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The 2015 Inter-sessional Science Board meeting: A note from the Science Board Chairman

Our Inter-sessional Science Board meeting (ISB-2015) was held May 18–20, 2015 in the port city of Busan, Korea. While in recent years the inter-sessional meeting has been held in conjunction with another PICES meeting or workshop, that was not the case this year, with ISB-2015 devoted solely to Science Board business. The venue and local logistics were organized by the Korea Institute of Ocean Science and Technology (KIOST).

Following the restructuring of PICES' FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems) integrative science program at PICES-2014, a FUTURE Scientific Steering Committee (SSC) was established to replace the original three Advisory Panels (AP-AICE, AP-COVE, and AP-SOFE). The SSC has 13 members representing all PICES member countries and is co-chaired by Drs. Steven Bograd (USA) and Hiroaki Saito (Japan). Full membership and FUTURE activities can be viewed at http://pices.int/members/scientific_programs/FUTURE/FUTURE-SSC.aspx. The SSC held its first meeting March 1–3, 2015 in La Jolla, USA, and reported to Science Board at ISB. In addition to minor adjustments to its terms of reference, the FUTURE SSC presented its Action Plan for 2015. The SSC proposed that two-way communication between FUTURE and other PICES expert groups be accomplished through assigned liaisons from the SSC to each Standing Committee and expert group. It is hoped this new structure will be valuable to advancing FUTURE, including the development of new FUTURE expert groups.

It is clear that as PICES grows as an organization so do the restraints on our time (and resources) as evidenced by the very full agenda at ISB-2015 and an equally full program planned for PICES-2015 in Qingdao, China (October 14–25, 2015). Science Board is cognizant of the many items requiring attention and the need to look for efficiencies where possible. For example, one of the essential business items at the Annual Meeting is identifying and developing a schedule of workshops, business meetings and topic sessions for the next meeting. It is especially important that workshop and topic session proposals be received by the Scientific and Technical Committees before they meet (*i.e.*, by noon on Tuesday) so that they can be discussed and prioritized within the committees before being brought to Science Board. A diverse and interesting scientific program for the PICES Annual Meeting is essential to

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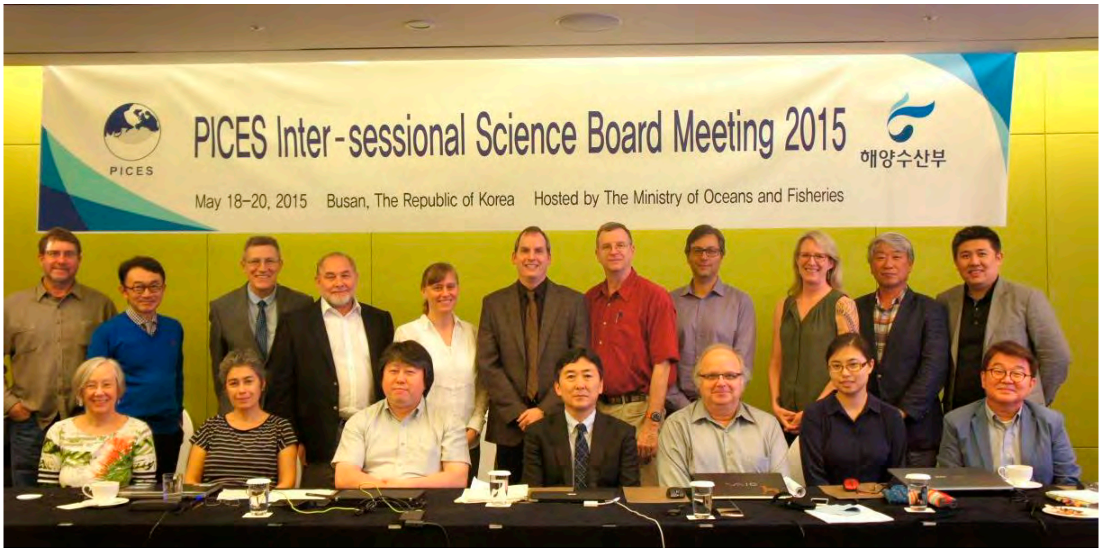


Participants at ISB-2015 (back row, from left): Steven Bograd (FUTURE SSC), Hiroaki Saito (Science Board Vice-Chairman, FUTURE SSC), Igor Shevchenko (representing Russia), Lev Bocharov (Governing Council), Jennifer Boldt (MONITOR), Thomas Therriault (Science Board Chairman), Harold (Hal) Batchelder (Deputy Executive Secretary), Enrique Curchitser (Governing Council), Elizabeth Logerwell (FIS), Kyung-Il Chang (POC), Chuanlin Huo (MEQ); (front row, from left) Laura Richards (PICES Chairman), Angelica Peña (BIO), Toru Suzuki (TCODE), Shigeru Itakura (Governing Council), Robin Brown (Executive Secretary), Rui Zheng (Advisor, SOA, China),and Chul Park (PICES Vice-Chairman, Governing Council).

maintain interest, collaborations, and participation. Workshops and expert group business meetings will continue to be held prior to the Opening Session, and all registered participants are welcome to attend any of these. Further, I encourage you to attend the FUTURE "Mini-Symposium" that will take place on Sunday, October 18, the day before the PICES Opening Session. The Mini-Symposium will begin with the SSC Co-Chairs' overview of the progress achieved by PICES towards FUTURE objectives, followed by short expert group reports and open discussion around the FUTURE roadmap and priorities. Remember, FUTURE is your integrated science program, so please attend and participate.

In 2006, Science Board Chairman Dr. Kuh Kim, suggested that there should be continuity in the management of Science Board business and proposed that one year prior to the end of the current Science Board Chairman's term, a new Chairman could be elected. This individual would serve for one year as Chairman-elect, and then for three years as Chairman, thereby providing the incoming individual time to become familiar with the roles and responsibilities of the position of Science Board Chairman while facilitating a more seamless transition for the organization. I am happy to say that there was Science Board consensus that this approach should be sustained. Nominations for the next Science Board Chairman will be accepted by the Secretariat until August 18, 2015 (2 months prior to the Annual Meeting).

2016 will mark the 25th anniversary of the establishment of PICES. To mark this milestone, Science Board discussed a number of ways that next year's Annual Meeting may differ from the usual format and will listen to suggestions from the Anniversary Planning Committee at PICES-2015 before final decisions are made. The theme of PICES-2016, to be hosted by the USA in San Diego, California, will be "*25 years of PICES: Celebrating the past, imagining the future*". As the theme implies, PICES will look back at its achievements during the last 2½ decades, but more importantly, will look forward to how PICES can continue to make itself relevant to the scientific community and stakeholders in PICES member countries during the next 25 years. I encourage forward-looking thinkers, especially early career scientists (our next generation), to submit topic sessions or workshop proposals for PICES-2016 that explore future scientific issues or challenges that PICES could undertake.

Milestone birthdays are time for reflection. To this end, PICES will be updating its Strategic Plan to coincide with the 25th anniversary. Committees are reviewing the current Strategic Plan and the PICES Study Group on *Revising the Strategic Plan* has been approved to review input and revise the Plan so that it will be ready for adoption at PICES-2016.

Science Board discussing PICES business during ISB-2015.

As the extent of PICES science increases, so too does its need for strategic collaboration with other organizations. One of our longest and strongest partnerships is with the International Council for the Exploration of the Sea (ICES). ICES and PICES have collaborated both formally and informally on many activities over the past 25 years, including the jointly sponsored Symposia series, "*Climate effects on the world's oceans*" (also cosponsored by IOC), the third one of which was held in March this year in Santos, Brazil (see the following articles from this important symposium in this issue), and the 6th Zooplankton Production Symposium, which will take place next May in Bergen, Norway. The PICES/ICES Section on *Climate Change Effects on Marine Ecosystems* (S-CCME) resulted, in part, from the development of a joint PICES-ICES framework for strategic cooperation; S-CCME will be holding a workshop in August in Seattle, USA on "*Modelling effects of climate change on fish and fisheries*".

Another strategic framework for cooperation on emerging issues is now in place with the North Pacific Anadromous Fish Commission (NPAFC), and has led to two collaborations this spring. PICES participated in a scoping workshop, hosted by NPAFC in February 2015, to establish an International Year of the Salmon. Watch for future developments on this in PICES Press or the NPAFC Newsletter. PICES also co-sponsored NPAFC's International Symposium on "*Pacific salmon and steelhead production in a changing climate: Past, present, and future*" (May 17–19, 2015, Kobe, Japan) where invited speakers, Drs. Shoshiro Minobe (Japan), Skip McKinnell (Canada; Keynote), and Ryan Rykaczewski (USA; Keynote) gave presentations. As you can see from this framework with NPAFC, it bodes well for other frameworks in development with NOWPAP (SG-SCOOP) and ISC (SG-SCISC).

Participants at first meeting of SG-SCISC, Kona, Hawaii, USA, July 13–14, 2015.

As noted, linkages also have been tightened with the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) with the establishment of a joint ISC-PICES Study Group for *Scientific Cooperation of ISC and PICES* (SG-SCISC) in April. The Study Group had a very productive first meeting on July 13–14, 2015, in Kona, Hawaii, and a follow-up meeting will take place at PICES-2015 this fall.

One of PICES' high priority activities is capacity building. This can occur via major symposia, such as the PICES/ICES Early Career Scientist Conference being planned for Busan, Korea in 2017, or it can take the form of PICES (co-)sponsorship of summer schools or training workshops, or by providing funds that enable early career scientists (ECS) to travel to PICES meetings or events. For example, PICES co-sponsored the Pacific Ecology and Evolution Conference (PEEC) held at Bamfield Marine Science Centre on the West Coast of Vancouver Island (see the article on PEEC 2015 in this newsletter for more details). I hope that this and other similar events will be a way of attracting and engaging young scientists in PICES marine science activities. If there are similar developments in other PICES member countries or other ways PICES can support ECSs, I encourage you to share your ideas with me or the PICES Secretariat.

Dr. Chul Park (white jacket) explaining the layout of the new KIOST facilities in Busan, scheduled to be completed in 2017, during a visit to the site after the completion of ISB-2015.

PICES-2015 is fast approaching. The theme of our Annual Meeting in Qingdao, China is "*Change and sustainability of the North Pacific*". For important dates, see the PICES Annual Meeting website. I look forward to seeing you there where an exciting, diverse (and full) agenda awaits!

Science Board Chairman
Thomas Therriault

2015 Symposium on "*Effects of climate change on the world's oceans*"

by Jacquelynne R. King

Over 280 participants assembled in Santos, Sao Paulo, Brazil (March 23–27, 2015) for the 3rd International Symposium on "*Effects of climate change on the world's oceans*". This symposium was jointly convened by PICES (North Pacific Marine Science Organization), ICES (International Council for the Exploration of the Sea), and IOC (Intergovernmental Oceanographic Commission of UNESCO), and locally organized by the Oceanographic Institute, University of Sao Paulo (OIUSB). Participants from 38 countries contributed 336 oral and poster presentations in Theme Sessions and workshops. The Symposium was organized by four Co-Convenors: Jacquelynne King (PICES, Canada), Manuel Barange, (ICES, UK), Luis Valdés, (IOC, Spain) and Alex Turra, (OIUSB, Brazil). Several members from each organization formed the Scientific Steering Committee, which set the Symposium's scientific program: Nicholas Bates (IOC, Bermuda/USA), Silvana Birchenough (ICES, UK), Maria de Fatima Borges (ICES, Portugal), John Gunn (IOC, Australia), Lina Hansson (IAEA, Monaco), Brian R. MacKenzie (ICES, Denmark), Shoshiro Minobe (PICES, Japan), Angelica Peña (PICES, Canada), Fangli Qiao (PICES, China) and Yunne-Jai Shin (IOC, France/South Africa).

This Symposium bridged research in physical and natural sciences to the human dimensions of climate change impacts, with a focus on coastal communities, management objectives and governance adaptation. Twelve Sessions (see list at end of this article) covered the latest developments in predicting changes in biodiversity, phenology, fisheries and ecosystems as well as in the physical systems that sustain these, and highlighted the risks and opportunities that climate change will bring to coastal communities and to society at large. Each day began with a Plenary Session that featured several Plenary Speakers (see list provided) to represent each of the Theme Sessions that ran in parallel for the remainder of the day. Five workshops were held prior to the Symposium. Elsewhere in this newsletter are summaries of the highlights and discussions of four of the workshops. Conveners of the fifth workshop submitted an overview paper to the Symposium proceedings that will be published in the *ICES Journal of Marine Science*.

Welcoming remarks on Monday, 23 March, were provided by Dr. Carlos Nobre of Brazil, former Chair of IGBP. This was followed by a Keynote Address from Dr. Chris Field (Carnegie Institution for Science, USA), Co-Chair of Working Group II of the Intergovernmental Panel on Climate Change Fifth Assessment Report (2014). Dr. Field set the scope for the Symposium by mapping the potential impacts of climate change to socioeconomic processes (adaptation, mitigation, governance) through assessment of risk and uncertainty of vulnerability, exposure and hazards.

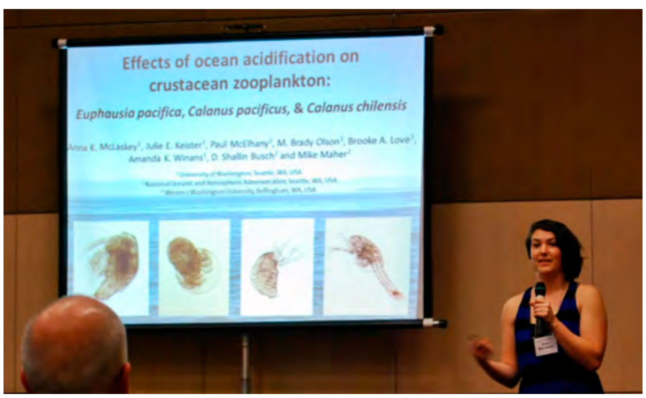
Workshop (W3) Co-Convenor, Dr. Louis Legendre (France). (Photo credit: Universidade de São Paulo)

Dr. Carlos Nobre (Scientific Advisory Board of the Panel on Global Sustainability (UNESCO) providing welcoming remarks at the Opening Session. (Photo credit: Universidade de São Paulo)

Attentive audience during the first Plenary Session.

Keynote Speaker, Dr. Chris Field (USA), making his address at the Plenary Session on Day 1.

Invited Speaker, Dr. Alexander V. Babanin (Australia), presenting in Theme Session S1.



Early career scientist, Anna McLaskey (USA) making her presentation in Theme Session S2.

Theme Session presentations highlighted the advancements that have been made in modeling and understanding climate change impacts on physical processes. There are now global low resolution models that can provide the foundations for generating hypotheses of climate change effects, some of which are already being applied to net primary production and zooplankton models. Ocean models continue to improve in process understanding, resolution and dynamics. However, site-specific ocean models remain poorly developed for some regions of the world's oceans.

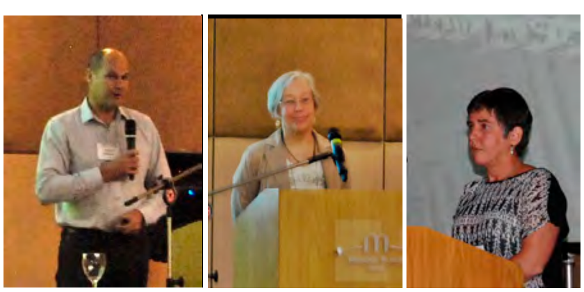
The diversity of biological science in the Theme Sessions provided participants with a wide range of research linking climate change impacts to marine organisms and their ecosystems. One of the immediate linkages is the change in ocean chemistry, with continued overwhelming evidence of increasing ocean acidification. However, coastal regions are subject to significant pH variability and thus some species may be quite tolerant to ocean acidification. Exciting work was presented on the acclimation and genetic adaptation to ocean acidification, deoxygenation and temperature increases. This does not remove the dangers of these impacts because any adaptation has costs, but indicates a more complex picture than previously accepted. Changes in process seasonality and intensity are readily observed, however, the transfer of energy through marine food webs will be determined by species' plasticity, life history strategies and their adaptation to non-linear physical processes such as upwelling. As our understanding of processes improve, so does our understanding of species' distributional changes in response to climate change. We are beginning to develop a higher level of detail in species' responses, and are learning that migrations will not be homogenous or always consistent, as they interact with habitat preferences, tolerances and with other components of ecosystems.

The poster displays proved to be very popular during the Symposium.

Welcome reception dance. Bill Sydeman in the lead; Hal Batchelder a close second.

The Symposium dinner was a chance to enjoy good conversation and an excellent meal.

The Symposium benefitted from significant input from social scientists, with two Theme Sessions that focused on socioeconomic aspects of climate change impacts on oceans. Social scientists are integrating physical and biological research results to human uses and reliance on marine ecosystems to help identify management options. The most effective policies will be those that outline transition and adaptive responses. Several presentations explored pathways of adaptation of societies to climate change and identified the disproportional impact of climate change on poor coastal societies in the developing world. In some places, tools are made available for societies to quantify their level of risk and thus to tailor local-specific responses. An area for future research in climate change impacts on the oceans will be the inclusion of human impacts, such as changes in land use and population growth, as additional considerations.



Plenary Speakers, (from left) Dr. Edward (Eddie) Allison (USA) presenting his talk at Session S11, Dr. Laura Richards (PICES) presenting at Session S12, and Dr. Coleen Moloney (South Africa) presenting at Session S9.

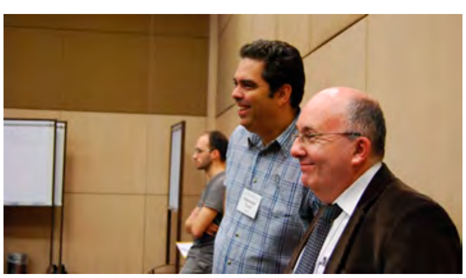
A chance to enjoy the beautiful seaside during the excursion afternoon break.

The award for the Symposium Best Presentation went to PICES' very own Shin-ichi Ito (University of Tokyo, Japan) for his presentation, "*Importance of advection to form a climate and ecological hotspot in the western North Pacific*". The Best Poster award was presented to Colleen Suckling (Bangor University, UK) for her poster, "*Metabolic responses of two species of brachyuran crustaceans to ocean acidification and reduced salinity*". There were a number of outstanding presentations by early career scientists, and awards for best presentations were given to: Rebecca Asch (Princeton University, USA) for her presentation, "*Projected mismatches between the phenology of phytoplankton blooms and fish spawning based on the GFDL Earth System Model (ESM2M)*"; Johanna Yletyinen (Stockholm Resilience Centre, Sweden) for her presentation, "*Understanding marine regime shifts: detecting possible changes in structures and functions in coastal and pelagic food webs*"; Emily Howells (New York University Abu Dhabi, United Arab Emirates) for her presentation, "*Adaptation of coral symbioses to extreme temperatures*"; and Philipp Brun (Technical University of Denmark, Denmark) for his presentation, "*The predictive potential of ecological niche models for plankton in the North Atlantic*". Presentations from all the sessions and workshops can be found on PICES' publications page at http://pices.int/meetings/international_symposia/2015/2015-Climate-Change/scope.aspx. Selected papers from oral and poster presentations from the Symposium and workshops will be included in a special issue of the *ICES Journal of Marine Science* scheduled for publication in 2016. In addition, it is anticipated that selected sessions and workshops may develop their own proposals for special volumes.

All Theme Sessions were well attended. This was for Session S5.

Symposium Co-Convenors, Drs. Manuel Barange (ICES, UK, top) and Luis Valdés (IOC, bottom) summarizing a very successful meeting.

Three of the Universidade de São Paulo early career scientists who provided local logistical support. Left to right: Lucas Barbosa, Rafael Romaneli, and Marina Ferreira Mourão Santana. Missing from photo is Marília Nagata Ragagnin.



Our Brazilian hosts: (Foreground, left) Dr. Alexander Turra (Symposium Co-Convenor, Universidade de São Paulo) and Dr. Michel de Mahiques (Symposium local coordinator, Universidade de São Paulo) enjoying a presentation.

We would like to say "*Obrigados*" to the local organizers, the OIUSB, for providing the logistics and social activities to support this Symposium. They brought a Brazilian 'easy-going' attitude to the event, and made everything happen smoothly. The venue selected by the local organizers allowed participants to readily catch talks from different parallel sessions and the social events brought everyone together to keep the discussions flowing – along with the drinks and food! The Convenors would like to acknowledge the PICES Secretariat for its assistance in the planning and coordination of all that is required to run an international symposium. Many individuals dealt with the details of organizing this Symposium and deserve our gratitude: Alexander Bychkov (PICES), Julia Yazvenko (PICES), Michel M. de Mahiques (OIUSB) and Adolf Kellermann (ICES). In addition to PICES, ICES and IOC sponsorship, the following organizations and agencies made financial or in-kind contributions:

- Brazilian National Council for Scientific and Technological Development (Brazil),
- Coordination for the Improvement of Higher Education Personnel (Brazil),
- São Paulo Research Foundation (Brazil),
- Fundação de Estudos e Pesquisas Aquáticas (Brazil),
- Government of Brazil,
- International Atomic Energy Agency, Ocean Acidification International Coordination Centre,
- Integrated Marine Biogeochemistry and Ecosystem Research,
- Laboratório de Hidrometeorologia - IAG-USP Programa SIHESP/FARESP,
- Ministry of Education, Brazil,
- National Oceanic and Atmospheric Administration (USA),
- North Pacific Research Board (USA),
- Office of Naval Research (Brazil),
- Scientific Committee on Oceanic Research,
- Surface Ocean-Lower Atmosphere Study.

The support of these sponsors made it possible to convene an international symposium of such high quality and enabled the participation of early career scientists and scientists from countries with economies in transition. Finally thank you to all those who participated: Presenters, Session and workshop Chairs, and the Scientific Steering Committee which helped to provide an excellent Scientific Program.

Symposium Theme Sessions

1. Role of advection and mixing in ocean biogeo-chemistry and marine ecosystems,
2. Ocean acidification,
3. Changing ocean chemistry: From trace elements and isotopes to radiochemistry and organic chemicals of environmental concern,
4. Regional models for predictions of climate change impacts: methods, uncertainties and challenges,
5. Coastal blue carbon and other ocean carbon sinks,

(Continued on page 11)

2015 Santos Joint BrOA (Brazilian Research on Ocean Acidification) and SOLAS (Surface Ocean Lower Atmosphere Study) Workshop

by Rodrigo Kerr, Leticia C. da Cunha and Ruy Kikuchi

The joint workshop (W2/W6), convened at the 3rd International Symposium on "*Effects of climate change on the world's oceans*" (March 23–27, 2015, Santos, Brazil) combined invited and selected talks, along with breakout group discussions corresponding to the main BrOA network and SOLAS topics. We realized that most of the original founders of BrOA were present (out of 24 workshop participants) and brought results of initiatives, experiments and collaborations; also, that these groups have acquired or built, independently or in collaboration with each other, new equipment and facilities that are distributed in a wide range of the territory. We agreed that it was necessary to push a common activity such as writing a position paper describing what we know, the groups involved in OA research, the infrastructure available, and the needs we identified to move forward on scientific aspects. It was unanimously agreed that we need a common ground on standardization of methods and data management as well as new technologies on sensors and platforms. During the discussions on the creation of a Latin American OA network, we realized that many of our requirements seemed to be common on a regional context. Thus, it was suggested that training workshops could be held, such as a SOLAS Summer School, focusing on standardization of procedures and new technologies for CO_2 system measurements that would target Latin American researchers.

Workshop highlights were that:

- Two years after its implementation, the BrOA network has now well established collaborations among its participants;
- BrOA laboratories have enhanced their analytical and experimental capacity;
- Workshop convenors will suggest the SOLAS International Project Office to have its next Summer School focusing on CO_2-system measurements, including new technologies for autonomous sensors;
- Workshop participants identified the need to enhance communication with policy makers, stakeholders, and general public on OA;
- The first concrete action is to implement a Latin American Ocean Acidification Network.

Workshop W2/W6 participants (workshop Convenors and authors of this article, Rodrigo Kerr, Leticia C. da Cunha, and Ruy Kikuchi are back row center, front row, third from left, and front row center, respectively).

Acknowledgement: The authors would like to thank Co-Convenor, Dr. Michelle Graco, for her contributions in organizing this workshop.

Prof. Rodrigo Kerr (rodrigokerr@furg.br; Universidade Federal do Rio Grande – FURG), Prof. Leticia C. da Cunha (lcotrim@uerj.br; Universidade do Estado do Rio de Janeiro – UERJ), and Prof. Ruy Kikuchi (kikuchi@ufba.br; Universidade Federal da Bahia – UFBA) are actively involved in ocean acidification (OA) research in Brazil.

Prof. Kerr and Prof. da Cunha main research interests are the changes in ocean biogeochemistry caused by OA. They are leading the Brazilian Research on Ocean Acidification Network (BrOA; www.broa.furg.br) since its establishment in 2012. Prof. Kikuchi is a member of BrOA, and his research group at UFBA has been performing studies on the ecology of coral reef ecosystems, including their response to climate change, present and past, and OA.

2015 Santos Workshop on "*Effects of climate change on the biologically-driven ocean carbon pumps*"

by Louis Legendre, Nianzhi Jiao, Uta Passow and Curtis Deutsch

More than 30 researchers from 9 countries participated in the workshop (W3) on "*Effects of climate change on the biologically-driven ocean carbon pumps*", which was held in Santos, Brazil, on March 21–22, 2015, during the 3rd International Symposium on "*Effects of climate change on the world's oceans*". The 2-day workshop was convened by the authors of this article.

The workshop considered observational, experimental and modeling approaches for the major biologically-driven pumps that sequester carbon in the ocean: the biological carbon pump (BCP) which involves vertical transport of particulate and dissolved organic carbon (POC and DOC) from surface water to depths, the microbial carbon pump (MCP) which refers to the microbial transformation of organic carbon from labile to refractory states, and the carbonate pump which is initiated by the precipitation of $CaCO_3$ by calcifying organisms (*i.e.*, calcification, which releases CO_2 to the atmosphere), and sinking to depth of calcite and aragonite laden particles (*e.g.*, Jiao *et al*., 2010; Passow and Carlson, 2012; Legendre *et al*., 2015). The carbon sequestered by the BCP and the MCP is estimated to be 0.3–0.7 Pg C $year^{-1}$ at 2000 m depth and 0.18 Pg C $year^{-1}$ over the whole water column, respectively (Legendre *et al*., 2015). These global values still require field, experimental and modeling studies. Many details regarding the functioning of the pumps need further elucidation, including (a) the importance of fragmentation of marine snow by zooplankton, which makes the resulting small particles available for colonization and degradation by attached bacteria and (b) the role of black carbon for aggregation and its ability to absorb DOC and viruses, processes which certainly are likely to influence the BCP and the MCP.

Workshop participants discussed developments and actions needed in the coming years to better understand how the ocean sequesters carbon, and to predict variations and trends under climate change scenarios. The research community needs to better understand the processes that control the biologically-driven pumps, and establish standard protocols for the core measurements of the rates of key processes. Some parameters are in urgent need of standard protocols, *e.g*., the production of refractory DOC and the re-mineralization of sinking particles. Environmental factors that influence these rates also need to be considered, especially those undergoing long-term trends from rising temperature and ocean acidification.

Experimental studies are of critical importance to identify and quantify key mechanisms from micro- to macro-scales. Large-scale mesocosm experiments are an important component for this work, and the proposed large manipulation facility called the "Marine Ecosystem Experimental Chamber System" is expected to allow experiments that will advance our understanding of the biologically-driven carbon pumps. Future improved models will need better input data for key processes, including potential changes in the stoichiometry, and drivers of aggregation and disaggregation by zooplankton and abiotic processes. The community needs to identify which plankton functional types should be included in models, particularly for *Bacteria*, *Archaea* and viruses. The combination of water column information from autonomous vehicles, such as bioArgo floats, gliders and laser counters, with sea-surface information from satellites, will greatly improve data availability for models and thus estimates of carbon sequestration.

The workshop recognized that the three biologically-driven carbon pumps interact with each other in terms of overall process, but are distinct in mechanisms. Future approaches will include simultaneous studies of these three major pumps at different time scales, and how climate change may affect their interactions. Moreover, a clear need for better collaborations among the three approaches (modeling, observational, and experimental) used to study the carbon pumps was identified and new collaborations planned.

Two specific highlights of Workshop W3 that could dramatically increase our understanding of carbon-pump processes are described next.

Impact of soot deposition on biologically-driven carbon pumps

Aerosol Black Carbon (BC) is emitted as soot during biomass burning (*e.g*., forest fires) and fossil fuel combustion. Evidence was presented at the workshop for the occurrence of BC-induced adsorption of dissolved organic matter followed by enhanced formation of marine aggregates (Fig. 1). The adsorption of viruses and bacteria is followed by an increase in the activity of particle-attached bacteria (Mari *et al*., 2014). A large fraction of atmospheric BC is deposited on the surface ocean and enters marine ecosystems. Owing to its high surface-active properties, BC modifies the functioning and the structure of pelagic ecosystems and the carbon pumps.

Marine Ecosystem Experimental Chamber System

Chinese researchers are proposing to build a unique, international experimental facility, called the Marine

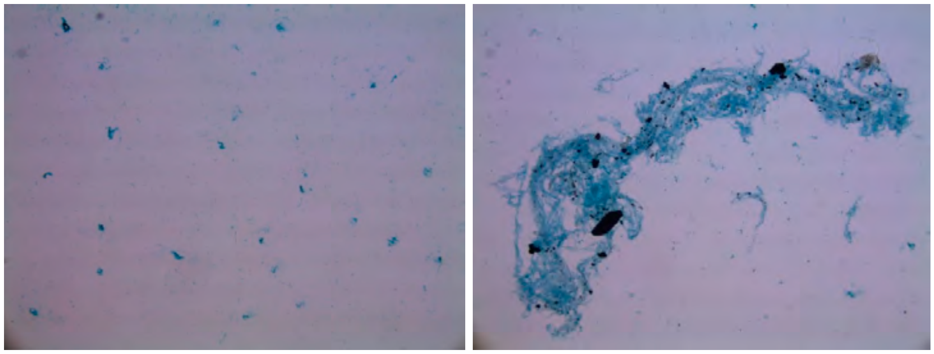


Fig. 1 Examples of Transparent Exopolymer Particles (TEP) produced in the laboratory under controlled turbulence conditions from the same solution of dissolved organic matter: in the control (left panel: without Black Carbon) and the treatment (right panel: addition of Black Carbon). The BC-induced formation of large TEP was concomitant with a significant decrease in dissolved organic carbon concentration.

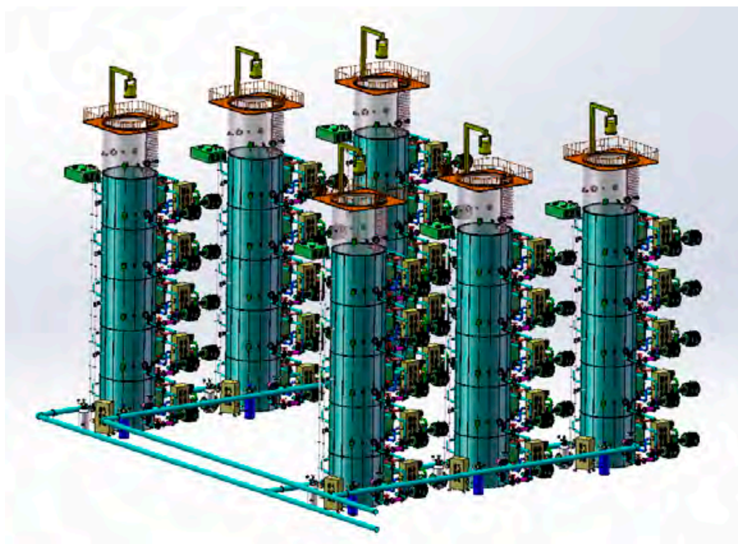


Fig. 2 Design of the planned Marine Ecosystem Experimental Chamber System (MECS).

Ecosystem Experimental Chamber System (MECS), to study the responses of pelagic ecosystems to climate and other anthropogenic changes. It will consist of an array of six (or more) land-based mesocosms (*i.e*., "tower tanks"), 30 to 50 m high and 5 to 8 m in diameter (Fig. 2). The environmental conditions in these artificial water columns will be fully controlled. Because the MECS will include several mesocosms, it could be used to test hypotheses using full-fledged experiments, *i.e*., with replications and controls. Unlike most existing large-volume experimental tanks that are designed for studying horizontal ocean processes (*e.g*., waves, tides, flows), the MECS will focus on vertical processes such as stratification, sedimentation, and vertical migrations. The system will allow a wide range of experimental manipulations of environmental variables and could be used for studying complex processes including biologically-driven carbon pumps. The MECS could be used for scenario studies simulating conditions such as global warming, ocean acidification, or hypoxia. The MECS would also be appropriate for assessing sustainable development practices, such as carbon sink engineering.

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Dr. Louis Legendre (legendre@obs-vlfr.fr) is Professor emeritus at Laval University (Québec City, Canada) and at the Pierre and Marie Curie University Paris 6 (France), and is currently working at the University's Villefranche-sur-Mer Marine Station. His fields and topics of research are biological oceanography and marine biogeochemistry, numerical ecology, and philosophy of science. He chairs the Scientific Council of the Oceanographic Institute (France and Monaco).

Dr. Uta Passow (uta.passow@lifesci.ucsb.edu) is a Professional Researcher at the Marine Science Institute, University of California Santa Barbara. She is interested in the functioning of the biological carbon pump, and how it is influenced by the presence of oil and by climate change.

Dr. Nianzhi Jiao (jiao@xmu.edu.cn) is a Professor of biological oceanography at the National Key Laboratory of Marine Environmental Science, Xiamen University, China, and member of the Chinese Academy of Sciences (CAS) and The World Academy of Sciences (TWAS). His recent research focus includes the Microbial Carbon Pump (MCP), and the responses of marine microbial processes to climate change and its environmental effects.

Dr. Curtis Deutsch (cdeutsch@uw.edu) is Associate Professor at the College of the Environment, University of Washington. His research is aimed at understanding the interactions between climate and ecosystems, focusing on biogeochemical cycles in the ocean, with a particular emphasis on the mechanisms that regulate the cycles of nutrients and oxygen over a range of time scales from years to millennia.

(Continued from page 7)

6. Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences,
7. Evolutionary response of marine organisms to climate change,
8. Climate change impacts on marine biodiversity and resilience,
9. Impact of climate change on ecosystem carrying capacity via food-web spatial relocations,
10. Forecasting climate change impacts on fish populations and fisheries,
11. Impacts on coastal communities,
12. Linking climate change to marine management objectives.

Symposium Plenary Speakers

- Edward (Eddie) Allison (School of Marine and Environmental Affairs, University of Washington, USA),
- Arne Biastoch (GEOMAR Helmholtz Centre for Ocean Research, Germany),
- Paulo H.R. Calil (Institute of Oceanography, University Federal de Rio Grande, Brazil),
- Lynda Chambers (Bureau of Meteorology, Phillip Island Nature Parks, Australia),
- Margareth Copertino (Universidade Federal do Rio Grande, Brazil),
- Jean-Pierre Gattuso (Laboratoire d'Océanographie de Villefranche, France),
- Patrick Lehodey (Space Oceanography Division, CLS, France),
- Lisa Levin (Scripps Institution of Oceanography, USA),
- Coleen Moloney (University of Cape Town, South Africa),
- Phillip Munday (James Cook University, Australia),
- Laura Richards (North Pacific Marine Science Organization),
- Micha Rijkenberg (Royal Netherlands Institute for Sea Research, The Netherlands).

Photo credit: Universidade de São Paulo

Dr. Jacquelynne King (Jackie.King@dfo-mpo.gc.ca) is a Research Scientist at the Pacific Biological Station (Fisheries and Oceans Canada) and an Adjunct Professor at the University of British Columbia. She received her PhD in Limnology from the University of Toronto in 1997 and began her career in marine ecology as a Post Doctoral Fellow studying North Pacific regime shifts. Her current research includes climate change impacts on marine ecosystems and methods of incorporating climate variability into stock assessment advice. She is also Program Head of the Canadian Pacific Shark Research Lab. Within PICES, Jackie was the Chairman of the Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts, a member of the Climate Forcing and Marine Ecosystem Response Task Team and Working Group (WG 16) on Climate Change, Shifts in Fish Production, and Fisheries Management. She is currently a member of the FIS Committee, the Section on Climate Change Effects on Marine Ecosystems, Working Group (WG 27) on North Pacific Climate Variability and Change, Study Group on Socio-Ecological-Environmental Systems, joint ISC-PICES Study Group for Scientific Cooperation of ISC and PICES, and FUTURE Scientific Steering Committee.

2015 Santos Workshop on "*Upwelling systems under future climate change*"

by Shoshiro Minobe, Enrique Curchitser, Kenneth Drinkwater

This workshop (W4) was conducted March 21–22, 2015, at the 3rd International Symposium on "*Effects of climate change on the world's oceans*" in Santos, Brazil. Eighteen people attended the workshop with about an equal representation of physical and biological scientists. Seven papers were presented during the first day. Co-Convenor Shoshiro Minobe began by introducing the main objectives of the workshop which were (i) to investigate the potential effects of climate change on upwelling systems including physics, biogeochemistry and the potential change in plankton and fish production using the most recent projections from global and regional models and (ii) to compare the responses at major upwelling areas around the globe, *i.e.*: Are there common responses or is each system unique?

Two talks highlighted the importance of correct wind-stress estimations for high-resolution ocean models for eastern boundary upwellings. Enrique Curchitser (Rutgers University, USA), an invited speaker, showed that simple downscaling using the regional ocean modeling system (ROMS) does not improve coastal upwelled SSTs in the Benguela Current system, and an *ad hoc* adjustment, *i.e*., shifting wind fields toward the coast, is useful for obtaining better SSTs, indicating the importance of near coastal winds. The strong dependency of upwelling on near coastal winds was also emphasized by Shoshiro Minobe (Hokkaido University, Japan) who analyzed two experiments of high-resolution Ocean General Circulation Model for Earth Simulator. In one experiment, the model was forced by high-resolution QuikSCAT winds and the other by low-resolution reanalysis winds. The upwelling signatures, including their biogeochemical impacts, were reasonably reproduced in the QuikSCAT wind experiment, but upwelling was very weak when forced by the reanalysis winds. Minobe suggested that the conventional interpolation inevitably causes the problem, and either downscaling of wind stress or more advanced inter/extrapolation methodology is needed for reasonably estimating near coastal wind fields crucial for upwelling. In addition to the atmospheric influence on upwelling, the opposite (ocean to atmosphere) influence was reported; Curchitser showed that cold SSTs due to upwelling modify the air temperature not only in the upwelling region but also in remote regions, using a ROMS embedded in a global climate model with two-way coupling for the California Current system. This result indicates that correct SST in relatively narrow upwelling regions plays an important role in shaping the earth's climate.

Two other modeling studies identified forcing factors that cause upwelling variability. Michael Jacox (University of California, USA) presented ROMS experiments for the California Current system with respect to three forcing factors, *i.e*., wind stress, heat/freshwater flux and remote forcing through meridional boundary conditions. He reported that the observed enhanced upwelling trend is mainly due to an increasing wind-stress trend, but interannual spikes in upwelling intensity are caused by remote forcing. Nele Tim (Helmholtz-Zentrum Geesthacht, Institute of Coastal Research, Germany) analyzed ensembles of 1000-yr climate model outputs of MPI-ESM focusing on the contribution of the external and internal forcings on upwelling variations in several regions over the globe on decadal or longer timescales. She concluded that most of the upwelling variability is internally driven.

Two data analysis studies were presented to examine upwelling changes under global warming. Marisol García-Reyes (Farallon Institute, USA) investigated several atmospheric datasets in order to examine Bakun's hypothesis in which faster near-surface warming over the continents than over the ocean causes a greater pressure gradient across the land–ocean boundary resulting in equatorward wind anomalies in eastern boundary current systems favorable for upwelling. She did not find changes of sea-level pressures or a relationship between sea-level pressure and surface air temperature consistent with the hypothesis, suggesting that other mechanisms were important. She also examined whether or not data confirm possible poleward shifts of atmospheric circulation patterns, such as the expansion of the tropics expected under the global warming. She did not find a clear signature, possibly due to superposed multidecadal variability. In another observational analysis, Patrícia Laginha Silva (Universidade do Algarve, Portugal) focused on stratification rather than winds. Even if winds that enhance upwelling occur in the future, expected stratification strengthening due to faster warming at the surface than at depth could weaken the upwelling. She investigated subsurface temperature changes off western Iberia by analyzing six decades' worth of observed temperature and salinity profiles. She found that subsurface warming occurred enhancing the thermocline. The warming was not uniform, but stronger in the southern region than in the northern part along the coast, and the coastal warming was faster than the offshore warming.

The final scheduled presentation by William Sydeman (Farallon Institute, USA), also an invited speaker, presented analyses on the relation between the upwelling and higher trophic-level variability, including fish and seabirds in the California Current system. He showed that the upwelling is closely related to biological variations on interannual timescales with clear El Niño signatures, and found that the important season of the upwelling for biology is winter rather than the upwelling peak season in summer. He also pointed out that drivers or controlling factors of large-scale atmospheric variability for the summertime upwelling are not known, and suggested that this is an important research question.

To stimulate discussion, Holger Auel from Bremen University (Bremen, Germany) presented an overview of the GENUS (Geochemistry and Ecology of the Namibian Upwelling System) project, which is focusing on the northern Benguela current system. It is carried out by various German university groups and marine research institutions in close cooperation with Namibian and South African partners and comprises different work packages including physical oceanography, biogeochemistry, ecophysiology, trophic structures and productivity as well as intense modeling (see http://genus.zmaw.de/ for details).

Possible future studies were energetically discussed, in particular associated with CLIVAR/IMBER's research focus on "Biophysical interactions and dynamics of upwelling systems", which sponsored the workshop and is led by Enrique Curchitser and Ken Drinkwater (Institute of Marine Research, Norway). Through the discussion combined with presentations, it became clear that there are long-lasting difficulties, which may also exist in the near future, and at the same time possibilities of rapid progress across different disciplines. While many are interested in Bakun's hypothesis, to address it one needs accurate downscaling of coastal upwelling including correct representation of the wind stress near the coast with an active influence from the ocean, but this may still be difficult for future climate conditions. This problem may also hinder our ability to solve the SST bias in coastal upwelling regions commonly occurring in climate models. One reasonable approach is downscaling using regional air–sea coupled models, and thus this direction should be encouraged. On the biological side, the complex dynamics of zooplankton and higher trophic levels makes it difficult to gain adequate understanding to predict them. An integrated modeling approach using physical climate models and simple biogeochemical models may be useful for investigating nutrient dynamics and phytoplankton at this stage, but questionable for zooplankton and higher trophic species.

Regardless of the these intrinsic problems that may not be solved quickly, it may still be useful to compare different upwelling systems for the last 30–50 years, *i.e*., different eastern boundary upwellings, the Kuroshio *vs*. the Gulf Stream (nutrient stream), and eddy-related upwelling in different regions, based upon close collaboration among physical, biogeochemical and biological researchers. Participants agreed that this activity is within reach and feasible for a format of a longer workshop. Also, biological researchers expressed their interest in understanding the seasonality of upwelling systems and hope to obtain more information from physical studies on this aspect.

Target upwelling regions were also discussed. Participants agreed that coastal upwelling in eastern boundary regions is primarily the target, but some argued that it should not exclude other systems, such as equatorial upwelling, dynamical uplift due to poleward flowing western boundary currents, and upwelling associated with mesoscale eddies in regions other than eastern boundary currents. In particular, western boundary currents are important in local fisheries and equatorial upwelling changes can play a dominant role in future reduction of global productivity of phytoplankton, as suggested by analyses of CMIP5 results.

Through the 1½ days of the workshop, the enthusiasm of participants for upwelling studies was impressive. This workshop provided a good opportunity for gathering people of different disciplines who are working on, and interested in, different upwelling systems. In particular, further discussion would be useful for the aforementioned CLIVAR/IMBER upwelling research focus.

Dr. Shoshiro Minobe (minobe@mail.sci.hokudai.ac.jp) is a Professor at the Graduate School of Sciences, Hokkaido University in Sapporo, Japan. His overall interest is to understand the ocean's role in the earth's climate system, and he is working on decadal climate variability over the North Pacific, ocean–atmosphere interactions, and recently, biogeochemistry data analysis. Shoshiro was a member of the Science Plan Writing Team for the PICES scientific program, FUTURE, and now co-chairs the Working Group on North Pacific Climate Variability (WG 27).

Dr. Enrique Curchitser (enrique@esm.rutgers.edu) is an Associate Professor at the Department of Environmental Sciences and the Institute of Marine and Coastal Sciences at Rutgers University, USA. His main research interests are at the intersection of climate and ecosystems. His current projects range from downscaled coupled bio-physical modeling in the California Current and Bering Sea, the impact of climate change on coral bleaching in the Coral Triangle and on the role of the Gulf Stream in the climate and social systems of the northeast U.S. He is a member of the PICES Physical Oceanography and Climate Committee, Working Group on Climate Variability and Change in the North Pacific (WG 27) and co-chairs Working Group on Regional Climate Models (WG 29).

Dr. Kenneth Drinkwater (ken.drinkwater@imr.no) is a fisheries oceanographer working at the Institute of Marine Research in Bergen, Norway. He has been conducting research on climate variability and its effects on the marine ecosystem, with a special interest in fish populations, mostly in the subarctic regions of the Atlantic Ocean. Ken is Co-Chairman of the Scientific Steering Committee (SSC) of the IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) Regional Program ESSAS (Ecosystem Studies of Sub-Arctic Seas) and ESSAS Working Group on Arctic-Subarctic Interactions. He is also on the SSC of IMBER and on the Scientific Steering Group of CLIVAR (Climate Variability and Predictability Program).

2015 Santos Workshop on "*Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries*"

by Katherine Mills, Roger Griffis, Alan Haynie, Gretta Pecl, and Andrew Pershing

Workshop W5 participants.

During the 3rd International Symposium on "*Effects of climate change on the world's oceans*" in Santos, Brazil (March 23–27, 2015), we convened Workshop W5 focusing on "*Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries*". Over 40 participants gathered to discuss the current extent and nature of climate change adaptation in marine fisheries, and the advances needed to support further adaptation efforts into the future.

The impacts of climate change on marine ecosystems and fish populations are being increasingly recognized. Fisheries—including fishing industry participants, processors and retailers, as well as the management and governance systems that regulate harvesting—are being affected by these impacts and are already adapting in a variety of ways. This workshop sought to understand how adaptation is occurring in marine fisheries in regions that are experiencing rapid changes in ocean temperature, with a focus on the northeast United States, Alaska, southeast Australia, the North Sea, and the northeast Atlantic (Fig. 1). The workshop was structured around three themes: (1) key elements of climate change adaptation in fisheries, (2) case studies from the focus regions, and (3) advances that are needed to support adaptation. We sought to develop insights into how climate adaptation is being approached and how it could progress in marine fisheries. Our findings will soon be summarized in a synthesis paper.

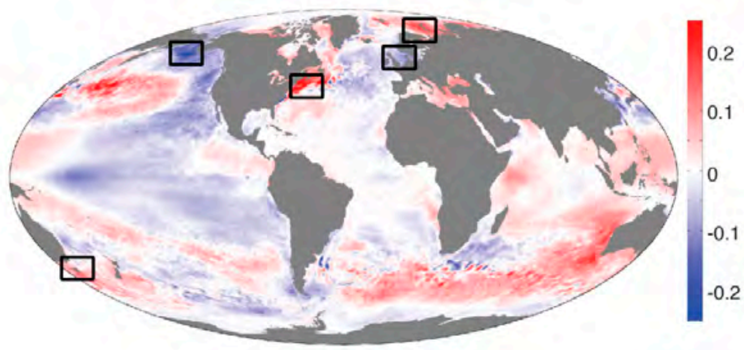


Fig. 1 Rate of change in sea surface temperature over the decade spanning 2004–2013. Focus areas for this workshop are shown by the black boxes.

From workshop presentations and discussions, it is clear that marine fisheries in the focus ecosystems are already being affected by climate-related changes in species life history parameters, spatial distributions, population productivity, phenology shifts, and disease prevalence. These species changes have many consequences for fisheries, such as affecting where and when fishing can take place, bycatch composition and encounter rates, and what species are available to consumers at their local fish markets. Fisheries are responding though numerous means—individual fishermen are changing their operational practices, climate information is being incorporated into fishery management processes, and some countries are undertaking national climate change planning initiatives for their fishing sectors. Climate impacts and the subsequent adaptation efforts span local to international spatial scales and seasonal to multi-decadal temporal scales (Fig. 2). However, examples of adaptation to date tend to emerge most strongly at sub-decadal and local to regional scales. Unfortunately, cases also exist of fisheries that have incurred substantial impacts when stock assessments, management measures, quota allocations, and supply chains have not adjusted quickly enough to rapidly changing environmental conditions.

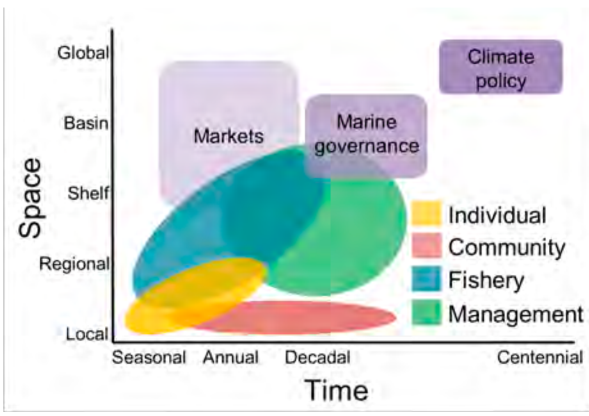


Fig. 2 Spatial and temporal scales of operational, management, economic, governance, and policy processes that affect marine fisheries and that may influence climate adaptation options and outcomes.

Climate adaptation efforts are grounded in and supported by certain attributes of the scientific, management, and governance systems. A science base built on observations, data, analysis, models, and synthesis provides a necessary foundation for adaptation, as it supports an awareness of ecosystem or fishery changes as well as information needed for evaluating decisions or responses. Furthermore, the availability of integrated interdisciplinary science to understand relationships between climate, fish, fishers, and fisheries facilitated many adaptation initiatives we examined. Advances in risk assessments, ecosystem indicators, ecosystem forecasts, and coupled social–ecological models have provided scientific information at relevant spatial and temporal scales to enable fishermen and managers to better respond to climate impacts in the face of considerable remaining uncertainty.

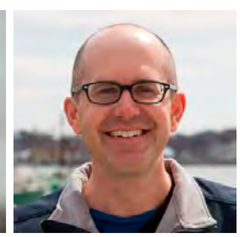
Despite the scientific developments that have supported adaptation, additional advances are critically needed. Social and economic data are often limited but essential for assessing response options and modeling outcomes in coupled social–ecological systems like fisheries. Biological data are routinely collected in the fishery systems we examined, but there is a need to better use this information to provide early warnings of impending changes and to more quickly implement programs to monitor vital rates of species moving into new areas (as well as fishing behavior for these species). Incorporating climate and ecosystem information into decision-making processes remains a challenge, although examples are emerging of effectively using climate factors in stock assessments, as contextual information in decision-making, and in forecasts that provide targeted information directly to the fishing industry. Other remaining scientific needs include: (1) projecting changes at scales that are relevant to fisheries; (2) developing information and a process to reconsider reference points, control rules, and quota allocation under climate change; and (3) devising scenarios of future resource dependence and management. Moreover, across both biological and human systems, there was recognition of the need to develop a mechanistic understanding of observed and impending impacts of climate change, rather than ‘simply’ a documentation of statistical relationships. Even so, nonlinearities and unexpected responses will necessitate a greater focus on risk management in the future.

While a scientific base is necessary for adaptation, it alone is not sufficient. Favorable governance conditions and stakeholder engagement have also proven important for facilitating climate adaptation in fisheries. In both Australia and the UK, climate adaptation for fisheries was largely initiated through national planning efforts that spanned multiple government agencies and that focused attention and resources on this topic. Although these processes were driven from the top down, they entailed significant levels of stakeholder engagement to understand changes in the ecosystem, identify potential industry responses, and establish clear objectives for the fishery management system. In many regions stakeholder coordination is also emerging from the bottom up, with fishermen acting on needs and opportunities for climate adaptation within their own operations or fisheries. Adaptation across the whole seafood supply chain is being considered in some regions, but the full range of stakeholders has not been brought into climate adaptation efforts in most areas. Stakeholder participation in assessing impacts and possible solutions was recognized as essential for the development of climate adaptation approaches for marine fisheries that would be viable within existing social, economic, and institutional contexts.

As the ecosystems in which fisheries operate change, management approaches and governance arrangements that enhance flexibility and adaptability are increasingly needed. Unfortunately, current management and governance systems are often much less dynamic than are the ecosystems within which they operate. As one example, allocation agreements among states or countries typically lack mechanisms for adjustments as stocks shift in spatial distribution. In addition, catch shares are commonly used as a management tool with a goal of increasing flexibility, but the ability of catch shares to achieve this goal depends on the design of the quota system itself. Further, consumer demand for new species of seafood can change slowly, so innovative marketing campaigns have been used to align demand with the supply of species available as distributions shift into new locations. Factoring the variability and non-stationarity associated with climate change into the design of management tools, institutional agreements, and governance systems is essential for supporting ongoing adaptation.

To conclude, fisheries are already being impacted by rapid warming of marine ecosystems and, in some cases, now operate in situations where the past is no longer a suitable analogue for the future. Efforts over the past 30 years to create structured orderly approaches to fisheries management have often removed the flexibility and adaptive capacity that is needed to respond to climate variability and climate change. Increasing flexibility in fishery management objectives and approaches requires responsive monitoring and science systems, forward-looking information at relevant spatial and temporal scales, and the development of risk-based approaches that can support sustainable resource management in the face of considerable uncertainty. In addition to these science and management advances, climate adaptation in fisheries will also be supported by increased stakeholder collaboration across the entire fishery system and by economic resources sufficient for investment in needed changes. While these advances will enhance climate adaptation in fisheries, it is also important to recognize that adaptation actions are being pursued now with existing tools and that, in many cases, the pace of change may preclude waiting for the perfect tools or more favorable governance conditions.

This workshop made an initial effort to assess the state of climate adaptation in fisheries in rapidly warming regions which have highly developed fisheries and management structures. Workshop participants also expressed interest in extending this type of assessment to small-scale fisheries. Identifying synergies and ways in which adaptation efforts can support both large- and small-scale fisheries may improve the efficiency of and capacity for adaptation across a range of fisheries types. Further, as the world population grows, we should anticipate that discussions of climate adaptation in fisheries will increasingly take place in the context of food security in addition to the more common focus on sustaining fisheries as we know them and preserving or increasing economic or social value. This context may provide a further impetus for adaptation but will also likely create an increased urgency. It is important that adaptation initiatives begin now and that analyses of the factors shaping adaptation outcomes be routinely conducted so that fisheries can be prepared to adapt more quickly as the urgency increases.

Dr. Katherine Mills (kmills@gmri.org) is an Associate Research Scientist at the Gulf of Maine Research Institute (USA). Her research focuses on understanding how changes in climate and ecosystem conditions affect fish and fisheries. Many of her current projects involve coupled social–ecological modeling and ecosystem forecasting to support climate adaptation planning and ecosystem-based management of marine fisheries.

Dr. Roger Griffis (roger.b.griffis@noaa.gov) is the Climate Change Coordinator for NOAA's National Marine Fisheries Service (NMFS). His current focus is on increasing the production, delivery and use of climate-related information in fisheries management, protected species recovery and habitat conservation. Efforts include implementation of the NMFS Climate Science Strategy, conducting marine species climate vulnerability assessments, and improving early warnings and responses to climate-related changes in marine ecosystems.

Dr. Alan Haynie (alan.haynie@noaa.gov) is an economist at the NOAA Fisheries Alaska Fisheries Science Center in Seattle, Washington (USA). Alan's research includes the spatial analysis of fisheries under changing environmental, biological, and market conditions and with the implementation of catch shares and different bycatch management systems. Alan is a member of the North Pacific Fishery Management Council's Bering Sea and Aleutian Islands Groundfish Plan Team.

Associate Professor Gretta Pecl (Gretta.Pecl@utas.edu.au) is the Deputy Associate Dean of Research and an Australian Research Council Future Fellow at the Institute for Marine and Antarctic Studies in Tasmania, Australia. She is an ecologist by training, however, most of her research is now interdisciplinary in nature, focusing on both climate change impacts and adaptation in marine systems. She is the co-convener of the Global Marine Hotspots Network and leads several large regional and national initiatives to address the challenges of marine climate change.

Dr. Andrew Pershing (apershing@gmri.org) is the Chief Scientific Officer of the Gulf of Maine Research Institute (USA). His research focuses on understanding how climate variability and change impact marine ecosystems, with a particular focus on the northwest Atlantic. He is actively involved in ecosystem and fisheries management issues and is currently serving on the Scientific and Statistical Committee of the New England Fishery Management Council.

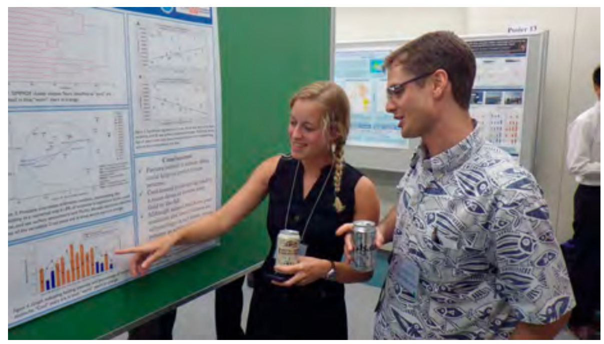
International Symposium on "*Pacific salmon and steelhead production in a changing climate: Past, present, and future*"

by Shigehiko Urawa

The North Pacific Anadromous Fish Commission (NPAFC) hosted an International Symposium on "*Pacific salmon and steelhead production in a changing climate: Past, present, and future*" on May 17–19, 2015, in Kobe, Japan. The Organizing Committee members were James Irvine (Pacific Biological Station, Canada), Ju Kyoung Kim (Fisheries Resources Agency, Korea), Alexander Zavolokin (TINRO-Center, Russia), Edward Farley (Auke Bay Laboratories, USA), Nancy Davis (NPAFC Secretariat), and Shigehiko Urawa (Chairperson; Fisheries Research Agency, Japan).

A total of 107 participants from Canada, Japan, Korea, Russia, USA, and Taiwan gathered in the beautiful port city of Kobe. There were five Topic Sessions in which 11 invited, 28 oral, and 43 poster papers were presented during the 3-day symposium. Presentations can be viewed at the NPAFC website.

Pacific salmon and steelhead trout are impacted by changes in climate occurring in long-term trends and short-term events. Understanding how climate change and variability impact their marine ecology is important to their future sustainability. Our symposium reviewed recent research on ecological mechanisms regulating marine distribution and production of anadromous populations, climate change impacts on salmonid populations, retrospective analysis of key populations as indicators of conditions in North Pacific marine ecosystems, and implications of stock identification and model development for management of salmon and steelhead. The goal of the symposium was to utilize the best available information on the marine ecology of salmonid populations to explain and forecast annual variation in their production.



Katherine Dale explaining results to PICES Keynote Speaker, Dr. Ryan Rykaczewski. (Photo credit: NPAFC Secretariat)

Participants of the International Symposium on "Pacific salmon and steelhead production in a changing climate: Past, present, and future" (May 17–19, 2015, Kobe, Japan). (Photo credit: NPAFC Secretariat)

Topic Session 1
Migration and survival mechanisms of salmonids during critical periods in their marine life history

Marc Trudel (Canada) and Ju Kyoung Kim (Korea) took charge as the Session Convenors. The Keynote Speakers were David Welch (Canada) and Kate Myers (USA).

1a. Initial period of marine life
A common hypothesis is that the initial period after migration to the sea is the most critical phase with respect to ocean survival of anadromous populations. However, this belief has not been universally adopted. In particular, Welch recommended retiring the current concept of critical periods and instead evaluating whether any particular life history period is really "critically" important.

Many presentations indicated considerable inter-annual variation in abundance, growth, and survival rates of juvenile salmon in the ocean. These variations may be related to climate-induced changes in habitat environments that operate at regional and local scales. Predation on juvenile salmonids by some predators is likely to change in the future as alternative prey respond to changing coastal environments associated with climate change, and predation by other predators may remain largely unaffected by such changes (Weitkamp *et al*.).

1b. Winter period
In southern areas of salmon distribution in the coastal North Pacific, such as Japan and California, increasing warming periods affecting ever expanding areas may well disrupt migration patterns of juvenile salmon as warming ocean temperatures can negatively impact their populations (Hayes and Harding, Kasugai *et al*.).

Historical winter research programs since the 1950s were well reviewed by Myers *et al.* In recent decades (1990s–2010s), new fisheries–oceanographic survey methods, stock identification techniques, remote sensing technologies, and analytical methods have expanded our understanding of the winter ecology of salmon. Myers *et al.* suggested that the development of quantitative multistage models of salmon ocean distribution linked to oceanographic features would help to identify key factors influencing winter distribution and improve understanding of potential climate change effects.

The ecosystems of the Western Subarctic Gyre and Gulf of Alaska provide major wintering habitats for various anadromous populations (Naydenko and Temnykh, Urawa *et al*.). Although the winter period has been identified as a defining phase for the biomass of anadromous populations, this hypothesis is uncertain due to limited information on their ocean life history and ecology during winter. Naydenko and Temnykh estimated that the reduction of lipid accumulation and somatic growth rate in overwintering salmon could be related to their seasonal cyclic changes of physiological processes, but not to poor food resources and prey availability in winter.

Chinook salmon increased energy stores with latitude, confirming genetic adaptation by northern latitude populations where increased energy stores are required to survive longer, darker, and colder winters (Moss *et al*.). Orsi *et al*. suggested that a critical marine period for Chinook salmon in Southeast Alaska occurs prior to summer (June) after their first ocean winter.

There is some evidence that overwinter mortality is size-selective in juvenile Pacific salmon although there is little evidence to date that year class strength is regulated by overwinter mortality (Trudel *et al*.). Further tests of the critical period hypothesis will require direct estimation of overwinter mortality over several years.

Session Convenors suggested the following research questions for future research:
(1) When and where do significant mortality events occur in the marine environment?
(2) How do these mortality events contribute to variability in marine survival?
(3) What is causing mortality of salmon in the ocean?
(4) Which fish survive better?

Topic Session 2
Climate change impacts on salmonid production and their marine ecosystems

This session was convened by Ed Farley (USA) and Olga Temnykh (Russia). Keynote Speakers included Suam Kim (Korea) and Ryan Rykaczewski (PICES, USA). Papers dealing with the effects of climate change and climate cycles on salmon and steelhead production and ocean ecosystem function and structure were sought for this session.

Keynote Speaker, Dr. Suam Kim, presenting on climate variability and Korean chum salmon production in Topic Session 2. (Photo credit: NPAFC Secretariat)

Over the last three decades, the climate statistics of the Pacific have exhibited a significant change that has impacted marine ecosystems (Rykaczewski and Lorenzo). There has been significant variation in marine production of Asian and North American salmonid populations that is linked to climate change. The recent CMIP5 (Coupled Model Intercomparison Project Phase 5) models show that warming is expected to be stronger in summer than winter over the Bering–Okhotsk seas and in the western subarctic

North Pacific. Thermal habitats of salmon will generally shift to the north and west due to warming, and summer salmon habitat may shrink more than winter habitat (Minobe *et al.*). Variation in salmon growth from 3D-NEMURO models is consistent with Pacific Decadal Oscillation variation and variation in total catch for salmon (Ueno *et al*.). Climate change may also impact the food web of masu salmon and their abundance in the Sea of Japan (Nagasawa).

Session 2 presenters felt there is a strong need for better information on ecological mechanisms regulating production of anadromous populations and on estimates of climate impacts on salmon populations in North Pacific marine ecosystems. Climate shifts can significantly alter the bioenergetics of the food chain. The Convenors suggested the key for advancing this knowledge is to integrate understanding of physical climate change with our understanding of the prey and energetics of salmon.

Topic Session 3
Retrospective analysis of key salmonid populations as indicators of marine ecosystem conditions

The Session Convenors were James Irvine (Canada) and Toshihiko Saito (Japan). Alexander Kaev (Russia) and Gregory Ruggerone (USA) were the Keynote Speakers.

Over the past several decades, there have been significant variations in the marine production of Asian and North American anadromous populations that are linked to climate change. Anadromous populations can function as an ecological indicator of marine ecosystems. Long-term monitoring of salmon populations, salmon ocean habitats, and their ecosystems can yield critical information for examination of changes in marine habitats. Time series information gathered on annual regional salmon production trends and biological and physical characteristics of salmon ocean habitat can provide the broad scale perspectives necessary for examining the underpinnings of ocean salmonid production, biological characteristics, and marine ecosystem conditions.

Studying the past (= retrospective studies) helps us better understand the present and the future. Archeological evidence has documented the presence of Japanese chum salmon in regions of suitable temperature (sea temperatures <16ºC) as far back as 7,000 years ago. Their distribution expanded ~4,000 years ago during a period of cooling. Retrospective information such as this makes it reasonable to assume future declines in abundance and distribution as temperatures increase (Ishida *et al*.). Many shorter-term studies also showed linkages between water temperature and salmon productivity. Temperature-related changes in marine survival appear to be responsible for variable returns of pink salmon in the Sakhalin–Kuril region over the last 45 years (Kaev).

Dr. Yukimasa Ishida discussing climate-related changes in fish species composition in Topic Session 3. (Photo credit: NPAFC Secretariat)

In the recent steelhead low marine survival period, survival was more strongly influenced by temperature than by smolt size (McCubbing and Braun). Pink salmon survival patterns were consistent within geographic regions of Japan (similar temperature patterns) but differed among regions with different temperature patterns (Saito *et al*.).

Temperature is often an indicator of mechanistic responses, which may represent food linkages. Early marine effects on growth and subsequent survival are extremely important (sockeye, Tucker *et al*.; Chinook, Yasumiishi *et al*., Lindley *et al*.). Reduced pollock abundance, which may be temperature related, appeared to increase foraging opportunities for chum salmon in the western Bering Sea and has led to a higher carrying capacity (Zavolokin and Radchenko).

As for density dependence related to carrying capacity, we need to think of ecosystem linkages including inter-specific competition. Pink salmon now represent more than 70% of all adult salmonids, and this abundance may have profound ecosystem consequences (Ruggerone *et al*.). Recently there have been reductions in the average size of northern chum salmon (Golub and Temnykh) which might be due to significant changes in their feeding conditions in the marine period of their life.

The Session Convenors identified the following needs for future advancement:
(1) more empirical data sets,
(2) continuing time series data collection,
(3) quantifying uncertainty in data,
(4) improving understanding of ecosystem linkages,
(5) increasing collaborations with climate modelers,
(6) increasing publicly accessible databases.

Topic Session 4
Application of stock identification and models for salmonid population management

This session was convened by Jeffrey Guyon (USA) and Michio J. Kishi (Japan). Lisa Seeb (USA) and Randall Peterman (Canada) were the Keynote Speakers.

4a. Stock identification development and applications for management

Accurate stock identification methods such as genetic, otolith mark analyses, chemical, and morphological techniques have been used to monitor stock-specific ocean distribution and abundance. Improvements in stock identification methods have continued to provide stock distribution information highlighting where and when salmonids migrate in the ocean. This information is critical for models incorporating ecosystem and environmental conditions to explore possible production scenarios and offer insights for management.

Genetic stock identification (GSI) has been an integral part of NPAFC-related scientific investigations for nearly two decades, with research activities coordinated through the Working Group on Stock Identification. Genetics data are now routinely used to determine the distribution and migration routes of salmon in the ocean; provide real time management information for commercial fisheries; and identify stock origin of fish captured during illegal, unreported, and unregulated fishing (Seeb).

A long-term GSI program for juvenile chum salmon in the eastern Bering Sea suggested the brood-year strength of Yukon River summer- and fall-run chum salmon may be determined early in the first year of life (Kondzela *et al*.). In the central Bering Sea, single nucleotide polymorphism (SNP) markers were used to monitor stock-specific abundance of immature chum salmon for the forecast of adult returns, and considerable annual variation of stock- or age-specific abundance was reported by Sato and Urawa. In the same survey area of the central Bering Sea, the stock composition of sockeye salmon was monitored through an analysis of microsatellite DNA variation that identified fish from Alaska, Russia, and Canada, helping to support a migration route for the species (Beacham *et al*.).

Alaska applies molecular tools (SNPs) to identify trends in stock composition of sockeye salmon as they return to Bristol Bay, and Chinook salmon as they migrate up the Yukon River. These projects are now informing fisheries management in real time (Templin *et al*.). Canada has also a similar genetic analysis program for the management of multi-run sockeye salmon stocks in the Fraser River (Latham *et al*.).

In the Okhotsk Sea, genetic identification of juvenile pink salmon was conducted to improve the forecast of spawning runs (Shpigalskaya *et al*.). Stock compositions were reported of juvenile sockeye salmon collected in the Bering Sea and Pacific Ocean waters off Kamchatka (Pilganchuk *et al*.).

Genetic results were also applied to monitor the genetic diversity and structure of a variety of salmon, including endangered Formosa salmon in a mountain area of central Taiwan (Hsu and Gwo), pink salmon at the southern limit of their distribution (Terui *et al*.), masu salmon (Song *et al*.), and chum salmon (Tsukagoshi *et al*.).

Improvements in statistical analyses were reported by Kitada *et al.* who employed an empirical Bayes F_{ST} to describe the fine-scale population structure of sockeye salmon spawning in a complex watershed. White-fleshed coho salmon was reported in populations from northern Southeast Alaska (Heard).

4b. Model development and applications for management

A key management problem for Pacific salmonids is how to best make decisions about fishing regulations, hatchery release strategies, and habitat protection activities (Peterman). This is particularly challenging for statistical and dynamic simulation models because of large annual variation in abundance of salmonid populations, as well as non-linear trends in productivity over long periods. The suitable release number of chum salmon was estimated based on an ecosystem approach using NEMURO and a cost function (Kishi *et al*.).

A Bayesian forward salmon run reconstruction was developed and applied to sockeye salmon stocks from the Fraser River and chum salmon stocks from British Columbia and Puget Sound (Rossi and Cox). This model estimates stock-specific harvest rate, run size, and run timing parameters from stock composition, catch, and escapement data and provides a flexible framework for post-season analysis and preseason/in-season planning.

An age-structured model was used to examine the contribution of wild fish to chum salmon populations in Japan (Suzuki *et al*.). They estimated that the contribution of natural production increased to approximately 35% in recent years, even under an intensive hatchery release program.

The stock-specific ocean habitat of Chinook salmon was estimated using fine-scale catch locations and genetic analysis of samples collected in salmon troll fisheries (Lawson *et al*.). Preliminary analysis suggests that salmon catch was associated with the upwelling front along the continental shelf break.

The Session Convenors observed that the number of presentations in the modeling portion of this Topic Session was relatively few. They recommended that in the future more presenters consider applying descriptive as well as statistic models in their presentations on other topics.

Topic Session 5
Forecasting salmonid production and linked ecosystems in a changing climate

The Session Convenors were Alexander Zavolokin (Russia) and Richard Beamish (Canada). (Unfortunately, Dr. Zavolokin was not able to attend the symposium.)

Richard Beamish, Masahide Kaeriyama (Japan), and Skip McKinnell (PICES, Canada) were invited to make Keynote presentations.

Accurate forecasting of returning salmon abundances is of great importance to management and for anticipating future variations in production affected by a changing climate. Forecasts of salmon abundance serve at least two useful purposes, regardless of whether they are accurate or not (McKinnell). If a forecast is accurate, it provides time for meaningful preparation by harvesters and fishery managers. If a forecast is inaccurate, it keeps hubris in check and may serve as a guide for developing new research directions.
Current abundance forecast methods use Bayesian approaches to capture uncertainty in Fraser River sockeye survival and resulting returns (Grant *et al*.). The forecast probability distributions are wide, given uncertainty in the specific mechanisms influencing Fraser sockeye survival and the very dramatic changes in survival in recent years. Sibling models, which compare adult returns from a brood year's younger age class to the subsequent age class, can be used as indicators of survival for the older ages. Forecasts produced by these models, though still highly uncertain, provide corroboration of abundance forecasts generated using alternative model forms.

Forecasting pink salmon returns is also challenging under conditions of a changing ocean climate because pink salmon only spend a single winter in the ocean before returning to spawn. Thus, they lack any leading indicator information generated from younger siblings (Orsi *et al*.). Early marine mortality of pink salmon can be highly variable and affects year class strength. Thus, conducting surveys assessing seaward migrating juveniles after this critical period can usually predict year class strength. However, subsequent ocean conditions during some years may impact pink salmon productivity. Of the ecosystem metrics considered, important variables for forecasting the adult pink salmon return are juvenile pink salmon catch per unit effort, timing, percentage of pink salmon in the catch, a predator index, and the North Pacific Index.

Global warming may affect a decrease in the carrying capacity and distribution area of Pacific salmon in the North Pacific Ocean and expand their distribution area to the Arctic Sea (Kaeriyama *et al*.). Ecological risk management consisting of adaptive management and the use of precautionary principles is a necessity for sustainable protection of Pacific salmon under conditions of a changing climate. For successful long-term risk management of Pacific salmon, the following items need to be kept in mind: (1) limited and fluctuating ocean carrying capacity, (2) a paradigm shift in aquatic sciences from traditional population level ecology to ecosystem level ecology, and (3) education on sustainability sciences of Pacific salmon for future generations (Kaeriyama *et al*.).

Maximizing the amount of energy available for growth in the early marine period is a mechanism that increases survival among all Pacific salmon species (Beamish). Increased energy efficiency for growth of juveniles in the early marine period is a key to optimizing hatchery production. A focus for new research is determining marine conditions that optimize energy budgets for growth and discovering how climate-related ecosystem changes alter these energy budgets.

Conclusions

The NPAFC science plan is a long-term comprehensive guideline for cooperative international research to achieve the vision of the NPAFC Convention: "*Conservation of anadromous populations in the North Pacific Ocean*". Member countries conduct national research programs under the plan. The goal of the current 2011–2015 Science Plan is to be able to explain and forecast the annual variation in Pacific salmon production (NPAFC Doc. 1255, available at www.npafc.org).

To provide the necessary focus for cooperative research under the 2010–2015 Science Plan, the Science Sub-Committee identified an overarching research theme, "*Forecast of Pacific Salmon Production in the Ocean Ecosystems under Changing Climate*", and five research components:
(1) Migration and survival mechanisms of juvenile salmon in the ocean ecosystems;
(2) Climate impacts on Pacific salmon production in the Bering Sea and adjacent waters;
(3) Winter survival of Pacific salmon in the North Pacific Ocean ecosystems;
(4) Biological monitoring of key salmon populations;
(5) Development and applications of stock identification methods and models for management of Pacific salmon.

The symposium was essential for reviewing the current NPAFC Science Plan and developing a new plan for 2016–2020. A considerable amount of new information was acquired on the marine ecology of salmonid populations to help explain and forecast annual variation in their production. The response of salmon to climate-driven environmental changes is variable and differs by species, stocks, life stages, geographical locations, and seasonal timing. The future of salmon still remains uncertain under several scenarios of climate change. Because of this, it is more important than ever that we promote new cooperative international research that provides better scientific information on the ecological mechanisms regulating production of anadromous populations and climate impacts in North Pacific marine ecosystems. It would be particularly useful if climate change/ecosystem/model research could be conducted in cooperation with other international partners with competency in these areas, such as PICES.

(Continued on page 24)

Mitigation of harmful algal blooms: The way forward

by David Kidwell

Harmful algal blooms (HABs) represent a broad suite of phytoplankton, macroalgae, and cyanobacteria that can have significant impacts on ecological resources, human health, and coastal economies. The specific impacts of HABs occur on multiple scales and will vary based on species, location, time of year, and proximity to key resources. Some blooms can disrupt entire ecological communities simply due to their accumulated biomass or reduction in light penetration. Others produce toxins that can cause a variety of human poisoning syndromes through either direct exposure to the organism's toxins or through the consumption of contaminated fish or shellfish (Glibert *et al*., 2005). Risk of human exposure can prevent the harvest of commercial, subsistence and recreational fisheries, close popular beaches, or prevent the use of community drinking water supplies that might be contaminated.

The causes of HABs are varied and not always well understood, but linkages of some blooms to excess nutrient inputs and hydrologic alterations provide some direction for prevention. Once a bloom has formed, mitigation actions have primarily focused on early warning and detection to eliminate or reduce human and resource exposure, or to provide rehabilitation to distressed wildlife. Efforts to control HABs, defined as a reduction of the magnitude or restriction in the spread after bloom formation, are generally limited to small-scale systems (*e.g*., ponds and small lakes). The challenge for larger systems (*e.g*., larger lakes and coastal areas) is balance between the application of an effective control method while limiting unintended side-effects that may disrupt ecosystems and communities. This article will provide a brief overview of HAB mitigation and control approaches and outline a path forward to enable informed decisions on balancing their effectiveness with concerns over possible side-effects.

Approaches for HAB mitigation

Research and development of techniques to control or mitigate a HAB is a promising area of research that can be separated into three categories based on their mode of action (Table 1). Physical mitigation methods are typically those that use physical means to remove cells or toxins from the water column, limit the spatial extent of a bloom, or render them unable to reproduce (Fig. 1). A widespread physical technique currently in use is a suite of devices that enables mixing of the water column to alter nutrient dynamics, disrupt algal cell processes, or eliminate stratification. While success has been demonstrated in smaller water bodies and embayments, application of these devices in coastal systems is limited. A number of sediment-based methods (*e.g.*, clay flocculation, sediment resuspension and burial) have been the focus of research efforts demonstrating mixed results (Sengco and Anderson, 2004; Shao *et al*., 2012). Recent efforts have combined physical and biological controls through resuspension to enhance natural processes to inoculate the water column with HAB-targeting bacteria.

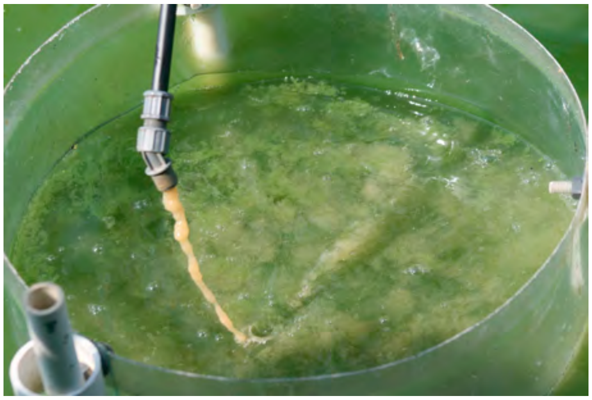


Fig. 1 In situ mesocosm testing of clay flocculation effects on a Microcystis aeruginosa bloom.

Table. 1 Suite of possible approaches for the control harmful algal bloom.

Categories of HAB Mitigation Techniques		
Physical Control	**Chemical Control**	**Biological Control**
Flocculation	Silica	Macroalgae
Sediment-based Methods	Barley Straw	Predator enhancements
Cell Harvesting and Removal	Biosurfactants	Bacteria and viruses
Water Column Mixing	Hydrogen Peroxide	Purified algicidal compounds
	Copper	

Chemical controls represent a suite of artificial and naturally-derived compounds that interfere with cellular growth and/or result in cell lysis through a variety of mechanisms. Bales of barley straw have been used as a HAB mitigation technique with some success in smaller, enclosed water bodies. Barley straw has been shown to have algistatic and algicidal effects and studies are underway to isolate and extract the responsible compounds for possible application in larger systems (hUallacháin and Fenton, 2010). Commercially available copper-based and nutrient altering (*e.g.*, phosphorus binding or silica additions) products have been used in freshwater systems and some coastal waters. Additional chemical-based control techniques include the use of biosurfactants and the application of hydrogen peroxide (Ahn *et al*., 2003; Barrington *et al*., 2013). All of these techniques, however, have not been fully demonstrated in coastal environments and their effectiveness in mitigating HAB impacts remains an open question.

Laboratory-based research and development of biological HAB control methods are based primarily on enhancements to natural processes and/or organisms that have demonstrated an ability to eliminate harmful algal species. Several species of macroalgae (*e.g*., *Ulva* spp., and *Graciliaria* spp.) have been known to impact HABs through nutrient competition or through allelopathic effects on HAB species (Nan *et al*., 2008; Lu *et al*., 2011). Many of the allelochemicals produced by macroalgae quickly degrade in the aquatic environment; thus the use of intact native macroalgae may be required to achieve sustained control. In addition to algae, some bacteria and viruses have algicidal or algistatic effects on phytoplankton, including HAB species. Substantial research has focused on isolation of the algicidal compounds from these organisms to develop a HAB control product (Tilney *et al*., 2014). Additional biologically-based approaches suggested for HAB mitigation include algal predator enhancements and other food-web based changes.

Balancing environmental and societal impacts

Of the existing suite of techniques that have been evaluated, many have a mode of action that is indiscriminant with possible broad effects, raising significant environmental and societal concerns (see NOAA 2015 for additional details). For example, a major concern for many techniques is a rapid increase in benthic biological oxygen demand and resultant hypoxic conditions following the death of a high biomass HAB. For biologically-based control options, possible unintended consequences and stringent regulations will likely limit the introduction of live or whole organisms to control a HAB. While especially relevant for the introduction of non-native species, similar concerns may likely exist for enhancements of native species and will likely require significant site-specific analyses to assess environmental and societal risks.

Likewise, there are significant concerns associated with many proposed chemical control techniques. Hydrogen peroxide, copper-based products, and other chemicals have a strong potential to result in significant environmental harm through mortality and/or other impacts to many non-target organisms. While some such chemicals have short environmental lives (*e.g.*, hydrogen peroxide), others have the potential to bioaccumulate (*e.g.*, copper). Other proposed chemical-based techniques, such as nutrient-altering products, can result in unintended water quality impairments that could violate local regulations and/or exacerbate the impacts of the HAB.

Similar worries have been raised about proposed physical control techniques. Many municipalities have strict water quality regulations on turbidity that would limit sediment inputs to coastal waters. Also, the resuspension of bottom sediments can reintroduce contaminants that had settled out of the water column. Efforts to control a HAB through sediment-based techniques also have the potential to directly impact key habitats (*e.g*., submerged aquatic vegetation) and living resources (*e.g*., clearance rates in bivalves).

Future HAB mitigation and control research should be driven by the need to balance the often competing priorities of control effectiveness and possible environmental side-effects (Fig. 2). Accomplishing this balance will require the development of a ‘mitigation and control toolbox’ that provides options for managers and local communities. To facilitate toolbox development, all techniques should have demonstrated effectiveness and evaluation of possible side-effects before widespread application and use. Taxon- or species-specific techniques that limit possible unintended consequences and specific treatment requirements, in parallel with on-going education and engagement with local communities, will be critical for addressing environmental and societal concerns. Development of best management practices and requirements for pre- and post-treatment monitoring will further help to facilitate transition from research to application. Ultimately, mitigation of HABs should attempt to minimize the risk of unintended consequences to ensure a treatment will not make the problem worse.

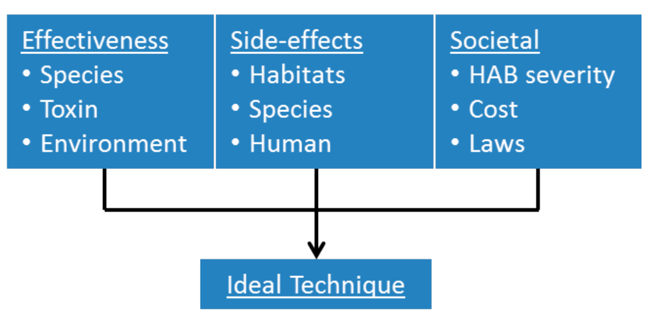


Fig. 2 Balancing multiple factors in selecting an optimal mitigation strategy and/or control technique for harmful algal blooms.

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(Continued from page 21)

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S-HAB contributions to FUTURE

by Vera L. Trainer, Mark L. Wells, and Charles G. Trick

Harmful Algal Blooms (HABs) are events that reflect undesirable disruption of plankton systems that negatively impact ecological structure, productivity, and human health, namely factors that are integral to the assessment of the coastal goals of FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems), PICES' integrative science program. While PICES' Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB) has been actively contributing to the PICES mission for over a decade, the specific goals and activities of S-HAB have paralleled FUTURE research themes in key areas:

1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?

Specifically S-HAB is interested in understanding the features of climate change that may affect the frequency, occurrence, and changing global distribution of HABs. In fact, harmful species and their toxins respectively provide "eco-indicators" and "physiological tracers" of ecosystem stress and the disruption of plankton systems that provide the carbon and energy foundation for marine food webs. These compositional changes can substantially affect the trajectory, vulnerability and resilience of upper trophic levels.

2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

S-HAB is participating in research and monitoring to determine the role of climate impacts such as ocean acidification, increasing temperature, changing stratification, altered light fields, changes in grazing pressures, and altered nutrients on harmful species.

3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

HABs are a societal-based definition reflecting negative changes in ecosystems, some of which are a direct result of human activities. S-HAB will co-convene a Topic Session with the Section on *Human Dynamics of Marine Systems* at PICES-2015 in Qingdao, China, that will address more closely this linkage between disruptive plankton systems and a range of human wellness issues. In addition, members are participating in the Marine Ecosystem Health and Well-Being (MarWeB) project, sponsored by the Government of Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF) to study the health and happiness of coastal communities in Indonesia and Guatemala that depend on aquaculture.

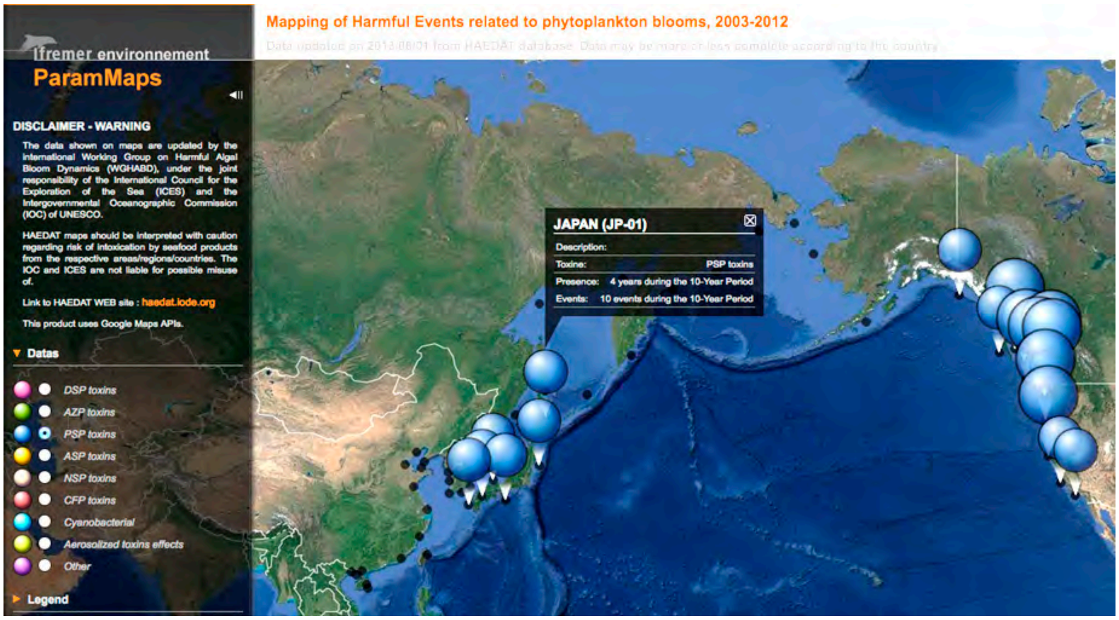
A goal of FUTURE is to provide meaningful "early warnings" of disruptive ecosystem states in a changing ocean. Fundamentally, major shifts in marine biochemistry and higher trophic levels reflect a largely "bottom up" control, driven by the interactive relationship between environmental conditions and the nature of primary production. Developing early recognition, and perhaps forecasting skill, of any ecosystem changes will critically depend on better understanding of several key disruptive plankton systems, including:

- High biomass, monospecific blooms (phytoplankton, macroalgae, grazers (red tides), hypoxia),
- Toxic blooms (toxic diatoms, fish-killing species, toxic dinoflagellates),
- Food-web disruptive blooms (*e.g*., ecological conditions that facilitate jellyfish blooms),
- Nutritionally inadequate blooms (physiological or species-driven changes in production of essential fatty acids).

S-HAB recognizes the need to go beyond the current focus on carbon processing/climate linkages to better assessment of ecological/climate linkages. This shift will require an entirely new approach to understand how climate variables interact to create "windows" of opportunity for ecosystem disruptive planktonic systems. At this stage, we cannot predict these disruptive systems, but can only establish how they may change temporally or geographically. These changes can be envisioned as providing an "environmental market report", similar to a stock market index – the presence of HABs serves both as an "indicator" and a "driver" in the decision-making process.

The Section is well positioned to provide key input to help define the edges of these "windows" that, when linked with appropriate physical and human dimension models, can provide "market forecast" outcomes. Specifically, S-HAB has collaborated on a number of efforts to achieve the goals described above via S-HAB workshop and topic session outputs (characterizing the ecophysiology of key HAB species in the PICES region; the economics of HABs events) during PICES Annual Meetings, and its participation in the IOC/UNESCO harmful algal event database (HAEDAT), the global database on HAB events.

To illustrate knowledge exchange–knowledge transfer activities of S-HAB, members have been participating in several stages of a more rigorous assessment of purported links between anticipated climate-driven changes and HABs. Phase 1 was a 5-day jointly sponsored PICES, NOAA, and SCOR/GEOHAB international workshop on "*HABs in a changing world*" held March 18–22, 2013, at the University of Washington Friday Harbor Labs in Washington State, USA, and co-organized by Mark Wells



PICES S-HAB entries into HAEDAT showing paralytic shellfish poisoning events from 2003–2012. An example "pop-up window" shows detailed information from the JP-01 area code of Japan (www.haedat.iode.org).

(PICES S-HAB) and Bengt Karlson (ICES/IOC-WGHABD). A focused group of internationally recognized HAB scientists with different expertise reviewed what is known and unknown about HAB/climate linkages (summarized in an article "*Harmful Algal Blooms in a Changing World*" in PICES Press, Vol. 21, No. 2, Summer 2013). A seminal review paper identifying the keystone parameters and research infrastructure needed to test these purported linkages will be published in the journal *Harmful Algae* in late summer 2015. This paper titled "*Harmful algal blooms and Climate change: What do we know and where do we go from here?*" is authored by Mark L. Wells[1], Vera L. Trainer[1], Theodore J. Smayda, Bengt S. O. Karlson, Charles G. Trick[1], Raphael M. Kudela, Akira Ishikawa, Stewart Bernard, Angela Wulff, Donald M. Anderson, and William P. Cochlan.[1]

The second phase of assessment of the links between climate change and HABs was a broader-scope Symposium on "*Harmful algal blooms and climate change*" that was held from May 19–22, 2015 in Göteburg, Sweden, jointly sponsored by PICES, the Swedish Research Council (FORMAS), SCOR/GEOHAB, NOAA, the Swedish Meteorological and Hydrological Institute, and the University of Göteburg, and endorsed by IOC and ICES. This workshop brought together 58 participants from across the globe to delineate the bounds of our understanding, to identify the major impediments that block knowledge advance, and to derive from these a list of more productive research strategies. Participants considered a wide range of climate change and other factors (*e.g.*, nutrient fluxes, ocean acidification, temperature, stratification, improved modeling skill, new methodologies and observation systems, and the need for a best practices manual to unify HAB research methods). The central ecological questions focused on how climate change will influence the character and prevalence of future HABs within the context of broader changes in planktonic systems. Participants also worked to identify the key steps to improve understanding of HAB effects on fisheries productivity and to develop the requisite forecasting abilities for HABs and other disruptive plankton systems.

There are key knowledge gaps in the underpinning of the intrinsic resilience and vulnerability of marine ecosystems to natural and anthropogenic forcing, how ecosystems of today will respond to natural and anthropogenic forcing in the future, and ultimately how societies will be affected by these altered ecosystems. It is reasonable to argue that the most uncertain of these gaps is constraining how planktonic systems shift from strongly sustaining to disruptive modes. To this end, S-HAB is continuing its efforts to coordinate observations and trend analysis of plankton data among PICES member countries, and link these to climate change science, and to contribute to the developing UNESCO-IOC Global HAB Status Report. The Scientific Steering Committee of the newly formed replacement for GEOHAB, GlobalHAB, will include expertise on freshwater HABs, benthic HABs, satellite observation systems, ecology, oceanography, toxins, human health links, and economic links and will have representation from all regions. Early discussions with IOC delegates have emphasized that PICES needs representation on the executive committee. This will ensure a collaborative functioning with global organizations that share similar aims to PICES, such as IOC, ICES, SCOR, IOCCG, and IAEA.

[1] PICES authors

Participants of the "HABs and climate change" symposium in Göteborg, Sweden, from May 19–22, 2015.

In this way, PICES will become a major partner in contributing to the strategic focus of this international effort. Other collaborators include IPHAB, OSPAR, HELCOM, GOOS and national and local programs including seafood safety monitoring and phytoplankton monitoring programs. The rationale behind more coordinated HAB/climate science research and monitoring include protection of public health and coastal economies including fisheries, aquaculture, ecosystem services and tourism.

In summary, the key strategies that S-HAB uses to contribute to FUTURE's research themes are: (1) to publish workshop and symposium reports that integrate "State of the Science" climate change with the character, distribution and intensity of future HAB scenarios, (2) to identify and prioritize future research needs that improve our forecasting abilities, (3) to continue to lead, organize, and participate in workshops and open science meetings that address HABs in the context of disruptive plankton systems, and (4) to help organize and develop the GlobalHAB research strategies and UNESCO-IOC Global HAB Status Report. S-HAB will continue to be a leader in global HAB research but the primary goal is to serve the PICES community by fostering a fundamental understanding of the drivers of change from productive to disruptive planktonic systems – critical knowledge that underpins the activities of FUTURE.

Dr. Vera Trainer (vera.l.trainer@noaa.gov) is a Supervisory Oceanographer with the Marine Biotoxin Program at the Northwest Fisheries Science Center, Seattle, USA. She is the Co-Chair of the PICES Section on Ecology of Harmful Algal Blooms in the North Pacific and is the President of the International Society for the Study of Harmful Algae (ISSHA). Her current research activities include refinement of analytical methods for both marine toxin and toxigenic species detection, assessment of environmental conditions that influence toxic bloom development, and characterizing the spatial extent of new toxins such as azaspiracids.

Dr. Mark Wells (mlwells@maine.edu) is a Professor of Oceanography in the School of Marine Sciences, University of Maine, USA. His current work spans the study of toxin production associated with harmful algal blooms, the interaction of trace metal chemistry with phytoplankton production in coastal and offshore seawaters, and the implementation of nanoscience and engineering concepts into the next generation sensor development for bioactive metals, phytoplankton community composition, and other indicators of ecosystem health. He is a member of the PICES Section on Ecology of Harmful Algal Blooms in the North Pacific.

Dr. Charles Trick (trick@uwo.ca) is a Distinguished Research Professor for Ecosystem Health at Western University, London, Canada, a position that emphasizes the merging of science, health/medicine, social and psychological aspects of environmental programs. Since receiving his Ph.D. in Oceanography, Charlie has worked in a variety of different coastal and open ocean projects. He has recently completed a sustainability assessment of the Persian Gulf and continues his research in marine and freshwater harmful algal blooms. In PICES, he is a member of the Section on Ecology of Harmful Algal Blooms in the North Pacific.

A psychological perspective on "human well-being": An international comparison of the well-being structure

by Juri Hori

Introduction

"Well-being" involves peoples' positive evaluations of their lives, such as positive emotions, engagement, satisfaction, and meaning (Diener and Seligman, 2004; Oscar, 2011). According to the definition by the Millennium Ecosystem Assessment (MA), human well-being (HWB) has multiple constituents including security, basic material for a good life, health, good social relations and freedom of choice and action (Fig. 1).

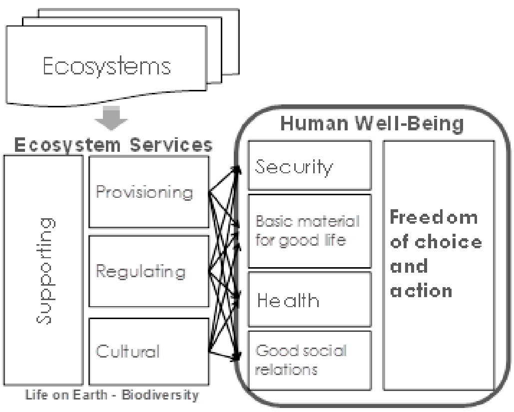


Fig. 1 Linkages between Ecosystem Services and Human Well-being (Ecosystems and human well-being: Synthesis report, 2005).

The PICES Section on *Human Dimensions of Marine Systems* (S-HD) is conducting a study on how HWB relates to marine ecosystem services in the North Pacific. This research is a part of a 5-year project on "*Marine Ecosystem Health and Human Well-Being*" (MarWeB) supported by the by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan.

How do we measure HWB?

Many social and psychological methodologies have contributed to a better understanding of one's sense of value or well-being. While economists focus mainly on economic utility or material wealth (Stevenson *et al.*, 2008), psychologists have been concentrating more on cultural values in individualism (Diener *et al.*, 1993; Hofstede, 2001; Diener and Seligman, 2002).

Here, we present results from two approaches for assessing HWB. First, we measured people's levels of "satisfaction" using the MA's five components of HWB as dependent variables (see Fig. 1, right-hand panel) and analyzed the inter-relationships among them. Second, we developed the "Well-being CUBE", composed of 35 "human needs" determined by psychology, which can evaluate the detailed characteristics of people's desired choices and actions (Fig. 2).

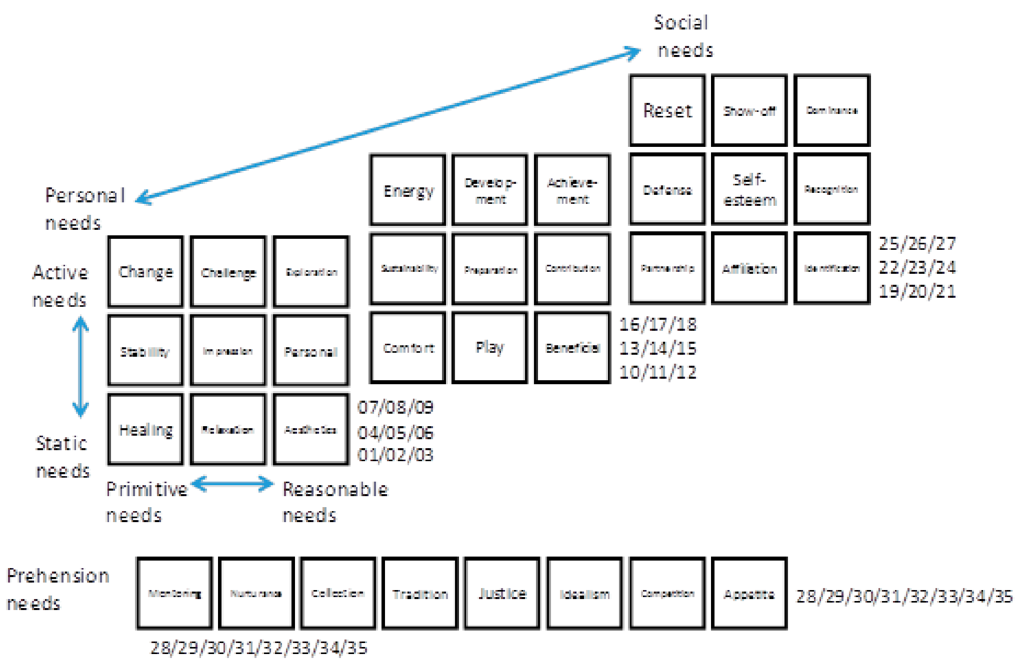


Fig. 2 Well-being CUBE composed of 35 human needs.

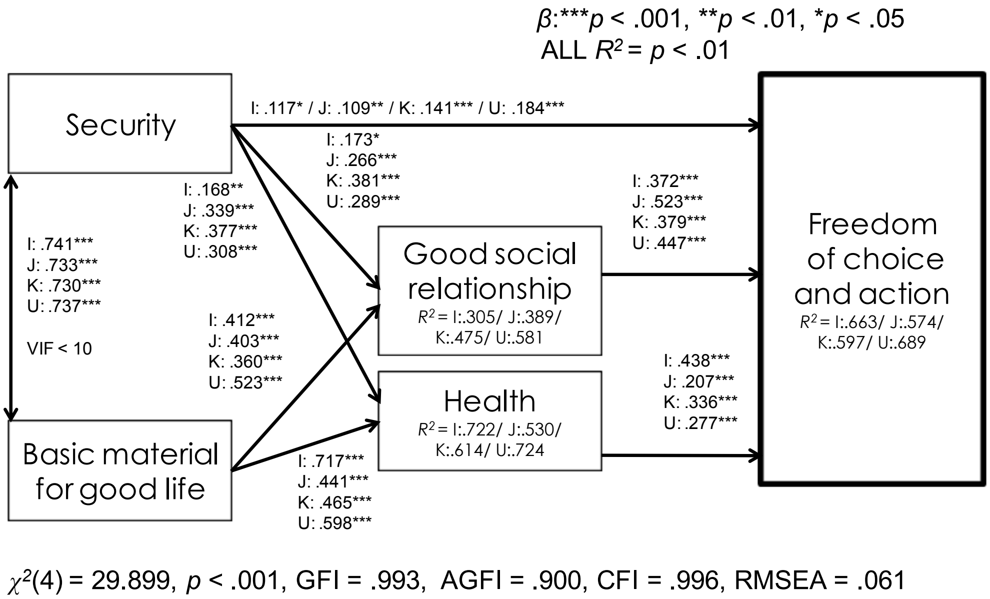
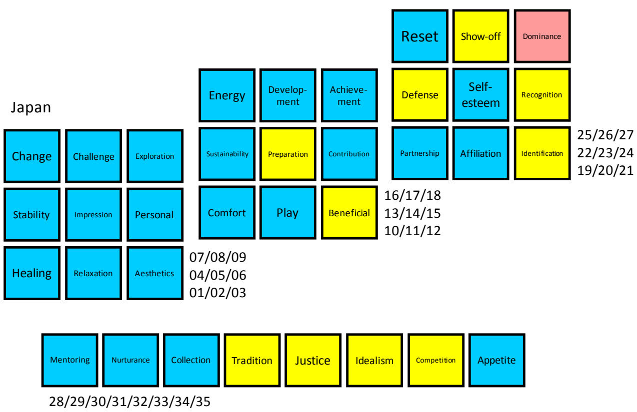
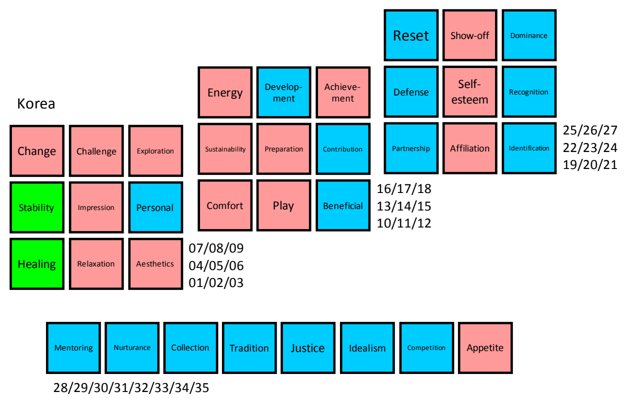


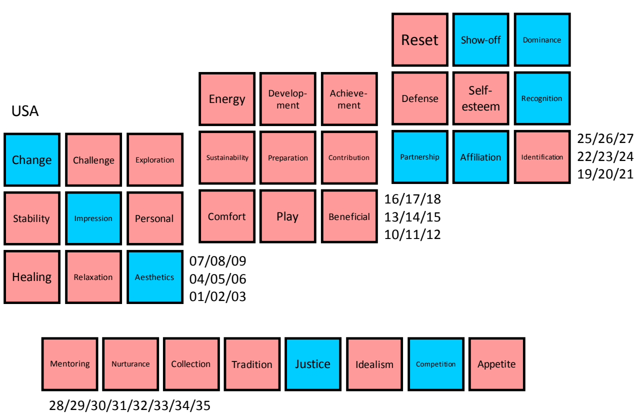
Fig. 3 Structural Equation Modeling (SEM) of the Millennium Ecosystem Assessment (MA) human well-being (HWB) (I = Indonesia, J = Japan, K = Korea, U = United States).



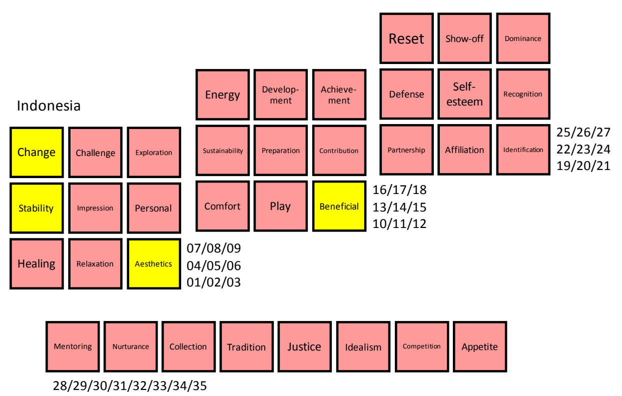
Japan-CUBE (2012)



Korea-CUBE (2013)



The United States-CUBE (2013)



Indonesia-CUBE (2014)

Fig. 4 Preliminary results of the human well-being (HWB) analysis in four countries.

Method

We measured the five components of the MA's HWB using 20 items. Each item was answered on a 1 to 5 scale ranging from "Very Dissatisfied" to "Very Satisfied". The Well-being CUBE (Fig. 2) was assessed using 35 items scored on a scale ranging from 1 to 5 ("Very Dissatisfied" to "Very Satisfied" and "No Expectation" to "High Expectation").

The first survey of 1000 people in Japan was conducted in 2012 to assess their relationships with the sea and to further develop a methodology. In 2013, the same questionnaire was used to survey 500 people in Korea and the United States. In 2014, we carried out a survey of 200 people in Indonesia.

The results from Structural Equation Modeling (SEM) analysis showed that each country has the same structure of the MA's HWB, but the primary paths to "freedom of choice and action" differ from country to country (Fig. 3). In the SEM, the structural model includes the relationships among the latent constructs. In Figure 3, one-headed arrows represent regression relationships, while the two-headed arrow represents correlational relations.

Preliminary results and next steps

The results from the Well-being CUBE analysis are summarized in Figure 4. *Red* shows high-expectation and satisfaction need, *blue* is low-expectation and satisfaction need, *yellow* is high-expectation and low-satisfaction need, and *green* is low-expectation and high-satisfaction need. Clear differences are evident among the four sampled countries.

Some initial findings include the fact that all countries surveyed have similar general concepts of HWB with regard to marine ecosystems. However, the specific understanding of how the marine ecosystem affects HWB differs among the countries and, therefore, what makes for a desirable relationship between people and the sea is different among countries. In order to grasp the big picture of HWB in the North Pacific, we are planning to collect data in the rest of the PICES member countries (Canada, China, and Russia) and in Guatemala within the lifespan of the MarWeB project.

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Juri Hori (jhori@rikkyo.ac.jp) is a psychologist at Department of Psychology of the Rikkyo University, Japan. Her major scientific interests are the effects of the sea on society and human well-being, including an international comparison of the well-being structure, and consensus building among the countries in the region. In PICES, Juri is a member of the Section on Human Dimensions of Marine Systems and the PICES project on "Marine ecosystem health and human well-being".

PICES calendar of events

PICES/ICES Intl. Workshop on "*Modeling effects of climate change on fish and fisheries*", August 10–12, 2015, Seattle, USA
PICES-2015, "*Change and Sustainability of the North Pacific*", October 15–25, 2015, Qingdao, China
CIAC 2015 on "*Recent advances in cephalopod science*", November 8–14, 2015, in Hakodate, Japan
9th International Conference on Marine Bioinvasions on "*Hulls, harbours and other invasion hotspots*", January 26–29, 2016, Sydney, Australia (co-sponsored by PICES)
ICES Symposium on "*Understanding marine socio-ecological systems: Including the human dimension in Integrated Ecosystem Assessments*", May 30–June 3, 2016, Brest, France (co-sponsored by PICES)
6th PICES/ICES Zooplankton Production Symposium on "*New challenges in a changing ocean*", May 9–13, 2016, Bergen, Norway
PICES/ICES Symposium on "*Drivers of small pelagic fish resources*", March 6–11, 2017, Victoria, Canada

A good relationship between local communities and seafood diversity

by Masahito Hirota

Background

Brackish waters, especially shrimp pond cultures, have been widely developed since the 1980s in South East Asian countries. However, deforestation for building ponds, and later, their abandonment due to mass diseases in cultures, have resulted in serious environmental degradation. Now, these problems are becoming a threat to the livelihood of the local inhabitants, giving rise to social instability at the local community level. To consider how to rectify this condition, the PICES Section on *Human Dimensions of Marine Systems*, in collaboration with the Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi, BPPT) of Indonesia, is studying the use of an environmentally friendly aquaculture technology called *Integrated multiple trophic aquaculture* (IMTA – a method of aquaculture in which fish, scallop and seaweed are managed tropically by bio-recycling so that the by-products from one species are used as food or fertilizer for another) to remediate the environment while applying a social science approach by working together with the local community. This research is a part of a 5-year project on "*Marine Ecosystem Health and Human Well-Being*" (MarWeB) supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan.

Activities

A work plan has been developed for a MarWeB-sponsored pond experiment, to be conducted at the National Center for Brackishwater Aquaculture in Karawang (Java Island, east from the Indonesian capital, Jakarta). The main purpose this experiment is to investigate the effects of IMTA on the economic return of pond operations, and the pond water quality defined in terms of macronutrient concentrations. The hypothesis being studied is whether the addition of bivalves and seaweed into the aquaculture ponds of fish or shrimp will allow successful growth of all species, and decrease the macronutrient concentrations in the pond waters.

To build the skills needed to conduct the pond experiment, a nutrient and phytoplankton training workshop, led by Drs. Mark Wells and Mitsutaku Makino, was held March 25–26, 2014, at the National Center for Brackishwater Aquaculture. Sixteen local Indonesian scientists participated (Fig. 1). The workshop was a success, with the objectives fully met and the methodological skills raised to the quality required for publication of the pond experiment results.

Using a social science approach, a commodity chain map of the IMTA products in the Karawang area (Fig. 2) has been prepared to assess what kind of businesses are locally supported, who consumers are, and how much is consumed of the multi-species produced from the IMTA (shrimps, milkfish, crab, *etc*.). We expect that, by changing shrimp monoculture to IMTA, it will be possible to retain sustainable pond culture, and suppress coastal erosion. In addition, there is high probability this will lead to new diverse job creations, and will ensure a rich variety of seafood as ingredients of everyday life in the community.

Spreading information on the effects of IMTA to the community

To establish IMTA, it is indispensable that communities receive correct and comprehensive information about this approach. Of course, shrimp monoculture is highly profitable and is an important source of employment, but to ensure sustainability, it is critical to present a well-balanced understanding of the IMTA benefits to the local population. To extend relevant information, the MarWeB project, in

Fig. 1 Participants of the Nutrient and phytoplankton training workshop held March 25–26, 2014, at the National Center for Brackishwater Aquaculture, Karawang, Indonesia.

(Continued on page 40)

Modeling the drift of marine debris generated by the 2011 tsunami in Japan

by Nikolai Maximenko, Amy MacFadyen, and Masafumi Kamachi

Role of modeling in addressing problems of marine debris

The tragic event of the March 11, 2011 tsunami in Japan has taken the lives of more than 15,000 people and generated an estimated 1.5 million tons of debris floating off eastern Honshu (Japan Ministry of Environment, 2014), an amount comparable to the annual budget of plastic marine debris of the entire North Pacific (Jambeck *et al*., 2015). This Japan tsunami marine debris (JTMD) was originally seen in photographs (Fig. 1), taken during rescue operations, as thick mats of very heterogeneous composition and sometimes reaching many kilometers in size. Several weeks later, after JTMD drifted off shore and dispersed, its monitoring became very difficult. Sparse reports from the sea were not able to provide a coherent description of the pattern and motion of JTMD and this task was adopted by numerical modelers. Even after the JTMD moved across the North Pacific and started arriving on the US/Canada west coast and, later, in Hawaii, reports from the shoreline provided very fragmentary information distorted by many biases. Questions like ‘Where is the JTMD now? How much of it is still floating? When is the next “wave” coming?’ can currently be answered only by models, utilizing the full strength of the Global Ocean Observing System (GOOS).

Since 2014, when PICES started a new project “Assessing the Debris Related Impact From Tsunami” (ADRIFT) on the North America and Hawaii coasts (Clarke Murray *et al*., 2015) funded by the Japan Ministry of Environment, scientists at the International Pacific Research Center (IPRC) of the University of Hawaii (UH), the U.S. NOAA Emergency Response Division (ERD), and the Japan modeling group, including members from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA), and Japan Atomic Energy Agency (JAEA) work together to provide modeling support to biological studies, focusing on identification of alien species colonizing JTMD and assessment of their potential impacts on the North American ecosystem.

Models used in the project

A suite of models, developed independently in the three participating groups, produced diversified outputs that were used to characterize the drift of JTMD and to assess the robustness of the conclusions under different model setups.

SCUD (Surface Currents from Diagnostics) is an empirical model, developed at IPRC/UH, forced with the data from satellite altimetry and scatterometry, and calibrated on a 1/4° global grid using trajectories of satellite-tracked drifting buoys (Maximenko and Hafner, 2010). The model calculates particle trajectories and evolution of tracer density, released on March 11, 2011, along the eastern coast of Honshu, Japan (Fig. 2).

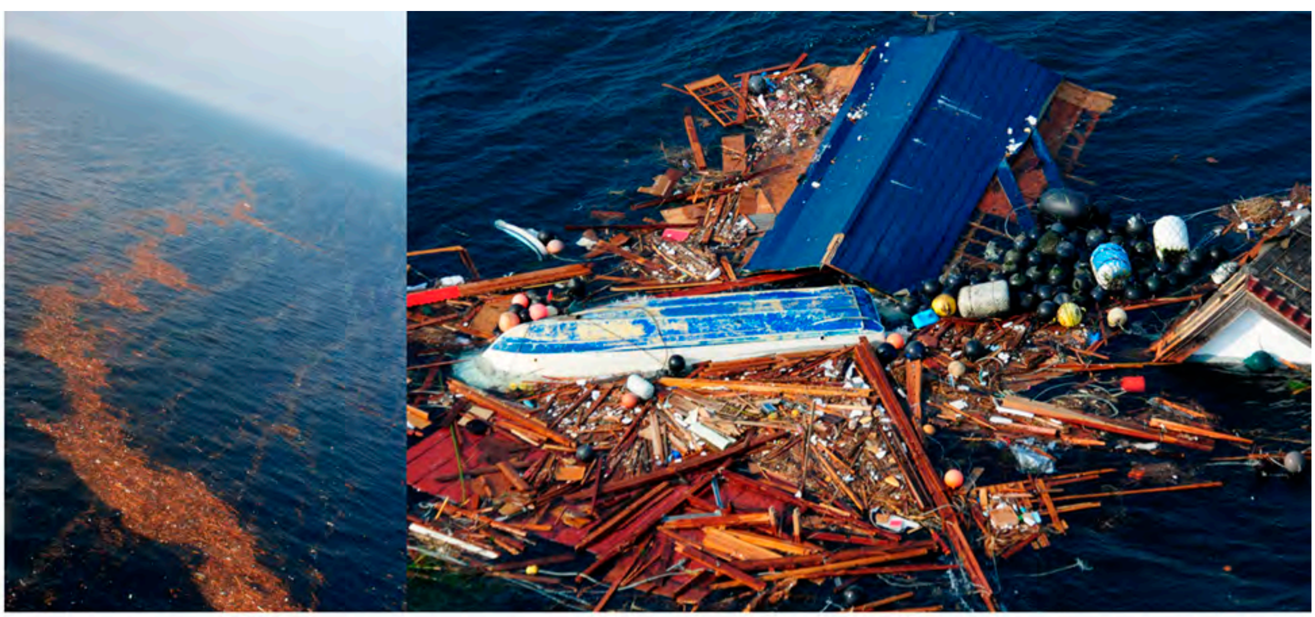

Fig. 1 An aerial view of debris near Sendai, Japan, on March 13, 2011. (Photographs courtesy of the US Navy)

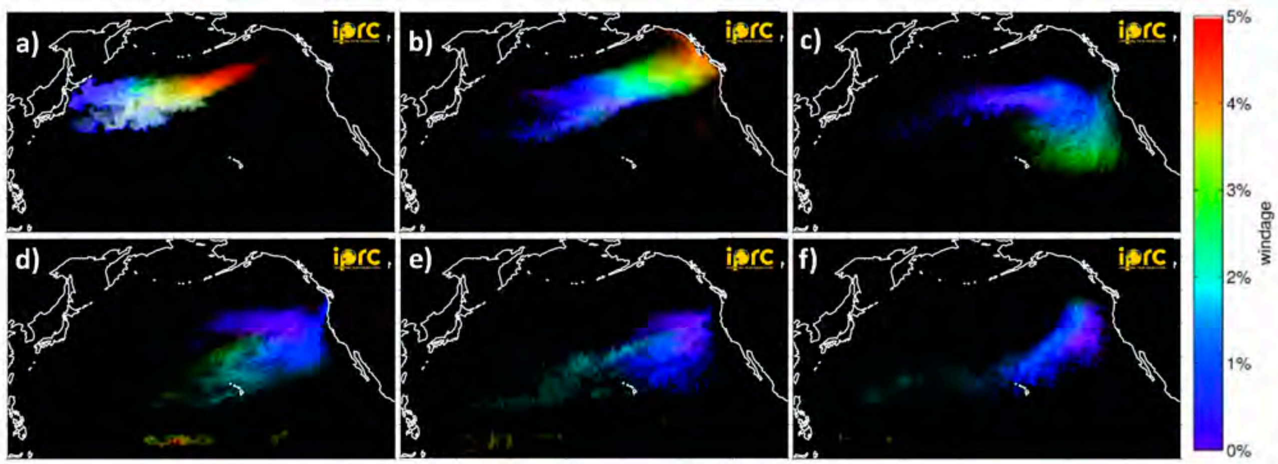

Fig. 2 *Motion of JTMD in SCUD model simulations. Colors indicate windage of the debris. Shown are maps for (a) September 1, 2011, (b) March 1, 2012, (c) September 1, 2012, (d) March 1, 2013, (e) September 1, 2013, and (f) March 1, 2014.*

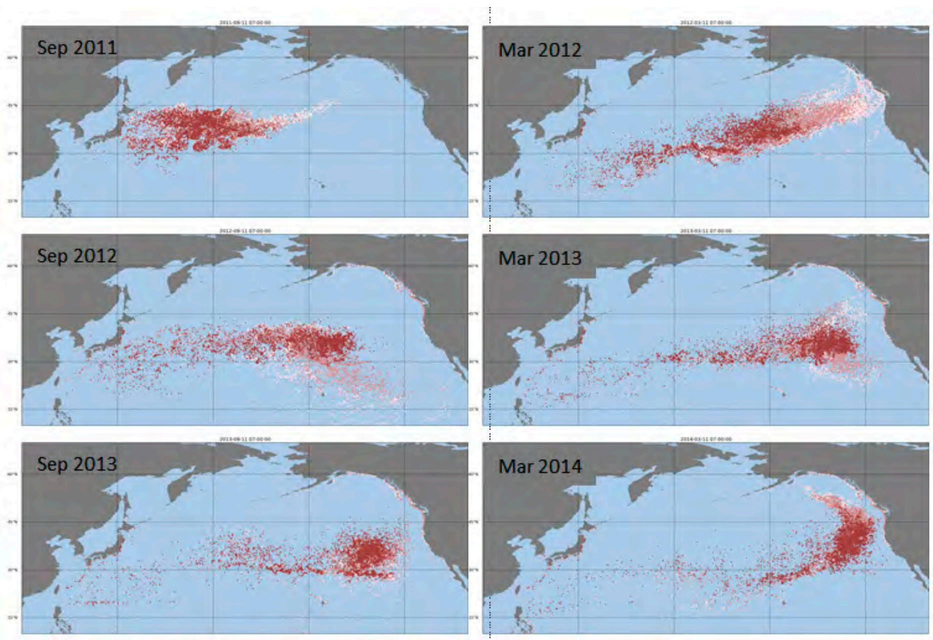

Fig. 3 *GNOME modeled particles simulate the movement of tsunami debris of varying types – from high-windage objects like styrofoam (white) to low-windage objects like wood (red). These six panels show the distribution of the model particles every 6 months from September 2011 (6 months post-tsunami; top left) to March 2014 (3 years post-tsunami; bottom right).*

The NOAA ERD team is using the GNOME (General NOAA Operational Model Environment) that was initially developed for predicting trajectories of marine pollutants (primarily floating oil). GNOME utilizes surface currents from the 1/12° operational HYCOM model from the Naval Research Laboratory and 1/4° global product from the NOAA Blended Sea Winds. In each model experiment 40,000 particles (Fig. 3) were initialized at 8 sites along the Japan coast, spanning a distance of ~700 km.

Numerical experiments of the Japan modeling group included hindcast calculation from March 2011 to August 2013 followed by the forecast through May 2016. The hindcast (Fig. 4) was based on data assimilation in the North Pacific ocean general circulation model MOVE, operated by JMA/MRI, having 1/10° resolution in the west and relaxed to a 1/2° grid elsewhere, and forced by the JMA's operational atmospheric system JCDAS. The forecast has been performed using the K7 system, operated by JAMSTEC, and having a global 1° resolution. Particle motion was computed using the SEA-GEARN dispersion model, operated by JAEA; 153,600 particles were released in model experiments offshore of Iwate, Miyagi, and Fukushima prefectures (Kawamura *et al*., 2014).

To account for a "windage" or a "leeway" (motion of floating objects under direct force of wind), a corresponding fraction (between 0 and 6%) of wind velocity, used to force the models, was added to the current vectors to produce drift velocities.

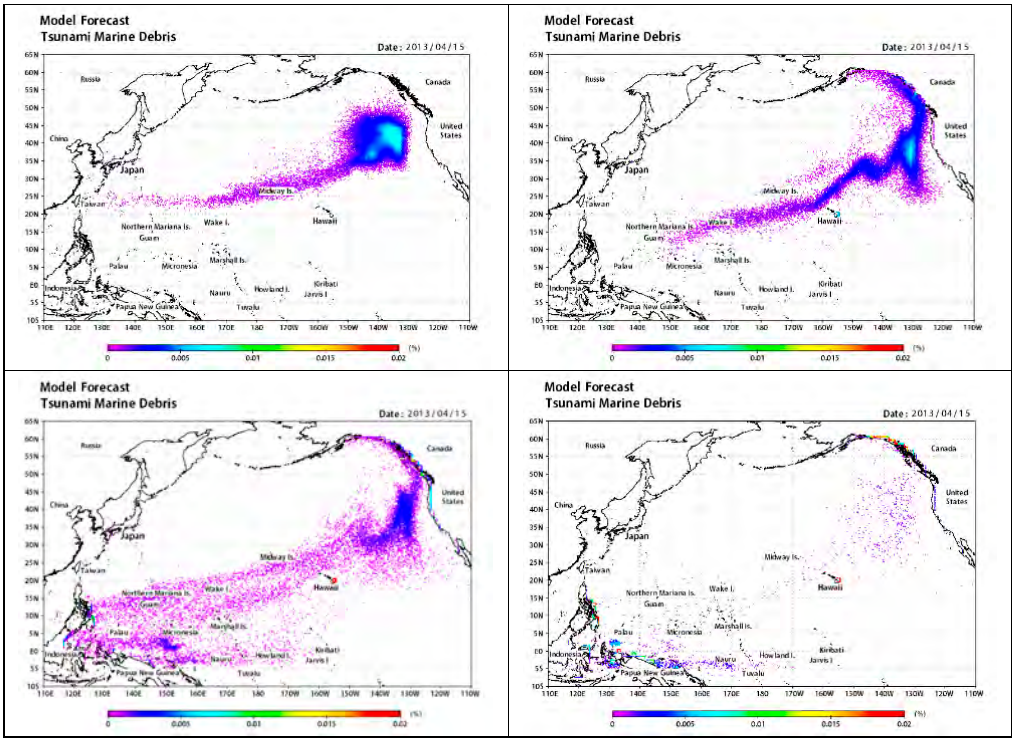

Fig. 4 April 15, 2013 distributions of SEA-GEARN/MOVE-K7 model particles for four values of windage: 0, 2.5, 3.5, and 5%. Colors indicate concentration of particles on a computational grid.

Model solutions

With all the complexity of the Kuroshio-Oyashio frontal zone, located east of Japan, climatological eastward currents and westerly winds lead all types of floating debris away from the eastern Japan coast towards North America. (Figure 5 exemplifies this eastward drift with trajectories of particles calculated in the SEA-GEARN/MOVE-K7 system for 5% windage.) Nevertheless, details of the drift such as speed, diffusivity, and long-tern destination are sensitive to the windage value. As illustrated by Figures 2–4 all three models unanimously suggest that in the first months after the March 11, 2011 tsunami, JTMD was sorted according to the windage properties. High-windage tracers were moving faster and started reaching the U.S./Canada west coast before the end of 2011. Much of this JTMD (red color in Fig. 2, white in Fig. 3, and bottom right panel in Fig. 4) ended on shore and only a small proportion could possibly drift along the coastline toward the south and then recirculate west-southwest between and around the Hawaiian Islands. Low-windage tracers (blue in Fig. 2, red in Fig. 3, and top left panel in Fig. 4) moved much slower and, after entering the eastern North Pacific, most of this debris was pulled into the convergence, located between Hawaii and California and known as the "garbage patch" for observed persistently high concentrations of microplastics, fishing gear, and other types of semi-submerged debris.

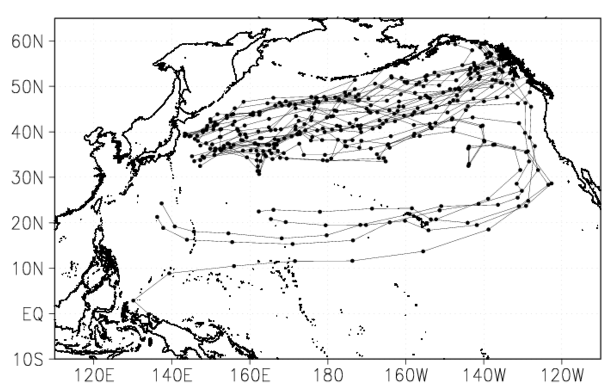

Fig. 5 Trajectories of particles with 5.0% windage between April 2011 and September 2013 in the SEA-GEARN/MOVE-K7 model (Kawamura et al., 2014).

In addition to the common types, low-windage JTMD brought to the patch such unusual items as overturned boats, wood (*e.g*., lumber from broken houses, electrical poles, and trees), propane cylinders, and a broad variety of other objects heavily overgrown with biofouling. Low-windage debris is hard to observe at sea but its presence in the areas projected by models was confirmed, for example, by unusually high number of collisions with woody debris, reported by participants of the Los-Angeles-Honolulu Transpac yacht race in the summer of 2013. Dynamics of the gyre exhibit strong seasonality. In late summer–fall, the garbage patch is stabilized by the "subtropical high" and converging currents keep debris in the ocean and prevent it from flushing ashore. In winter–spring, however, the "Aleutian low" perturbs the circulation so that stretched edges of the patch reach the U.S./Canada west coast in the east and Hawaii in the west and bring debris to the shores.

Model comparison with observations

Marine debris datasets, allowing quantitative comparison with model solutions, are very rare. In this project, we combined information from NOAA on Disaster Debris sightings, Japan's Office of Ocean Policy, and IPRC/UH dataset. To reduce the dependence on unknown windage parameters, the analysis was narrowed down to one type of JTMD: boats, skiffs, and vessels. The advantage of this choice is that boats are easier to trace back to their origin and, even when exact identification is not possible, the probability of significant dataset contamination by non-JTMD boats is small. The merged dataset, covering years 2011–2014, includes 277 reports whose geographical distribution and timing are shown in Figure 6. There was a general transition from reports in the western Pacific in 2011 to the east in 2012–2013 and possibly to the southeast in 2013–2014. The pattern of the reports suggests strong interaction between two factors: the presence of JTMD and presence of the observer. The absence of the reports from high latitudes east of the date line is likely due to gaps in the observational network and bad weather conditions.

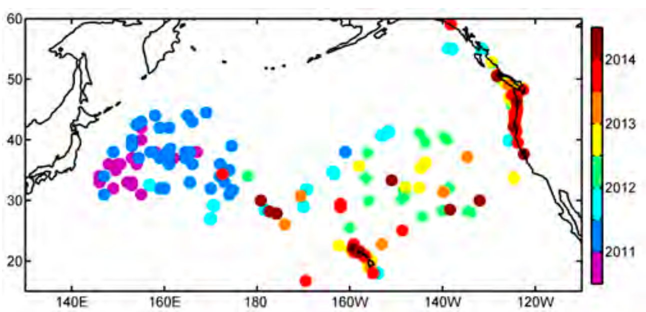

Fig. 6 Reported locations of boats/skiffs/ships and (colors) times of the reports. Color bar spans January 2011–December 2014 and labeled ticks mark central moments of the years.

Remarkably, 1 to 4 months after the tsunami (purple dots in Fig. 6) boat reports already demonstrated very strong dispersion. This could be due to the presence of two strong eastward jets, associated with the Kuroshio Extension and Subarctic Front, surrounded with much slower background flows. It could also result from a broad range of different windages. Indeed, depending on the orientation of the same boat in water (Fig. 7), its exposure to the wind and its resultant drift can be quite different.

The highest concentration of reports appears on the U.S./Canada west coast between 40°N (northern California) and 51°N (northern tip of Vancouver Island) where 79 boats were reported in 2011–2014 (Fig. 6). After applying a low-pass filter, observations combine into three main peaks with the maxima in summer 2012, winter–spring 2013, and spring–summer 2014 (Fig. 8). Remarkably, all three models used in this study reveal similar peaks. Additionally, the SEA-GEARN/MOVE-K7 system, which was designed to study JTMD motion in the northwestern Pacific in the first months after the tsunami, adequately captured the 2012 peak in North America.

Comparison between the models and reports led to a number of interesting conclusions. While boats and ships were originally expected to fall into a high-windage category, best correspondence was found for intermediate windage parameter values: 1.6% for SCUD and 2.5–3.5% for GNOME and SEA-GEARN/MOVE-K7. This is consistent with the conditions of the reported boats, many of which were damaged, filled with water, heavily fouled, and/or flipped over. There is a possibility that much of the high-windage debris ended in remote areas of Alaska and northern British Columbia where observations are scarce. Interestingly, observed peaks lag behind model timelines by 1 to 3 months. This lag may reflect a delay between the moment of a boat landing and the time when it was reported. For example, a recent aerial survey of Vancouver Island (Clarke Murray *et al.*, 2015) revealed at least two new boats, missing from reports, whose arrival times will be hard to determine.

Knowing the correct windage range helps to improve modeling of JTMD trajectories, patterns, and timelines. Because of the differences in surface currents representation, optimal windage values can be different for different models. These differences combined with the incompleteness of the observational dataset can explain some inconsistencies between the amplitudes of individual peaks in Figure 8. By scaling the SCUD timeline (blue line in Fig. 8) we estimate that 400–700 boats remained floating at the end of 2014. Projected back to the start point, the model gives 500–1000 as an estimate of the initial number of floating boats in March 2011. Given the large error bars, these figures are not contradictions of other estimates. On November 16, 2011, the Japan Coast Guard detected 506

Fig. 7 Examples of JTMD boat orientation in water (from left to right): normal, upright but filled with water, upside down, and vertical. (Photographs courtesy of the Japan Coast Guard: http://www.kaiho.mlit.go.jp/info/kouhou/jisin/20110311miyagi/hyouryuu.htm)

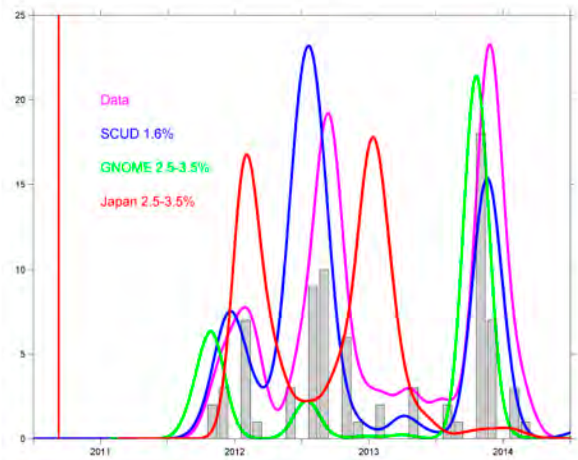

Fig. 8 Monthly counts of boats on the U.S./Canada west coast (gray bars) and low-pass filtered timelines of boat fluxes in observations (magenta) and model experiments with different windages: 1.6% for SCUD (blue) and 2.5–3.5% averages for GNOME (green) and SEA-GEARN/MOVE-K7 (red). Vertical red line marks March 11, 2011. Units on y-axis are boat counts for monthly reports and conventional for other timelines.

skiffs/vessels, drifting off the devastated shoreline. The Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan estimated the total number of fishing skiffs/vessels that were lost or crushed by the tsunami as 18,936 but how many of these vessels drifted away remains unknown. The Ministry of the Environment (MoE) of Japan estimated that the total amount of skiffs and vessels that became JTMD was about 102,000 tons but the total tonnage of skiffs/vessels that floated away was only 1,000 tons.

Scaled SCUD solution estimates that less than 10% of the tracer washes ashore annually and suggests that more than 70% of JTMD with windage close to 1.6% was still floating at the end of 2014. This means that boats from the 2011 tsunami, built to withstand rough ocean conditions, will likely continue coming to the U.S./Canada coastline for several years. At the same time, JTMD wandering in the gyre gradually mixes with marine debris from other sources and loses its identity.

Future progress in marine debris modeling requires radically improved at-sea and on-shore observing systems as well as better model description of processes on the sea surface (such as breaking wind waves) and their effects on floating objects.

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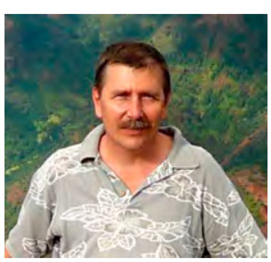
Acknowledgments: The ADRIFT project is funded by the Ministry of the Environment (MoE) of Japan through the North Pacific Marine Science Organization (PICES). The Japan modeling group acknowledges past support received from the Japan Office of Ocean Policy and MoE for JTMD simulations. Help from Jan Hafner, Gisela Speidel, Kin Lik Wang, Christina Curto (IPRC), Nir Barnea, Peter Murphy, and Lexter Tapawan (NOAA) and many contributors to the dataset is acknowledged. The SCUD model was built with partial support from the NASA Ocean Surface Topography Science Team (OSTST).



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Drs. Maximenko, MacFadyen, and Kamachi are the PI's of the modeling component of the ADRIFT project.

Opening of the Hakodate Research Center for Fisheries and Oceans

by Yasunori Sakurai and Dharmamony Vijai

Fig. 1 Hakodate Research Center for Fisheries and Oceans

A new state-of-the-art marine research facility was opened by Japan in June 2014 in Hakodate (Fig. 1), and is fostering collaborative research between industry and academia for ocean and fisheries research. Hakodate is a city of international tourism renowned for its night view from Mt. Hakodate, its exotic cityscape and an inviting atmosphere. Facing the Tsugaru Strait where the Tsushima and Oyashio Currents meet, Hakodate offers an optimal environment for the location of research facilities for marine science and the development of fisheries and related industries. Hakodate is also the base of numerous research facilities and offices of marine and oceanic industries, including the Faculty of Fisheries Sciences, Hokkaido University.

In March 2003, Hakodate initiated a city plan entitled the "Conception of International Fisheries and Ocean City, Hakodate". The Conception prescribes Hakodate's goal of becoming an international base of the academic research on fisheries and marine science by taking advantage of its natural setting and the strong industry-academia-government cooperation that will facilitate original and cutting-edge research and development capable of producing useful and innovative technologies. The ultimate goal of the Conception is to contribute to the development of scientific technology and to revitalize the regional industry and economy by creating new products and industries (see Table 1).

Table 1 The basic principle of the "Conception of International Fisheries and Ocean City, Hakodate"

Basic policy	1. enhance the current scientific environment and invite more related academic research institute to the region, 2. strengthen the cooperation between industry and academia, 3. invite businesses and help start-up related businesses, 4. promote tourism in harmony with science.
Main measures	1. Attract academic research institutes on fisheries and ocean, 2. Promote cooperation between the region and academia, 3. Link tourism and academia, 4. Integrate ocean awareness into the local atmosphere.
Objective	For Hakodate to be a Fisheries and Ocean City: A base for international fisheries and the promotion of ocean life.
Ripple effects	1. Contribute to the national policy of technological advancement, 2. Create new industries by taking advantage of the cooperation among industry, academia and local government, 3. Create jobs, 4. Revitalize industries and local economy.

Overview of Center facilities and equipment

1. Main building:
    - 4 storeys (7,543.61 m^2),
    - 31 rooms,
    - Shared experimental facilities (biology and chemistry labs, breeding/culture area, large tank),
    - Meeting rooms, conference hall, training rooms, *etc*.
2. Ocean research building:
    - 2 storeys (974.40 m^2),
    - Laboratories,
    - Precision equipment warehouse.
3. Sea-water intake building:
    - 1 storey (287.99 m^2),
    - Direct seawater intake facilities,
    - Seawater filtering units.
4. Garage building:
    - 1 storey (60.79 m^2),
    - Warehouse.

The Center operates on a lease system where academic research institutes and private companies can avail required facilities and rooms on a timely basis. A quay is right in front of the Center where research vessels can berth.

Large experimental tank

In order to perform breeding/rearing and engineering experiments the Center installed a large tank (depth: 6 m; length: 10 m; width: 5 m; 300 tons in volume, Fig. 2). The tank is constructed of reinforced concrete lined with acrylic (transparent) viewing windows.

The first experiments (July to September 2014) using this tank was conducted by the first author of this article, Faculty of Fisheries Sciences, Hokkaido University, who is an expert on cephalopod reproductive biology. The range of experiments conducted on squid in the experimental tank have included:

- Maintenance of live Japanese flying squid (Fig. 3a),
- Feeding experiments,
- Spawning behavior,
- Effects of thermoclines on egg mass settlement (Fig. 3b),
- Paralarval recruitment,
- Behavior in response to different LED lights.

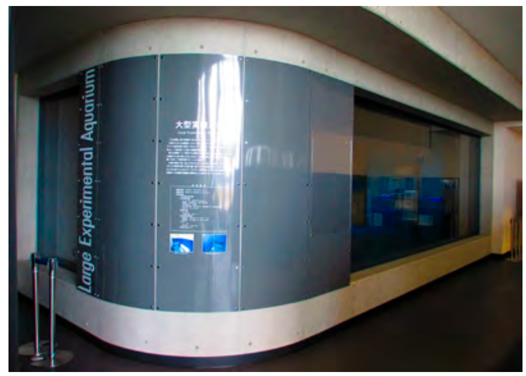

Fig. 2 Large experimental tank.

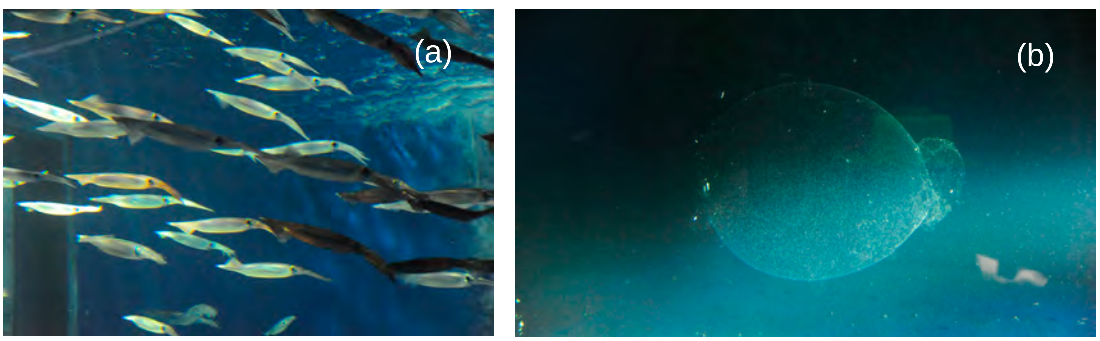

Fig. 3 (a) Japanese flying squid in captivity; (b) Egg mass sustained by a thermocline in the tank.

Reference: http://center.marine-hakodate.jp/

Dr. Yasunori Sakurai (sakurai@fish.hokudai.ac.jp) is a Professor at the Faculty of Fisheries Sciences, Hokkaido University in Hakodate, Japan. His research interests include 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 biology of marine mammals (Steller sea lion and seals). He has directed a number of national research projects and programs with focus on ecosystem-based management for sustainable fisheries in Japan. Dr. Sakurai served on several PICES expert groups and committees and has been a member of the Cephalopod International Advisory Counsel (CIAC) and Scientific Steering Committee of Ecosystem Study of Sub-Arctic Ecosystem (ESSAS). He has been President of the Japanese Society for Fisheries Oceanography (JSFO) since 2009.

Dr. Dharmamony Vijai (keralavijai@yahoo.co.in) is a Research Scientist working on North Pacific neon flying squid and Japanese common squid at the School of Fisheries Sciences, Hokkaido University. He was a research fellow at the Central Marine Fisheries Research Institute (CMFRI), Kochi, India from 2009–2011. Dr. Vijai's research interests include cephalopod behavior, reproductive biology, and distribution.

The state of the western North Pacific during the 2014/2015 cold season

by Takashi Yoshida

The western North Pacific during the 2014/2015 cold season was characterized by persistent below-average sea surface temperatures (SSTs) around 30°N (Fig. 1), as also seen during the first half of 2014 and its warm season. The negative anomaly weakened in April 2015 and turned positive in May 2015.

The winter maximum sea ice extent in the Sea of Okhotsk was the lowest ever at 0.67 million km^2 in late February. This was 42% below the 30-year average of 1.17 million km^2 and 21% below the previous record low of 0.86 million km^2 (set in 1983/1984). The seasonal maximum exhibits a long-term downward trend of 7.1×10^4 km^2 per decade, which corresponds to 4.5% of the Sea of Okhotsk's total area (Figs. 2 and 3).

During the winter season, the northern part of Japan often experienced snowstorms caused by extremely developed low-pressure systems that lingered over the sea east of Japan for several days. One significant system of this kind remained over the sea east of Hokkaido from December 16 to December 18, causing storm surge conditions in the area around Nemuro City on December 17.

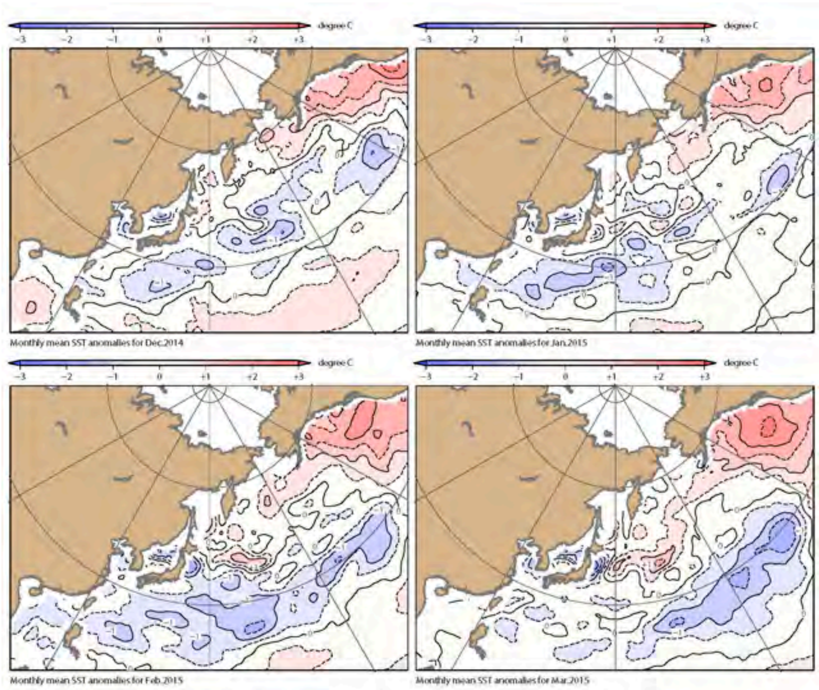

Fig. 1 Monthly mean sea surface temperature (SST) anomalies for December 2014 and January, February and March 2015. Monthly mean SSTs are based on JMA's COBE-SST (Centennial in situ Observation-Based Estimates of variability of SST and marine meteorological variables). Anomalies are deviations from the 1981–2010 climatology.

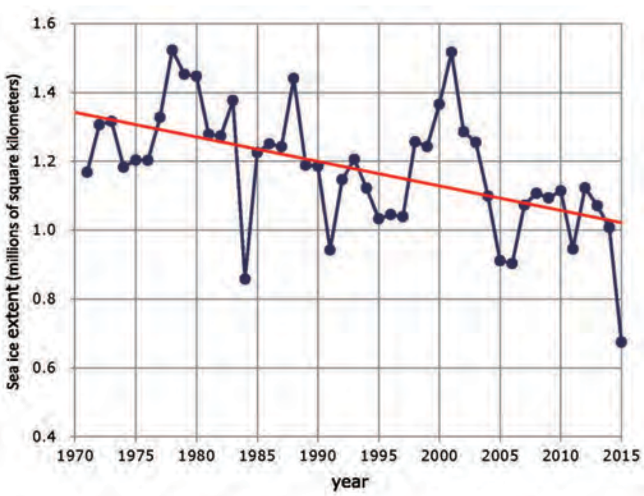

Fig. 2 Time-series representation of winter maximum sea ice extent values in the Sea of Okhotsk from 1971 to 2015. The red line represents the long-term linear trend.

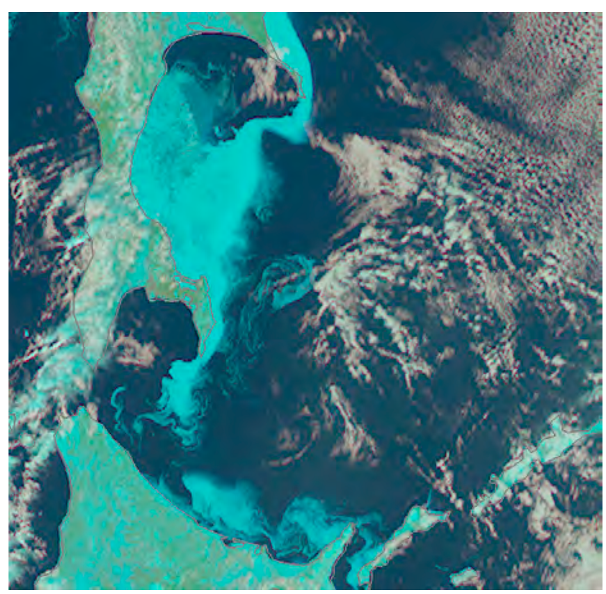

Fig. 3 Satellite image of sea ice in the southern part of the Sea of Okhotsk on March 6, 2015 captured by JMA's next-generation Himawari-8 geostationary meteorological satellite (launched at 5:16 UTC on October 7, 2014). Himawari-8's RGB composite imagery enhances clouds in white and sea ice in cyan, and shows the exact distribution of sea ice.

Dr. Takashi Yoshida (tyoshida@met.kishou.go.jp) is the Head of the Office of Marine Prediction at the Japan Meteorological Agency in Tokyo. His group is tasked with issuing various oceanographic products, including wave analysis, coastal sea level monitoring, ocean temperature and current monitoring, sea ice analysis and their forecasts. He was involved in PICES as a member of Working Group on Subarctic Gyre (WG 6) and contributed Western Pacific assessments to PICES Press previously in the 1990s.

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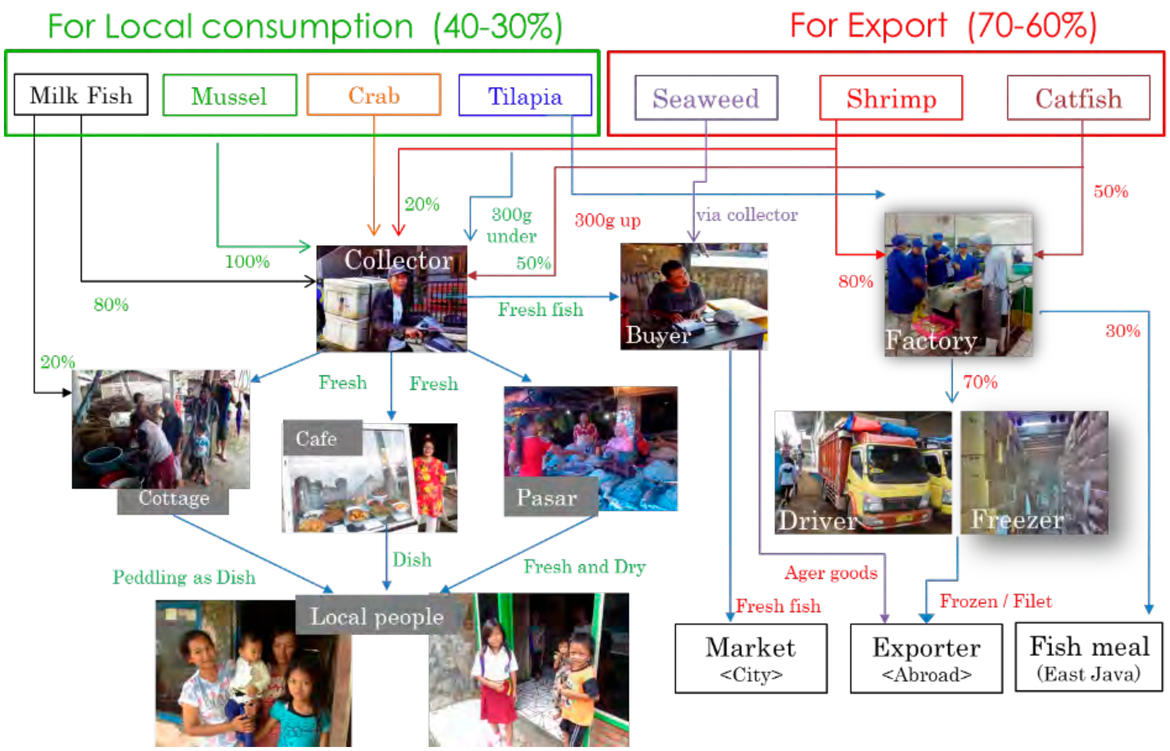

Fig. 2 The commodity chain map of IMTA products in the Karawang area, Indonesia.

cooperation with BPPT, has held two international workshops in Indonesia in March 2013 and March 2014 (for a review of the first workshop see PICES Press, 2013, Vol. 21, No. 2, pp. 18–19). These workshops drew not only local and international scientists, concerned with pond aquaculture, but also attracted special attention of the Indonesian press. Through the mass media, we have successfully raised the awareness of the general public about seafood sustainability. For the future, it is expected that the Indonesian community will establish and lead local IMTA programs in order to rectify their own well-being.

Dr. Masahito Hirota (mmhirota@affrc.go.jp) is a Research Scientist at the National Research Institute of Fisheries, Fisheries Research Agency, Japan. Masahito's field of research is studying the commodity chain mechanism from a social science aspect, mainly in South East Asian countries, with the aim to communicate with scientists in different fields and exchange knowledge to raise awareness about human well-being. Within PICES, he is a member of the Fishery Science Committee and Section Human Dimension of Marine Systems. Masahito also serves on the MarWeB Project Science Team, leading activities on seafood business and supply chain management.

The Bering Sea: Current status and recent trends

by Lisa Eisner

Climate and oceanography

The eastern Bering Sea shelf experienced weather during the past cold season of 2014–15 that was overall quite similar to the cold season of 2013–14. For the period of October 2014 through March 2015, mean air temperatures were 1–2°C warmer than normal on the southern portion of the shelf and about 3°C warmer than normal in the north. The warm weather can be attributed mostly to relatively warm and moist air aloft over the Bering Sea shelf due to a ridge of anomalously high geopotential heights extending from the western Bering Sea to mainland Alaska. The result was suppression in the development of extremely cold air masses over Alaska, the usual source of the lower-atmospheric flow for the Bering Sea shelf. This is also illustrated with a time series of air temperatures at St. Paul (Fig. 1) which shows a tendency for relatively warm weather and only short periods of moderately below-normal temperatures, especially in the first half of the winter.

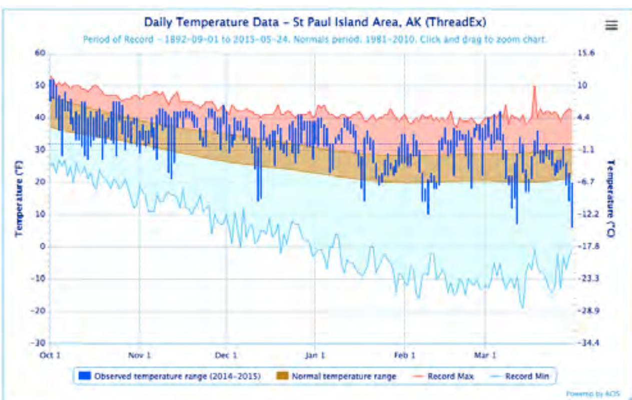

Fig. 1 Daily air temperatures at St. Paul, Alaska (PASN) for October 2014 through March 2015. The blue bars indicate the range between minimum and maximum temperatures; the daily average and record minimum and maximum temperatures are also indicated. Figure courtesy of Nick Bond.

The past cold season included anomalously high sea level pressure (SLP) from the western Bering Sea across western mainland Alaska into the northern Gulf of Alaska, and lower than normal SLP south of the Alaska Peninsula (Fig. 2). The consequence for the mean winds was weak anomalies for the northern Bering Sea shelf and moderate anomalies from the northeast for the southern shelf. The ocean temperature anomalies on the southern shelf were on the order of 1°C above normal for the season as a whole. The relative warmth of this water prevented ice from reaching as far south as usual even though there were periods of sustained northerly winds late in the cold season, such as during the middle part of April 2015.

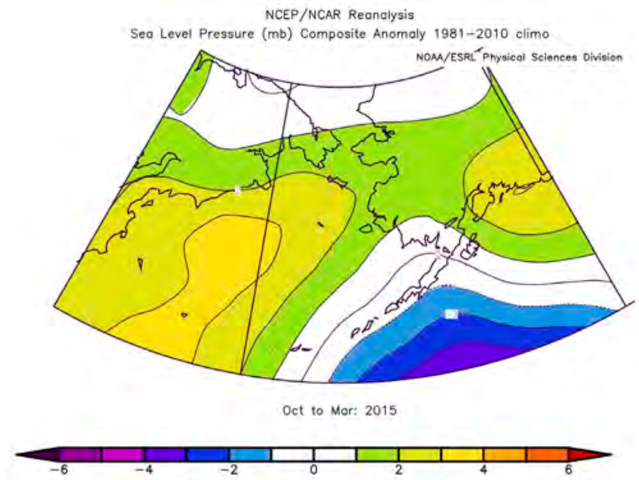

Fig. 2 NOAA mean sea level pressure (mb) anomaly (deviations from 1981–2010 climatology) for October 2014 through March 2015. Figure courtesy of Nick Bond.

R/V Sikuliaq ice trials

The R/V *Sikuliaq*, "young sea ice" in Inupiaq, is a new U.S. oceanographic research vessel, 80 m in length with a hardened hull (not an ice breaker) rated to move through sea ice as thick as 0.8 m. This vessel will enable researchers to conduct sampling during shoulder seasons (spring and fall) in sub-Arctic and Arctic regions.

Ice trials were conducted over 23 days from March 19 to April 7, 2015 in the eastern Bering Sea. The scientific crew consisted of 14 marine scientists including oceanographers, and marine mammal, sea bird and ice observers. Sampling included: 1) underway data collection using ship-mounted sensors to measure meteorological conditions, ocean currents, seawater temperature, salinity, fluorescence, and sea floor depth, and from the bridge, making visual observations of marine mammals and birds and ice conditions, 2) oceanographic stations to measure water column and seafloor physics and biota, and 3) ice stations where scientists collected sea ice cores, measured sea ice thickness, and listened for marine mammals using dipping hydrophones. A small, Sea Otter ROV was used at two locations to explore under the sea ice. On board processing of samples was conducted in the ship's laboratories (*e.g.*, phytoplankton taxonomic identification), and experiments were conducted in the ship's environmental chamber (*e.g.*, measurements of copepod respiration). Oceanographic sampling was done at 23 stations with ice sampling at 5 of these locations (Fig. 3). Overall, the ship performed well, the science party was impressed by the ship and *Sikuliaq* team, and scientific sampling was very successful.

For more details, see:

- http://news.sciencemag.org/earth/2015/04/new-u-s-arctic-vessel-shipshape-scientists-report

and

- https://arcticodyssey.wordpress.com/.

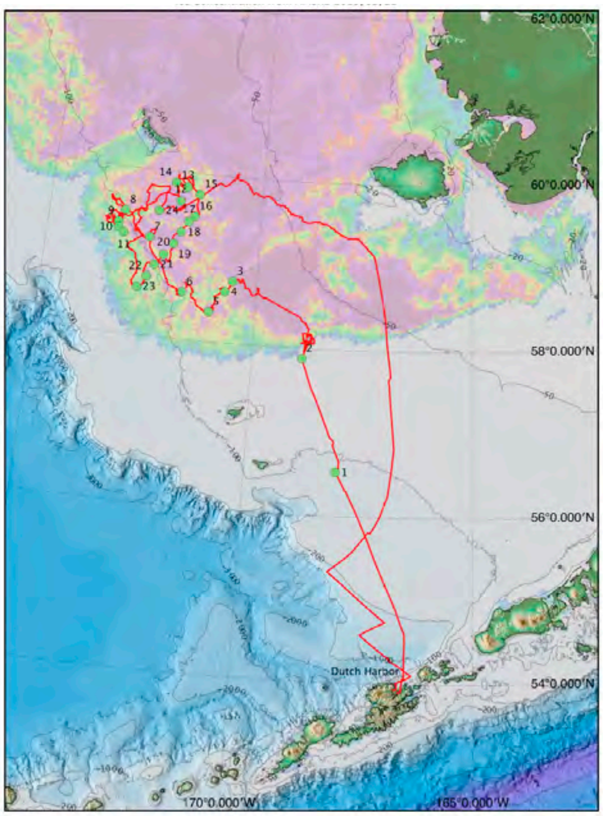

Fig. 3 *Cruise track (red line) and locations of oceanographic stations (numbered green dots) from the ice trial cruise of the R/V Sikuliaq. Ice concentration from the Advanced Microwave Scanning Radiometer 2(AMSR2) satellite for March 22, 2015 is overlain. Figure by Steve Roberts.*

Saildrones in the eastern Bering Sea

The Innovative Technology for Arctic Exploration (ITAE) program is a new and collaborative initiative, working to develop technologies for exploratory use in the U.S. Arctic. As part of this effort, Saildrones, unmanned near-surface vehicles equipped with meteorological and oceanographic sensors, were released into the Bering Sea (for the first time) by the National Oceanic and Atmospheric Association (NOAA) Pacific Marine Environmental Laboratory (PMEL), in partnership with the University of Washington (UW), University of Alaska Fairbanks (UAF), and Saildrone Inc.

One important goal for effective assessment of the Arctic environment and ecosystem is the operation of high-resolution sensors on autonomous platforms near sea ice. PMEL has been working with Saildrone Inc. to incorporate meteorological and oceanographic sensors in the design including wind, air temperature and humidity, barometer, surface water temperature and salinity, dissolved oxygen and chlorophyll *a* fluorescence. The Saildrone is made of state-of-the-art carbon fiber composites, uses basic sailing principles and is solar powered. This new autonomous platform is 6.1 m tall (above the water line), reaches almost 5.8 m in length and can carry a payload up to 90 kg. The Saildrone moves quickly through the water, 2 to 5 times faster than other available autonomous vehicles.

Fig. 4 *Saildrone launch in Dutch Harbor, Alaska. ©Saildrone Inc.*

Deployment occurred dockside in Dutch Harbor, Alaska, on April 23 and 24, 2015 (Fig. 4). A series of sea trials were conducted approximately 40 nm north of Dutch Harbor. With successful initial testing, the two Saildrones moved towards Bering Sea mooring M2 for comparative measurement studies with the NOAA Ship *Oscar Dyson* during the NOAA Ecosystem and Fisheries-Oceanography Coordinated Investigations group (EcoFOCI) spring mooring cruise (April 24 to May 10, 2015) in the southeastern Bering Sea (Fig. 5). For much of the deployment, the Saildrones followed along the 70 m isobath, a historical sampling line for EcoFOCI, and are now moving towards Bering Sea mooring M5 and northward. Once the mission is complete in mid-July, the two Saildrones will be recovered in Nome, Alaska. Read more about the project at http://itae.ocean.washington.edu/ and http://pmel.noaa.gov/.

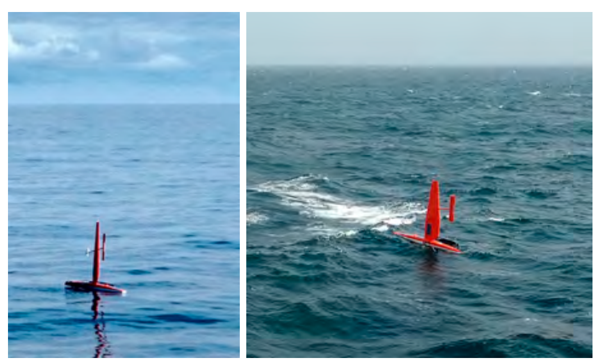

Fig. 5 *Saildrones in the eastern Bering Sea during the spring mooring cruise. Photos by Lisa Eisner.*

EcoFOCI eastern Bering Sea surveys

In 2015, EcoFOCI is conducting surveys in the Gulf of Alaska, eastern Bering Sea, and Chukchi Sea from March to September on six research vessels, including the NOAA Ships *Oscar Dyson* and *Ron Brown*. This will be the thirtysecond field season for EcoFOCI, an umbrella program between PMEL and the Recruitment Processes program at the Alaska Fisheries Science Center (AFSC). As part of the field season, the surface mooring M2 was successfully deployed for the twenty-first consecutive year (Fig. 6) during the recent *Oscar Dyson* spring mooring cruise. Oceanographic variables, phytoplankton production and taxonomy, and zooplankton were sampled in addition to comparative measurement studies with two Saildrones (described above) at M2 and along the 70 m isobath.

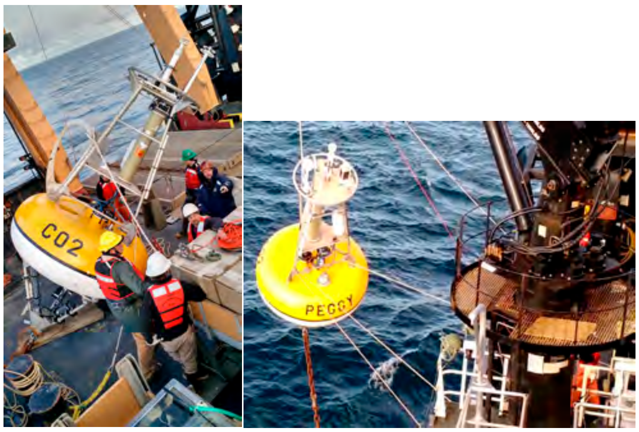

Fig. 6 Deployment of the surface M2 mooring from the R/V Oscar Dyson during April 2015. Photos by Lisa Eisner.

Eastern Bering Sea integrated ecosystem surveys by EcoFOCI in collaboration with other AFSC programs are traditionally conducted during even years, alternating with surveys of the Gulf of Alaska in odd years. However, to determine whether 2014 was a short-term warm year anomaly or is the first in a series of consecutive warm years, supplemental funding was provided from NOAA Fisheries to conduct time-sensitive critical fisheries oceanography research in the eastern Bering Sea during late summer/early fall 2015; this was an opportunity to study ecosystem change in progress. A successive warm year could potentially initiate a multi-trophic ecosystem shift that will ultimately be detrimental to commercial fisheries, including walleye pollock. Since receiving this funding, scientists have observed that warm year ecosystem conditions have persisted through the winter (described above in the climate and oceanography section); present indications are that 2015 will be one of the warmest years on record.

Upcoming Bering Sea surveys

- The AFSC, NOAA will conduct its annual bottom trawl survey on board two vessels – the F/V *Alaska Knight* and the F/V *Vesteraalen* on the shelf between the depths of 20 and 200 m from Bristol Bay northward to latitude 62°N, from May 28 to August 4, 2015.
- The AFSC and PMEL (includes EcoFOCI), NOAA will conduct oceanography and pelagic fish surveys on board the NOAA Ship *Oscar Dyson* on the southeastern shelf, September 5 to October 6, 2015.
- The AFSC, NOAA and Alaska Department of Fish and Game (ADFG) will conduct joint northeastern Bering Sea fisheries oceanography surveys to estimate juvenile Chinook abundance and fishing power differences between the F/V *Alaskan Endeavor* and the ADFG RV *Pandalus* as part of the ADFG Chinook Salmon Research Initiative. Surveys are planned for September 2015.

Deep-Sea Research II, Bering Sea special issues

- The North Pacific Research Board announced the publication of the third special issue of *Deep-Sea Research Part II*, with 24 new papers on data from the Bering Sea Project.
- The fourth and final special issue of *Deep-Sea Research Part II* from the Bering Sea Project is currently being finalized.

Acknowledgements: Many thanks to the scientists who helped create this report: Dr. Nicholas Bond, Dr. Calvin Mordy and Heather Tabisola at JISAO, PMEL; Dr. Phyllis Stabeno at NOAA, PMEL; Dr. Janet-Duffy-Anderson; Dr. Robert Lauth and Jim Murphy at NOAA, AFSC; Dr. Carin Ashjian at Woods Hole Oceanographic Institution.

Dr. Lisa Eisner (lisa.eisner@noaa.gov) is a Biological/Fisheries Oceanographer at the Alaska Fisheries Science Center of NOAA-Fisheries in Juneau, Alaska and Seattle, Washington. Her research focuses on oceanographic processes that influence phytoplankton and zooplankton dynamics and fisheries in the eastern Bering and Chukchi seas. She has been the lead oceanographer for the U.S. component of the BASIS program (Bering Aleutian Salmon International Surveys). She is a member of PICES' Technical Committee on Monitoring (MONITOR) and is a co-PI on current (and past) eastern Bering Sea and Chukchi Sea research programs.

The warm Blob continues to dominate the ecosystem of the northern California Current

by William Peterson, Marie Robert and Nicholas Bond

Elevated sea surface temperatures (SSTs) related to the warm 'Blob' continued to dominate the physical and biological oceanography of the northeast Pacific through summer–autumn 2014 (Bond *et al*., 2015) and into winter, spring and early summer of 2015. The anomalous blob of warm surface waters that had been present throughout the North Pacific in summer 2014 was associated with a weak North Pacific High (NPH) and a delay to the start of the coastal upwelling season in the northern California Current (NCC). Upwelling, as tracked by the Bakun Upwelling Index, did not begin until June 2014. By late summer, with a weakening of the NPH, the Blob began to move eastward and onshore in the northern California Current (Fig. 1). The date of arrival at Newport, Oregon (44.6°N latitude), was September 16, 2014 (Fig. 2) shown by a sudden increase in SST of nearly 7°C that occurred over the course of one hour! The untimely arrival of this event, coupled with a delay in the onset of coastal upwelling, resulted in the shortest upwelling season on record for the NCC. The onshore movement of the Blob and cooling in the Central Pacific produced a spatial pattern of SST that resembled a positive PDO pattern – PDO values were the most positive ever recorded for winter months (+ 2.51 in December 2014 and + 2.45 in January 2015). Higher positive PDO values have been observed previously, but only during the summer months (the five highest summertime PDO values: July 1983, 3.51; August 1941, 3.31; June 1942, 3.01; August 1984, 2.83; and June 1997, 2.76).

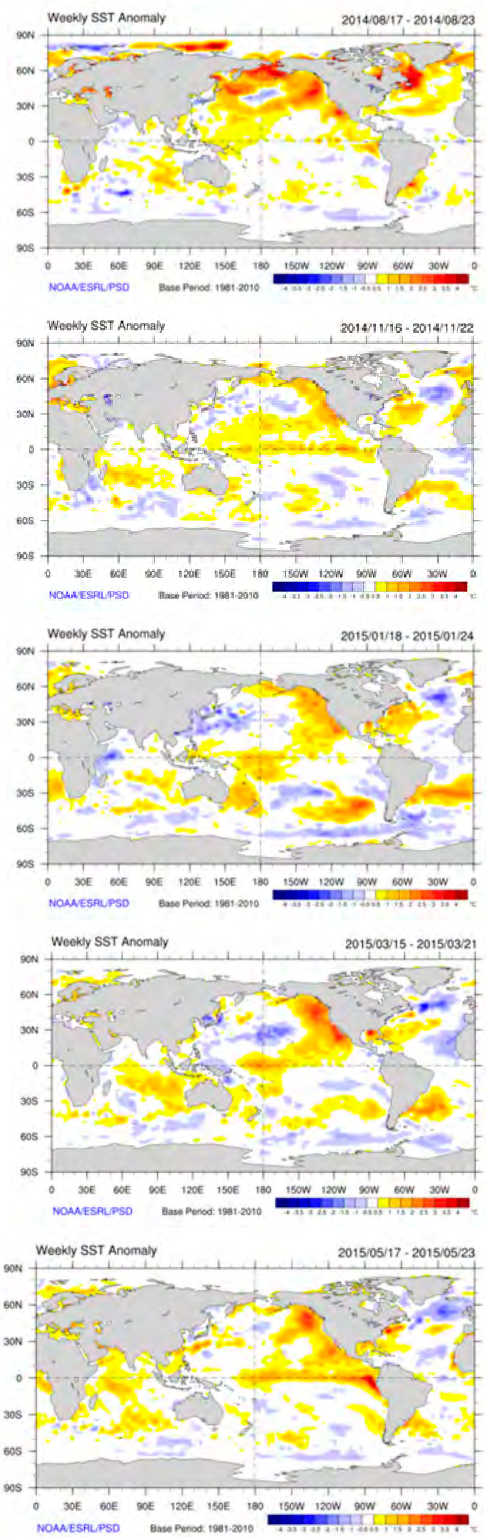

Fig. 1 (left) Spatial pattern of sea surface temperature (SST) across the North Pacific from (top) mid-August, November 2014 and January, March and May 2015 showing the fully-developed Blob (August 2014), the result of eastward propagation into the California Current and development of a positive PDO SST pattern, and development of the El Niño at the equator (March and May 2015).

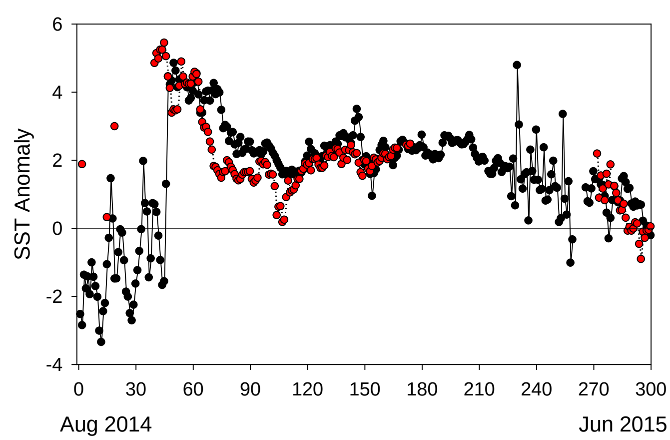

Fig. 2 SST at Buoy 46050 (20 miles (32 km) off Newport, Oregon) showing that the surface expression of the Blob arrived on September 16, 2014; the magnitude of the SST anomalies resembled the 1997–98 El Niño. Black = 2014–15, Red = 1997–98 El Niño.

The water which moved shoreward and into the coastal California Current had surface temperature and salinity characteristics of warm and fresh water (11–12°C and salinity ~ 31); this water type was present over the upper 50–80 m of the water column in shelf and slope waters of the NCC. Farther offshore, extending out to 200 miles (320 km) from the coast in January and April 2015 were surface waters of 11–12°C and salinity of ~ 32.5. Below this layer, the waters were 'normal' during winter 2014–15 with T-S at a depth of 150 m in slope waters of 8.51°C and 33.69 (climatology 8.46°C and 33.77; Huyer *et al.*, 2007); oceanic waters to 200 miles from shore in January and April had similar values. In contrast, the waters along Line P, farther north (48°34.5N to 50°00N), were not 'normal' in February 2015 down to a depth of about 200 m. This important offshore anomaly was better mixed but still very much present in June, with values of the temperature anomalies between 0.5 and 1.0°C at 200 m. (Fig. 3).

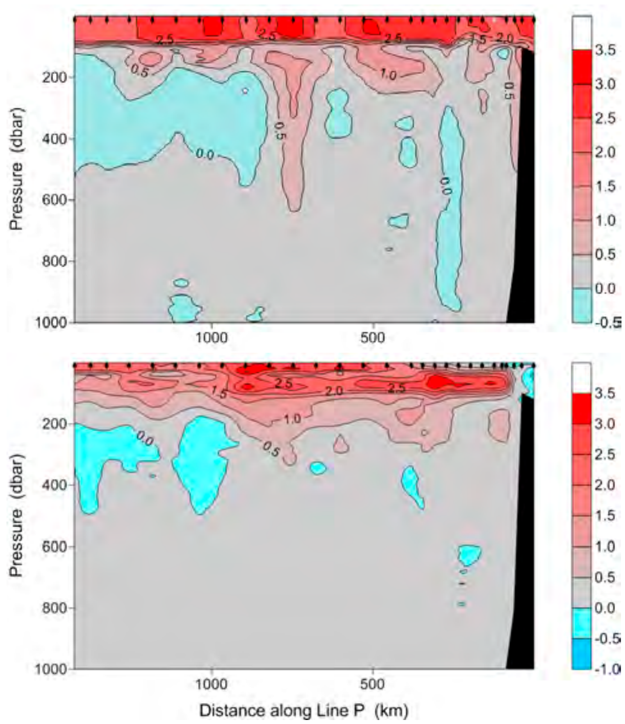

Fig. 3 Temperature anomaly along Line P in (top) February and (bottom) June 2015 with respect to the 1956–1991 averages.

The zooplankton species sampled in the NCC indicate that the water which came ashore at Newport (44.6°N) in autumn 2014 was from an offshore and southerly source, illustrated by an anomalously high number of copepod species (shown by the 'species richness' plot in Figure 4). A total of 8 copepod species were new to the shelf waters (examples include *Acartia negligens* and *Subeucalanus crassus*; six other species are as yet unidentified) and an additional 9 species (all as yet unidentified, largely because all are present as juvenile stages) in slope and oceanic waters off Newport. These 17 copepod species, having sub-tropical and tropical affinities, are all new records for the NCC.

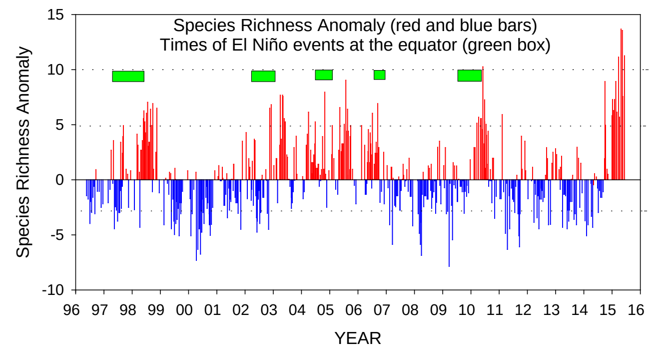

Fig. 4 Copepod species richness at station NH 05, 5 miles (9 km) off the Oregon coast. This station has been sampled biweekly since May 1996 for a total of 508 sampling dates. Note that the very high species richness observed in 2015 is unrelated to any past El Niño event.

With respect to fishes and seabirds, we found eggs of both sardines and anchovies in our net tows off Newport in February and March, a "first" for the Oregon coast as these two species usually spawn off southern California at this time of year. Sardines in more typical years migrate north to waters of the NCC in summer, where they may spawn again. The northern population of anchovy spawn off the Columbia River in summer. Anecdotal observations of note have been the presence of tropical seabirds in the NCC. Two seabird mortality events involving thousands of the local Cassin's Auklet were noted off the Farallon Islands on November 16 and off the northern Oregon coast on December 22, 2014. This tiny seabird dives to depths of 50 m in search of krill, and likely perished because they could not penetrate below the thick buoyant layer of warm waters to cooler waters that might have krill.

Coastal upwelling in the NCC at 45°N began on April 12 in 2015, very close to the long-term (30+ year average) of April 9. However, the power of the winds was insufficient to vertically mix the buoyant warm surface layer, and the weak wind speeds only transported surface waters *ca*. 9 km offshore, resulting in upwelling only within a narrow band very near the coast. Upwelling along Line P was similarly confined to a very defined coastal area, as seen in the sigma-t signal of Figure 5. Massive blooms of phytoplankton developed. However, three harmful algal bloom species (*Pseudo-nitzschia* and *Alexandrium* as well as a few cells of *Akashiwo sanguinea*) were conspicuous. This bloom persisted for more than one month (late April to early June) and the relatively high concentrations of the species resulted in elevated concentrations of domoic acid (and paralytic shellfish poisoning) and saxitoxins (amnesic shellfish poisoning) which led Oregon and Washington states to close the harvest of razor clams (*Siliqua patula)* and mussels (*Mytilus* spp.), and the harvest of Dungeness crabs (*Cancer magister*) in Washington state. At the time of this writing, the harvest closures remain in effect.

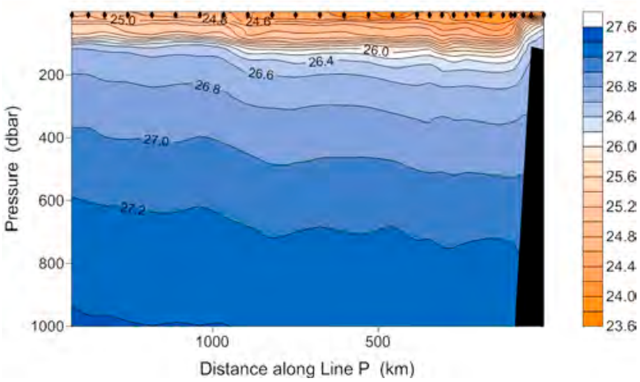

Fig. 5 Sigma-t field (kg/m³) along Line P in June 2015 showing the coastal upwelling.

The months of May and June 2015 included a positive sea level pressure (SLP) anomaly pattern over the northeast Pacific Ocean that resembled that of the winter of 2013-14, during the period when warming was particularly prominent off the coast of the Pacific Northwest. The distribution of the anomalous SLP also produced a notable north–south contrast in the coastal wind forcing. In particular, upwelling-favorable wind anomalies occurred in the northern portion of the California Current System along Oregon and Washington, and downwelling-favorable wind anomalies occurred south of roughly Pt. Conception, California. The upwelling winds in the north brought moderation of the positive temperature anomalies in the immediate vicinity of the coast. It is unknown whether the winds will continue to be of this sense, and whether this narrow strip of cooler and more productive water will end up representing a sort of refuge for marine organisms preferring cooler conditions.

Finally, the most recent zooplankton samples collected June 2015 indicate that the offshore warm water copepod species continue to be present (20 species observed in the June 10 samples as compared to the 20-year climatology of 9.1 species; Hooff and Peterson, 2006). Although the 'northern lipid-rich' species had higher numbers in this sample than in May 2015, they only accounted for 25% of the total (whereas climatology suggests that *ca*. 80–90% should be northern species at this time of year). The increased proportion of northern copepod species is an indicator that the NCC may slowly be returning to 'normal'. However, the very real threat of a major El Niño by autumn 2015 may make this observation moot.

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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, as Chairman of the CCCC REX (Regional Experiment) Task Team. He served as member of the FUTURE Advisory Panel on Status, Outlooks, Forecasts and Engagement, and as Co-Chairman of Working Group (WG 23) on Comparative Ecology of Krill in Coastal and Oceanic Waters around the Pacific Rim. Currently he is a member of the Biological Oceanography Committee.

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2015 Pacific Ecology and Evolution Conference

by Danielle Courcelles

Set in picturesque Bamfield on the west coast of Vancouver Island, British Columbia, the 36th annual Pacific Ecology and Evolution Conference (PEEC) was held from February 27 to March 1, 2015, at the Bamfield Marine Sciences Centre (BMSC). Each year the conference is organized and run by students from either Simon Fraser University (SFU), the University of British Columbia (UBC), or the University of Victoria (UVic). This year's conference was organized by graduate students from UBC, and it provided an opportunity for early career researchers to meet with their peers to present their research, build networks, and exchange ideas.

PEEC 2015 had 66 participants, and there were 48 oral presentations and 15 poster presentations. Oral presentations were grouped into six themes:

(1) *Evolution and local adaptation*, a glance into new research in regard to adaptations that have allowed species to succeed in their environment;
(2) *Species and environmental interactions*, which focused on abiotic and biotic factors that affect population demographics, individual growth and behaviour, and nutrient cycling;
(3) *Conservation*, where researchers identified species-specific threats and suggested new conservation strategies for these species;
(4) *Modelling and biomechanics*, where traditional model predictions were validated or improved, and a method for testing efficient locomotion in shark species was explained;
(5) *Aquatic and marine management*, which focused on management of both exploited and unexploited species; and
(6) *Management of terrestrial species and ecosystems*, where researchers made suggestions for improved management of terrestrial species.

Poster presentations were separated into five topics:

(1) *Evolution and genetics*, which focused on the evolution of species and communities under various conditions;
(2) *Management*, which considered aquatic systems as well as beach ecosystems;
(3) *Ecology*, which covered a broad spectrum of species ranging from fungi to bears;
(4) *Parasites*, where researchers determined the prevalence and community composition of parasites among aquatic species and birds; and
(5) *Human-affected ecosystems*, which focused on micro-plastics in aquatic environments in addition to disturbances mediating carbon sequestration in forests.

After the student presentations, Drs. Maia Hoeberechts and David Riddell from Ocean Networks Canada (ONC) conducted a seminar describing the ONC oceanographic observatories located in the Strait of Georgia and Pacific Ocean, spanning the Juan de Fuca and Explorer tectonic plates. Following this seminar, Maia and Dave hosted a workshop on how to access and navigate ONC's free online data portal which can be used to access oceanographic data from a wide variety of deep ocean, coastal, and surface sensors collected by ONC.

Bamfield Marine Sciences Centre, Bamfield, British Columbia.

In addition to the stunning scenery that characterizes Bamfield, everyone enjoyed an unusually sunny afternoon that naturally encouraged students to explore the area after the workshop. Skiffs were arranged to transport participants across Bamfield Inlet, providing access to the beach. Many people spent the afternoon enjoying the last rays of sunshine, scrambling up rocks, peeking into tide pools, and generally enjoying the feeling of sand between their toes. A tour of BMSC facilities was also conducted. However the afternoon was spent, everyone was well relaxed prior to the Time Travel themed dance party later that evening where many danced into the early morning hours.

The final activity of the conference was a keynote speech by Dr. Michael Hawkes, Professor in the Faculty of Science – Botany, at the University of British Columbia. He spoke of his passion for travelling and science, and his ability to meld his passions together by finding research opportunities throughout the world. While peppered with pictures and anecdotes of his travels, his final messages to early career researchers were clear: It may be easier than you think to realize your passions, and do not be afraid to work on side projects not directly related to your research.

Overall, the conference was a great success, largely due to the hard work of the organizing committee and the conference sponsors. Thank you to the staff of the Frances Barkley and Bamfield Marine Science Centre for helping with transportation and lodging of participants. We would also like to thank our sponsors, in particular the North Pacific Marine Science Organization (PICES) and Ocean Networks Canada (ONC), the University of British Columbia (UBC), Simon Fraser University (SFU), the University of Alberta (U of A), and the University of Victoria (UVic) for their generous donations. Lastly, thank you to all the PEEC participants who made for a wonderful conference.

Completing her Masters of Science at the University of British Columbia, Danielle Courcelles (dcourcelles@alumni.ubc.ca) is studying the effects of run-of-river hydropower dams on Coastal Tailed Frog tadpoles. Specifically, she is interested in whether sediment deposition is altered during low flow periods in the summer and whether biofilm growth or quality changes.

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