxia and Consequences for Coastal Areas (2005–2009), served as a member of the IMBER Scientific Steering Committee (2004–2009) and was a project leader for IOC/WESTPAC Atmospheric Input Studies (1993–2008).

Dr. Hyung-Ku Kang (kanghk@kordi.re.kr) is a principal scientist of the Marine Living Resources Research Department at KORDI. He has been the Executive Secretary of the Korea GLOBEC/IMBER Committee since 2000. He is interested in physiological ecology of marine zooplankton, including reproduction, feeding and population dynamics of copepods, and is a member of PICES Working Group on Comparative Ecology of Krill in Coastal and Oceanic Waters around the Pacific Rim.

2010 Sendai Ocean Acidification Workshop

by Kenneth Denman, Yukihiro Nojiri and Hans-Otto Pörtner

The oceans are becoming acidified as carbon dioxide from fossil fuel emissions enters surface ocean waters from the atmosphere. Global surface pH has already decreased by more than 0.1 units, (IPCC WG1 AR4 Report, Chapter 5, 2007), and may decrease by another 0.4 units by the end of this century under the high CO_2 emission scenario. Some regions of the ocean may have a significant decrease in the $CaCO_3$ saturation state even with the same atmospheric CO_2 change. The key question that should be addressed in future studies on the effects of increasing $P\mathrm{CO_2}$ in the ocean may be stated as: What will be the responses and adaptive capacities of individual species and whole ecosystems to a multi-decadal decrease in pH of 0.1–0.5 units?

A 1-day workshop on "*Potential impacts of ocean acidification on marine ecosystems and fisheries*", co-convened by the authors of this article, was held immediately prior (April 25, 2010) to the International Symposium on "*Climate change effects on fish and fisheries*" in Sendai, Japan. Talks and posters presented at the workshop reported on manipulation experiments and observations on the effects of elevated CO_2 on organisms at all trophic levels of fisheries foodwebs, and modelling approaches to predict the impact of continuing increases in atmospheric CO_2.

The first talk (Denman *et al*.) presented observational evidence of open ocean increases in $P\mathrm{CO_2}$ and decreases in pH, followed by model projections of global mean and spatial patterns of the decrease in pH until the end of this century. Several talks and posters reported on studies of organisms with calcium carbonate skeletal structures subjected to various experimental exposures to low pH (high $P\mathrm{CO_2}$) waters in controlled laboratory or field situations. Other talks and posters described physiological and behavioural responses of animals to elevated CO_2 conditions. One poster evaluated the adequacy of a number of ecosystem models to simulate adaptation over long time scales to changes in CO_2 (and other related variables) associated with climate change.

Nakamura *et al*. reported on a depression of metabolism and growth in coral larvae with elevated CO_2 levels. Similiary, Lartey-Antwi and Anderson found decreased growth rates of flat-tree oysters. Suwa and Shirayama presented data obtained with a system precisely mimicking constant and fluctuating CO_2 levels, where the fluctuating levels showed less impact on the growth and skeletal structures of echinoderm larvae than CO_2 levels set permanently high. Kurihara provided an overview on different levels of CO_2 sensitivities according to taxon and in early life stages. Ishimatsu *et al*., Munday *et al*. and Dissanayake *et al*. reported on changes in various processes indicating tolerance limits, decreased aerobic scope and behavioural changes in shrimp and young fish in response to elevated CO_2 levels, with species-specific differences even among closely related fish species. Salau introduced a model of reduced carrying capacity for pteropods as pH decreases, and the feedback effects on pink salmon: as a result, even and odd year differences in salmon stock size will increase over time with management implications for repeating strong and weak returns in alternating years. Rumrill *et al*. (poster) presented long-term observations of an estuary showing decreasing pH and effects on oysters in the outer saline estuary and increasing pH probably resulting from changes in precipitation and freshwater runoff. Takami *et al*. demonstrated how elevated CO_2 levels

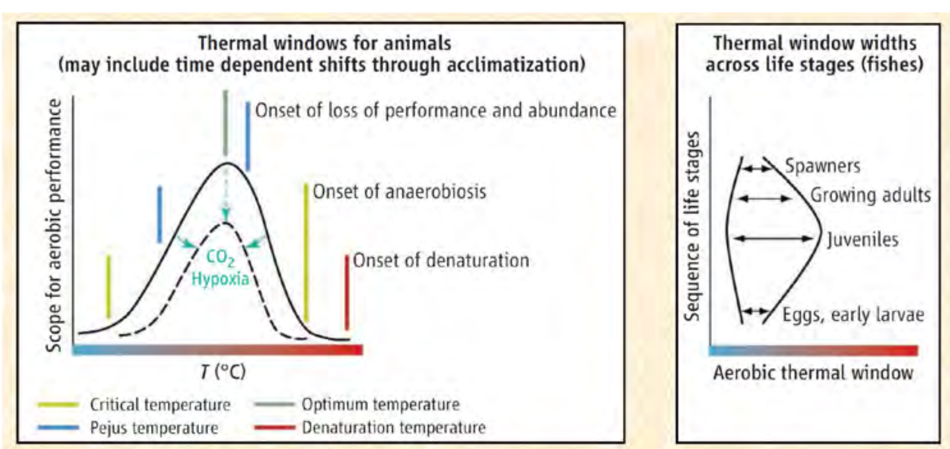


Fig. 1 Animal physiology and climate change showing (left panel) how the 'thermal window' for normal activity by marine animals may shrink with decreasing oxygen concentrations and increasing CO_2 concentrations, and (right panel) how the thermal window changes with life stage (from Pörtner and Farrell, 2008, Science, 322, 690–692) [see page 31].

slow and disturb development in abalone, and Sugie *et al*. (poster) found enhanced drawdown in Si/N by Bering Sea phytoplankton as pH fell and Fe was limited. Kim and Kim (poster) used brine shrimp as a model for identifying changes in the expression of individual genes during exposure to low pH. Finally, Le Quesne and Pinnegar (poster) analyzed several ecosystem models, emphasizing that parameterizations of various physiological processes would be needed to support the evaluation of responses to changing pH.

Noteworthy findings can be summarized as follows:

- Overall, investigators are observing different sensitivity levels among investigated organisms (some closely related), ranging from calcification and growth to development, behaviours and ecosystem level responses. The consideration and introduction of environmental variability changes the pattern and level of response. In light of the complexity and diversity of responses observed, it is thus too early to draw general conclusions regarding the responses of ecosystems to elevated CO_2.
- The inclusion of pre-industrial levels (around 280 ppm CO_2) in experimental protocols, as well as the precise control of diel CO_2 cycling, was considered highly valuable in studying the impact of ocean acidification. In fact, one study reported improvement in calcified structures in echinoderm larvae under pre-industrial compared with present-day levels of ambient CO_2. Investigations of mechanisms under high $P\mathrm{CO}_2$ need be complemented by testing the role of such responses under expectable $P\mathrm{CO}_2$ according to ocean acidification scenarios.
- Studies of behavioural and physiological responses to elevated CO_2 levels for organisms that are not necessarily calcifiers are less mature, but are exciting because so little is known.

Recommendations and Key Questions from the workshop include:

- Pre-industrial control runs should be done more often, since organisms have already adapted from that point.
- Experiments often include current day $P\mathrm{CO}_2$ (~380 ppm) and an elevated CO_2 level of ~1000 ppm. If emissions are controlled to try to achieve <3°C global warming, then intermediate levels of, say, 450, 550, and 700 ppm, have to be considered. Both these recommendations require precise $P\mathrm{CO}_2$ (pH) control.

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Dr. Kenneth Denman (ken.denman@ec.gc.ca) is a Senior Scientist at the Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada and at the Canadian Centre for Climate Modelling and Analysis, Environment Canada, c/o University of Victoria, Victoria, BC, Canada. His research focuses on modeling the responses and adaptation of marine planktonic ecosystems and biogeochemical cycles to climate change. He has been a Coordinating Lead Author in the IPCC Working Group 1 Second (1996) and Fourth (2007) Assessment Reports, a member of the Joint Scientific Committee of the World Climate Research Programme, and a member of the Scientific Steering Committees of SOLAS (Surface Ocean and Lower Atmosphere Study), GOOS (Global Ocean Observing System) and JGOFS (Joint Global Ocean Flux Study).

Dr. Yukihiro Nojiri (nojiri@nies.go.jp) is a Vice-Director of the Center for Global Environmental Research at the National Institute for Environmental Studies, Japan, and also a manager at the Greenhouse Gas Inventory Office of Japan. Since 1995, his major research has focused on ocean carbon studies, including ocean surface pCO_2 *observation by commercial ships over the Pacific, mesoscale iron fertilization and ocean acidification manipulation experiments. Yukihiro serves as a member of the Scientific Steering Committees of IOCCP (International Ocean Carbon Coordination Project) and SOLAS.*

Dr. Hans-Otto Pörtner (hans.poertner@awi.de) is a Professor of integrative ecophysiology at the Alfred-Wegener-Institute of Polar and Marine Research in Bremerhaven, Germany. His research focuses on the mechanisms regulating the specialization of marine animals and their ecosystems on climate regimes. He has shaped the development of the concept of oxygen and capacity limited thermal tolerance as a matrix integrating temperature, oxygen and CO_2 *effects on marine animals and ecosystems. He has been a Lead Author in the IPCC Special Report on carbon capture and storage. Presently, he co-chairs the German program on ocean acidification, and serves as a work package leader of the European program on ocean acidification as well as a steering group member of the conference series on "Oceans in a High* CO_2 *World".*

2010 Sendai Coupled Climate-to-Fish-to-Fishers Models Workshop

by Salvador E. Lluch-Cota, Enrique N. Curchitser and Shin-ichi Ito

A 1-day workshop on "*Coupled climate-to-fish-to-fishers models for understanding mechanisms underlying low frequency fluctuations in small pelagic fish and projecting its future*", co-convened by the authors of this article, was held immediately prior (April 25, 2010) to the International Symposium on "*Climate change effects on fish and fisheries*" in Sendai, Japan. Low-frequency variability of abundance of small pelagic fish is one of the most emblematic and best-documented cases of population fluctuations not wholly explained by fishing effort. Over the last 25 years, diverse observations have led to several hypotheses. However, because of limited-duration time series, testing hypotheses has proven extremely difficult with available statistical and empirical tools. As a result, the mechanistic basis for how physical, biogeochemical, and biological factors interact to produce the various patterns of synchronous variability across widely separated systems remains unknown. Identification of these mechanisms is necessary for exploring projections and building scenarios of the amplitude and timing of stock fluctuations and their responses to human interactions (fisheries) and climate change. The workshop was intended to compare state-of-the-art modeling tools and discuss what expertise is necessary to tackle this important scientific and environmental problem.

The workshop, attended by about 50 scientists, started with an opening address by the convenors. Six oral presentations were given. Ryan Rykaczewski used bioenergetic models to compare anchovy and sardine growth potential in the California Current region and suggested that anchovy growth is dependent on the community structure of near-shore eutrophic waters, and that sardine growth is possible under offshore oligotrophic conditions. Additionally, he discussed the importance of accurate representation of plankton size structure for mechanistic models of sardine and anchovy populations.

Wolfgang Fennel introduced a NPZDF (nutrient, phytoplankton, zooplankton, detritus and fish production) model with two-way coupling between prey and predators, hence, mass balance between NPZD and fish or prey fish and predator fish are conserved. The model was applied to the Baltic Sea, where the fish dynamics is dominated by two prey (sprat and herring) and one predator (cod). To demonstrate performance of the model, the effects of eutrophication and fishery scenarios were addressed (Fig. 1).

Three 3-D NPZDF models were presented by George Triantafyllou, Shin-ichi Ito and Kate Hedström. Triantafyllou *et al.* introduced a super Individual-Based Model (IBM) of the European anchovy in which particles representing fish have information of fish population, adding to those of age,

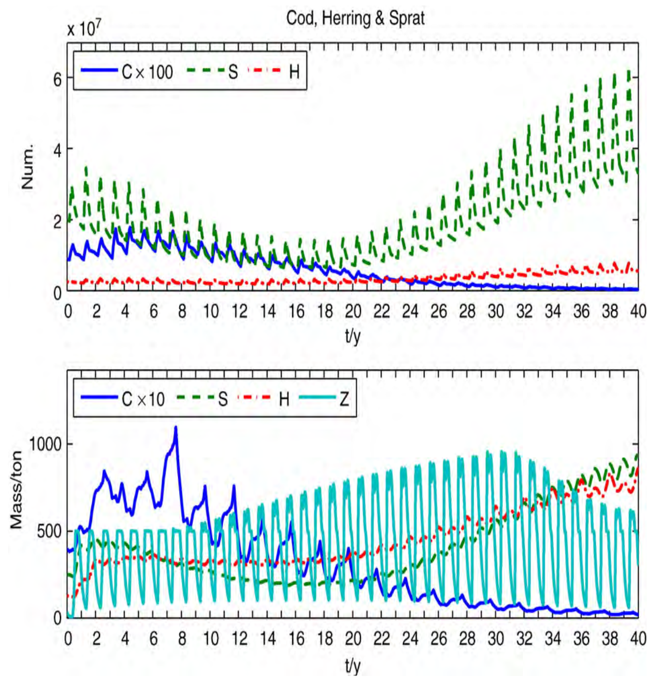

Fig. 1 The variation of total abundance of cod, sprat, and herring (upper, per km^3) and the variations of the total biomass of cod, sprat, herring, and zooplankton (lower, per km^3) derived from hindcast by Fennel's NPZDF model (W. Fennel, Journal of Marine Systems, 2010, 81, 184–195).

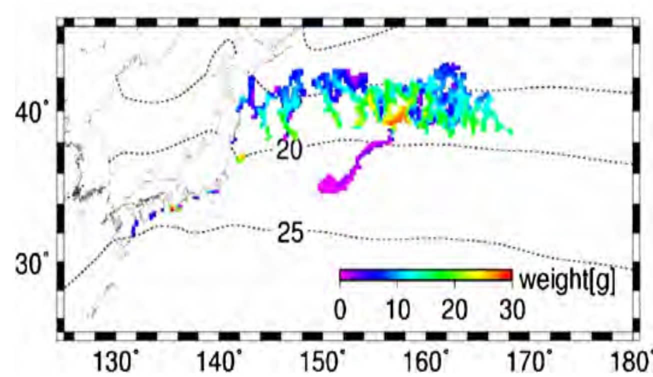

Fig. 2 Seasonally mean spatial weight distributions of Japanese sardine (0-year-old) in autumn simulated by a super-IBM model. The contours show climatological seasonal sea surface temperature from the World Ocean Atlas 2005 (Okunishi et al., Ecological Modelling, 2009, 220, 462–479).

position, length, and weight of the fish. This Lagrangian model is coupled to a biophysical model based on the Princeton Ocean Model (POM) and the European Regional Seas Model (ERSEM). Moreover, the ERSEM was assimilated to satellite-derived phytoplankton density. Ito *et al.* introduced a super-IBM of the Japanese sardine (Fig. 2) and clearly showed the significance of the density-dependence effect on fish distribution and growth. They also demonstrated the importance of predators on migration of prey fish. Hedströme *et al*. used a community biophysical model; the Regional Ocean Modeling System (ROMS) for the physical circulation model and NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) for the NPZD model. They intend to include a fishery effect in their model and extend it to an end-to-end model. They noted difficulties of such a state-of-art NPZDF model, including spatially locating eggs after spawning and scaling the predator–prey interactions among fish species.

In the final talk, Kenneth Rose addressed issues that arise with developing complicated models in general, and new issues specific to the development of end-to-end models.

Open discussion was held in the afternoon session. Based on the presentation by Rose, participants discussed end-to-end models and how they deal with different issues, particularly zooplankton dynamics and linkages with upper and lower trophic levels. Several attendees expressed concern over the uncertainty and increasing error derived from coupling different models, especially when outcomes from one model are used as input for a chain of other models. Also, strong concern was expressed on how to evaluate performance or validate the models because of the multi-scale nature of these models. No single data set seems to be sufficient. After recognizing the valuable review by Plagányi (FAO Fish. Tech. Paper 477, 2007), the group discussed the need to quantitatively compare performance of models for different processes and promote the use of the best modeling approach option for each question. In this sense, keeping modeling approaches diverse was considered a better strategy than agreeing to a single model. Assemblages of models, as done by the climate community, does not seem to be a feasible approach for end-to-end models. However, the group believed it would be useful for small pelagic fish and climate change research to compile and/or develop different models for at least some of the major small pelagic fishing regions, specifically the Benguela, California, Humboldt, and Kuroshio/Oyashio Currents.



Dr. Salvador E. Lluch-Cota (slluch@cibnor.mx) works in the Fisheries Ecology Program at Centro de Investigaciones Biológicas del Noroeste (CIBNOR) in La Paz, B.C.S., Mexico. He has studied climate impacts on marine fisheries and ecosystems for more than 15 years. Salvador is currently the Principal Investigator for an interdisciplinary project on massive fisheries and climate change in Mexican waters and for two other projects dealing with the analysis of coastal ecosystems of the Baja California Peninsula. He is serving as International GLOBEC SSC member from 2006 to 2011 and as President of the Mexican Fisheries Society and the Mexican Chapter of the American Fisheries Society from 2007 to 2011. Currently, Salvador is involved in building the scientific plan proposal for SPACC II.

Dr. Enrique Curchitser (enrique@marine.rutgers.edu) is a physical oceanographer at Rutgers University in New Jersey, U.S.A. In spite of living near the Atlantic, most of his work focuses on the Pacific Ocean. His main interests are the intersection of climate and biology, regional climate impacts, and numerical modeling. His current projects range from downscaling climate scenarios in the northeastern Pacific and Bering Sea to trying to understand the low-frequency fluctuations in global sardine populations. Enrique is a member of PICES Working Group on Evaluation of Climate Change Projections.

Dr. Shin-ichi Ito (goito@affrc.go.jp) is Chief Scientist of the Physical Oceanography Section at the Tohoku National Fisheries Research Institute of the Fisheries Research Agency of Japan. Shin-ichi completed his graduate work in physical oceanography at Hokkaido University and became an observational physical oceanographer at the institute. His main field is the Oyashio Current and the mixed water region. He has deployed more than 30 moorings and is handling a water glider. His research includes development of a fish growth model coupled to the lower trophic level ecosystem model NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography.For Including Saury and Herring). Shin-ichi is Co-Chairman of the ESSAS Working Group on Modeling Ecosystem Response. Within PICES, he serves on the Physical Oceanography and Climate Committee (POC), FUTURE Advisory Panel on Status, Outlooks, Forecasts, and Engagement (SOFE-AP), and joint PICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish (WGFCCIFS).

2010 Sendai Salmon Workshop on Climate Change

by James Irvine

A 1-day workshop examining climate change impacts on salmon was organized by scientists working with the North Pacific Anadromous Fish Commission (NPAFC) and was held immediately prior (April 25, 2010) to the International Symposium on "*Climate change effects on fish and fisheries*" in Sendai, Japan. The NPAFC assembles and documents various types of biostatistical information, including catch and hatchery release statistics and recently published a *Long-term Research and Monitoring Plan* forecasting how salmon will respond to climate change (http://www.npafc.org/new/index.html).

The workshop consisted of 9 oral presentations (20 min), 5 posters (authors were also allowed to give a 10-min oral presentation), and 2 discussion sessions. Presentations were diverse and informative. The majority (12 of 14) focused on Pacific salmon (9 on marine aspects, 2 on fresh water aspects, and 1 on knowledge/database), while 2 papers dealt with Atlantic salmon.

Irvine and Fukuwaka gave an overview of abundance trends for Pacific salmon at the scale of the North Pacific, Asia, and North America. All nations commercial catch data indicate that marine production of Pacific salmon is at all time high levels (Fig. 1), dominated by chum and pink salmon, albeit with significant contributions from hatcheries. Focusing on chum and pink salmon, Fukuwaka *et al*. found high levels of synchrony among regions in catch, although the response to various climate indices varied. Hyunju Seo, who presented the paper by Kaeriyama *et al*., showed that rising temperatures have increased the growth and survival for Hokkaido age-1 chum salmon. However, this apparent benefit may ultimately lead to population density-dependent effects reducing the growth and extending the maturation schedule for chum salmon in the Bering Sea. Farley *et al*. reported results from the eastern Bering Sea that fortuitously covered four consecutive warm years (2002–2005) followed by four cool years (2006–2009). Warm years tended to benefit age-0 walleye pollock, resulting in generally higher growth potential for salmon. Mundy and Evenson concluded that the timing of spawning migrations of high latitude chinook will become more variable as warming continues. Wainwright and Weitkamp predicted that climate change effects on Oregon coho salmon will be largely negative, although great uncertainty in biological responses remains. Reed *et al*. applied an evolutionary model to forecast how some Fraser River sockeye salmon might respond to predicted changes in river temperature resulting from global warming. They concluded that the persistence of some salmon populations will depend on their ability to adapt quickly, which will be determined by the existence of sufficient genetic variation. Peterman *et al*. described the development of a new website intended to help in designing salmon monitoring programs. Wasserman documented the successful experience of the Skagit Climate Science Consortium that is integrating scientific analyses at the watershed level in order to manage salmon populations experiencing climate change. Piou and Prévost and Prusov *et al*. described their findings on Atlantic salmon in the Scorff River (France) and the White Sea (northwest Russia), respectively. Piou and Prévost's models project climate change-related life history effects, concluding that marine conditions and freshwater flow regimes are of utmost importance in determining stock abundance. Prusov *et al*. documented changes in Atlantic salmon growth and age

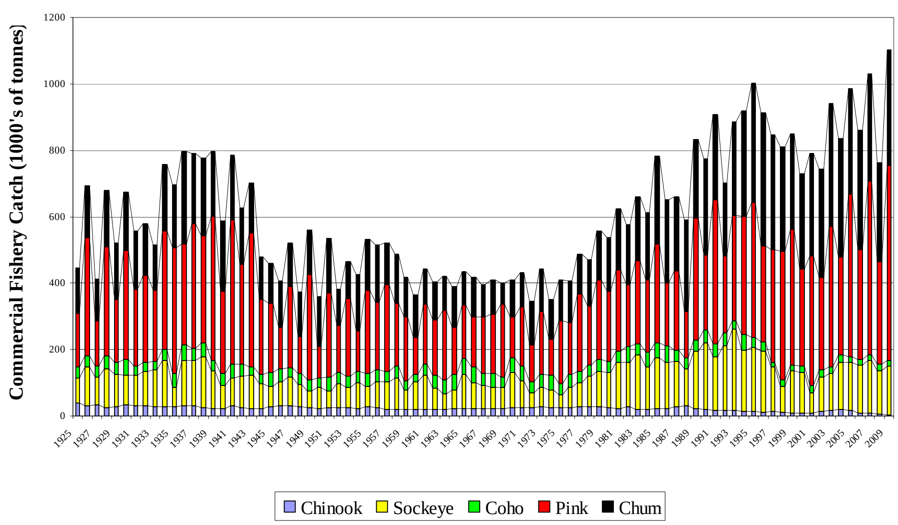

Fig. 1 All nations commercial Pacific salmon catch.

compositions during recent years of increasing temperatures but concluded that changes in management practices have thus far had the greatest impact on the status of northern populations of Atlantic salmon. Miyakoshi *et al.* documented changes in coastal temperatures around Hokkaido and described plans to adjust the release timing of young chum salmon to take advantage of these changes, and thereby increase salmon survivals. Ishida and colleagues' archeological work showed that the distribution of chum salmon in Japan during an earlier warmer period was more northerly than it is today, and predicted similar northerly shifts in salmon distribution with climate change. Jennifer Neilson, presenting the paper by Ruggerone *et al*., showed that chinook salmon growth was related to their previous growth history and pink salmon abundance, while coho salmon growth was strongly linked with pollock abundance, which was linked to temperature.

Following the oral presentations, separate discussion sessions considered the broad topics of forecasting impacts and long-term research needs. Although it was not possible to thoroughly debate all the above questions in the limited time available, there appeared to be consensus on some issues:

- The North Pacific currently produces large amounts of salmon, but rates of increase seen during the last 30 years will not continue.
- Climate change is already affecting salmon differently in northern and southern regions. There will be additional northward shifts in the southern boundary of salmon distribution. There was no consensus on whether or not the Arctic will become a more important area for salmon production.
- Marine production of pink and chum salmon is increasing, but there was no consensus how much of this might be due to ecosystem changes *vs.* enhancement.
- A proper understanding of climate effects on salmon requires consideration of each life history stage. Phases to focus on include: freshwater residence, early marine (first couple of months) and the first winter at sea.
- Important areas of future research include: improving our understanding of effects of interactions between hatchery and wild salmon in their early marine environment, and linkages between coastal oceanography and young salmon growth and survival.
- Integrated research programs with experts from multiple disciplines and countries are most likely to improve our knowledge base.

Acknowledgements: Many thanks to Drs. Masa-aki Fukuwaka (Japan), Suam Kim (Korea), Vladimir Radchenko (Russia), Loh-Lee Low (U.S.A.), and Shigehiko Urawa (NPAFC) for assistance in convening the workshop, with the author of this article, and preparing this report; Dr. Skip McKinnell (PICES Deputy Executive Secretary) for encouraging and promoting the workshop, and other participants for contributing their findings and ideas at the workshop.

Dr. James (Jim) Irvine (James.Irvine@dfo-mpo.gc.ca) is a research scientist at the Pacific Biological Station in Nanaimo, BC. He currently chairs the Stock Assessment Working Group of the North Pacific Anadromous Fish Commission (NPAFC) that recently published an overview of salmon abundance trends in the North Pacific, and also co-chairs Canada's Fisheries and Oceanography Working Group that prepares the annual State of the Ocean Report for Canada's Pacific Region and neighbouring waters.

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Twenty-three papers were presented during the poster session. The topics ranged from observations and modeling of physical phenomena (circulation, mixed layers, typhoons, river discharge, *etc*.), paleoceanography and ocean acidification to lower trophic level processes.

The symposium ended with a discussion session focused on coordination of regional research in the western North Pacific. Most participants agreed that the past activities of CJK-GLOBEC, mainly providing a forum for the western North Pacific science, should continue. There was a consensus that regional coordination should be sought as energetic research will continue in the region. To this end, a science plan and related research proposals have to be developed. It is expected that the perspectives of the program will be broad, while there will be regional foci. Since the new PICES integrative science program, FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems), is a contributing regional program to IMBER, there are many common scientific interests between IMBER and FUTURE. PICES also has a CREAMS Advisory Panel which focuses on the East Asian marginal seas. It was agreed to have a joint meeting of national IMBER representatives and FUTURE/CREAMS members for development of the regional program during the 5th PEACE (Program of the East Asian Cooperative Experiments) Ocean Workshop to be held September 11–12, 2010, in Gangneung, Korea. Finally, the next CJK-IMBER symposium was tentatively scheduled for November 2011 in Shanghai, PR China.

2010 Sendai Zooplankton Workshop

by William Peterson and Kazuaki Tadokoro

The goal of a workshop, co-convened by the authors of this article immediately prior (April 25, 2010) to the International Symposium on "*Climate change effects on fish and fisheries*" in Sendai, Japan, was to provide an opportunity for those keenly interested in "*how data on zooplankton and krill can be used to better understand and forecast the impacts of climate change on fisheries*" to discuss the topic in an informal workshop atmosphere. Contributions were requested which demonstrated explicitly how information on copepods and euphausiids might lead to a better understanding of the linkages between physics and fish. We worked hard to invite people, but in the end we received only 8 abstracts, and thus decided to have a half-day workshop. When the happy day arrived, we did not know what to expect in terms of participation, and we were delighted and very pleased to find the room filled to its capacity, with more than 50 people in attendance. This is evidence of great interest in learning more about mechanistic linkages between physics through the zooplankton to fish.

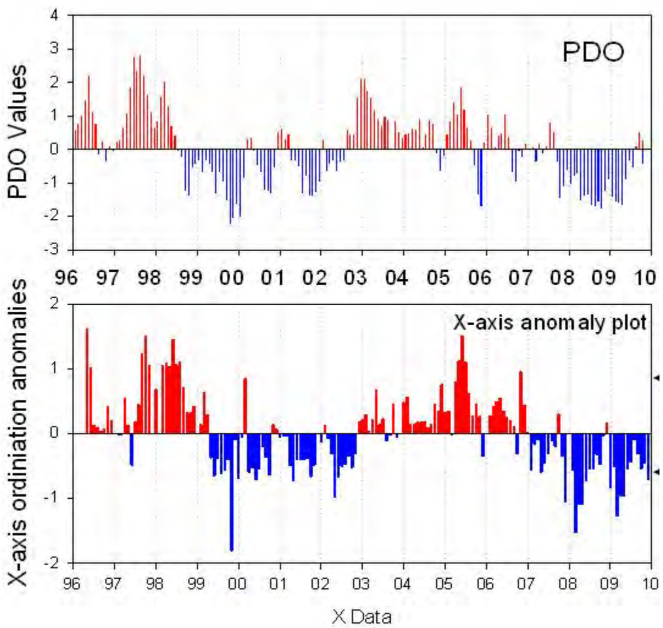

Fig. 1 PDO (upper panel) and monthly anomalies of the x-axis scores of a NMDS of copepod community structure (lower panel).

The meeting was opened by William (Bill) Peterson (NOAA Fisheries, U.S.A.), who presented an overview of some mechanisms that link physical forcing with zooplankton and fisheries response in the North Pacific. As one of the examples, he demonstrated a link between the Pacific Decadal Oscillation (PDO) and the copepod community structure (Fig. 1). The positive (negative) phase of the PDO results in the advection of warm (cold) water to the coast in the northern California Current. As a consequence, "warm" and "cold" water copepod species and communities dominate coastal waters; changes in community structure lag changes in the PDO by a few months.

Ryan Rykaczewski (Princeton Geophysical Fluid Dynamics Laboratory, U.S.A.) gave a Pacific basin-scale perspective on how the Kuroshio and California currents might be linked. He examined basin-wide variability in the depth of the nutricline across the mid-latitude North Pacific using a global, earth system model and found that variability in the depth of wintertime convection in the western North Pacific stimulates anomalies in the vertical distribution of nitrate, and that these anomalies propagate from west to east with the North Pacific Current, with a transit time on the scale of decades.

Bill Peterson discussed his two favorite hypotheses: (1) lipids and cold water copepod species, and (2) source water which feeds the northern California Current, and how these two are linked with salmon survival.

Jay Peterson (Hatfield Marine Science Center, U.S.A.) showed that there have been chronic changes in the upwelling ecosystem off Newport over the last 40 years. First, there has been an increase in the number of copepod species routinely found along the coast (0.11 species per year); second, an intensification of oxygen-depleted bottom waters on the shelf; and third, a deepening in the depth from which water upwells.

Tracy Shaw (Hatfield Marine Science Center) discussed relationships between timing and strength of upwelling and euphausiid spawning. She showed that *Euphausia pacifica* spawning is strongly associated with the timing of the onset of upwelling, but not with upwelling strength. *Thysanoessa spinifera*, on the other hand, spawn prior to and during upwelling and seem to be more strongly affected by water temperature. Future changes in the timing of the spring transition are likely to affect *E. pacifica* spawning behavior. A warmer ocean will likely lead to a decrease in *T. spinifera* abundance and spawning. Both scenarios will affect the availability of euphausiids as a food source for higher trophic level predators.

Motomitsu Takahashi (Nagasaki National Fisheries Research Institute, Japan), presented his work carried out during a short visit at the Peterson's laboratory. He looked at otoliths of late-larval and juvenile northern anchovy and Pacific sardine collected off Oregon in the summer of 2005, an unusual year in which upwelling began very late, in mid-July. The results suggested that the fish responded quickly to the intensification of upwelling after mid-July due

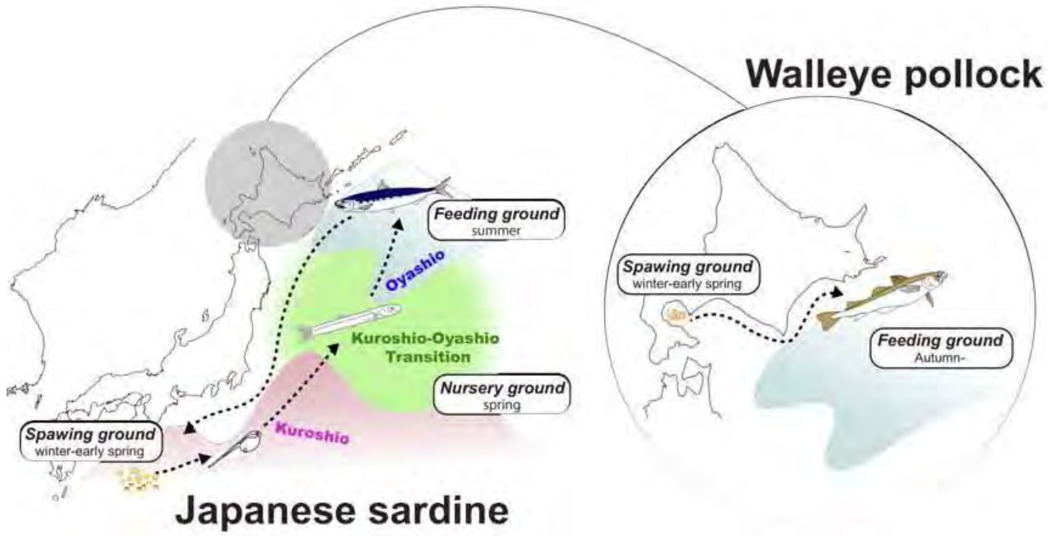

Fig. 2 Overview of the zooplankton from viewpoint of food for fish resources in the western North Pacific.

to the development of a bloom of phytoplankton and a surge in production of cold water copepod species. Increased secondary productivity led quickly to enhance the larval growth rate of northern anchovy.

Kazuaki Tadokoro (Tohoku National Fisheries Research Institute, Japan) provided an overview of the zooplankton from viewpoint of food for fish resources in the western North Pacific (Fig. 2). He reminded us that a great deal of work has been done on the large *Neocalanus* copepod species in the Oyashio-Kuroshio region, with relatively little work on the small copepods species upon which larval and juvenile sardines feed. More research is needed on both food habits of juvenile planktivorous fishes as well as on the zooplankton upon which they feed.

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Dr. William (Bill) Peterson (bill.peterson@noaa.gov) is an oceanographer and Senior Scientist with the Northwest Fisheries Science Center, based in Newport, Oregon, at the Hatfield Marine Science Center. Bill is a Team Leader for the "Climate Change and Ocean Productivity" program. One of the core activities of this program is the biweekly oceanographic cruises carried out by his laboratory along the Newport Hydrographic Line, where hydrography, nutrients, chlorophyll, zooplankton and krill are measured. This ongoing activity was initiated in 1996. A key outcome of these monitoring cruises is that the data are now used to forecast successfully the returns of salmon to the Columbia River and coastal rivers of Washington. Bill has been active within PICES since his first meeting (1998), serving on the Executive Committee of the Climate Change and Carrying Capacity (CCCC) Program Implementation Panel, and as Chairman of the CCCC REX (Regional Experiment) Task Team. Now he is a member of the Biological Oceanography Committee and Co-Chairman of Working Group 23 on "Comparative Ecology of Krill in Coastal and Oceanic Waters around the Pacific Rim". Concerning the photo, the presence of the NOAA ship in the background (R/V Bell Shimada) is significant because the entire fleet of NOAA ships based in the Pacific Northwest will be adopting Newport as their new Fleet Headquarters in 2012.

Dr. Kazuaki Tadokoro (den@affrc.go.jp) is a biological oceanographer at the Tohoku National Fisheries Research Institute of the Fisheries Research Agency of Japan. He received his PhD from the University of Tokyo in 1997. Then he worked in the National Research Institute of Far Seas Fisheries, Hokkaido National Fisheries Research Institute, Ocean Research Institute of the University of Tokyo, JAMSTEC, and Hokkaido University. His research interests focus on the influence of the climate change on marine ecosystems of the North Pacific. Kazuaki is also collecting samples for and managing the Odate collection, known as a long-term zooplankton collection at the Tohoku National Fisheries Research Institute.

2010 Sendai Workshop on "*Networking across Global Marine Hotspots*"

by Gretta Pecl, Stewart Frusher, Warwick Sauer and Alistair Hobday

A 1-day workshop on "*Networking across global marine hotspots*" was held on April 25, 2010, immediately prior to the international symposium on "*Climate change effects on fish and fisheries*" in Sendai, Japan. The workshop was co-convened by the authors of this article and designed to (1) highlight where global marine 'hotspots' occur throughout our oceans, (2) summarize the information currently emerging on biological climate change impacts in these areas, and (3) discuss the potential for developing a global network of scientists, policy makers and managers working in marine hotspots. The workshop attracted considerable interest and was attended by approximately 50 scientists, including invitees from the identified hotspot regions.

The premise behind the workshop was that areas typified by above-average ocean temperature increases, or ocean 'hotspots', are the planet's early warning system for understanding the impacts and adaptation options for marine climate change. Networking and synthesising outcomes from across hotspots can facilitate accelerated learning and also indicate sensible pathways for maximising adaptation and minimising impacts for other global regions. Research, development, management and communication can all be delivered faster, and with greater certainty, through a coordinated network across global hotspots. In these regions:

- Impacts associated with global warming will be observed earlier;
- Species or ecosystem models developed for prediction can be validated earlier than in other slower changing regions; and
- Adaptation options can be developed, implemented and tested first.

The workshop was introduced by Gretta Pecl who described our approach to defining hotspots, their location, and the rationale for the use of sea surface temperature (SST) to determine potential hotspots to include in a global network. Temperature is the most commonly used variable in marine species distribution studies, and as a metric of marine climate change. It is considered to be the major driver of distribution, abundance, phenology and life history. Temperature was also the most commonly identified metric in the presentations at both our workshop and at the main symposium in the days following the workshop. There was extensive discussion on the merits of using SST to define hotspots and on other potential metrics that are also important, such as productivity, acidification, upwelling and oxygen depletion zones. While it was noted that there are other metrics, the general consensus was that SST is a key factor affecting biological processes, and is also the most accessible global data for defining regions that were rapidly changing, and thus provides the first opportunity to inform society of climate change impacts and adaptation options. It was noted that temperature *per se* may not be the driver as it could be a proxy for wind regime changes and/or current shifts.

The intent behind the workshop was not to develop an exhaustive list of global hotspots, but rather to provide a platform to explore the idea of a network covering fast-changing areas across the globe. There was broad agreement that the network would welcome participation by other areas that are also experiencing significant biological change (*e.g.*, areas experiencing noteworthy changes in productivity) or large socio-economic impacts (such as developing countries highly dependent on fisheries).

Based on historical (last 50 years) and projected (next 50 years) rates of ocean warming, 24 regional hotspots were identified that were warming faster than 90% of the oceans. These hotspots covered tropical, temperate, sub-temperate and polar regions, developed and developing countries with a range of adaptive capacities, a variety of ecosystem types, and areas with varying degrees of anthropogenic pressures and disturbances.

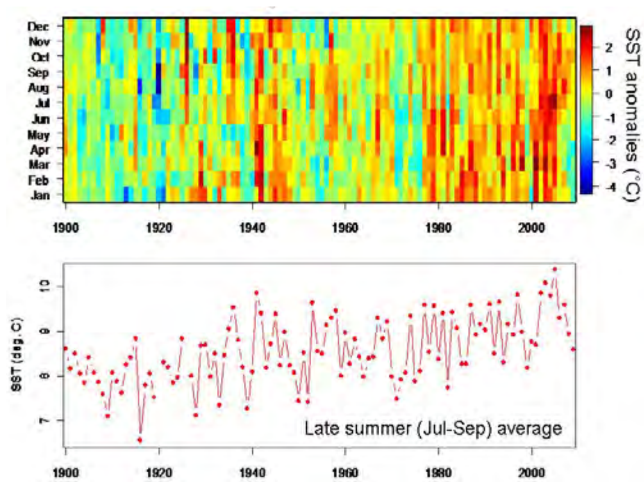

Fig. 1 Sea surface temperature (SST) anomalies in the eastern Bering Sea (from Franz Mueter's workshop presentation).

Invited presentations covered the following hotspot regions: Southeastern Australia, Southern Africa/Benguela system, Galapagos archipelago, Mozambique Channel, eastern Bering Sea, British Columbia, North Sea, Japan Sea, East China Sea/Taiwan Strait, South China Sea, and coastal zone of Vietnam. Most speakers provided details on published or unpublished *in situ* temperature records demonstrating significant recent increase in temperatures, 'validating' the selection of regions as hotspots (*e.g.*, see Fig. 1 from Franz

Mueter's talk on the eastern Bering Sea). However, in many cases temperature either was, or was suspected to be, a proxy for current and/or wind regime changes. Common themes emerging from across these regions with high rates of temperature increase included areas of significant deoxygenation, increased frequency of harmful algal blooms, shifts in species diversity of phyto/zooplantkon communities (mainly from large to small individuals) and increased diversity and species richness of fish. Many presenters provided evidence of large-scale range shifts for a wide variety of species, including movements to deeper waters in some cases. In several regions, large changes in the distribution and abundance of range-shifting species resulted in these acting as 'invasives' creating negative ecosystem impacts (*e.g*., pipefishes in the North Sea and long-spined sea urchins in Tasmania). Interestingly, regions with naturally high climate variability were not less sensitive to climate change factors, instead appearing to be at least equally vulnerable to change and not necessarily 'pre-adapted'. For example, Kyushu in southern Japan and Galapagos archipelago both experience very large seasonal variations in temperature (11–28º and 18–30ºC, respectively), and yet have, in recent decades, undergone regime changes in the inshore areas. In several hotspots redistribution of fisheries effort and associated changes in fleet structure and operations has led to current or impending management implications for harvesting of 'shifting biomass', especially across jurisdictional boundaries.

Formal presentations were followed by a series of discussion topics. The first of these identified the value and practical functions that a global hotspot network could achieve. These were:

(1) Providing a mechanism for scientists, managers and policy makers to communicate and see how science was being translated into policy and practical adaptive management measures in those regions of the world where impacts were occurring;

Dr. Gretta Pecl (Gretta.Pecl@utas.edu.au) is a Fulbright Fellow and a Senior Research Fellow leading several projects within the Climate Change Impacts and Adaptation Theme at the Tasmanian Aquaculture and Fisheries Institute. Her current research activity spans a range of topics, including range extensions associated with climate change, evaluating adaptation options in socio-ecological systems, assessing population and fishery responses to climate change, and using citizen science approaches for ecological monitoring and engagement (http://www.REDMAP.org.au). She was Lead Author of the recent Australian Federal Department of Climate Change interdisciplinary report into the impacts and adaptation response options for the Tasmanian Rock Lobster Fishery (http://www.climatechange.gov.au/en/publications/coastline/east-coast-rock-lobster.aspx). Gretta is currently working in Alaska for her Fulbright Fellowship, a project developed specifically to facilitate collaboration and knowledge exchange between northern and southern hemisphere marine hotspot regions.

Dr. Stewart Frusher (Stewart.Frusher@utas.edu.au) is Associate Professor at the Tasmanian Aquaculture and Fisheries Institute at the University of Tasmania, where he leads the Climate Change Impacts and Adaptation for Marine Resources theme. He co-convenes the bio-physical node of Australia's Adaptation Network for Marine Biodiversity and Resources with Dr. Hobday. His interests are in providing the research to sustainably manage fisheries resources so that they continue to provide social and economic benefits to society. Stewart has extensive experience in crustacean resources and is becoming more involved in the development of interdisciplinary teams to address fisheries issues.

Dr. Warwick Sauer (W.Sauer@ru.ac.za) is Professor and Head of the Department of Ichthyology and Fisheries Science at Rhodes University in South Africa. His interests are in fisheries ecology and management, particularly in the translation of science into practical fisheries management. He serves on a number of management bodies, including the International Cephalopod Advisory Council, and has been involved in numerous regional research projects covering Sub Saharan Africa and the western Indian Ocean. He currently is a member of the Project Coordination Unit for the Agulhas and Somali Large Marine Ecosystem Project, and coordinates training and capacity building initiatives across the Agulhas region.

Dr. Alistair Hobday (Alistair.Hobday@csiro.au) is a Principal Research Scientist at CSIRO in Australia, and leads the Marine Climate Impacts and Adaptation research area (http://www.cmar.csiro.au/climateimpacts). His research has focused on the physical drivers and impacts of climate change on the distribution of marine species around Australia. As a result of his work on fisheries, aquaculture and biodiversity issues, Alistair has been asked to assist with development on national strategy to respond to climate risks. With Dr. Frusher, he co-convenes the bio-physical node of Australia's Adaptation Network for Marine Biodiversity and Resources. He also co-chairs of the international GLOBEC/IMBER program CLIOTOP (Climate Impacts on Top Ocean Predators).

(2) Facilitating comparative studies through:
   - promotion of consistency in data collection, analysis, and reporting, and
   - potential for greater certainty in projection models through first opportunities for validation;
(3) Providing (based on comparisons between regions) greater certainty in the understanding of impacts for stakeholders (*i.e.*, other stakeholders are experiencing similar issues);
(4) Allowing for shared learning and capacity building about adaptation science (successes and failures);
(5) Providing, as the hotspots regions are at the forefront of climate change, valuable insights into the impacts, model validation and the success or failures of adaptation planning for the broader global community.

The workshop participants agreed that a global network of researchers, managers and policy makers working in marine hotspot locations was an appropriate action for providing the science-to-policy framework that would guide climate change adaptation globally.

The final discussion session focused on a path forward and identified the following actions:
(1) A Consensus Statement would be produced to be signed by participants. Participants would be encouraged to obtain in principal support from their respective research/management institutions as further support for the network.
(2) A summary paper of the physical changes documented in last few decades in each region, including observed (or predicted) biological/ecological/fisheries impacts including changes in distribution, abundance and phenology at each of the trophic levels and any observed ecosystem changes and the flow on effects to cultural, social and economic impacts.
(3) A website would be developed for communication of the network and hosting an initial workshop to determine a strategic and operational plan for the network.
(4) Funds would be sought to run targeted workshops on identified areas of need, such as monitoring methodologies, inter-disciplinary approaches for linking science to practical management, *etc*.
(5) Funds would be sought to establish demonstration projects. Examples of such projects could include:
   - identification of key monitoring sites for global comparisons;
   - evaluation of tools/approaches for implementing adaptation options that identify and balance the trade offs in ecological, social and economic indices using some of hotspot regions as case studies.

The workshop was sponsored by Australia's National Climate Change Adaptation Research Facility's Marine Biodiversity and Resources Network (MBRN). The MBRN is an interdisciplinary network aimed at building adaptive capacity and adaptive response strategies for the effective management of Australia's marine biodiversity and natural marine resources under climate change.

NCCARF
National
Climate Change Adaptation
Research Facility
Adaptation Research Network
MARINE BIODIVERSITY AND RESOURCES

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Mikiko Kuriyama (National Research Institute of Fisheries Science, Japan) reported on long-term variations in copepod community in relation to the climatic change in the Kuroshio waters off southern Japan from 1971 to 2009. She revealed that copepod abundances were high in the early 1970s and after the 1990s, and low in the 1980s. *Paracalanus parvus*, as one of the important prey for the Japanese sardine, was abundant through the study period.

The final talk by Toru Kobari (Kagoshima University, Japan) demonstrated decadal changes in seasonal timing and population age structure of *Eucalanus* in the Oyasiho from a time series initiated in the 1970s. He showed that a decline in copepod abundance originated at the early life stages, and was associated with a shift of atmospheric and oceanographic conditions. Possible biological mechanisms to account for the decline were reduced egg production, lower survival for the portion of the annual cohort with late birth date, and overwintering of the survivors at younger stages.

Each talk was discussed thoroughly, with many questions from the audience. The workshop ended with an open discussion which resulted in the following recommendations: (1) zooplankton time series that are based on either size of copepod taxa, or on species abundance have far greater value than time series of "total biomass" or "volume" of the catch; (2) future workshops on the same topic would be welcomed warmly; and (3) more specialized workshops should be convened whereby zooplankton ecologists with long time series would work with fisheries people from the same region to try harder to relate interannual variations in zooplankton abundance and species composition with variations in some key aspects of pelagic fishes life history – either recruitment or growth.

The Ocean, Salmon, Ecology and Forecasting in 2010

by Bruce MacFarlane, Skip McKinnell and Robert Emmett

The 12th Salmon Ocean Ecology Meeting in session (March 24–25, 2010, Santa Cruz, California, U.S.A.).

The 12th Salmon Ocean Ecology Meeting was held on March 24–25, 2010, in Santa Cruz, California, U.S.A. It brought together ~100 researchers working on projects from the central North Pacific Ocean to the coasts and estuaries of Southeast Alaska to central California.

Thirty-five oral presentations and two posters described findings from the latest salmon ocean ecology research on the west coast of North America. Others, like Javier Ciancio who is from Centro Nacional Patagónico-CONICET in Argentina (now at NOAA's Southwest Fisheries Science Center Laboratory in Santa Cruz), presented findings on the trophic relationships of introduced salmonids in Patagonia. Chinook salmon (*Oncorhynchus tshawytcha*) and anadromous brown trout (*Salmo trutta*) have primarily piscivorous diets that resemble the diet of Magellanic penguins. The diet of steelhead trout (*O. mykiss*) on the other hand, was similar to that of the rockhopper penguin which feeds mostly on zooplankton. Thus, penguin distributions may be useful for defining potential oceanic ranges for these salmonids as catch rates at sea are so low that standard methods are not practical. Graham Goulette (NOAA Fisheries Maine Field Station in Orono, ME) gave a presentation on the decline of Atlantic salmon abundance in the Northwest Atlantic Ocean with evidence that decreased marine survival, not just freshwater habitat degradation, is contributing to the regional decline. One of the more novel presentations was by John Field, a fish biologist from the Santa Cruz Laboratory, who provided a synopsis of the biology of Humboldt squid (*Dosidicus gigas*) on the west coast of North America. Although its abundance has not been quantified by surveys, it is clearly increasing along with its range expansion to (at least) Southeast Alaska, well into the ranges of all Pacific

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Dr. Bruce MacFarlane (Bruce.MacFarlane@noaa.gov) is the leader of the Salmon Ecology program at NOAA's Southwest Fisheries Science Center Laboratory in Santa Cruz, CA, U.S.A., and an Adjunct Professor of Ecology and Evolutionary Biology at the University of California, Santa Cruz. For the past 30 years, he has conducted physiological ecology research on anadromous and marine fishes. Currently, his focus is on California's salmon and steelhead, particularly their ocean ecology and the use of telemetry to learn more about their spatial patterns of movement and mortality.

Dr. Skip McKinnell (mckinnell@pices.int) helps out when he can. He is the Deputy Executive Secretary of PICES and currently an Editor-in-Chief of the PICES North Pacific Ecosystem Status Report that is scheduled for publication in 2010.

Dr. Robert Emmett (Robert.Emmett@noaa.gov) has been working for NOAA Fisheries forever – 30 years. His primary research activities are presently focused on salmon marine survival and population fluctuations in coastal pelagic fishes (sardine, anchovy, herring and smelt).

The State of the Northeast Pacific during the Winter of 2009/2010

by William Crawford

In December 2009, we sent in our PICES Report of the northeast Pacific Ocean, noting that typical El Niño warm conditions had not yet arrived in the coastal Gulf of Alaska despite a mature El Niño in the tropical Pacific Ocean. However, within a few weeks the storm tracks changed, the Aleutian Low pressure system deepened to new lows, and all through January and February 2010 the Gulf of Alaska coastal temperatures climbed quickly.

So what happened in December 2009? In a typical El Niño, the Aleutian Low pressure system from December to March drops in pressure and increases its area (Fig. 1). The west coast of North America, from California to Alaska, generally sees more southerly warm winds from Oregon to Alaska and more storms in California during El Niño.

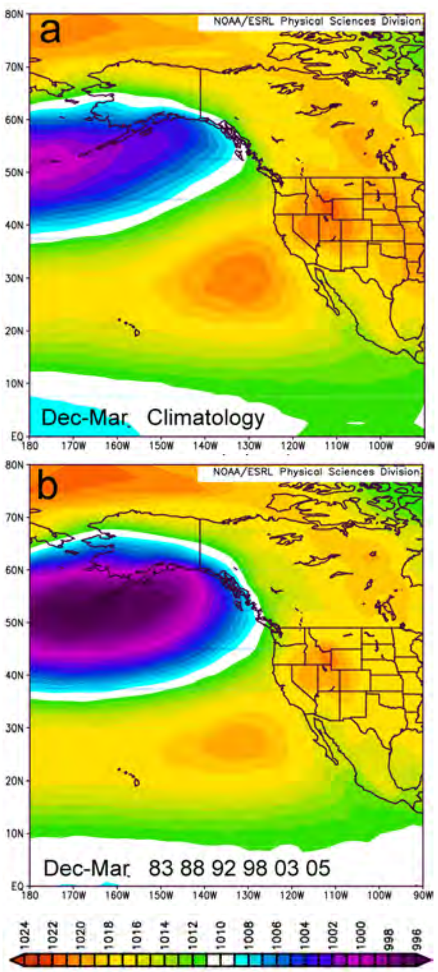

Fig. 1 Sea surface pressure average from December to March inclusive: (a) climatology from 1968–1996. (b) El Niño events in 1982/83, 1987/88, 1991/92, 1997/98, 20020/03, 2004/05. Air pressure is in millibars according to the scale at the bottom. Image provided by NOAA/ESRL Physical Sciences division (http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl).

We blame the late arrival of warm winds in 2009–2010 on the Arctic Oscillation, which hit near-record negative values from December 2009 to February 2010. This oscillation is plotted in Figure 2, along with Niño 3.4 temperature anomalies. During the negative Arctic Oscillation, the high pressure regions of the Arctic spread to the south, as can be seen over western North America in Figure 3a.

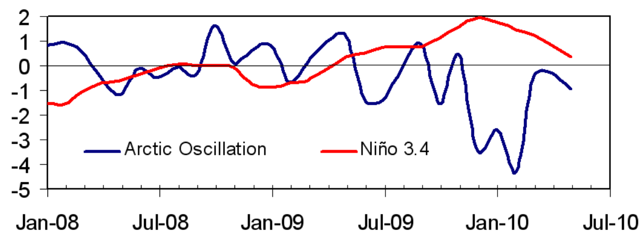

Fig. 2 Time series of monthly values of the Arctic Oscillation and Niño 3.4 temperature anomalies.

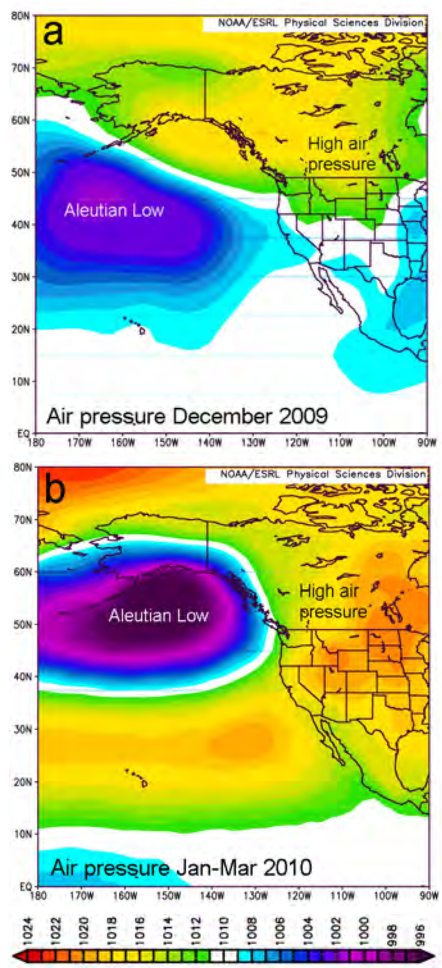

Fig. 3 Sea surface pressure averages through winter 2009/10. Air pressure is in millibars according to the scale at the bottom. Image provided by NOAA/ESRL Physical Sciences division.

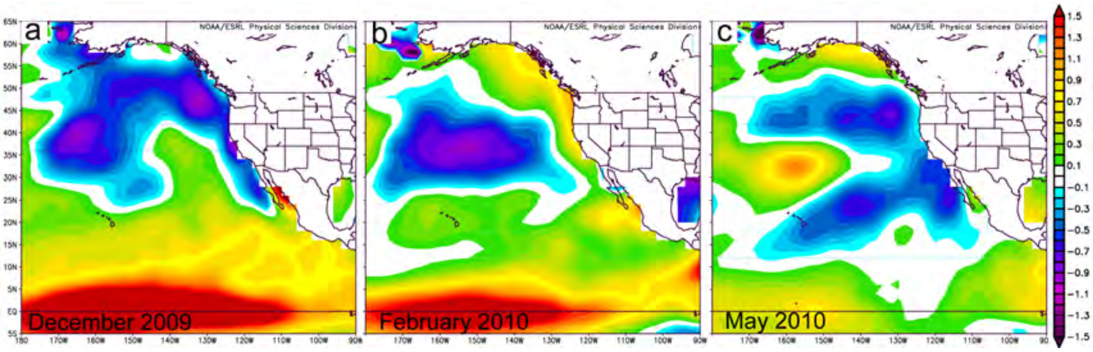

Fig. 4 Sea surface temperature anomalies for (a) December 2009, (b) February 2010 and (c) May 2010. Anomalies are in °C at intervals of 0.1°C, according to the scale at the right. Image provided by NOAA/ESRL Physical Sciences division.

In December 2009, the high pressure cell over western Canada and northwestern contiguous U.S.A. brought very cold air from the north. According to the Global Snow Laboratory of Rutgers University, more of North America was covered by snow than in any other December on record (going back to 1966). The ski runs of the Vancouver Olympics filled with snow, but it was not to last. If there was a contest between the high pressure of the Arctic Oscillation pushing south, and the Aleutian Low pressure system of an El Niño winter pushing north, the Aleutian Low lost in December 2009, but dominated in January and February 2010. Figure 3b reveals an Aleutian Low as intense as during the massive El Niño winters of 1982/83 and 1997/98. Its southerly winds carried warm air and water northwards along the North American west coast, and also downwelled warm water at the coastline. These same winds quickly melted snow on the Olympic ski hills, and only by importing snow did the Vancouver Olympic Games succeed in February.

Ocean temperature anomalies are plotted in Figure 4. El Niño appears as a warm region along the Equator. Note the cool waters in eastern Gulf of Alaska in December 2009, which had persisted for about two years. The intense Aleutian Low of January to February warmed the west coast in February 2010, but by May 2010 these warm surface temperatures were confined to Central American and Alaskan waters. Equatorial anomalies were close to zero in May, signaling the end of the 2009/10 El Niño.

Dr. William (Bill) Crawford (Bill.Crawford@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, British Columbia. He is co-editor of Canada's annual State of the Pacific Ocean Report and serves as president of the Canadian Meteorological and Oceanographic Society.

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- Long period culture experiments/multi-generation studies are both needed to try to obtain information on long term adaptive capacity and evolutionary change, but are usually restricted to species with generation times of less than 1 year. Comparisons of species from various climate regimes and CO_2 environments may help to circumvent these constraints in long-lived species.
- In experimental studies diel, seasonal and inter-annual variability of CO_2 levels should be simulated, if relevant for the respective ecosystem. Such experiments would be required to identify slow trends embedded in highly variable environments.
- Population genetic and functional genomic analyses need to be applied more widely.
- Models have to be examined as to whether they formulate physiological and behavioural processes that are dependent on changing environmental drivers such as $P\mathrm{CO_2}$ or temperature.
- Some aquaculture species respond differently than their "wild" counterparts. Have they already become adapted to higher $P\mathrm{CO_2}$, for example by being cultured in water supplied from depths below the mixed layer that already has elevated $P\mathrm{CO_2}$ relative to the depths at which the wild populations live?
- Can we learn from species already experiencing higher $P\mathrm{CO_2}$ naturally? For example some species of copepods and euphausiids migrate several hundreds of meters vertically on diel and seasonal timescales (diapause), where at depth they are exposed to $P\mathrm{CO_2}$ levels of 500 to 1000 ppm.
- Very importantly, experimental protocols must include behavioural and physiological dependencies on multiple variables that we expect to change with the climate: $P\mathrm{CO_2}$, dissolved oxygen, temperature, micro-nutrients (Fe), *etc*. [*e.g*., see Fig. 1 showing a shrinking "thermal window" (aerobic scope – difference between maximal and resting metabolic rates) with decreasing O_2 and increasing $P\mathrm{CO_2}$ (and temperature?)].
- Sensitivities need to be systematically identified across taxa and in between species comparisons.
- Through a combined experimental and modeling approach, can we start to evaluate possible changes in whole ecosystem structure resulting from the possible disappearance and replacement of key species?

The State of the Western North Pacific in the Second Half of 2009

by Shiro Ishizaki

Sea surface temperature

Figure 1 shows the monthly mean sea surface temperature (SST) anomalies in the western North Pacific from July to December 2009, computed with respect to JMA's (Japan Meteorological Agency) 1971–2000 climatology. Monthly mean SSTs are calculated from JMA's MGDSST (**M**erged satellite and *in-situ* data **G**lobal **D**aily **SST**), which is based on NOAA/AVHRR data, AQUA/AMSR-E data and *in-situ* observations. Time series of 10-day mean SST anomalies are presented in Figure 2 for 9 regions indicated in the bottom panel.

Positive SST anomalies exceeding +1ºC prevailed around 38ºN, 165ºE during the entire period. In July, positive SST anomalies exceeding +1ºC were found along 15ºN east of 150ºE, and SSTs were below normal around 28ºN, 162ºE. These anomalies were reduced in magnitude and disappeared in October. Positive SST anomalies dominated in the equatorial Pacific, especially east of 160ºE. In July and August, SSTs were generally above normal to the south of Japan. From July to August, SSTs were below normal in the Sea of Japan, where their anomalies turned positive in October (regions 1 and 3 in Fig. 2). After August, positive SST anomalies exceeding +1ºC were found in the East China Sea (region 8 in Fig. 2).

Kuroshio path

Figure 3 shows a time series of the location of the Kuroshio path for the reviewed period. The Kuroshio took a non-large-meandering path off the coast to the south of Honshu Island (between 135ºE and 140ºE). In September, the latitude of the Kuroshio axis at the Izu Ridge (about 140ºE) moved northward from about 32ºN (south of Hachijo Island) to about 33.5ºN (north of Hachijo Island). After November, the Kuroshio flowed at about 33ºN (around Hachijo Island).

Carbon dioxide

JMA has been conducting observations for carbon dioxide (CO_2) in the surface ocean and atmosphere in the western North Pacific, on board the R/V *Ryofu Maru* and the R/V *Keifu Maru*. Figure 4 illustrates the distribution of the difference in CO_2 partial pressure (pCO_2) between the surface seawater and the overlying air (denoted as ΔpCO_2) observed in the western North Pacific for each season of 2009. The sign of ΔpCO_2 determines the direction of CO_2 gas exchange across the air–sea interface, indicating that the ocean is a source (or sink) for atmospheric CO_2 in the case of positive (or negative) values of ΔpCO_2.

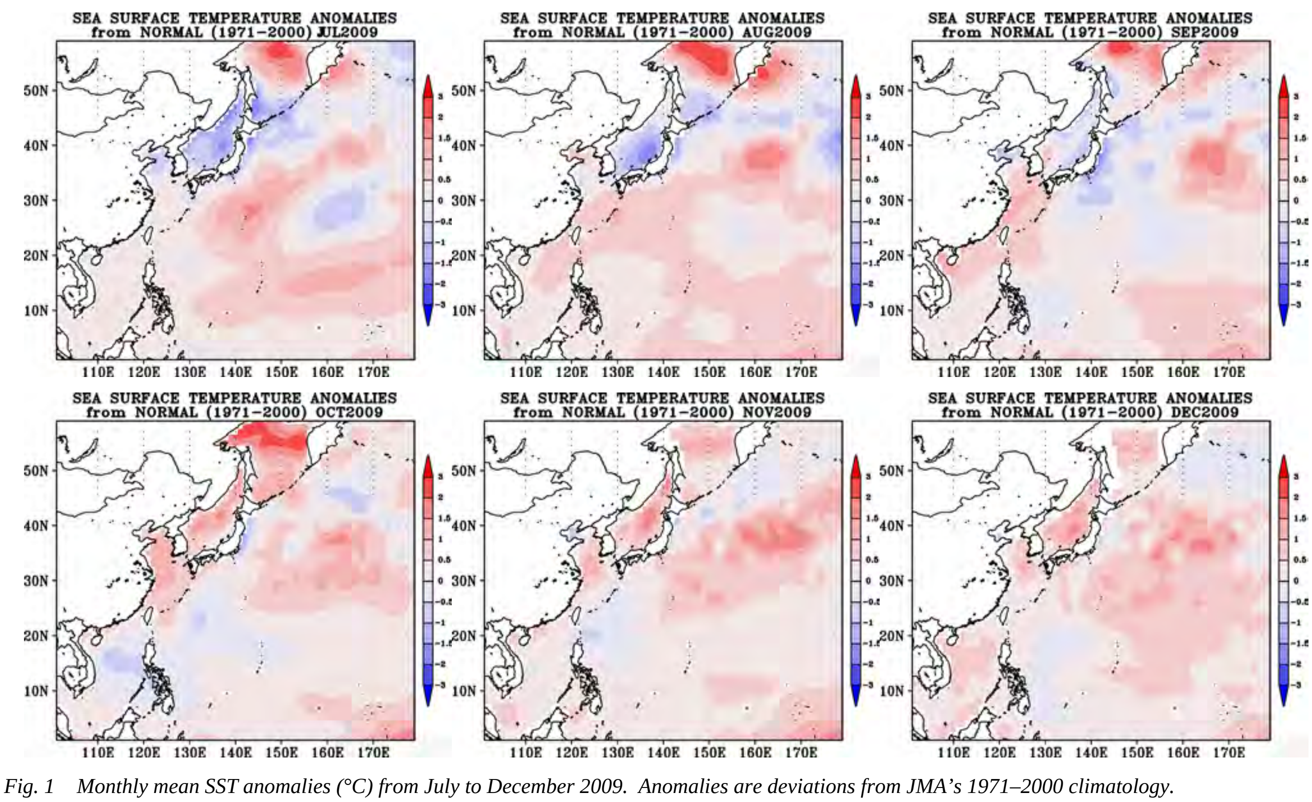
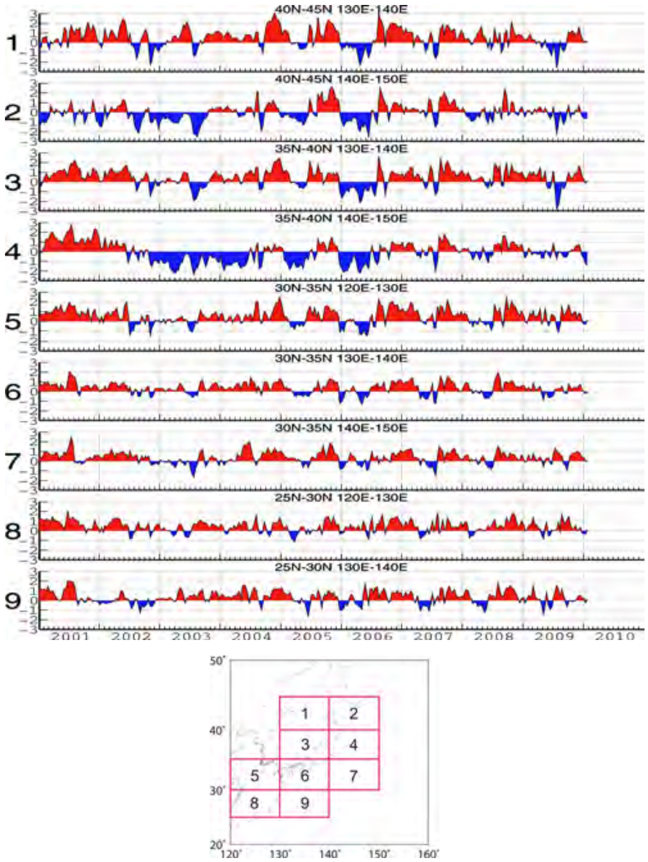
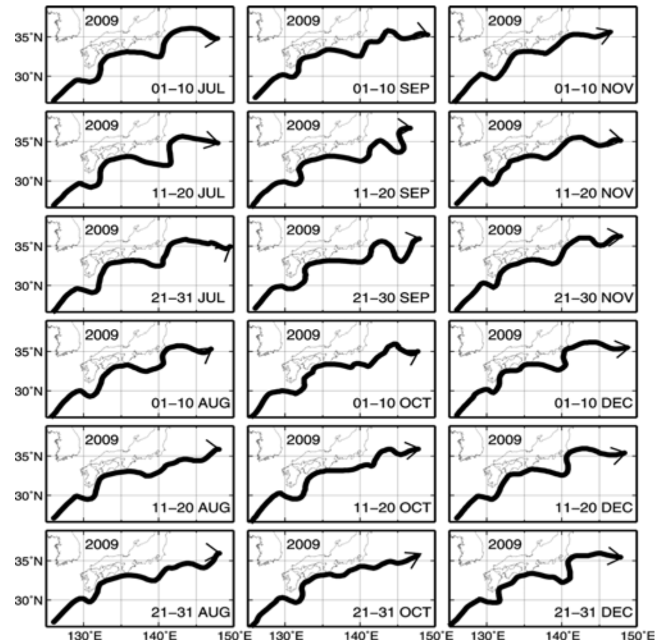


Fig. 1 Monthly mean SST anomalies (°C) from July to December 2009. Anomalies are deviations from JMA's 1971–2000 climatology.





Left column:

Fig. 2 Time series of 10-day mean SST anomalies (°C) averaged for the sub-areas shown in the bottom panel. Anomalies are deviations from JMA's 1971–2000 climatology.

Right column:

Fig. 3 Location of the Kuroshio path from July to December 2009.

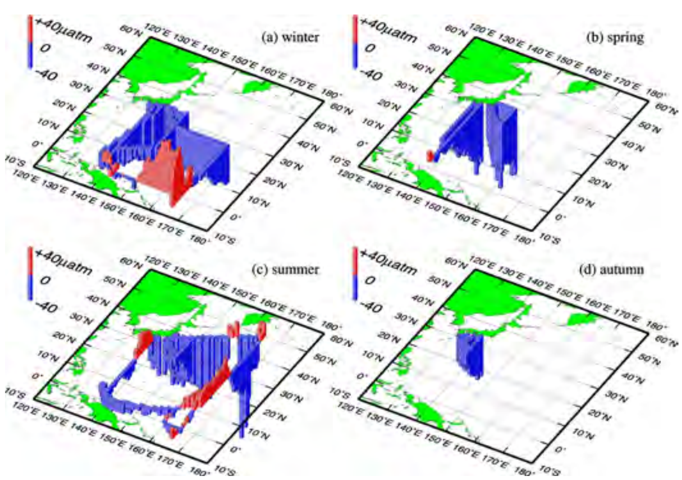


Fig. 4 Difference in CO_2 partial pressure between the ocean and the atmosphere in the western North Pacific in 2009. Red/blue pillars show that oceanic pCO_2 is higher/lower than atmospheric pCO_2. Seasons are for the Northern Hemisphere.

In the subtropical region, typically between 10–35ºN, the ocean widely acted as a CO_2 sink in the winter and spring of 2009. Some CO_2 source areas were found in the summer of 2009.

In the eastern part of the equatorial region, the ocean acted as a strong CO_2 source in the winter of 2008 because of the presence of water with a high concentration of CO_2 in the area. Even though the previous La Niña event had ended in the spring of 2008, trade winds were still intense in the western and central Pacific. This suggests that the CO_2-rich water found in the eastern area was derived from the eastern equatorial Pacific, where the surface water has high CO_2 concentration. The intense trade winds weakened after the spring, and no strong CO_2 source area was found in the summer of 2009.

Shiro Ishizaki (s_ishizaki@met.kishou.go.jp) is a Scientific Officer of the Office of Marine Prediction at the Japan Meteorological Agency (JMA). He works as a member of a group in charge of oceanic information in the western North Pacific. Using the data assimilation system named "Ocean Comprehensive Analysis System", this group provides an operational surface current prognosis (for the upcoming month) as well as seawater temperature and an analysis of currents with a 0.25 $\times$ 0.25 degree resolution for waters adjacent to Japan. Shiro is now involved in developing a new analysis system for temperature, salinity and currents that will be altered with the Ocean Comprehensive Analysis System.

The Bering Sea: Current Status and Recent Events

by Jeffrey Napp

Current status of the Bering Sea ecosystem

Cold, cold, and more cold. Forget what you heard about changing atmospheric conditions and indices. Ignore what you read here and heard at the PICES Annual Meeting and Alaska Marine Science Symposium about the possibility of an "average" winter in the eastern Bering Sea. The cold conditions, begun in 2006, remained during the winter / spring of 2010, with ice around the Pribilof Islands until at least the middle of May. The initial ice retreat started in March of 2010, but in April and May, the region experienced weak, but sustained winds out of the north, pushing the ice farther south. The continued pushing and reorganization of ice promoted ice rafting with many large floes with significant jumbling of ice above the surface. Eventually, the area between St. Matthew and St. Lawrence Islands became ice free, while the area around the Pribilof Islands still had significant ice cover. This year may represent one of the latest ice retreats for the southeastern shelf in about 50 years.

The enduring ice and cold temperatures experienced in the region are somewhat at odds with what was happening in the atmosphere. For example, the multi-variate El Niño index was positive through the winter. Normally, this predisposes the wintertime atmospheric circulation to feature a deeper and eastward-displaced Aleutian Low. It is generally associated with warmer than normal air temperatures for western Alaska and the eastern Bering Sea because of the greater frequency and strength of low pressure centers of maritime origin, and a lower incidence of high pressure centers of Siberian and Arctic origin. The distribution of anomalous sea level pressure (SLP) that occurred during the winter (December to March) of 2009/10 (Fig. 1) closely resembles the composite pattern during El Niños of the last 50–60 years.

The surface air temperatures during the winter of 2009/10 were anomalously warm for the far eastern portion of Asia, and for much of Alaska. In contrast, a localized pocket of significantly negative air temperature anomalies occurred over the southeastern Bering Sea (Fig. 2). These cool air temperatures can be attributed to the state of the underlying ocean, *i.e*., the cold water temperatures that were a result, in part, of the anomalous water temperatures at the end of last summer (2009). Insolation during the summer was insufficient to bring the water temperatures up to the climatological mean. Thus, we observed feedback between the ocean and atmosphere where the previous year's heat balance resulted in anomalously cold conditions which suppressed the heating of the atmosphere by the ocean in the current year. In turn, the colder air temperatures promoted the growth and southward advection of sea ice.

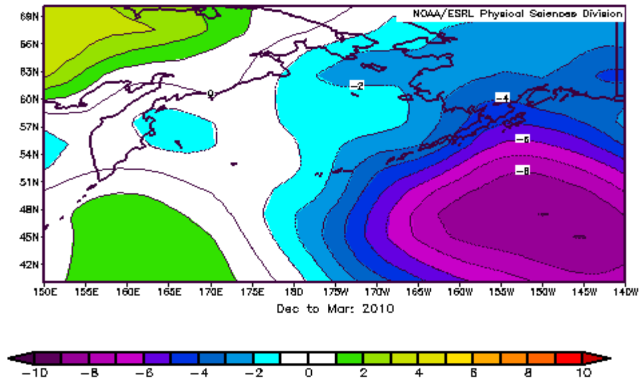


Fig. 1 Winter 2009/10 sea level pressure anomalies computed using a composite or mean sea level pressure for 1968–1998. Image provided by NOAA/ESRL Physical Sciences division (http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl).

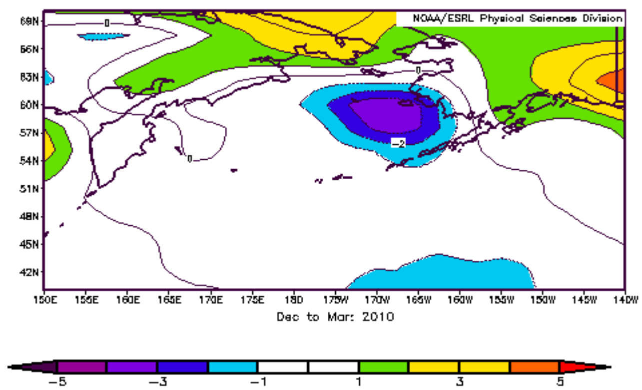


Fig. 2 Winter 2009/10 air temperature anomalies. Image provided by NOAA/ESRL Physical Sciences division.

Two other factors are hypothesized to have strongly influenced this year's late ice retreat: a late winter cold snap and anomalous northerly winds. An extended period of unusually cold weather occurred from late February through mid-March 2010. During this period, the low-level wind anomalies were from the northwest, bringing relatively cold and dry air originating from eastern Siberia. St. Paul Island recorded air temperatures consistently 10°C lower than normal during this 3-week period. Cold-air outbreaks near the end of winter are especially effective at generating sea ice in the southern portion of the shelf.

In addition to the late winter cold snap, the eastern Bering Sea experienced anomalous northerlies in spring. The period from April 26 to May 21, 2010 included an anomalous ridge of high pressure extending from the western Bering Sea into eastern Siberia (Fig. 3). To the east of this ridge, over the southeastern Bering Sea shelf, the northerly component of the winds averaged about 4 m/s, as compared with mean values at this time of year of ~2 m/s. An important consequence was a seasonally late advance in sea ice on the Bering Sea shelf during May 2010. The advance in sea ice in this case can be attributed to advection since air temperatures were generally near normal. Through their impacts on the distribution of sea ice during the spring bloom, these kinds of episodic weather events may be of particular importance to the ecosystem.

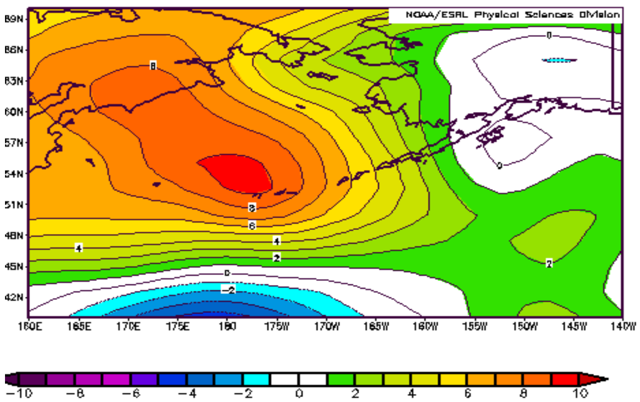


Fig. 3 Mean sea level pressure anomalies from April 26–May 21, 2010. Image provided by NOAA/ESRL Physical Sciences division.

Thus, the cold conditions this past winter in the eastern Bering Sea resulted from a series of both regional and basin-wide events, including the state of the ocean during the previous summer. The events, their timing, and magnitude all contributed to the end result – a very cold winter with delayed retreat of sea ice.

The indices used to characterize the climate system have been anything but static during the cool to cold period of 2006–2010 for the Bering Sea. The El Niño of 2009/10 is over and there are increasing indications, based on observational trends and a variety of model projections, that a La Niña is likely to develop by fall 2010. While the Pacific Decadal Oscillation (PDO) index was weakly positive during the first four months of 2010, it might be anticipated to trend negative due to the developing La Niña. The Arctic Oscillation (AO) index was strongly negative through February, but has decreased in magnitude and oscillated between positive and negative values since then (Fig. 4). As reported in the last issue of PICES Press, winter values for the AO had not been of this sign and magnitude since the late 1970s.

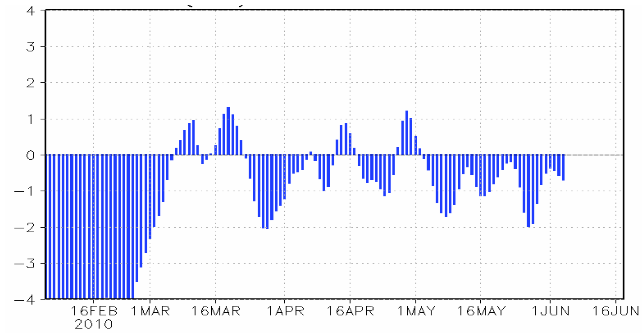


Fig. 4 Daily Arctic Oscillation index (http://www.cpc.noaa.gov/products/precip/CWlink/daily_ao_index/ao_index.html).

2010 Bering Sea field season

This is the last field year for the current BEST/BSIERP partnership (see http://bsierp.nprb.org). Due to scheduled maintenance for the U.S. Coast Guard (USCG) Icebreaker *Healy*, the March cruise was on the USCG Icebreaker *Polar Sea*; a full report of this successful cruise is available at http://bsierp.nprb.org/fieldwork/2010/polarsea01.html. The spring and summer cruises are using the R/V *Thomas G. Thompson*. The spring cruise was scheduled to begin later this year than in the past two years (May rather than April), and considering the earlier predictions of an average spring in the Bering Sea, there was concern that the spring cruise would be late for initialization of the spring bloom. Mechanical issues and the Chilean earthquake further delayed the start of this cruise. However, the exceptionally late ice retreat put those concerns to rest, ironically replaced by difficulties occupying planned stations due to heavy sea ice in the intended operations area. Field reports from the spring cruise are available at http://bsierp.nprb.org/fieldwork/2010/thompson01.html. The summer cruise is scheduled to begin on June 17, and reports from that cruise – and from other BEST/BSIERP field, LTK, and modeling efforts – will be available on the project website.

Several of the intended spring and summer cruises to the eastern Bering Sea have been cancelled or modified. For example, after the U.S. announced that Bristol Bay was no longer open to oil exploration, funding for some cruises sponsored by the U.S. Minerals Management Service was cancelled. In addition, this year, the T/S *Oshoro Maru* (Hokkaido University, Japan) will concentrate its summer

(*continued on page 39*)

Dr. Jeffrey (Jeff) Napp (jeff.napp@noaa.gov) is a Biological/Fisheries Oceanographer at the Alaska Fisheries Science Center of NOAA–Fisheries. He is Head of the Recruitment Processes Program at the Center and co-leader (with Dr. Phyllis Stabeno) of NOAA's Ecosystems and Fisheries Oceanography Coordinated Investigations (EcoFOCI). His research is focused on physical and biological processes at lower trophic levels that affect recruitment variability in fish populations. Jeff was active as a Principal Investigator in past Bering Sea research programs (NOAA's Bering Sea FOCI, Southeast Bering Sea Carrying Capacity), and currently is a Principle Investigator on the NPRB-sponsored Bering Sea Integrated Ecosystem Research Plan (BSIERP) project. He formerly served on the BEST (Bering Ecosystem Study) Science and Implementation Plan Steering Committee. Jeff is also a member of the PICES Technical Committee on Monitoring.

PICES Seafood Safety Project: Guatemala Training Program

by Vera L. Trainer, Charles G. Trick, Mark Wells, William Cochlan and Julian Herndon

A PICES Seafood Safety Project was initiated in 2007 in response to the need to develop a system for harmful aquatic organism data collection and exchange in the Pacific Ocean, to assist both in the prevention of impacts on fisheries and to build the capacity of scientists studying this topic in developing countries in the Pacific Rim. The Project is funded by a voluntary contribution from Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF), through the Fisheries Agency of Japan (JFA), and is conducted by the PICES Section on *Ecology of Harmful Algal Blooms in the North Pacific*, with Dr. Vera Trainer (Northwest Fisheries Science Center, U.S.A.), who is co-chairing this Section, as the Principal Investigator. The Project focuses on preparing and teaching country-specific training courses most required to ensure seafood safety in Pacific countries outside the PICES region, *i.e.*, in Southeast Asia and in Central America and South America. The first PICES HAB training class was held from January 15–23, 2009, in Manila, Philippines, and was highly successful (PICES Press, 2009, Vol. 17, No. 2, pp. 5–7).

Selection of country and sustainable model

In 2009–2010, the community research partnership approach to seafood safety training, adopted by the Project (see the above cited article for details), has been expanded to Guatemala. The choice of Guatemala as a country fulfilling the project guidelines was determined through assessment of a response from Dr. Leonel Carrillo Ovalle, (Center for Marine Studies and Aquaculture (CEMA) at the University of San Carlos, Guatemala) to a questionnaire distributed via the IOC (Intergovernmental Oceanographic Commission of UNESCO) network, and conversations with Drs. Leonardo Guzman, Chairman of IPHAB (IOC International Panel on Harmful Algal Blooms) and member of HAB-FANSA (IOC HAB Working Group for South America) and José Luis Peña Manjarrez, Chairman of ANCA (IOC HAB Working Group for Central America and Caribbean) at the IPHAB Conference (April 22–25, 2009, Paris). Based on our discussions with these individuals representing Central America and South America, it was concluded that Guatemala was a perfect match to the criteria used for country selection in the PICES Seafood Safety Project, such as (1) the magnitude of the HAB problem, (2) the need for training, and (3) the likelihood of sustainability.

The sustainable model for the implementation of the PICES-led initiative in Guatemala included:

- *Initiation and implementation at the community level*: Dr. Carrillo Ovalle, our primary in-country contact, has developed strong partnerships with all the institutions responsible for management of red tides, known as "marea roja" in Guatemala.
- *Engagement of participants in cross-disciplinary research and management groups*: Through cross-fertilization, individuals can gain a balanced perspective on both the value of the project and of their own contribution.
- *Building partnerships for extended interactions and commitments*: Continued education and knowledge transfer are essential for the proper capacity building, and our communications with Dr. Carrillo Ovalle will persist through monthly Skype calls to assist with data interpretation and to assess further needs.

Development of training program in Guatemala

During our initial visit to Guatemala in September 2009, we had discussions with personnel at several institutions:

- University of San Carlos (USAC): Dr. Leonel Carrillo Ovalle, Professor-Investigator at CEMA/USAC and representative of Guatemala and a country focal point at IOC;
- National Institute for Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH), the organization responsible for emergency response to natural disasters (earthquake, volcanoes, harmful algal blooms, *etc*.) in Guatemala: Engineer Eddy Sanchez, Director of INSIVUMEH and President of the National Commission on Red Tides, and Engineer Mario Bautista, General Deputy Director of INSIVUMEH;
- Fisheries and Aquaculture Management Unit (UNIPESCA): Mr. Manuel Cabrera (Director), Mr. Manuel de Jesús Ixquiac (Coordinator), Mr. Ruben Bran Lopez (seafood safety inspector responsible for, monitoring of biotoxins), and Vinicio Juarez (GIS specialist responsible for the mouse bioassays);
- Naval Academy: Head of Academy, and Captains A. Porras and L. Veliz. There is a letter of understanding between the Naval Academy and CEMA that allows for cooperation in training and resource use (*i.e.*, small boats used for sampling);
- Universidad Del Valle (private university in Guatemala City): Dr. Lucia Gutierrez.

Our visit confirmed that the greatest need for training included:

- training in screening methods for detection of paralytic shellfish poisoning (PSP) toxins;
- a review of phytoplankton identification, with specific focus on harmful species in Guatemala;
- instructions in basic concepts in oceanography, as there is no oceanography program in Guatemala.

Participants and instructors of the PICES Seafood Safety Project training class at the University of San Carlos, Guatemala City, Guatemala, February 2010.

Naval school students and officers, shrimp farmers, fisheries agents, port authority officials and instructors pose for a group photograph at the completion of the training class at the Naval Academy at the Pacific Naval Command, San Jose, Guatemala, February 2010.

Training classes

From February 15–19, 2010, we held training classes at the USAC in Guatemala City, and at the Naval Academy in San José on the Pacific coast of Guatemala near the border to El Salvador. There were 31 participants at the 4-day intensive course at USAC: 25 CEMA/USAC students, 4 inspectors from UNIPESCA and 2 members of the National Health Laboratory (LNS-Laboratorio Nacional de Salud). Participants of the 2½-day training class at the Naval Academy, including the Pacific Coast Guard Commander, 2 Caribbean Command members, 4 Pacific Command members, 4 UNIPESCA inspectors, 3 members of the Quetzal Port Authority, the lab manager for an Acuamaya shrimp farm and 2 agronomists. The quality of teaching and the students' understanding of concepts were assessed through impromptu quizzes and a final exam. A notebook was provided to all participants, which included an agenda, a summary of HAB syndromes in humans, a phytoplankton key, individual micrographs of HAB species of concern in

Clockwise from top left: (1) Manuel de Jesús Ixquiac, UNIPESCA, Dr. Vera Trainer (NOAA/PICES), Leonel Carrillo Ovalle (CEMA, University of San Carlos) after a television interview about the PICES training class in Guatemala City; (2) Drs. William Cochlan (San Francisco State University/PICES, far left) and Mark Wells (University of Maine/PICES) explaining the volume calculation for a depth-integrated net tow to CEMA students; (3) Mr. Brian Bill (PICES instructor) works with University of San Carlos students on microscopic identification of marine phytoplankton; (4) Mr. Julian Herndon (PICES instructor) explains the parts of the microscope to health department officials (he also was the official Spanish translator for the class); (5) Drs. Charles Trick (University of Western Ontario/PICES, left) and Mark Wells explaining the use of a Secchi disk; (6) Dr. Alison Robertson (U.S. Food and Drug Administration) explaining sample purification techniques, used prior to toxin detection, by high performance liquid chromatography.

Guatemala, and handouts on toxin detection methods, including the Jellett PSP test and Abraxis shipboard Enzyme-Linked Immunosorbent Assay (ELISA).

A follow-up training class held from April 26–29, 2010, was organized in collaboration with the U.S. Food and Drug Administration (Dr. Alison Robertson) and focused on High Performance Liquid Chromatography (HLPC) and Mass Spectrometry (MS) for domoic acid and saxitoxins. A total of 8 scientists were present, including chemists and biologists from CEMA/USAC, LNS and UNIPESCA. Training included lectures on the chemistry of marine toxins and the theory of chromatography, and practical laboratory exercises on sample extraction and clean-up for both paralytic shellfish toxins and domoic acid, data analysis and interpretation of HPLC chromatographs, and enzyme-linked immunosorbent assay for paralytic shellfish toxins. Oyster samples collected from the Guatemala Pacific coast were analyzed and compared to reference standards.

The close collaboration of university scientists with peers in industry and government management groups form the basis for a strong project in Guatemala. Over the next year, Jellett PSP rapid tests and ELISA will be evaluated by LNS. A combination of techniques will be used to assess the accuracy of toxin screening methods. Chemical methods (HPLC and LC/MS) will provide structural confirmation of toxins present in samples tested by biologically-based methods (ELISA, Jellett and the standard mouse bioassay). A Memorandum of Understanding will be implemented to clarify project goals and to assure steady progress. Monthly Skype calls with our CEMA colleagues will allow PICES investigators to provide advice on data analysis and interpretation.

The training program went very well, and we are pleased in our efforts to improve the Guatemalan trainees' understanding of marine coastal systems and provide practical means to safeguard seafood products from harmful algae in this country. This training was, in our opinion, a very effective and worthwhile use of PICES experts' time and funds to assist one of the developing nations. We would like to acknowledge MAFF and JFA for funding this project, allowing us the opportunity to conduct much needed important work. We also thank our colleague, Dr. Yasukatsu Oshima of Kitasato University for kindly providing reference materials for this class.

(*continued from page 35*)

survey around the Aleutian Islands chain and will not sample the eastern Bering Sea shelf as it has done most years since 1955. There are still plans to expand an annual summer bottom trawl survey, conducted by NOAA's Groundfish Assessment Program at the Alaska Fisheries Science Center, into the Northern Bering Sea Research Area this summer (http://www.fakr.noaa.gov/NPFMC/ current_issues/ecosystem/NBSRA_files/NBSRA_outline509.pdf).

Recent developments for the Arctic

The U.S. arctic waters are still being considered as an area open to oil and gas extraction. However, in response to the emergency in the Gulf of Mexico at the Deepwater Horizon MC232 site, permit applications filed by the Shell Oil Company for exploratory drilling this summer were not granted. A large number of scientific research cruises were planned to the lease sites in this area to coincide with the exploratory drilling. At this time, it is not clear which previously planned science projects will sample this summer.

A draft document entitled "*NOAA's Arctic Vision and Strategy*" (http://www.arctic.noaa.gov/docs/arctic_strat_2010.pdf) was recently released to provide background information for the nation's emerging ocean science efforts in the Arctic.

Upcoming science meetings

There are multiple science symposia and workshops occurring in 2010 and 2011 that may be of interest to researchers working in the Bering Sea. Some of these are:

- ESSAS Annual Science Meeting (August 30–September 2, 2010, Reykjavik, Iceland);
- PICES Annual Meeting (October 22–31, 2010, Portland, Oregon, U.S.A.);
- 5th International Zooplankton Production Symposium (March 14–18, 2011, Pucón, Chile);
- ESSAS Open Science Meeting (May 22–26, 2011, Seattle, Washington, U.S.A.).

The International Symposium on "*Climate change effects on fish and fisheries*" convened this spring in Sendai, Japan, was a huge success, bringing together fisheries scientists from all over the world (several reports from this symposium can be found in this issue of PICES Press). A special volume is planned and several of the authors of presentations on climate and fisheries in the Bering Sea, intend to submit manuscripts to that special journal issue.

Acknowledgements: Many thanks to the following PICEeans who helped create this report: Drs. Nicholas Bond, Phyllis Stabeno and Thomas van Pelt.

The Pacific Ocean Boundary Ecosystem and Climate Study (POBEX)

by Emanuele Di Lorenzo, Julie E. Keister, Vincent Combes and Harold Batchelder

The POBEX project (www.pobex.org) is an international effort that brings researchers from North America, Japan and South America together to investigate the mechanisms of climate-related variability in three Pacific boundary ecosystems: Gulf of Alaska (GOA) and California Current System (CCS) referred to as the Northeast Pacific (NEP), the Humboldt or Peru-Chile Current System (PCCS), and the Kuroshio-Oyashio Extension (KOE) region.

The POBEX team includes Principle Investigators from U.S. institutions, sponsored by the NSF-GLOBEC program (E. Di Lorenzo, A. Bracco, J.E. Keister, P.T. Strub, A. Thomas, P.J.S. Franks, S. Bograd, W. Peterson, R. Mendelssohn, F. Schwing) and collaborators from Japan (S. Chiba, Y. Sasai, H. Sasaki, M. Nonaka, B. Taguchi, A. Ishida) and South America (O. Pizarro, R. Escribano, S. Hormazabal, J. Rutllant, V. Montecino).

The main objectives of POBEX are to: (1) understand and quantify how large-scale climate variability has affected boundary ecosystems in the Pacific, and (2) explore the range of uncertainties in responses of these ecosystems to climate change. Specifically, POBEX attempts to quantify how changes in regional ocean processes (*e.g.*, upwelling, transport dynamics, mixing and mesoscale structure) at each boundary control phytoplankton and zooplankton dynamics, and the extent to which these regional ocean dynamics are driven by large-scale climate modes such as the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), El Niño Southern Oscillation (ENSO), and potentially others. In doing so, POBEX tests the degree to which changes in each study region reflect a bottom-up control of the ecosystems that is synchronized by large-scale Pacific climate.

To explore how low-frequency variations of upwelling and horizontal transport affect the lower trophic levels of the Pacific boundary marine ecosystems, POBEX is following a two-phase approach. In the first phase, now almost complete, the project has generated a series of high-resolution (10 km) regional ocean model hindcasts in the GOA, CCS, PCCS and KOE. These model hindcasts, available at http://data.eas.gatech.edu, are used in combination with model passive tracer releases to develop indices that quantify the low-frequency changes in upwelling and transport statistics. For each of the boundary regions, we generate an ensemble of historical hindcasts covering the period 1950–present to separate the deterministic and intrinsic (mesoscale eddies) component of ocean variability. In the second phase—still ongoing—the transport indices developed during Phase 1 are used to test the degree to which lower-trophic level ecosystem variability can be explained by changes in physical variability. Specifically, we test the extent to which observed changes in phytoplankton are connected to modeled changes in the strength, structure and timing of upwelling, and explore specific hypotheses of how changes in zooplankton abundance and species diversity are linked to changes in modeled horizontal transport.

Phase 1: Upwelling and transport statistics along the Pacific boundaries *(V. Combes)*

The upwelling and cross-shelf transport dynamics along the Pacific eastern boundary (GOA, CCS and PCCS) are explored using high-resolution (10 km) hindcasts of the Regional Ocean Modeling System (ROMS) for the last 60 years. We report results from three model domains illustrated in Figure 1. As described above, in each regional model domain a set of passive tracers is injected along the coast, both in the surface and subsurface, to quantify the transport dynamics. Below, we present a short summary of the primary findings on low-frequency transport variability along the eastern Pacific boundary.

The Gulf of Alaska

The marine ecosystem of the GOA is very rich despite an open ocean that is characterized by high nutrient and low chlorophyll-*a* concentration and coastal downwelling. Primary production of the GOA is limited by low iron, perhaps due to low aeolian iron input (Martin and Fitzwater, 1988, *Nature*, Vol. 331, 341–343), and recent observational studies suggest that advection of iron-rich coastal water may be the primary mechanism controlling open ocean productivity. Specifically, there is evidence that mesoscale eddies along the coastal GOA entrain iron-rich coastal waters into the ocean interior. The statistics of coastal waters transport are computed using a model passive tracer, which is continuously released at the coast at the surface (white hatched box on Fig. 1). On average along the Alaska Current, we find that at the surface, while the advection of tracers by the average flow is directed towards the coast, consistent with the dominant downwelling regime of the GOA, it is the mean eddy fluxes that contribute to offshore advection into the gyre interior. South of the Alaskan Peninsula, both the advection of tracers by the average flow and the mean eddy fluxes contribute to the mean offshore advection. On interannual and longer time scales, the offshore transport of the passive tracer in the Alaskan Stream does not correlate with large-scale atmospheric forcing, or with local winds (intrinsic variability). In contrast, in the Alaska Current region, stronger offshore transport of the passive tracer coincides with periods of stronger downwelling (forced variability), in particular during positive phases of the PDO, which trigger the development of stronger eddies known as "Haida" and "Sitka" eddies (Combes *et al*., 2007, *Prog. Oceanogr.*, Vol. 75 (2), 266–286; Combes *et al*., 2009, *J. Phys. Oceanogr.*, Vol. 39 (4), 1050–1059).

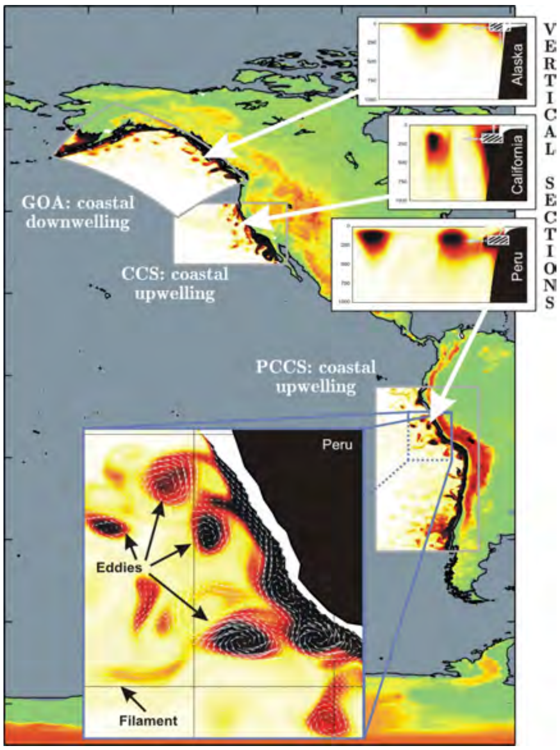


Fig. 1 Snapshot of passive tracer concentration for the model domains (GOA, CCS, PCCS). A tracer is continuously released (white hatched boxes inset). White arrows correspond to the current velocity (only plotted when tracer concentration is high). Top right panels show vertical sections of tracer across mesoscale eddies.

The California Current System

South of the GOA, the CCS is a typical eastern boundary current coastal upwelling system. To characterize the effects of linear (Ekman upwelling) and non-linear (eddy activity) circulation regimes on the statistics of low-frequency advection of coastal waters, an ensemble of passive tracers is released in the numerical model in the subsurface between 150 and 250-m depth at the coast (white hatched box on Fig. 1). The resultant concentration of the tracer at the surface provides an index of coastal upwelling. We find that the low-frequency upwelling and the surface offshore transport of the upwelled nutrient-rich coastal water are strongly correlated with the alongshore wind stress, and with the NPGO (large-scale climate variability index). Our results also show that the poleward California Undercurrent, at about 200-m depth, affects the alongshore transport and provides nutrient-rich waters to the Central California dominant upwelling cell. However, if we look only at the surface transport dynamics, the offshore transport of the surface coastal water is associated with mesoscale eddy activity; both surface and subsurface waters propagate offshore mainly through cyclonic eddies (top-right panel vertical section in Fig. 1) (Combes *et al.*, 2010a, *J. Phys. Oceanogr.*, submitted).

The Peru-Chile Current System

In the southern hemisphere, the PCCS is one of the world's most productive regions in fish landings, providing ~20% of the world marine catches despite covering less than 1% of the world's ocean surface. This high productivity results principally from the upwelling of nutrient-rich water into the photic zone. Both changes in surface wind and coastally trapped Kelvin waves control the variability of the coastal upwelling. We assessed the effect of ocean remote forcing by comparing the output of two model simulations that do and do not include the presence of waves at their boundaries. Similar to the analyses performed in the CCS, a passive tracer approach is used to characterize the coastal upwelling variability of the PCCS. The evolution of the passive tracers indicates that, off the coast of Peru, the ENSO strongly modulates the efficiency of coastal upwelling, due principally to the propagation of downwelling equatorial Kelvin waves rather than to changes in the local wind stress. Our results show that the central Chile upwelling region is also very sensitive to the Kelvin waves generated at the equator, and is considerably reduced during strong El Niño events. Different model experiments have also been conducted to explore the sensitivity of the PCCS upwelling to air–sea fluxes of momentum (ECMWF *vs*. NCEP surface wind stress forcings). Similar to the CCS region, we find that mesoscale eddies play an important role in the offshore advection of nutrient-rich coastal waters. Both cyclonic and anticyclonic eddies (bottom-left panel on Fig. 1) are able to transport nutrient-rich coastal waters (Combes *et al*., 2010b, *J. Phys. Oceanogr.*, submitted).

The passive tracer experiments, performed in the GOA, CCS, and PCCS, provide a dynamical framework to understand the dynamics of the upwelling/downwelling and horizontal transport of water masses. Indices derived from the passive tracer can be used as proxies of the vertical and horizontal advection of important biogeochemical quantities, essential in understanding the ecosystem variability along the Pacific eastern boundary.

Phase 2: Linking transport dynamics to lower-trophic ecosystem variability (J.E. Keister)

In Phase 2, we investigate the effects of large-scale climate variability on lower trophic levels with passive tracer release data generated during Phase 1. Specifically, long-term time-series of biological observations in the CCS, KOE, and PCCS are used to test hypotheses of how changes in advective transport associated with the large-scale climate modes, drive changes in the lower trophic levels.

Our initial experiments were conducted in the northern CCS where zooplankton have been collected approximately bi-weekly to monthly since 1996 off Newport, Oregon by William Peterson and colleagues. The continental shelf zooplankton community off Oregon cycles between communities that are dominated by species with warm-water associations and those dominated by species with cold-water associations (*e.g*., Peterson and Keister, 2003, *Deep-Sea Res. II*, Vol. 50, 2499–2517; Hooff and Peterson 2006, *Limnol Oceanogr*. Vol. 51, 2607–2620). The non-seasonal, low-frequency variability in species composition strongly correlates with the PDO. Using an index of the zooplankton community developed from ordination of the copepods (called the Copepod Community Index, or "CCI"), we compare the zooplankton community to transport statistics to determine the extent that advection explains observed biological changes. The high-resolution regional ocean model developed in Phase 1 is applied over the Oregon Shelf region with independent passive tracers released in the surface layer at the NORTH, SOUTH, EAST and WEST boundaries. These tracers are used to test the hypothesis that *changes in warm* vs. *cold zooplankton species are associated with the intrusion of warmer (colder) waters from the southern (northern) boundary*. The passive tracer experiment results are consistent with this hypothesis; we find that a reconstruction of the CCI with a weighted average of the modeled transport time-series from all boundaries correlates with R=0.34 to the raw (monthly) time series (Fig. 2A), but when lowpass filtered, the low-frequency component correlates with R=0.95 (Fig. 2B, from Keister *et al*., 2010, *Global Change Biol.*, submitted). This shows that changes in horizontal surface transport can explain nearly all of the multi-year variance in zooplankton communities in this region. We also find that most of the explanatory power is associated with the NORTH/WEST and SOUTH tracers, with the NORTH and WEST tracer time-series being very highly correlated with each other. These high correlations indicate that when the PDO is positive, there is less advection of cold-water species from the north and stronger advection of warm-water species from the west, in addition to those coming from the south. Looking more closely at the relationships among the zooplankton community, transport, and climate variability, we find that a zooplankton community reconstruction calculated over the full 50+ year model time period, correlates strongly with a model reconstruction of the PDO (R=0.55, not shown). The lowpass filtered time series (Fig. 2C) correlates more strongly (R=0.87) and reveals decadal variability superimposed upon multi-year cycles of ~6- to 7-year duration. The observational data (1996–present) falls in a period of fluctuating but primarily positive anomalies, indicating a relative dominance of warm-water zooplankton compared to previous decades.

In our next investigations, we will compute similar transport statistics for the deep circulation that is important to diapausing copepods and taxa which perform deep vertical migrations, and will compare those statistics to a relevant subset of the zooplankton community. Moving to the western Pacific boundary, we will compare the role of transport in controlling zooplankton variability in the KOE region, in collaboration with Sanae Chiba and colleagues at JAMSTEC. Chiba and her colleagues hypothesize that observed changes in zooplankton biomass and distributions seen in the Oyashio and Transition region are driven by climate-related changes in the strength and position of the Kuroshio and Oyashio Currents (Chiba *et al*., 2009, *Global Change Biol.*, Vol. 15, 1846–1858). The changes are related to the PDO, indicating that some degree of across-basin synchrony in lower trophic level response to climate change may exist. As in the CCS, we will directly explore the effect of transport on zooplankton communities using passive tracer release experiments.

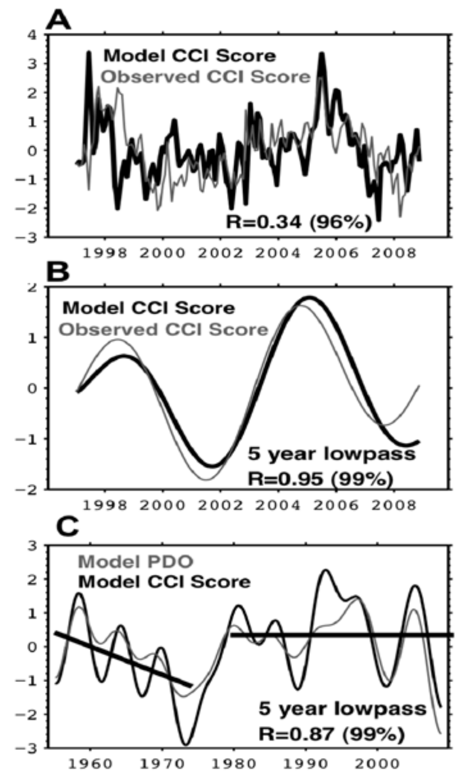


Fig. 2 Model reconstruction of the Copepod Community Index (CCI): (a) compared with the monthly-averaged observations, (b) as above, but 5-year lowpass filtered, and (c) reconstructed over the full >50-year model time period and compared to the 1st Principal Component of the model SST, which represents the PDO. The model CCI is constructed using the four passive tracers: NORTH, SOUTH, EAST, and WEST (modified from Keister et al., 2010).

***Synergies between POBEX and PICES** (H. Batchelder)*

The POBEX investigations are aimed at elucidating the mechanistic physical basis for potential bottom-up control of these Pacific boundary ecosystems by large-scale climate forcing. While the detailed mechanisms may differ in the various ecosystems, it is important to understand what the key processes are so that future (and specifically those of FUTURE) investigations, such as those being examined by PICES' Climate, Oceanographic Variability and Ecosystems Advisory Panel (COVE-AP), can integrate the process-based understanding into model-based assessments and forecasts. PICES' new integrative science program named FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems) was developed to enhance the PICES nations' scientific capability to understand and forecast the consequences of future climate and anthropogenic change to marine ecosystems. To accomplish this, we need to document past changes in ecosystems and climate forcing, and identify the detailed mechanisms that relate the two. Without the underlying mechanistic basis relating climate variation to ecosystem patterns and changes, it would be difficult, perhaps impossible, to skillfully project the "potential ecosystem consequences" of future climate scenarios of the type developed by the Intergovernmental Panel on Climate Change (IPCC) and by PICES' Working Group on *Evaluation of Climate Change Projections*. Moreover, the POBEX program's emphasis on quantifying the uncertainty in the processes will supply critical information to PICES' Status, Outlooks, Forecasts and Engagement Advisory Panel (SOFE-AP), which is tasked with identifying and communicating the uncertainties (or skill) of ecosystem assessments and forecasts to potential users. Thus, the studies of POBEX will provide great advances on key issues of both COVE and SOFE, and significantly contribute to the goals of FUTURE. It should be noted that POBEX and most GLOBEC studies have assumed that the connection between climate variability (including global warming) and ocean ecosystems occurs through bottom-up processes (see Fig. 1 of Batchelder and Kashiwai, 2007, *Ecol. Model.*, Vol. 202, 7–11). Additional studies are needed to consider whether bottom-up forcing is truly the dominant mechanism, or whether top-down forcing (direct impacts of climate on fish or higher trophic levels) is equally important in marine ecosystems.

Acknowledgments: We thank Alexander Bychkov (PICES Executive Secretary) for inviting us to submit this article, and for his patience with the authors.

From left to right, Julie Keister, Vincent Combes, Emanuele Di Lorenzo with his one-year-old Isaac getting started on fishing, and Hal Batchelder

Dr. Emanuele (Manu) Di Lorenzo (edl@gatech.edu) is an Associate Professor at the School of Earth and Atmospheric Sciences, Georgia Institute of Technology, U.S.A. His research interests and experience span a wide range of topics from physical oceanography to ocean climate and marine ecosystems. More specific focus is on dynamics of basin and regional ocean circulation, inverse modeling, Pacific low-frequency variability, and impacts of large-scale climate variability on marine ecosystem dynamics. In PICES he is a member of the Working Group on Evaluations of Climate Change Projections and of the Advisory Panel on Climate Ocean Variability and Ecosystems (COVE-AP). He also serves on the U.S. Comparative Analysis of Marine Ecosystem (CAMEO) Science Steering Committee.

Dr. Julie Keister (jkeister@u.washington.edu) is an Assistant Professor in the School of Oceanography, University of Washington, U.S.A. Her research focuses on understanding the physical and biological processes that affect zooplankton communities in coastal ecosystems, especially how variability in advection affects zooplankton distributions on kilometer-to-basin scales, and how climate impacts those relationships. She has been active in PICES for over a decade and is currently the PICES convenor of the 5th International Zooplankton Production Symposium, which will be held in March 2011, in Pucón, Chile.

Dr. Vincent Combes (vincent.combes@eas.gatech.edu) received his PhD degree in June 2010 at the Georgia Institute of Technology, U.S.A. He is currently working as a Post Doctorate at Oregon State University. His background includes hydraulics, fluid mechanics and regional physical oceanography. His research focuses on eastern boundary dynamics, in particular, upwelling and offshore low-frequency variability. Within POBEX, Vincent has played a major role in coordinating the collaborations with South American scientists and spent a year in Chile developing regional ocean model applications for ecosystem studies.

Dr. Harold (Hal) Batchelder (hbatchelder@coas.oregonstate.edu) is a Professor in the College of Oceanic and Atmospheric Sciences at Oregon State University, U.S.A. His present research focuses on individual based modeling the biological-physical coupling of marine environments and marine populations, including studies on Calanus finmarchicus in the North Atlantic, and krill and juvenile salmon in the Northeast Pacific. In PICES, he served as Co-Chairman of the Climate Change and Carrying Capacity (CCCC) Program and as a member on PICES Science Board from 2001–2009, and presently is a member on the Status, Outlooks, Forecasts and Engagement Advisory Panel (SOFE-AP). He is also active in the Marine Ecosystem Model Inter-comparison Project (MEMIP) of PICES. He served as Coordinator of the U.S. GLOBEC National Program for 6 years, and Executive Director of the U.S. GLOBEC Northeast Pacific regional program for 12 years.

PICES Calendar

- PICES Annual Meeting (http://www.pices.int/meetings/annual/PICES-2010/2010-background.aspx), October 22–31, 2010, Portland, Oregon, U.S.A.)
- 26th Lowell Wakefield Symposium on "*Ecosystems 2010: Global progress on ecosystem-based fisheries management*" (http://seagrant.uaf.edu/conferences/2010/wakefield-ecosystems/index.php), November 8–11, 2010, Anchorage, U.S.A.
- 5th International Zooplankton Production Symposium: Population connections, community dynamics, and climate variability (http://www.pices.int/zooplankton2011.aspx), March 14–18, 2011, Pucón, Chile
- 2nd ESSAS Open Science Meeting on "*Comparative studies of climate effects on polar and sub-polar ecosystems: Progress in observation and prediction*" (http://www.pices.int/essas2011.aspx), May 22–26, 2011, Seattle, Washington, U.S.A.
- 2nd PICES/ICES/IOC Symposium on "*Effects of climate change on the world's oceans*", May 14–18, 2012, Yeosu, Korea (as one of the official events related to Ocean Expo-2012)
- 2nd ICES/PICES Early Career Scientists Conference, June 2012, Mallorca, Spain

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salmonids. They are voracious feeders that prey on Pacific hake, Pacific sardine, and several species of rockfishes and myctophids. Recently, a chinook salmon was found in a squid stomach. This increasingly abundant species has the ability to change the structure of marine pelagic and mesopelagic ecosystems.

This meeting provides a great opportunity for students of salmon at sea to present their research in an informal *international* setting to a group of colleagues (and potential colleagues) who share this interest. Thanks to Asit Masumder for encouraging a delegation of students and researchers from the University of Victoria to join him in making the sojourn to Santa Cruz. A strength of this meeting is its multi-disciplinary scope, where salmon biologists can interact with oceanographers (of all persuasions) to develop a better understanding of the biology of Pacific salmon at sea. This meeting was particularly helpful in facilitating scientists from the eastern Pacific to share new findings, research methods, and to coordinate field collections. As a result, in 2010, there will be a coast-wide ocean survey of salmonids from British Columbia to California, with some of the scientists from the U.S. Atlantic coast participating in the survey. The cross-fertilization of people, ideas, and techniques will help provide new information on salmon ocean ecology in all the oceans inhabited by salmonids. The 13th Salmon Ocean Ecology Meeting will be held in Seattle on March 23–24, 2011 in Seattle, Washington, U.S.A. Those interested in attending can contact John Ferguson (John.W.Ferguson@noaa.gov).

Since 2007 in Newport (Oregon, U.S.A.), each meeting has ended with a *salmon forecasting forum* where anyone who wishes to participate can offer a quantitative outlook, forecast, or projection of salmon returns in the future (typically the upcoming year). The results are tabulated annually (to keep everyone honest). This year in Santa Cruz, the first performance review was conducted to ascertain which forecasts, if any, during the 3-year period, had performed well. Although the winner of the *Chateau Emmett* vintage bottle declared "*I am not a salmon forecaster*", eco-physiologist Brian Beckman of NOAA's Northwest Fisheries Science Center was told that his forecasts of coho salmon (*O. kisutch*) marine survival (based on Insulin Growth Factor measured on postsmolts captured at sea in the year of release) tracked observed marine survival best during the 3-year period.

Brian Beckman, not appearing skeptical, when told of his award winning record of coho salmon survival forecasts.

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E-mail: secretariat@pices.int http://www.pices.int